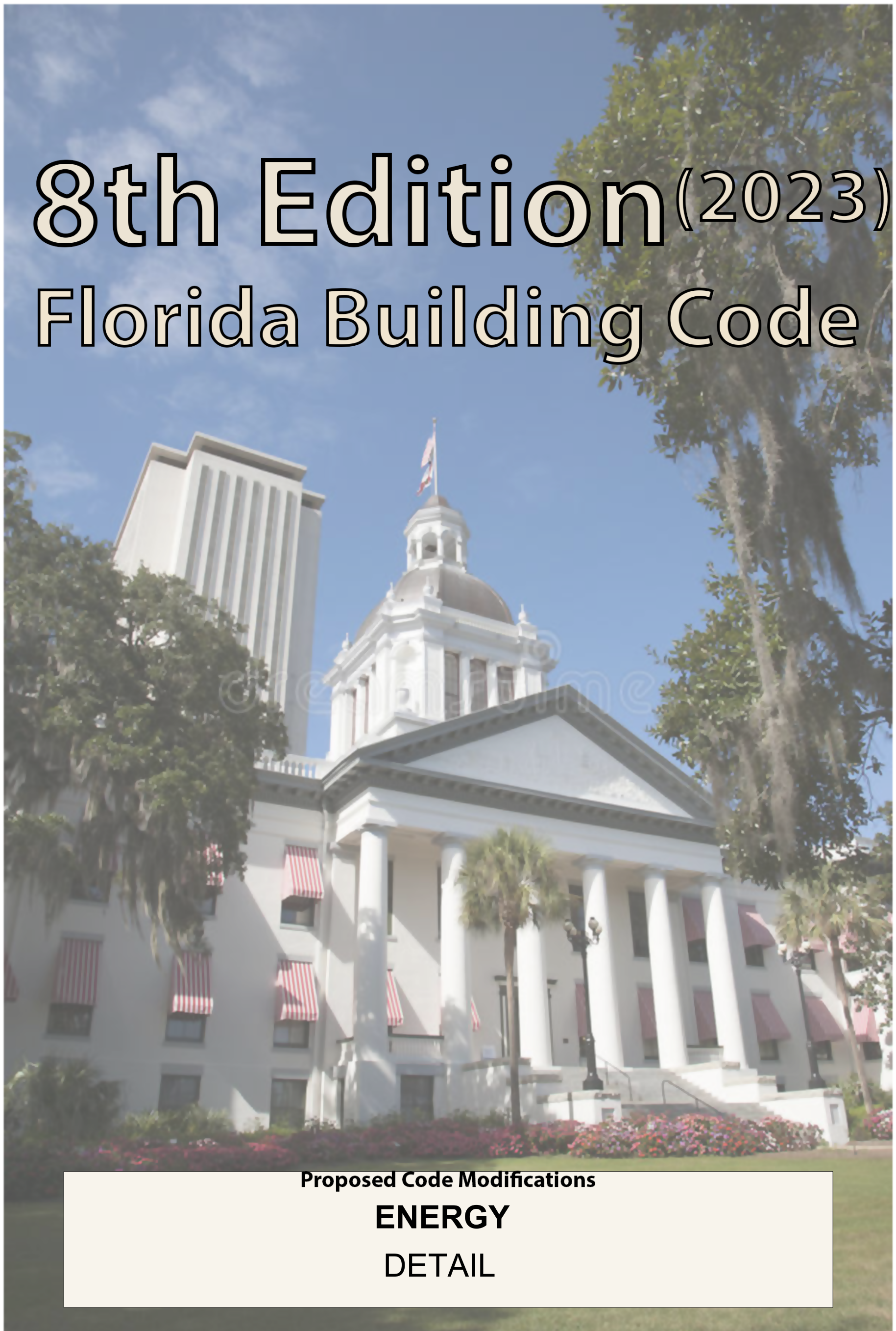


This document created by the Florida Department of Business and Professional Regulation -

850-487-1824

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10457

1

Date Submitted	02/15/2022	**Section**	1	**Proponent**	Jeff Sonne for FSEC
Chapter	10	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

Summary of Modification

Update Form R402 and resolve inconsistencies.

Rationale

The proposed mod updates Form R402 to include new SEER2 and HSPF2 efficiency ratings, adds space cooling and heating system entry fields and details, and resolves water heating UEF inconsistencies. No changes to code stringency (just shows new federal equipment efficiency requirements).

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None; only updates and improves Form R402.

Impact to building and property owners relative to cost of compliance with code

None; only updates and improves Form R402.

Impact to industry relative to the cost of compliance with code

None; only updates and improves Form R402.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes; benefits public by updating and improving Form R402.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves code by updating and improving Form R402.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not discriminate; updates and improves Form R402.

Does not degrade the effectiveness of the code

Increases code effectiveness by updating and improving Form R402.

Alternate Language

1st Comment Period History

EN10457-A2

Proponent Jeff Sonne for FSEC **Submitted** 4/16/2022 2:36:00 PM **Attachments** Yes

Rationale:

This alternative keeps the original 10457 mod except as follows: - In response to alt. language comment A1, and instead of the A1 change, recommend the table title clarification provided here in A2. Since this table is in Form R402 which is prescriptive, it does not create a requirement for performance compliance, but the table name change should help reduce confusion. - In response to general comment G1, the proponent agrees and adds signature spaces to Form R402.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact; clarification only.

Impact to building and property owners relative to cost of compliance with code

No impact; clarification only.

Impact to industry relative to the cost of compliance with code

No impact; clarification only.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes; clarifies code.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes; clarifies code.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

No; only clarifies code.

Does not degrade the effectiveness of the code

No; only clarifies code.

1st Comment Period History

EN10457-A1

Proponent Gary Kozan **Submitted** 4/11/2022 9:46:29 AM **Attachments** Yes

Rationale:

EN10457 is proposing updates to Appendix D, Form R402. We agree with these updates, but this would be a good time to make other needed corrections to the form. The hot water piping insulation locations described in R403.5.3 are PRESCRIPTIVE, not MANDATORY. Therefore this section would not apply when taking the performance-based approach outlined in R401.2, and should not appear on Form R402.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No enforcement cost impact to local entities

Impact to building and property owners relative to cost of compliance with code

no compliance cost impact to building and property owners

Impact to industry relative to the cost of compliance with code

no compliance cost impact to industry

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Corrects errors in current form

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves the code by making needed corrections for a more consistent application

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not discriminate against materials, products, or systems

Does not degrade the effectiveness of the code

Does not degrade the effectiveness of the code

1st Comment Period History

EN10457-G1

Proponent	Timothy de Carion	Submitted	3/4/2022 2:47:32 PM	Attachments	No

Comment:

I agree and support this proposed code change. In addition to the modification proposed, I recommend that the Name and Signature Section for both the preparer and the owner agent have seperate lines for a printed name and a signature. Signatures are normally not readable and a place for a printed name is needed for contact in addition to the line for the required signature for certification.

1st Comment Period History

EN10457-G2

Proponent	Amanda Hickman	Submitted	4/14/2022 11:15:20 AM	Attachments	No

Comment:

LBA does not support the modification, as it is not appropriate for Florida and/or is not cost justified.

See attached.

~~MANDATORY~~ OTHER REQUIREMENTS			
Component	**Section**	**Summary of Requirement(s)**	**Check**
Air leakage	R402.4	To be caulked, gasketed, weatherstripped or otherwise sealed per Table R402.4.1.1. Recessed lighting IC-rated as having <= 2.0 cfm tested to ASTM E 283.Windows and doors: 0.3 cfm/sq.ft. (swinging doors: 0.5 cfm/sf) when tested to NFRC 400 or AAMA/WDMA/CSA 101/I.S. 2/A440. Fireplaces: Tight-fitting flue dampers & outdoor combustion air.	
Programmable thermostat	R403.1.2	A programmable thermostat is required for the primary heating or cooling system.	
Air distribution system	R403.3.2 R403.3.4	Ducts shall be tested as per Section R403.3.2 by either individuals as defined in Section553.993(5) or (7), *Florida Statutes*, or individuals licensed as set forth in Section 489.105(3) (f), (g) or (i), *Florida Statutes*. Air handling units are not allowed in attics.	
Water heaters	R403.5	Comply with efficiencies in Table C404.2. Hot water pipes insulated to >= R-3 to kitchen outlets, other cases. Circulating systems to have an automatic or accessible manual OFF switch. Heat trap required for vertical pipe risers.	
Cooling/heating equipment	R403.7	Sizing calculation performed & attached. Special occasion cooling or heating capacity requires separate system or variable capacity system.	
Swimming pools & spas	R403.10	Spas and heated pools must have vapor-retardant covers or a liquid cover or other means proven to reduce heat loss except if 70% of heat from site-recovered energy. Off/timer switch required. Gas heaters minimum thermal efficiency is 82%. Heat pump pool heaters minimum COP is 4.0.	
Lighting equipment	R404.1	At least 90% of permanently installed lighting fixtures shall be high-efficacy lamps.	

I hereby certify that the plans and specifications covered by this form are in compliance with the *Florida Building Code, Energy Conservation.*

PREPARED BY: ______________ Date: ______

PREPARED BY SIGNATURE: ________________

I hereby certify that this building is in compliance with the *Florida Building Code, Energy Conservation.*

OWNER/AGENT: ______________ Date: ______

OWNER/AGENT SIGNATURE: ________________

Review of plans and specifications covered by this form indicate compliance with the *Florida Building Code, Energy Conservation*. Before construction is complete, this building will be inspected for compliance in accordance with Section 553.908, F.S.

CODE OFFICIAL: ________ Date:________

CODE OFFICIAL SIGNATURE: ________________

Make additional corrections to Appendix D, Form R402 - MANDATORY REQUIREMENTS TABLE:

Water heaters R403.5 Comply with efficiencies in Table C404.2. ~~Hot water pipes insulated to >= R-3 to kitchen outlets, other cases.~~ Circulating systems to have an automatic or accessible manual OFF switch. Heat trap required for vertical pipe risers.

See attached PDF. Additional Form R402 changes may be necessary to reflect other applicable 2023 code changes that are approved.

Florida Building Code, Energy Conservation

Residential Building Thermal Envelope Approach

FORM R402-202~~0~~3 **_R_-Value Computation Method** **Florida Climate Zone**

PROJECT NAME AND ADDRESS:		**BUILDER:**
		PERMITTING OFFICE:
		JURISDICTION NUMBER:
OWNER:		**PERMIT NUMBER:**
PERMIT TYPE:		**NUMBER OF UNITS:**
WORST CASE?		**CONDITIONED FLOOR AREA:**

Scope: Compliance with Section R402.1.2 of the *Florida Building Code, Energy Conservation*, shall be demonstrated by the use of Form R402 for single- and multiple-family residences of three stories or less in height, additions to existing residential buildings, alterations, renovations, and building systems in existing buildings, as applicable. To comply, a building must meet or exceed all of the energy efficiency requirements and applicable mandatory requirements summarized on this form. If a building does not comply with this method, or by the UA Alternative method, it may still comply under Section R405 or R406 of the *Florida Building Code, Energy Conservation*.

General Instructions:

1. Fill in all the applicable spaces of the "INSTALLED" row in the INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT table with the information requested. All "INSTALLED" values must be equal to or more efficient than the required levels. "AVG" indicates an area weighted average is allowed; "LOWEST" indicates the lowest *R*-value to be installed must be entered.
2. Complete the tables for air infiltration and installed equipment.
3. Read the MANDATORY REQUIREMENTS table and check each box to indicate your intent to comply with all applicable items.
4. Read, sign and date the "Prepared By" certification statement at the bottom of this form. The owner or owner's agent must also sign and date the form.

INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[1]

REQUIRE-MENT	FENESTRATION *U*-FACTOR[2, 3, 4]	SKYLIGHT[2] *U*-FACTOR	GLAZED FENESTRATION SHGC[2, 3]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE[5]	MASS WALL *R*-VALUE[5, 6]	FLOOR *R*-VALUE	BASEMENT WALL *R*-VALUE	SLAB[7] *R*-VALUE & DEPTH	CRAWL SPACE WALL *R*-VALUE
CLIMATE ZONE 1	NR	0.75	0.25	30	13	3/4	13	0	0	0
CLIMATE ZONE 2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
VALUE	AVG	AVG	AVG	LOWEST	LOWEST	LOWEST	LOWEST	LOWEST	LOWEST	LOWEST
INSTALLED:										

R-Value Calculation Method - [PASS / FAIL]

For SI: 1 foot = 304.8 mm; NR = No requirement.

(1) *R*-values are minimums. *U*-factors and SHGC are maximums. When insulation is installed in a cavity which is less than the label or design thickness of the insulation, the installed R-value of the insulation shall not be less than the R-value specified in the table.

(2) The fenestration *U*-factor column excludes skylights. The SHGC column applies to all glazed fenestration. Exception: Skylights may be excluded from glazed fenestration SHGC requirements in Climate Zones 1 through 3 where the SHGC for such skylights does not exceed 0.30.

(3) For impact rated fenestration complying with Section R301.2.1.2 of the *Florida Building Code, Residential* or Section 1609.1.2 of the *Florida Building Code, Building*, the maximum *U*-factor shall be 0.65 in Climate Zone 2. An area-weighted average of *U*-factor and SHGC shall be accepted to meet the requirements, and up to 15 square feet of glazed fenestration area are exempted from the *U*-factor and SHGC requirement based on Section R402.3.1, R402.3.2 and R402.3.3.

(4) One side-hinged opaque door assembly up to 24 square feet is exempted from this *U*-factor requirement based on Section R402.3.4.

(5) *R*-values are for insulation material only as applied in accordance with manufacturer's installation instructions.

(6) The second *R*-value applies when more than half the insulation is on the interior of the mass wall.

(7) R-5 shall be added to the required slab edge *R*-values for heated slabs. Insulation depth shall be the depth of the footing or 2 feet, whichever is less in Climate Zones 1 through 3 for heated slabs.

Air infiltration:	Blower door test is required on the building envelope to verify leakage ≤ 7 ACH50; test report must be provided to code official before CO is issued. *Florida Building Code, Energy Conservation* Section R402.4.1.2 testing exception may apply for additions, alterations, or renovations.

EQUIPMENT REQUIREMENTS AND INSTALLED VALUES

Fill in the "INSTALLED EFFICIENCY LEVEL" column with the information requested. For multiple systems of the same type, indicate the minimum efficient system. All "INSTALLED" values must be equal to or more efficient than the required level. If a listed "SYSTEM TYPE" is not to be installed, write in "N/A" for not applicable.

SYSTEM TYPE	MINIMUM EFFICIENCY LEVEL REQUIRED	INSTALLED EFFICIENCY LEVEL
Air distribution system[1]	Not allowed in attic	Location:
Air handling unit	Factory Sealed	Factory Sealed? Y/N
Duct *R*-Value	= R-8 (Ducts in unconditioned attics, Diameter => 3 in.) = R-6 (Ducts in unconditioned non attics, Diam. => 3 in.) = R-6 (Ducts in unconditioned attics, Diameter < 3 in.) = R-4.2 (Ducts in uncond not attics, Diam. < 3 in.) All ducts are in conditioned space (No minimum)	*R*-Value (In unc. attic) = *R*-Value (In unc. non attics) = *R*-value (Small ducts in attic) = *R*-Value (Small ducts in unc) = All in conditioned space? Y/N
Air Leakage/Duct test	Air handler installed: Total leakage = 4 cfm/100 s.f. Air handler not installed: Total leakage = 3 cfm/100 s.f.	Total leakage (cfm/100 s.f.) = Air handler installed? Y/N
Duct testing	Test not required if all ducts and AHU are within the building thermal envelope and for additions or alterations where ducts extended from existing heating and cooling system through unconditioned space are < 40 linear ft.	Test report required? Y/N
Air conditioning systems:	Minimum federal standard required by NAECA[2]	
Central system < ~~6~~45,000 Btu/h Central system ≥ 45,000 Btu/h	SEER2=14.~~0~~3 SEER2=13.8	Cap. (Btu/h)= SEER2 (Min)=
PTAC, PTHP, SPVAC, or SPVHP	EER [from Table C403.2.3(3)]	Type= Cap. (Btu/h)= EER (Min)=
Other:	See Tables C403.2.3(1)-(11)	Type = Effic.(Min) =
Heating systems:	Minimum federal standard required by NAECA[2]	
Electric resistance	Not allowed in Climate Zone 2	
Heat Pump ~~<= 65,000 Btu/h~~	HSPF2 ≥ ~~8.2~~7.5	HSPF2 (Min) =
Gas Furnace, non-weatherized	~~HSPF~~AFUE ≥ 80%	AFUE (Min) =
Oil Furnace, non-weatherized	~~HSPF~~AFUE ≥ 83%	AFUE (Min) =
PTHP or SPVHP	COP_H [from Table C403.2.3(3)]	Type= Cap. (Btu/h)= COP_H (Min)=
Other:	See Tables C403.2.3(1)-(11)	Type = Effic.(Min)=
Water heating system (storage type):	Minimum federal standard required by NAECA[2]	Capacity =
Electric[3, 6]	UEF: 40 gal.: ~~0.923~~0.931, 50 gal.: ~~0.921~~0.930, 60 gal.: ~~2.051~~2.176	UEF (Min) =
Gas fired[4, 6]	UEF: 40 gal.: ~~0.580~~0.64, 50 gal.: ~~0.563~~0.627, 60 gal.: ~~0.766~~0.789	UEF (Min) =
Other (describe)[5, 6]:		Type= Effic.(Min)=

Equipment Efficiency - [PASS / FAIL]

(1) Ducts & AHU installed "substantially leak free" per Section R403.3.2. Test required by either individuals as defined in Section 553.993(5) or (7), *Florida Statutes*, or individuals licensed as set forth in Section 489.105(3)(f), (g), or (i), *Florida Statutes*. The total leakage test is not required for ducts and air handlers located entirely within the building thermal envelope, and for additions where ducts from an existing heating and cooling system extended to the addition through unconditioned space are less than 40 linear ft.

(2) Minimum efficiencies are those set by the *National Appliance Energy Conservation Act* of 1987 for typical residential equipment and are subject to NAECA rules and regulations. For other types of equipment, see Tables C403.2.3 (1-11) of the Commercial Provisions of the *Florida Building Code, Energy Conservation.*

(3) For electric storage volumes <= 55 gallons, minimum UEF = 0.9349 – (0.0001 * volume). For electric storage volumes > 55 gallons, minimum UEF = 2.2418 – (0.0011 * volume).

(4) For natural gas storage volumes <= 55 gallons, minimum UEF = 0.692 – (0.0013 * volume). For natural gas storage volumes > 55 gallons, minimum UEF = 0.8072 – (0.0003 * volume).

(5) For electric tankless, min. UEF = 0.92. For natural gas tankless, min. UEF = 0.81.

(6) Referenced UEFs shown are for ~~medium~~high draw pattern value provided by manufacturer.

MANDATORY REQUIREMENTS			
Component	**Section**	**Summary of Requirement(s)**	**Check**
Air leakage	R402.4	To be caulked, gasketed, weatherstripped or otherwise sealed per Table R402.4.1.1. Recessed lighting IC-rated as having <= 2.0 cfm tested to ASTM E 283.Windows and doors: 0.3 cfm/sq.ft. (swinging doors: 0.5 cfm/sf) when tested to NFRC 400 or AAMA/WDMA/CSA 101/I.S. 2/A440. Fireplaces: Tight-fitting flue dampers & outdoor combustion air.	
Programmable thermostat	R403.1.2	A programmable thermostat is required for the primary heating or cooling system.	
Air distribution system	R403.3.2 R403.3.4	Ducts shall be tested as per Section R403.3.2 by either individuals as defined in Section553.993(5) or (7), *Florida Statutes*, or individuals licensed as set forth in Section 489.105(3) (f), (g) or (i), *Florida Statutes*. Air handling units are not allowed in attics.	
Water heaters	R403.5	Comply with efficiencies in Table C404.2. Hot water pipes insulated to >= R-3 to kitchen outlets, other cases. Circulating systems to have an automatic or accessible manual OFF switch. Heat trap required for vertical pipe risers.	
Cooling/heating equipment	R403.7	Sizing calculation performed & attached. Special occasion cooling or heating capacity requires separate system or variable capacity system.	
Swimming pools & spas	R403.10	Spas and heated pools must have vapor-retardant covers or a liquid cover or other means proven to reduce heat loss except if 70% of heat from site-recovered energy. Off/timer switch required. Gas heaters minimum thermal efficiency is 82%. Heat pump pool heaters minimum COP is 4.0.	
Lighting equipment	R404.1	Not less than 90% of the lamps in permanently installed luminaires shall have an efficacy of at least 45 lumens-per-watt or shall utilize lamps with an efficacy of not less than 65 lumens-per-watt.	

I hereby certify that the plans and specifications covered by this form are in compliance with the *Florida Building Code, Energy Conservation.* PREPARED BY: Date I hereby certify that this building is in compliance with the *Florida Building Code, Energy Conservation.* OWNER/AGENT: Date	Review of plans and specifications covered by this form indicate compliance with the *Florida Building Code, Energy Conservation* Before construction is complete, this building will be inspected for compliance in accordance with Section 553.908, F.S. CODE OFFICIAL: ________ Date:_______

R403.5.3Hot water pipe insulation (Prescriptive).

Insulation for hot water pipe with a minimum thermal resistance (R-value) of R-3 shall be applied to the following:

1. ***1.Piping ³/₄ inch (19.1 mm) and larger in nominal diameter.***
2. ***2.Piping serving more than one dwelling unit.***
3. ***3.Piping located outside the conditioned space.***
4. ***4.Piping from the water heater to a distribution manifold.***
5. ***5.Piping located under a floor slab.***
6. ***6.Buried in piping.***
7. ***7.Supply and return piping in recirculation systems other than demand recirculation systems.***

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10245

2

Date Submitted	02/11/2022	**Section**	104.4	**Proponent**	Douglas Baggett
Chapter	1	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

10251 10445 10123 10446 10448 10459 10463

Summary of Modification

This proposed modification is to clarify and provide a consistent requirement for all inspecting parties to be independent and objective from the project.

Rationale

This modification would provide a consistent requirement for all inspecting parties to be independent and objective. The current code states the third-party certified agencies need to be independent and separate from the project, which implies the engineers and/or designers do not need to be independent. Making this requirement the same for all testing authorities would demonstrate fair business practice, as well as, go towards limiting conflicts of interest, biased testing and unqualified individuals from performing inspections and tests.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This would have little to no financial impact on the local entity, aside from updating the verbiage on solicitations and policies.

Impact to building and property owners relative to cost of compliance with code

This would have little to no financial impact on building and property owners, aside from updating the verbiage on solicitations and policies.

Impact to industry relative to the cost of compliance with code

This would have little to no financial impact on the industry if implemented moving forward.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The public can be assured the testing agency has no vested interest in the design, construction or project as a whole, and therefore, is objective and can be trusted.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This modification will improve the code by allowing for clarifying and equalizing requirements of individuals or firms tasked with inspecting and/or testing building components

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposed modification does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not degrade the effectiveness of the code

No, this proposed modification does not degrade the effectiveness of the code, it enhances it.

C104.4 Approved inspection agencies. The *code official* is authorized to accept inspection reports in whole or in part from either individuals as defined in Section 553.993(5) or (7), *Florida Statutes* or third-party inspection agencies. None of the individuals, their organizations or third party agencies shall be ~~not~~ affiliated with the building design ~~or~~ construction, or installation provided such agencies are *approved* as to qualifications and reliability relevant to the building components and systems they are inspecting.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10251

3

Date Submitted	02/11/2022	**Section**	104.4.1	**Proponent**	Douglas Baggett
Chapter	1	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No

Alternate Language Yes

Related Modifications

10245

Summary of Modification

This proposed modification serves to define and set apart from all other testing agencies, what and who constitutes an authorized commissioning agent.

Rationale

The process of commissioning buildings and their systems is very involved and requires more than simply inspecting and functionally testing equipment. Lumping the commissioning agencies' requirements into the same category as All Inspection Agencies leaves too much room for interpretation which can result in ineffective testing and inefficient systems. Studies have shown that commissioning, when done correctly, can net an energy savings of 9%-30% on average. In order to ensure commissioning is done correctly, it should be conducted by an independent, certified commissioning agent(s).

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This modification will require the local entity to add specific verbiage and requirements when adding commissioning to a building project (whether it's renovation or new construction). In addition, the local entity may need to create a separate solicitation for a project.

Impact to building and property owners relative to cost of compliance with code

Commissioning is already required and, therefore, should already be part of the construction project's budget. There should not be any additional costs.

Impact to industry relative to the cost of compliance with code

The potential impact cannot be determined since it’s unknown how often commissioning has been conducted by individuals associated or affiliated with the design, construction and/or installation of the systems. There could be an increase to some construction project costs.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The health, safety and welfare of the general public will be improved by ensuring the mechanical, electrical and plumbing systems have been inspected and certified by a duly authorized, certified and objective third-party that is specifically trained in those systems.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This modification will improve the code to allow for clear, equal and fair requirements of individuals or firms tasked with inspecting and/or testing building components

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposed modification does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not degrade the effectiveness of the code

No, this proposed modification does not degrade the effectiveness of the code, it enhances it.

Alternate Language

1st Comment Period History

EN10251-A2

Proponent Douglas Baggett **Submitted** 4/13/2022 1:55:06 PM **Attachments** Yes

Rationale:

The current language allows for bias and conflicts of interest to occur on projects requiring commissioning. The commissioning effort should be completed by someone independent and objective from the project, doing so ensures the Owner's voice, priorities and requirements are completely fulfilled without bias. (This proposed mod. may be better suited for section C408.1.2)

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Little to none

Impact to building and property owners relative to cost of compliance with code

Little to none

Impact to industry relative to the cost of compliance with code

Little to none

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The health, safety and welfare of the general public will be improved by ensuring the mechanical, electrical and plumbing systems have been inspected and certified by a duly authorized, certified and objective third-party that is specifically trained in those systems.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposed modification will improve the code by removing any potential for conflicts of interest on the construction project

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposed modification does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not degrade the effectiveness of the code

No, this proposed modification does not degrade the effectiveness of the code, it enhances it.

~~C104.4.1~~ C408.1.2 Buildings/systems requiring commissioning must be performed by a certified ~~design professional, mechanical engineer, electrical engineer or approved~~ third-party commissioning agent. Agencies providing commissioning services, inspections and/or functional tests, shall be independent from ~~all~~ the aspects of the project ~~in so far as, the firm the individual works for/represents, cannot have a contract to provide another service for that same project/building.~~ being commissioned so as to avoid potential conflicts of interest. This includes, but is not limited to, the following instances:

- If commissioning is to be part of the design phase, the design engineer cannot commission his/her own work
- A contractor that performs test and balance work, cannot also commission the same hvac system, nor can anyone else from the company that contractor works for.

In the instance where a Mechanical Contractor contracts out the Test and Balance work CAN also contract out the Commissioning work, but it cannot be contracted to the same firm.

The individual conducting the commissioning, and the firm they work for, must be certified for commissioning by one of the following organizations: AABC Commissioning Group (ACG), National Environmental Balancing Bureau (NEBB), Building Commissioning Association (BCA), American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), or the Association of Energy Engineers (AEE).

C104.4.1 Requirement. Buildings/systems requiring commissioning must be performed by a certified Design Professional, Mechanical Engineer, Electrical Engineer or a certified and approved third-party agency. Firms and individuals providing commissioning services, inspections and/or functional tests, shall be independent from all aspects of the project, in so far as, the firm the individual works for/represents, cannot have a contract, or be in the employment of someone that does, to provide another service for that same project/building. The individual conducting the commissioning, and the firm they work for, must be certified for commissioning by one of the following organizations: AABC Commissioning Group (ACG), National Environmental Balancing Bureau (NEBB), Building Commissioning Association (BCA), American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), or the Association of Energy Engineers (AEE).

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10363

4

Date Submitted	02/13/2022	**Section**	104.2.6	**Proponent**	Joseph Belcher
Chapter	1	**Affects HVHZ**	Yes	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language Yes**

Related Modifications

Correlating changes to Sections C408.2, C408.2.4.1, C408.2.4.2, C408.2.5, and C408.3.2.

Summary of Modification

Modification to require the Preliminary Inspection Report be provided to the code official before the final inspection.

Rationale

It has been reported that many projects do not request commissioning because the local building department does not request the documentation. The code change is necessary to enhance enforcement of the commissioning provisions of the FBC-EC. Requiring documentation to be submitted to the building official as well as the owner will ensure the building department is kept advised of the project and the progress of the commissioning process and will lead to improved enforcement.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact as the change merely requires providing the documentation to the code official.

Impact to building and property owners relative to cost of compliance with code

No impact as the change merely requires providing the documentation to the code official. .

Impact to industry relative to the cost of compliance with code

No impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The proposal has a reasonable and positive impact on the health, safety, and welfare of the public by enhancing enforcement of the code.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The proposal strengthens the code by enhancing enforcement of the commissioning provisions of the code.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The change does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities.

Does not degrade the effectiveness of the code

The proposed change does not degrade the effectiveness of the code and improves the effectiveness of the code.

Alternate Language

1st Comment Period History

EN10363-A2

Proponent Timothy de Carion **Submitted** 3/4/2022 3:29:37 PM **Attachments** Yes

Rationale:

I agree with the proponent that the preliminary commisioning report should be given to the code official before a final inspection is requested. I also support leaving the existing wording about giving the building owner information also.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None

Impact to building and property owners relative to cost of compliance with code

Saves building owner money by disclosure of problems

Impact to industry relative to the cost of compliance with code

none

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

no

Does not degrade the effectiveness of the code

No

C104.2.6 Final inspection. The building shall have a final inspection and shall not be occupied until approved. The final inspection shall include verification of the installation and proper operation of all required building controls, and documentation verifying activities associated with required building commissioning have been conducted and findings of noncompliance corrected. Buildings, or portions thereof, shall not be considered for a final inspection until the code official has received the Preliminary Commissioning Report and has also received a letter of transmittal from the building owner acknowledging that the building owner has received the Preliminary Commissioning Report as required in Section C408.2.4.

C104.2.6 Final inspection. The building shall have a final inspection and shall not be occupied until approved. The final inspection shall include verification of the installation and proper operation of all required building controls, and documentation verifying activities associated with required building commissioning have been conducted and findings of noncompliance corrected. Buildings, or portions thereof, shall not be considered for a final inspection until the code official has received ~~a letter of transmittal from the building owner acknowledging that the building owner has received~~ the Preliminary Commissioning Report as required in Section C408.2.4.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10412

5

Date Submitted	02/14/2022	**Section**	202	**Proponent**	Jennifer Hatfield
Chapter	2	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Slight edit to current definition to align with same definition in Florida Commercial Energy, as well as IECC, to ensure proper terminology is used when it comes to defining "vertical fenestration."

Rationale

This proposal is being submitted on behalf of the Fenestration & Glazing Industry Alliance (formerly AAMA). This code modification simply replaces the word “moveable” with “operable” to a) be consistent with the IECC-Residential Energy definition and b) be consistent with how in both the Florida and IECC – Commercial Energy definition, the term used is “operable.” Moveable and operable have two different meanings and the appropriate term when defining a window is “operable.”

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact

Impact to building and property owners relative to cost of compliance with code

No impact

Impact to industry relative to the cost of compliance with code

No impact

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Simply makes the definition consistent and uses appropriate terminology.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves the code by providing a consistent definition and using appropriate terminology.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

It does not.

Does not degrade the effectiveness of the code

It does not.

VERTICAL FENESTRATION. Windows (fixed or ~~moveable~~ operable), opaque doors, glazed doors, glazed block and combination opaque/glazed doors composed of glass or other transparent or translucent glazing materials and installed at a slope of a least 60 degrees (1.05 rad) from horizontal.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

6

EN10406

Date Submitted	02/14/2022	**Section**	303.1.3	**Proponent**	Jennifer Hatfield
Chapter	3	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Adds new ANSI/NFRC 203 standard for Tubular Daylighting Devices to be measured and rated.

Rationale

This proposal is being submitted on behalf of the Fenestration & Glazing Industry Alliance (formerly AAMA). This proposal brings forward language from the IECC, requiring Tubular Daylighting Devices to be measured and rated in accordance with NFRC 203, when addressing VT annual. The traditional NFRC 200/202 Visible Transmittance rating procedure, rates the Visible Transmittance of conventional skylights using a single, direct-normal incidence angle condition, and represents a skylight's VT for light that is "normal" (i.e. perpendicular) to the skylight's surface. As a result, it does not account for the skylight's effective system transmittance under the wide range of lower, incident sunlight angles that actually strike the skylight's dome surface over the course of a year. To address this, the new ANSI/NFRC 203 protocol applies enhanced physical Visible Transmittance testing of a TDD/skylight product using 18 precisely-controlled incidence angles, and measures/rates a TDD/skylight product's functional, annualized visible light transmittance characteristics accounting for the product's roof-top dome optics, light shaft (or "well" as defined in Code Section C402.4.2), and interior ceiling diffuser and/or aperture elements. It is also important to note that ANSI/NFRC 203 is the only rating standard that is used for measuring and rating the Visible Transmittance of the TDD fenestration product category.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact.

Impact to building and property owners relative to cost of compliance with code

No impact

Impact to industry relative to the cost of compliance with code

Minor to no impact as these products are already being measured and rated in accordance with this standard.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Provides for a standard to measure and rate these devices that does not currently exist in the Code.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves the code by providing a standard within the code for these devices where one does not currently exist.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

It does not.

Does not degrade the effectiveness of the code

It does not.

C303.1.3 Fenestration product rating.
***U*-factors of fenestration products shall be determined as follows:**

1. For windows, doors and skylights, *U*-factor ratings shall be determined in accordance with NFRC 100.

2. Where required, for garage door and rolling doors, *U*-factor ratings shall be determined in accordance with either NFRC 100 or ANSI/DASMA 105.

***U*-factors shall be determined by an accredited, independent laboratory, and *labeled* and certified by the manufacturer.**

Products lacking such a *labeled U*-factor shall be assigned a default *U*-factor from Table C303.1.3(1) or C303.1.3(2). The solar heat gain coefficient (SHGC) and *visible transmittance* (VT) of glazed fenestration products (windows, glazed doors and skylights) shall be determined in accordance with NFRC 200 by an accredited, independent laboratory, and *labeled* and certified by the manufacturer. Products lacking such a *labeled* SHGC or VT shall be assigned a default SHGC or VT from Table C303.1.3(3). For Tubular Daylighting Devices, VT_{annual} shall be measured and rated in accordance with ANSI/NFRC 203.

Add new Standard in Chapter 6 (CE) Referenced Standards, under NFRC, as follows:

203 – 2020:	**Procedure for Determining Visible Transmittance of Tubular Daylighting Devices**	**C303.1.3**

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN9903

7

Date Submitted	01/27/2022	**Section**	303.1.5	**Proponent**	pete quintela
Chapter	3	**Affects HVHZ**	Yes	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

This proposed modification increases the two compliance requirement options to the roof system solar reflectance values for low-slope roofs on commercial/nonresidential buildings directly above conditioned spaces and it is only applicable to Climate Zone 1A

Rationale

This proposed modification increases the roofing systems solar reflectance which will lead to less heat transmission into the building, resulting in a reduced cooling load demand, and a consequent decrease on energy consumption. By decreasing roof temperature, the life of the roof may be extended. This proposal also provides secondary benefits, such as reduced urban heat island effect.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None

Impact to building and property owners relative to cost of compliance with code

Energy savings

Impact to industry relative to the cost of compliance with code

Minimal. Based on the example of a standard new construction, two-plies and a mineral surfaced cap sheet built-up roof costing $275 per square. The cost difference between a regular mineral surfaced cap sheet and an energy compliant cap sheet is $50 per square. The $50 increase is approximately 20%.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The proposed code change increases the amount of solar energy reflected away from low slope roof systems. Higher reflective materials lower the heat retained by the roof, lessens heat exposure to residents and reduces heat related health risks.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Decreases cooling load energy use, extends the life of the roof system, improves the energy efficiency of the code, reduces urban heat island effect.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

NO

Does not degrade the effectiveness of the code

NO

1st Comment Period History

EN9903-G1

Proponent	Timothy de Carion	Submitted	3/9/2022 11:06:00 AM	Attachments	Yes

Comment:

Letter of Endorsement from the City of Pompano Beach

1st Comment Period History

EN9903-G2

Proponent	Timothy de Carion	Submitted	3/9/2022 11:26:21 AM	Attachments	Yes

Comment:

Endorsement Letter from the City of Hollywood

1st Comment Period History

EN9903-G3

Proponent	Susannah Troner	Submitted	3/29/2022 11:39:48 PM	Attachments	No

Comment:

Writing to express support for proposed code modification EN9903 for additional commercial cool roof reflectance requirements for low-slope roofs in Climate Zone 1A. The proposed code modification provides community health and safety benefits which is the core purpose of the Florida Building Code. The Autocase Triple Bottom Line Economic Analysis submitted with the proposed code modification verifies these community health and safety benefits as well as lifetime economic benefit for building owners and tenants who will save significant money over the life of the building. The proposed code modifications also provide additional environmental benefits to the community. The analysis focuses on one prototype building so the benefits would be exponentially more significant when multiplied by the annual number of new low-slope roof commercial roofs in a community.

1st Comment Period History

EN9903-G4

Proponent	Monica Ospina	Submitted	4/8/2022 3:55:51 PM	Attachments	No

Comment:

Writing to express support for the proposed code modification EN9903 for additional commercial roof requirements. The submitted Economic Analysis and other supporting documentation verify that the changes will help building owners and tenants save money over the life of the building and provides many health and safety benefits to the community.

1st Comment Period History

EN9903-G5

Proponent Jackson Becce Submitted 4/13/2022 9:23:03 AM Attachments No

Comment:

The Smart Surfaces Coalition (SSC) SUPPORTS the increase in solar reflectance thresholds for commercial low-slope roofs in climate zones 1A as part of the FBC. This proposal would have a significant impact on energy and related monetary savings and heat reduction, resulting in health and saftey improvements, among other benefits. There are already many commercially available products that allow low-slope commercial buildings to achieve the desired 3-year SRI threshold outlined in the code with no cost differential.

1st Comment Period History

EN9903-G6

Proponent kamrath christian Submitted 4/13/2022 12:31:22 PM Attachments No

Comment:

I support proposed code modification EN9903 for additional commercial cool roof reflectance requirements for low-slope roofs in Climate Zone 1A. We need to be building smarter and in a way that accounts for future hotter conditions. The economic analysis submitted with the proposed code modification verifies community health and safety benefits which are part of the core purpose of the Florida Building Code. Multiple studies over the years have also verified economic benefits for building owners and tenants who save on their electric bills over the life of the building. The proposed code modifications also provide additional environmental benefits to the community.

1st Comment Period History

EN9903-G7

Proponent Brenda Krebs Submitted 4/13/2022 3:02:44 PM Attachments No

Comment:

For low-slope roofs in Climate Zone 1A, I fully back the proposed code modification EN9903 for additional commercial cool roof reflectance requirements. The economic analysis, which was submitted with the proposed code modification, serves as verification of community health and safety benefits that are an integral part of the Florida Building Code's core purpose. Numerous studies over the years have also verified economic benefits over the life cycle of the buildings for both building owners and tenants who save on their electric bills. The proposed code modifications also provide additional community environmental benefits.

1st Comment Period History

EN9903-G8

Proponent Nicholas Gunia Submitted 4/14/2022 10:03:52 AM Attachments No

Comment:

As past Chair of the Miami Branch of the South Florida Chapter of the US Green Building Council, I am writing to voice my support for EN9903 for additional commercial cool roof requirements. I believe the proposed changes will help building owners and tenants save money over time and benefit the environment. As such, the proposed changes should be adopted.

1st Comment Period History

EN9903-G9

Proponent Jefferson Tcheou Submitted 4/14/2022 2:59:51 PM Attachments No

Comment:

Commenting in support of code modification EN9903. The Autocase Analysis states that a prototype 5,000 sf commercial building with thermoplastic membrane roofing provides an economic value of $150k over 25 years. This potentially could save a tremendous amount of energy resources and money. Steps towards a greener future are much needed.

1st Comment Period History

EN9903-G10

Proponent	Estela Tost	Submitted	4/14/2022 6:31:38 PM	Attachments	Yes

Comment:

I am in support of the proposed modification EN9903 for additional commercial cool roof requirements. The supporting documents and data validates that this change will support building owners and tenants in reduction of operating expenses while providing enhanced safety and health benefits

1st Comment Period History

EN9903-G11

Proponent	Richard Logan	Submitted	4/15/2022 9:51:56 AM	Attachments	No

Comment:

AIA Florida Supports this code modification

1st Comment Period History

EN9903-G12

Proponent	Sandra St. Hilaire	Submitted	4/15/2022 2:42:09 PM	Attachments	No

Comment:

I support proposed code modification EN9903 for additional commercial cool roof reflectance requirements for low-slope roofs in Climate Zone 1A. The economic analysis submitted with the proposed code modification verifies community health, resilience and safety benefits which are part of the core purpose of the Florida Building Code. Multiple studies over the years have also verified economic benefits for building owners and tenants who save on their electric bills over the life of the building. The proposed code modifications also provide additional environmental benefits to the community.

1st Comment Period History

EN9903-G13

Proponent	Mike Gibaldi	Submitted	4/15/2022 4:33:11 PM	Attachments	No

Comment:

I fully support this easy way to conserve energy. Florida must do all we can to reduce inefficient energy use. This change will passively save energy for years and years in in every structure where it gets implemented.

1st Comment Period History

EN9903-G14

Proponent	Chris Sanchez	Submitted	4/15/2022 5:06:49 PM	Attachments	No

Comment:

I support proposed code modification EN9903 for additional commercial cool roof reflectivity requirements for low-slope roofs in Climate Zone 1A. The economic analysis submitted with the proposed code modification verifies community health and safety benefits which are part of the core purpose of the Florida Building Code. In addition, multiple studies have verified the economic benefits associated for building owners and tenants who save on their electric bills over the life of the building. The proposed code modifications also provide additional environmental benefits to the community.

1st Comment Period History

Proponent	Marta Marello	Submitted	4/17/2022 3:48:39 PM	Attachments	No

Comment:

I support proposed code modification EN9903 for additional commercial cool roof reflectance requirements for low-slope roofs in Climate Zone 1A. The proposed code modification will provide economic savings and as well as community health and safety benefits which are part of the core purpose of the Florida Building Code. Additionally, the proposed code modification will assist building owners and tenants in saving on their electric bills and be more resilient in the face of extreme weather events and extreme heat.

T*ADD Section C303.1.5 to Chapter 3 General*

C303.1.5 Roof solar reflectance and thermal emittance

Low-sloped roofs directly above cooled conditioned spaces in Climate Zones 1a shall comply with one or more of the options in Table C402.3.

C402.3 Roof solar reflectance and thermal emittance.

Low-sloped roofs directly above cooled conditioned spaces in Climate Zones 1, 2 and 3 shall comply with one or more of the options in Table C402.3.

Exceptions: The following roofs and portions of roofs are exempt from the requirements of Table C402.3:

1. Portions of the roof that include or are covered by the following:

1.1. Photovoltaic systems or components.

1.2. Solar air or water-heating systems or components.

1.3. Roof gardens or landscaped roofs.

1.4. Above-roof decks or walkways.

1.5. Skylights.

1.6. HVAC systems and components, and other opaque objects mounted above the roof.

2. Portions of the roof shaded during the peak sun angle on the summer solstice by permanent features of the building or by permanent features of adjacent buildings.

3. Portions of roofs that are ballasted with a minimum stone ballast of 17 pounds per square foot [74 kg/m2] or 23 psf [117 kg/m2] pavers.

4. Roofs where not less than 75 percent of the roof area complies with one or more of the exceptions to this section.

TABLE C402.3MINIMUM ROOF REFLECTANCE AND EMITTANCE OPTIONS [a]

Three-year aged solar reflectance [b] of 0.55 (0.63 for Climate Zone 1A) and 3-year aged thermal emittance [c] of 0.75
Three-year-aged solar reflectance index [d] of 64 (75 for Climate Zone 1A)

[a.] The use of area-weighted averages to comply with these requirements shall be permitted. Materials lacking 3-year-aged tested values for either solar reflectance or thermal emittance shall be assigned both a 3-year-aged solar reflectance in accordance with Section C402.3.1 and a 3-year-aged thermal emittance of 0.90.

[b.] Aged solar reflectance tested in accordance with ASTM C1549, ASTM E903 or ASTM E1918 or CRRC-1 Standard.

[c.] Aged thermal emittance tested in accordance with ASTM C1371 or ASTM E408 or CRRC-1 Standard.

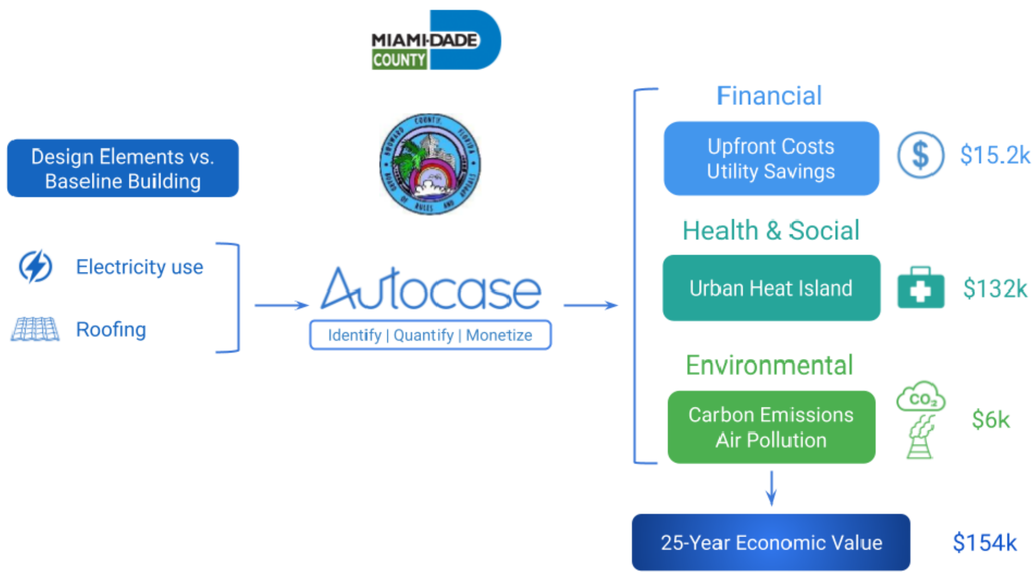
[d.] Solar reflectance index (SRI) shall be determined in accordance with ASTM E1980 using a convection coefficient of 2.1 Btu/h · ft2 ·°F (12W/m2 · K). Calculation of aged SRI shall be based on aged tested values of solar reflectance and thermal emittance.

Autocase

Triple Bottom Line Analysis of a Cool Roof Policy Proposal

Project Overview and Analysis Results

Miami-Dade and Broward County Boards of Rules and Appeals are committed to providing education and interpreting building codes, and when necessary, proposing building code modifications based on informed, responsible economic investment, to ensure the welfare and safety of building inhabitants and surrounding communities. A business case tool was utilized by Autocase to monetarily quantify and value the economic benefits of proposed cool roof requirement changes to augment current building standards. The analysis demonstrated a lifetime economic value of the proposed roofing policy of $154,100 over 25 years for a prototypical 5,000 square foot commercial building with thermoplastic membrane roofing installed, when comparing a dark roof with a solar reflectance (SR) of 5% to a cool roof with a SR of 63%.



Key Results

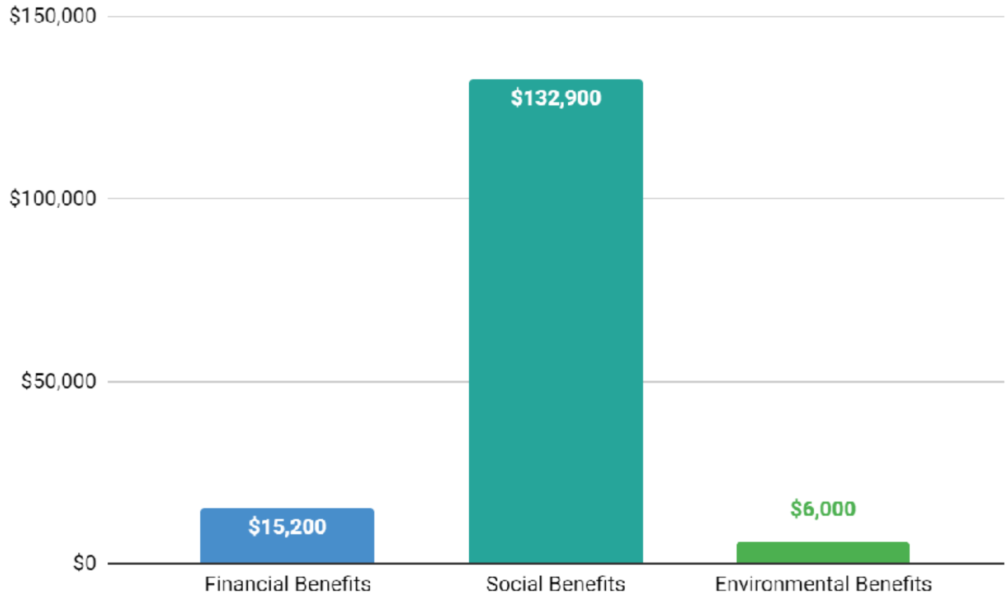
Using data provided by peer-reviewed literature, the Autocase tool was able to quantify the triple bottom line economic value of the cool roof policy intervention proposed by Miami-Dade and Broward Counties. Over a 25-year operational period, the new requirements would provide the following benefits for one prototypical 5,000 square foot commercial building with thermoplastic membrane roofing installed:

- Direct Financial Savings ("in pocket") of **$15,200**
- Health & Social Benefits amounting to **$132,900**
- Environmental Benefits of **$6,000**
- Triple Bottom Line Total Economic Benefits estimated at **$154,100** for one 5,000 square foot building.

The benefits of the proposed roofing policy would apply to more than one building in actuality. Therefore, if one assumes a hypothetical situation where the policy is applied to 500 commercial buildings, the lifetime benefits for this scenario could be extrapolated to $77 million of economic value over 25 years for a pool of 500 prototypical 5,000 square foot commercial buildings with thermoplastic membrane roofing installed.

Triple Bottom Line Detailed Results

Figure 1: Net Present Value of Economic Impacts - Cool Roof SR: 5% to SR: 63% over 25 years ($2021)



Financial Benefits: Lower electricity consumption through reduced cooling loads offered by the cool roof provides electricity bill savings estimated at $15,200. Lower peak electricity demand also helps electric utility providers avoid expensive power purchases from other utilities on the open market.

Health & Social Benefits: Choosing a high reflective roof material will also reduce the surrounding ambient temperature of the building and benefit the community in terms of avoided heat related illnesses estimated at $132,900.

Environmental Benefits: Lowering electricity consumption reduces the local climate and health impacts from carbon dioxide emissions and other air pollutants generated by the local electrical grid worth $6,000 in combined total savings.

To better understand the cost impacts stemming from the proposed cool roof policy as compared to standard dark roof surfaces, the results are further segmented into respective low-slope roofing categories in Table 1 (below), along with the expected cost premiums for installing high reflective surfaces. This scenario is meant to capture the holistic triple bottom line economic impacts from mandating cool roofs with a SR value of 63%, as compared to a dark roof with a SR value of 5%.

High reflective roofing can have significant impacts on the operational costs of a building and has the potential to reduce cooling loads by 55%. For example, a building with a dark roof is expected to require 8.4 kBtu/ft² per year to cool the space, as compared to 3.7 kBtu/ft² per year if a cool roof with a SR of 63% was installed (Oak Ridge National Laboratory, 2020).

There was a positive return on investment for all three types of roofs analyzed (see Table 1). Even in the cases that a cool roof is slightly more costly upfront to install (as compared to dark roof surfaces), such additional expenditures are paid back through financial savings from electricity bills, reduced urban heat island effect, as well as by avoiding electrical grid related air pollution, including carbon emissions.

Most low slope commercial roofs currently use single-ply roof coverings such as Thermoplastic Polyolefin (TPO) and Polyvinyl Chloride (PVC), and other thermoplastic membrane roofing products which represent over 58% of new construction roof systems (NRCA, 2015), most of which already meet the proposed level of performance. Therefore, implementing this change will have no cost effect on single-ply roof projects. There are no cost premiums associated with these types of installations since a white or light colored surface can be chosen at no additional charge (U.S. Department of Energy, 2010) and these roofing materials are widely available.

Built-Up Roofs require an upgraded mineral surfaced cap sheet that increase material costs, resulting in an expected premium of $0.50/ft². Modified Bitumen roofs that have an asphalt coating require a field applied coating on top of the asphaltic coating that has an expected cost premium of $1.78/ft² (U.S. Department of Energy, 2010).

Table 1: Net Present Value (NPV) of Economic Impacts - Cool Roof SR: 5% to SR: 63% over 25 years ($2021)

Category	Stakeholder	Impact	Built-Up Roof - Mineral surfaced cap sheet	Thermoplastic Membranes	Modified Bitumen - Asphalt coating
Financial	Owner	Upfront Capital Costs	-$2,500	$0	-$8,900
Financial	Owner	Financial Savings from Electricity	$15,200	$15,200	$15,200
Social	Community	Health - Heat Island Effect	$132,900	$132,900	$132,900
Environmental	Community	Carbon Emission Reductions	$4,000	$4,000	$4,000
Environmental	Community	Air Pollution Reductions	$2,000	$2,000	$2,000

Financial Benefits	$12,700	$15,200	$6,300
Social Benefits	$132,900	$132,900	$132,900
Environmental Benefits	$6,000	$6,000	$6,000

Triple Bottom Line Lifetime Benefits	**$151,600**	**$154,100**	**$145,200**
Financial Return on Investment (ROI)	**506.1%**	**N/A**	**70.2%**

The built-up roof with a mineral surfaced cap sheet has a financial return on investment of 506.1% and a financial payback period of 5 years and 6 months, resulting in a total NPV/ft² of $30.32/ ft².

Since the thermoplastic membranes do not have a cost premium, the return on investment and payback period cannot be calculated, however the total NPV/ft² for this roof type is $30.82/ ft².

The modified bitumen with an asphalt coating has a financial return on investment of 70.2% and a financial payback period of 15 Years and 8 Months, resulting in a total NPV/ft² of $29.04/ ft².

There is currently no minimum solar reflectance requirement in the Florida Building Code (FBC), as the prescriptive path is optional. The prescriptive path option of the FBC includes a SR value of 55%, which is considered to be the typical minimum cool roof requirement according to the U.S. Department of Energy (U.S. DOE, 2010). Since the policy proposes a marginal increase in the SR value to 63% (from a SR of 55%), there is no expected cost premium based on extensive research across available literature and industry sources, as reflected by the $0 upfront capital cost line item in Table 2 (below).

The proposed cool roof policy, mandating a solar reflectance (SR) value of 63%, led to a lifetime triple bottom line value of $23,620 in economic benefits over 25 years, when compared against the SR value of 55% included in the optional Florida Building Code prescriptive path.

Table 2: Net Present Value (NPV) of Economic Impacts - Cool Roof SR: 55% to SR: 63% over 25 years ($2021)

Category	Stakeholder	Impact	Net Present Value (NPV)	$ NPV / ft²
Financial	Owner	Upfront Capital Costs	$0	$0.00
Financial	Owner	Financial Savings from Electricity	$2,090	$0.42
Social	Community	Health - Heat Island Effect	$20,700	$4.14
Environmental	Community	Carbon Emission Reductions	$550	$0.11
Environmental	Community	Air Pollution Reductions	$280	$0.06
Financial Benefits			$2,090	$0.42
Social Benefits			$20,700	$4.14
Environmental Benefits			$830	$0.17
Triple Bottom Line Lifetime Benefits			**$23,620**	**$4.73**

Appendix: Key Inputs & Assumptions

Basic Project Assumptions

This analysis assumes the prototypical commercial building to have a gross floor area of 5,000 ft^2.

This project has been evaluated over a 25 year operational period. In order to account for the time value of money, Autocase displays project results in terms of net present value, discounting all year-over-year impacts at a real discount rate of 3% with all results presented in 2021 dollars.

Inputs for Proposed Cool Roof Policy - SR: 5% to SR: 63%

Impact Category	Design Element	Baseline Building	Built-Up Roof - Mineral surfaced cap sheet	Thermoplastic Membranes	Modified Bitumen - Asphalt coating	Units
Roofing	Cost Premiums	$0.00	$0.50	$0.00	$1.78	$/ft²
Roofing	Solar Reflectance (SR)	5%	63%	63%	63%	SR
Roofing	Solar Reflectance Index (SRI)	5.5	76	76	76	SRI
Energy	Electricity Use Intensity (EUI) - Cooling Load	8.36	3.73	3.73	3.73	EUI (kBtu/ft²)

Inputs for Proposed Cool Roof Policy - SR: 55% to SR: 63%

Impact Category	Design Element	Baseline Building	Cool Roof Proposal	Units
Roofing	Cost Premiums	$0.00	$0.00	$/ft²
Roofing	Solar Reflectance (SR)	55%	63%	SR
Roofing	Solar Reflectance Index (SRI)	65	76	SRI
Energy	Electricity Use Intensity (EUI) - Cooling Load	4.37	3.73	EUI (kBtu/ft²)

External Research Conducted

To estimate the expected cost premiums from installing a roof with higher reflectivity, external research was conducted by leveraging government literature and contacting roofing industry professionals including the Royal American Management and Single Ply Roofing Industry (SPRI) organizations.

According to Senior Code Officers in the County, it is expected that built-up roofs require an upgraded energy performing cap sheet resulting in a 20% material cost increase for most projects.

Upfront capital costs for other roofing types were estimated from the guidelines for selecting cool roofs published by the U.S. Department of Energy (2010), which analyzed the cost premiums associated with installing a high reflective cool roof over a traditional dark roof surface. In addition, to inflate such cost estimates from 2010 dollars to 2021 dollars, the U.S. Bureau of Labor Statistics (BLS) (2021) was leveraged to estimate year-over-year increases in the expected cost of roofing materials.

Cooling load energy use estimates for operating the building with a dark roof and various cool roofs (SRs of 5%, 55%, and 63%) were collected from the Cool Roof Calculator released by the U.S. Department of Energy's Oak Ridge National Laboratory (2020) that outlined the expected amount of electricity required to operate and cool the building on an annual energy use intensity basis ($kBtu/ft^2$).

To calculate the solar reflective indexes (SRIs) from the various solar reflectance values given by the project team, the SRI calculator from Lawrence Berkeley National Laboratory (2014) was used.

About Autocase

Autocase uses cost benefit analysis for translating economic impacts into triple bottom line metrics. Autocase believes in the contribution of economics, and specifically Triple Bottom Line Cost Benefit Analysis (TBL-CBA), to the optimal design of buildings and infrastructure. We have performed economic analyses for a multitude of private and public sector clients such as Pratt Whitney, Arup, Stantec, HOK, Corgan, Gensler, Burohappold Engineering, EPCOR Utilities, Dallas Fort Worth International Airport, Hartsfield-Jackson Atlanta International Airport, San Francisco International Airport, Port of Long Beach New York, City of San Antonio, City of Vancouver, Los Angeles County, and many more.

Learn more at: https://autocase.com

Works Cited

Lawrence Berkeley National Laboratory. (2014). SRI Calculator. Heat Island Group. Retrieved from: https://heatisland.lbl.gov/resources/technical-resources

National Roofing Contractors Association (NRCA). (2015). NRCA Market Survey. Retrieved from: https://industry.nrca.net/eWeb/DynamicPage.aspx?webcode=NRCAStorePrdDetails&site=nrca&es3_key=0bcb33c9-8df5-4300-bdce-9f35dcc4cac4&prd_key=1E588B2F-D314-450D-AA05-1190258C06B3

Oak Ridge National Laboratory. (2020). Cool Roof Calculator. Innovations in Buildings. Retrieved from: https://web.ornl.gov/sci/buildings/tools/cool-roof/

U.S. Department of Energy. (2010). Guidelines for Selecting Cool Roofs. Energy Efficiency & Renewable Energy. Building Technologies Program. Retrieved from: https://www.energy.gov/sites/prod/files/2013/10/f3/coolroofguide.pdf

U.S. Bureau of Labor Statistics (BLS). (2021). Databases, Tables & Calculators by Subject. BLS - PPI industry data for Other concrete product manufacturing-Precast concrete slabs and tile, roof and floor units, not seasonally adjusted. Retrieved from: https://beta.bls.gov/dataViewer/view/timeseries/PCU32739032739011

City of Miami

ASAEL ACE MARRERO, RA, RID, AIA, ICC
Building Director

ARTHUR NORIEGA, V
City Manager

January 13, 2022

Mr. Mo Madani
Florida Building Commission
2601 Blair Stone Road
Tallahassee, FL 32399-1027

Dear Mr. Madani,

The City of Miami supports proposed cool roof modifications to 2023 Florida Energy Conservation Code for Climate Zone 1A., as submitted to the Florida Building Commission by Broward County/Miami-Dade County BORA. The proposal will save money over the long-term for commercial building owners and tenants, help maintain comfortable indoor air temperatures for occupants, and reduce ambient air temperatures that endanger community health.

Tested and certified cool roof materials with the reflectance specifications contained in the proposal are widely available and typically cost no more than equivalent products with lower specifications. Even in those few circumstances where there might be a greater initial expense, it would be offset by cumulative savings from lower cooling costs over the long term. Cost savings in the southern region of Florida are multiplied greatly because cooling is needed year-round and little energy for heating is needed during winter. Cool roof materials also extend roof service life, generating further savings to property owners.

We also support these "cooler" roof code changes because heat issues are becoming a serious public health concern in Climate Zone 1A. The proposed code changes will ensure that more solar energy is reflected away from heat-retaining concrete and asphalt in our community's built environment. By retaining and emitting heat, these materials can significantly raise ambient heat levels across the landscape and heat-related health risks to residents, especially outdoor workers and people without sufficient air conditioning or ventilation. Studies have shown that cool roofs can reduce average urban heat intensity by approximately 23% and have the potential to limit dangerous extreme temperatures during heatwaves.

The Florida Building Code exists to ensure the general welfare, health, and safety of building inhabitants and surrounding communities. The proposed code modifications advance these goals and will provide meaningful economic and public health benefits. For these reasons, we support the proposed Cool Roof modifications to the 2023 Energy Conservation Code for Climate Zone 1A.

Yours sincerely,

Maurice Pons,
Building Official
City of Miami Building Department

cc: Broward County Board of Rules and Appeals, James Dipietro (JDiPietro@broward.org)
Miami-Dade County Board and Code Administration Division, Jaime Gascon Jaime.Gascon@miamidade.gov)

BROWARD COUNTY
Board of Rules & Appeals
ONE NORTH UNIVERSITY DRIVE, SUITE 3500-B, PLANTATION, FLORIDA 33324
PHONE (954) 765-4500 FAX: (954) 765-4504
http://www.broward.org/codeappeals

To: Mo. Madani, Technical Director, DBPR Building Codes and Standards Office

From: James Dipietro

Date: January 19, 2022

RE: Miami Dade County "Cool Roof" Code Modification Proposal

Please accept this letter from staff as an endorsement of the proposed "cool roof" modification to 2023 Florida Energy Conservation Code for Climate Zone 1A, as submitted to the Florida Building Commission by Miami-Dade County BORA.

Since 1999, several widely used building energy-efficiency standards, including ASHRAE 90.1, ASHRAE 90.2, the International Energy Code, and California's Title 24 have adopted cool-roof credits or requirements. Manufactures have invested many hours doing research, development, and testing, of these products, and they are now easily obtained from all the major suppliers.

Over the last 20 years the FECC has increased the minimum efficiency standards for windows, doors, skylights, air conditioners, water heaters, and lighting fixtures. Sadly, the codes have basically ignored the great benefits of energy efficient roofing product materials by not setting minimum standards. Many designers are now aware of these benefits and are specifying these products on new commercial buildings because of the significant long-term savings. As code officials, we must set minimum standards for construction materials and cannot ignore the cost savings and benefits of using a "cool roof" roofing product anymore. These cost savings in Broward County Florida are multiplied greatly because cooling is needed year-round and little energy for heating is needed during winter. Cool roof materials also extend roof service life, generating further savings to property owners.

The Florida Building Code exists to ensure the general welfare, health, and safety of building inhabitants and surrounding communities. The proposed code modifications advance these goals and will provide meaningful economic and public health benefits. For these reasons, we support the proposed Cool Roof modifications to the 2023 Energy Conservation Code for Climate Zone 1A.

Respectfully,

James Dipietro
Administrative Director
Broward County Board of Rules and Appeals
jdipietro@broward.org 954-765-4500 ext. 9892

FLORIDA DEPARTMENT OF
Business & Professional Regulation

Florida dbpr

Proposed Code Modifications
USER: Estela Tost

OFFICE OF THE SECRETARY

* Required fields

Modification #	EN9903-G10
Name	Estela Tost
Address	8500 SW 117 Avenue Suite 120
City	Miami
State	FL
Zip Code	33183
Email	estelat@baptisthealth.net
Primary Phone	(305) 903-9471
Alternate Phone	(786) 594-6913
Fax	
Code Change Cycle	2023 Triennial First Comment Period 03/03/2022 - 04/17/2022
Code Version	2023
Sub Code	Energy Conservation
Chapter & Topic	Chapter 3 - [RE] - General Requirements
Section	303.1.5
	-

Status	Pending DBPR Review

General Comment*

I am in support of the proposed modification EN9903 for additional commercial cool roof requirements. The supporting documents and data validates that this change will support building owners and tenants in reduction of operating expenses while providing enhanced safety and health benefits

Upload Comment File

Date Submitted	04/14/2022

Department of Development Services
Building Division

CITY OF Hollywood FLORIDA

tel: 954.921.3335
fax: 954.921.3037

January 5, 2022

Mr. Mo Madani
Florida Building Commission
2601 Blair Stone Road
Tallahassee, FL 32399-1027

Dear Mr. Madani,

The City of Hollywood supports the proposed cool roof modifications to 2023 Energy Conservation Code for Climate Zone 1A, as submitted to the Florida Building Commission by Miami-Dade County. The proposal will save money over the long-term for commercial building owners and tenants, help maintain comfortable indoor air temperatures for occupants, and reduce outdoor ambient air temperatures that endanger community health.

Cool roof materials with the reflectance specifications contained in the proposal are widely available and typically cost no more than equivalent products with lower specifications. Even in those few circumstances where there might be a greater initial expense, it would be offset by cumulative savings from lower cooling costs over the long term. Cool roof materials also extend roof service life, generating further savings to property owners.

We also support these "cooler" roof code changes because heat issues are becoming a serious public health concern in Climate Zone 1A. The proposed code changes will ensure that more solar energy is reflected away from heat-retaining concrete and asphalt in our community's built environment. By retaining and emitting heat, these materials can significantly raise outdoor ambient heat levels across the landscape and increase heat-related health risks to residents, especially outdoor workers and people without sufficient air conditioning or ventilation. Studies have shown that cool roofs can reduce average urban heat intensity by approximately 23% and have the potential to limit dangerous extreme temperatures during heatwaves.

The Florida Building Code exists to ensure the health and safety of building inhabitants and surrounding communities and to support cost-effective maintenance and operation of structures. The proposed code modifications advance these goals and will provide meaningful economic and public health benefits. For these reasons, we support the proposed Cool Roof modifications to 2023 Energy Conservation Code for Climate Zone 1A.

2600 Hollywood Boulevard
P.O. Box 229045
Hollywood, Florida
33022-9045

hollywoodfl.org

Yours sincerely,

Russell A Long

Russell Long
Chief Building Official
Building Division, Development Services
City of Hollywood

cc: Broward County Board of Rules and Appeals, James Dipietro (JDiPietro@broward.org)
Miami-Dade County Board and Code Administration Division, Jaime Gascon (Jaime.Gascon@miamidade.gov)

DEPARTMENT OF DEVELOPMENT SERVICES
CITY OF POMPANO BEACH
BUILDING INSPECTIONS DIVISION
100 West Atlantic Boulevard – Room 360

Date: November 23, 2021

To: Broward County Board of Rules and Appeals

From: Michael Rada, Building Official

Subject: Energy Conservation Code Modification

Gentlemen.

Thank you for the opportunity for our Building Department to opine on the proposed modification to the Energy Conservation Code.

The municipality of the City of Pompano Beach has a current population of over 100,000 residents. We have districts of Commercial, Industrial and Residential use throughout our City and are experiencing very aggressive growth in all aspects of construction.

Our Leadership has maintained a progressive vision of sustainability for all future development within our City.

We believe the proposed modification to the Energy Conservation Code to adopt an increase in solar reflectance for all new Commercial roofs would have a huge impact on limiting greenhouse emissions and overall energy consumption.

We sincerely appreciate your consideration for allowing the City of Pompano Beach to support your endeavor.

Respectfully.

Michael Rada, Building Official
City of Pompano Beach

C:\Users\RADMIC\Desktop\BORA letter of support.doc 11/23/2021 11:17 AM

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN9845

8

Date Submitted	01/19/2022	**Section**	402.5	**Proponent**	Timothy de Carion
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Sub Code Section Mod# Why? Energy 402.5.9 EN8736 Original 402.5.9 Building cavities was replaced. Energy 402.5.10 NEW Maintain current Florida section from existing 402.5.9 by moving it to 402.5.10

Summary of Modification

Mod. clarifies mandatory sections referenced in C402.5. Previous section C402.5 included up to section C402.8 as mandatory provisions. C402.5 updates language to include "C402.5.1 through C402.5.10"

Rationale

Section C402.5.9 from current 2020 Energy code should remain as a mandatory provision of the building thermal envelope. Many designers assume an acoustical tile ceiling is an air barrier. This code section will address this violation and this section refers to the definition of air barrier. Without new section C402.10 as mandatory requirement, significant energy is wasted. Florida specific humidity and condensation problems occur around grills when vented or unvented cavities are not sealed airtight from the conditioned space. Drop ceilings shall not be used as an air barrier to vented and unvented cavities Without including section C402.5.9 from the current 2020 code, the drop ceiling cavities over T-bar ceilings would not be specifically addressed in the code. 1) Vented Cavities above drop ceilings with loose leaky tiles should not be used as an air barrier with an open ventilated or unventilated cavity to the outside of the building. (See air barrier definition.) 2) 402.5.10.2 addresses unvented Cavities above drop ceilings and the need to seal this area above a drop ceiling. 3) 402.5.10.3 addresses the free flow of air between tenants and the required air barrier. 4) 402.5.10.4 addresses cavities used as plenums that must be sealed airtight.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Building inspectors already require openings into the building's conditioned space to be sealed. No additional inspections will be needed.

Impact to building and property owners relative to cost of compliance with code

No impact

Impact to industry relative to the cost of compliance with code

No impact

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Propose modification prevents humidity, condensation, and mold issues from developing, which improves the health of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This code mod clarifies that cold air should remain in the conditioned space and hot humid air should be kept out of the conditioned space. It specifically addresses building cavities.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This code mod. does not discriminate against any product, methods or systems.

Does not degrade the effectiveness of the code

This code mod. does not degrade the effectiveness of the code.

C402.5 Air leakage—thermal envelope (Mandatory). The building thermal envelope shall comply with Sections C402.5.1 through C402.5.~~8~~ 10, or the building thermal envelope shall be tested in accordance with Section C402.5.1.2.3. Where compliance is based on such testing, the building shall also comply with Sections C402.5.5, C402.5.6 and C402.5.7.

C402.5.10 Building cavities.

C402.5.10.1 Vented dropped ceiling cavities. Where vented dropped ceiling cavities occur over conditioned spaces, the ceiling shall be considered to be both the upper thermal envelope and pressure envelope of the

building and shall contain a continuous air barrier between the conditioned space and the vented unconditioned space that is also sealed to the air barrier of the walls. See the definition of air barrier in Section C202.

C402.5.10.2 Unvented dropped ceiling cavities. Where unvented dropped ceiling cavities occur over conditioned spaces that do not have an air barrier between the conditioned and unconditioned space (such as T-bar

ceilings), they shall be completely sealed from the exterior environment (at the roof plane) and adjacent spaces by a continuous air barrier that is also sealed to the air barrier of the walls. In that case, the roof assembly shall

constitute both the upper thermal envelope and pressure envelope of the building.

C402.5.10.3 Separate tenancies. Unconditioned spaces above separate tenancies shall contain dividing partitions between the tenancies to form a continuous air barrier that is sealed at the ceiling and roof to prevent

airflow between them.

C402.5.10.4 Air distribution system components.

Building cavities designed to be air distribution system components shall be sealed according to the criteria for air ducts, plenums, etc., in Section C403.2.9.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

9

EN9963

Date Submitted	02/15/2022	**Section**	402.2.7	**Proponent**	Amanda Hickman
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

None

Summary of Modification

New Section: C402.2.7 Airspaces

Rationale

This modification provides language for reflective and non-reflective air spaces consistent with ASHRAE's Handbook of Fundamentals. Airspaces are common in building assemblies, but the term itself is not defined in the code. Airspaces are permitted to be counted as contributing toward satisfying the building envelope thermal requirements. Properly constructed airspaces can contribute to the thermal performance of an assembly. This section provides provisions for that purpose.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Yes, will improve enforceability of the code through clarification of airspace language.

Impact to building and property owners relative to cost of compliance with code

No impact to cost of compliance with the code. This is already common practice.

Impact to industry relative to the cost of compliance with code

No impact to cost of compliance with the code. This is already common practice.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, will ensure more energy efficiency.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes, codifies and clarifies common practice.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

No, it only clarifies an already common practice.

Does not degrade the effectiveness of the code

No, it only clarifies an already common practice.

C402.2.7 Airspaces. Where the R-value of an airspace is used for compliance in accordance with Section C402.1, the airspace shall be enclosed in an unventilated cavity bounded on all sides by building components.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN9972

10

Date Submitted	02/02/2022	**Section**	405.1	**Proponent**	Timothy de Carion
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Modification corrects a glitch in the 2020 code for missing lighting requirements for walk-in coolers. Section C403.2.14 has no lighting requirements for walk-in coolers. Section of C403.10.1 of the 2018 IECC was not adopted. Adding item #11 from Section C403.10.1 fixes this glitch.

Rationale

By deleting the wording in C405.1 about walk-in cooler/freezer lighting that sends you on a looking for lighting requirements that do not exist in the code, this fixes that glitch. By adding Section C405.1.1 (from IECC) for mandatory efficient lighting and the option of an occupancy sensor for non efficent lighting, it will fix this glitch, makes it easy to find, gives options, saves energy.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No additional inspections required.

Impact to building and property owners relative to cost of compliance with code

Energy efficient lighting has a proven long term pay back to the added initial cost. Options of a possible occupancy sensor will add to the long term savings. No need to have the lights remain on inside a walk-in cooler when it's not occupied and waste energy.

Impact to industry relative to the cost of compliance with code

See attached

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Modification will reduce electrical energy consumption so more would not have to be generated.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Fixes current glitch in the code.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Many products exist for compliance

Does not degrade the effectiveness of the code

No

1st Comment Period History

EN9972-G1

Proponent	pete quintela	Submitted	3/29/2022 12:24:28 PM	Attachments	No

Comment:

Appears to be glitch in the current code, approval of this proposed modification will fix current code. I recommend approval.

SECTION C405

ELECTRICAL POWER AND LIGHTING SYSTEMS

C405.1 General (Mandatory). This section covers lighting system controls, the maximum lighting power for interior and exterior applications and electrical energy consumption. Dwelling units within multifamily buildings shall comply with Section R404.1. All other dwelling units shall comply with Section R404.1, or with Sections C405.2.4 and C405.3. Sleeping units shall comply with Section C405.2.4, and with Section R404.1 or C405.3. ~~Lighting installed in walk-in coolers, walk-in freezers, refrigerated warehouse coolers and refrigerated warehouse freezers shall comply with the lighting requirements of Section C403.2.14.~~

C405.1.1 Walk-in cooler lighting

Lights in walk-in coolers, walk-in freezers, refrigerated warehouse coolers and refrigerated warehouse freezers shall either use light sources with an efficacy of not less than 40 lumens per watt, including ballast losses, or shall use light sources with an efficacy of not less than 40 lumens per watt, including ballast losses, in conjunction with a device that turns off the lights within 15 minutes when the space is not occupied.

WARELIGHT

PROJECT NAME: ______________________ CATALOG NUMBER:____________________
NOTES:_______________________ FIXTURE SCHEDULE:__________________________

WARELIGHT LED VAPOR TIGHT

WareLight LED vapor tight fixtures are designed to save energy and meet your lighting requirements in harsher than normal environments. They are vandal resistant and can be used indoors or outdoors. They provide superior light distribution and are intended for applications where moisture and/or dust may be present.

FEATURES:

- Wattage available: 20W, 38W and 52W
- Lifetime: 100,000 Hours
- Warranty: 5 Years
- Stainless steel latches
- The 0-10V Dimming type is continuous
- The product can dim to 10%
- Voltage: 120-277V
- CRI: 80
- CCT: 5000K
- Efficacy: 131Lm/W
- DLC Premium Listed
- IP66 Rated
- UL 1598 suitable for wet locations
- UL 8750 LED equipment in Lighting Products
- Temperature Rated at (-40°C to +50°C)(-40°F to 122°F)

MOUNTING OPTIONS:

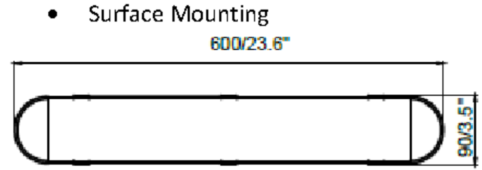
- V-Hook ready
- Surface Mounting

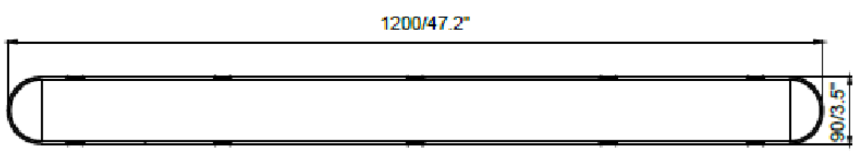
APPLICATIONS:

- Cold storage locations
- Food processing locations
- Parking structures
- Industrial locations
- Metal/Wood Shops

SPECIFICATIONS:

2FT
Length: 23.6"
Width: 3.5"
Depth: 3.1"
Weight: 3.31 lbs
4FT
Length: 47.2"
Width: 3.5"
Depth: 3.1"
Weight: 4.41 lbs





WAREHOUSE-LIGHTING.COM

Warehouse-Lighting.com
2750 South 163rd St
New Berlin, WI 53151

Warehouse-Lighting.com
Phone: 888-454-4480
info@warehouse-lighting.com

WARELIGHT

LED WARELIGHT WRAP LIGHTS					
Series and Length	LED	Wattage	CCT Temperature	0-10V Dimming	Multi-Volt
WL-VT2- WL-VT4- WL-VT4-	LED-	20W- 38W- 52W-	50K-	DM010-	MV

Performance and Certification Information (120v)

Series	DLC ID	DLC Casting Watts	DLC Rated Lm	Listings
WL-VT2-LED-20W-50K-DM010-MV	PLZ0XRPM20VP	20W	2620	UL, DLC
WL-VT4-LED-38W-50K-DM010-MV	PL2NDCTO8LM6	38W	4978	UL, DLC
WL-VT4-LED-52W-50K-DM010-MV	PLD8NJBF8F2J	52W	6812	UL, DLC

WAREHOUSE-LIGHTING.COM

Warehouse-Lighting.com
2750 South 163rd St
New Berlin, WI 53151

Warehouse-Lighting.com
Phone: 888-454-4480
info@warehouse-lighting.com

OSFHU-CTW

Occupancy Sensor, Fixture Mount, PIR, High Bay, 2 Interchangeable Lenses and Aisle Mask, Cold Storage Model, White

High-Bay Fixture Mount Occupancy Sensor lighting control, Adjustable 360° Low Bay (8'-20') and High Bay (20'-40') Lenses, Aisle Mask, Cold Storage, Passive Infrared Technology, 120/208/220/230/240/277/347V; 50/60Hz. Quick-snap threaded nipple, Instant Start-up, Return-to-last state after power outage, Auto-Sensitivity gain from temperature increase, False-detection protection, Super Bright Green LED. USMCA Compliant, Commercial Grade - White, Title 24 Compliant, ASHRAE 90.1 Compliant

The OSFHU high-bay occupancy sensor is specifically designed for high mounted areas such as warehouses, manufacturing and other high ceiling applications. The OSFHU installs directly to an industrial fluorescent luminaire or an electrical junction box. It is a self-contained sensor and relay that turns individual light fixtures on or off based on occupancy in the detection zone. It comes with three interchangeable lenses for use in either a 360-degrees high-bay or 360-degrees low-bay general area or an aisle way. The OSFHU provides reliable coverage up to 40 ft. Mounting heights. The OSFHU is also available in a model for cold storage applications with temperatures as low as -40-degrees f. To improve the field-of-view for deep body fixtures, a separate offset adapter accessory (OSFOA-00W) can be used to position the sensor below the fixture body. The adapter simply snaps into a 1/2-inch knockout on the end of the industrial fixture to attach the sensor.

Color : White

UPC Code : 078477354377

Country Of Origin : Please Contact Customer Service.

Technical Information

Product Features

Application : Cold Storage, Aisle, Warehouses, Manufacturing facilities, High ceiling applications

Commissioning : Manual

Mounting : Fixture Mount

Product Line : OSFHU

Sensor Technology : Passive Infrared (PIR)

Sensor Type : Occupancy

Time Delay : 30s-20m

Mechanical Specifications

Color : White

Construction : High-impact, injection molded plastic housing

Grade : Commercial

Mounting Type : Fixture Mount

Sensor Mounting Configuration : External

Size : Height 3.50" (8.99mm), Width 3.50" (8.99mm), Depth 1.25" (30.75mm)

Performance Specifications

Coverage (Sq.Ft.) : 8-40 FT

Pattern : 360°

Electrical Specifications

Frequency : 50/60Hz

Load Rating : 800VA @ 120VAC Ballast, 1200VA @ 277VAC Ballast, 1500VA @ 347VAC Ballast, 2000VA @ 480VAC Ballast, Motor: 1/4 HP Load @ 120V

Neutral Wire Connection : Required

Voltage : 120-347 VAC

Wiring : Line-Black, Load-Red, Neutral-White

Standards and Certifications

Listings : UL and CUL Listed (OSFHU models). Can be used to comply with IECC, ASHRAE 90.1, and Title 24, Part 6 occupancy sensing requirements.

Title 24 Compliant : Yes

Environmental Specifications

Environment : Cold Storage

Relative Humidity : 20% to 90% non-condensing

Storage Temperature Range : -40° to 160°F (-40° to 71°C)

Type

Product Type : Occupancy Sensor

Warranty

Warranty : 5-Year Limited

Features and Benefits

- Quicksnap: built into the 1/2" nipple, this locking mechanism allows for the fastest and easiest mounting not requiring a threaded lock-nut
- Reduce time and materials: easily reach the ballast at either end of the fixture without requiring more wire or connectors with the included 21" wire leads
- Fast, easy time delay setting: can be set at any time without requiring power to the sensor; time delay is variable from 30s-20m
- Instantly verify fixture operation and wiring connections: "instant ON" closing relay fires lamps in under 5 seconds
- High Inrush Stability (H.I.S. Technology): Zero crossing circuitry optimizes relay operation for reliable, long-life operationRobust mechanical latching relay is durable for all load types
- Adjusts the PIR sensitivity as ambient temperature rises to increase detection of heat movement through the field-ofview
- Return to last state: for safety and energy savings, the OSFHU contains a latching relay so that in the event power is lost to the device, the device will return to the last known state of the relay
- False detection intelligence: for increased energy savings and to mitigate nuisance tripping, the super bright LED indicates advanced detection has been activated and the lights will only turn ON when true occupancy has been determined

SPECIFICATION SUBMITTAL

JOB NAME:	CATALOG NUMBERS:	
JOB NUMBER:		

Leviton Manufacturing Co., Inc.
201 North Service Road, Melville, NY 11747
Telephone: +1-800-323-8920 · FAX: +1-800-832-9538 · Tech Line (8:30AM-7:30PM E.S.T. Monday-Friday): +1-800-824-3005

Leviton Manufacturing of Canada, Ltd.
165 Hymus Boulevard, Pointe Claire, Quebec H9R 1E9 · Telephone: +1-800-469-7890 · FAX: +1-800-824-3005 · www.leviton.com/canada

Leviton S. de R.L. de C.V.
Lago Tana 43, Mexico DF, Mexico CP 11290 · Tel.: (+52)55-5082-1040 · FAX: (+52)5386-1797 · www.leviton.com.mx

Visit our Website at: www.leviton.com

Leviton has a global presence.
If you would like to know where your local Leviton office is located please go to: www.leviton.com/international/contacts/

EN9972Impact Statement

Leviton OSFHU-CTW High Bay Occupancy Sensor

★★★★★ (3)

- Fast, simple installation
- Zero-crossing circuitry
- Green LED indicates occupancy detection
- Interchangeable lenses for 360 degrees high-bay, 360 degrees low-bay, and aisle way patterns
- The aisle lens is designed to provide detection of 60 ft. long by 20 ft. wide for heights up to 40 ft. mounting

Buying options

About this page

$64.41
+$4.51 est. tax
Free delivery
Free 90-day returns
Home Depot
Trusted store · 4.6/5 ★ (1.5K)
Visit site

$62.00
+$0.00 est. tax
$13.86 delivery by Tue, Feb 8
Energy Avenue
Visit site

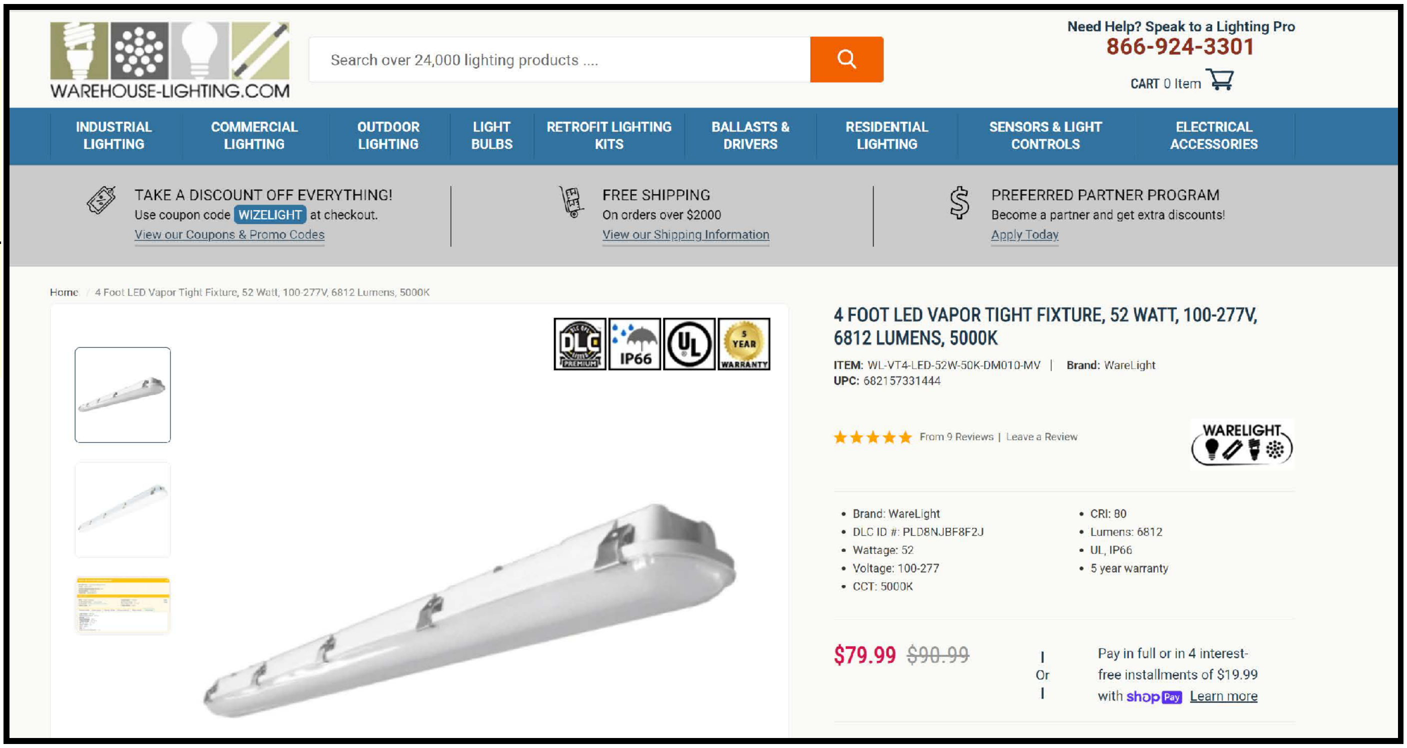
LOW PRICE
$52.92
+$0.00 est. tax
$11.40 delivery by Wed, Feb 9
Gordon Electric Supply
4.8/5 ★ (1.9K store reviews)
Visit site

Compare prices from 10+ stores

Page: 1

Mod_9972_Impact_sensor price.pdf

EN9972Impact Statement



Page: 1

Mod_9972_Impact_led fix price.pdf

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN9974

11

Date Submitted	02/02/2022	**Section**	405.9	**Proponent**	John Hall
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

None

Summary of Modification

This modification creates new section C405.9 to require electric vehicle charging equipment (EVSE) in all new commercial construction. The number of EV Ready and EV Capable parking spaces required would be determined by the attached chart that is part of the modification.

Rationale

Florida is ranked number two in the United States for the number of registered electric vehicle as of the latest ranking in June 2021. EVs provide significant economic benefits for consumers through fuel and maintenance cost savings, and have been identified as a key climate strategy to reduce GHG emissions from the U.S. transportation sector. The interest in EVs has grown alongside greater EV model availability and increased vehicle range. Every major auto manufacturer in the world has announced a plan to electrify a significant portion of their vehicle fleets over the next 3-5 years. Ford recently announced an $11 billion investment to reach their goal of 40 EV models by 2022. The goal for GM: 20 EV models by 2023; for VW: 27 EV models by 2022; for Toyota: 10 BEVs by the early 2020's; and similar goals for Volvo, Daimler, Nissan, BMW, and Fiat-Chrysler. However, the lack of access to EV charging stations continues to be a critical barrier to EV adoption. In particular, there are significant logistical barriers for commercial building tenants to upgrade existing electrical infrastructure and install new EV charging stations. A lack of pre-existing EV charging infrastructure, such as electrical panel capacity, raceways, and pre-wiring, can make the installation of a new charging station cost-prohibitive for a potential EV-owner. The installation of an EV charging station is made three to four times less expensive when the infrastructure is installed during the initial construction phase as opposed to retrofitting existing buildings to accommodate the new electrical equipment.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This modification will increase the number of inspections to be performed. The cost of enforcement will be offset by permit fees.

Impact to building and property owners relative to cost of compliance with code

The proposed modification increases the cost of construction. Costs for new EV Capable parking spaces i range from $300 to $850 per space. Costs for new EV Ready spaces range from $800 to $1300. The cost for EVSE retrofit in can be three or more times the cost of installations in new construction.

Impact to industry relative to the cost of compliance with code

Industry will likely benefit from this modification. Industry is adjusting by adopting a business model that involves installation, maintenance, and operation by an off site entity that then shares a portion of the revenue with the property or business owner.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This modification provides an additional resource to reduce greenhouse gas emissions from petroleum fueled vehicles, thus contributing to the reduction in the effects of climate change, which has been identified as a hazard too the health and welfare of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This modification strengthens the code by providing guidance on the installation electric vehicle service equipment.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This modification does not discriminate against any materials, products, methods, or systems of construction of demonstrated capabilities.

Does not degrade the effectiveness of the code

This modification does not degrade the effectiveness of the code. To the contrary, this modification provides guidance on the installation of electric vehicle service equipment.

Alternate Language

1st Comment Period History

EN9974-A1

Proponent	Bryan Holland	**Submitted**	3/28/2022 5:20:22 PM	**Attachments**	Yes

Rationale:
This alternative proposed modification makes a few minor revisions to the original proposed modification. This includes editorial revisions to the definitions and the rules to provide technical clarity. Otherwise, NEMA fully supports the concept of EV-ready provisions in the FBC-EC as proposed and substantiated in the original proposed modification. NEMA urges the TAC(s) and Commission approve this proposed modification.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This alternative proposed modification provides clear and enforceable language for the AHJ.

Impact to building and property owners relative to cost of compliance with code

This alternative proposed modification will increase the cost of compliance for buildings/property owners at time of initial construction while reducing the cost of compliance for an existing building that does not have the capacity or infrastructure in-place for the installation of EVSE.

Impact to industry relative to the cost of compliance with code

This alternative proposed modification will increase the cost of compliance for industry.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This alternative proposed modification improves the general welfare of the public as the electrification of transportation becomes a fundamental of modern society.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This alternative proposed modification improves the code.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This alternative proposed modification does not discriminate against materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

This alternative proposed modification improves the code.

1st Comment Period History

EN9974-G1

Proponent	John Hall	Submitted	3/31/2022 10:35:28 AM	Attachments	No

Comment:

I support the alternate language comment submitted by Bryan Holland and endorse it's submission to the TAC(s) for consideration of inclusion in the 2023 FBC.

1st Comment Period History

EN9974-G2

Proponent	Susannah Troner	Submitted	4/12/2022 11:24:34 PM	Attachments	No

Comment:
Writing to express strong SUPPORT for proposed code modification EN 9974. The transportation sector, dominated by traditional internal combustion engine vehicles, currently generates 55% of our community’s carbon pollution. EVs greatly reduce this pollution. Therefore this code modification will help minimize future impacts such as sea level rise and intensification of storms that are associated with carbon pollution (GHGs). These pollution reductions

resulting from the code change will lead to community health and safety benefits which are core objectives of the Florida Building Code. Our office is fielding more inquiries every day from stakeholders regarding the lack of EVSE and standardization and perceived costs. It is time to standardize the process and require EV Ready Spaces and EV Capable Spaces for new commercial construction. This will help prevent future EVSE scarcity and extreme costs associated with facility retrofits.

1st Comment Period History

EN9974-G3

Proponent	kamrath christian	Submitted	4/13/2022 12:35:56 PM	Attachments	No

Comment:

I am writing to express strong SUPPORT for proposed code modification EN 9974. The transportation sector, dominated by traditional internal combustion engine vehicles, generates 55% of our community's carbon pollution. EVs greatly reduce this pollution and help create healthier environments. And we need to be doing everything we can to reduce carbon pollution faster to stem the accelleration of rising water levels and climate disruption. Therefore this code modification will help minimize future impacts such as sea level rise and intensification of storms that are associated with carbon pollution (GHGs). Pollution reductions resulting from the code change will lead to community health and safety benefits which are core objectives of the Florida Building Code. Our County's office is fielding more inquiries every day from stakeholders regarding the lack of EVSE and standardization, and perceived costs. It is time to standardize the process and require EV Ready Spaces and EV Capable Spaces for new commercial construction. This will help prevent future EVSE scarcity and extreme costs associated with facility retrofits.

1st Comment Period History

EN9974-G4

Proponent	Matthew Chen	Submitted	4/13/2022 4:44:23 PM	Attachments	No

Comment:

SemaConnect, a leading provider of EV charging solutions with many EVSE projects in Florida, supports proposed code modification EN 9974, which establishes modest but necessary EVSE commercial requirements for new construction. We also support the proposed alternative modification submitted by Bryan Holland. We respectfully recommend inclusion of the proposed alternative modification in the 2023 Florida Building Code.

1st Comment Period History

EN9974-G5

Proponent	Nicholas Gunia	Submitted	4/14/2022 10:09:32 AM	Attachments	No

Comment:

As past Chair of the Miami Branch of the South Florida Chapter of the US Green Building Council, I am writing to voice my support for EN10370 for requiring new commercial to have EVSE. I believe the proposed changes will help future-proof our commercial buildings given the rise of EVs. As such, the proposed changes should be adopted.

1st Comment Period History

EN9974-G6

Proponent	Amanda Hickman	Submitted	4/14/2022 11:16:08 AM	Attachments	No

Comment:

LBA does not support the modification, as it is not appropriate for Florida and/or is not cost justified.

1st Comment Period History

EN9974-G7

Proponent	Jared Walker	Submitted	4/14/2022 2:25:00 PM	Attachments	No

Comment:

EN 9974 - Electric vehicle charging infrastructure (EVSE) commercial requirements The Electrification Coalition (EC) is a national, nonpartisan, not-for-profit organization committed to promoting policies and actions that facilitate the deployment of electric vehicles on a mass scale to combat the national security, economic, and public health impacts associated with our nation's dependence on oil. The EC SUPPORTS proposed code modification EN 9974, establishing modest but necessary EVSE commercial requirements for new construction. Mass adoption of EVs is key to addressing the U.S.'s reliance on oil, which currently powers 91% of our nation's transportation system. Not only will ongoing transportation electrification policies such as Miami Dade's code modification (EN 9974) accelerate EV adoption, but fostering investments in the future of electric transportation will be a boon to Miami-Dade's economy and job growth.

1st Comment Period History

EN9974-G8

Proponent	Estela Tost	Submitted	4/14/2022 6:56:52 PM	Attachments	Yes

Comment:

I am in support of EN9974 Electrical Vehicle Charging Station infrastructure for new commercial construction

1st Comment Period History

EN9974-G9

Proponent	Richard Logan	Submitted	4/15/2022 9:57:28 AM	Attachments	No

Comment:

AIA Florida supports this code modification with the alternate language

1st Comment Period History

EN9974-G10

Proponent	James Ellis	Submitted	4/15/2022 2:34:08 PM	Attachments	No

Comment:

EV Connect, a leading electric vehicle infrastructure network and services provider with many EVSE projects in Florida, SUPPORTS proposed code modification EN 9974, which establishes modest but necessary commercial EVSE requirements for new construction. EV Connect encourages this body to consider diversity of electric supply for more than 10 parking spaces in accordance with 2017 NFPA 70. Please Note: An omission of the number "20" in Table C405.9.2.1 under Total Number of Parking Spaces requires revision for clarity.

1st Comment Period History

EN9974-G11

Proponent	Sandra St. Hilaire	Submitted	4/15/2022 2:44:53 PM	Attachments	No

Comment:

Writing to express strong SUPPORT for proposed code modification EN 9974. The transportation sector, dominated by traditional internal combustion engine vehicles, generates 55% of our community's carbon pollution. EVs greatly reduce this pollution. Therefore this code modification will help minimize future impacts such as sea level rise and intensification of storms that are associated with carbon pollution (GHGs). Pollution reductions resulting from the code change will lead to community health and safety benefits which are core objectives of the Florida Building Code. Our office is fielding more inquiries every day from stakeholders regarding the lack of EVSE and standardization, and perceived costs. It is time to standardize the process and require EV Ready Spaces and EV Capable Spaces for new commercial construction. This will help prevent future EVSE scarcity and extreme costs associated with facility retrofits.

1st Comment Period History

EN9974-G12

Proponent	Mike Gibaldi	Submitted	4/15/2022 4:50:58 PM	Attachments	No

Comment:

No brainer here. Our firm with hundreds of EVSE charging ports installed throughout the State, fully SUPPORTS this proposed code modification which establishes modest but necessary EVSE commercial requirements for new construction. This will encourage more emission-free driving in Florida which will in turn greatly reduce CO2 pollution.

1st Comment Period History

EN9974-G13

Proponent	Chris Sanchez	Submitted	4/15/2022 5:12:18 PM	Attachments	No

Comment:

I am strongly in favor of the proposed modifications to EN 9974. The transportation sector currently generates 55% of our community's carbon pollution. EVs greatly reduce this pollution by shifting from tail-pipe to electricity grid. Therefore this code modification will help minimize future impacts such as sea level rise and intensification of storms that are associated with carbon pollution (GHGs). Pollution reductions resulting from the code change will lead to community health and safety benefits which are core objectives of the Florida Building Code. Our office is fielding more inquiries every day from stakeholders regarding the lack of EVSE and standardization, and perceived costs. It is time to standardize the process and require EV Ready Spaces and EV Capable Spaces for new commercial construction. This will help prevent future EVSE scarcity and extreme costs associated with facility retrofits.

1st Comment Period History

EN9974-G14

Proponent	Marta Marello	Submitted	4/17/2022 4:02:30 PM	Attachments	No

Comment:

I express strong SUPPORT for proposed code modification EN 9974. It is time to standardize the process and require EV Ready Spaces and EV Capable Spaces for new commercial construction. As more EV models are coming onto the market and the share of EVs increases, it is important to integrate EVSE in buildings in a cost-effective way and avoid very costly retrofits. The transportation sector is the number one cause of our region's carbon pollution. EVs greatly reduce this pollution. Pollution reductions resulting from the code change will lead to community health and safety benefits which are core objectives of the Florida Building Code. Miami-Dade County's Office of Resilience has responded to an increasing number of inquiries from stakeholders regarding the lack of EVSE, EVSE standardization, and perceived costs.

C405.9. Electric Vehicle Service Equipment

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE). Equipment for plug-in power transfer including the ungrounded, grounded, and equipment grounding conductors, and the Electric Vehicle connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatus installed specifically for the purpose of transferring energy between the premises wiring and the Electric Vehicle.

EV CAPABLE SPACE. Electrical distribution equipment capacity and space to support a minimum 40-ampere, 208-volt or 240-volt branch circuit for each EV parking space, and the installation of necessary wiring methods and materials to supply *EVSE.*

EV READY SPACE. A designated parking space which is provided with one 40-ampere, 208-volt or 240-volt individual branch circuit for *EVSE* supplying *Electric Vehicles*. The circuit shall terminate in a suitable termination point such as a receptacle, outlet box, enclosure, or an *EVSE*, and be located in close proximity to the proposed location of the EV parking spaces.

C405.9.2. Electric Vehicle (EV) power transfer for new construction. New construction shall facilitate future installation and use of *EVSE* in accordance with the NFPA 70.

C405.9.2.1. New commercial buildings. *EV Ready Spaces* and *EV Capable Spaces* shall be provided in accordance with Table C405.9.1. Where the calculation of percent served results in a fractional parking space, it shall be shall rounded up to the next whole number. The electrical distribution equipment circuit directory shall identify the spaces reserved to support EV power transfer as “EV Capable” or “EV Ready”. The box or enclosure provided for future EVSE shall be marked “FOR EVS USE.” The marking shall comply with NFPA 70, Section 110.25

TABLE C405.9.2.1.

***EV READY SPACE* AND *EV CAPABLE SPACE* REQUIREMENTS**

Total Number of Parking Spaces	**Minimum number of *EV Ready Spaces***	**Minimum number of *EV Capable Spaces***
1	1	-
2 – 10	2	-
11 – 15	2	3
16 – 19	2	4
21 - 25	2	5
26+	2	20% of total parking spaces

C405.9.2.2. Identification. Construction documents shall indicate the raceway or cable assembly termination point and proposed location of future EV spaces and EVSE. Construction documents shall also provide information on the wiring methods, wiring schematics, and electrical load calculations to verify that the service capacity and premises wiring system have sufficient capacity to simultaneously charge all EVs at all required EV spaces at the full rating of the *EVSE.*

SECTION C405

ELECTRICAL POWER AND LIGHTING SYSTEMS

C405.1General (Mandatory).

This section covers lighting system controls, the maximum lighting power for interior and exterior applications and electrical energy consumption.

Dwelling units within multifamily buildings shall comply with Section R404.1. All other dwelling units shall comply with Section R404.1, or with Sections C405.2.4 and C405.3. Sleeping units shall comply with Section C405.2.4, and with Section R404.1 or C405.3. Lighting installed in walk-in coolers, walk-in freezers, refrigerated warehouse coolers and refrigerated warehouse freezers shall comply with the lighting requirements of Section C403.2.14.

C405.9. Electric Vehicle Service Equipment

-

-

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE). The conductors, including the ungrounded, grounded, and equipment grounding conductors, and the Electric Vehicle connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatus installed specifically for the purpose of transferring energy between the premises wiring and the Electric Vehicle.

EV CAPABLE SPACE. Electrical panel capacity and space to support a minimum 40-ampere, 208/240-volt branch circuit for each EV parking space, and the installation of raceways, both underground and surface mounted, to support the *EVSE*.

EV READY SPACE. A designated parking space which is provided with one 40-ampere, 208/240-volt dedicated branch circuit for EVSE servicing *Electric Vehicles*. The circuit shall terminate in a suitable termination point such as a receptacle, junction box, or an *EVSE*, and be located in close proximity to the proposed location of the EV parking spaces.

C405.9.2. Electric Vehicle (EV) charging for new construction. New construction

shall facilitate future installation and use of *Electric Vehicle Supply Equipment (EVSE)* in accordance with the NFPA 70.

C405.9.2.1. New commercial buildings. *EV Ready Spaces* and *EV Capable Spaces* shall be provided in accordance with Table C405.9.1. Where the calculation of percent served results in a fractional parking space, it shall be shall rounded up to the next whole number. The service panel or sub panel circuit directory shall identify the spaces reserved to support EV charging as "EV Capable" or "EV Ready". The raceway location shall be permanently and visibly marked as "EV Capable".

TABLE C405.9.2.1.

***EV READY SPACE* AND *EV CAPABLE SPACE* REQUIREMENTS**

Total Number of Parking Spaces	**Minimum number of *EV Ready Spaces***	**Minimum number of *EV Capable Spaces***
1	1	-
2 – 10	2	-
11 – 15	2	3
16 – 19	2	4
21 - 25	2	5
26+	2	20% of total parking spaces

-

C405.9.2.2. Identification. Construction documents shall indicate the raceway termination point and proposed location of future EV spaces and EV chargers. Construction documents shall also provide information on amperage of future *EVSE*, raceway methods, wiring schematics and electrical load calculations to verify that the electrical panel service capacity and electrical system, including any on-site distribution transformers, have sufficient capacity to simultaneously charge all EVs at all required EV spaces at the full rated amperage of the *EVSE*.

BCIS Home | Log Out | User Registration | Hot Topics | Submit Surcharge | Stats & Facts | Publications | Contact Us | BCIS Site Map | Links | Search |

Proposed Code Modifications
USER: Estela Tost

Proposed Code Modifications Menu > Modification Search > Modification List > Modification Detail > Submit a Comment > **General Comment Detail**

OFFICE OF THE SECRETARY

* Required fields

Modification #	EN9974-G8
Name	Estela Tost
Address	8500 SW 117 Avenue Suite 120
City	Miami
State	FL
Zip Code	33183
Email	estelat@baptisthealth.net
Primary Phone	(305) 903-9471
Alternate Phone	(786) 594-6913
Fax	
Code Change Cycle	2023 Triennial First Comment Period 03/03/2022 - 04/17/2022
Code Version	2023
Sub Code	Energy Conservation
Chapter & Topic	Chapter 4 - [CE] - Commercial Energy Efficiency
Section	405.9
	-
Status	Pending DBPR Review

General Comment*

I am in support of EN9974 Electrical Vehicle Charging Station infrastructure for new commercial construction

Upload Comment File

Date Submitted	04/14/2022

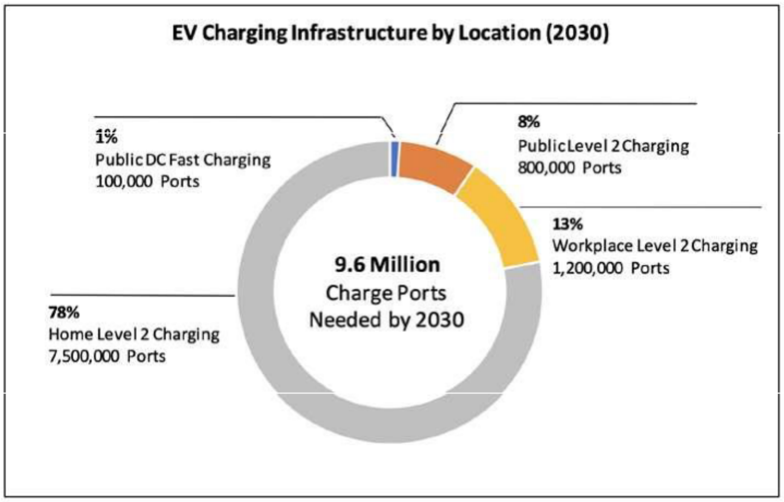
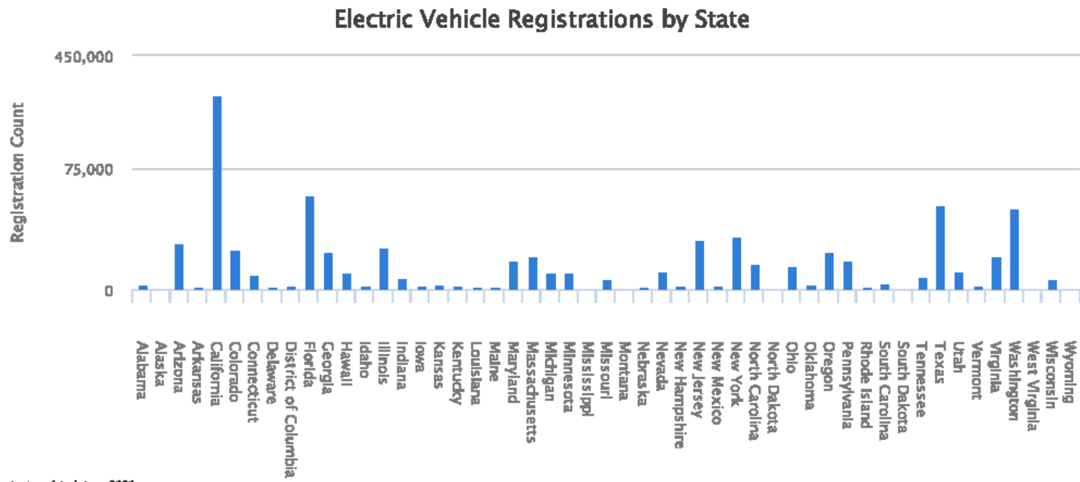


Figure 1. EV Charging Infrastructure in 2030 Based on EEI/IEI Forecast.



Last updated: June 2021
Printed on: January 10

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

12

EN9993

Date Submitted	02/01/2022	**Section**	403	**Proponent**	Bryan Holland
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

This proposed modification adds requirements for fault detection and diagnostics (FDD) for new buildings with an HVAC system serving a gross conditioned floor area of 100,000 square feet or larger.

Rationale

Fault Detection and Diagnostics (FDD) technology significantly reduces costs and improves operational efficiency. It incorporates a standard library of fault rules that can be customized to predict equipment failures and advise personnel of preventive actions. Before the emergence of FDD software solutions, many organizations relied on institutional knowledge in order to fix or maintain their wide variety of equipment. After the development of FDD tech, this type of info (the numerous symptoms, causes and recommended actions) that may have only existed in the heads of senior personnel or, if lucky, in print or electronic archives, could now be used in algorithms to help organizations move from reactionary “break/fix” maintenance to more modern, more cost-effective predictive maintenance. Return on investment studies indicate typical ROI within 12 to 18 months following installation. Please see the attached reports from the Lawrence Berkeley National Laboratory and American Society of Heating, Refrigerating and Air-Conditioning Engineers/Pacific Northwest National Laboratory. This proposed modification improves the code and meets the mandate outlined in F.S. 553.886 that states; "the Florida Building Code must facilitate and promote the use of cost-effective energy conservation, energy-demand management, and renewable energy technologies in buildings.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposed modification will require the local entity to confirm FDD is included on the construction documents at time of plan review and has been installed and operational at time of inspection.

Impact to building and property owners relative to cost of compliance with code

This proposed modification will increase the cost of compliance with the code but will result in improved HVAC system efficiency and have a return on investment not greater than 18 months from time of installation.

Impact to industry relative to the cost of compliance with code

This proposed modification will increase the cost of compliance with the code for industry. FDD software and hardware is readily available in the marketplace by a multitude of manufacturers. FDD design, installation, and operation requires specialized training.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposed modification will improve the health and welfare of the general public by improving HVAC system efficacy and reducing operating costs for large HVAC systems.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposed modification improves the code and meets the mandate outlined in F.S. 553.886 that states; "the Florida Building Code must facilitate and promote the use of cost-effective energy conservation, energy-demand management, and renewable energy technologies in buildings."

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposed modification does not discriminate against any materials, methods, or systems of constructions.

Does not degrade the effectiveness of the code

This proposed modification improves the effectiveness of the code.

1st Comment Period History

EN9993-G1

Proponent	Muthusamy Swami	Submitted	4/17/2022 12:49:49 PM	Attachments	No

Comment:

The change requires permanently installed sensors, sample data every 15 minutes, and communicate faults and recommended repair remotely. R-1 and R-2 group buildings are exempted from this requirement. The proposed code change increases construction cost but it is economical per FSEC’s cost-benefit analysis with an average payback period of under 2.5 years and with a SIR value range of 1.57 - 15.21. Note that this proposed code impacts building floor area greater than 100,000 square foot. FSEC encourages this change.

C403.2.15 Fault Detection and Diagnostics. New buildings with a gross conditioned floor area of 100,000 square feet (9290 square meters) or larger shall include a fault detection and diagnostics (FDD) system to monitor the HVAC system's performance and automatically identify faults. The FDD system shall:

1. Include permanently installed sensors and devices to monitor the HVAC system's performance;

2. Sample the HVAC system's performance at least once per 15 minutes;

3. Automatically identify and report HVAC system faults;

4. Automatically notify authorized personnel of identified HVAC system faults;

5. Automatically provide prioritized recommendations for repair of identified faults based on analysis of data collected from the sampling of HVAC system performance; and

6. Be capable of transmitting the prioritized fault repair recommendations to remotely located authorized personnel.

LBNL-2001075

BERKELEY LAB

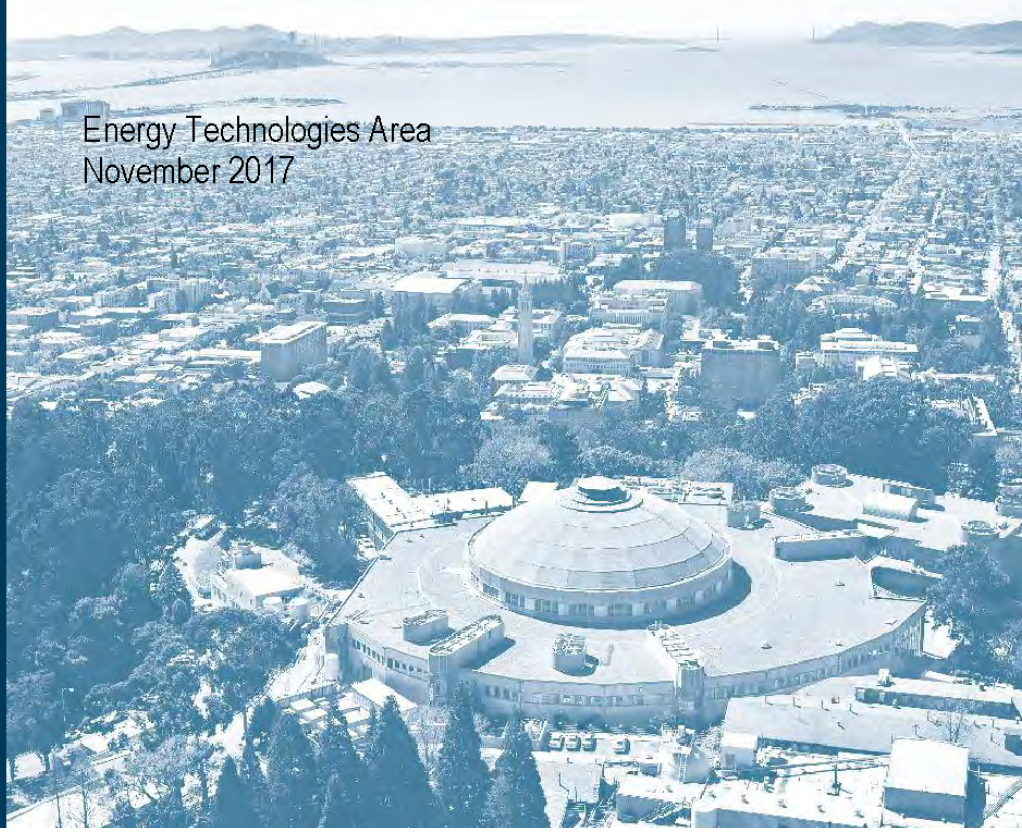
Lawrence Berkeley National Laboratory

Characterization and Survey of Automated Fault Detection and Diagnostic Tools

Jessica Granderson and Rupam Singla
Building Technology and Urban Systems Division
Lawrence Berkeley National Laboratory

Ebony Mayhorn, Paul Ehrlich and Draguna Vrabie
Pacific Northwest National Laboratory

Stephen Frank
National Renewable Energy Laboratory



Energy Technologies Area
November 2017

Disclaimer

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor The Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or The Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or The Regents of the University of California.

Acknowledgement

This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Building Technologies Office, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231. The authors thank Amanda Farthing, Xin Jin, and Grant Wheeler (National Renewable Energy Laboratory), as well as Guanjing Lin (Lawrence Berkeley National Laboratory), for their support with the developer interviews that were conducted in this work. We also recognize each of the fault detection and diagnostic tool developers who participated in this survey.

Executive Summary

Background

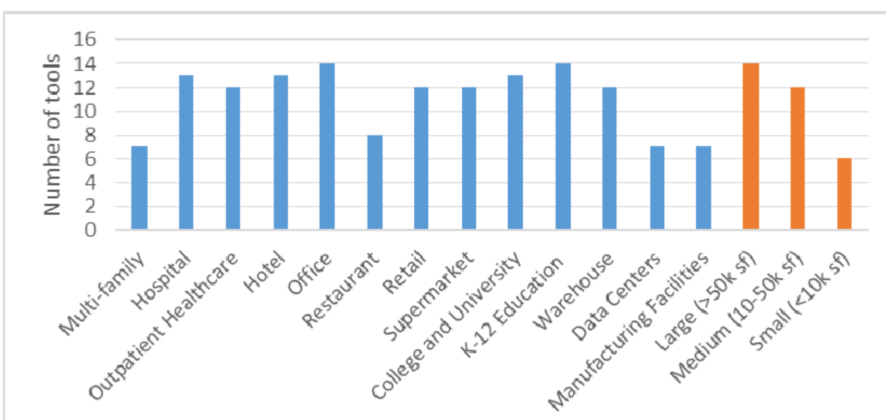
It is estimated that 5%–30% of the energy used in commercial buildings is wasted due to faults and errors in the operation of the control system. Tools that are able to automatically identify and isolate these faults offer the potential to greatly improve performance, and to do so cost effectively. This document characterizes the diverse landscape of these automated fault detection and diagnostic (AFDD) technologies, according to a common framework that captures key distinguishing features and core elements.

Approach

To understand the diversity of technologies that provide AFDD, a framework was developed to capture key elements to distinguish the functionality and potential application of one offering from another. The AFDD characterization framework was applied to 14 currently available technologies, comprising a sample of market offerings. These 14 technologies largely represent solutions that integrate with building automation systems, that use temporary in field measurements, or that are implemented as retrofit add-ons to existing equipment. To characterize them, publicly available information was gathered from product brochures and websites, and from technical papers. Additional information was acquired through interviews and surveys with the developers of each AFDD tool. The study concludes with a discussion of technology gaps, needs for the commercial sector, and promising areas for future development.

Key Findings

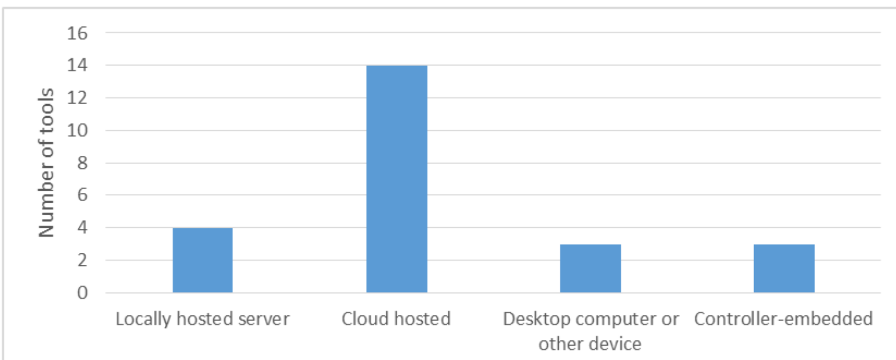
Today's AFDD technologies are being used in nearly all commercial building sectors. Smaller facilities, however, are less commonly served, and when they are it is often through portfolios of small buildings as opposed to single sites.



Market presence of surveyed FDD tools

Software-as-a-service models have quickly become the norm for AFDD technologies; even vendors providing on premise and desktop applications also tend to offer SaaS options. A compelling evolution in the industry is seen in the expansion of market delivery of FDD through third-party service providers using the tools as a way to provide value-add to their customers. This expansion offers the potential to increase access to the technology and its associated benefits for a new class of owners who otherwise may not be using it, however third parties' costs may vary significantly and each cost component should be defined in full to be able to compare across delivery options.

Intended users of surveyed AFDD tools



Location of surveyed AFDD tools

While rule-based methodologies to detect and diagnose faults are still heavily used, vendors are beginning to use process history-based techniques. Independent of the FDD methodology used, vendors report a high degree of commonality in the systems and types of faults that their products can cover. That is, coverage of systems and faults is driven more by site data availability than by product offering. Most AFDD tools surveyed accept real-time BAS data and external meters and sensors; many accept historical data from the BAS, and several accept equipment's onboard/ internal measures without going through the BAS. The majority of the AFDD tool vendors surveyed cover major the HVAC systems found in commercial buildings, as well as lighting systems and whole building energy use. Many tools have large libraries that are able to determine at least some types of faults across all systems for whatever data can be provided. Nearly all of the tool vendors surveyed are able to detect faults in the major categories, including: sensors, energy consumption, economizers and ventilation, commercial refrigeration, cooling/heating systems, equipment cycling, scheduling, and lighting or other end uses. Configuration of the technologies does require site-specific tuning. While this is not a fully automated process, some elements of the process may be automated for streamlining.

Distinguishing factors are often associated with the additional features offered to complement the AFDD, and with the available delivery models. The market offers great diversity in additional analytics and reporting capabilities, integration architectures, and purchase models, making it possible to custom fit the technology to the needs of the organization. While custom solutions are desirable for some portions of the buildings market— such as campuses, enterprises, and large or complex facilities—others may benefit from higher degrees of commoditization.

An important theme in interpreting the findings from this survey is that many products are sold with an emphasis on broad-scale applicability, and in analyzing the features and capabilities across all offerings as whole, there is indeed a high degree of similarity. However, it is critical for prospective technology users to probe providers to understand the precisely what is entailed in a given offering's implementation of a feature of interest. For example, there are many ways to prioritize faults and estimate their impacts, and effective prioritization may be dependent on customer input. Similarly, root cause analysis (diagnosis) may be supported for just a subset of faults, or require manual input from operational staff. Analogously, ease of integration with different makes and vintages of BAS is another critical element of implementation for which "the devil is in the details."

Outstanding Needs

FDD technology is seeing increased uptake in the market, and is constantly developing and evolving. Best practice implementations can deliver significant improvements in energy efficiency, utility expenses, operations and maintenance processes, and operational performance—all with rapid return on investment. However, for the full potential to be realized at scale, a core set of interrelated informational, organizational, and technical needs and barriers must be addressed.

The primary informational barriers for prospective users are rooted in interpreting the value proposition of FDD for their facilities, and in accessing best practices in implementation — for example all-in costs and benefits, effective use of contractors and service providers, and integration with higher level energy management practices. Organizationally, successful implementation of AFDD can be slowed by a need to diverge from existing business practices and norms. While the costs are modest compared to capital projects and can be quickly recovered, decision makers must buy in to an increase in operation and maintenance expenses and be willing to manage a certain degree of risk. Finally, from a technical standpoint, IT and data integration represent one of the largest challenges. Even once data is accessible through cross-system integration, it must be interpreted for use in analytic applications. The current lack of common standards in data, metadata, and semantic representation also poses difficulties in scaling. Lastly, today's AFDD offerings can prove difficult and expensive to apply in smaller commercial buildings.

Future Work

AFDD has matured significantly since its first introduction into commercial buildings. Based on information gathered through this survey and discussion with both vendors and users, several opportunities emerge to further advance the technology. Continued development of algorithms that include machine learning and other promising techniques could reduce tuning needs, simplify configuration, and enhance diagnostic power. Following the trends in other industries, there is also potential to move beyond diagnostics into prognostics and predictive maintenance. Machine-to-machine integration presents further opportunity for advancement to realize pervasive "plug-and-play" functionality, thereby enabling tighter coupling of AFDD with computerized maintenance management systems, meter analytics, and operations and asset management tools. Finally, there are gains to be achieved through the development of corrective and adaptive controls, in combination with tool chains that can ensure that operational design intent is correctly implemented and maintained over the duration of the operational stage in the building lifecycle.

1. Overview

Energy Management and Information Systems (EMIS) comprise a broad family of tools and services to analyze, monitor, and control commercial building equipment and energy use. These technologies include, for example, meter analytics or energy information systems (EIS), some types of automated fault detection and diagnostic tools (AFDD), benchmarking and utility bill tracking tools, and building automation systems. These technologies may encompass uses that include monitoring-based and ongoing commissioning, remote audits and virtual assessments, enterprise monitoring and asset tracking, continuous savings estimation, and energy anomaly detection. There are a wide a wide variety of EMIS products available on the commercial market, and they are increasingly heavily marketed to the energy management community.

It is estimated that 5%–30% of the energy used in commercial buildings is wasted due to faults and errors in the operation of the control system[1, 2, 3]. Tools that are able to automatically identify and isolate these faults offer the potential to greatly improve performance, and to do so cost effectively.

This document characterizes the diverse landscape of technologies that offer AFDD functionality, according to a common framework that captures key distinguishing features and core elements. These technologies can reside on local servers or in the cloud, as well as at the network edge within equipment or controller-embedded solutions.

The primary audience for this document is building owners and operators, who are seeking an understanding of the functionality available in AFDD products and services to inform piloting and procurement decisions. It also may be useful to utility energy efficiency program stakeholders who are interested in emerging technologies to test and pilot for incentive programs. A secondary audience includes developers of AFDD solutions who are looking for information to inform and target their efforts.

In the following sections of this review we present a general overview of FDD and other analytics technology types, followed by a common framework to distinguish among various types of AFDD tools. We then apply this framework to evaluate a sampling of AFDD tools and discuss the findings. The evaluation focused primarily on solutions that integrate with building automation systems, that use temporary in-field measurements, or that are implemented as retrofit add-ons to existing equipment; it did not include OEM-embedded AFDD offerings (although in a few instances these variants are available through the AFDD vendor). We conclude with a discussion of technology gaps, needs for the commercial sector, and promising areas for future development.

[1] Roth, K. W., D. Westphalen, M. Y. Feng, P. Llana, and L. Quartararo. *Energy Impact of Commercial Building Controls and Performance Diagnostics: Market Characterization, Energy Impact of Building Faults and Energy Savings Potential.* 2005. Report prepared by TIAC LLC for the U.S. Department of Energy.

[2] Katipamula, S., and M. Brambley. 2005. "Methods for fault detection, diagnostics, and prognostics for building systems – a review, part 1." *HVAC&R Research* 11(1): 3–25.

[3] Fernandez, N., et al. 2017. *Impacts on commercial building controls on energy savings and peak load reduction.* Pacific Northwest National Laboratory. PNNL Report Number PNNL-25985.

2. Introduction to Fault Detection and Diagnostics

FDD is the process of identifying (detecting) deviations from normal or expected operation (faults) and resolving (diagnosing) the type of problem or its location. FDD has been used for decades to great success in industries that include aerospace, nuclear, and industrial applications, and its use in building operation and control applications is growing. In practice, FDD in buildings is most commonly conducted for heating, ventilation, and air conditioning (HVAC) systems, however as a process, FDD is applicable to all systems in the building. Although currently underutilized, FDD is a powerful approach to ensuring efficient building operations.

As further detailed in the characterization framework that follows, AFDD technology may be delivered through a variety of implementation models. The FDD code may be integrated into either server-based software, desktop software, or software that is embedded in an equipment controller. The AFDD algorithms may rely on historical or near-real time data from building automation systems (BAS), from data local to the equipment or controller, from external sensors and meters, or from some combination of these data sources. AFDD software may be used by the building operator or energy manager, or may be delivered through analysis-as-a-service contracts that do not require direct "in-house" use of the technology.

The software tools that offer AFDD may include additional functionality such as energy consumption monitoring and analytics, visualization, benchmarking, reporting of key performance indicators, or fault prioritization and impact assessment. The server-based offerings rely on continuous data acquisition and analysis; these types of AFDD tools are commonly considered part of the broader family of tools called Energy Management and Information Systems (EMIS). Although not within the scope of this document, other EMIS technologies such as meter analytics or energy information systems, automated (HVAC) system optimization, and building automation systems are powerful tools for ensuring persistent low-energy commercial building operations—both at the facility and enterprise levels.

3. FDD Technology Characterization Framework

To understand the diversity of technologies that provide AFDD, a characterization framework was developed to capture key elements that can be used to distinguish the functionality and potential application of one offering from another. Content contained in this framework was developed through review with a subset of providers, and is based on the authors' collective subject matter expertise, knowledge of AFDD technology and its use in commercial building energy management applications. The categories in the framework are defined in the following sections, with characteristics spanning delivery to market, technical capabilities, and additional software functionality.

3.1 Delivery to Market

Company or institution name: The developer of the AFDD technology.

Tool name: The name of the AFDD software or service offering.

Software type: Whether the AFDD is offered as a commercial product or service, or as open source code.

Availability to market: Whether the AFDD is commercially available or still being researched (pre-commercial).

Current markets served: What markets are currently served in terms of:

- Building type (multi-family, hospital, outpatient healthcare, hotel, office, restaurant, retail, supermarket, college and university, K–12 education, warehouse).
- Building size (large [> 50k square feet (sf)], medium [10–50k sf], small [< 10k sf]).

Software location: Whether the AFDD software is cloud hosted, locally hosted on an "on-site" server, located on a desktop computer or other device, or controller-embedded.

Purchase model: Whether the AFDD software is a one-time purchase, software as a service (with monthly or annual fee), or other. Additionally, whether the AFDD software comes with updates and/or periodic maintenance in the initial offering costs, or whether additional purchase is required.

Intended users: Whether the AFDD software is intended for use by the vendor (for analysis-as-a-service), an engineering manager/operator/site staff, and/or a third-party service provider.

Software configuration: Whether the party typically responsible for the AFDD software installation and configuration is the software vendor; an integrator, distributor, or third-party service provider; or an engineering manager/operator/site staff.

Data sources: Whether the AFDD software relies upon data from BAS real-time data (i.e., live, continuous), from BAS historical data (e.g., trend logs, csv, xls), from on-board or internal equipment measures, or from external meters and sensors.

Data ownership: Whether the owner(s) of the AFDD software tool inputs and outputs is the end-customer, the FDD software vendor, and/or a third-party service provider.

FDD method tailoring: Whether the AFDD software requires tailoring of the tuning algorithm parameters and associated thresholds manually or automatically, or whether it is not applicable or unnecessary.

Notification of findings: Whether the AFDD software tool delivers results through a software user interface with fault findings, through a service to the user that includes periodic reports of fault findings, and/or through automated notifications, e.g., via email or text.

3.2 Technical Capabilities

Systems covered: Whether the FDD software has existing libraries and rules for the following systems: air conditioners/heat pumps (including packaged rooftop units), chillers and towers, air handler units (AHUs) and variable air volumes (VAVs), fan coil units (FCUs), commercial refrigeration, lighting, boilers/furnaces, water heaters, and/or whole-building.

Categories of faults detectable: These are broad categories of faults that the AFDD tool is able to detect and potentially diagnose. The fault categories included in this framework include:

- Sensor errors/faults
- Energy consumption (explicit energy use fault)
- Economizers and ventilation
- Control-related pressurization issues
- Commercial refrigeration (related to vapor/compression)
- Space cooling/heating (related to vapor/compression)
- Heating system (boiler, heat exchanger, furnace, etc.)
- Cooling system (chillers, towers, etc.)
- Equipment cycling
- Pump and fan systems
- Scheduling (too little, too long, wrong time, etc.)
- Simultaneous heating and cooling
- Lighting or other end uses

Note that problems such as mechanical failures and departures from setpoint or intended sequences may be included under multiple fault categories in the list above.

Methods/algorithms: These are the categories of analytical methods used in the AFDD software. The schematic diagram below depicts the definition of algorithm types that are used in this framework.

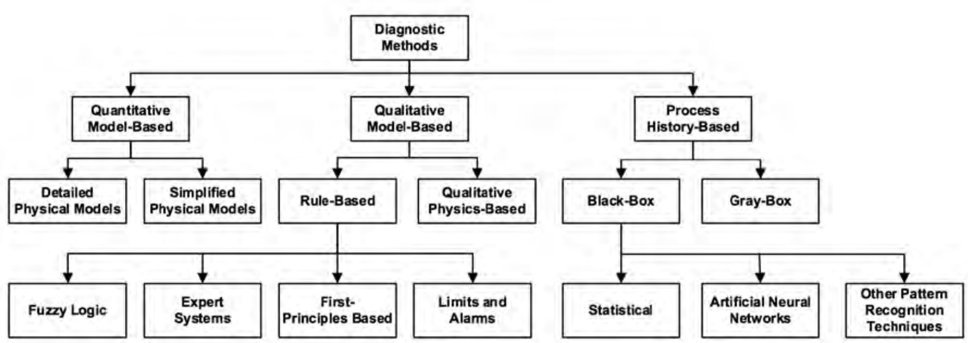


Figure 1. Depiction of algorithm types used in this framework, from Katipamula and Brambley, 2005[2]

As illustrated in Figure 1, FDD methods may be model-based or based purely on process history data. The model-based methods rely upon knowledge of the underlying physical processes and first principles governing the system(s) being analyzed. Quantitative model-based approaches are not yet frequently employed in commercial AFDD tool offerings, however qualitative model-based approaches which include rule-based FDD, have been extensively used in the industry and provide intuitive representations of engineering principles. The process history-based (data-driven) approaches do not rely upon knowledge of first principles, but may leverage some degree of engineering knowledge; they rely upon data from the system in operation. These include statistical regression models, neural networks, and other methods. Process history-based AFDD algorithms are increasingly being explored for use in commercial tool offerings. Although the distinctions between these method types may become blurry (even to developers), AFDD users may have interest in understanding whether a technology uses rules-based techniques versus newer data driven approaches, or less commonly employed first principles – or a combination of several approaches.

Detection and diagnosis capabilities: Whether the AFDD tool is capable of identifying fault presence (reporting a fault without specification of the physical location, severity, or root cause), fault location, fault severity (degree of faultiness as opposed to impact on energy or dollars, which is covered in “additional functionality”), root cause, and/or estimated costs of resolution and payback.

3.3 Additional Functionality

Other features: Additional features of the AFDD tool that are not represented above, and may include:

- Detection of equipment degradation
- Fault prioritization
- Automated work order request system integration
- Assessment of energy impacts
- Conversion of energy impacts to cost impacts
- Assessment of cost impacts other than energy cost, e.g., reduced equipment life
- Meter data analytics
- Time series visualization and plotting
- Key performance indicator (KPI) tracking and reporting
- Longitudinal and cross-sectional benchmarking (within a given portfolio or via ENERGY STAR Portfolio Manager)

4. Technology Characterization Findings

The AFDD characterization framework was applied to 14 currently available technologies, comprising a sample of market offerings (see the Appendix for a list of those surveyed). These technologies were identified based on factors including:

- Diversity across defining characteristics to illustrate market breadth
- Known use in commercial buildings based on the authors' knowledge of the market and engagement with the community of AFDD users
- Vendor or developer willingness and ability to share information necessary for a full characterization

It is important to emphasize that inclusion in this survey does not indicate endorsement, and conversely, absence from the survey does not indicate non-endorsement.

To characterize the technologies, publicly available information was gathered from product brochures and websites, and from technical papers. Additional information was acquired through interviews and surveys with the vendors and developers of each AFDD tool. The information that was acquired was therefore based on self-reporting from the technology provider. It was not within the scope of this effort to independently verify reported functionality and characteristics of each technology that is included. Moreover, as the market is constantly evolving and technologies are continuously modified, these market findings represent a snapshot in time. Although specific offerings may evolve, it is expected that the characterization framework itself will remain a viable tool to distinguish key AFDD technology elements well into the future.

The tables in the Appendix provide a summary of the capability of each tool surveyed, with respect to each category in the characterization framework.

4.1 Delivery to Market

All tool vendors surveyed offered proprietary, commercially available software and/or hardware. However, several of the software vendors noted that they provide an open application programming interface (API) to support integration with third-party applications.

The markets currently served by the AFDD tool vendors are represented in Figure 2. Multi-family, restaurant, data centers, and manufacturing facilities are less commonly served, with a mostly even coverage of other sectors. In addition to the market segments shown in the figure, several tool vendors noted additional facility types such as industrial subsectors, arenas, multi-event facilities, and correctional facilities. The technologies are commonly used in large and medium facilities, with less penetration in smaller buildings. Several tool vendors also noted that they do not serve a particular building size and that their product would be applicable to any size building.

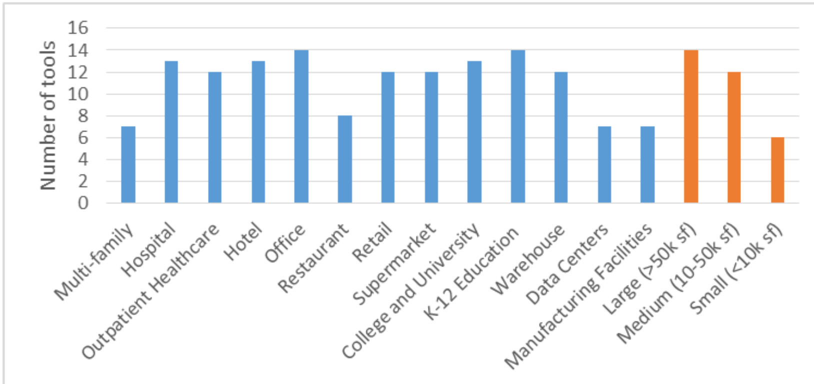


Figure 2.Market presence of surveyed FDD tools

As shown in Figure 3, the software for all 14 tool vendors can be cloud hosted; eight of them offer that as the only option. Additionally, four AFDD tools can be installed on a locally hosted on-site server, and three can be located on a desktop computer or other device (such as a handheld device). Three can be controller-embedded, reflecting emerging variants in software delivery that can entail relationships with OEMs.

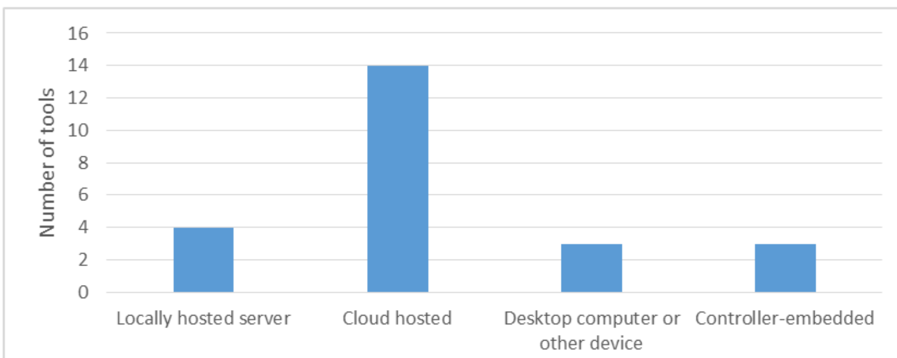


Figure 3. Software location

AFDD tool vendors offer a wide range of variability in purchase models. Many vendors noted that there is no standard, and that often the purchase model is tailored to what the customer wants. Typically tools that are hosted on the cloud offer a software-as-a-service (SaaS) model with ongoing updates and maintenance included for either an annual or a monthly fee. Maintenance and updates may come bundled or optionally in an upfront fee, or can be deferred for later purchase.

As reflected in the tallies in Figure 4, all of the AFDD tool vendors surveyed have multiple intended users. The traditional model of in-house technology used by the end customer is still prevalent—all vendors surveyed listed engineering manager/operator/site staff as an intended user. However, tools are increasingly being used by and resold by third-party service providers as a value-add to customers, with all of the AFDD tool vendors surveyed also listing a third-party service provider as an intended user. Nine vendors provide analysis-as-a-service directly to their clients and are therefore an intended user of the tool. This is expected to grow as the market matures and alternative business models are explored by the industry.

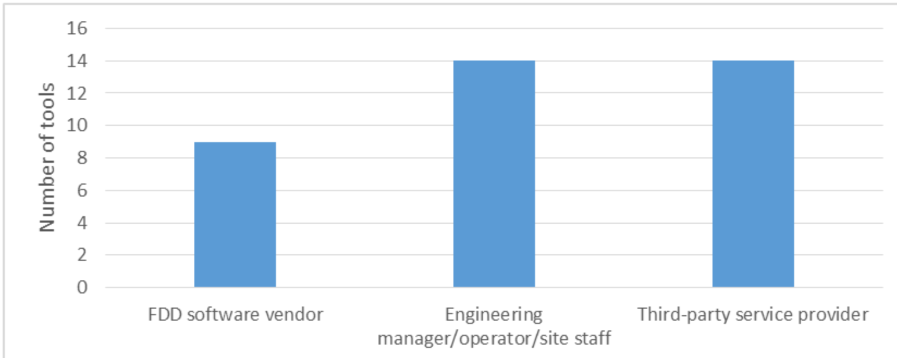


Figure 4. Intended Users

The majority of the AFDD tools are installed and configured by some combination of the software vendor, an integrator/distributor/third-party service provider, and the engineering manager/operator/site staff, as shown in Figure 5. In most cases, the vendor plus a third party do the configuration, working from owner requirements. In some cases multiple parties are required for the installation, and in some cases the vendor offers several options for who does the installation.

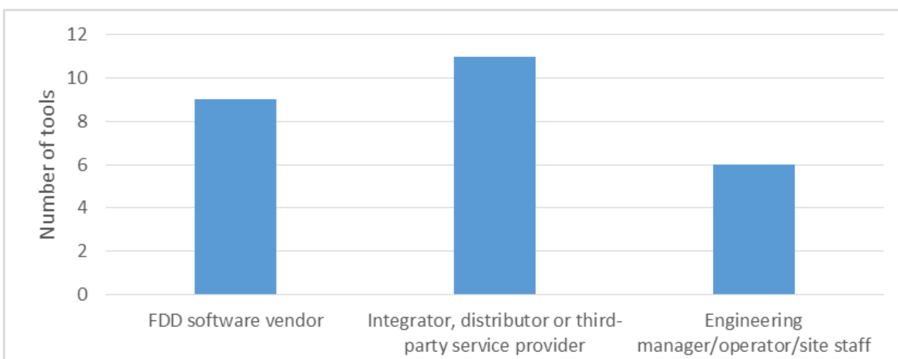


Figure 5. Parties involved in software configuration

There is a range of input data that are required by AFDD tools and a range of data that they can accept, as shown in Figure 6. Most of the tools take in real-time BAS data, which would be expected, given the large number of cloud-based solutions that serve as a BAS overlay. Eleven tools are also able to utilize historical data from the BAS. Most of the tools are also able to utilize external meters and sensors. Three tools are able to utilize equipment's onboard/ internal measures without going through the BAS. Typically not all of the data points that *can* be processed by the tool are required, and the technologies operate based on the data that are available. Though the tool vendor may have a short list of critical points, additional data are used to enhance the spectrum of diagnostics that can be performed.

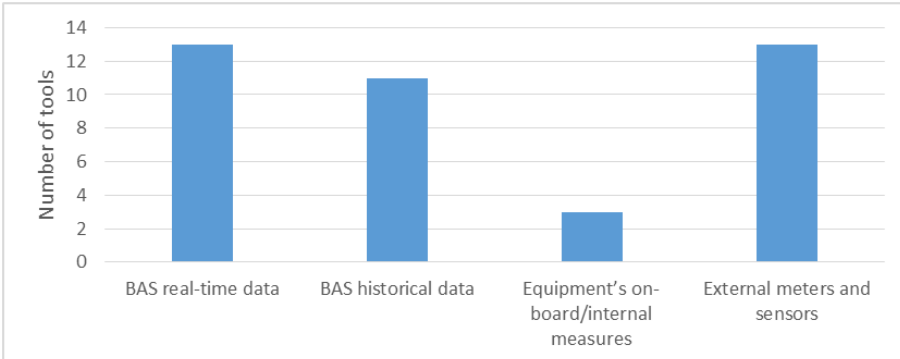


Figure 6. Data sources for surveyed FDD tools

All AFDD tool vendors note that primarily, the customer owns the data. Additionally, two vendors noted that they themselves also have ownership over the data and one other tool vendor noted that a third-party service provider has ownership over the data. Several tool vendors noted that they retain the right to use aggregate and anonymous data for benefit of all their users; for example, to provide peer benchmarking analyses.

All 14 tools require some degree of tuning or tailoring algorithm configuration and implementation. While none offer fully automated tuning, six vendors noted that they provide automated routines and/or GUIs to streamline the process. At least one tool comes with a fault library with default thresholds, with which the customer may subsequently tune parameters or hire consultants to help.

All of the AFDD tool vendors provide access and viewing of fault findings through a software interface, as shown in Figure 7. In addition to user-facing GUIs, the majority of offerings surveyed also provide services to periodically output reports of fault findings. All but two of the tools provide automated notifications via text, e-mail, or even other novel communications options such as tweets. Several tool vendors have the capability to have reports sent via e-mail at user-defined intervals (daily, weekly, monthly) and on customer demand.

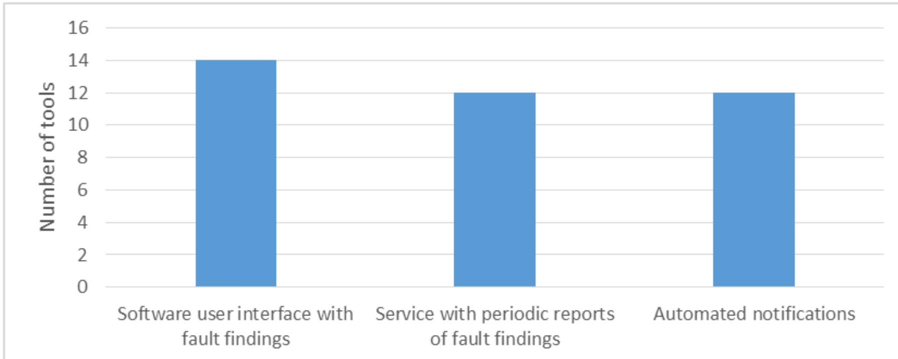


Figure 7. Notification of findings

4.2 Technical Capabilities

As seen in Figure 8, the majority of the AFDD tool vendors surveyed cover most of the systems that were included in the survey (AC/heat pump which includes packaged rooftop units, chillers and towers, AHU and VAV, FCUs, commercial refrigeration, lighting, boilers/furnaces, water heaters, and whole-building). Many tools have large libraries that are able to determine at least some types of faults across all systems for whatever data can be provided. Several vendors reported that they additionally include energy recovery ventilators (ERVs), other terminal units besides VAV boxes, solar panels, industrial processes, variable refrigerant flow (VRF) systems, BAS controls, cogeneration, and manufacturing equipment.

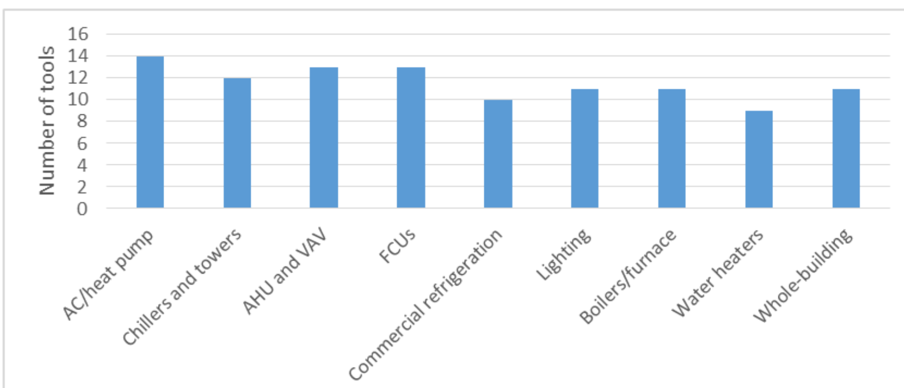


Figure 8. Systems covered

Nearly all of the tool vendors surveyed are able to detect faults in the majority of the fault categories in the survey: sensor errors/faults, energy consumption, economizers and ventilation, control-related pressurization issues, commercial refrigeration, space cooling/heating, heating system, cooling system, equipment cycling, pump and fan systems, scheduling, simultaneous heating and cooling, and lighting or other end uses. Many tools have large libraries that are able to determine at least some types of faults for whatever data can be provided. See Figure 9 for details.

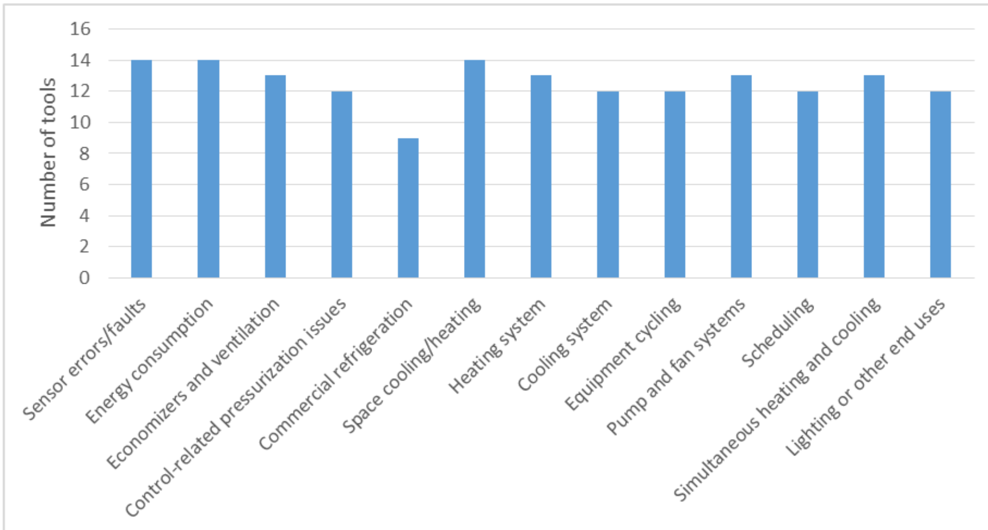


Figure 9. Categories of detectable faults

Most of the tools (12 out of 14) use rule-based algorithms, the majority of which apply some combination of expert systems, first principles-based, and limits and alarms. Many of the rule-based tools are supplemented with other approaches, and in one case the offering is a platform that is most commonly programmed and configured to deliver rule-based algorithms, but also includes machine learning functions. Three tools use black-box process history-based approaches; one of these also uses a gray-box approach. Two tools use quantitative model-based approaches. Figure 10 illustrates these findings graphically—dark shading indicates approaches used by ten or more tools, medium shading indicates approaches used by two or three tools, and light shading indicates approaches used by one or no tools.

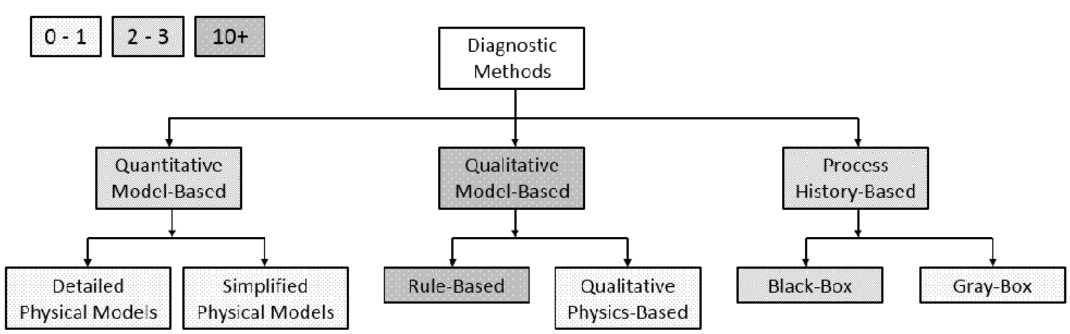


Figure 10. Methods and algorithms

As shown in Figure 11, all vendors surveyed reported the ability to identify fault presence as well as physical fault location. All but one tool is able to identify potential root causes. Depending on the specific fault identified, root case identification may be more or less precise, or in some cases, not possible. In addition, all but one reported some quantification of fault severity, e.g., degree of leakage. The degree of faultiness may be determined based on the frequency of a fault, fault magnitude (e.g., how far a point is away from setpoint), and fault duration. Several tools associate fault severity with assessment of the degree to which energy, energy cost, comfort, and maintenance costs are affected. At least one of these tools prioritizes the faults, then displays only one fault at a time to the user.

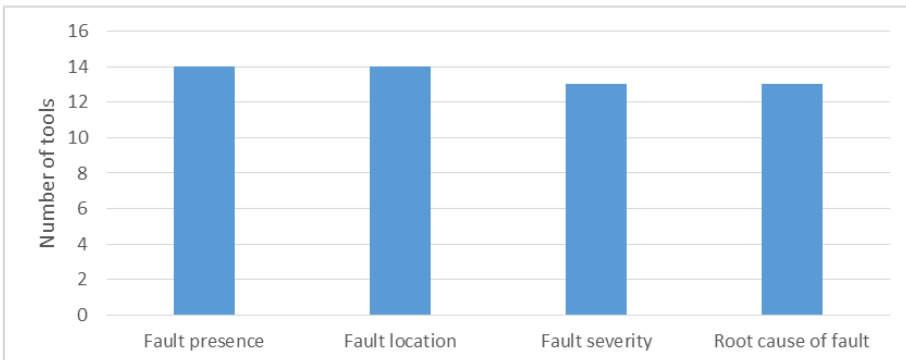


Figure 11. Detection and diagnosis capabilities

4.3 Additional Functionality

AFDD tools are commonly delivered with many supplementary features. Out of the tools surveyed, the most common features were time series visualization and plotting, quantification of energy impacts, and fault prioritization, as shown in Figure 12. Other very common features were equipment degradation, conversion of energy impacts to cost impacts, KPI tracking and reporting, automated work order request system integration, and meter data analytics. Less common but still prevalent features were cost impacts other than energy cost (such as the cost of pending equipment failure), longitudinal and cross-sectional benchmarking, and estimated cost of fault resolution and payback.

In addition, tool vendors noted a number of other features, including feedback for load management and demand response applications, verification of corrective actions, savings measurement and verification (M&V), equipment level M&V, asset data and service history, and issue-tracking systems. These other features were not exhaustively reviewed in the survey (or Tabulated findings in the Appendix) but are important complements to the AFDD capabilities.

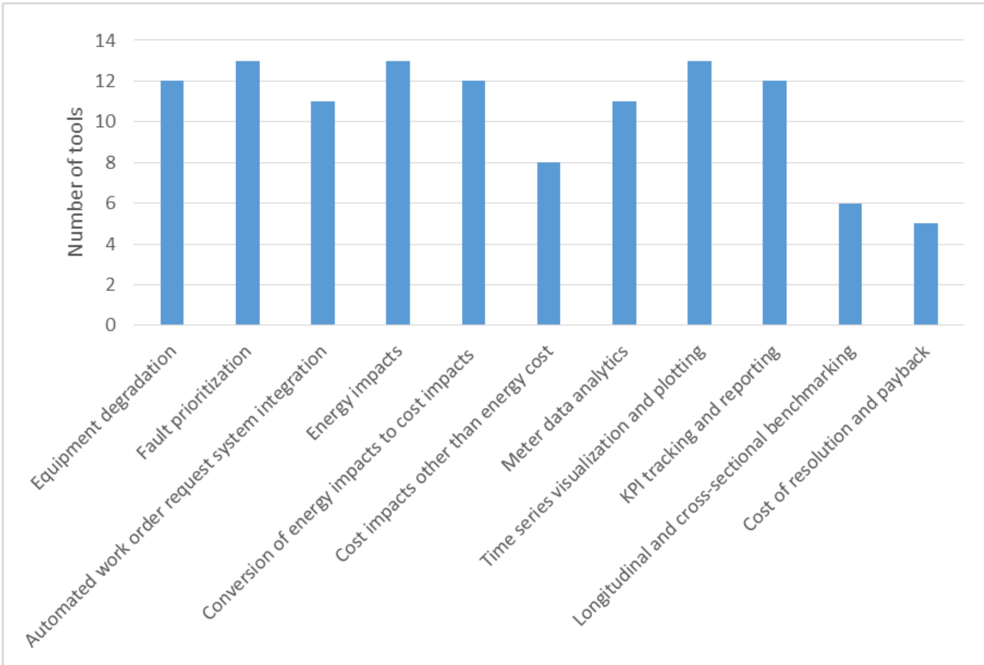


Figure 12. Relative frequency of a selected set of additional features of AFDD tools

5. Industry Needs and Future Development

This survey focused on AFDD solutions that integrate with building automation systems, that use temporary in-field measurements, or that are implemented as retrofit add-ons to existing equipment. As indicated in the findings, today's AFDD technologies are being used in nearly all commercial building sectors. Smaller facilities, however, are less commonly served, and when they are it is often through portfolios of small buildings as opposed to single sites. Cost effectiveness and complexity of implementation may vary as the technology is applied to different sectors and building sizes. For example, with a historic emphasis on HVAC systems and larger buildings, solutions for built-up systems may be simultaneously more developed, yet also more complex than those for packaged systems.

Software-as-a-service models have quickly become the norm for AFDD technologies; even vendors providing on-premise and desktop applications also tend to offer SaaS options. A compelling evolution in the industry is seen in the expansion of market delivery of FDD through third-party service providers using the tools as a way to provide value-add to their customers. Illustrated in Figure 13, these third-party services may cover a spectrum of activities. This is in contrast to earlier models that relied on in-house direct organizational use, and also from analysis-as-a-service provided by the AFDD vendor. This expansion offers the potential to increase access to the technology and its associated benefits for a new class of owners who otherwise may not be using it, however third parties' costs may vary significantly and each cost component should be defined in full to be able to compare across delivery options.

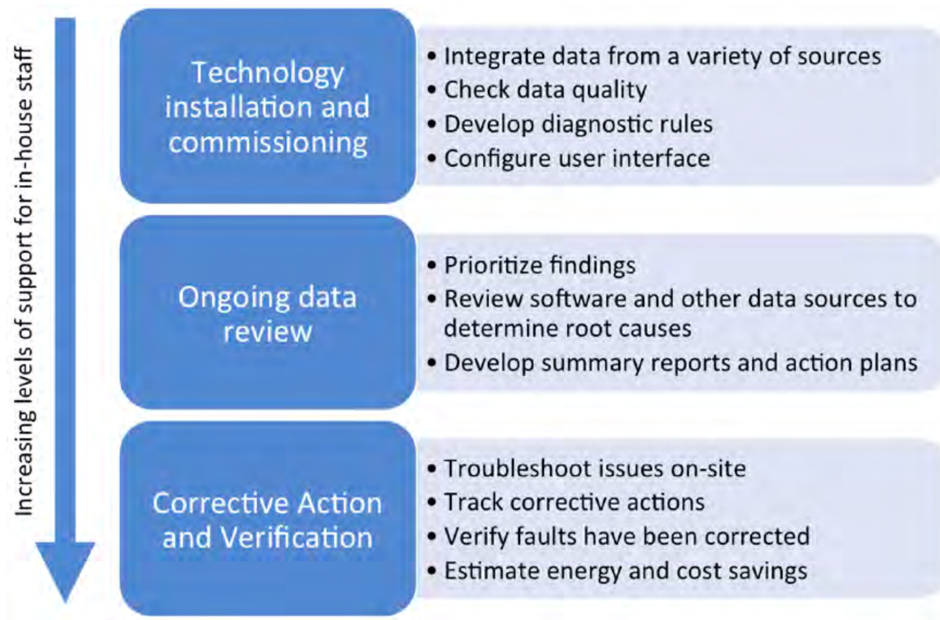


Figure 13. A spectrum of analytics-focused activities that service providers may offer their customers

While rule-based methodologies to detect and diagnose faults are still the norm, vendors are beginning to use process history-based techniques. Independent of the FDD methodology used, vendors report a high degree of commonality in the systems and types of faults that their products can cover. That is, coverage of systems and faults is driven more by site data availability than by product offering. Configuration of the technologies does require site-specific tuning, which may be conducted by vendors and service providers with varying degrees of involvement from site staff. While this is not a fully automated process, some elements of the process may be automated for streamlining.

Distinguishing factors are often associated with the additional features offered to complement the AFDD, and with the available delivery models. The market offers great diversity in additional analytics and reporting capabilities, integration architectures, and purchase models, making it possible to custom fit the technology to the needs of the organization. While custom solutions are desirable for some portions of the buildings market— such as campuses, enterprises, and large or complex facilities—other portions of the market may benefit from higher degrees of commoditization.

An important theme in interpreting the findings from this survey is that many products are sold with an emphasis on broad-scale applicability, and in analyzing the features and capabilities across all offerings as whole, there is a high degree of similarity. However, actual implementation needs can differ widely from one application case to another. Moreover, it is critical for prospective technology users to probe providers to understand the precisely what is entailed in a given offering's implementation of a feature of interest. For example, there are many ways to prioritize faults and estimate their impacts, ranging from those that rely upon static assumptions of fault persistence versus intermittence, to those that rely upon more dynamic calculations of concurrent operational conditions – and effective prioritization may be dependent on customer input. Similarly, root cause analysis (diagnosis) may be supported for just a subset of faults, or require manual input from operational staff. Analogously, ease of integration with different makes and vintages of BAS is another critical element of implementation for which "the devil is in the details."

FDD technology is seeing increased uptake in the market, and is constantly developing and evolving. Best practice implementations can deliver significant improvements in energy efficiency, utility expenses, operations and maintenance processes, and operational performance—all with rapid return on investment (see the Smart Energy Analytics Campaign Year 1 Report[4] for a snapshot of EIS, FDD and ASO performance and cost). However, for the full potential to be realized at scale, a core set of interrelated informational, organizational, and technical needs and barriers must be addressed.

Informational:

1. Prospective users remain challenged in interpreting the value proposition of FDD for their facilities. Common questions include: what will it really take to make this work for my buildings? What will the all-in costs and benefits be, up-front, and in the long-term? How do I navigate this developing market with numerous evolving players and product options?
2. Prospective users also face more specific implementation questions such as: What is the distinction between automated fault detection and diagnostics (AFDD) and BAS alarms, and which products support one versus the other? What are best practices for tuning and avoidance of false positives? What is the benefit of integrating AFDD within higher-level energy management practices such as strategic energy management and ongoing monitoring-based commissioning? How do I best integrate the support of contractors and service providers with in-house activities?

[4] Smart Energy Analytics Campaign. Synthesis of year 1 outcomes in the Smart Energy Analytics Campaign [Internet]. 2017 [accessed on September 25, 2017]. Available from: https://smart-energy-analytics.org/

Organizational:

3. Successful implementation of AFDD can be slowed by a need to diverge from existing business practices and norms. While the costs are modest compared to capital projects and can be quickly recovered, decision makers must buy in to an increase in operation and maintenance expenses and be willing to manage a certain degree of risk. Translation of information into action requires allocation of resources for staff time and training to act upon on identified fixes; it also requires effective operational response processes.

Technical:

4. While improving, IT and data integration represent one of the largest barriers to scale. It is complex, expensive and crosses organizational business units, and communications infrastructures are not easily leveraged for installation of analytics technologies.
5. Once data is accessible through cross-system integration, it must be interpreted for use in analytic applications. The current lack of common standards in data, metadata, and semantic representation also poses difficulties in scaling.
6. Similar to many efficiency solutions, today's AFDD offerings can be difficult and expensive to apply in smaller commercial buildings. Smaller facilities do not commonly have building automation systems or energy management staff and present much tighter payback constraints due to smaller energy expenditures.

A number of academic, industry, utility, and federal efforts are seeking to address these barriers. These collective efforts are far too varied and numerous to comprehensively describe, however, a few examples from current work sponsored by the U.S. Department of Energy (DOE) are provided as an illustration.

- The University of New Haven is conducting a public-facing field evaluation[5] of approximately 10 AFDD solutions to quantify technology costs and benefits, and is partnering with the utility community to inform the development of incentive programs for scaled regional deployment.
- The National Renewable Energy Laboratory (NREL) is conducting early-stage development of AFDD solutions for small commercial facilities that are based on simulation modeling and smart meter data.[6]
- Lawrence Berkeley National Laboratory (LBNL) is administering the Smart Energy Analytics Campaign[7] to provide technical assistance to AFDD and other analytics users, track gaps and benefits, and synthesize barriers.

---

[5] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Department of Energy announces scaling up the next generation of building efficiency packages funding awards [Internet]. 2017 [accessed on August 29, 2017]. Available from: https://energy.gov/eere/buildings/articles/department-energy-announces-scaling-next-generation-building-efficiency

[6] Frank, S., et al. 2016. Hybrid model-based and data-driven fault detection and diagnostics for commercial buildings. *Proceedings of the 2016 ACEEE Summer Study on Energy Efficiency in Buildings.*

[7] Smart Energy Analytics Campaign. Smart Energy Analytics Campaign [Internet]. 2017 [accessed on August 29, 2017]. Available from: https://smart-energy-analytics.org/

- LBNL and NREL are conducting public-facing multi-site field evaluations of technologies for rooftop unit AFDD and combined FDD/HVAC optimization.[8] Performance results are intended to inform the market at large, with a particular focus on public and private sector portfolio owners.

AFDD has matured significantly since its first introduction into commercial buildings. Based on information gathered through this survey and discussion with both vendors and users, several opportunities emerge to further advance the technology. Some of these are technical development challenges, and some strongly tied to the interplay between market demand and business choices concerning standardization and interoperability.

Continued development of algorithms that include machine learning and other promising techniques could reduce tuning needs, simplify configuration, and enhance diagnostic power. Following the trends in other industries, there is also potential to move beyond fault diagnostics into controls optimization, prognostics, and predictive maintenance. Integration of physics-based models to complement data-driven approaches holds promise to increase diagnostic power and support predictive analytics.

Machine-to-machine integration presents further opportunity for advancement. For example, truly pervasive “plug-and-play” functionality is still being developed, as are solutions to automatically extract and semantically interpret data across diverse systems and data types. The ability to interface AFDD tools with computerized maintenance management systems (CMMS) is just beginning to be explored, and will streamline the process of operationalizing action-taking based on the findings from analytics tools. Similarly, the practice of energy management will be enhanced through an ability to more tightly couple today’s disparate systems and platforms with more pervasive data and connectivity for controls optimization, FDD, site and portfolio meter analytics, and operations and asset management. While an “all in one” tool is not likely, nor necessarily optimal, some convergence for users would be beneficial.

Finally, there are gains to be achieved through the development of corrective and adaptive controls, in combination with tool chains that can ensure that operational design intent is correctly implemented and maintained over the duration of the operational stage in the building lifecycle.

[8] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. BuildingIQ Inc: Predictive Energy Optimization [Internet]. 2017 [accessed on August 29, 2017]. Available from: https://energy.gov/eere/buildings/downloads/buildingiq-inc-predictive-energy-optimization

Appendix

Table 1 summarizes aspects of market delivery for each tool surveyed, and Table 2 summarizes their AFDD technical capabilities and additional software features.

Table 1. Market delivery aspects of each tool surveyed

Tool name	Company	Building type of markets served	Building size of markets served	Software location	Purchase model	Intended users	Software configuration	Data sources	Data ownership	FDD method tailoring	Notification of findings
SkySpark (platform)	SkyFoundry	Hospital, Outpat. Health., Hotel, Office, Restaurant, Retail, Supermarket, College and Univ, K-12 Ed, Warehouse	Large, Medium, Small	Cloud hosted, Desktop computer or other device, Controller-embedded	One time purchase with maintenance included; SaaS through partners	FDD vendor, Site staff, Third-party provider	Third-party provider; Site staff	BAS real-time and historical data, Equipment on-board/internal measures, External meters and sensors	End-customer	Manual	Software user interface, Service with periodic reports, Automated notifications
SkySpark (implementn.)	CBRE|ESI	Hospital, Office, Retail, Supermarket, College and Univ, K-12 Ed	Large, Medium	Locally hosted server, Cloud hosted	SaaS. Optional updates and maintenance after first year	Site staff, Third-party provider	Third-party provider	BAS real-time and historical data, External meters and sensors	End-customer, FDD vendor, Third-party provider	Manual	Software user interface, Service with periodic reports, Automated notifications
True Analytics	Ecorithm	Multi-fam., Hospital, Hotel, Office, College and Univ, K-12 Ed, Warehouse	Large	Cloud hosted	SaaS. Updates and maintenance included	Site staff, Third-party provider	FDD vendor, Third-party provider	BAS real-time and historical data	End-customer	Manual and Automated	Software user interface, Service with periodic reports
Clockworks	KGS	Multi-fam., Hospital, Outpat. Health., Hotel, Office, Retail, Supermarket, College and Univ, K-12 Ed, Warehouse	Large, Medium	Cloud-hosted (via platform-as-a-service)	SaaS. Updates and maintenance included	FDD vendor, Site staff, Third-party provider	FDD vendor, Third-party provider	BAS real-time and historical data, External meters and sensors	End-customer	Manual	Software user interface, Service with periodic reports, Automated notifications

Tool name	Company	Building type of markets served	Building size of markets served	Software location	Purchase model	Intended users	Software configuration	Data sources	Data ownership	FDD method tailoring	Notification of findings
Kaizen	CopperTree Analytics	Multi-fam., Hospital, Outpat. Health., Hotel, Office, Restaurant, Retail, Supermarket, College and Univ, K-12 Ed, Warehouse	Large, Medium, Small	Cloud hosted	SaaS. Use partners as value-added resell distributers Updates and maintenance included	FDD vendor, Site staff, Third-party provider	FDD vendor, Third-party provider	BAS real-time and historical data, External meters and sensors	End-customer	Manual and Automated	Software user interface, Service with periodic reports, Automated notifications
BuildPulse	BuildPulse Inc.	Hospital, Outpat. Health., Hotel, Office, Retail, College and Univ, K-12 Ed	Large, Medium	Cloud hosted	SaaS. Updates and maintenance included	FDD vendor, Site staff, Third-party provider	Third-party provider, Site staff	BAS real-time data, External meters and sensors	End-customer	Manual and Automated	Software user interface, Service with periodic reports, Automated notifications
Analytika	Cimetrics	Hospital, Outpat. Health., Hotel, Office, Supermarket, College and Univ, K-12 Ed, Warehouse, Mfg Facilities	Large, Medium	Cloud hosted	SaaS. Updates and maintenance included	FDD vendor, Site staff, Third-party provider	FDD vendor	BAS real-time and historical data, External meters and sensors	End-customer	Manual and Automated	Software user interface, Service with periodic reports, Automated notifications
Niagara Analytics 2.0	Tridium	Multi-fam., Hospital, Outpat. Health., Hotel, Office, Restaurant, Retail, Supermarket, College and Univ, K-12 Ed, Warehouse, Data Centers, Mfg Facilities	Large, Medium, Small	Locally hosted server, Cloud hosted, Controller-embedded	One time purchase with optional updates and maintenance	FDD vendor, Site staff, Third-party provider	FDD vendor, Third-party provider	BAS real-time and historical data, Equipment on-board/internal measures, External meters and sensors	End-customer	Manual and Automated	Software user interface, Automated notifications
IntelliCommand	JLL	Hospital, Outpat. Health., Hotel, Office, Retail, Supermarket, College and Univ, K-12 Ed, Warehouse, Data Centers, Mfg Facilities	Large, Medium	Cloud hosted	SaaS. Updates and maintenance included	Site staff, Third-party provider	FDD vendor	BAS real-time and historical data, External meters and sensors	End-customer	Manual	Software user interface, Service with periodic reports, Automated notifications

Tool name	Company	Building type of markets served	Building size of markets served	Software location	Purchase model	Intended users	Software configuration	Data sources	Data ownership	FDD method tailoring	Notification of findings
Balance	EEI	Multi-fam, Hospital, Outpat. Health., Hotel, Office, Restaurant, Retail, Supermarket, College and Univ, K-12 Ed, Warehouse, Data Centers, Mfg Facilities	Large, Medium	Cloud hosted	SaaS. Updates and maintenance included.	FDD vendor, Site staff, Third-party provider	FDD vendor, Third-party provider, Site staff	BAS real-time and historical data, External meters and sensors	End-customer, FDD vendor	Manual	Software user interface, Service with periodic reports
Facility Analytix	ICONICS	Hospital, Outpat. Health., Hotel, Office, Restaurant, Retail, Supermarket, College and Univ, K-12 Ed, Warehouse, Data Centers, Mfg Facilities	Large	Locally hosted server, Cloud hosted	One-time purchase or SaaS. Maintenance included, updates optional	Site staff, Third-party provider	FDD vendor, Third-party provider, Site staff	BAS real-time and historical data, External meters and sensors	End-customer	Manual	Software user interface, Service with periodic reports, Automated notifications
eIQ	Transformative Wave	Hospital, Outpat. Health., Hotel, Office, Restaurant, Retail, Supermarket, College and Univ, K-12 Ed, Warehouse, Data Centers, Mfg Facilities	Large, Medium, Small	Cloud hosted	SaaS. Updates and maintenance included	FDD vendor, Site staff, Third-party provider	FDD vendor, Third-party provider, Site staff	BAS real-time and historical data, External meters and sensors	End-customer	Manual	Software user interface, Automated notifications
ClimaCheck Onsite/ ClimaCheck Online	ClimaCheck	Multi-fam, Hospital, Outpat. Health., Hotel, Office, Restaurant, Retail, Supermarket, College and Univ, K-12 Ed, Warehouse, Data Centers, Mfg Facilities	Large, Medium, Small	Locally hosted server, Cloud hosted, Desktop computer or other device	Onsite: One-time purchase. Optional updates Online: Updates and maintenance included.	FDD vendor, Site staff, Third-party provider	Third-party provider, Site staff	BAS real-time data, External meters and sensors	End-customer	Manual and Automated	Software user interface, Service with periodic reports, Automated notifications
HVAC Service Assistant, SA Mobile, Onboard controller	Field Diagnostic Services	Multi-fam, Outpat. Health., Hotel, Office, Restaurant, Retail, Supermarket, K-12 Ed, Warehouse, Data Centers	Large, Medium, Small	Cloud hosted, Desktop computer or other device, Controller-embedded	One-time purchase or SaaS. Updates included	Site staff, Third-party provider		Equipment on-board/internal measures, External meters and sensors	End-customer	Manual	Software user interface, Service with periodic reports, Automated notifications

Table 2. Technical capabilities and additional features of each tool surveyed

Tool name	Company	Systems covered	Categories of faults detectable	Methods/algorithms	Detection and diagnosis capabilities	Additional functionality
SkySpark	SkyFoundry	AC/HP, Chillers & towers, AHU & VAV, FCU, Com. refrig., Lighting, Boilers/furnace, Water heaters, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Com. refrig., Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Rule-based. Platform supports full programmability of rules and includes machine learning functions for use in FDD algorithms.	Fault presence, location, severity, root cause	Equip degradation, Fault prioritization, Auto work order, Energy impacts, Energy cost impacts, Other cost impacts, Meter data analytics, Time series visualization, KPI tracking and reporting, Benchmarking, Cost of resolution and payback
SkySpark (implementn.)	CBRE|ESI	AC/HP, Chillers & towers, AHU & VAV, FCU, Lighting, Boilers/furnace, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Rule-based	Fault presence, location, severity, root cause	Equip degradation, Fault prioritization, Auto work order, Energy impacts, Energy cost impacts, Meter data analytics, Time series visualization, KPI tracking and reporting, Benchmarking, Cost of resolution and payback
True Analytics	Ecorithm	AC/HP, Chillers & towers, AHU & VAV, FCU, Com. refrig., Lighting, Boilers/furnace, Water heaters, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Com. refrig., Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Qual. Model-based, Rule-based, Expert Systems, First Principles-based, Machine learning techniques, fast-sampling algorithms, and the spectral method.	Fault presence, location, severity, root cause	Equip degradation, Fault prioritization, Energy impacts, Meter data analytics, Time series visualization, KPI tracking and reporting, Benchmarking
Clockworks	KGS	AC/HP, Chillers & towers, AHU & VAV, FCU, Com. refrig., Lighting, Boilers/furnace, Water heaters, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Com. refrig., Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Simplified Physical Models, Expert Systems, First Principles-based, Limits and Alarms, Statistical	Fault presence, location, severity, root cause	Equip degradation, Fault prioritization, Auto work order, Energy impacts, Energy cost impacts, Meter data analytics, Time series visualization, KPI tracking and reporting, Benchmarking

Tool name	Company	Systems covered	Categories of faults detectable	Methods/algorithms	Detection and diagnosis capabilities	Additional functionality
Kaizen	CopperTree Analytics	AC/HP, Chillers & towers, AHU & VAV, FCU, Com. refrig., Lighting, Boilers/furnace, Water heaters, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Com. refrig., Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Rule-based. Includes an open library of rules for users to download, publish and share	Fault presence, location, severity, root cause	Equip degradation, Fault prioritization, Auto work order, Energy impacts, Energy cost impacts, Other cost impacts, Meter data analytics, Time series visualization, KPI tracking and reporting
BuildPulse	BuildPulse Inc.	AC/HP, Chillers & towers, AHU & VAV, FCU, Lighting, Boilers/furnace, Water heaters, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Rule-based, Qualitative model	Fault presence, location, severity, root cause	Equip degradation, Fault prioritization, Auto work order, Energy impacts, Energy cost impacts, Other cost impacts, Meter data analytics, Time series visualization, KPI tracking and reporting, Benchmarking, Cost of resolution and payback
Analytika	Cimetrics	AC/HP, Chillers & towers, AHU & VAV, FCU, Com. refrig., Lighting, Boilers/furnace, Water heaters, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Com. refrig., Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Quant. Model-based, Qual. Model-based, Rule-based, Expert Systems, First Principles-based, Limits and Alarms, Process History-based, Black Box, Statistical, Gray Box	Fault presence, location, severity, root cause	Equip degradation, Fault prioritization, Auto work order, Energy impacts, Energy cost impacts, Other cost impacts, Meter data analytics, Time series visualization, KPI tracking and reporting, Benchmarking
Niagara Analytics 2.0	Tridium	AC/HP, Chillers & towers, AHU & VAV, FCU, Com. refrig., Lighting, Boilers/furnace, Water heaters, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Com. refrig., Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Rule-based, Limits and Alarms	Fault presence, location, severity, root cause	Equip degradation, Fault prioritization, Auto work order, Energy impacts, Energy cost impacts, Other cost impacts, Meter data analytics, Time series visualization, KPI tracking and reporting, Cost of resolution and payback
IntelliCommand	JLL	AC/HP, Chillers & towers, AHU & VAV, FCU, Com. refrig., Lighting, Boilers/furnace, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Rule-based, Limits and Alarms, Statistical, Other Pattern Recognition Techniques	Fault presence, location, severity, root cause	Equip degradation, Fault prioritization, Auto work order, Energy impacts, Energy cost impacts, Other cost impacts, Meter data analytics, Time series visualization, KPI tracking and reporting

Tool name	Company	Systems covered	Categories of faults detectable	Methods/algorithms	Detection and diagnosis capabilities	Additional functionality
Balance	EEI	AC/HP, Chillers & towers, AHU & VAV, FCU, Com. refrig., Lighting, Boilers/furnace, Water heaters, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Com. refrig., Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Rule-based, Expert Systems, First-Principles Based	Fault presence, location, severity	Equip degradation, Fault prioritization, Auto work order, Energy impacts, Energy cost impacts, Other cost impacts, Meter data analytics, Time series visualization, KPI tracking and reporting, Cost of resolution and payback
Facility Analytix	ICONICS	AC/HP, Chillers & towers, AHU & VAV, FCU, Com. refrig., Lighting, Boilers/furnace, Water heaters, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Com. refrig., Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Rule-based, First Principles-based, Limits and Alarms	Fault presence, location, severity, root cause	Fault prioritization, Auto work order, Energy impacts, Energy cost impacts, Other cost impacts, Meter data analytics, Time series visualization, KPI tracking and reporting
eIQ	Transformative Wave	AC/HP	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Space Clg./Htg., Htg. system, Pump & fan systems, Sim. htg. & clg.	Rule-based, Expert Systems, Limits and Alarms	Fault presence, location, root cause	Fault prioritization, Energy impacts, Energy cost impacts, Time series visualization
ClimaCheck Onsite/ ClimaCheck Online	ClimaCheck	AC/HP, Chillers & towers, AHU & VAV, FCU, Com. refrig.	Sensor errors, Energy consumption, Econ. & vent., Com. refrig., Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Thermodynamic Evaluation, Energy Signatures	Fault presence, location, severity, root cause	Equip degradation, Energy impacts, Energy cost impacts, Time series visualization, KPI tracking and reporting
HVAC Service Assistant, SA Mobile, Onboard controller	Field Diagnostic Services	AC/HP, AHU & VAV, FCU	Sensor errors, Energy consumption, Space Clg./Htg.		Fault presence, location, severity, root cause	Equip degradation, Fault prioritization, Auto work order

VOLUME 11, NUMBER 2 HVAC&R RESEARCH APRIL 2005

REVIEW ARTICLE

Methods for Fault Detection, Diagnostics, and Prognostics for Building Systems— A Review, Part II

Srinivas Katipamula, PhD
Member ASHRAE

Michael R. Brambley, PhD
Member ASHRAE

Received December 23, 2003; accepted July 20, 2004
Part I of this article was published in Volume 11, Number 1, January 2005.

This paper is the second of a two-part review of methods for automated fault detection and diagnostics (FDD) and prognostics whose intent is to increase awareness of the HVAC&R research and development community to the body of FDD and prognostics developments in other fields as well as advancements in the field of HVAC&R. The first part of the review focused on generic FDD and prognostics, provided a framework for categorizing methods, described them, and identified their primary strengths and weaknesses (Katipamula and Brambley 2005). In this paper we address research and applications specific to the fields of HVAC&R, provide a brief discussion on the current state of diagnostics in buildings, and discuss the future of automated diagnostics in buildings.

INTRODUCTION

Poorly maintained, degraded, and improperly controlled equipment wastes an estimated 15% to 30% of energy used in commercial buildings. Much of this waste could be prevented with widespread adoption of automated condition-based maintenance. Automated fault detection and diagnostics (FDD) along with prognostics provide a cornerstone for condition-based maintenance of engineered systems. Although FDD has been an active area of research in other fields for more than a decade, applications for heating, ventilating, air conditioning, and refrigeration (HVAC&R) and other building systems have lagged those in other industries. Nonetheless, over the last decade there has been considerable research and development targeted toward developing FDD methods for HVAC&R equipment. Despite this research, there are still only a handful of FDD tools that are deployed in the field.

This paper, which is the second of two parts, provides a review of fault detection, diagnostics, and prognostics (FDD&P) research in the HVAC&R field and concludes with discussions of the current state of applications for buildings and likely contributions to operating and maintaining buildings in the future. In the first paper (Katipamula and Brambley 2005), we provided an overview of FDD&P, starting with descriptions of the fundamental processes and some important definitions, and then identified the strengths and weaknesses of methods across the broad spectrum of approaches.

Srinivas Katipamula is a senior research scientist and **Michael R. Brambley** is a staff scientist at Pacific Northwest National Laboratory, Richland, Washington.

FDD RESEARCH IN HVAC&R

In this section we review FDD research relating to refrigerators, air conditioners, chillers, and air-handling units (AHUs), which represent most of the HVAC&R FDD research completed to date. This review is an update to the review previously published by Katipamula et al. (2001) and includes recent FDD publications. For information on FDD for other building systems refer to Pape et al. (1990), Dexter and Benouarets (1996), Georgescu et al. (1993), Jiang et al. (1995), and Han et al. (1999) for HVAC&R plants; Fasolo and Seborg (1995) for HVAC&R control systems; Li et al. (1996, 1997) for heating systems; Isermann and Nold (1988) and Dalton et al. (1995) for pumps; Noura et al. (1993) for large thermal plants; Isermann and Ballé (1997) for applications for motors; and Dodier and Kreider (1999) for whole-building systems.

Refrigerators

One of the early applications of FDD was to vapor-compression-cycle-based refrigerators (McKellar 1987; Stallard 1989). Although McKellar (1987) did not develop an FDD system, he identified common faults for a refrigerator based on the vapor-compression cycle and investigated the effects of the faults on the thermodynamic states at various points in the cycle. He concluded that the suction pressure (or temperature), discharge pressure (or temperature), and the discharge-to-suction pressure ratio were sufficient for developing an FDD system. The faults considered were compressor valve leakage, fan faults (condenser and evaporator), evaporator frosting, partially blocked capillary tubes, and improper refrigerant charge (under and over charge).

Building upon McKellar's work, Stallard (1989) developed an automated FDD system for refrigerators. A rule-based expert system was used with simple limit checks for both detection and diagnosis. Condensing temperature, evaporating temperature, condenser inlet temperature, and the ratio of discharge-to-suction pressure were used directly as classification features. Faults were detected and diagnosed by comparing the change in the direction of the measured quantities with expected values and matching the changes to expected directional changes associated with each fault.

Air Conditioners and Heat Pumps

There are many applications of FDD to air conditioners and heat pumps based on the vapor-compression cycle. Some of these studies are discussed below (Yoshimura and Ito 1989; Kumamaru et al. 1991; Inatsu et al. 1992; Wagner and Shoureshi 1992; Rossi 1995; Rossi and Braun 1996, 1997; Breuker 1997; Breuker and Braun 1998b; Ghiaus 1999; Chen and Braun 2000). Breuker and Braun (1998a) summarized common faults in air conditioners and their impact on performance. In addition, the frequency of fault occurrence and the relative cost of service for various faults were estimated from service records.

Yoshimura and Ito (1989) used pressure and temperature measurements to detect problems with condenser, evaporator, compressor, expansion valve, and refrigerant charge on a packaged air conditioner. The differences between measured values and expected values were used to detect faults. Expected values were estimated from manufacturers' data, and the thresholds for fault detection were experimentally determined in the laboratory. Both detection and diagnosis were conducted in a single step. No details were provided as to how the thresholds for detection were selected.

Wagner and Shoureshi (1992) developed two different fault detection methods and compared their abilities to detect five different faults in a small heat pump system in the laboratory. The five faults included abrupt condenser and evaporator fan failures, capillary tube blockage, compressor piston leakage, and seal system leakage. The first method was based on limit and trend

Table 1. Symptom Patterns for Selected Faults (Grimmelius et al. 1995)

Fault Modes	Compressor Suction Pressure	Compressor Suction Temperature	Compressor Discharge Pressure	Compressor Discharge Temperature	Compressor Pressure Ratio	Oil Pressure	Oil Temperature	Oil Level	Crankcase Pressure	Compressor Electric Power	Subcooling of Refrigerant	ΔT Refrigerant and Cooling Water	ΔT Cooling Water	Inlet Temperature at Expansion Valve	Filter Pressure Drop	Evaporator Outlet Pressure	Superheat	ΔT Chilled Water	Evaporator Outlet Temperature	Number of Acting Cylinders
Compressor, Suction Side, Increase in Flow Resistance	↓	→	→	→	→	↓	→	→	↓	↓	→	→	→	→	→	↑	↑	↓	→	→
Compressor, Discharge Side, Increase in Flow Resistance	↑	→	↑	→	→	↑	→	→	↑	→	→	→	→	→	→	↑	↑	↓	→	→
Condenser, Cooling Water Side, Increase in Flow Resistance	→	→	↑	→	→	→	→	→	→	↑	↓	→	↑	→	→	→	→	→	→	→
Fluid Line Increase in Flow Resistance	→	→	→	→	→	→	→	→	→	↓	→	→	→	↓	→	→	↑	↑	→	→
Expansion Valve, Control Unit, Power Element Loose from Pipe	↑	→	→	→	→	↑	→	→	↑	↑	→	→	→	→	→	↑	↓	↑	→	→
Evaporator, Chilled Water Side, Increase in Flow Resistance	↓	→	→	→	→	↓	→	→	↓	↓	→	→	→	→	→	↓	↑	↑	→	→

checking (qualitative model-based), and the second method was a simplified physical model-based approach. In the second approach, differences between predictions from a simplified physical model and the monitored observations are transformed into useful statistical quantities for hypothesis testing. The transformed statistical quantities are then compared to predetermined thresholds to detect faults.

The two fault detection strategies were operated in parallel on a heat pump in a psychrometric room. The qualitative method was able to detect four of five faults that were introduced abruptly, while the simplified physical model-based method was successful in only detecting two faults. Because the selection of thresholds for both methods is critical in avoiding false alarms and reduced sensitivity, Wagner and Shoureshi (1992) provide a brief discussion of how to trade off diagnostic sensitivity against false alarms. Their implementation is only capable of detecting faults and does not include diagnosis, evaluation, and decision making.

Rossi (1995) described the development of a statistical rule-based fault detection and diagnostic method for air-conditioning equipment with nine temperature measurements and one humidity measurement. The FDD method is capable of detecting and diagnosing condenser fouling, evaporator fouling, liquid-line restriction, compressor valve leakage, and refrigerant leakage. In addition to the detection and diagnosis, Rossi and Braun (1996) also describe an implementation of fault evaluation. A detailed explanation of the fault evaluation method can be found in Rossi and Braun (1997). The methods were demonstrated in limited testing with a rooftop air conditioner in the laboratory.

Breuker (1997) performed a more detailed evaluation of the methods developed by Rossi (1995). The detailed evaluation relied on steady-state and transient tests of a packaged air conditioner in a laboratory over a range of conditions and fault levels (Breuker and Braun 1998b). Seven polynomial models (ranging from first to third order) were developed to characterize the performance of the air conditioner (evaporating, condensing, and compressor outlet temperatures, suction line superheat, liquid line subcooling, temperature rise across the condenser, and temperature drop across the evaporator) using steady-state data representing normal (unfaulted) operations. The steady-state normal data are also used to determine the statistical thresholds for fault detection, while transient data with faults were used to evaluate FDD performance. Breuker and Braun (1998b) concluded that refrigerant leakage, condenser fouling, and liquid line restriction were detected and diagnosed before 8% reduction in capacity or COP occurred. The technique, however, was less successful in detecting evaporator fouling and compressor valve leakage. The authors also concluded that increasing the measurements from 6 (2 inputs and 4 outputs) to 10 (3 inputs and 7 outputs) and using higher order polynomial models improved the performance by a factor of two.

Ghiaus (1999) presented a bond-graph model for a direct-expansion vapor-compression system and applied it to diagnosing two faults in an air conditioner. The author states that this qualitative approach of modeling faults does not need *a priori* knowledge of possible faults as long as the bond model is complete and accurate.

Chillers

Several researchers have applied FDD methods to detect and diagnose faults in vapor-compression-based chillers; some of the studies are summarized below (Grimmelius et al. 1995; Gordon and Ng 1994, 1995; Stylianou and Nikanpour 1996; Tsutsui and Kamimura 1996; Peitsman and Bakker 1996; Stylianou 1997; Bailey 1998; Sreedharan and Haves 2001; Castro 2002). Comstock et al. (1999) and Reddy et al. (2001) provide a detailed review of FDD literature relating to chiller systems up to their respective times. Comstock et al. (2002) presented a list of common chiller faults and their impacts on performance.

Grimmelius et al. (1995) developed a fault diagnostic system for a chiller, in which fault detection and diagnostics are carried out in a single step. The FDD method uses a reference model based on multivariate linear regression that was developed with data from a properly operating chiller to estimate values for process variables for a healthy (unfaulted) chiller. These estimates are subsequently used to generate residuals (i.e., differences between actual measured values and the values from the reference model). Patterns of these residuals are compared to characteristic patterns corresponding to faulted conditions, and scores are assigned indicating the degree to which the patterns match the pattern corresponding to each fault mode. Fault modes with good fits (high scores) are judged as probably existing in the chiller. Fault modes with poor fits (low scores) are judged as unlikely to exist in the chiller, and faults with intermediate scores are labeled as possibly existing. Twenty different measurements are used including

Table 2. Scoring of Fault Modes for a Highly Idealized Example

Fault Mode/ Score		Symptom 1	Symptom 2	Symptom 3	Symptom 4	Total Score	Normalized Score
F1		↓	→	↓	↑		
	Scores	10	10	10	10	40	1.0
F2		↑	→	↑	→		
	Scores	0	9	0	3	12	0.3
Measurement-Based Pattern		↓	→	↓	↑		

temperatures, pressures, power consumption, and compressor oil level. In addition to the measured variables, some derived variables, such as liquid subcooling, superheat, and pressure drop, are used. The inputs to the model also include the outdoor ambient temperature and load conditions.

To identify potential fault modes, the chiller is classified into seven components: compressor, condenser, evaporator, expansion valve, liquid line immediately downstream of the condenser and including a filter drier, liquid line with solenoid and sight glass between the other liquid line and the evaporator, and the crankcase heater. Fault modes are associated with any component that is serviceable, which leads to 58 different fault modes. A cause and effect study of the 58 fault modes helped establish the expected influence of the faults on the components, measured variables, and subsequent chiller behavior. Symptoms are defined as a difference in any measured or derived variable from its expected value for normal unfaulted operation (i.e., the value given by the reference model). Symptoms associated with all 58 fault modes were generated and arranged into symptom patterns. Fault modes having identical symptom patterns were aggregated into a single fault mode, reducing the total number of fault modes from 58 to 37. These symptom patterns are arranged in a symptom matrix as shown in Table 2, with each row giving the symptom pattern associated with a particular fault. A symptom (cell in the matrix) shown by an arrow pointing up, ↑, indicates a value for the variable greater than that given by the reference model. Likewise, an arrow pointing down, ↓, indicates a symptom corresponding to a value for the variable less than the value from the reference model, and a horizontal arrow, →, indicates the fault has no effect on the corresponding variable.

To diagnose a fault, a symptom pattern corresponding to a set of measurements is compared to the symptom patterns for all of the fault modes. Scores are assigned to each fault mode indicating the probability that its symptom pattern matches the measured symptom pattern as follows. For each fault mode, each symptom is compared to its corresponding measured symptom and assigned a score between 0 and 10. If the symptom for the fault mode matches the measured symptom very well, it is assigned a high score (close to 10). If it weakly matches, it is assigned a score around 5, and if it does not match well at all, it is assigned a score close to zero. A total score for each fault mode is generated by adding the individual scores of all symptoms and dividing the total by the maximum possible score per pattern (i.e., the number of symptoms in the pattern multiplied by 10) to obtain a normalized score. These normalized scores are then classified into three categories. A normalized score of 0.9 or higher indicates a probable fault, a score between 0.5 and 0.9 indicates a possible fault, and scores lower than 0.5 indicate that the fault is likely not present.

A highly simplified example is shown in Table 2. Symptom patterns for two faults, F1 and F2, are shown along with a symptom pattern derived from measurements. Each pattern consists of symptoms based on four variables. Scores have been assigned to the symptoms in each pattern based on how well the symptom shown in the symptom matrix corresponds to the symptom based on measurements. For example, Symptom 1 for fault mode F1 corresponds identically to Symptom 1 in the pattern derived from measurements, so it is assigned a score of 10. The normalized scores in this example lead to the conclusion that fault F1 with a score of 1.0 probably exists in this system and fault F2 with a score of 0.3 is likely not present. In actual implementation, this methodology accounts for uncertainty in measurements by establishing threshold bands around numerical values of measured and derived variables and using the proximity to them in assigning scores to symptoms. The exact algorithm for assigning numerical scores, however, is not available in the paper.

Although the method proved effective in identifying faults in systems before the chiller system failed completely, faults with only a few symptoms tended to get high scores more often. Because the reference model is a simple regression model developed with data from a specific test chiller, the same model cannot be used on other chillers but instead new models would need to be developed for each chiller. Nonetheless, this generic approach provided a foundation for diagnostic work that followed.

Stylianou and Nikanpour (1996) used the universal chiller model developed by Gordon and Ng (1995) and the pattern matching approach outlined by Grimmelius et al. (1995) as part of their FDD system. Like Grimmelius et al. (1995), Stylianou and Nikanpour also perform detection and diagnosis in a single step. The methods used in the FDD system included a thermodynamic model for fault detection and pattern recognition from expert knowledge for diagnosis of selected faults. The diagnoses of the faults are performed by an approach similar to that outlined by Grimmelius et al. (1995). Seventeen different measurements (pressures, temperatures, and flow rates) were used to detect four different faults: refrigerant leak, refrigerant line flow restriction, condenser water-side flow resistance, and evaporator water-side flow resistance.

The FDD system is subdivided into three parts: one used to detect problems when the chiller is off, one used during chiller start-up, and one used at steady-state conditions. The off-cycle module is deployed when the chiller is turned off and is primarily used to detect faults in the temperature sensors. The temperature sensor readings at different locations on the system are compared to one another after the chiller is shut down and reaches steady state (under the assumption that the temperature of refrigerant will reach equilibrium conditions and reach the ambient state when the chiller is shut down overnight). The differences are then compared to the difference observed during commissioning (if the sensors are calibrated during commissioning, the differences should be zero). The monitored rate of change of a sensor value is used to check whether a particular sensor has reached steady state or not before comparing measurements across sensors.

The start-up module is deployed during the first 15 minutes after the chiller is started. The module uses four measured inputs (discharge temperature, crankcase oil temperature, and refrigerant temperatures entering and leaving the evaporator) scanned at five-second intervals to detect refrigerant flow faults, which are easier to detect before the system reaches steady state. To detect faults, the transient trends in measured variables during start-up are compared to the baseline trend from normal start-up. For example, a shift (in time or magnitude) in the peak of the discharge temperature may indicate liquid refrigerant flood back, refrigerant loss, or a refrigerant line restriction. Because ambient conditions affect the baseline response, the baseline response has to be normalized before a comparison is made.

The steady-state module is deployed after the chiller reaches steady state (steady-state condition is established by monitoring the rate of change of the sensor values just as in off-cycle analysis) and stays deployed until the chiller is turned off. In this mode, the module performs two functions: (1) verifies performance of the system and (2) detects and diagnoses selected faults.

Table 3. Fault Patterns Used in the Diagnostic Module (Stylianou and Nikanpour 1996)

Fault	Discharge Temperature	High Pressure Liquid Line Temperature	Discharge Pressure	Low Pressure Liquid Line Temperature	Suction Line Temperature	Suction Pressure	ΔT_{cond}	ΔT_{Evap}
Restriction in Refrigerant Line	↑	↓	↓	↓	↑	↓	↓	↑
Refrigerant Leak	↑	↓	↓	↓	↑	↓	↓	↑
Restriction in Cooling Water	↑	↑	↑	↓	↓	↓	↑	↓
Restriction in Chilled Water	↑	↓	↓	↓	↓	↓	↓	↓

Performance is verified using the thermodynamic models developed by Gordon and Ng (1995). For fault diagnostics, linear regression models are used to generate estimates of pressure and temperature variables that are then compared to actual measurements in an approach similar to that described by Grimmelius et al. (1995). The estimated variables are compared to the measured values, and the residuals are matched to predefined patterns corresponding to the various faults using a rule-base (as shown in Table 3).

Although Stylianou and Nikanpour (1996) extended the previous work of Gordon and Ng (1995) and Grimmelius et al. (1995), their evaluation of the FDD systems was not comprehensive and lacked several key elements including sensitivity and rate of false alarms. In addition, it is not clear whether the start-up module can be generalized easily.

Stylianou (1997) replaced the rule-based model used to match the patterns shown in Table 3 with a statistical pattern recognition algorithm. This algorithm uses the residuals generated from comparison of predicted (using linear regression models) and measured pressures and temperatures to generate patterns that identify faults. Because this approach relies on the availability of training data for both normal and faulty operation, it may be difficult to implement in the field. Only limited testing of the method was presented in the paper.

Tsutsui and Kamimura (1996) developed a model based on a topological-case-based reasoning (TCBR) technique and applied it to an absorption chiller. Case-based reasoning is a knowledge-based problem-solving technique that solves new problems by adapting old solutions. It is based on defining neighborhoods that provide the needed measure of similarity between cases. In contrast, TCBR defines "the neighborhood theoretically, based on the assumption that the input/output relationship is locally continuous" (Tsutsui and Kamimura 1996). Tsutsui and Kamimura (1996) also compared the diagnostic capabilities of TCBR with a linear regression model. The authors state that although the linear regression model had a better overall modeling error (mean error) than the TCBR model, the TCBR model was better at identifying abnormal conditions.

Peitsman and Bakker (1996) used two types of black-box models (artificial neural networks [ANNs] and auto regressive with exogenous inputs [ARX[1]]) to detect faults in the system and at the component level of a reciprocating chiller system. The inputs to the system models included condenser supply water temperature, evaporator supply glycol temperature, instantaneous power of the compressor, and flow rate of cooling water entering the condenser (for the ANN only). The choice of the inputs was limited to those that are commonly available in the field. Using these inputs with both the ANN and ARX models, 14 outputs were estimated. For the ANN models, inputs from the current and the previous time step and outputs from two previous time steps were used.

Peitsman and Bakker (1996) compared diagnostic capabilities of two types of models—a multiple input/output ARX model and ANN models. They used a two-level approach in which system-level models were used to detect "faulty" operation and component-level models were used to diagnose the cause of the fault. They developed 14 system-level models and 16 component-level models to detect and diagnose faults in a chiller; however, only one example (air in the system) is described in their paper. ANN models appeared to have a slightly better performance than the ARX models in detecting faults at both the system and the component levels. The authors also note that it is critical to find a global minimum when using ANN models. If an incorrect initial state is chosen, it may lead to a local minimum rather than the global minimum.

Bailey (1998) also used an ANN model to detect and diagnose faults in an air-cooled chiller with a screw compressor. The detection and diagnosis were carried out in a single step. The faults evaluated included refrigerant under- and overcharge, oil under- and overcharge, condenser fan loss (total failure), and condenser fouling. The measured data included superheat for heat exchanger circuits 1 and 2, subcooling from circuits 1 and 2, power consumption, suction pressure for circuits 1 and 2, discharge pressures for circuits 1 and 2, chilled water inlet and outlet temperatures from the evaporator, and chiller capacity. Each heat exchanger circuit has its own compressor. The ANN model was applied to normal and "faulty" test data collected from a 70-ton laboratory air-cooled chiller with screw compressor.

Sreedharan and Haves (2001) compared three chiller models for their ability to reproduce the observed performance of a centrifugal chiller. Although the evaluation was meant to find the most suitable model for chiller FDD, no FDD system was proposed or developed. Two models were based on first principles (from Gordon and Ng [1995] and a modified ASHRAE Primary Toolkit from Bourdouxhe et al. [1997]) and the third was an empirical model. While each model has some distinct advantages and disadvantages, they concluded that the accuracies of all three models were similar. Hydeman et al. (2002) reported that the three models compared by Sreedharan and Haves (2001) were not accurate in predicting the power consumption of chillers with variable condenser water flow and centrifugal chillers operating with variable-speed drives at low loads. They reformulated the Gordon and Ng model and found that it performed better than the three models described above.

Castro (2002) used a physical model developed by Rossi (1995) along with a k-nearest neighbor classifier to detect faults and a rule base to diagnose five different faults (condenser and evaporator fouling, liquid line restriction, and refrigerant under- and overcharge) in a reciprocating chiller. The FDD implementation detected and diagnosed condenser fouling, refrigerant undercharge at faults level of 20% or greater, and evaporator fouling and liquid line restriction at fault levels of 30% or greater.

[1]Refer to Box and Jenkins (1976) for more details on ARX type models.

Air-Handling Units

There are several studies relating to FDD methods for air-handling units (both the airside and the waterside); some of these are summarized in this section (Norford and Little 1993; Glass et al. 1995; Yoshida et al. 1996; Haves et al. 1996; Lee et al. 1996a, 1996b; Lee et al. 1997; Peitsman and Soethout 1997; Brambley et al. 1998; Katipamula et al. 1999; House et al. 1999; Ngo and Dexter 1999; Yoshida and Kumar 1999; Seem et al. 1999; Karki and Karjalainen 1999; Morisot and Marchio 1999; House et al. 2001; Dexter and Ngo 2001; Kumar et al. 2001; Salsbury and Diamond 2001; Carling 2002; Norford et al. 2002; Wang and Chen 2002; Pakanen and Sundquist 2003).

Norford and Little (1993) classify faults in ventilating systems, consisting of fans, ducts, dampers, heat exchangers, and controls. They then review two forms of steady-state parametric models for the electric power used by supply fans and propose a third, that of correlating power with a variable-speed drive control signal. The models are compared based on prediction accuracy, sensor requirements, and their ability to detect faults.

Using the three proposed models, four different types of faults associated with fan systems are detected: (1) failure to maintain supply air temperature, (2) failure to maintain supply air pressure setpoint, (3) increased pressure drop, and (4) malfunction of fan motor coupling to fan and fan controls. Although the paper by Norford and Little (1993) lacks details on how the faults were evaluated, error analysis and associated model fits were discussed. The results indicate that all three models were able to identify at least three of the four faults. The diagnosis of the faults is inferred after the fault is detected.

Glass et al. (1995) use a qualitative model-based approach to detect faults in an air-handling unit. The method uses outdoor, return, and supply air temperatures and control signals for the cooling coil, heating coil, and the damper system. Although Glass et al. (1995) mention that the diagnosis is inferred from the fault conditions, no clear explanation or examples are provided. Detection starts by analyzing the measured variables to verify whether steady-state conditions exist. Then, the controller values are converted to qualitative signal data and, using a model for expected values and measured temperature data, qualitative signals are estimated. Faults are detected based on discrepancies between measured qualitative controller outputs and corresponding model predictions based on the temperature measurements. Examples of qualitative states for the damper signal include "maximum position," "minimum position," "closed," and "in between." When the quantitative value of the damper signal approaches the maximum value, the corresponding qualitative value of "maximum" is assigned to the measured controller output. The results of testing the method on a laboratory AHU were mixed because the method requires steady-state conditions to be achieved before fault detection is undertaken. Fault detection sensitivity and ability to deal with false alarms are not discussed.

Yoshida et al. (1996) use ARX and the extended Kalman filter approach to detect abrupt faults with simulated test data for an AHU. Although the fault diagnosis approach is clearly described, the authors note that diagnosis is not feasible with the ARX method but that the Kalman filter approach could be used for diagnosis. Fault detection sensitivity and ability to deal with false alarms are not discussed.

Haves et al. (1996) use a combination of two models to detect coil fouling and valve leakage in the cooling coil of an AHU. The methodology was tested with data produced by the HVACSIM+ simulation tool (Clark 1985). A radial bias function (RBF) models the local behavior of the AHU and is updated using a recursive gradient-based estimator. The data generated by exercising the RBF over the operating range of the system are used in the estimation of the parameters for the physical model (UA and percent leakage) using a direct search method. Detection is accomplished by comparing estimated parameters to fault-free parameters.

Lee et al. (1996a) used two methods to detect eight different faults (mostly abrupt faults) in a laboratory test AHU. The first method uses discrepancies between measured and expected variables (residuals) to detect the presence of a fault. The expected values are estimated at nominal operating conditions. The second method compares parameters estimated using autoregressive moving average with exogenous input (ARMX) and ARX models with the normal (or expected) parameters to detect faults. The faults evaluated included complete failure of the supply and return fans, complete failure of the chilled-water circulation pump, stuck cooling-coil valve, complete failure of temperature sensors, complete failure of the static pressure sensor, and failure of the supply and return air fan flow stations. Because each of the eight faults has a unique signature, no separate diagnosis is necessary.

Lee et al. (1996b) used an ANN to detect the same faults described previously (Lee et al. 1996a). The ANN was trained using the normal data and data that represented each of the eight faults. Inputs to the ANN were values for seven normalized residuals, and the outputs were nine values that constitute patterns that represent the normal mode and the eight fault modes. Instead of generating the training data with faults, idealized training patterns were specified by considering the dominant symptoms of each fault. For example, supply fan failure implies that the supply fan speed is zero, the supply air pressure is zero, the supply fan control signal is maximum, and the difference between the flow rates in the supply and return ducts is zero. Using similar reasoning, a pattern of dominant training residuals was generated for each fault (see Table 4). A dominant symptom residual is assigned a value of +1 if the residual is positive and –1 if the residual is negative; all other residuals are assigned a value of 0. The ANN was trained using the pattern shown in Table 4. Normalized residuals were calculated for faults that were artificially generated in the laboratory AHU. The normalized residuals vector at each time step was then used with the trained ANN to identify the fault. Although the ANN was successful in detecting the faults from laboratory data, it is not clear how successful this method would be in general because the faults generated in the laboratory setting were severe and without noise.

Lee et al. (1997) extended the previous work described in Lee et al. (1996b). In the 1997 analysis, Lee et al. (1997) used two ANN models to detect and diagnose faults. The AHU is decomposed into various subsystems such as the pressure control subsystem, the flow-control subsystem, the cooling-coil subsystem, and the mixing-damper subsystem. The first ANN model is trained to identify the subsystem in which a fault occurs, while the second ANN model is trained to diagnose the specific cause of a fault at the subsystem level. An approach similar to the one used in Lee et al. 1996b is used to train both ANN models. Lee et al. (1997) note that this two-stage approach simplifies generalization by replacing a single ANN that encompasses all considered faults with a number of less complex ANNs, each one dealing with a subset of the residuals and symptoms. Although 11 faults are identified for detection and diagnosis, fault detection and diagnosis are presented for only one fault in the paper.

Peitsman and Soethout (1997) used several different ARX models to predict the performance of an AHU and compared the predictions to measured values to detect faults. The training data for the ARX models were generated using HVACSIM+. The AHU is modeled at two levels. The first level is the system level, where the complete AHU is modeled with one ARX model. The second level is the component level, where the AHU is subdivided into several subsystems such as the return fan, the mixing box, and the cooling coil. Each component is modeled with a separate ARX model. The first level ARX model is used to detect a problem and the second level models are used to diagnose the problem. Most abrupt faults were correctly identified and diagnosed, while slowly evolving faults were not detected. There is a potential for a conflict between the two levels with this approach; for example, the top-level ARX model could detect a fault with the AHU, while the second-level ARX models do not indicate any faults. Furthermore, there is a potential for multiple diagnoses at the second level. Peitsman and Soethout (1997)

Table 4. Normalized Patterns for AHU Fault Diagnosis Used in ANN Training (Lee et al. 1996b)

Fault Diagnosis	Network Inputs – Residuals: Supply Pressure	Difference in Supply and Return Airflow	Supply Air Temperature	Control Signal to Cooling Coil	Supply Fan Speed	Return Fan Speed	Cooling Coil Valve Position	Network Outputs								
Normal (no fault)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Supply Fan	–1	–1	0	1	–1	0	0	0	1	0	0	0	0	0	0	0
Return Fan	0	1	0	0	0	–1	0	0	0	1	0	0	0	0	0	0
Pump	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
Cooling Coil Valve	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
Temperature Sensor	0	0	–1	–1	0	0	0	0	0	0	0	0	1	0	0	0
Pressure Transducer	–1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Supply Fan Flow Station	0	–1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Return Fan Flow Station	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1

indicated that some of this multiple diagnosis could be discriminated by ranking of diagnoses according to their improbability; however, no details were provided on how to implement such a scheme.

House et al. (1999) compared several classification techniques for fault detection and diagnosis of seven different faults in an AHU. The data for the comparison were generated using an HVACSIM+ simulation model. Using the residuals, as defined in Lee et al. (1996a, 1996b), five different classification methods are evaluated and compared for their ability to detect and diagnose faults. The five classification methods include: ANN classifier, nearest neighbor classifier, nearest prototype classifier, a rule-based classifier, and a Bayes classifier.

Based on the performance of classification methods, the Bayes classifier appears to be a good choice for fault detection. For diagnosis, the rule-based method proves to be a better choice for the classification problems considered, where the various classes of faulty operations were well separated and could be distinguished by a single dominant symptom or feature.

Ngo and Dexter (1999) developed a semi-qualitative analysis of measured data using generic fuzzy reference models to diagnose faults with the cooling coil of an AHU. The method uses sets of training data with and without faults to develop generic fuzzy reference models for diagnosing faults in a cooling coil. The faults include leaky valve, waterside fouling, valve stuck closed, valve stuck midway, and valve stuck open. The fuzzy reference models describe in qualitative terms the steady-state behavior of a particular class of equipment with no faults present and when each of the faults has occurred. Measured data are used to identify a partial fuzzy model that describes the steady-state behavior of the equipment at a particular operating point. The partial fuzzy model is then compared to each of the reference models using a fuzzy matching scheme to determine the degree of similarity between the partial model and the reference models. Ngo and Dexter (1999) provide a detailed description of fault detection sensitivity and false alarm rates.

Yoshida and Kumar (1999) evaluated two model-based methods to identify abrupt (sudden) faults in an AHU. They report that both ARX and adaptive forgetting through multiple models (AFMM) seem promising for use in on-line fault detection of AHUs. They report that ARX models require only a minimal knowledge of the system, and the potential limitation of the technique is that it requires long periods to stabilize its parameters. On the other hand, Yoshida and Kumar (1999) report that the AFMM method requires long moving averages to suppress false alarms. When this is done, faults of lesser magnitude cannot be easily detected. Implementation details are not provided, and only one example of fault detection is provided.

Morisot and Marchio (1999) use an ANN-based approach to detect degradation of performance of a cooling coil in an AHU. The ANN network includes an input layer (six inputs), a hidden layer (four nodes), and an output layer (two outputs). The inputs include entering air temperature and humidity, entering and leaving water temperatures, fan-control signal, and cooling-coil-valve-control signal. The outputs are the leaving air temperature and humidity. The authors highlight the difficulties of using ANNs with real measured data, which include a need for an exhaustive training data set and the inability of the ANNs to extrapolate values outside the range of the training data. The proposed alternative is to use a simulation model to generate the training data for the ANN. Using this alternative approach, the authors test the ability of the ANN to detect two faults (air-side fouling and a sensor fault).

Dexter and Ngo (2001) outline a multi-step fuzzy model-based FDD approach to detecting and diagnosing faults with AHUs. This approach involves classifying measured data with fuzzy rules and comparing them to a set of fuzzy reference models for normal and faulty operations. The fuzzy reference models for a specific system are developed from data that are generated from simulations. Each rule is assigned a rule-confidence in the range from zero to one, where zero indicates no confidence and one indicates complete confidence in the rule correctly describing the behavior. Rule-confidence values are estimated from the data. The authors state that this method prevents false alarms because it accounts for major sources of uncertainty. The multi-step approach is shown to be capable of detecting and isolating faults in a cooling coil (leaking valves and fouling).

Kumar et al. (2001) propose a method based on an auto regressive exogenous model and a recursive parameter estimation algorithm to detect faults with AHUs. They conclude that changes in parameter estimates from real data cannot be directly used to detect faults; instead a statistical analysis of the frequency response of the model parameters is needed to detect faults.

Salsbury and Diamond (2001) develop a simplified physical model-based approach to both control and detect faults in AHUs. Results from a field test on a single AHU demonstrate the fault detection capabilities but also highlight some of the practical implementation difficulties including selection of model parameters, reliability of sensor signals, and difficulty in establishing a baseline of "correct" operation of the AHU.

Carling (2002) assesses the performance of three fault detection methods for AHUs: (1) qualitative model-based approach outlined in Glass et al. (1995), (2) rule-based approach outlined in House et al. (2001), and (3) simplified steady-state model-based. The normal and "faulty" data used for the assessment were collected from real systems for an offline analysis. The "faulty data" were collected by introducing artificial faults in the AHU. The qualitative model was easy to set up, generated few false alarms, but also detected fewer faults. The rule-based method detected more faults but required some analysis and customization during setup. The third method detected more faults but also generated more false alarms and took considerable time to set up and customize. It also required installation of additional sensors.

Norford et al. (2002) present results from controlled field tests for detecting and diagnosing faults in AHUs. These tests were part of an ASHRAE research project (RP-1020), which was to demonstrate FDD methods for AHUs. The first FDD method used a first-principles model-based approach, and the second one was based on semi-empirical polynomial correlations of submetered electrical power with flow rates or process control signals generated from historical data. Although data representing faulty operation were based on blind tests, the faults were selected from a predefined set for an agreed set of conditions and magnitudes. The criteria used in the evaluation of the two FDD methods were sensitivity, robustness, the number of sensors required, and ease of implementation.

Both methods were successful in detecting faults but had difficulty in diagnosing the actual cause of the fault. The first principles-based method requires more sensors and more training data and misdiagnosed more often than the semi-empirical method.

CURRENT STATE FOR DIAGNOSTICS IN BUILDINGS

During the 1990s, significant growth occurred in research on the development of fault detection and diagnostic methods for HVAC&R systems. Still, very few commercial FDD products exist today, and the ones that do are very specialized or not fully automated. There are several reasons for lack of widespread availability and deployment of FDD systems: lack of demand by the building operations and maintenance (O&M) community, possibly as a result of insufficient information on the improvements possible from automated FDD, lack of adequate sensors installed on building systems, reliable sensors being too costly, high perceived cost-to-benefit ratio of deploying FDD systems with current sensor technologies, lack of acceptable benchmarks to quantify the potential benefits from deploying FDD systems, lack of easy access to real-time data unless FDD is built directly into building automation systems, and lack of infrastructure to gather data from existing building automation systems (BASs) for add-on applications.

Most papers reviewed for this study did not cover the evaluation and decision stages of a generic O&M support system using FDD; yet to be useful in the field FDD must be embedded in complete building management and decision support systems. Katipamula et al. (1999), Rossi and Braun (1996), and Breuker and Braun (1998b) have addressed the evaluation aspect of the O&M support system, and Katipamula et al. (2002) and Brambley and Katipamula (2003) proposed a decision step for AHUs. Furthermore, many of the FDD methods have only been tested in laboratory or special test environments (Castro et al. 2003). Some FDD tools have been tested in the field (Katipamula et al. 2003; Castro et al. 2003; Braun et al. 2003). The detection sensitivity of the methods and occurrence rates for false alarms have not been thoroughly investigated in real buildings yet. Although the R&D reviewed is focused on methods for automating FDD, most papers do not address the automation itself in sufficient detail. Efficiently and cost-effectively creating the code that implements these methods represents an important aspect of creating usable tools based on these methods.

A significant number of papers address FDD methods based on process history. In most cases, models based on process history are specific to the system from which the training data are collected. In order to make these methods broadly applicable, the models need to be developed in factory settings for equipment model lines or automatically online in an as-installed setting. Automation of the model development process is critical to controlling the costs of FDD systems. Preliminary work on online modeling has been done by Reddy et al. (2001), but more work is needed in this general area.

Another major limitation of most FDD methods developed to date is that they work well when a single dominant fault is present in a system, but if multiple faults occur simultaneously or are present when FDD is done initially, many of the methods fail to properly detect or diagnose the causes of the faults. Braun et al. (2003) extended the previous work by Rossi and Braun (1996) and Breuker and Braun (1998b) to diagnose multiple simultaneous faults. More work is needed in development of methods that can reliably handle multiple faults.

FUTURE FOR AUTOMATED DIAGNOSTICS IN BUILDINGS

The application of automated FDD to building HVAC&R is still in its infancy. Key technical problems still requiring solutions include:

- eliminating the need to handcraft FDD systems
- automating generation of FDD systems
- selecting the best FDD method for each type of HVAC&R application and the constraints applicable to it
- developing the balance of system for operation and maintenance support tools—evaluation and decision support
- development of prognostics to transform HVAC&R maintenance from corrective and preventive to predictive condition-based maintenance
- lowering the cost of obtaining data for FDD and O&M support

To the extent that FDD requires handcrafting for each installation, costs will likely be prohibitive. Three generically different solutions for this problem exist: (1) deploy FDD in service tools with databases sufficient to cover many equipment model lines, (2) deploy FDD as part of on-board equipment control packages, and (3) develop methods for automatically generating FDD tools. The first approach has already been introduced to the market in a hand tool for air-conditioning service providers (Honeywell 2003). More tools of this type, embedding automated FDD, are likely to evolve. The second approach of embedding monitoring and safety controls capabilities in on-board equipment control is already underway to some extent by manufacturers of equipment and equipment control packages (such as chillers for safety reasons but not for system performance). Capabilities deployed to date appear limited and details of methods are difficult to obtain because of their proprietary nature, but FDD deployment is beginning to emerge via this route. The third approach involving rapid generation, possibly in an automated manner, requires further research not only into the methods for FDD but also for automated code generation (in the fields of software development, adaptive systems, genetic systems, etc.).

Additional R&D is needed in the field of FDD itself to further develop fundamental methods for FDD, selection and specialization of methods to the constraints of the built environment (e.g., pressure to keep costs low and a data-poor environment in buildings), application and testing of FDD to the various systems, equipment, and components used in buildings, and development and application of FDD for building systems of the future, which are likely to include integration with on-site electricity generation, management of electric loads, real-time purchasing of electricity, and other interactions with the electric power grid of the future, and transition to new fuels (e.g., energy carriers such as hydrogen). All provide rich areas for research and development that will improve the performance and efficiency of commercial and residential buildings.

Prognostics are critical to transitioning building equipment maintenance as practiced today to condition based so that it accounts for the expected remaining life of equipment and its performance degradation over time. Only with this information can decisions be made regarding the optimal scheduling of maintenance. The field of prognostics presents a rich area of investigation and development for the HVAC&R research community. Little has been published to date on prognostics for HVAC&R.

Beyond research into FDD methodologies and their application to building systems, the HVAC&R field is faced with the opportunity to develop an entirely new class of tools and to add them to building automation systems. FDD methods may provide a core capability for enhanced operation and maintenance support systems of the future, but the balance of those systems must be developed. Packaging is critical to success in the market. Tools must be developed that meet the needs and fit into the environment of building operators and maintenance service providers and provide them value.

Probably the most constraining of all problems facing the application of FDD&P to HVAC&R is the dearth of data. Relatively small numbers of sensors are generally installed in building systems and the quality (accuracy, precision, and reliability) of the sensors that are installed is inadequate for many uses. Sensors frequently fail or drift out of calibration and remain that way for long periods of time until fortuitously discovered. Performance, cost, and durability need to be addressed to promote better sensing in buildings.

With the development of low-cost reliable sensor technology (Kintner-Meyer and Brambley 2002; Kintner-Meyer et al. 2002), a major hurdle to commercial deployment of FDD systems would be overcome. This would potentially speed the deployment of third party FDD tools and integration of FDD into individual equipment controllers and building automation systems to provide continuous monitoring, real-time fault detection and diagnostic information, and recommendations for maintenance service and would lead to much improved maintenance of HVAC&R systems. Ultimately, as networking infrastructure matures, the use of automated FDD systems should enable a small support staff to operate, monitor, and maintain a large number of different systems from a remote, centralized location. Local FDD systems could communicate across a network to provide reports on the health of the equipment that they monitor. Failures that lead to loss of comfort could be identified quickly before significant impacts on comfort or equipment damage occurs. In many cases, degradation faults could be identified well before they lead to loss of comfort or uneconomical operation, allowing more efficient scheduling of (and lower costs for) maintenance service.

At present, no fully automated FDD systems have been integrated into individual controllers for commercial HVAC&R equipment. In general, larger equipment applications (e.g., chillers) can absorb more add-on costs than smaller ones (e.g., rooftop units) and, therefore, automated FDD will probably appear first in larger equipment.

Open communication standards for building automation systems are catching on, and use of Internet and intranet technologies is pervasive. These developments enable FDD systems to be deployed more readily. In addition, the structure of the industry that provides services for the operations and maintenance of buildings is changing; companies are consolidating and offering whole-building operations and maintenance packages. Furthermore, as utilities are deregulated, they will begin to offer new services, including complete facility management. With complete and distributed facility management, the cost-to-benefit of deploying FDD systems will improve because the cost can be spread over a large number of buildings (Katipamula et al. 1999). To benefit from these changes, facility managers, owners, operators, and energy service providers are challenged to acquire or develop new capabilities and resources to better manage this information and, in the end, their buildings and facilities.

Although the incentives for application of FDD systems for HVAC&R and other building systems have never been greater, there still are several obstacles to their development and deployment. Beyond research and development, there is a need to quantify the benefits, to establish benchmarks for acceptable costs, and to provide market information. Assessing and demonstrating value for these technologies is an opportunity for public/private partnerships. Public agencies can help reduce risk to facility owners and operators while promoting and accelerating transition to a more efficient buildings sector by demonstrating the value of these technologies and transforming the market to accelerate adoption where public benefits warrant. FDD&P promises to help transform the buildings sector to a new level of energy and operational performance and efficiency.

ACKNOWLEDGMENTS

The review presented in this paper was funded partially by the Office of Building Technology Programs in the Office of Energy Efficiency and Renewable Energy of the US Department of Energy as part of the Building Systems Program at Pacific Northwest National Laboratory. The Laboratory is operated for the US Department of Energy by Battelle Memorial Institute under contract DE-AC06-76RLO 1830.

REFERENCES

Bailey, M.B. 1998. The design and viability of a probabilistic fault detection and diagnosis method for vapor compression cycle equipment. Ph.D. thesis, School of Civil Engineering of University of Colorado, Boulder, Colorado.

Bourdouxhe, J.P., M. Grodent, and J. Lebrun. 1997. *HVAC1 Toolkit: Algorithms and Subroutines for Primary HVAC Systems Energy Calculations.* Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

Box, G.E.P., and G.M. Jenkins. 1976. *Time Series Analysis, Forecasting and Control.* San Francisco: Holden-Day.

Brambley, M.R., R.G. Pratt, D.P. Chassin, and S. Katipamula. 1998. Automated diagnostics for outdoor air ventilation and economizers. *ASHRAE Journal* 40(10):49-55.

Brambley M.R., and S. Katipamula. 2003. Automating commissioning activities: An update with an example. In *Proceedings of 11th National Conference on Building Commissioning.*

Braun, J.E., T. Lawrence, K. Mercer, and H. Li. 2003. *Fault Detection and Diagnostics for Rooftop Air Conditioners.* P-500-03-096-A1, California Energy Commission, Sacramento, California.

Breuker, M.S. 1997. Evaluation of a statistical, rule-based fault detection and diagnostics method for vapor compression air conditioners. Master's thesis, School of Mechanical Engineering, Purdue University, Purdue, Indiana.

Breuker, M.S., and J.E. Braun. 1998a. Common faults and their impacts for rooftop air conditioners. *International Journal of Heating, Ventilating, Air Conditioning and Refrigerating Research* 4(3):303-318.

Breuker, M.S., and J.E. Braun. 1998b. Evaluating the performance of a fault detection and diagnostic system for vapor compression equipment. *International Journal of Heating, Ventilating, Air Conditioning and Refrigerating Research* 4(4):401-425.

Carling, P. 2002. Comparison of three fault detection methods based on field data of an air-handling unit. *ASHRAE Transactions* 108(1).

Castro, N.S., J. Schein, C. Park, M.A. Galler, S.T. Bushby and J.M. House. 2003. *Results from Simulation and Laboratory Testing of Air Handling Unit and Variable Air Volume Box Diagnostic Tools.* National Institute of Standards and Technology, Gaithersburg, MD, NISTIR 6964.

Castro, N. 2002. Performance evaluation of a reciprocating chiller using experimental data and model predictions for fault detection and diagnosis. *ASHRAE Transactions* 108(1).

Chen, B., and J.E. Braun. 2000. Evaluation the potential on-line fault detection and diagnostics for rooftop air-conditioners. *Proceedings of the 2000 International Refrigeration Conference, Purdue University, W. Lafayette, IN.*

Clark, D.R. 1985. *HVACSIM+ Program Reference Manual.* NBSIR 84-2996, National Institute of Standards and Testing, Gaithersburg, Maryland.

Comstock, M.C., B. Chen, and J.E. Braun. 1999. *Literature Review for Application of Fault Detection and Diagnostic Methods to Vapor Compression Cooling Equipment.* HL 1999-19, Report #4036-2, Ray Herrick Laboratories, Purdue University.

Comstock, M.C., J.E. Braun, and E.A. Groll. 2002. A survey of common faults in chillers. *ASHRAE Transactions* 108(1).

Dalton T., R.J. Patton, and P.J.H. Miller. 1995. Methods of fault detection for a centrifugal pump system. *On-Line Fault Detection and Supervision in the Chemical Process Industries, IFAC Workshop*, Newcastle Upon Tyne, UK. New York: Pergamon Press.

Dexter, A.L., and M. Benouarets. 1996. Generic Approach to Identifying Faults in HVAC Plants. *ASHRAE Transactions* 102(1):550-556.

Dexter, A.L., and D. Ngo. 2001. Fault diagnosis in air-conditioning systems: a multi-step fuzzy model-based approach. *International Journal of Heating, Ventilating, Air Conditioning and Refrigerating Research* 7(1):83-102.

Dodier, R.H., and J.F. Kreider. 1999. Detecting whole building energy problems. *ASHRAE Transactions* 105(1).

Fasolo, P.S., and D.E. Seborg. 1995. Monitoring and fault detection for an HVAC control system. *International Journal of Heating, Ventilation, Air-Conditioning and Refrigeration Research* 99(1):3-13.

Georgescu, C., A. Afshari, and G. Bornard. 1993. A model-based adaptive predictor fault detection method applied to building heating, ventilating, and air-conditioning process. *TOOLDIAG' 93.* Organized by Département d'Etudes et de Recherches en Automatique, Toulouse, Cedex, France.

Ghiaus, C. 1999. Fault diagnosis of air-conditioning systems based on qualitative bond graph. *Energy and Buildings* 30:221-232.

Glass, A.S., P. Gruber, M. Roos, and J. Todtli. 1995. Qualitative model-based fault detection in air-handling units. *IEEE Control Systems Magazine* 15(4):11-22.

Gordon, J.M., and K.C. Ng. 1994. Thermodynamic modeling of reciprocating chillers. *Journal of Applied Physics* 75(6):2769-74.

Gordon, J.M., and K.C. Ng. 1995. Predictive and diagnostic aspects of a universal thermodynamic model for chillers. *International Journal of Heat and Mass Transfer* 38(5):807-18.

Grimmelius, H.T., J.K. Woud, and G. Been. 1995. On-line failure diagnosis for compression refrigerant plants. *International Journal of Refrigeration* 18(1):31-41.

Han, C.Y., Y. Xiao, and C.J. Ruther. 1999. Fault detection and diagnosis of HVAC systems. *ASHRAE Transactions* 105(1).

Haves, P., T. Salsbury, and J.A. Wright. 1996. Condition monitoring in HVAC subsystems using first principles. *ASHRAE Transactions* 102(1):519-527.

Honeywell. 2003. Advanced portable AC diagnostics: The HVAC service assistant. Number 63-9178 Rev 5/03. Honeywell, Golden Valley, Minnesota. Available on the Web at http://hbctechlit.honeywell.com/request.cfm?form=63-9178.

House, J.M., W.Y. Lee, and D. R. Shin. 1999. Classification techniques for fault detection and diagnosis of an air-handling unit. *ASHRAE Transactions* 105(1):1087-1097.

House, J.M., H. Vaezi-Nejad, and J.M. Whitcomb. 2001. An expert rule set for fault detection in air-handling units. *ASHRAE Transactions* 107(1).

Hydeman, M., N. Webb, P, Sreedharan, and S. Blanc. 2002. Development and testing of a reformulated regression-based electric chiller model. *ASHRAE Transactions* 108(2):1118-1127.

Inatsu, H., H. Matsuo, K. Fujiwara, K. Yamada, and K. Nishizawa. 1992. Development of refrigerant monitoring systems for automotive air-conditioning systems. *Society of Automotive Engineers*, SAE Paper No. 920212.

Isermann, R., and S. Nold. 1988. Model based fault detection for centrifugal pumps and AC drives. In *11th IMEKO World Congress. Houston, USA*, pp. 16-21.

Isermann, R., and P. Ballé. 1997. Trends in the application of model-based fault detection and diagnosis of technical process. *Control Eng. Practice* 5(5):709-719.

Jiang, Y., J. Li, and X. Yang. 1995. Fault direction space method for on-line fault detection. *ASHRAE Transactions* 101(2):219-228.

Karki, S., and S. Karjalainen. 1999. Performance factors as a basis of practical fault detection and diagnostic methods for air-handling units. *ASHRAE Transactions* 105(1):1069-1077.

Katipamula, S., R.G. Pratt, D.P. Chassin, Z.T. Taylor, K. Gowri, and M.R. Brambley. 1999. Automated fault detection and diagnostics for outdoor-air ventilation systems and economizers: Methodology and results from field testing. *ASHRAE Transactions* 105(1).

Katipamula, S., R.G. Pratt, and J.E. Braun. 2001. Building systems diagnostics and predictive maintenance. Chapter 7.2 in *CRC Handbook for HVAC&R Engineers*, (Ed: J. Kreider), CRC Press, Boca Raton, Florida.

Katipamula, S., M.R. Brambley, and L. Luskay. 2002. Automated proactive techniques for commissioning air-handling units. *Journal of Solar Energy Engineering* 125:282-291.

Katipamula, S., M.R Brambley, N.N Bauman, and R.G Pratt. 2003. Enhancing building operations through automated diagnostics: Field test results. In *Proceedings of 2003 International Conference for Enhanced Building Operations*, Berkeley, CA.

Katipamula, S., and M.R. Brambley. 2005. Methods for fault detection, diagnostics and prognostics for building systems—A Review, Part I. *International Journal of Heating, Ventilating, Air Conditioning and Refrigerating Research* 11(1):3-26.

Kintner-Meyer, M., and M.R. Brambley. 2002. Pros & cons of wireless. *ASHRAE Journal* 44(11):54-61.

Kintner-Meyer M., M.R. Brambley, T.A. Carlon, and N.N. Bauman. 2002. Wireless sensors: Technology and cost-savings for commercial buildings. In *Teaming for Efficiency: Proceedings, 2002 ACEEE Summer Study on Energy Efficiency in Buildings*: Aug. 18-23, 2002, Vol. 7; Information and Electronic Technologies; Promises and Pitfalls., pp. 7.121-7.134. American Council for Energy Efficient Economy, Washington, D.C.

Kumamaru., T., T. Utsunomiya, Y. Iwasaki, I. Shoda, and M. Obayashi. 1991. A fault diagnosis systems for district heating and cooling facilities. *Proceedings of the International Conference on Industrial Electronics, Control, and Instrumentation*, Kobe, Japan (IECON '91), pp. 131-136.

Kumar, S.S. Sinha, T. Kojima, and H. Yoshida. 2001. Development of parameter based fault detection and diagnosis technique for energy efficient building management system. *Energy Conversion and Management* 42:833-854.

Lee, W.Y., C. Park, and G.E. Kelly. 1996a. Fault detection of an air-handling unit using residual and recursive parameter identification methods. *ASHRAE Transactions* 102(1):528-539.

Lee, W.Y., J.M. House, C. Park, and G.E. Kelly. 1996b. Fault diagnosis of an air-handling uni using artificial neural networks. *ASHRAE Transactions* 102(1):540-549.

Lee, W.Y., J.M. House, and D.R. Shin. 1997. Fault detection of an air-handling unit using residual and recursive parameter identification methods. *ASHRAE Transactions* 102(1):528-539.

Li, X., V. Hossein, and J. Visier. 1996. Development of a fault diagnosis method for heating systems using neural networks. *ASHRAE Transactions* 102(1):607-614.

Li, X., J. Visier, and H. Vaezi-Nejad. 1997. A neural network prototype for fault detection and diagnosis of heating systems. *ASHRAE Transactions* 103(1):634-644.

McKellar, M.G. 1987. Failure diagnosis for a household refrigerator. Master's thesis, School of Mechanical Engineering, Purdue University, Purdue, Indiana.

Morisot, O., and D. Marchio. 1999. Fault detection and diagnosis on HVAC variable air volume system using artificial neural network. *Proc. IBPSA Building Simulation 1999, Kyoto, Japan.*

Ngo, D., and A.L. Dexter. 1999. A robust model-based approach to diagnosing faults in air-handling units. *ASHRAE Transactions* 105(1).

Norford, L.K., and R.D. Little. 1993. Fault detection and monitoring in ventilation systems. *ASHRAE Transactions* 99(1):590-602.

Norford, L.K., J.A. Wright, R.A. Buswell, D. Luo, C.J. Klaassen, and A. Suby. 2002. Demonstration of fault detection and diagnosis methods for air-handling units (ASHRAE 1020-RP). *International Journal of Heating, Ventilating, Air Conditioning and Refrigerating Research* 8(1):41-71.

Noura, H., C. Aubrun, D. Sauter, and M. Robert. 1993. A fault diagnosis and reconfiguration method applied to thermal plant. *TOOLDIAG' 93*, Organized by Département d'Etudes et de Recherches en Automatique, Toulouse, Cedex, France.

Pakanen, J., and T. Sundquist. 2003. Automation-assisted fault detection of air-handling unit; Implementing the method in a real building. *Energy and Buildings* 35:193-202.

Pape, F.L.F., J.W. Mitchell, and W.A. Beckman. 1990. Optimal control and fault detection in heating, ventilating, and air-conditioning systems. *ASHRAE Transactions* 97(1):729-736.

Peitsman, H.C., and V. Bakker. 1996. Application of black-box models to HVAC systems for fault detection. *ASHRAE Transactions* 102(1):628-640.

Peitsman, H.C., and L.L. Soethout. 1997. ARX models and real-time model-based diagnosis. *ASHRAE Transactions* 103(1):657-671.

Reddy, T.A., D. Niebur, J. Gordon, J. Seem, K.K. Andersen, G. Cabrera, Y. Jia, and P. Pericolo. 2001. Final report: Development and comparison of on-line model training techniques for model-based FDD methods applied to vapor compression chillers, ASHRAE Research Project 1139-RP, ASHRAE, GA.

Rossi, T.M. 1995. Detection, diagnosis, and evaluation of faults in vapor compression cycle equipment. Ph.D. thesis, School of Mechanical Engineering, Purdue University, Purdue, Indiana.

Rossi, T.M., and J.E. Braun. 1996. Minimizing operating costs of vapor compression equipment with optimal service scheduling. *International Journal of Heating, Ventilating, Air Conditioning and Refrigerating Research* 2(1):3-26.

Rossi, T.M., and J.E. Braun. 1997. A statistical, rule-based fault detection and diagnostic method for vapor compression air conditioners. *International Journal of Heating, Ventilating, Air Conditioning and Refrigerating Research* 3(1):19-37.

Salsbury, T.I., and R.C. Diamond. 2001. Fault detection in HVAC systems using model-based feedforward control. *Energy and Buildings* 33:403-415.

Seem, J., J.M. House, and R.H. Monroe. 1999. On-line monitoring and fault detection. *ASHRAE Journal* 41(7):21-26.

Sreedharan, P., and P. Haves. 2001. Comparison of chiller models for use in model-based fault detection. *International Conference for Enhanced Building Operations (ICEBO)*, organized by Texas A&M University, Austin, TX.

Stallard, L.A. 1989. Model based expert system for failure detection and identification of household refrigerators. Master's thesis, School of Mechanical Engineering, Purdue University, Purdue, Indiana.

Stylianou, M., and D. Nikanpour. 1996. Performance monitoring, fault detection, and diagnosis of reciprocating chillers. *ASHRAE Transactions* 102(1):615-627.

Stylianou, M. 1997. Classification functions to chiller fault detection and diagnosis. *ASHRAE Transactions* 103(1):645-648.

Tsutsui, H., and K. Kamimura. 1996. Chiller condition monitoring using topological case-based modeling. *ASHRAE Transactions* 102(1):641-648.

Wagner, J., and R. Shoureshi. 1992. Failure detection diagnostics for thermofluid systems. *Journal of Dynamic Systems, Measurement, and Control* 114(4):699-706.

Wang, S., and Y. Chen. 2002. Fault-tolerant control for outdoor ventilation air flow rate in buildings based on neural networks. *Building and Environment* 37:691-704.

Yoshida, H., T. Iwami, H. Yuzawa, and M. Suzuki. 1996. Typical faults of air-conditioning systems, and fault detection by ARX Model and extended kalman filter. *ASHRAE Transactions* 102(1):557-564.

Yoshida, H., and S. Kumar. 1999. ARX and AFMM model-based on-line real-time data base diagnosis of sudden fault in AHU of VAV system. *Energy Conversion & Management* 40:1191-1206.

Yoshimura, M., and N. Ito. 1989. Effective diagnosis methods for air-conditioning equipment in telecommunications buildings. *INTELEC 89: The Eleventh International Telecommunications Energy Conference*, October 15 – 18, 1989, Centro dei, Firenze, 21:1-7.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

13

EN9994

Date Submitted	02/01/2022	**Section**	403	**Proponent**	Bryan Holland
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

This proposed modification adds requirements for economizer fault detection and diagnostics (FDD) for air-cooled unitary direct-expansion units variable refrigerant flow (VRF) units that are equipped with an economizer.

Rationale

Commercial HVAC systems have been shown to have problems with economizer function, control and performance in field studies and utility-sponsored maintenance programs. This results in reduced energy efficiency and potential energy savings from the economizer with fan-only operation. Adding such systems will provide building owners key information regarding the operation of their HVAC systems. Fault Detection and Diagnostics (FDD) technology significantly reduces costs and improves operational efficiency. It incorporates a standard library of fault rules that can be customized to predict equipment failures and advise personnel of preventive actions. Before the emergence of FDD software solutions, many organizations relied on institutional knowledge in order to fix or maintain their wide variety of equipment. After the development of FDD tech, this type of info (the numerous symptoms, causes and recommended actions) that may have only existed in the heads of senior personnel or, if lucky, in print or electronic archives, could now be used in algorithms to help organizations move from reactionary “break/fix” maintenance to more modern, more cost-effective predictive maintenance. Return on investment studies indicate typical ROI within 12 to 18 months following installation. Please see the attached reports from the Lawrence Berkeley National Laboratory and American Society of Heating, Refrigerating and Air-Conditioning Engineers/Pacific Northwest National Laboratory. This proposed modification improves the code and meets the mandate outlined in F.S. 553.886 that states; "the Florida Building Code must facilitate and promote the use of cost-effective energy conservation, energy-demand management, and renewable energy technologies in buildings.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposed modification will require the local entity to confirm Economizer FDD is included on the construction documents at time of plan review and has been installed and operational at time of inspection.

Impact to building and property owners relative to cost of compliance with code

This proposed modification will increase the cost of compliance with the code but will result in improved HVAC system efficiency and have a return on investment not greater than 18 months from time of installation.

Impact to industry relative to the cost of compliance with code

This proposed modification will increase the cost of compliance with the code for industry. FDD software and hardware is readily available in the marketplace by a multitude of manufacturers. FDD design, installation, and operation requires specialized training.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposed modification will improve the health and welfare of the general public by improving HVAC system efficacy and reducing operating costs for HVAC economizers.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposed modification improves the code and meets the mandate outlined in F.S. 553.886 that states; "the Florida Building Code must facilitate and promote the use of cost-effective energy conservation, energy-demand management, and renewable energy technologies in buildings.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposed modification does not discriminate against any materials, methods, or systems of constructions.

Does not degrade the effectiveness of the code

This proposed modification improves the effectiveness of the code.

C403.3.5 Economizer fault detection and diagnostics. Air-cooled unitary direct-expansion units listed in the tables in Section C403.2.3 and variable refrigerant flow (VRF) units that are equipped with an economizer in accordance with Sections C403.3 through C403.3.4 shall include a fault detection and diagnostics system complying with the following:

1. The following temperature sensors shall be permanently installed to monitor system operation:

1.1. Outside air.

1.2. Supply air.

1.3. Return air.

2. Temperature sensors shall have an accuracy of ±2°F (1.1°C) over the range of 40°F to 80°F (4°C to 26.7°C).

3. Refrigerant pressure sensors, where used, shall have an accuracy of ±3 percent of full scale.

4. The unit controller shall be configured to provide system status by indicating the following:

4.1. Free cooling available.

4.2. Economizer enabled.

4.3. Compressor enabled.

4.4. Heating enabled.

4.5. Mixed air low limit cycle active.

4.6. The current value of each sensor.

5. The unit controller shall be capable of manually initiating each operating mode so that the operation of compressors, economizers, fans and the heating system can be independently tested and verified.

6. The unit shall be configured to report faults to a fault management application available for access by day-to-day operating or service personnel, or annunciated locally on zone thermostats.

7. The fault detection and diagnostics system shall be configured to detect the following faults:

7.1. Air temperature sensor failure/fault.

7.2. Not economizing when the unit should be economizing.

7.3. Economizing when the unit should not be economizing.

7.4. Damper not modulating.

7.5. Excess outdoor air.

LBNL-2001075

BERKELEY LAB

Lawrence Berkeley National Laboratory

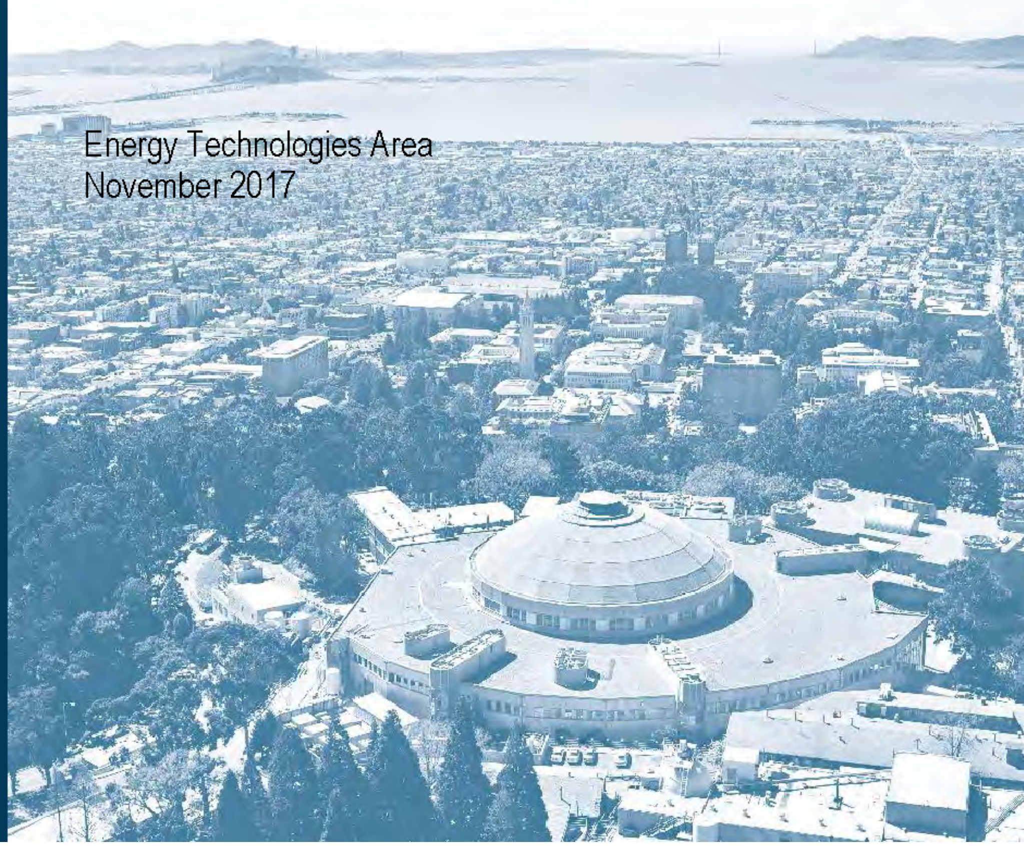
Characterization and Survey of Automated Fault Detection and Diagnostic Tools

Jessica Granderson and Rupam Singla
Building Technology and Urban Systems Division
Lawrence Berkeley National Laboratory

Ebony Mayhorn, Paul Ehrlich and Draguna Vrabie
Pacific Northwest National Laboratory

Stephen Frank
National Renewable Energy Laboratory

Energy Technologies Area
November 2017



Disclaimer

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor The Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or The Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or The Regents of the University of California.

Acknowledgement

This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Building Technologies Office, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231. The authors thank Amanda Farthing, Xin Jin, and Grant Wheeler (National Renewable Energy Laboratory), as well as Guanjing Lin (Lawrence Berkeley National Laboratory), for their support with the developer interviews that were conducted in this work. We also recognize each of the fault detection and diagnostic tool developers who participated in this survey.

Executive Summary

Background

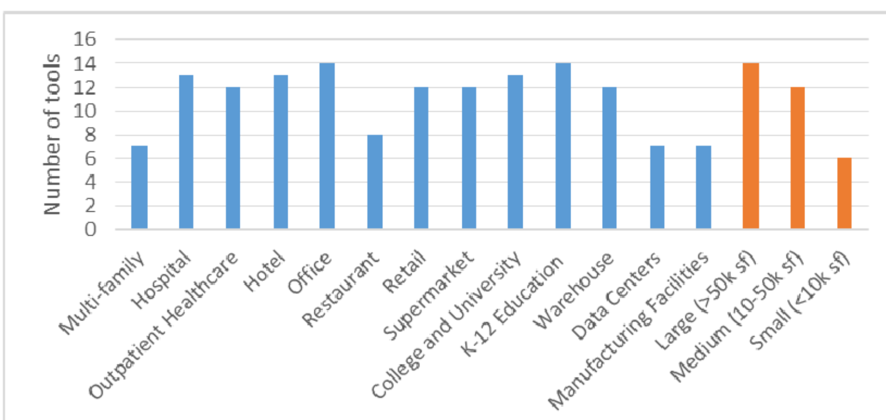
It is estimated that 5%–30% of the energy used in commercial buildings is wasted due to faults and errors in the operation of the control system. Tools that are able to automatically identify and isolate these faults offer the potential to greatly improve performance, and to do so cost effectively. This document characterizes the diverse landscape of these automated fault detection and diagnostic (AFDD) technologies, according to a common framework that captures key distinguishing features and core elements.

Approach

To understand the diversity of technologies that provide AFDD, a framework was developed to capture key elements to distinguish the functionality and potential application of one offering from another. The AFDD characterization framework was applied to 14 currently available technologies, comprising a sample of market offerings. These 14 technologies largely represent solutions that integrate with building automation systems, that use temporary in field measurements, or that are implemented as retrofit add-ons to existing equipment. To characterize them, publicly available information was gathered from product brochures and websites, and from technical papers. Additional information was acquired through interviews and surveys with the developers of each AFDD tool. The study concludes with a discussion of technology gaps, needs for the commercial sector, and promising areas for future development.

Key Findings

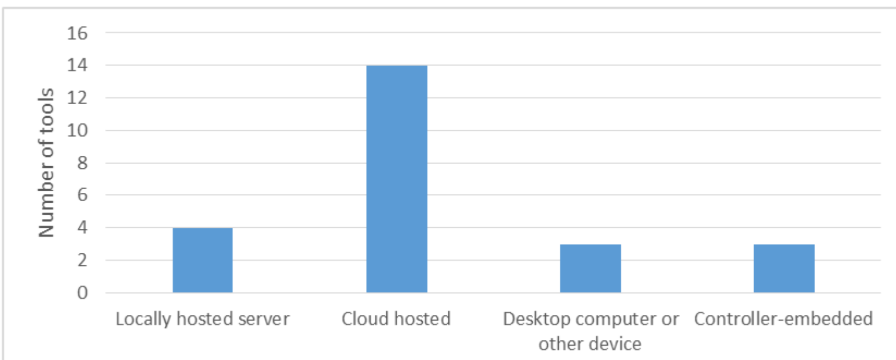
Today's AFDD technologies are being used in nearly all commercial building sectors. Smaller facilities, however, are less commonly served, and when they are it is often through portfolios of small buildings as opposed to single sites.



Market presence of surveyed FDD tools

Software-as-a-service models have quickly become the norm for AFDD technologies; even vendors providing on premise and desktop applications also tend to offer SaaS options. A compelling evolution in the industry is seen in the expansion of market delivery of FDD through third-party service providers using the tools as a way to provide value-add to their customers. This expansion offers the potential to increase access to the technology and its associated benefits for a new class of owners who otherwise may not be using it, however third parties' costs may vary significantly and each cost component should be defined in full to be able to compare across delivery options.

Intended users of surveyed AFDD tools



Location of surveyed AFDD tools

While rule-based methodologies to detect and diagnose faults are still heavily used, vendors are beginning to use process history-based techniques. Independent of the FDD methodology used, vendors report a high degree of commonality in the systems and types of faults that their products can cover. That is, coverage of systems and faults is driven more by site data availability than by product offering. Most AFDD tools surveyed accept real-time BAS data and external meters and sensors; many accept historical data from the BAS, and several accept equipment's onboard/ internal measures without going through the BAS. The majority of the AFDD tool vendors surveyed cover major the HVAC systems found in commercial buildings, as well as lighting systems and whole building energy use. Many tools have large libraries that are able to determine at least some types of faults across all systems for whatever data can be provided. Nearly all of the tool vendors surveyed are able to detect faults in the major categories, including: sensors, energy consumption, economizers and ventilation, commercial refrigeration, cooling/heating systems, equipment cycling, scheduling, and lighting or other end uses. Configuration of the technologies does require site-specific tuning. While this is not a fully automated process, some elements of the process may be automated for streamlining.

Distinguishing factors are often associated with the additional features offered to complement the AFDD, and with the available delivery models. The market offers great diversity in additional analytics and reporting capabilities, integration architectures, and purchase models, making it possible to custom fit the technology to the needs of the organization. While custom solutions are desirable for some portions of the buildings market— such as campuses, enterprises, and large or complex facilities—others may benefit from higher degrees of commoditization.

An important theme in interpreting the findings from this survey is that many products are sold with an emphasis on broad-scale applicability, and in analyzing the features and capabilities across all offerings as whole, there is indeed a high degree of similarity. However, it is critical for prospective technology users to probe providers to understand the precisely what is entailed in a given offering's implementation of a feature of interest. For example, there are many ways to prioritize faults and estimate their impacts, and effective prioritization may be dependent on customer input. Similarly, root cause analysis (diagnosis) may be supported for just a subset of faults, or require manual input from operational staff. Analogously, ease of integration with different makes and vintages of BAS is another critical element of implementation for which "the devil is in the details."

Outstanding Needs

FDD technology is seeing increased uptake in the market, and is constantly developing and evolving. Best practice implementations can deliver significant improvements in energy efficiency, utility expenses, operations and maintenance processes, and operational performance—all with rapid return on investment. However, for the full potential to be realized at scale, a core set of interrelated informational, organizational, and technical needs and barriers must be addressed.

The primary informational barriers for prospective users are rooted in interpreting the value proposition of FDD for their facilities, and in accessing best practices in implementation — for example all-in costs and benefits, effective use of contractors and service providers, and integration with higher level energy management practices. Organizationally, successful implementation of AFDD can be slowed by a need to diverge from existing business practices and norms. While the costs are modest compared to capital projects and can be quickly recovered, decision makers must buy in to an increase in operation and maintenance expenses and be willing to manage a certain degree of risk. Finally, from a technical standpoint, IT and data integration represent one of the largest challenges. Even once data is accessible through cross-system integration, it must be interpreted for use in analytic applications. The current lack of common standards in data, metadata, and semantic representation also poses difficulties in scaling. Lastly, today's AFDD offerings can prove difficult and expensive to apply in smaller commercial buildings.

Future Work

AFDD has matured significantly since its first introduction into commercial buildings. Based on information gathered through this survey and discussion with both vendors and users, several opportunities emerge to further advance the technology. Continued development of algorithms that include machine learning and other promising techniques could reduce tuning needs, simplify configuration, and enhance diagnostic power. Following the trends in other industries, there is also potential to move beyond diagnostics into prognostics and predictive maintenance. Machine-to-machine integration presents further opportunity for advancement to realize pervasive "plug-and-play" functionality, thereby enabling tighter coupling of AFDD with computerized maintenance management systems, meter analytics, and operations and asset management tools. Finally, there are gains to be achieved through the development of corrective and adaptive controls, in combination with tool chains that can ensure that operational design intent is correctly implemented and maintained over the duration of the operational stage in the building lifecycle.

1. Overview

Energy Management and Information Systems (EMIS) comprise a broad family of tools and services to analyze, monitor, and control commercial building equipment and energy use. These technologies include, for example, meter analytics or energy information systems (EIS), some types of automated fault detection and diagnostic tools (AFDD), benchmarking and utility bill tracking tools, and building automation systems. These technologies may encompass uses that include monitoring-based and ongoing commissioning, remote audits and virtual assessments, enterprise monitoring and asset tracking, continuous savings estimation, and energy anomaly detection. There are a wide a wide variety of EMIS products available on the commercial market, and they are increasingly heavily marketed to the energy management community.

It is estimated that 5%–30% of the energy used in commercial buildings is wasted due to faults and errors in the operation of the control system[1, 2, 3]. Tools that are able to automatically identify and isolate these faults offer the potential to greatly improve performance, and to do so cost effectively.

This document characterizes the diverse landscape of technologies that offer AFDD functionality, according to a common framework that captures key distinguishing features and core elements. These technologies can reside on local servers or in the cloud, as well as at the network edge within equipment or controller-embedded solutions.

The primary audience for this document is building owners and operators, who are seeking an understanding of the functionality available in AFDD products and services to inform piloting and procurement decisions. It also may be useful to utility energy efficiency program stakeholders who are interested in emerging technologies to test and pilot for incentive programs. A secondary audience includes developers of AFDD solutions who are looking for information to inform and target their efforts.

In the following sections of this review we present a general overview of FDD and other analytics technology types, followed by a common framework to distinguish among various types of AFDD tools. We then apply this framework to evaluate a sampling of AFDD tools and discuss the findings. The evaluation focused primarily on solutions that integrate with building automation systems, that use temporary in-field measurements, or that are implemented as retrofit add-ons to existing equipment; it did not include OEM-embedded AFDD offerings (although in a few instances these variants are available through the AFDD vendor). We conclude with a discussion of technology gaps, needs for the commercial sector, and promising areas for future development.

---

[1] Roth, K. W., D. Westphalen, M. Y. Feng, P. Llana, and L. Quartararo. *Energy Impact of Commercial Building Controls and Performance Diagnostics: Market Characterization, Energy Impact of Building Faults and Energy Savings Potential*. 2005. Report prepared by TIAC LLC for the U.S. Department of Energy.

[2] Katipamula, S., and M. Brambley. 2005. "Methods for fault detection, diagnostics, and prognostics for building systems – a review, part 1." *HVAC&R Research* 11(1): 3–25.

[3] Fernandez, N., et al. 2017. *Impacts on commercial building controls on energy savings and peak load reduction*. Pacific Northwest National Laboratory. PNNL Report Number PNNL-25985.

2. Introduction to Fault Detection and Diagnostics

FDD is the process of identifying (detecting) deviations from normal or expected operation (faults) and resolving (diagnosing) the type of problem or its location. FDD has been used for decades to great success in industries that include aerospace, nuclear, and industrial applications, and its use in building operation and control applications is growing. In practice, FDD in buildings is most commonly conducted for heating, ventilation, and air conditioning (HVAC) systems, however as a process, FDD is applicable to all systems in the building. Although currently underutilized, FDD is a powerful approach to ensuring efficient building operations.

As further detailed in the characterization framework that follows, AFDD technology may be delivered through a variety of implementation models. The FDD code may be integrated into either server-based software, desktop software, or software that is embedded in an equipment controller. The AFDD algorithms may rely on historical or near-real time data from building automation systems (BAS), from data local to the equipment or controller, from external sensors and meters, or from some combination of these data sources. AFDD software may be used by the building operator or energy manager, or may be delivered through analysis-as-a-service contracts that do not require direct “in-house” use of the technology.

The software tools that offer AFDD may include additional functionality such as energy consumption monitoring and analytics, visualization, benchmarking, reporting of key performance indicators, or fault prioritization and impact assessment. The server-based offerings rely on continuous data acquisition and analysis; these types of AFDD tools are commonly considered part of the broader family of tools called Energy Management and Information Systems (EMIS). Although not within the scope of this document, other EMIS technologies such as meter analytics or energy information systems, automated (HVAC) system optimization, and building automation systems are powerful tools for ensuring persistent low-energy commercial building operations—both at the facility and enterprise levels.

3. FDD Technology Characterization Framework

To understand the diversity of technologies that provide AFDD, a characterization framework was developed to capture key elements that can be used to distinguish the functionality and potential application of one offering from another. Content contained in this framework was developed through review with a subset of providers, and is based on the authors’ collective subject matter expertise, knowledge of AFDD technology and its use in commercial building energy management applications. The categories in the framework are defined in the following sections, with characteristics spanning delivery to market, technical capabilities, and additional software functionality.

3.1 Delivery to Market

Company or institution name: The developer of the AFDD technology.

Tool name: The name of the AFDD software or service offering.

Software type: Whether the AFDD is offered as a commercial product or service, or as open source code.

Availability to market: Whether the AFDD is commercially available or still being researched (pre-commercial).

Current markets served: What markets are currently served in terms of:

- Building type (multi-family, hospital, outpatient healthcare, hotel, office, restaurant, retail, supermarket, college and university, K–12 education, warehouse).
- Building size (large [> 50k square feet (sf)], medium [10–50k sf], small [< 10k sf]).

Software location: Whether the AFDD software is cloud hosted, locally hosted on an “on-site” server, located on a desktop computer or other device, or controller-embedded.

Purchase model: Whether the AFDD software is a one-time purchase, software as a service (with monthly or annual fee), or other. Additionally, whether the AFDD software comes with updates and/or periodic maintenance in the initial offering costs, or whether additional purchase is required.

Intended users: Whether the AFDD software is intended for use by the vendor (for analysis-as-a-service), an engineering manager/operator/site staff, and/or a third-party service provider.

Software configuration: Whether the party typically responsible for the AFDD software installation and configuration is the software vendor; an integrator, distributor, or third-party service provider; or an engineering manager/operator/site staff.

Data sources: Whether the AFDD software relies upon data from BAS real-time data (i.e., live, continuous), from BAS historical data (e.g., trend logs, csv, xls), from on-board or internal equipment measures, or from external meters and sensors.

Data ownership: Whether the owner(s) of the AFDD software tool inputs and outputs is the end-customer, the FDD software vendor, and/or a third-party service provider.

FDD method tailoring: Whether the AFDD software requires tailoring of the tuning algorithm parameters and associated thresholds manually or automatically, or whether it is not applicable or unnecessary.

Notification of findings: Whether the AFDD software tool delivers results through a software user interface with fault findings, through a service to the user that includes periodic reports of fault findings, and/or through automated notifications, e.g., via email or text.

3.2 Technical Capabilities

Systems covered: Whether the FDD software has existing libraries and rules for the following systems: air conditioners/heat pumps (including packaged rooftop units), chillers and towers, air handler units (AHUs) and variable air volumes (VAVs), fan coil units (FCUs), commercial refrigeration, lighting, boilers/furnaces, water heaters, and/or whole-building.

Categories of faults detectable: These are broad categories of faults that the AFDD tool is able to detect and potentially diagnose. The fault categories included in this framework include:

- Sensor errors/faults
- Energy consumption (explicit energy use fault)
- Economizers and ventilation
- Control-related pressurization issues
- Commercial refrigeration (related to vapor/compression)
- Space cooling/heating (related to vapor/compression)
- Heating system (boiler, heat exchanger, furnace, etc.)
- Cooling system (chillers, towers, etc.)
- Equipment cycling
- Pump and fan systems
- Scheduling (too little, too long, wrong time, etc.)
- Simultaneous heating and cooling
- Lighting or other end uses

Note that problems such as mechanical failures and departures from setpoint or intended sequences may be included under multiple fault categories in the list above.

Methods/algorithms: These are the categories of analytical methods used in the AFDD software. The schematic diagram below depicts the definition of algorithm types that are used in this framework.

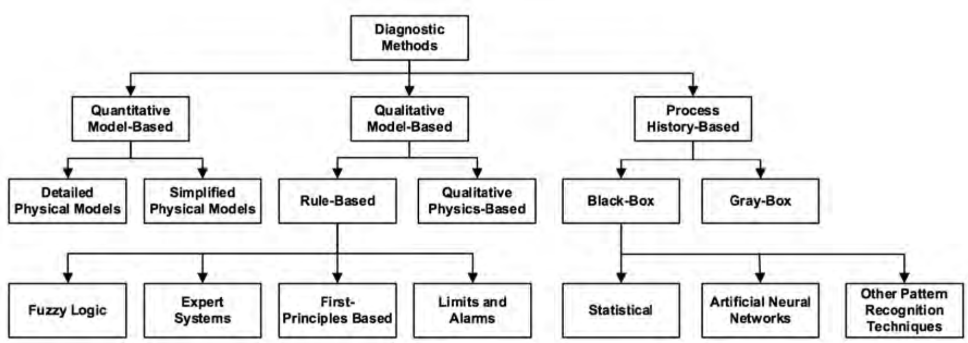


Figure 1. Depiction of algorithm types used in this framework, from Katipamula and Brambley, 2005[2]

As illustrated in Figure 1, FDD methods may be model-based or based purely on process history data. The model-based methods rely upon knowledge of the underlying physical processes and first principles governing the system(s) being analyzed. Quantitative model-based approaches are not yet frequently employed in commercial AFDD tool offerings, however qualitative model-based approaches which include rule-based FDD, have been extensively used in the industry and provide intuitive representations of engineering principles. The process history-based (data-driven) approaches do not rely upon knowledge of first principles, but may leverage some degree of engineering knowledge; they rely upon data from the system in operation. These include statistical regression models, neural networks, and other methods. Process history-based AFDD algorithms are increasingly being explored for use in commercial tool offerings. Although the distinctions between these method types may become blurry (even to developers), AFDD users may have interest in understanding whether a technology uses rules-based techniques versus newer data driven approaches, or less commonly employed first principles – or a combination of several approaches.

Detection and diagnosis capabilities: Whether the AFDD tool is capable of identifying fault presence (reporting a fault without specification of the physical location, severity, or root cause), fault location, fault severity (degree of faultiness as opposed to impact on energy or dollars, which is covered in “additional functionality”), root cause, and/or estimated costs of resolution and payback.

3.3 Additional Functionality

Other features: Additional features of the AFDD tool that are not represented above, and may include:

- Detection of equipment degradation
- Fault prioritization
- Automated work order request system integration
- Assessment of energy impacts
- Conversion of energy impacts to cost impacts
- Assessment of cost impacts other than energy cost, e.g., reduced equipment life
- Meter data analytics
- Time series visualization and plotting
- Key performance indicator (KPI) tracking and reporting
- Longitudinal and cross-sectional benchmarking (within a given portfolio or via ENERGY STAR Portfolio Manager)

4. Technology Characterization Findings

The AFDD characterization framework was applied to 14 currently available technologies, comprising a sample of market offerings (see the Appendix for a list of those surveyed). These technologies were identified based on factors including:

- Diversity across defining characteristics to illustrate market breadth
- Known use in commercial buildings based on the authors' knowledge of the market and engagement with the community of AFDD users
- Vendor or developer willingness and ability to share information necessary for a full characterization

It is important to emphasize that inclusion in this survey does not indicate endorsement, and conversely, absence from the survey does not indicate non-endorsement.

To characterize the technologies, publicly available information was gathered from product brochures and websites, and from technical papers. Additional information was acquired through interviews and surveys with the vendors and developers of each AFDD tool. The information that was acquired was therefore based on self-reporting from the technology provider. It was not within the scope of this effort to independently verify reported functionality and characteristics of each technology that is included. Moreover, as the market is constantly evolving and technologies are continuously modified, these market findings represent a snapshot in time. Although specific offerings may evolve, it is expected that the characterization framework itself will remain a viable tool to distinguish key AFDD technology elements well into the future.

The tables in the Appendix provide a summary of the capability of each tool surveyed, with respect to each category in the characterization framework.

4.1 Delivery to Market

All tool vendors surveyed offered proprietary, commercially available software and/or hardware. However, several of the software vendors noted that they provide an open application programming interface (API) to support integration with third-party applications.

The markets currently served by the AFDD tool vendors are represented in Figure 2. Multi-family, restaurant, data centers, and manufacturing facilities are less commonly served, with a mostly even coverage of other sectors. In addition to the market segments shown in the figure, several tool vendors noted additional facility types such as industrial subsectors, arenas, multi-event facilities, and correctional facilities. The technologies are commonly used in large and medium facilities, with less penetration in smaller buildings. Several tool vendors also noted that they do not serve a particular building size and that their product would be applicable to any size building.

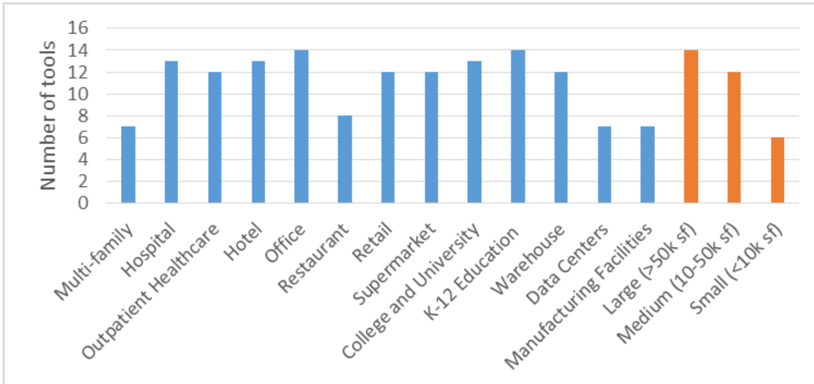


Figure 2.Market presence of surveyed FDD tools

As shown in Figure 3, the software for all 14 tool vendors can be cloud hosted; eight of them offer that as the only option. Additionally, four AFDD tools can be installed on a locally hosted on-site server, and three can be located on a desktop computer or other device (such as a handheld device). Three can be controller-embedded, reflecting emerging variants in software delivery that can entail relationships with OEMs.

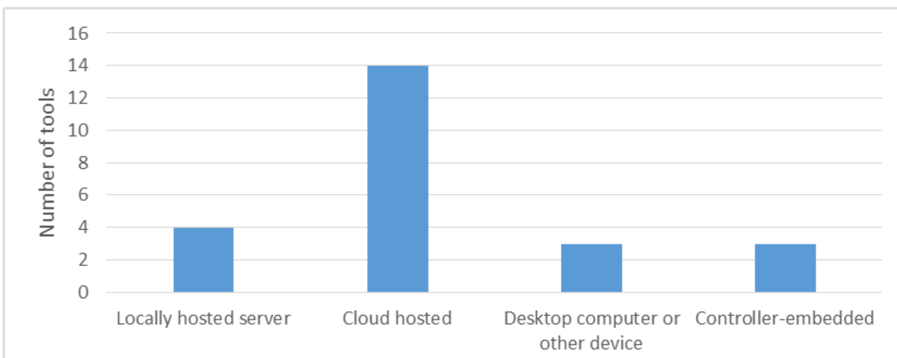


Figure 3. Software location

AFDD tool vendors offer a wide range of variability in purchase models. Many vendors noted that there is no standard, and that often the purchase model is tailored to what the customer wants. Typically tools that are hosted on the cloud offer a software-as-a-service (SaaS) model with ongoing updates and maintenance included for either an annual or a monthly fee. Maintenance and updates may come bundled or optionally in an upfront fee, or can be deferred for later purchase.

As reflected in the tallies in Figure 4, all of the AFDD tool vendors surveyed have multiple intended users. The traditional model of in-house technology used by the end customer is still prevalent—all vendors surveyed listed engineering manager/operator/site staff as an intended user. However, tools are increasingly being used by and resold by third-party service providers as a value-add to customers, with all of the AFDD tool vendors surveyed also listing a third-party service provider as an intended user. Nine vendors provide analysis-as-a-service directly to their clients and are therefore an intended user of the tool. This is expected to grow as the market matures and alternative business models are explored by the industry.

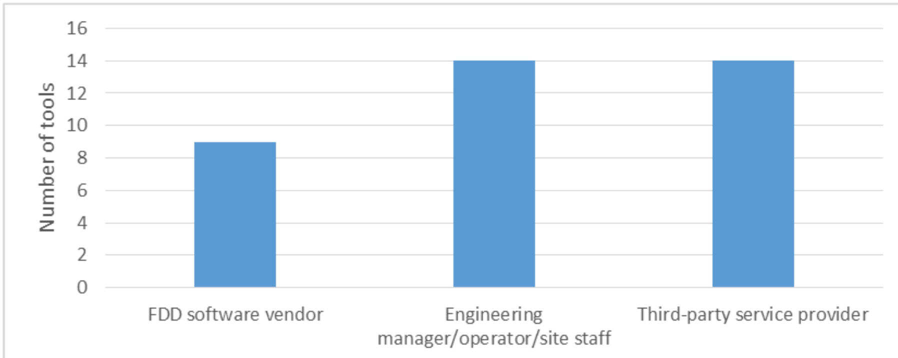


Figure 4. Intended Users

The majority of the AFDD tools are installed and configured by some combination of the software vendor, an integrator/distributor/third-party service provider, and the engineering manager/operator/site staff, as shown in Figure 5. In most cases, the vendor plus a third party do the configuration, working from owner requirements. In some cases multiple parties are required for the installation, and in some cases the vendor offers several options for who does the installation.

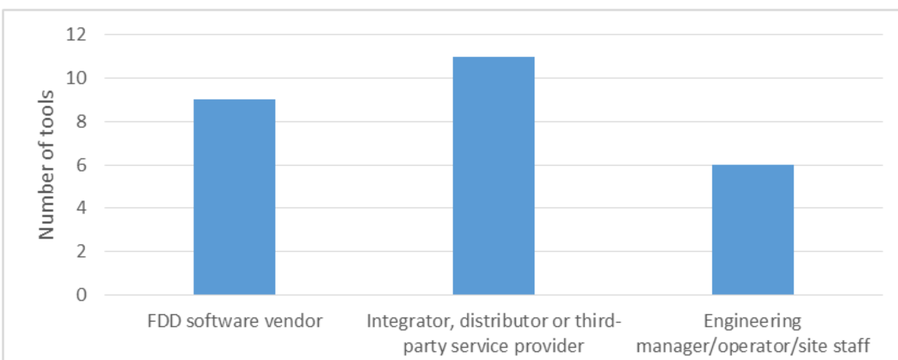


Figure 5. Parties involved in software configuration

There is a range of input data that are required by AFDD tools and a range of data that they can accept, as shown in Figure 6. Most of the tools take in real-time BAS data, which would be expected, given the large number of cloud-based solutions that serve as a BAS overlay. Eleven tools are also able to utilize historical data from the BAS. Most of the tools are also able to utilize external meters and sensors. Three tools are able to utilize equipment's onboard/ internal measures without going through the BAS. Typically not all of the data points that *can* be processed by the tool are required, and the technologies operate based on the data that are available. Though the tool vendor may have a short list of critical points, additional data are used to enhance the spectrum of diagnostics that can be performed.

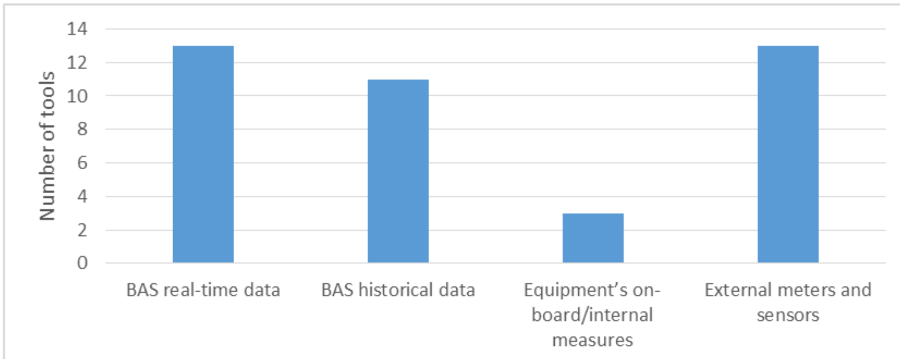


Figure 6. Data sources for surveyed FDD tools

All AFDD tool vendors note that primarily, the customer owns the data. Additionally, two vendors noted that they themselves also have ownership over the data and one other tool vendor noted that a third-party service provider has ownership over the data. Several tool vendors noted that they retain the right to use aggregate and anonymous data for benefit of all their users; for example, to provide peer benchmarking analyses.

All 14 tools require some degree of tuning or tailoring algorithm configuration and implementation. While none offer fully automated tuning, six vendors noted that they provide automated routines and/or GUIs to streamline the process. At least one tool comes with a fault library with default thresholds, with which the customer may subsequently tune parameters or hire consultants to help.

All of the AFDD tool vendors provide access and viewing of fault findings through a software interface, as shown in Figure 7. In addition to user-facing GUIs, the majority of offerings surveyed also provide services to periodically output reports of fault findings. All but two of the tools provide automated notifications via text, e-mail, or even other novel communications options such as tweets. Several tool vendors have the capability to have reports sent via e-mail at user-defined intervals (daily, weekly, monthly) and on customer demand.

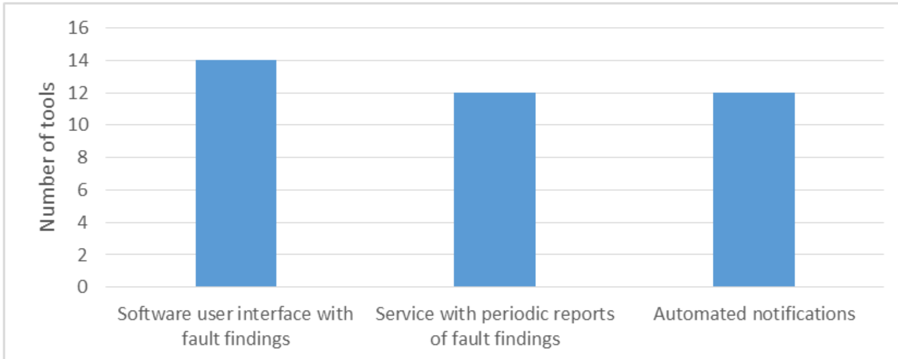


Figure 7. Notification of findings

4.2 Technical Capabilities

As seen in Figure 8, the majority of the AFDD tool vendors surveyed cover most of the systems that were included in the survey (AC/heat pump which includes packaged rooftop units, chillers and towers, AHU and VAV, FCUs, commercial refrigeration, lighting, boilers/furnaces, water heaters, and whole-building). Many tools have large libraries that are able to determine at least some types of faults across all systems for whatever data can be provided. Several vendors reported that they additionally include energy recovery ventilators (ERVs), other terminal units besides VAV boxes, solar panels, industrial processes, variable refrigerant flow (VRF) systems, BAS controls, cogeneration, and manufacturing equipment.

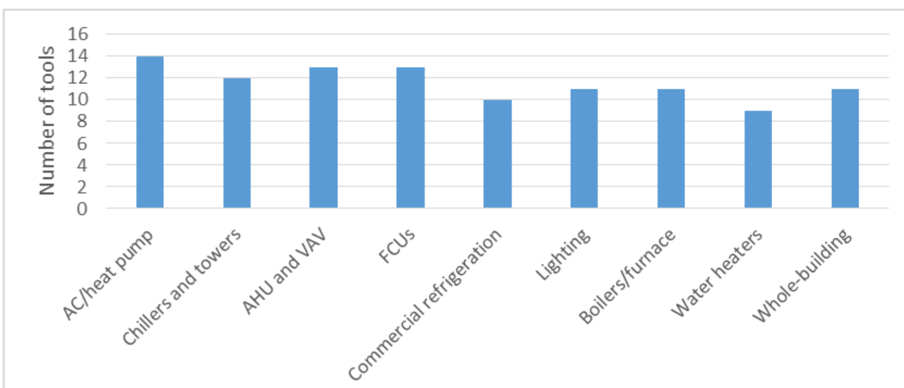


Figure 8. Systems covered

Nearly all of the tool vendors surveyed are able to detect faults in the majority of the fault categories in the survey: sensor errors/faults, energy consumption, economizers and ventilation, control-related pressurization issues, commercial refrigeration, space cooling/heating, heating system, cooling system, equipment cycling, pump and fan systems, scheduling, simultaneous heating and cooling, and lighting or other end uses. Many tools have large libraries that are able to determine at least some types of faults for whatever data can be provided. See Figure 9 for details.

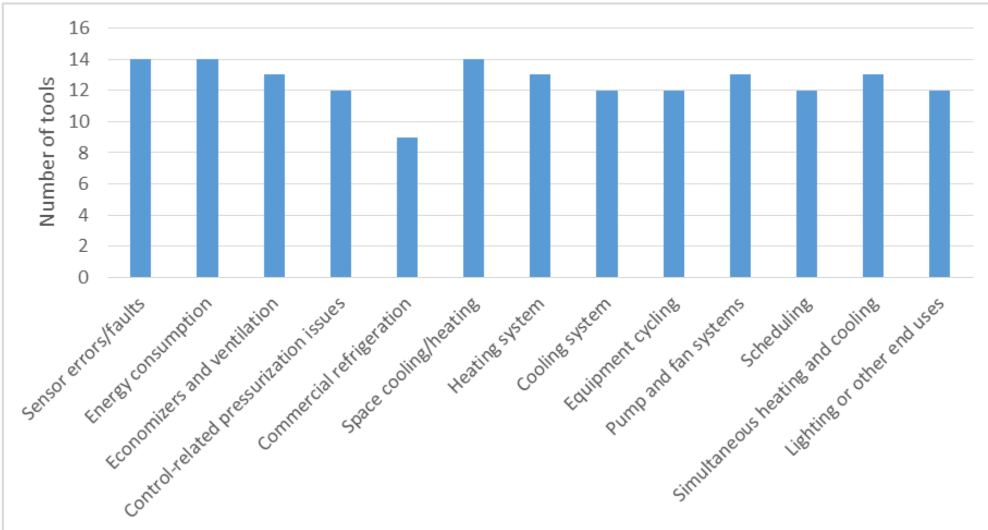


Figure 9. Categories of detectable faults

Most of the tools (12 out of 14) use rule-based algorithms, the majority of which apply some combination of expert systems, first principles-based, and limits and alarms. Many of the rule-based tools are supplemented with other approaches, and in one case the offering is a platform that is most commonly programmed and configured to deliver rule-based algorithms, but also includes machine learning functions. Three tools use black-box process history-based approaches; one of these also uses a gray-box approach. Two tools use quantitative model-based approaches. Figure 10 illustrates these findings graphically—dark shading indicates approaches used by ten or more tools, medium shading indicates approaches used by two or three tools, and light shading indicates approaches used by one or no tools.

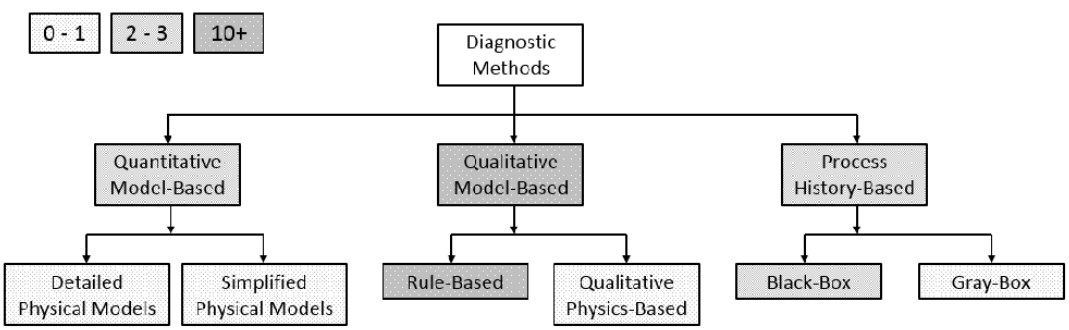


Figure 10. Methods and algorithms

As shown in Figure 11, all vendors surveyed reported the ability to identify fault presence as well as physical fault location. All but one tool is able to identify potential root causes. Depending on the specific fault identified, root case identification may be more or less precise, or in some cases, not possible. In addition, all but one reported some quantification of fault severity, e.g., degree of leakage. The degree of faultiness may be determined based on the frequency of a fault, fault magnitude (e.g., how far a point is away from setpoint), and fault duration. Several tools associate fault severity with assessment of the degree to which energy, energy cost, comfort, and maintenance costs are affected. At least one of these tools prioritizes the faults, then displays only one fault at a time to the user.

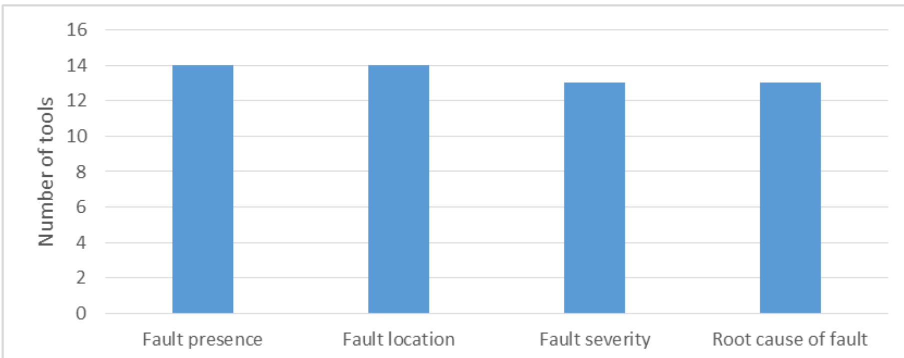


Figure 11. Detection and diagnosis capabilities

4.3 Additional Functionality

AFDD tools are commonly delivered with many supplementary features. Out of the tools surveyed, the most common features were time series visualization and plotting, quantification of energy impacts, and fault prioritization, as shown in Figure 12. Other very common features were equipment degradation, conversion of energy impacts to cost impacts, KPI tracking and reporting, automated work order request system integration, and meter data analytics. Less common but still prevalent features were cost impacts other than energy cost (such as the cost of pending equipment failure), longitudinal and cross-sectional benchmarking, and estimated cost of fault resolution and payback.

In addition, tool vendors noted a number of other features, including feedback for load management and demand response applications, verification of corrective actions, savings measurement and verification (M&V), equipment level M&V, asset data and service history, and issue-tracking systems. These other features were not exhaustively reviewed in the survey (or Tabulated findings in the Appendix) but are important complements to the AFDD capabilities.

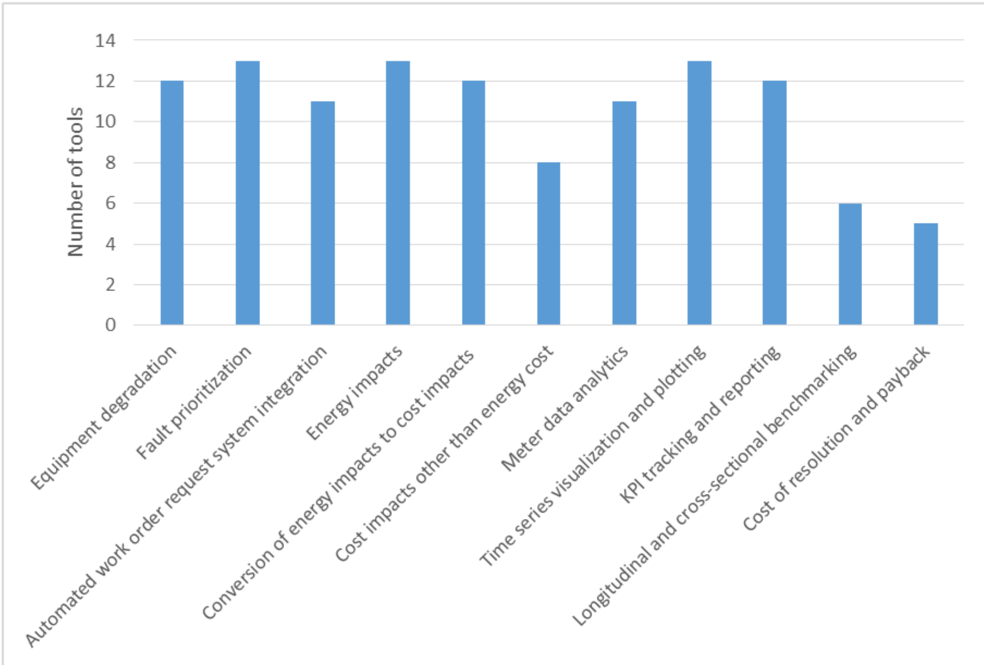


Figure 12. Relative frequency of a selected set of additional features of AFDD tools

5. Industry Needs and Future Development

This survey focused on AFDD solutions that integrate with building automation systems, that use temporary in-field measurements, or that are implemented as retrofit add-ons to existing equipment. As indicated in the findings, today's AFDD technologies are being used in nearly all commercial building sectors. Smaller facilities, however, are less commonly served, and when they are it is often through portfolios of small buildings as opposed to single sites. Cost effectiveness and complexity of implementation may vary as the technology is applied to different sectors and building sizes. For example, with a historic emphasis on HVAC systems and larger buildings, solutions for built-up systems may be simultaneously more developed, yet also more complex than those for packaged systems.

Software-as-a-service models have quickly become the norm for AFDD technologies; even vendors providing on-premise and desktop applications also tend to offer SaaS options. A compelling evolution in the industry is seen in the expansion of market delivery of FDD through third-party service providers using the tools as a way to provide value-add to their customers. Illustrated in Figure 13, these third-party services may cover a spectrum of activities. This is in contrast to earlier models that relied on in-house direct organizational use, and also from analysis-as-a-service provided by the AFDD vendor. This expansion offers the potential to increase access to the technology and its associated benefits for a new class of owners who otherwise may not be using it, however third parties' costs may vary significantly and each cost component should be defined in full to be able to compare across delivery options.

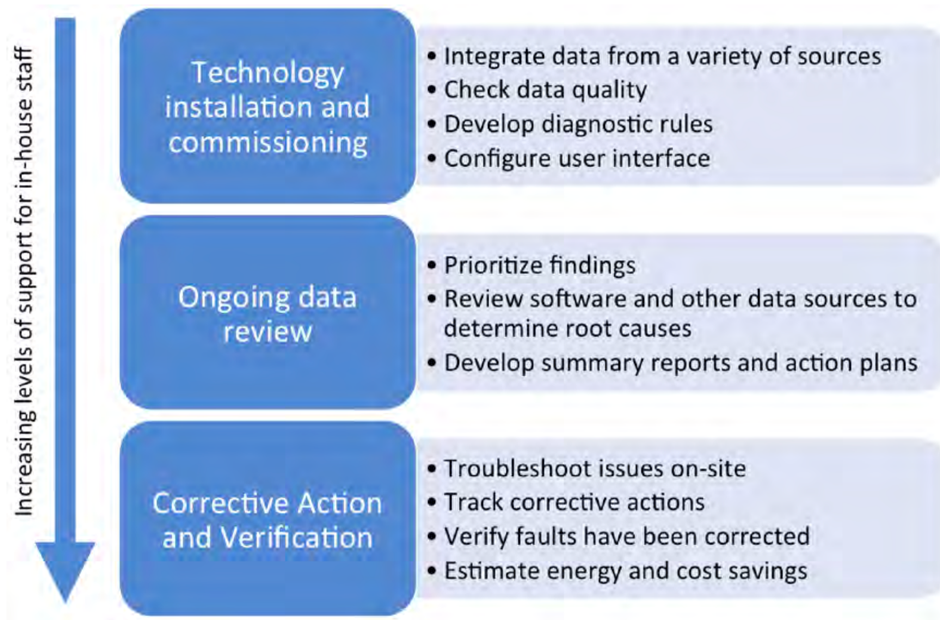


Figure 13. A spectrum of analytics-focused activities that service providers may offer their customers

While rule-based methodologies to detect and diagnose faults are still the norm, vendors are beginning to use process history-based techniques. Independent of the FDD methodology used, vendors report a high degree of commonality in the systems and types of faults that their products can cover. That is, coverage of systems and faults is driven more by site data availability than by product offering. Configuration of the technologies does require site-specific tuning, which may be conducted by vendors and service providers with varying degrees of involvement from site staff. While this is not a fully automated process, some elements of the process may be automated for streamlining.

Distinguishing factors are often associated with the additional features offered to complement the AFDD, and with the available delivery models. The market offers great diversity in additional analytics and reporting capabilities, integration architectures, and purchase models, making it possible to custom fit the technology to the needs of the organization. While custom solutions are desirable for some portions of the buildings market— such as campuses, enterprises, and large or complex facilities—other portions of the market may benefit from higher degrees of commoditization.

An important theme in interpreting the findings from this survey is that many products are sold with an emphasis on broad-scale applicability, and in analyzing the features and capabilities across all offerings as whole, there is a high degree of similarity. However, actual implementation needs can differ widely from one application case to another. Moreover, it is critical for prospective technology users to probe providers to understand the precisely what is entailed in a given offering's implementation of a feature of interest. For example, there are many ways to prioritize faults and estimate their impacts, ranging from those that rely upon static assumptions of fault persistence versus intermittence, to those that rely upon more dynamic calculations of concurrent operational conditions – and effective prioritization may be dependent on customer input. Similarly, root cause analysis (diagnosis) may be supported for just a subset of faults, or require manual input from operational staff. Analogously, ease of integration with different makes and vintages of BAS is another critical element of implementation for which "the devil is in the details."

FDD technology is seeing increased uptake in the market, and is constantly developing and evolving. Best practice implementations can deliver significant improvements in energy efficiency, utility expenses, operations and maintenance processes, and operational performance—all with rapid return on investment (see the Smart Energy Analytics Campaign Year 1 Report[4] for a snapshot of EIS, FDD and ASO performance and cost). However, for the full potential to be realized at scale, a core set of interrelated informational, organizational, and technical needs and barriers must be addressed.

Informational:

1. Prospective users remain challenged in interpreting the value proposition of FDD for their facilities. Common questions include: what will it really take to make this work for my buildings? What will the all-in costs and benefits be, up-front, and in the long-term? How do I navigate this developing market with numerous evolving players and product options?
2. Prospective users also face more specific implementation questions such as: What is the distinction between automated fault detection and diagnostics (AFDD) and BAS alarms, and which products support one versus the other? What are best practices for tuning and avoidance of false positives? What is the benefit of integrating AFDD within higher-level energy management practices such as strategic energy management and ongoing monitoring-based commissioning? How do I best integrate the support of contractors and service providers with in-house activities?

[4] Smart Energy Analytics Campaign. Synthesis of year 1 outcomes in the Smart Energy Analytics Campaign [Internet]. 2017 [accessed on September 25, 2017]. Available from: https://smart-energy-analytics.org/

Organizational:

3. Successful implementation of AFDD can be slowed by a need to diverge from existing business practices and norms. While the costs are modest compared to capital projects and can be quickly recovered, decision makers must buy in to an increase in operation and maintenance expenses and be willing to manage a certain degree of risk. Translation of information into action requires allocation of resources for staff time and training to act upon on identified fixes; it also requires effective operational response processes.

Technical:

4. While improving, IT and data integration represent one of the largest barriers to scale. It is complex, expensive and crosses organizational business units, and communications infrastructures are not easily leveraged for installation of analytics technologies.
5. Once data is accessible through cross-system integration, it must be interpreted for use in analytic applications. The current lack of common standards in data, metadata, and semantic representation also poses difficulties in scaling.
6. Similar to many efficiency solutions, today's AFDD offerings can be difficult and expensive to apply in smaller commercial buildings. Smaller facilities do not commonly have building automation systems or energy management staff and present much tighter payback constraints due to smaller energy expenditures.

A number of academic, industry, utility, and federal efforts are seeking to address these barriers. These collective efforts are far too varied and numerous to comprehensively describe, however, a few examples from current work sponsored by the U.S. Department of Energy (DOE) are provided as an illustration.

- The University of New Haven is conducting a public-facing field evaluation[5] of approximately 10 AFDD solutions to quantify technology costs and benefits, and is partnering with the utility community to inform the development of incentive programs for scaled regional deployment.
- The National Renewable Energy Laboratory (NREL) is conducting early-stage development of AFDD solutions for small commercial facilities that are based on simulation modeling and smart meter data.[6]
- Lawrence Berkeley National Laboratory (LBNL) is administering the Smart Energy Analytics Campaign[7] to provide technical assistance to AFDD and other analytics users, track gaps and benefits, and synthesize barriers.

---

[5] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Department of Energy announces scaling up the next generation of building efficiency packages funding awards [Internet]. 2017 [accessed on August 29, 2017]. Available from: https://energy.gov/eere/buildings/articles/department-energy-announces-scaling-next-generation-building-efficiency

[6] Frank, S., et al. 2016. Hybrid model-based and data-driven fault detection and diagnostics for commercial buildings. *Proceedings of the 2016 ACEEE Summer Study on Energy Efficiency in Buildings.*

[7] Smart Energy Analytics Campaign. Smart Energy Analytics Campaign [Internet]. 2017 [accessed on August 29, 2017]. Available from: https://smart-energy-analytics.org/

- LBNL and NREL are conducting public-facing multi-site field evaluations of technologies for rooftop unit AFDD and combined FDD/HVAC optimization.[8] Performance results are intended to inform the market at large, with a particular focus on public and private sector portfolio owners.

AFDD has matured significantly since its first introduction into commercial buildings. Based on information gathered through this survey and discussion with both vendors and users, several opportunities emerge to further advance the technology. Some of these are technical development challenges, and some strongly tied to the interplay between market demand and business choices concerning standardization and interoperability.

Continued development of algorithms that include machine learning and other promising techniques could reduce tuning needs, simplify configuration, and enhance diagnostic power. Following the trends in other industries, there is also potential to move beyond fault diagnostics into controls optimization, prognostics, and predictive maintenance. Integration of physics-based models to complement data-driven approaches holds promise to increase diagnostic power and support predictive analytics.

Machine-to-machine integration presents further opportunity for advancement. For example, truly pervasive "plug-and-play" functionality is still being developed, as are solutions to automatically extract and semantically interpret data across diverse systems and data types. The ability to interface AFDD tools with computerized maintenance management systems (CMMS) is just beginning to be explored, and will streamline the process of operationalizing action-taking based on the findings from analytics tools. Similarly, the practice of energy management will be enhanced through an ability to more tightly couple today's disparate systems and platforms with more pervasive data and connectivity for controls optimization, FDD, site and portfolio meter analytics, and operations and asset management. While an "all in one" tool is not likely, nor necessarily optimal, some convergence for users would be beneficial.

Finally, there are gains to be achieved through the development of corrective and adaptive controls, in combination with tool chains that can ensure that operational design intent is correctly implemented and maintained over the duration of the operational stage in the building lifecycle.

[8] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. BuildingIQ Inc: Predictive Energy Optimization [Internet]. 2017 [accessed on August 29, 2017]. Available from: https://energy.gov/eere/buildings/downloads/buildingiq-inc-predictive-energy-optimization

Appendix

Table 1 summarizes aspects of market delivery for each tool surveyed, and Table 2 summarizes their AFDD technical capabilities and additional software features.

Table 1. Market delivery aspects of each tool surveyed

Tool name	Company	Building type of markets served	Building size of markets served	Software location	Purchase model	Intended users	Software configuration	Data sources	Data ownership	FDD method tailoring	Notification of findings
SkySpark (platform)	SkyFoundry	Hospital, Outpat. Health., Hotel, Office, Restaurant, Retail, Supermarket, College and Univ, K-12 Ed, Warehouse	Large, Medium, Small	Cloud hosted, Desktop computer or other device, Controller-embedded	One time purchase with maintenance included; SaaS through partners	FDD vendor, Site staff, Third-party provider	Third-party provider; Site staff	BAS real-time and historical data, Equipment on-board/internal measures, External meters and sensors	End-customer	Manual	Software user interface, Service with periodic reports, Automated notifications
SkySpark (implementn.)	CBRE|ESI	Hospital, Office, Retail, Supermarket, College and Univ, K-12 Ed	Large, Medium	Locally hosted server, Cloud hosted	SaaS. Optional updates and maintenance after first year	Site staff, Third-party provider	Third-party provider	BAS real-time and historical data, External meters and sensors	End-customer, FDD vendor, Third-party provider	Manual	Software user interface, Service with periodic reports, Automated notifications
True Analytics	Ecorithm	Multi-fam., Hospital, Hotel, Office, College and Univ, K-12 Ed, Warehouse	Large	Cloud hosted	SaaS. Updates and maintenance included	Site staff, Third-party provider	FDD vendor, Third-party provider	BAS real-time and historical data	End-customer	Manual and Automated	Software user interface, Service with periodic reports
Clockworks	KGS	Multi-fam., Hospital, Outpat. Health., Hotel, Office, Retail, Supermarket, College and Univ, K-12 Ed, Warehouse	Large, Medium	Cloud-hosted (via platform-as-a-service)	SaaS. Updates and maintenance included	FDD vendor, Site staff, Third-party provider	FDD vendor, Third-party provider	BAS real-time and historical data, External meters and sensors	End-customer	Manual	Software user interface, Service with periodic reports, Automated notifications

Tool name	Company	Building type of markets served	Building size of markets served	Software location	Purchase model	Intended users	Software configuration	Data sources	Data ownership	FDD method tailoring	Notification of findings
Kaizen	CopperTree Analytics	Multi-fam., Hospital, Outpat. Health., Hotel, Office, Restaurant, Retail, Supermarket, College and Univ, K-12 Ed, Warehouse	Large, Medium, Small	Cloud hosted	SaaS. Use partners as value-added resell distributers Updates and maintenance included	FDD vendor, Site staff, Third-party provider	FDD vendor, Third-party provider	BAS real-time and historical data, External meters and sensors	End-customer	Manual and Automated	Software user interface, Service with periodic reports, Automated notifications
BuildPulse	BuildPulse Inc.	Hospital, Outpat. Health., Hotel, Office, Retail, College and Univ, K-12 Ed	Large, Medium	Cloud hosted	SaaS. Updates and maintenance included	FDD vendor, Site staff, Third-party provider	Third-party provider, Site staff	BAS real-time data, External meters and sensors	End-customer	Manual and Automated	Software user interface, Service with periodic reports, Automated notifications
Analytika	Cimetrics	Hospital, Outpat. Health., Hotel, Office, Supermarket, College and Univ, K-12 Ed, Warehouse, Mfg Facilities	Large, Medium	Cloud hosted	SaaS. Updates and maintenance included	FDD vendor, Site staff, Third-party provider	FDD vendor	BAS real-time and historical data, External meters and sensors	End-customer	Manual and Automated	Software user interface, Service with periodic reports, Automated notifications
Niagara Analytics 2.0	Tridium	Multi-fam., Hospital, Outpat. Health., Hotel, Office, Restaurant, Retail, Supermarket, College and Univ, K-12 Ed, Warehouse, Data Centers, Mfg Facilities	Large, Medium, Small	Locally hosted server, Cloud hosted, Controller-embedded	One time purchase with optional updates and maintenance	FDD vendor, Site staff, Third-party provider	FDD vendor, Third-party provider	BAS real-time and historical data, Equipment on-board/internal measures, External meters and sensors	End-customer	Manual and Automated	Software user interface, Automated notifications
IntelliCommand	JLL	Hospital, Outpat. Health., Hotel, Office, Retail, Supermarket, College and Univ, K-12 Ed, Warehouse, Data Centers, Mfg Facilities	Large, Medium	Cloud hosted	SaaS. Updates and maintenance included	Site staff, Third-party provider	FDD vendor	BAS real-time and historical data, External meters and sensors	End-customer	Manual	Software user interface, Service with periodic reports, Automated notifications

Tool name	Company	Building type of markets served	Building size of markets served	Software location	Purchase model	Intended users	Software configuration	Data sources	Data ownership	FDD method tailoring	Notification of findings
Balance	EEI	Multi-fam, Hospital, Outpat. Health., Hotel, Office, Restaurant, Retail, Supermarket, College and Univ, K-12 Ed, Warehouse, Data Centers, Mfg Facilities	Large, Medium	Cloud hosted	SaaS. Updates and maintenance included.	FDD vendor, Site staff, Third-party provider	FDD vendor, Third-party provider, Site staff	BAS real-time and historical data, External meters and sensors	End-customer, FDD vendor	Manual	Software user interface, Service with periodic reports
Facility Analytix	ICONICS	Hospital, Outpat. Health., Hotel, Office, Restaurant, Retail, Supermarket, College and Univ, K-12 Ed, Warehouse, Data Centers, Mfg Facilities	Large	Locally hosted server, Cloud hosted	One-time purchase or SaaS. Maintenance included, updates optional	Site staff, Third-party provider	FDD vendor, Third-party provider, Site staff	BAS real-time and historical data, External meters and sensors	End-customer	Manual	Software user interface, Service with periodic reports, Automated notifications
eIQ	Transformative Wave	Hospital, Outpat. Health., Hotel, Office, Restaurant, Retail, Supermarket, College and Univ, K-12 Ed, Warehouse, Data Centers, Mfg Facilities	Large, Medium, Small	Cloud hosted	SaaS. Updates and maintenance included	FDD vendor, Site staff, Third-party provider	FDD vendor, Third-party provider, Site staff	BAS real-time and historical data, External meters and sensors	End-customer	Manual	Software user interface, Automated notifications
ClimaCheck Onsite/ ClimaCheck Online	ClimaCheck	Multi-fam, Hospital, Outpat. Health., Hotel, Office, Restaurant, Retail, Supermarket, College and Univ, K-12 Ed, Warehouse, Data Centers, Mfg Facilities	Large, Medium, Small	Locally hosted server, Cloud hosted, Desktop computer or other device	Onsite: One-time purchase. Optional updates Online: Updates and maintenance included.	FDD vendor, Site staff, Third-party provider	Third-party provider, Site staff	BAS real-time data, External meters and sensors	End-customer	Manual and Automated	Software user interface, Service with periodic reports, Automated notifications
HVAC Service Assistant, SA Mobile, Onboard controller	Field Diagnostic Services	Multi-fam, Outpat. Health., Hotel, Office, Restaurant, Retail, Supermarket, K-12 Ed, Warehouse, Data Centers	Large, Medium, Small	Cloud hosted, Desktop computer or other device, Controller-embedded	One-time purchase or SaaS. Updates included	Site staff, Third-party provider		Equipment on-board/internal measures, External meters and sensors	End-customer	Manual	Software user interface, Service with periodic reports, Automated notifications

Table 2. Technical capabilities and additional features of each tool surveyed

Tool name	Company	Systems covered	Categories of faults detectable	Methods/algorithms	Detection and diagnosis capabilities	Additional functionality
SkySpark	SkyFoundry	AC/HP, Chillers & towers, AHU & VAV, FCU, Com. refrig., Lighting, Boilers/furnace, Water heaters, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Com. refrig., Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Rule-based. Platform supports full programmability of rules and includes machine learning functions for use in FDD algorithms.	Fault presence, location, severity, root cause	Equip degradation, Fault prioritization, Auto work order, Energy impacts, Energy cost impacts, Other cost impacts, Meter data analytics, Time series visualization, KPI tracking and reporting, Benchmarking, Cost of resolution and payback
SkySpark (implementn.)	CBRE|ESI	AC/HP, Chillers & towers, AHU & VAV, FCU, Lighting, Boilers/furnace, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Rule-based	Fault presence, location, severity, root cause	Equip degradation, Fault prioritization, Auto work order, Energy impacts, Energy cost impacts, Meter data analytics, Time series visualization, KPI tracking and reporting, Benchmarking, Cost of resolution and payback
True Analytics	Ecorithm	AC/HP, Chillers & towers, AHU & VAV, FCU, Com. refrig., Lighting, Boilers/furnace, Water heaters, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Com. refrig., Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Qual. Model-based, Rule-based, Expert Systems, First Principles-based, Machine learning techniques, fast-sampling algorithms, and the spectral method.	Fault presence, location, severity, root cause	Equip degradation, Fault prioritization, Energy impacts, Meter data analytics, Time series visualization, KPI tracking and reporting, Benchmarking
Clockworks	KGS	AC/HP, Chillers & towers, AHU & VAV, FCU, Com. refrig., Lighting, Boilers/furnace, Water heaters, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Com. refrig., Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Simplified Physical Models, Expert Systems, First Principles-based, Limits and Alarms, Statistical	Fault presence, location, severity, root cause	Equip degradation, Fault prioritization, Auto work order, Energy impacts, Energy cost impacts, Meter data analytics, Time series visualization, KPI tracking and reporting, Benchmarking

Tool name	Company	Systems covered	Categories of faults detectable	Methods/algorithms	Detection and diagnosis capabilities	Additional functionality
Kaizen	CopperTree Analytics	AC/HP, Chillers & towers, AHU & VAV, FCU, Com. refrig., Lighting, Boilers/furnace, Water heaters, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Com. refrig., Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Rule-based. Includes an open library of rules for users to download, publish and share	Fault presence, location, severity, root cause	Equip degradation, Fault prioritization, Auto work order, Energy impacts, Energy cost impacts, Other cost impacts, Meter data analytics, Time series visualization, KPI tracking and reporting
BuildPulse	BuildPulse Inc.	AC/HP, Chillers & towers, AHU & VAV, FCU, Lighting, Boilers/furnace, Water heaters, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Rule-based, Qualitative model	Fault presence, location, severity, root cause	Equip degradation, Fault prioritization, Auto work order, Energy impacts, Energy cost impacts, Other cost impacts, Meter data analytics, Time series visualization, KPI tracking and reporting, Benchmarking, Cost of resolution and payback
Analytika	Cimetrics	AC/HP, Chillers & towers, AHU & VAV, FCU, Com. refrig., Lighting, Boilers/furnace, Water heaters, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Com. refrig., Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Quant. Model-based, Qual. Model-based, Rule-based, Expert Systems, First Principles-based, Limits and Alarms, Process History-based, Black Box, Statistical, Gray Box	Fault presence, location, severity, root cause	Equip degradation, Fault prioritization, Auto work order, Energy impacts, Energy cost impacts, Other cost impacts, Meter data analytics, Time series visualization, KPI tracking and reporting, Benchmarking
Niagara Analytics 2.0	Tridium	AC/HP, Chillers & towers, AHU & VAV, FCU, Com. refrig., Lighting, Boilers/furnace, Water heaters, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Com. refrig., Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Rule-based, Limits and Alarms	Fault presence, location, severity, root cause	Equip degradation, Fault prioritization, Auto work order, Energy impacts, Energy cost impacts, Other cost impacts, Meter data analytics, Time series visualization, KPI tracking and reporting, Cost of resolution and payback
IntelliCommand	JLL	AC/HP, Chillers & towers, AHU & VAV, FCU, Com. refrig., Lighting, Boilers/furnace, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Rule-based, Limits and Alarms, Statistical, Other Pattern Recognition Techniques	Fault presence, location, severity, root cause	Equip degradation, Fault prioritization, Auto work order, Energy impacts, Energy cost impacts, Other cost impacts, Meter data analytics, Time series visualization, KPI tracking and reporting

Tool name	Company	Systems covered	Categories of faults detectable	Methods/algorithms	Detection and diagnosis capabilities	Additional functionality
Balance	EEI	AC/HP, Chillers & towers, AHU & VAV, FCU, Com. refrig., Lighting, Boilers/furnace, Water heaters, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Com. refrig., Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Rule-based, Expert Systems, First-Principles Based	Fault presence, location, severity	Equip degradation, Fault prioritization, Auto work order, Energy impacts, Energy cost impacts, Other cost impacts, Meter data analytics, Time series visualization, KPI tracking and reporting, Cost of resolution and payback
Facility Analytix	ICONICS	AC/HP, Chillers & towers, AHU & VAV, FCU, Com. refrig., Lighting, Boilers/furnace, Water heaters, Whole-building	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Com. refrig., Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Rule-based, First Principles-based, Limits and Alarms	Fault presence, location, severity, root cause	Fault prioritization, Auto work order, Energy impacts, Energy cost impacts, Other cost impacts, Meter data analytics, Time series visualization, KPI tracking and reporting
eIQ	Transformative Wave	AC/HP	Sensor errors, Energy consumption, Econ. & vent., Pressurization issues, Space Clg./Htg., Htg. system, Pump & fan systems, Sim. htg. & clg.	Rule-based, Expert Systems, Limits and Alarms	Fault presence, location, root cause	Fault prioritization, Energy impacts, Energy cost impacts, Time series visualization
ClimaCheck Onsite/ ClimaCheck Online	ClimaCheck	AC/HP, Chillers & towers, AHU & VAV, FCU, Com. refrig.	Sensor errors, Energy consumption, Econ. & vent., Com. refrig., Space Clg./Htg., Htg. system, Clg. system, Equip cycling, Pump & fan systems, Scheduling, Sim. htg. & clg., Lighting or other end uses	Thermodynamic Evaluation, Energy Signatures	Fault presence, location, severity, root cause	Equip degradation, Energy impacts, Energy cost impacts, Time series visualization, KPI tracking and reporting
HVAC Service Assistant, SA Mobile, Onboard controller	Field Diagnostic Services	AC/HP, AHU & VAV, FCU	Sensor errors, Energy consumption, Space Clg./Htg.		Fault presence, location, severity, root cause	Equip degradation, Fault prioritization, Auto work order

VOLUME 11, NUMBER 2 HVAC&R RESEARCH APRIL 2005

REVIEW ARTICLE

Methods for Fault Detection, Diagnostics, and Prognostics for Building Systems— A Review, Part II

Srinivas Katipamula, PhD
Member ASHRAE

Michael R. Brambley, PhD
Member ASHRAE

Received December 23, 2003; accepted July 20, 2004
Part I of this article was published in Volume 11, Number 1, January 2005.

This paper is the second of a two-part review of methods for automated fault detection and diagnostics (FDD) and prognostics whose intent is to increase awareness of the HVAC&R research and development community to the body of FDD and prognostics developments in other fields as well as advancements in the field of HVAC&R. The first part of the review focused on generic FDD and prognostics, provided a framework for categorizing methods, described them, and identified their primary strengths and weaknesses (Katipamula and Brambley 2005). In this paper we address research and applications specific to the fields of HVAC&R, provide a brief discussion on the current state of diagnostics in buildings, and discuss the future of automated diagnostics in buildings.

INTRODUCTION

Poorly maintained, degraded, and improperly controlled equipment wastes an estimated 15% to 30% of energy used in commercial buildings. Much of this waste could be prevented with widespread adoption of automated condition-based maintenance. Automated fault detection and diagnostics (FDD) along with prognostics provide a cornerstone for condition-based maintenance of engineered systems. Although FDD has been an active area of research in other fields for more than a decade, applications for heating, ventilating, air conditioning, and refrigeration (HVAC&R) and other building systems have lagged those in other industries. Nonetheless, over the last decade there has been considerable research and development targeted toward developing FDD methods for HVAC&R equipment. Despite this research, there are still only a handful of FDD tools that are deployed in the field.

This paper, which is the second of two parts, provides a review of fault detection, diagnostics, and prognostics (FDD&P) research in the HVAC&R field and concludes with discussions of the current state of applications for buildings and likely contributions to operating and maintaining buildings in the future. In the first paper (Katipamula and Brambley 2005), we provided an overview of FDD&P, starting with descriptions of the fundamental processes and some important definitions, and then identified the strengths and weaknesses of methods across the broad spectrum of approaches.

Srinivas Katipamula is a senior research scientist and **Michael R. Brambley** is a staff scientist at Pacific Northwest National Laboratory, Richland, Washington.

FDD RESEARCH IN HVAC&R

In this section we review FDD research relating to refrigerators, air conditioners, chillers, and air-handling units (AHUs), which represent most of the HVAC&R FDD research completed to date. This review is an update to the review previously published by Katipamula et al. (2001) and includes recent FDD publications. For information on FDD for other building systems refer to Pape et al. (1990), Dexter and Benouarets (1996), Georgescu et al. (1993), Jiang et al. (1995), and Han et al. (1999) for HVAC&R plants; Fasolo and Seborg (1995) for HVAC&R control systems; Li et al. (1996, 1997) for heating systems; Isermann and Nold (1988) and Dalton et al. (1995) for pumps; Noura et al. (1993) for large thermal plants; Isermann and Ballé (1997) for applications for motors; and Dodier and Kreider (1999) for whole-building systems.

Refrigerators

One of the early applications of FDD was to vapor-compression-cycle-based refrigerators (McKellar 1987; Stallard 1989). Although McKellar (1987) did not develop an FDD system, he identified common faults for a refrigerator based on the vapor-compression cycle and investigated the effects of the faults on the thermodynamic states at various points in the cycle. He concluded that the suction pressure (or temperature), discharge pressure (or temperature), and the discharge-to-suction pressure ratio were sufficient for developing an FDD system. The faults considered were compressor valve leakage, fan faults (condenser and evaporator), evaporator frosting, partially blocked capillary tubes, and improper refrigerant charge (under and over charge).

Building upon McKellar's work, Stallard (1989) developed an automated FDD system for refrigerators. A rule-based expert system was used with simple limit checks for both detection and diagnosis. Condensing temperature, evaporating temperature, condenser inlet temperature, and the ratio of discharge-to-suction pressure were used directly as classification features. Faults were detected and diagnosed by comparing the change in the direction of the measured quantities with expected values and matching the changes to expected directional changes associated with each fault.

Air Conditioners and Heat Pumps

There are many applications of FDD to air conditioners and heat pumps based on the vapor-compression cycle. Some of these studies are discussed below (Yoshimura and Ito 1989; Kumamaru et al. 1991; Inatsu et al. 1992; Wagner and Shoureshi 1992; Rossi 1995; Rossi and Braun 1996, 1997; Breuker 1997; Breuker and Braun 1998b; Ghiaus 1999; Chen and Braun 2000). Breuker and Braun (1998a) summarized common faults in air conditioners and their impact on performance. In addition, the frequency of fault occurrence and the relative cost of service for various faults were estimated from service records.

Yoshimura and Ito (1989) used pressure and temperature measurements to detect problems with condenser, evaporator, compressor, expansion valve, and refrigerant charge on a packaged air conditioner. The differences between measured values and expected values were used to detect faults. Expected values were estimated from manufacturers' data, and the thresholds for fault detection were experimentally determined in the laboratory. Both detection and diagnosis were conducted in a single step. No details were provided as to how the thresholds for detection were selected.

Wagner and Shoureshi (1992) developed two different fault detection methods and compared their abilities to detect five different faults in a small heat pump system in the laboratory. The five faults included abrupt condenser and evaporator fan failures, capillary tube blockage, compressor piston leakage, and seal system leakage. The first method was based on limit and trend

Table 1. Symptom Patterns for Selected Faults (Grimmelius et al. 1995)

Fault Modes	Compressor Suction Pressure	Compressor Suction Temperature	Compressor Discharge Pressure	Compressor Discharge Temperature	Compressor Pressure Ratio	Oil Pressure	Oil Temperature	Oil Level	Crankcase Pressure	Compressor Electric Power	Subcooling of Refrigerant	ΔT Refrigerant and Cooling Water	ΔT Cooling Water	Inlet Temperature at Expansion Valve	Filter Pressure Drop	Evaporator Outlet Pressure	Superheat	ΔT Chilled Water	Evaporator Outlet Temperature	Number of Acting Cylinders
Compressor, Suction Side, Increase in Flow Resistance	↓	→	→	→	→	↓	→	→	↓	↓	→	→	→	→	→	↑	↑	↓	→	→
Compressor, Discharge Side, Increase in Flow Resistance	↑	→	↑	→	→	↑	→	→	↑	→	→	→	→	→	→	↑	↑	↓	→	→
Condenser, Cooling Water Side, Increase in Flow Resistance	→	→	↑	→	→	→	→	→	→	↑	↓	→	↑	→	→	→	→	→	→	→
Fluid Line Increase in Flow Resistance	→	→	→	→	→	→	→	→	→	↓	→	→	→	↓	→	→	↑	↑	→	→
Expansion Valve, Control Unit, Power Element Loose from Pipe	↑	→	→	→	→	↑	→	→	↑	↑	→	→	→	→	→	↑	↓	↑	→	→
Evaporator, Chilled Water Side, Increase in Flow Resistance	↓	→	→	→	→	↓	→	→	↓	↓	→	→	→	→	→	↓	↑	↑	→	→

checking (qualitative model-based), and the second method was a simplified physical model-based approach. In the second approach, differences between predictions from a simplified physical model and the monitored observations are transformed into useful statistical quantities for hypothesis testing. The transformed statistical quantities are then compared to predetermined thresholds to detect faults.

The two fault detection strategies were operated in parallel on a heat pump in a psychrometric room. The qualitative method was able to detect four of five faults that were introduced abruptly, while the simplified physical model-based method was successful in only detecting two faults. Because the selection of thresholds for both methods is critical in avoiding false alarms and reduced sensitivity, Wagner and Shoureshi (1992) provide a brief discussion of how to trade off diagnostic sensitivity against false alarms. Their implementation is only capable of detecting faults and does not include diagnosis, evaluation, and decision making.

Rossi (1995) described the development of a statistical rule-based fault detection and diagnostic method for air-conditioning equipment with nine temperature measurements and one humidity measurement. The FDD method is capable of detecting and diagnosing condenser fouling, evaporator fouling, liquid-line restriction, compressor valve leakage, and refrigerant leakage. In addition to the detection and diagnosis, Rossi and Braun (1996) also describe an implementation of fault evaluation. A detailed explanation of the fault evaluation method can be found in Rossi and Braun (1997). The methods were demonstrated in limited testing with a rooftop air conditioner in the laboratory.

Breuker (1997) performed a more detailed evaluation of the methods developed by Rossi (1995). The detailed evaluation relied on steady-state and transient tests of a packaged air conditioner in a laboratory over a range of conditions and fault levels (Breuker and Braun 1998b). Seven polynomial models (ranging from first to third order) were developed to characterize the performance of the air conditioner (evaporating, condensing, and compressor outlet temperatures, suction line superheat, liquid line subcooling, temperature rise across the condenser, and temperature drop across the evaporator) using steady-state data representing normal (unfaulted) operations. The steady-state normal data are also used to determine the statistical thresholds for fault detection, while transient data with faults were used to evaluate FDD performance. Breuker and Braun (1998b) concluded that refrigerant leakage, condenser fouling, and liquid line restriction were detected and diagnosed before 8% reduction in capacity or COP occurred. The technique, however, was less successful in detecting evaporator fouling and compressor valve leakage. The authors also concluded that increasing the measurements from 6 (2 inputs and 4 outputs) to 10 (3 inputs and 7 outputs) and using higher order polynomial models improved the performance by a factor of two.

Ghiaus (1999) presented a bond-graph model for a direct-expansion vapor-compression system and applied it to diagnosing two faults in an air conditioner. The author states that this qualitative approach of modeling faults does not need *a priori* knowledge of possible faults as long as the bond model is complete and accurate.

Chillers

Several researchers have applied FDD methods to detect and diagnose faults in vapor-compression-based chillers; some of the studies are summarized below (Grimmelius et al. 1995; Gordon and Ng 1994, 1995; Stylianou and Nikanpour 1996; Tsutsui and Kamimura 1996; Peitsman and Bakker 1996; Stylianou 1997; Bailey 1998; Sreedharan and Haves 2001; Castro 2002). Comstock et al. (1999) and Reddy et al. (2001) provide a detailed review of FDD literature relating to chiller systems up to their respective times. Comstock et al. (2002) presented a list of common chiller faults and their impacts on performance.

Grimmelius et al. (1995) developed a fault diagnostic system for a chiller, in which fault detection and diagnostics are carried out in a single step. The FDD method uses a reference model based on multivariate linear regression that was developed with data from a properly operating chiller to estimate values for process variables for a healthy (unfaulted) chiller. These estimates are subsequently used to generate residuals (i.e., differences between actual measured values and the values from the reference model). Patterns of these residuals are compared to characteristic patterns corresponding to faulted conditions, and scores are assigned indicating the degree to which the patterns match the pattern corresponding to each fault mode. Fault modes with good fits (high scores) are judged as probably existing in the chiller. Fault modes with poor fits (low scores) are judged as unlikely to exist in the chiller, and faults with intermediate scores are labeled as possibly existing. Twenty different measurements are used including

Table 2. Scoring of Fault Modes for a Highly Idealized Example

Fault Mode/ Score	Symptom 1	Symptom 2	Symptom 3	Symptom 4	Total Score	Normalized Score
F1	↓	→	↓	↑		
Scores	10	10	10	10	40	1.0
F2	↑	→	↑	→		
Scores	0	9	0	3	12	0.3
Measurement-Based Pattern	↓	→	↓	↑		

temperatures, pressures, power consumption, and compressor oil level. In addition to the measured variables, some derived variables, such as liquid subcooling, superheat, and pressure drop, are used. The inputs to the model also include the outdoor ambient temperature and load conditions.

To identify potential fault modes, the chiller is classified into seven components: compressor, condenser, evaporator, expansion valve, liquid line immediately downstream of the condenser and including a filter drier, liquid line with solenoid and sight glass between the other liquid line and the evaporator, and the crankcase heater. Fault modes are associated with any component that is serviceable, which leads to 58 different fault modes. A cause and effect study of the 58 fault modes helped establish the expected influence of the faults on the components, measured variables, and subsequent chiller behavior. Symptoms are defined as a difference in any measured or derived variable from its expected value for normal unfaulted operation (i.e., the value given by the reference model). Symptoms associated with all 58 fault modes were generated and arranged into symptom patterns. Fault modes having identical symptom patterns were aggregated into a single fault mode, reducing the total number of fault modes from 58 to 37. These symptom patterns are arranged in a symptom matrix as shown in Table 2, with each row giving the symptom pattern associated with a particular fault. A symptom (cell in the matrix) shown by an arrow pointing up, ↑, indicates a value for the variable greater than that given by the reference model. Likewise, an arrow pointing down, ↓, indicates a symptom corresponding to a value for the variable less than the value from the reference model, and a horizontal arrow, →, indicates the fault has no effect on the corresponding variable.

To diagnose a fault, a symptom pattern corresponding to a set of measurements is compared to the symptom patterns for all of the fault modes. Scores are assigned to each fault mode indicating the probability that its symptom pattern matches the measured symptom pattern as follows. For each fault mode, each symptom is compared to its corresponding measured symptom and assigned a score between 0 and 10. If the symptom for the fault mode matches the measured symptom very well, it is assigned a high score (close to 10). If it weakly matches, it is assigned a score around 5, and if it does not match well at all, it is assigned a score close to zero. A total score for each fault mode is generated by adding the individual scores of all symptoms and dividing the total by the maximum possible score per pattern (i.e., the number of symptoms in the pattern multiplied by 10) to obtain a normalized score. These normalized scores are then classified into three categories. A normalized score of 0.9 or higher indicates a probable fault, a score between 0.5 and 0.9 indicates a possible fault, and scores lower than 0.5 indicate that the fault is likely not present.

A highly simplified example is shown in Table 2. Symptom patterns for two faults, F1 and F2, are shown along with a symptom pattern derived from measurements. Each pattern consists of symptoms based on four variables. Scores have been assigned to the symptoms in each pattern based on how well the symptom shown in the symptom matrix corresponds to the symptom based on measurements. For example, Symptom 1 for fault mode F1 corresponds identically to Symptom 1 in the pattern derived from measurements, so it is assigned a score of 10. The normalized scores in this example lead to the conclusion that fault F1 with a score of 1.0 probably exists in this system and fault F2 with a score of 0.3 is likely not present. In actual implementation, this methodology accounts for uncertainty in measurements by establishing threshold bands around numerical values of measured and derived variables and using the proximity to them in assigning scores to symptoms. The exact algorithm for assigning numerical scores, however, is not available in the paper.

Although the method proved effective in identifying faults in systems before the chiller system failed completely, faults with only a few symptoms tended to get high scores more often. Because the reference model is a simple regression model developed with data from a specific test chiller, the same model cannot be used on other chillers but instead new models would need to be developed for each chiller. Nonetheless, this generic approach provided a foundation for diagnostic work that followed.

Stylianou and Nikanpour (1996) used the universal chiller model developed by Gordon and Ng (1995) and the pattern matching approach outlined by Grimmelius et al. (1995) as part of their FDD system. Like Grimmelius et al. (1995), Stylianou and Nikanpour also perform detection and diagnosis in a single step. The methods used in the FDD system included a thermodynamic model for fault detection and pattern recognition from expert knowledge for diagnosis of selected faults. The diagnoses of the faults are performed by an approach similar to that outlined by Grimmelius et al. (1995). Seventeen different measurements (pressures, temperatures, and flow rates) were used to detect four different faults: refrigerant leak, refrigerant line flow restriction, condenser water-side flow resistance, and evaporator water-side flow resistance.

The FDD system is subdivided into three parts: one used to detect problems when the chiller is off, one used during chiller start-up, and one used at steady-state conditions. The off-cycle module is deployed when the chiller is turned off and is primarily used to detect faults in the temperature sensors. The temperature sensor readings at different locations on the system are compared to one another after the chiller is shut down and reaches steady state (under the assumption that the temperature of refrigerant will reach equilibrium conditions and reach the ambient state when the chiller is shut down overnight). The differences are then compared to the difference observed during commissioning (if the sensors are calibrated during commissioning, the differences should be zero). The monitored rate of change of a sensor value is used to check whether a particular sensor has reached steady state or not before comparing measurements across sensors.

The start-up module is deployed during the first 15 minutes after the chiller is started. The module uses four measured inputs (discharge temperature, crankcase oil temperature, and refrigerant temperatures entering and leaving the evaporator) scanned at five-second intervals to detect refrigerant flow faults, which are easier to detect before the system reaches steady state. To detect faults, the transient trends in measured variables during start-up are compared to the baseline trend from normal start-up. For example, a shift (in time or magnitude) in the peak of the discharge temperature may indicate liquid refrigerant flood back, refrigerant loss, or a refrigerant line restriction. Because ambient conditions affect the baseline response, the baseline response has to be normalized before a comparison is made.

The steady-state module is deployed after the chiller reaches steady state (steady-state condition is established by monitoring the rate of change of the sensor values just as in off-cycle analysis) and stays deployed until the chiller is turned off. In this mode, the module performs two functions: (1) verifies performance of the system and (2) detects and diagnoses selected faults.

Table 3. Fault Patterns Used in the Diagnostic Module (Stylianou and Nikanpour 1996)

Fault	Discharge Temperature	High Pressure Liquid Line Temperature	Discharge Pressure	Low Pressure Liquid Line Temperature	Suction Line Temperature	Suction Pressure	ΔT_{cond}	ΔT_{Evap}
Restriction in Refrigerant Line	↑	↓	↓	↓	↑	↓	↓	↑
Refrigerant Leak	↑	↓	↓	↓	↑	↓	↓	↑
Restriction in Cooling Water	↑	↑	↑	↓	↓	↓	↑	↓
Restriction in Chilled Water	↑	↓	↓	↓	↓	↓	↓	↓

Performance is verified using the thermodynamic models developed by Gordon and Ng (1995). For fault diagnostics, linear regression models are used to generate estimates of pressure and temperature variables that are then compared to actual measurements in an approach similar to that described by Grimmelius et al. (1995). The estimated variables are compared to the measured values, and the residuals are matched to predefined patterns corresponding to the various faults using a rule-base (as shown in Table 3).

Although Stylianou and Nikanpour (1996) extended the previous work of Gordon and Ng (1995) and Grimmelius et al. (1995), their evaluation of the FDD systems was not comprehensive and lacked several key elements including sensitivity and rate of false alarms. In addition, it is not clear whether the start-up module can be generalized easily.

Stylianou (1997) replaced the rule-based model used to match the patterns shown in Table 3 with a statistical pattern recognition algorithm. This algorithm uses the residuals generated from comparison of predicted (using linear regression models) and measured pressures and temperatures to generate patterns that identify faults. Because this approach relies on the availability of training data for both normal and faulty operation, it may be difficult to implement in the field. Only limited testing of the method was presented in the paper.

Tsutsui and Kamimura (1996) developed a model based on a topological-case-based reasoning (TCBR) technique and applied it to an absorption chiller. Case-based reasoning is a knowledge-based problem-solving technique that solves new problems by adapting old solutions. It is based on defining neighborhoods that provide the needed measure of similarity between cases. In contrast, TCBR defines "the neighborhood theoretically, based on the assumption that the input/output relationship is locally continuous" (Tsutsui and Kamimura 1996). Tsutsui and Kamimura (1996) also compared the diagnostic capabilities of TCBR with a linear regression model. The authors state that although the linear regression model had a better overall modeling error (mean error) than the TCBR model, the TCBR model was better at identifying abnormal conditions.

Peitsman and Bakker (1996) used two types of black-box models (artificial neural networks [ANNs] and auto regressive with exogenous inputs [ARX[1]]) to detect faults in the system and at the component level of a reciprocating chiller system. The inputs to the system models included condenser supply water temperature, evaporator supply glycol temperature, instantaneous power of the compressor, and flow rate of cooling water entering the condenser (for the ANN only). The choice of the inputs was limited to those that are commonly available in the field. Using these inputs with both the ANN and ARX models, 14 outputs were estimated. For the ANN models, inputs from the current and the previous time step and outputs from two previous time steps were used.

Peitsman and Bakker (1996) compared diagnostic capabilities of two types of models—a multiple input/output ARX model and ANN models. They used a two-level approach in which system-level models were used to detect “faulty” operation and component-level models were used to diagnose the cause of the fault. They developed 14 system-level models and 16 component-level models to detect and diagnose faults in a chiller; however, only one example (air in the system) is described in their paper. ANN models appeared to have a slightly better performance than the ARX models in detecting faults at both the system and the component levels. The authors also note that it is critical to find a global minimum when using ANN models. If an incorrect initial state is chosen, it may lead to a local minimum rather than the global minimum.

Bailey (1998) also used an ANN model to detect and diagnose faults in an air-cooled chiller with a screw compressor. The detection and diagnosis were carried out in a single step. The faults evaluated included refrigerant under- and overcharge, oil under- and overcharge, condenser fan loss (total failure), and condenser fouling. The measured data included superheat for heat exchanger circuits 1 and 2, subcooling from circuits 1 and 2, power consumption, suction pressure for circuits 1 and 2, discharge pressures for circuits 1 and 2, chilled water inlet and outlet temperatures from the evaporator, and chiller capacity. Each heat exchanger circuit has its own compressor. The ANN model was applied to normal and “faulty” test data collected from a 70-ton laboratory air-cooled chiller with screw compressor.

Sreedharan and Haves (2001) compared three chiller models for their ability to reproduce the observed performance of a centrifugal chiller. Although the evaluation was meant to find the most suitable model for chiller FDD, no FDD system was proposed or developed. Two models were based on first principles (from Gordon and Ng [1995] and a modified ASHRAE Primary Toolkit from Bourdouxhe et al. [1997]) and the third was an empirical model. While each model has some distinct advantages and disadvantages, they concluded that the accuracies of all three models were similar. Hydeman et al. (2002) reported that the three models compared by Sreedharan and Haves (2001) were not accurate in predicting the power consumption of chillers with variable condenser water flow and centrifugal chillers operating with variable-speed drives at low loads. They reformulated the Gordon and Ng model and found that it performed better than the three models described above.

Castro (2002) used a physical model developed by Rossi (1995) along with a k-nearest neighbor classifier to detect faults and a rule base to diagnose five different faults (condenser and evaporator fouling, liquid line restriction, and refrigerant under- and overcharge) in a reciprocating chiller. The FDD implementation detected and diagnosed condenser fouling, refrigerant undercharge at faults level of 20% or greater, and evaporator fouling and liquid line restriction at fault levels of 30% or greater.

[1]Refer to Box and Jenkins (1976) for more details on ARX type models.

Air-Handling Units

There are several studies relating to FDD methods for air-handling units (both the airside and the waterside); some of these are summarized in this section (Norford and Little 1993; Glass et al. 1995; Yoshida et al. 1996; Haves et al. 1996; Lee et al. 1996a, 1996b; Lee et al. 1997; Peitsman and Soethout 1997; Brambley et al. 1998; Katipamula et al. 1999; House et al. 1999; Ngo and Dexter 1999; Yoshida and Kumar 1999; Seem et al. 1999; Karki and Karjalainen 1999; Morisot and Marchio 1999; House et al. 2001; Dexter and Ngo 2001; Kumar et al. 2001; Salsbury and Diamond 2001; Carling 2002; Norford et al. 2002; Wang and Chen 2002; Pakanen and Sundquist 2003).

Norford and Little (1993) classify faults in ventilating systems, consisting of fans, ducts, dampers, heat exchangers, and controls. They then review two forms of steady-state parametric models for the electric power used by supply fans and propose a third, that of correlating power with a variable-speed drive control signal. The models are compared based on prediction accuracy, sensor requirements, and their ability to detect faults.

Using the three proposed models, four different types of faults associated with fan systems are detected: (1) failure to maintain supply air temperature, (2) failure to maintain supply air pressure setpoint, (3) increased pressure drop, and (4) malfunction of fan motor coupling to fan and fan controls. Although the paper by Norford and Little (1993) lacks details on how the faults were evaluated, error analysis and associated model fits were discussed. The results indicate that all three models were able to identify at least three of the four faults. The diagnosis of the faults is inferred after the fault is detected.

Glass et al. (1995) use a qualitative model-based approach to detect faults in an air-handling unit. The method uses outdoor, return, and supply air temperatures and control signals for the cooling coil, heating coil, and the damper system. Although Glass et al. (1995) mention that the diagnosis is inferred from the fault conditions, no clear explanation or examples are provided. Detection starts by analyzing the measured variables to verify whether steady-state conditions exist. Then, the controller values are converted to qualitative signal data and, using a model for expected values and measured temperature data, qualitative signals are estimated. Faults are detected based on discrepancies between measured qualitative controller outputs and corresponding model predictions based on the temperature measurements. Examples of qualitative states for the damper signal include "maximum position," "minimum position," "closed," and "in between." When the quantitative value of the damper signal approaches the maximum value, the corresponding qualitative value of "maximum" is assigned to the measured controller output. The results of testing the method on a laboratory AHU were mixed because the method requires steady-state conditions to be achieved before fault detection is undertaken. Fault detection sensitivity and ability to deal with false alarms are not discussed.

Yoshida et al. (1996) use ARX and the extended Kalman filter approach to detect abrupt faults with simulated test data for an AHU. Although the fault diagnosis approach is clearly described, the authors note that diagnosis is not feasible with the ARX method but that the Kalman filter approach could be used for diagnosis. Fault detection sensitivity and ability to deal with false alarms are not discussed.

Haves et al. (1996) use a combination of two models to detect coil fouling and valve leakage in the cooling coil of an AHU. The methodology was tested with data produced by the HVACSIM+ simulation tool (Clark 1985). A radial bias function (RBF) models the local behavior of the AHU and is updated using a recursive gradient-based estimator. The data generated by exercising the RBF over the operating range of the system are used in the estimation of the parameters for the physical model (UA and percent leakage) using a direct search method. Detection is accomplished by comparing estimated parameters to fault-free parameters.

Lee et al. (1996a) used two methods to detect eight different faults (mostly abrupt faults) in a laboratory test AHU. The first method uses discrepancies between measured and expected variables (residuals) to detect the presence of a fault. The expected values are estimated at nominal operating conditions. The second method compares parameters estimated using autoregressive moving average with exogenous input (ARMX) and ARX models with the normal (or expected) parameters to detect faults. The faults evaluated included complete failure of the supply and return fans, complete failure of the chilled-water circulation pump, stuck cooling-coil valve, complete failure of temperature sensors, complete failure of the static pressure sensor, and failure of the supply and return air fan flow stations. Because each of the eight faults has a unique signature, no separate diagnosis is necessary.

Lee et al. (1996b) used an ANN to detect the same faults described previously (Lee et al. 1996a). The ANN was trained using the normal data and data that represented each of the eight faults. Inputs to the ANN were values for seven normalized residuals, and the outputs were nine values that constitute patterns that represent the normal mode and the eight fault modes. Instead of generating the training data with faults, idealized training patterns were specified by considering the dominant symptoms of each fault. For example, supply fan failure implies that the supply fan speed is zero, the supply air pressure is zero, the supply fan control signal is maximum, and the difference between the flow rates in the supply and return ducts is zero. Using similar reasoning, a pattern of dominant training residuals was generated for each fault (see Table 4). A dominant symptom residual is assigned a value of +1 if the residual is positive and –1 if the residual is negative; all other residuals are assigned a value of 0. The ANN was trained using the pattern shown in Table 4. Normalized residuals were calculated for faults that were artificially generated in the laboratory AHU. The normalized residuals vector at each time step was then used with the trained ANN to identify the fault. Although the ANN was successful in detecting the faults from laboratory data, it is not clear how successful this method would be in general because the faults generated in the laboratory setting were severe and without noise.

Lee et al. (1997) extended the previous work described in Lee et al. (1996b). In the 1997 analysis, Lee et al. (1997) used two ANN models to detect and diagnose faults. The AHU is decomposed into various subsystems such as the pressure control subsystem, the flow-control subsystem, the cooling-coil subsystem, and the mixing-damper subsystem. The first ANN model is trained to identify the subsystem in which a fault occurs, while the second ANN model is trained to diagnose the specific cause of a fault at the subsystem level. An approach similar to the one used in Lee et al. 1996b is used to train both ANN models. Lee et al. (1997) note that this two-stage approach simplifies generalization by replacing a single ANN that encompasses all considered faults with a number of less complex ANNs, each one dealing with a subset of the residuals and symptoms. Although 11 faults are identified for detection and diagnosis, fault detection and diagnosis are presented for only one fault in the paper.

Peitsman and Soethout (1997) used several different ARX models to predict the performance of an AHU and compared the predictions to measured values to detect faults. The training data for the ARX models were generated using HVACSIM+. The AHU is modeled at two levels. The first level is the system level, where the complete AHU is modeled with one ARX model. The second level is the component level, where the AHU is subdivided into several subsystems such as the return fan, the mixing box, and the cooling coil. Each component is modeled with a separate ARX model. The first level ARX model is used to detect a problem and the second level models are used to diagnose the problem. Most abrupt faults were correctly identified and diagnosed, while slowly evolving faults were not detected. There is a potential for a conflict between the two levels with this approach; for example, the top-level ARX model could detect a fault with the AHU, while the second-level ARX models do not indicate any faults. Furthermore, there is a potential for multiple diagnoses at the second level. Peitsman and Soethout (1997)

Table 4. Normalized Patterns for AHU Fault Diagnosis Used in ANN Training (Lee et al. 1996b)

	Network Inputs – Residuals															
Fault Diagnosis	**Supply Pressure**	**Difference in Supply and Return Airflow**	**Supply Air Temperature**	**Control Signal to Cooling Coil**	**Supply Fan Speed**	**Return Fan Speed**	**Cooling Coil Valve Position**	**Network Outputs**								
Normal (no fault)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Supply Fan	–1	–1	0	1	–1	0	0	0	1	0	0	0	0	0	0	0
Return Fan	0	1	0	0	0	–1	0	0	0	1	0	0	0	0	0	0
Pump	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
Cooling Coil Valve	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
Temperature Sensor	0	0	–1	–1	0	0	0	0	0	0	0	0	1	0	0	0
Pressure Transducer	–1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Supply Fan Flow Station	0	–1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Return Fan Flow Station	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1

indicated that some of this multiple diagnosis could be discriminated by ranking of diagnoses according to their improbability; however, no details were provided on how to implement such a scheme.

House et al. (1999) compared several classification techniques for fault detection and diagnosis of seven different faults in an AHU. The data for the comparison were generated using an HVACSIM+ simulation model. Using the residuals, as defined in Lee et al. (1996a, 1996b), five different classification methods are evaluated and compared for their ability to detect and diagnose faults. The five classification methods include: ANN classifier, nearest neighbor classifier, nearest prototype classifier, a rule-based classifier, and a Bayes classifier.

Based on the performance of classification methods, the Bayes classifier appears to be a good choice for fault detection. For diagnosis, the rule-based method proves to be a better choice for the classification problems considered, where the various classes of faulty operations were well separated and could be distinguished by a single dominant symptom or feature.

Ngo and Dexter (1999) developed a semi-qualitative analysis of measured data using generic fuzzy reference models to diagnose faults with the cooling coil of an AHU. The method uses sets of training data with and without faults to develop generic fuzzy reference models for diagnosing faults in a cooling coil. The faults include leaky valve, waterside fouling, valve stuck closed, valve stuck midway, and valve stuck open. The fuzzy reference models describe in qualitative terms the steady-state behavior of a particular class of equipment with no faults present and when each of the faults has occurred. Measured data are used to identify a partial fuzzy model that describes the steady-state behavior of the equipment at a particular operating point. The partial fuzzy model is then compared to each of the reference models using a fuzzy matching scheme to determine the degree of similarity between the partial model and the reference models. Ngo and Dexter (1999) provide a detailed description of fault detection sensitivity and false alarm rates.

Yoshida and Kumar (1999) evaluated two model-based methods to identify abrupt (sudden) faults in an AHU. They report that both ARX and adaptive forgetting through multiple models (AFMM) seem promising for use in on-line fault detection of AHUs. They report that ARX models require only a minimal knowledge of the system, and the potential limitation of the technique is that it requires long periods to stabilize its parameters. On the other hand, Yoshida and Kumar (1999) report that the AFMM method requires long moving averages to suppress false alarms. When this is done, faults of lesser magnitude cannot be easily detected. Implementation details are not provided, and only one example of fault detection is provided.

Morisot and Marchio (1999) use an ANN-based approach to detect degradation of performance of a cooling coil in an AHU. The ANN network includes an input layer (six inputs), a hidden layer (four nodes), and an output layer (two outputs). The inputs include entering air temperature and humidity, entering and leaving water temperatures, fan-control signal, and cooling-coil-valve-control signal. The outputs are the leaving air temperature and humidity. The authors highlight the difficulties of using ANNs with real measured data, which include a need for an exhaustive training data set and the inability of the ANNs to extrapolate values outside the range of the training data. The proposed alternative is to use a simulation model to generate the training data for the ANN. Using this alternative approach, the authors test the ability of the ANN to detect two faults (air-side fouling and a sensor fault).

Dexter and Ngo (2001) outline a multi-step fuzzy model-based FDD approach to detecting and diagnosing faults with AHUs. This approach involves classifying measured data with fuzzy rules and comparing them to a set of fuzzy reference models for normal and faulty operations. The fuzzy reference models for a specific system are developed from data that are generated from simulations. Each rule is assigned a rule-confidence in the range from zero to one, where zero indicates no confidence and one indicates complete confidence in the rule correctly describing the behavior. Rule-confidence values are estimated from the data. The authors state that this method prevents false alarms because it accounts for major sources of uncertainty. The multi-step approach is shown to be capable of detecting and isolating faults in a cooling coil (leaking valves and fouling).

Kumar et al. (2001) propose a method based on an auto regressive exogenous model and a recursive parameter estimation algorithm to detect faults with AHUs. They conclude that changes in parameter estimates from real data cannot be directly used to detect faults; instead a statistical analysis of the frequency response of the model parameters is needed to detect faults.

Salsbury and Diamond (2001) develop a simplified physical model-based approach to both control and detect faults in AHUs. Results from a field test on a single AHU demonstrate the fault detection capabilities but also highlight some of the practical implementation difficulties including selection of model parameters, reliability of sensor signals, and difficulty in establishing a baseline of "correct" operation of the AHU.

Carling (2002) assesses the performance of three fault detection methods for AHUs: (1) qualitative model-based approach outlined in Glass et al. (1995), (2) rule-based approach outlined in House et al. (2001), and (3) simplified steady-state model-based. The normal and "faulty" data used for the assessment were collected from real systems for an offline analysis. The "faulty data" were collected by introducing artificial faults in the AHU. The qualitative model was easy to set up, generated few false alarms, but also detected fewer faults. The rule-based method detected more faults but required some analysis and customization during setup. The third method detected more faults but also generated more false alarms and took considerable time to set up and customize. It also required installation of additional sensors.

Norford et al. (2002) present results from controlled field tests for detecting and diagnosing faults in AHUs. These tests were part of an ASHRAE research project (RP-1020), which was to demonstrate FDD methods for AHUs. The first FDD method used a first-principles model-based approach, and the second one was based on semi-empirical polynomial correlations of submetered electrical power with flow rates or process control signals generated from historical data. Although data representing faulty operation were based on blind tests, the faults were selected from a predefined set for an agreed set of conditions and magnitudes. The criteria used in the evaluation of the two FDD methods were sensitivity, robustness, the number of sensors required, and ease of implementation.

Both methods were successful in detecting faults but had difficulty in diagnosing the actual cause of the fault. The first principles-based method requires more sensors and more training data and misdiagnosed more often than the semi-empirical method.

CURRENT STATE FOR DIAGNOSTICS IN BUILDINGS

During the 1990s, significant growth occurred in research on the development of fault detection and diagnostic methods for HVAC&R systems. Still, very few commercial FDD products exist today, and the ones that do are very specialized or not fully automated. There are several reasons for lack of widespread availability and deployment of FDD systems: lack of demand by the building operations and maintenance (O&M) community, possibly as a result of insufficient information on the improvements possible from automated FDD, lack of adequate sensors installed on building systems, reliable sensors being too costly, high perceived cost-to-benefit ratio of deploying FDD systems with current sensor technologies, lack of acceptable benchmarks to quantify the potential benefits from deploying FDD systems, lack of easy access to real-time data unless FDD is built directly into building automation systems, and lack of infrastructure to gather data from existing building automation systems (BASs) for add-on applications.

Most papers reviewed for this study did not cover the evaluation and decision stages of a generic O&M support system using FDD; yet to be useful in the field FDD must be embedded in complete building management and decision support systems. Katipamula et al. (1999), Rossi and Braun (1996), and Breuker and Braun (1998b) have addressed the evaluation aspect of the O&M support system, and Katipamula et al. (2002) and Brambley and Katipamula (2003) proposed a decision step for AHUs. Furthermore, many of the FDD methods have only been tested in laboratory or special test environments (Castro et al. 2003). Some FDD tools have been tested in the field (Katipamula et al. 2003; Castro et al. 2003; Braun et al. 2003). The detection sensitivity of the methods and occurrence rates for false alarms have not been thoroughly investigated in real buildings yet. Although the R&D reviewed is focused on methods for automating FDD, most papers do not address the automation itself in sufficient detail. Efficiently and cost-effectively creating the code that implements these methods represents an important aspect of creating usable tools based on these methods.

A significant number of papers address FDD methods based on process history. In most cases, models based on process history are specific to the system from which the training data are collected. In order to make these methods broadly applicable, the models need to be developed in factory settings for equipment model lines or automatically online in an as-installed setting. Automation of the model development process is critical to controlling the costs of FDD systems. Preliminary work on online modeling has been done by Reddy et al. (2001), but more work is needed in this general area.

Another major limitation of most FDD methods developed to date is that they work well when a single dominant fault is present in a system, but if multiple faults occur simultaneously or are present when FDD is done initially, many of the methods fail to properly detect or diagnose the causes of the faults. Braun et al. (2003) extended the previous work by Rossi and Braun (1996) and Breuker and Braun (1998b) to diagnose multiple simultaneous faults. More work is needed in development of methods that can reliably handle multiple faults.

FUTURE FOR AUTOMATED DIAGNOSTICS IN BUILDINGS

The application of automated FDD to building HVAC&R is still in its infancy. Key technical problems still requiring solutions include:

- eliminating the need to handcraft FDD systems
- automating generation of FDD systems
- selecting the best FDD method for each type of HVAC&R application and the constraints applicable to it
- developing the balance of system for operation and maintenance support tools—evaluation and decision support
- development of prognostics to transform HVAC&R maintenance from corrective and preventive to predictive condition-based maintenance
- lowering the cost of obtaining data for FDD and O&M support

To the extent that FDD requires handcrafting for each installation, costs will likely be prohibitive. Three generically different solutions for this problem exist: (1) deploy FDD in service tools with databases sufficient to cover many equipment model lines, (2) deploy FDD as part of on-board equipment control packages, and (3) develop methods for automatically generating FDD tools. The first approach has already been introduced to the market in a hand tool for air-conditioning service providers (Honeywell 2003). More tools of this type, embedding automated FDD, are likely to evolve. The second approach of embedding monitoring and safety controls capabilities in on-board equipment control is already underway to some extent by manufacturers of equipment and equipment control packages (such as chillers for safety reasons but not for system performance). Capabilities deployed to date appear limited and details of methods are difficult to obtain because of their proprietary nature, but FDD deployment is beginning to emerge via this route. The third approach involving rapid generation, possibly in an automated manner, requires further research not only into the methods for FDD but also for automated code generation (in the fields of software development, adaptive systems, genetic systems, etc.).

Additional R&D is needed in the field of FDD itself to further develop fundamental methods for FDD, selection and specialization of methods to the constraints of the built environment (e.g., pressure to keep costs low and a data-poor environment in buildings), application and testing of FDD to the various systems, equipment, and components used in buildings, and development and application of FDD for building systems of the future, which are likely to include integration with on-site electricity generation, management of electric loads, real-time purchasing of electricity, and other interactions with the electric power grid of the future, and transition to new fuels (e.g., energy carriers such as hydrogen). All provide rich areas for research and development that will improve the performance and efficiency of commercial and residential buildings.

Prognostics are critical to transitioning building equipment maintenance as practiced today to condition based so that it accounts for the expected remaining life of equipment and its performance degradation over time. Only with this information can decisions be made regarding the optimal scheduling of maintenance. The field of prognostics presents a rich area of investigation and development for the HVAC&R research community. Little has been published to date on prognostics for HVAC&R.

Beyond research into FDD methodologies and their application to building systems, the HVAC&R field is faced with the opportunity to develop an entirely new class of tools and to add them to building automation systems. FDD methods may provide a core capability for enhanced operation and maintenance support systems of the future, but the balance of those systems must be developed. Packaging is critical to success in the market. Tools must be developed that meet the needs and fit into the environment of building operators and maintenance service providers and provide them value.

Probably the most constraining of all problems facing the application of FDD&P to HVAC&R is the dearth of data. Relatively small numbers of sensors are generally installed in building systems and the quality (accuracy, precision, and reliability) of the sensors that are installed is inadequate for many uses. Sensors frequently fail or drift out of calibration and remain that way for long periods of time until fortuitously discovered. Performance, cost, and durability need to be addressed to promote better sensing in buildings.

With the development of low-cost reliable sensor technology (Kintner-Meyer and Brambley 2002; Kintner-Meyer et al. 2002), a major hurdle to commercial deployment of FDD systems would be overcome. This would potentially speed the deployment of third party FDD tools and integration of FDD into individual equipment controllers and building automation systems to provide continuous monitoring, real-time fault detection and diagnostic information, and recommendations for maintenance service and would lead to much improved maintenance of HVAC&R systems. Ultimately, as networking infrastructure matures, the use of automated FDD systems should enable a small support staff to operate, monitor, and maintain a large number of different systems from a remote, centralized location. Local FDD systems could communicate across a network to provide reports on the health of the equipment that they monitor. Failures that lead to loss of comfort could be identified quickly before significant impacts on comfort or equipment damage occurs. In many cases, degradation faults could be identified well before they lead to loss of comfort or uneconomical operation, allowing more efficient scheduling of (and lower costs for) maintenance service.

At present, no fully automated FDD systems have been integrated into individual controllers for commercial HVAC&R equipment. In general, larger equipment applications (e.g., chillers) can absorb more add-on costs than smaller ones (e.g., rooftop units) and, therefore, automated FDD will probably appear first in larger equipment.

Open communication standards for building automation systems are catching on, and use of Internet and intranet technologies is pervasive. These developments enable FDD systems to be deployed more readily. In addition, the structure of the industry that provides services for the operations and maintenance of buildings is changing; companies are consolidating and offering whole-building operations and maintenance packages. Furthermore, as utilities are deregulated, they will begin to offer new services, including complete facility management. With complete and distributed facility management, the cost-to-benefit of deploying FDD systems will improve because the cost can be spread over a large number of buildings (Katipamula et al. 1999). To benefit from these changes, facility managers, owners, operators, and energy service providers are challenged to acquire or develop new capabilities and resources to better manage this information and, in the end, their buildings and facilities.

Although the incentives for application of FDD systems for HVAC&R and other building systems have never been greater, there still are several obstacles to their development and deployment. Beyond research and development, there is a need to quantify the benefits, to establish benchmarks for acceptable costs, and to provide market information. Assessing and demonstrating value for these technologies is an opportunity for public/private partnerships. Public agencies can help reduce risk to facility owners and operators while promoting and accelerating transition to a more efficient buildings sector by demonstrating the value of these technologies and transforming the market to accelerate adoption where public benefits warrant. FDD&P promises to help transform the buildings sector to a new level of energy and operational performance and efficiency.

ACKNOWLEDGMENTS

The review presented in this paper was funded partially by the Office of Building Technology Programs in the Office of Energy Efficiency and Renewable Energy of the US Department of Energy as part of the Building Systems Program at Pacific Northwest National Laboratory. The Laboratory is operated for the US Department of Energy by Battelle Memorial Institute under contract DE-AC06-76RLO 1830.

REFERENCES

Bailey, M.B. 1998. The design and viability of a probabilistic fault detection and diagnosis method for vapor compression cycle equipment. Ph.D. thesis, School of Civil Engineering of University of Colorado, Boulder, Colorado.

Bourdouxhe, J.P., M. Grodent, and J. Lebrun. 1997. *HVAC1 Toolkit: Algorithms and Subroutines for Primary HVAC Systems Energy Calculations.* Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

Box, G.E.P., and G.M. Jenkins. 1976. *Time Series Analysis, Forecasting and Control.* San Francisco: Holden-Day.

Brambley, M.R., R.G. Pratt, D.P. Chassin, and S. Katipamula. 1998. Automated diagnostics for outdoor air ventilation and economizers. *ASHRAE Journal* 40(10):49-55.

Brambley M.R., and S. Katipamula. 2003. Automating commissioning activities: An update with an example. In *Proceedings of 11th National Conference on Building Commissioning.*

Braun, J.E., T. Lawrence, K. Mercer, and H. Li. 2003. *Fault Detection and Diagnostics for Rooftop Air Conditioners.* P-500-03-096-A1, California Energy Commission, Sacramento, California.

Breuker, M.S. 1997. Evaluation of a statistical, rule-based fault detection and diagnostics method for vapor compression air conditioners. Master's thesis, School of Mechanical Engineering, Purdue University, Purdue, Indiana.

Breuker, M.S., and J.E. Braun. 1998a. Common faults and their impacts for rooftop air conditioners. *International Journal of Heating, Ventilating, Air Conditioning and Refrigerating Research* 4(3):303-318.

Breuker, M.S., and J.E. Braun. 1998b. Evaluating the performance of a fault detection and diagnostic system for vapor compression equipment. *International Journal of Heating, Ventilating, Air Conditioning and Refrigerating Research* 4(4):401-425.

Carling, P. 2002. Comparison of three fault detection methods based on field data of an air-handling unit. *ASHRAE Transactions* 108(1).

Castro, N.S., J. Schein, C. Park, M.A. Galler, S.T. Bushby and J.M. House. 2003. *Results from Simulation and Laboratory Testing of Air Handling Unit and Variable Air Volume Box Diagnostic Tools.* National Institute of Standards and Technology, Gaithersburg, MD, NISTIR 6964.

Castro, N. 2002. Performance evaluation of a reciprocating chiller using experimental data and model predictions for fault detection and diagnosis. *ASHRAE Transactions* 108(1).

Chen, B., and J.E. Braun. 2000. Evaluation the potential on-line fault detection and diagnostics for rooftop air-conditioners. *Proceedings of the 2000 International Refrigeration Conference, Purdue University, W. Lafayette, IN.*

Clark, D.R. 1985. *HVACSIM+ Program Reference Manual.* NBSIR 84-2996, National Institute of Standards and Testing, Gaithersburg, Maryland.

Comstock, M.C., B. Chen, and J.E. Braun. 1999. *Literature Review for Application of Fault Detection and Diagnostic Methods to Vapor Compression Cooling Equipment.* HL 1999-19, Report #4036-2, Ray Herrick Laboratories, Purdue University.

Comstock, M.C., J.E. Braun, and E.A. Groll. 2002. A survey of common faults in chillers. *ASHRAE Transactions* 108(1).

Dalton T., R.J. Patton, and P.J.H. Miller. 1995. Methods of fault detection for a centrifugal pump system. *On-Line Fault Detection and Supervision in the Chemical Process Industries, IFAC Workshop*, Newcastle Upon Tyne, UK. New York: Pergamon Press.

Dexter, A.L., and M. Benouarets. 1996. Generic Approach to Identifying Faults in HVAC Plants. *ASHRAE Transactions* 102(1):550-556.

Dexter, A.L., and D. Ngo. 2001. Fault diagnosis in air-conditioning systems: a multi-step fuzzy model-based approach. *International Journal of Heating, Ventilating, Air Conditioning and Refrigerating Research* 7(1):83-102.

Dodier, R.H., and J.F. Kreider. 1999. Detecting whole building energy problems. *ASHRAE Transactions* 105(1).

Fasolo, P.S., and D.E. Seborg. 1995. Monitoring and fault detection for an HVAC control system. *International Journal of Heating, Ventilation, Air-Conditioning and Refrigeration Research* 99(1):3-13.

Georgescu, C., A. Afshari, and G. Bornard. 1993. A model-based adaptive predictor fault detection method applied to building heating, ventilating, and air-conditioning process. *TOOLDIAG' 93.* Organized by Département d'Etudes et de Recherches en Automatique, Toulouse, Cedex, France.

Ghiaus, C. 1999. Fault diagnosis of air-conditioning systems based on qualitative bond graph. *Energy and Buildings* 30:221-232.

Glass, A.S., P. Gruber, M. Roos, and J. Todtli. 1995. Qualitative model-based fault detection in air-handling units. *IEEE Control Systems Magazine* 15(4):11-22.

Gordon, J.M., and K.C. Ng. 1994. Thermodynamic modeling of reciprocating chillers. *Journal of Applied Physics* 75(6):2769-74.

Gordon, J.M., and K.C. Ng. 1995. Predictive and diagnostic aspects of a universal thermodynamic model for chillers. *International Journal of Heat and Mass Transfer* 38(5):807-18.

Grimmelius, H.T., J.K. Woud, and G. Been. 1995. On-line failure diagnosis for compression refrigerant plants. *International Journal of Refrigeration* 18(1):31-41.

Han, C.Y., Y. Xiao, and C.J. Ruther. 1999. Fault detection and diagnosis of HVAC systems. *ASHRAE Transactions* 105(1).

Haves, P., T. Salsbury, and J.A. Wright. 1996. Condition monitoring in HVAC subsystems using first principles. *ASHRAE Transactions* 102(1):519-527.

Honeywell. 2003. Advanced portable AC diagnostics: The HVAC service assistant. Number 63-9178 Rev 5/03. Honeywell, Golden Valley, Minnesota. Available on the Web at http://hbctechlit.honeywell.com/request.cfm?form=63-9178.

House, J.M., W.Y. Lee, and D. R. Shin. 1999. Classification techniques for fault detection and diagnosis of an air-handling unit. *ASHRAE Transactions* 105(1):1087-1097.

House, J.M., H. Vaezi-Nejad, and J.M. Whitcomb. 2001. An expert rule set for fault detection in air-handling units. *ASHRAE Transactions* 107(1).

Hydeman, M., N. Webb, P, Sreedharan, and S. Blanc. 2002. Development and testing of a reformulated regression-based electric chiller model. *ASHRAE Transactions* 108(2):1118-1127.

Inatsu, H., H. Matsuo, K. Fujiwara, K. Yamada, and K. Nishizawa. 1992. Development of refrigerant monitoring systems for automotive air-conditioning systems. *Society of Automotive Engineers*, SAE Paper No. 920212.

Isermann, R., and S. Nold. 1988. Model based fault detection for centrifugal pumps and AC drives. In *11th IMEKO World Congress. Houston, USA*, pp. 16-21.

Isermann, R., and P. Ballé. 1997. Trends in the application of model-based fault detection and diagnosis of technical process. *Control Eng. Practice* 5(5):709-719.

Jiang, Y., J. Li, and X. Yang. 1995. Fault direction space method for on-line fault detection. *ASHRAE Transactions* 101(2):219-228.

Karki, S., and S. Karjalainen. 1999. Performance factors as a basis of practical fault detection and diagnostic methods for air-handling units. *ASHRAE Transactions* 105(1):1069-1077.

Katipamula, S., R.G. Pratt, D.P. Chassin, Z.T. Taylor, K. Gowri, and M.R. Brambley. 1999. Automated fault detection and diagnostics for outdoor-air ventilation systems and economizers: Methodology and results from field testing. *ASHRAE Transactions* 105(1).

Katipamula, S., R.G. Pratt, and J.E. Braun. 2001. Building systems diagnostics and predictive maintenance. Chapter 7.2 in *CRC Handbook for HVAC&R Engineers*, (Ed: J. Kreider), CRC Press, Boca Raton, Florida.

Katipamula, S., M.R. Brambley, and L. Luskay. 2002. Automated proactive techniques for commissioning air-handling units. *Journal of Solar Energy Engineering* 125:282-291.

Katipamula, S., M.R Brambley, N.N Bauman, and R.G Pratt. 2003. Enhancing building operations through automated diagnostics: Field test results. In *Proceedings of 2003 International Conference for Enhanced Building Operations*, Berkeley, CA.

Katipamula, S., and M.R. Brambley. 2005. Methods for fault detection, diagnostics and prognostics for building systems—A Review, Part I. *International Journal of Heating, Ventilating, Air Conditioning and Refrigerating Research* 11(1):3-26.

Kintner-Meyer, M., and M.R. Brambley. 2002. Pros & cons of wireless. *ASHRAE Journal* 44(11):54-61.

Kintner-Meyer M., M.R. Brambley, T.A. Carlon, and N.N. Bauman. 2002. Wireless sensors: Technology and cost-savings for commercial buildings. In *Teaming for Efficiency: Proceedings, 2002 ACEEE Summer Study on Energy Efficiency in Buildings*: Aug. 18-23, 2002, Vol. 7; Information and Electronic Technologies; Promises and Pitfalls., pp. 7.121-7.134. American Council for Energy Efficient Economy, Washington, D.C.

Kumamaru., T., T. Utsunomiya, Y. Iwasaki, I. Shoda, and M. Obayashi. 1991. A fault diagnosis systems for district heating and cooling facilities. *Proceedings of the International Conference on Industrial Electronics, Control, and Instrumentation*, Kobe, Japan (IECON '91), pp. 131-136.

Kumar, S.S. Sinha, T. Kojima, and H. Yoshida. 2001. Development of parameter based fault detection and diagnosis technique for energy efficient building management system. *Energy Conversion and Management* 42:833-854.

Lee, W.Y., C. Park, and G.E. Kelly. 1996a. Fault detection of an air-handling unit using residual and recursive parameter identification methods. *ASHRAE Transactions* 102(1):528-539.

Lee, W.Y., J.M. House, C. Park, and G.E. Kelly. 1996b. Fault diagnosis of an air-handling uni using artificial neural networks. *ASHRAE Transactions* 102(1):540-549.

Lee, W.Y., J.M. House, and D.R. Shin. 1997. Fault detection of an air-handling unit using residual and recursive parameter identification methods. *ASHRAE Transactions* 102(1):528-539.

Li, X., V. Hossein, and J. Visier. 1996. Development of a fault diagnosis method for heating systems using neural networks. *ASHRAE Transactions* 102(1):607-614.

Li, X., J. Visier, and H. Vaezi-Nejad. 1997. A neural network prototype for fault detection and diagnosis of heating systems. *ASHRAE Transactions* 103(1):634-644.

McKellar, M.G. 1987. Failure diagnosis for a household refrigerator. Master's thesis, School of Mechanical Engineering, Purdue University, Purdue, Indiana.

Morisot, O., and D. Marchio. 1999. Fault detection and diagnosis on HVAC variable air volume system using artificial neural network. *Proc. IBPSA Building Simulation 1999, Kyoto, Japan.*

Ngo, D., and A.L. Dexter. 1999. A robust model-based approach to diagnosing faults in air-handling units. *ASHRAE Transactions* 105(1).

Norford, L.K., and R.D. Little. 1993. Fault detection and monitoring in ventilation systems. *ASHRAE Transactions* 99(1):590-602.

Norford, L.K., J.A. Wright, R.A. Buswell, D. Luo, C.J. Klaassen, and A. Suby. 2002. Demonstration of fault detection and diagnosis methods for air-handling units (ASHRAE 1020-RP). *International Journal of Heating, Ventilating, Air Conditioning and Refrigerating Research* 8(1):41-71.

Noura, H., C. Aubrun, D. Sauter, and M. Robert. 1993. A fault diagnosis and reconfiguration method applied to thermal plant. *TOOLDIAG' 93*, Organized by Département d'Etudes et de Recherches en Automatique, Toulouse, Cedex, France.

Pakanen, J., and T. Sundquist. 2003. Automation-assisted fault detection of air-handling unit; Implementing the method in a real building. *Energy and Buildings* 35:193-202.

Pape, F.L.F., J.W. Mitchell, and W.A. Beckman. 1990. Optimal control and fault detection in heating, ventilating, and air-conditioning systems. *ASHRAE Transactions* 97(1):729-736.

Peitsman, H.C., and V. Bakker. 1996. Application of black-box models to HVAC systems for fault detection. *ASHRAE Transactions* 102(1):628-640.

Peitsman, H.C., and L.L. Soethout. 1997. ARX models and real-time model-based diagnosis. *ASHRAE Transactions* 103(1):657-671.

Reddy, T.A., D. Niebur, J. Gordon, J. Seem, K.K. Andersen, G. Cabrera, Y. Jia, and P. Pericolo. 2001. Final report: Development and comparison of on-line model training techniques for model-based FDD methods applied to vapor compression chillers, ASHRAE Research Project 1139-RP, ASHRAE, GA.

Rossi, T.M. 1995. Detection, diagnosis, and evaluation of faults in vapor compression cycle equipment. Ph.D. thesis, School of Mechanical Engineering, Purdue University, Purdue, Indiana.

Rossi, T.M., and J.E. Braun. 1996. Minimizing operating costs of vapor compression equipment with optimal service scheduling. *International Journal of Heating, Ventilating, Air Conditioning and Refrigerating Research* 2(1):3-26.

Rossi, T.M., and J.E. Braun. 1997. A statistical, rule-based fault detection and diagnostic method for vapor compression air conditioners. *International Journal of Heating, Ventilating, Air Conditioning and Refrigerating Research* 3(1):19-37.

Salsbury, T.I., and R.C. Diamond. 2001. Fault detection in HVAC systems using model-based feedforward control. *Energy and Buildings* 33:403-415.

Seem, J., J.M. House, and R.H. Monroe. 1999. On-line monitoring and fault detection. *ASHRAE Journal* 41(7):21-26.

Sreedharan, P., and P. Haves. 2001. Comparison of chiller models for use in model-based fault detection. *International Conference for Enhanced Building Operations (ICEBO)*, organized by Texas A&M University, Austin, TX.

Stallard, L.A. 1989. Model based expert system for failure detection and identification of household refrigerators. Master's thesis, School of Mechanical Engineering, Purdue University, Purdue, Indiana.

Stylianou, M., and D. Nikanpour. 1996. Performance monitoring, fault detection, and diagnosis of reciprocating chillers. *ASHRAE Transactions* 102(1):615-627.

Stylianou, M. 1997. Classification functions to chiller fault detection and diagnosis. *ASHRAE Transactions* 103(1):645-648.

Tsutsui, H., and K. Kamimura. 1996. Chiller condition monitoring using topological case-based modeling. *ASHRAE Transactions* 102(1):641-648.

Wagner, J., and R. Shoureshi. 1992. Failure detection diagnostics for thermofluid systems. *Journal of Dynamic Systems, Measurement, and Control* 114(4):699-706.

Wang, S., and Y. Chen. 2002. Fault-tolerant control for outdoor ventilation air flow rate in buildings based on neural networks. *Building and Environment* 37:691-704.

Yoshida, H., T. Iwami, H. Yuzawa, and M. Suzuki. 1996. Typical faults of air-conditioning systems, and fault detection by ARX Model and extended kalman filter. *ASHRAE Transactions* 102(1):557-564.

Yoshida, H., and S. Kumar. 1999. ARX and AFMM model-based on-line real-time data base diagnosis of sudden fault in AHU of VAV system. *Energy Conversion & Management* 40:1191-1206.

Yoshimura, M., and N. Ito. 1989. Effective diagnosis methods for air-conditioning equipment in telecommunications buildings. *INTELEC 89: The Eleventh International Telecommunications Energy Conference*, October 15 – 18, 1989, Centro dei, Firenze, 21:1-7.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10014

14

Date Submitted	02/01/2022	**Section**	403	**Proponent**	Bryan Holland
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

This proposed modification reduces the threshold where variable flow and variable speed drives (VSD) are required for hydronic pumping systems.

Rationale

This proposed modification reduces the threshold where variable flow and variable speed drives (VSD) are required for pumping systems. Variable flow systems use less pumping energy than constant flow systems. Variable pumping systems also produce larger system temperature differences that can enhance chiller efficiency and condensing boiler efficiency (although these effects are not included in the savings calculations). Variable flow systems can reduce flow either by throttling flow and then having the pump ride the pump curve; to reduce flow and energy at higher pressure or by using a VSD. Using a variable speed drive provides similar flow control at a lower energy cost, as pressure differential is reduced. Operation of variable flow systems is less expensive than constant flow systems and variable speed drives increase the savings compared to throttling control. An analysis of energy impact shows that annual savings from expanding the use of motor speed control in the proposal ranges from $1,303 to $401 for 10 to 2 horsepower heating pumps and from $1821 to $386 for 10 to 2 horsepower cooling pumps in typical HVAC systems. Savings for larger pumps are proportional. The cost for VSD and associated controls is approximately $3,920 for 2 horsepower pumps. Costs for larger pumps are proportional.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposed modification will not have an impact on the local entity relative to enforcement of the code.

Impact to building and property owners relative to cost of compliance with code

This proposed modification will increase the cost of compliance with the code but will result in a return on investment by improving the efficacy of hydronic pumping system operation.

Impact to industry relative to the cost of compliance with code

This proposed modification will increase the cost of compliance with the code for industry. VSD systems are readily available in the marketplace by a multitude of manufacturers. VSD design, installation, and operation requires specialized training.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposed modification will improve the health and welfare of the general public by improving HVAC system efficacy and reducing operating costs for large HVAC systems.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposed modification improves the code and meets the mandate outlined in F.S. 553.886 that states; "the Florida Building Code must facilitate and promote the use of cost-effective energy conservation, energy-demand management, and renewable energy technologies in buildings.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposed modification does not discriminate against any materials, methods, or systems of constructions.

Does not degrade the effectiveness of the code

This proposed modification improves the effectiveness of the code.

1st Comment Period History

EN10014-G1

Proponent Muthusamy Swami Submitted 4/17/2022 12:52:31 PM Attachments No

Comment:

FSEC agrees with the rationale for this proposed code change. With improving technology for VFD pumps and first cost reduction, these technologies have become cost effective. Therefore, FSEC encourages adoption of this code modification.

C403.4.2.4 Part-load controls.

Hydronic systems greater than or equal to ~~500,000 Btu/h (146.5 kW)~~ 300,000 Btu/h (146.5 kW) in design output capacity supplying heated or chilled water to comfort conditioning systems shall include controls that ~~have the capability~~ are configured to do all of the following:

1. Automatically reset the supply-water temperatures in response to varying building heating and cooling demand using coil valve position, zone-return water temperature, building-return water temperature or outside air temperature. The temperature shall be capable of being reset by not less than 25 percent of the design supply-to-return water temperature difference.
2. Automatically vary fluid flow for hydronic systems with a combined motor capacity of ~~10 hp (7.5 kW)~~ 2 hp (1.5 kW) or larger with three or more control valves or other devices by reducing the system design flow rate by not less than 50 percent by designed valves that modulate or step open and close, or pumps that modulate or turn on and off as a function of load.
3. Automatically vary pump flow on heating-water systems, chilled-water systems and heat rejection loops serving water-cooled unitary air conditioners with a combined motor capacity of ~~10 hp (7.5 kW)~~ 2 hp (1.5 kW) or larger by reducing pump design flow by not less than 50 percent, utilizing adjustable speed drives on pumps, or multiple-staged pumps where not less than one-half of the total pump horsepower is capable of being automatically turned off. Pump flow shall be controlled to maintain one control valve nearly wide open or to satisfy the minimum differential pressure.

Exceptions:

1. Supply-water temperature reset for chilled-water systems supplied by off-site district chilled water or chilled water from ice storage systems.
2. Minimum flow rates other than 50 percent as required by the equipment manufacturer for proper operation of equipment where using flow bypass or end-of-line 3-way valves.
3. Variable pump flow on dedicated equipment circulation pumps where configured in primary/secondary design to provide the minimum flow requirements of the equipment manufacturer for proper operation of equipment.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

15

EN10070

Date Submitted	02/03/2022	**Section**	402.5	**Proponent**	Bryan Holland
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

This proposed modification adds detailed requirements on how to maintain the integrity of the air barrier associated with the installation of electrical and communication boxes.

Rationale

While it is clear that C402.5 currently requires all building and system components that penetrate the air barrier need to be sealed to prevent air leakage, additional guidance is needed on what options are available to achieve this objective when it comes to electrical and communication boxes. This proposal corrects this gap in the code by providing a prescriptive requirement for all boxes and to ensure the use of air-sealed boxes are tested and marked per the NEMA standard.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposed modification will assist the local entity relative to enforcement by having prescription language that can be verified and enforced properly.

Impact to building and property owners relative to cost of compliance with code

This proposed modification will not change the cost of construction as electrical and communication boxes are currently required to meet these requirements.

Impact to industry relative to the cost of compliance with code

This proposed modification will not impact industry relative to the cost of compliance as the prescriptive requirements are already common practices in the field and the use of air-sealed boxes are increasing in popularity, but not mandatory.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposed modification will improve the health and welfare of the general public by improving the performance of boxes that penetrate the air barrier resulting in energy loses in both cooling and heating seasons.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposed modification improves the code by providing detailed and prescriptive requirements that are both readily achievable and enforceable.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposed modification does not discriminate against any materials, methods, or systems of constructions.

Does not degrade the effectiveness of the code

This proposed modification improves the effectiveness of the code.

C402.5.1.1 Air barrier construction. The continuous air barrier shall be constructed to comply with the following:

5. Electrical and communication boxes shall comply with C402.5.10 to maintain the integrity of the air barrier.

C402.5.10 Electrical and Communication Boxes. Electrical and Communication boxes that penetrate the air barrier of the building thermal envelope, and that do not comply with C402.5.11.1, shall be caulked, taped, gasketed, or otherwise sealed to the air barrier element being penetrated. All openings on the concealed portion of the box shall be sealed. Where present, insulation shall rest against all concealed portions of the box.

C402.5.10.1 Air-sealed boxes. Where air-sealed boxes are installed, they shall be marked in accordance with NEMA OS 4. Air-sealed boxes shall be installed in accordance with the manufacturer's instructions.

Add new Standard to Chapter 6 [CE] Referenced Standards under "NEMA"

OS 4-2016 Requirements for Air-Sealed Boxes for Electrical and Communication Applications

C402.5.10.1

EN10070Text Modification

NEMA OS 4

Requirements for Air-Sealed Boxes for Electrical and Communication Applications

Page: 1

Mod_10070_Text_OS 4-2016.pdf

Published by

National Electrical Manufacturers Association
1300 North 17th Street, Suite 900
Rosslyn, Virginia 22209

www.nema.org

NOTICE AND DISCLAIMER

The information in this publication was considered technically sound by the consensus of persons engaged in the development and approval of the document at the time it was developed. Consensus does not necessarily mean that there is unanimous agreement among every person participating in the development of this document.

The National Electrical Manufacturers Association (NEMA) standards and guideline publications, of which the document contained herein is one, are developed through a voluntary consensus standards development process. This process brings together volunteers and/or seeks out the views of persons who have an interest in the topic covered by this publication. While NEMA administers the process and establishes rules to promote fairness in the development of consensus, it does not write the document and it does not independently test, evaluate, or verify the accuracy or completeness of any information or the soundness of any judgments contained in its standards and guideline publications.

NEMA disclaims liability for any personal injury, property, or other damages of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, application, or reliance on this document. NEMA disclaims and makes no guaranty or warranty, expressed or implied, as to the accuracy or completeness of any information published herein, and disclaims and makes no warranty that the information in this document will fulfill any of your particular purposes or needs. NEMA does not undertake to guarantee the performance of any individual manufacturer or seller's products or services by virtue of this standard or guide.

In publishing and making this document available, NEMA is not undertaking to render professional or other services for or on behalf of any person or entity, nor is NEMA undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances. Information and other standards on the topic covered by this publication may be available from other sources, which the user may wish to consult for additional views or information not covered by this publication.

NEMA has no power, nor does it undertake to police or enforce compliance with the contents of this document. NEMA does not certify, test, or inspect products, designs, or installations for safety or health purposes. Any certification or other statement of compliance with any health- or safety-related information in this document shall not be attributable to NEMA and is solely the responsibility of the certifier or maker of the statement.

CONTENTS

FIGURES

ANNEXES

Foreword

Building and energy codes for energy-efficient construction place a high priority on preserving the building thermal envelope. Installation of doors; windows; and mechanical, electrical, and other systems within exterior walls and ceilings and other separations between conditioned and unconditioned spaces results in penetrations in the air barrier. When these penetrations are not effectively sealed, the air barrier is compromised, resulting in air leakage, both in and out, which increases the energy usage necessary to maintain the desired condition of the air inside the structure.

Besides external walls and ceilings in a building, uninsulated interior walls and interior floor-ceiling cavities not designed specifically for air exchange, present pathways for air leakage. Even though air barriers are not commonly installed here, consideration should be given to using effective sealing techniques at wall, ceiling, and floor penetrations in these areas.

Sealing air-barrier penetrations is not always as simple as applying more insulation, caulk, or expanding foam. Products such as electrical outlet boxes, having design features that address effective sealing of the air-barrier penetrations, also reduce potentially undesirable effects that can result from the use of unspecified sealing techniques.

Annex B of this standard provides pertinent references to the applicable building and energy codes and to other helpful references.

In the preparation of this standards publication, input of users and other interested parties has been sought and evaluated. Inquiries, comments, and proposed or recommended revisions should be submitted by contacting:

Senior Technical Director, Operations
National Electrical Manufacturers Association
1300 North 17th Street, Suite 900
Rosslyn, Virginia 22209

This standards publication was developed by the Outlet and Switch Box Section. Section approval does not necessarily imply that all section members voted for its approval or participated in its development. At the time it was approved, the section was composed of the following members:

2D2C, Inc.—http://www.2d2c.com—Lincolnshire, IL
Allied Moulded Products, Inc.— http://www.alliedmoulded.com—Bryan, OH
Arlington Industries, Inc.—http://www.aifittings.com—Scranton, PA
Eaton's B-Line Business—http://www.cooperbline.com—Highland, IL
Crouse-Hinds by Eaton—http://www.crouse-hinds.com—Syracuse, NY
Emerson Automation Solutions—http://www.emersonindustrial.com/en-US/businesses/Pages/appletongroup.aspx—Rosemont, IL
Pentair Engineered Electrical & Fastening Solutions—http://www.erico.com—Solon, OH
Hubbell Incorporated—http://www.hubbell.com—Shelton, CT
Legrand/Pass & Seymour—http://www.passandseymour.com—Syracuse, NY
RACO—http://www.hubbell.com/Electrical/Raco.aspx—South Bend, IN
Sigma Electric Manufacturing Corporation—http://www.sigmaelectric.com—Garner, NC
Southwire Company—http://www.southwire.com/—Carrollton, GA
Thomas & Betts, A Member of the ABB Group—http://www.tnb.com—Memphis, TN
Wiremold/Legrand—http://www.wiremold.com—West Hartford, CT

Section 1
General

1.1 Scope

This standard establishes a performance test and classification scheme for outlet boxes: wall boxes, ceiling boxes, and floor boxes used for electrical and communication applications having design provisions for reducing the flow of air (air leakage) through the box and at its installed interface with the building structure, when installed as intended for normal use as instructed by the manufacturer.

The classification scheme in this standard meets the intent of the International Energy Conservation Code (IECC) and covers boxes installed in walls, ceilings, and floors where an air barrier is required.

This standard does not cover design or performance of electrical outlet boxes that are addressed in ANSI/UL 514A, CSA C22.2 No.18.1, NMX-J-023-ANCE, ANSI/UL 514C, CSA C22.2 No.18.2, ANSI/NEMA OS1, ANSI/NEMA OS2, IEC 60670-1, IEC 60670-21, or IEC 60670-23.

This standard does not cover environmental classifications for boxes or enclosures addressed in ANSI/UL 50E, CSA C22.2 No. 94.2, or NMX-J-235/2-ANCE.

1.2 References

The following normative documents contain provisions that through reference in this text constitute provisions of this standards publication. By reference herein, these publications are adopted, in whole or in part as indicated, in this standards publication. Unless otherwise stated, references are to the latest edition of the standard.

ASTM International (ASTM)
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959

ASTM E283-04 (2012), *Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen*

Association of Standards and Certification (ANCE)
Av. Lázaro Cárdenas
No. 869
Nueva Industrial Vallejo
Ciudad de México
C.P. 07700 México

NMX-J-023-ANCE, *Metallic Outlet Boxes*
NMX-J-235/2-ANCE, *Enclosures for Electrical Equipment, Environmental Considerations*

Canadian Standards Association (CSA)
5060 Spectrum Way
Mississauga, ON L4W 5N6 Canada

CSA C22.2 No.18.1-13, *Metallic outlet boxes*
CSA C22.2 No.18.2-06 (R2016), *Nonmetallic outlet boxes*
CSA C22.2 No. 94.2-15, Enclosures for electrical equipment, environmental considerations

International Electrotechnical Commission (IEC)
3, rue de Varembé, 1st Floor
Case postale 131
CH -1211 Geneva 20 Switzerland

IEC 60670-1:2015, *Boxes and enclosures for electrical accessories for household and similar fixed installations—Part 1: General requirements*

IEC 60670-21:2004+AMD1:2016 CSV, *Boxes and enclosures for electrical accessories for household and similar fixed installations—Part 21: Particular requirements for boxes and enclosures with provision for suspension means*

IEC 60670-23:2006+AMD1:2016 CSV, *Boxes and enclosures for electrical accessories for household and similar fixed installations—Part 23, Particular requirements for floor boxes and enclosures*

International Code Council (ICC)
500 New Jersey Avenue, NW, 6th Floor
Washington, DC 20001

International Energy Conservation Code (IECC)-2015

Underwriters Laboratories (UL)
333 Pfingsten Road
Northbrook, IL 60062

ANSI/UL 50E, *Enclosures for Electrical Equipment, Environmental Considerations*
ANSI/UL 514A, *Metallic Outlet Boxes*
ANSI/UL 514C, *Standard for Nonmetallic Outlet Boxes, Flush-Device Boxes, and Covers*

1.3 Definitions

air barrier: Material(s) assembled and joined together to provide a barrier to air leakage through the building envelope. An air barrier may be a single material or a combination of materials. [IECC 2015]

For the purpose of this standard, a box providing sealing at the air barrier is a component of the air barrier.

air-sealed boxes: Electrical or communication boxes that are classified and comply with the appropriate provisions of this standard.

building thermal envelope: Basement walls, exterior walls, floor, roof, and any other building elements that enclose conditioned space or provide a boundary between conditioned space and exempt or unconditioned space. [IECC 2015]

conditioned space: An area or room within a building being heated or cooled, containing uninsulated ducts, or with a fixed opening directly into an adjacent conditioned space.

Section 2
Construction

The product's construction shall comply with all requirements of the relevant product standards in accordance with applicable electrical codes.

> Note: Consideration should be given to the impact on compliance with provisions of other standards and requirements for outlet boxes when adapted for classification to this standard. Among these considerations are flammability and temperature rating of materials, electrical continuity (bonding) between metallic components, and the impact on fire resistance ratings for boxes in fire-resistive walls and floor-ceiling assemblies.

Section 3
Performance Criteria

3.1 Air Leakage Performance

Boxes that penetrate the air barrier of the building thermal envelope shall limit air leakage between conditioned and unconditioned spaces when installed as intended. When tested in accordance with section 4, boxes shall have an air leakage rate no greater than 2.0 cubic feet per minute (CFM) (0.944 L/s) at 1.57 psf (75 Pa) test pressure differential.

Section 4
Test Method

4.1 Procedure

4.1.1 General

The procedure for determining the rate of air leakage through electrical outlet boxes shall be in accordance with ASTM E283.

4.1.2 Sampling

The aggregate opening of all samples tested shall be a minimum of 75 in^2. The samples tested shall be of the same construction and type.

4.2 Sample Preparation

4.2.1 Assembly of Wiring Methods

Assembly shall be in accordance with the manufacturer's instructions when provided.

4.2.1.1 Boxes for Use with Cable or Tubing and Conduit

Boxes having provision for conduit or tubing and cable shall be separately tested according to 4.2.1.2 and 4.2.1.3, as applicable.

4.2.1.2 Boxes for Use with Cable Only

Boxes for use with cable shall be tested with one cable and a cable fitting, if required. The largest size cable for which the box is intended shall be tested.

4.2.1.3 Boxes for Use with Conduit or Tubing Only

Boxes for use with conduit or tubing shall be tested as an assembly, with one conduit or tube of the largest trade size for which the box is intended attached by a fitting, if required. The conduit or tube shall be of a length that fits within the test chamber and shall be sealed at the end opposite the box entry.

4.2.2 Mounting in Test Chamber

4.2.2.1

Boxes shall be mounted to the front wall of the test chamber in a fashion that replicates how the sealing feature of the box interacts with the drywall or floor in a typical installation (See Figures 1 and 2).

4.2.2.2

A cut-out of the appropriate size for the box shall be provided in the front wall of the test chamber with a minimum ⅛-inch clearance on all sides. A rigid support plate of a width not exceeding ½ inch may be used to secure the box to the test wall if the mounting method defined in the manufacturer's instructions cannot otherwise replicate the typical sealing interface in the test setup.

Figure 1
Inside Chamber Door with Boxes Mounted

4.2.2.3

No cover plates, covers, or devices shall be installed unless indicated in the manufacturer's supplied instructions as essential for achieving air sealing. Openings for the device are permitted to be obturated.

Boxes equipped with bar hangers or other attachment(s) shall be tested with the bar hanger or attachment(s) assembled. Bar hangers or other attachment(s) are not required to be mounted to the test chamber and are permitted to be modified to fit within the test chamber.

Figure 2
Outside Chamber Door with Boxes Mounted

4.3 Air Flow Measurement

See Annex A for example test apparatus with an internal means for measuring air flow, such as in a blower door/duct leakage test system.

Section 5
Marking and Documentation

5.1 Product Marking

The smallest shipping unit is permitted to be marked "NEMA OS 4" when boxes comply with this standard.

Boxes that comply with this standard are permitted to be marked "NEMA OS 4" or "OS 4." When used, the marking shall be legible and visible on the inside of the box.

5.2 Installation Instructions

Any particular installation techniques or components that are required to achieve compliance with this standard shall be specified by the manufacturer.

Annex A
(Informative)
Description of Typical Blower Door/Duct Leakage–Style Apparatus for Internal Air Leakage Measurements

A.1 General

This annex provides guidance for constructing a typical blower door/duct leakage system apparatus for internal measurement of air leakage in accordance with ASTM E283, around and through an electrical outlet box (see Figure 3 for typical apparatus configuration).

To ensure accuracy, the test facility should be set up in an area that has very low air movement. Direct air movement from fans or HVAC discharge vents should never be directed toward the apparatus during a test.

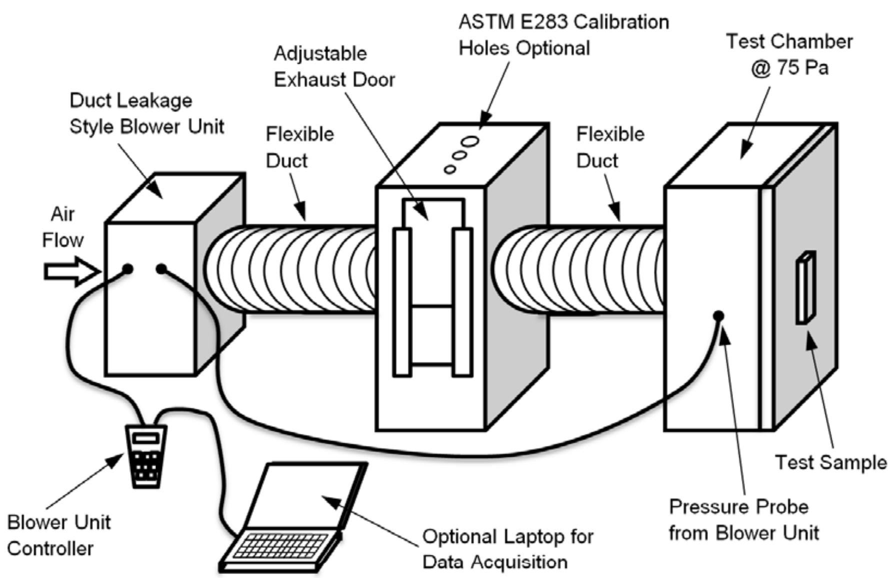


Figure 3
Block Diagram of Blower Door/Duct Leakage–Style Test Apparatus

A.2 Test Chamber

The test chamber can be constructed of any material that will be air-tight when closed and has removable air-tight test panels, each containing cutouts for the particular size and number of outlet boxes to be tested (see Figure 4). Typically, a 2–3 cubic foot enclosure that can hold 75 Pa of internal pressure is adequate. The door of the enclosure is removable so the enclosure can be easily reconfigured with a solid door for calibration/setup or any door configured with a test sample. The pressure probe from the blower unit (the blue tube in Figure 4) is installed in the test chamber. The control unit of the blower is programmed to maintain 75 Pa in the test chamber. Installation of an air diffuser inside the test chamber (Figure 6) is recommended to keep the air from blowing directly on the test sample.

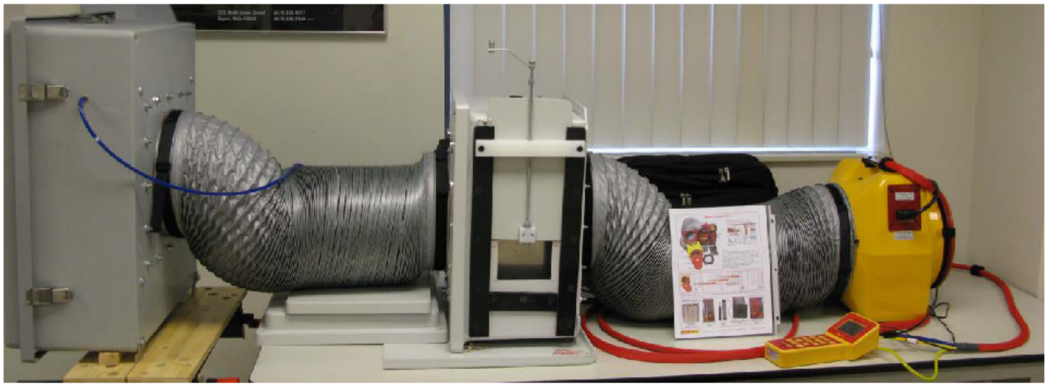


Figure 4
Fabricated Test Chamber with Test Panel Installed

A.3 Air Exhaust/Calibration Chamber

The air exhaust/calibration chamber (Figure 5) has an adjustable door to control the air exhausted from the blower unit. During a typical setup, a test chamber door with no openings is installed on the test chamber. The adjustable door is adjusted to obtain 75 Pa pressure in the test chamber at 100 CFM. This is now the baseline for the test. The test chamber door is exchanged with one that is fitted with a test sample. The blower system input increases as needed to maintain 75 Pa in the test chamber. The unit can optionally be equipped with use double pries, not quotes calibration holes as defined in ASTM E283.

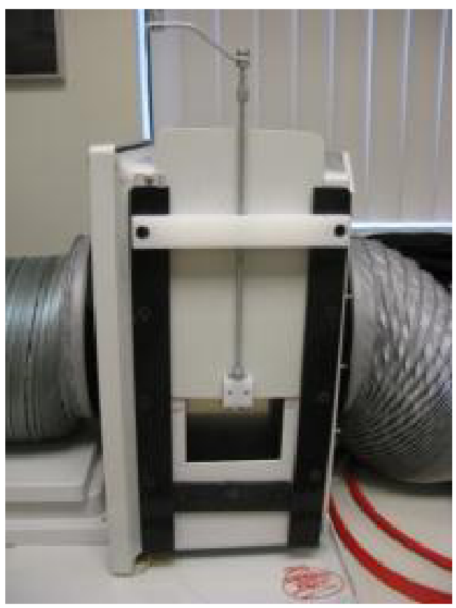


Figure 5
Air Exhaust/Calibration Chamber

A.4 Air Leakage Calculation

The 100 CFM Baseline air pressure (CFM^B) established during calibration is to be subtracted from the pressure reading from the test (CFM^T). The result (CFM^C) is the air leakage through the sample and is used to determine compliance in accordance with clause 3.1.

$$\frac{CFM^T - CFM^B}{Number\ of\ boxes} = CFM^{per\ box}$$

A.5 Air Diffuser in Test Chamber

Installation of some means of diffusing the air coming into the test chamber is recommended so it does not blow directly on the test samples. In the example shown in Figure 6, a steel plate is mounted on standoffs in front of the opening where the duct feeding air into the test chamber is located.

Figure 6
Air Diffuser in Test Chamber

<This page intentionally left blank>

Annex B
(Informative)
Applicable Building and Energy Codes and Other Resources

Primary Resources

International Energy Conservation Code (IECC)
Section C402.4.1.2, "Air Barrier Compliance Options"
Section R402.4, "Air Leakage (Mandatory)"
Section R402.4.4, "Rooms Containing Fuel-Burning Appliances"
Table R402.4.1.1, "Air Barrier and Insulation Installation"
(Definition of air-sealed box)

International Residential Code (IRC)
Chapter 11, Energy Efficiency

International Building Code (IBC)
Chapter 13, Energy Efficiency

Secondary Resources

ANSI/ASHRAE 90.2-2007, *Energy Efficient Design of Low-Rise Residential Buildings*
ANSI/NFRC 400-2014, *Procedure for Determining Fenestration Product Air Leakage*
ASHRAE/IES Standard 90.1-2016, *Energy Standard for Buildings Except Low-Rise Residential Buildings*
ASTM E283-04 (2012), *Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen*
ASTM E779-10, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*
ASTM E2178-13, *Standard Test Method for Air Permeance of Building Materials*
International Green Construction Code 2015 (IGCC)
National Building Code of Canada 2015 (Natural Resources Canada)
NRCan Standard R-2000 (Canada)
National Energy Code of Canada for Houses (NECH)
National Energy Code of Canada for Buildings (NECB) 2015
NEMA LSD 58-2010, *Air Infiltration Ratings for Recessed Luminaires*
NEMA Engineering Bulletin 95 (2007), *Thermal Effects of Type NM-B Cable Encased in Spray-Foam Insulation Used in Residences*

§

<u>TAC</u>: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10077

16

Date Submitted	02/03/2022	**Section**	401.2	**Proponent**	Bryan Holland
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

<u>**Comments**</u>

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

This proposed modification reinstates sections 8.4.2 and 8.4.3 of the ASHRAE 90.1 standard to the optional compliance path in C401.2 and the electrical power applicability in C405.5.1.

Rationale

The exclusion of section 8.4.2 and 8.4.3 of the ASHRAE 90.1 Standard, when that compliance path is selected for compliance in C401.2 and when complying with C405.5.1 (DS 2016-033), is in direct violation of F.S. 553.886 that states; "the Florida Building Code must facilitate and promote the use of cost-effective energy conservation, energy-demand management, and renewable energy technologies in buildings" and reduces the energy efficiency of buildings established by the United States Department of Energy under Section 304(a) of the Energy Conservation and Production Act (ECPA). Automatic receptacle control and electrical energy monitoring are now both mandatory requirements of the 2021 IECC and ASHRAE 90.1-2019.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposed modification will require the local entity to confirm the design and installation of ARC and Energy Monitoring systems at time of plan review and inspection.

Impact to building and property owners relative to cost of compliance with code

This proposed modification will increase the cost of compliance with the code but will result in improved energy conservation and the effective use of energy over time. Both ARC and Energy Monitoring systems do require specialized training for design, installation, and use/operation.

Impact to industry relative to the cost of compliance with code

This proposed modification will increase the cost of compliance with the code for industry. ARC and Energy Monitoring systems have an initial design and installation cost not currently required in the code.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposed modification will improve the health and welfare of the general public by improving the energy saving and energy conservation of commercial buildings through application of these specialized systems.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposed modification improves the code and meets the mandate outlined in F.S. 553.886 that states; "the Florida Building Code must facilitate and promote the use of cost-effective energy conservation, energy-demand management, and renewable energy technologies in buildings.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposed modification does not discriminate against any materials, methods, or systems of constructions.

Does not degrade the effectiveness of the code

This proposed modification improves the effectiveness of the code.

1st Comment Period History

EN10077-G1

Proponent Muthusamy Swami Submitted 4/17/2022 12:46:37 PM Attachments No

Comment:

Response: FSEC agrees that we should not exclude the “Automatic receptacle control and electrical energy monitoring” requirements. Current technologies that support the code requirements are cost-effective. Electrical energy monitoring is part and parcel of advanced maintenance plans and failure diagnostics. FSEC has done economic analysis of Section 8.4.3 of the 2019 ASHRAE 90.1 and determined to be cost-effective with SIR value range of 3.44 - 14.01. Note that building floor size less than 25,000 square foot are exempted from Section 8.4.3 requirement.

C401.2 Application.

Commercial buildings shall comply with one of the following:

1. The requirements of ANSI/ASHRAE/IESNA 90.1, excluding section 9.4.1.1(g)~~, section 8.4.2 and section 8.4.~~3 of the standard.

C405.5.1 Applicability.

This section applies to all building power distribution systems. The provisions for electrical distribution for all sections of this code are subject to the design conditions in ASHRAE Standard 90.1

~~**Exception:** Compliance with ASHRAE 90.1 Sections 8.4.2, 8.4.3 and 9.4.1.1(g) are not required.~~

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

17

EN10079

Date Submitted	02/03/2022	**Section**	405.5.3	**Proponent**	Bryan Holland
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

This proposed modification adds "customer-owned service conductors" to the voltage drop requirement with an exception for service conductors installed by or under the exclusive control of the electric utility.

Rationale

Voltage drop occurs on all conductors of a premises wiring system. However, only branch circuit and feeder conductors are currently addressed in the code. This proposal adds customer-owned service conductors but only if they are installed by and under the exclusive control of the owner. Where the electric utility installs and controls the service conductors, they are exempt from this rule. Voltage drop is a total waste of energy that can easily be mitigated by limiting these losses to 5% from the service point to the furthest outlet.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposed modification will require the local entity to confirm the voltage drop calculations have been applied to customer-owned service conductors at time of plan review and inspection.

Impact to building and property owners relative to cost of compliance with code

This proposed modification will increase the cost of compliance with the code where service conductor runs are excessively long, however, the energy savings will result in ROI over time.

Impact to industry relative to the cost of compliance with code

This proposed modification will increase the cost of compliance with the code for industry where larger service conductor sizes are required to recue voltage drop below 5%.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposed modification will improve the health and welfare of the general public by improving system efficiency and ensure energy loses are limited to 5% across the entire wiring system.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposed modification improves the code and meets the mandate outlined in F.S. 553.886 that states; "the Florida Building Code must facilitate and promote the use of cost-effective energy conservation, energy-demand management, and renewable energy technologies in buildings.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposed modification does not discriminate against any materials, methods, or systems of construction.

Does not degrade the effectiveness of the code

This proposed modification improves the effectiveness of the code.

C405.5.3 Voltage drop.

~~The conductors for feeders and branch circuits combined shall be sized for a maximum of 5 percent voltage drop total.~~ The total voltage drop across the combination of customer-owned service conductors, feeder conductors and branch circuit conductors shall not exceed 5 percent.

Exception: Customer-owned service conductors installed by or under the exclusive control of the electric utility.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

18

EN10085

Date Submitted	02/04/2022	**Section**	405.9	**Proponent**	Bryan Holland
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes

Alternate Language No

Related Modifications

Summary of Modification

This proposed modification adds requirements for automatic receptacle control to the code.

Rationale

Plug loads can represent up to 30% of the electrical energy used in a commercial building. And much like lighting that is automatically controlled to turn off when no human occupancy is present, this proposal provides prescriptive criteria for ensuring nonessential receptacle loads are turned off when no human occupancy is present. A CASE initiative study found that in smaller 10,000 sqft office buildings, the annual electrical savings was 4,900 kwh/yr and a demand savings of 1.97 kw. Based on installed costs and utilization of lighting control system elements already installed to support the plug load control, simple payback was 4.2 years. In larger 175,000 sqft office building, annual electrical savings was 107,000 kwh/yr and demand savings of 23.6 kw with a simple payback calculated at 2.4 years. This proposal meets the mandate outlined in F.S. 553.886 that states; "the Florida Building Code must facilitate and promote the use of cost-effective energy conservation, energy-demand management, and renewable energy technologies in buildings.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposed modification will require the local entity to confirm the design and installation of ARC at time of plan review and inspection.

Impact to building and property owners relative to cost of compliance with code

This proposed modification will increase the cost of compliance with the code where dedicated or advanced techniques are used for ARC. Energy savings are immediate and ROI is less than 5 years.

Impact to industry relative to the cost of compliance with code

This proposed modification will increase the cost of compliance with the code for industry. ARC technology has been in the marketplace for over ten years. The installation and use of ARC does require specialized training.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposed modification will improve the health and welfare of the general public by improving energy savings and energy conservation by the control of plug loads.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposed modification improves the code and meets the mandate outlined in F.S. 553.886 that states; "the Florida Building Code must facilitate and promote the use of cost-effective energy conservation, energy-demand management, and renewable energy technologies in buildings.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposed modification does not discriminate against any materials, methods, or systems of constructions.

Does not degrade the effectiveness of the code

This proposed modification improves the effectiveness of the code.

1st Comment Period History

EN10085-G1

Proponent	Muthusamy Swami	Submitted	4/17/2022 12:56:11 PM	Attachments	No

Comment:

This proposed code change is the same as Section 8.4.2 of the 2019 ASHRAE 90.1. ASHARE adopted this code at least since 2013 but FBCEC (2017, and 2020) has excluded it. See proposed code change EN10077 (item #1 in this document) FSEC has not done any cost-effectiveness analysis but PNNL and others claim it is cost-effective. FSEC encourages adoption of this proposed code change because it is current technology.

C405.11 Automatic receptacle control. The following shall have automatic receptacle control complying with Section C405.11.1.

1. At least 50 percent of all 125V, 15- and 20-amp receptacles installed in enclosed offices, conference rooms, rooms used primarily for copy or print functions, breakrooms, classrooms and individual workstations, including those installed in modular partitions and module office workstation systems.

2. At least 25 percent of branch circuit feeders installed for modular furniture not shown on the construction documents.

C405.11.1 Automatic receptacle control function. Automatic receptacle controls shall comply with the following:

1. Either split controlled receptacles shall be provided with the top receptacle controlled, or a controlled receptacle shall be located within 12 inches (304.8 mm) of each uncontrolled receptacle.

2. One of the following methods shall be used to provide control:

2.1. A scheduled basis using a time-of-day operated control device that turns receptacle power off at specific programmed times and can be programmed separately for each day of the week. The control device shall be configured to provide an independent schedule for each portion of the building of not more than 5,000 square feet (464.5 m2) and not more than one floor. The occupant shall be able to manually override an area for not more than 2 hours. Any individual override switch shall control the receptacles of not more than 5,000 feet (1524 m).

2.2. An occupant sensor control that shall turn off receptacles within 20 minutes of all occupants leaving a space.

2.3. An automated signal from another control or alarm system that shall turn off receptacles within 20 minutes after determining that the area is unoccupied.

3. All controlled receptacles shall be permanently marked in accordance with NFPA 70 and be uniformly distributed throughout the space.

4. Plug-in devices shall not comply.

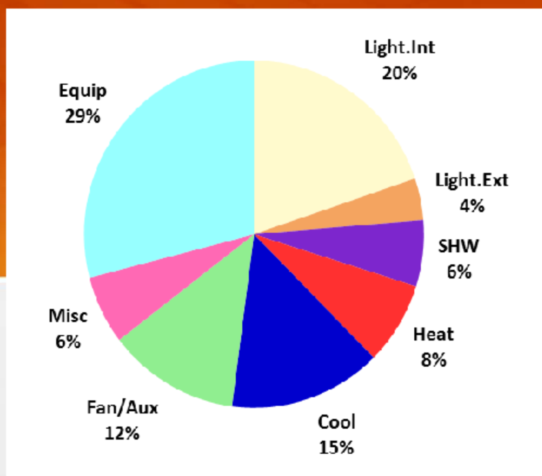
Exceptions: Automatic receptacle controls are not required for the following:

1. Receptacles specifically designated for equipment requiring continuous operation (24 hours per day, 365 days per year).

2. Spaces where an automatic control would endanger the safety or security of the room or building occupants.

3. Within a single modular office workstation, noncontrolled receptacles are permitted to be located more than 12 inches (304.8 mm), but not more than 72 inches (1828 mm) from the controlled receptacles serving that workstation.

PNNL-24043



Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

End-Use Opportunity Analysis from Progress Indicator Results for ASHRAE Standard 90.1-2013

December 2014

R Hart
Y Xie

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

This document was printed on recycled paper.
(9/2003)

PNNL-24043

End-Use Opportunity Analysis from Progress Indicator Results for ASHRAE Standard 90.1-2013

R Hart
Y Xie

December 2014

Prepared for
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

This report and an accompanying spreadsheet posted online[1] compile the end use building simulation results for prototype buildings throughout the United States. The results represent the energy use of each edition of ANSI/ASHRAE/IES[2] Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*. Pacific Northwest National Laboratory examined the simulation results to determine how the remaining energy was used.

Figure S.1 shows end-use cost data by building type weighted by national construction by climate zone. Prototype results are grouped by similar type, including Office, Warehouse (Wh), Retail, Hotel, Apartment (Apt), School, Medical, and Food Service (Food Svc). The widths of the building type (vertical) bars are scaled to represent each building type's share of impact on national building energy cost. The end uses include heating, ventilation, and air conditioning (HVAC) fans and pumps (Fan Aux), Cooling (Cool), Heating (Heat), service hot water (SHW), interior lighting (Light Int), exterior lighting (Light Ext), miscellaneous loads including refrigeration, elevators and transformers (Misc), and plug loads, cooking, and information technology (IT) equipment (Equip). The area of each block represents the proportion of national energy cost for each end use. The entire width of the plot matches national building energy use based on Standard 90.1-2013.

[1] PNNL. 2014. *2013EndUseTables.xlsx*. Pacific Northwest National Laboratory, Richland, WA. Available at http://www.energycodes.gov/sites/default/files/documents/2013EndUseTables.zip.

[2] ANSI – American National Standards Institute; ASHRAE – American Society of Heating, Refrigerating, and Air-Conditioning Engineers; IES – Illuminating Engineering Society

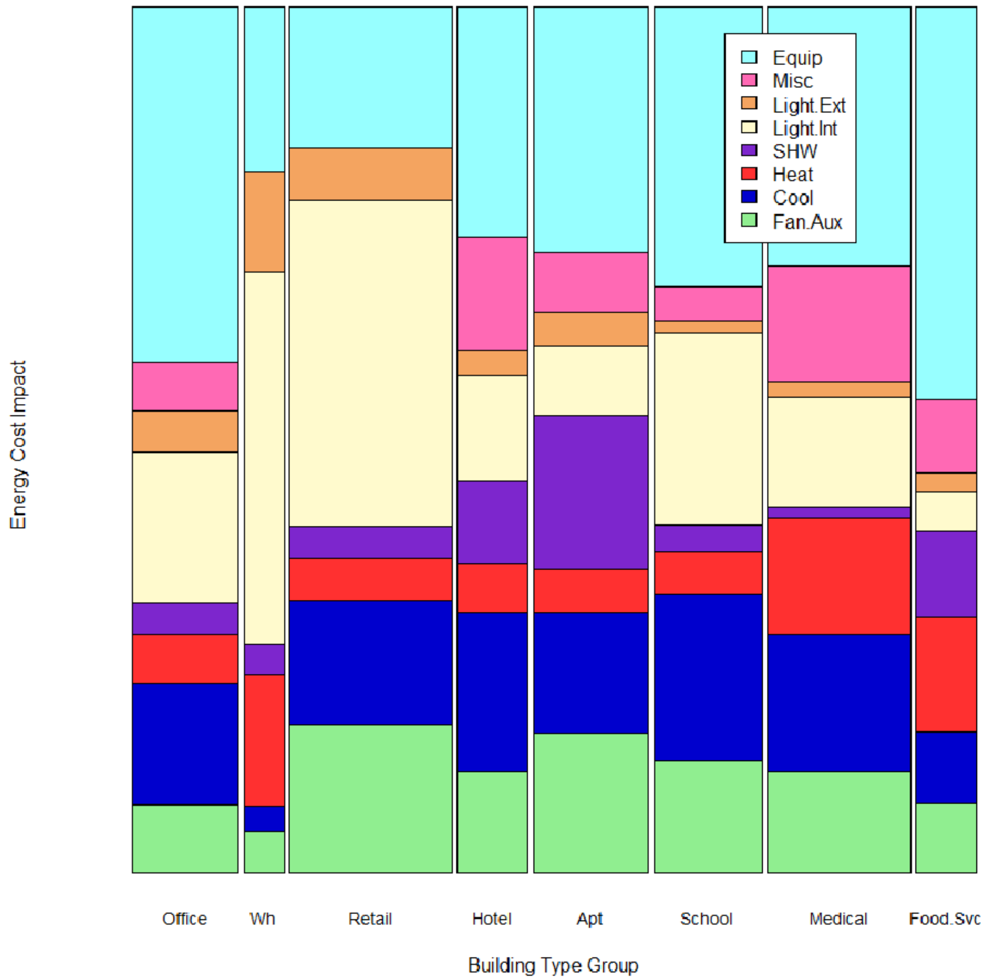


Figure S.1. Commercial energy cost impact by end use U.S. weighted, after 90.1-2013

Acknowledgments

The data that was used as the basis for this end use analysis was developed by the Pacific Northwest National Laboratory codes team for the 2013 progress indicator that measured improvements in the ANSI/ASHRAE/IES Standard 90.1-2013 vs. earlier editions of Standard 90.1. Their long-term work on development and enhancement of the building prototypes used in that analysis made this report possible. Team members include Michael Rosenberg, Mark Halverson, Raul Athalye, YuLong Xie, Weimin Wang, Jian Zhang, Supriya Goel, and Vrushali Mendon, with team leadership by Bing Liu and Jamie Holladay. Editing was provided by Mike Parker and Matt Wilburn. Members of the ASHRAE Standing Standards Project Committee 90.1 provided valuable feedback to development of the prototypes and typical buildings, and funding was provided by the U.S. Department of Energy.

Page: 8

Mod_10085_Text_PNNL - End-Use Opportunity Analysis from Progress Indicator Results for ASHRAE Standard 90.1-2013.pdf

EN10085Text Modification

Acronyms and Abbreviations

ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BECP	Building Energy Codes Program
CZ	climate zone
ECI	energy cost index
EUI	energy use index
HVAC	heating, ventilation, and air conditioning
IES	Illuminating Engineering Society
IT	information technology
MHC	McGraw-Hill Construction
PNNL	Pacific Northwest National Laboratory
SSPC	Standing Standard Project Committee
WBCI	weighted building cost index

Contents

Figures

Tables

Background and Method

End Uses Analyzed

Pacific Northwest National Laboratory (PNNL) conducts analysis to project the energy use of each edition of ANSI/ASHRAE/IES[1] Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings* (ASHRAE 2004, 2007, 2010, 2013). The comparison of the savings of each edition to the prior edition is called the "progress indicator." Based on analysis of the Standard 90.1-2013 (ASHRAE 2013) progress indicator, PNNL examined the detailed results to determine how the remaining energy was used. Where helpful, miscellaneous (e.g., elevator) and equipment (cooking and information technology [IT] equipment) results were extracted to increase the precision of end-use categories. This report provides analysis results using the simple and detailed breakdowns as shown in Table 1.

Table 1. Simple and detailed end-use category descriptions

Simple Breakdown Abbreviation	Color Code	Detailed Breakdown Abbreviation	End-Use Description
Light.int		Light.int	Interior lighting
Light.ext		Light.ext	Exterior lighting
SHW		SHW	Service hot water
Heat		Heat	Space heating
		Humidify	Humidification (dehumidification in heat and cool)
Cool		Cool	Mechanical cooling (including unitary heat rejection)
		Ht.Rej	Heat rejection, cooling towers (unitary is in cool)
Fan.Aux		Fans	Heating, ventilation, and air conditioning (HVAC) supply, return and exhaust fans
		Ht.Rcvy	Heat recovery fan and wheel energy
		Pumps	Hydronic pumping, including SHW recirculation
Misc		Refrig	Refrigeration equipment and kitchen refrigerators and freezers
		Elevator	Elevators
		Txfmr	In-building transformers
Equip		Cook	Cooking equipment
		IT	Computer room IT and telephone equipment
		Equip	Other plug loads and equipment including non-kitchen refrigerators

The graphs in this report are based on energy cost index (ECI) and most use the simple breakdown.

Prototype Buildings for the Progress Indicator

To determine the savings impact from various editions of ANSI/ASHRAE/IES Standard 90.1, PNNL developed prototype commercial building models. They have been described in detail previously in *Achieving the 30% Goal: Energy and Cost Savings Analysis of ASHRAE Standard 90.1-2010* (Thornton et al. 2011). As noted in that report, PNNL developed a suite of 16 prototype buildings covering the majority of the commercial building stock and mid-rise to high-rise buildings. The prototypes used in the

[1] American National Standards Institute/American Society of Heating, Refrigerating, and Air-Conditioning Engineers/Illuminating Engineering Society of North America.

simulations are intended to represent a cross section of common commercial building types and cover the building types that comprise 80% of new commercial construction floor area. The 16 prototype building models were reviewed extensively by building industry experts on the ASHRAE Standing Standard Project Committee (SSPC) 90.1 during development and assessment of multiple editions of Standard 90.1. These prototype models, their detailed characteristics, and their development are described in detail on the Building Energy Codes Program (BECP) web site.[2] A detailed description of the prototypes may also be found in the completed savings analysis of Standard 90.1-2010: *Energy and Cost Savings Analysis of ASHRAE Standard 90.1-2010*, which can be found on the BECP web site.[3] The prototype models described in that report have since been modified as described in the document *Enhancements to ASHRAE Standard 90.1 Prototype Building Models* (PNNL 2014b), also available at the same web site.

The energy analysis of the 16 prototype buildings shown in Table 2 was completed with the EnergyPlus building simulation program (DOE 2013). The results from that analysis are further analyzed to produce this end-use analysis. Each prototype building model is defined as characteristic of a certain class of buildings, mostly corresponding to a classification scheme established in the 2003 DOE/Energy Information Administration Commercial Building Energy Consumption Survey (EIA 2003). Building configurations of the prototype models are shown in Figure 1.

Table 2. ASHRAE commercial prototype building models

Building Type	Prototype building	Prototype Abbreviation	Prototype Floor Area (ft^2)
Office	Small Office	OfcS	5,502
	Medium Office	OfcM	53,628
	Large Office	OfcL	498,588
Retail	Stand-Alone Retail	RtlB	24,692
	Strip Mall	RtlS	22,500
School	Primary School	SchP	73,959
	Secondary School	SchS	210,887
Medical	Outpatient Health Care	MedC	40,946
	Hospital	MedH	241,501
Hotel	Small Hotel	HotS	43,202
	Large Hotel	HotL	122,120
Warehouse	Non-Refrigerated Warehouse	Whse, Wh	52,045
Food Service	Fast Food Restaurant	Fast	2,501
	Sit-Down Restaurant	Rest	5,502
Apartment	Mid-Rise Apartment	AptM	33,741
	High-Rise Apartment	AptH	84,360

[2] Prototype detail on BECP web site at www.energycodes.gov/development/commercial/90.1_models.
[3] BECP web site at www.energycodes.gov/achieving-30-goal-energy-and-cost-savings-analysis-ashrae-ASHRAE Standard-901-2010.

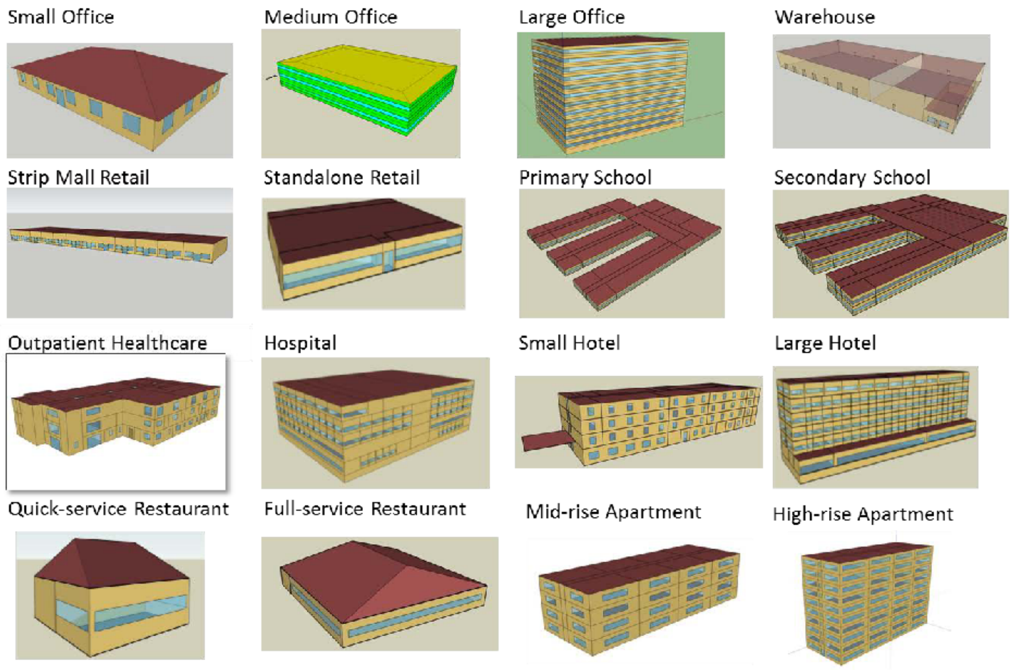


Figure 1. Prototypes analyzed for the end-use dataset

Detailed Tables and Lists

In addition to the graphs included here, an Excel workbook with detailed results for each prototype at the detailed end-use level is available online (PNNL 2014a).[4] That workbook contains a worksheet for each prototype and a matrix of tables with summary national results and detailed results for each climate zone. In addition to ECI, site energy use index (EUI) results, source EUI results, and gas and electric end-use results are included. The workbook also contains the following tables:

- U.S. average summary results, based on construction weighting,
- climate zone detail for Standard 90.1 in 2004, 2007, 2010, and 2013, and
- percentage savings from Standard 90.1-2004 to 90.1-2013.

The workbook also includes a worksheet (i.e., the "DetPri" tab) that provides all detailed ECIs by end use and prototype, sorted by remaining use after Standard 90.1-2013 and sorted by savings from Standard 90.1-2013 when compared to 90.1-2004.

[4] Available at http://www.energycodes.gov/sites/default/files/documents/2013EndUseTables.zip.

Cost Breakdown Results

The resulting data from the analysis is presented in one of several ways:

- Weighted by U.S. 2003−2007 new construction to give an idea of the impact on total U.S. commercial energy cost (Jarnagin and Bandyopadhyay 2010). Such weightings are usually for the nation as a whole, but may focus on energy cost for a particular climate zone. The weightings are based on factors shown in Table 8. Where results are noted as weighted by building type, this data is used. While the data is from early in the first decade of this millennium, it avoids the economic and construction downturn that would be inherent in more recent data.
- Partial weighting is applied to subset building prototypes to arrive at the use and cost breakdown for a building type. For instance, to find the end-use costs for the Office type, the end-use costs for the large, medium, and small offices are weighted proportionally by the individual prototype construction weightings.
- Unweighted results represent the end-use cost experienced by a particular building type and provide a good idea of the ECI on a floor area basis.

Throughout, the cost is based on the energy rates from the Scalar Method for Standard 90.1-2013 proposal analysis: 0.1032/kWh for electricity and $0.99/therm for fossil fuels.[5]

[5] The ASHRAE Scalar Method identifies a fossil fuel rate that is primarily applied to heating energy use. For this reason, the fossil fuel rate is a blended heating rate and includes proportional (relative to national heating fuel use) costs for natural gas, propane, heating oil, and electric heat. Heating energy use in the prototypes for fossil fuel equipment is calculated in therms based on natural gas equipment, but in practice, natural gas equipment may be operated on propane, or boilers that are modeled as natural gas may use oil in some regions.

U.S. End-Use Cost Breakdown, 90.1-2013

Figure 2 provides a breakdown of building energy costs after implementation of Standard 90.1-2013 across U.S. climate zones, weighted by U.S. new construction.

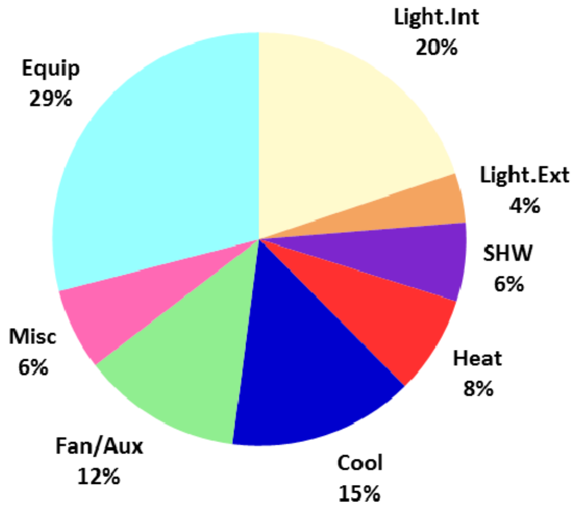


Figure 2. End-use cost for buildings in all U.S. climate zones

Figure 3 shows the same weighted national energy cost with a finer breakdown of end uses and an increase in significant digits for the percentages.

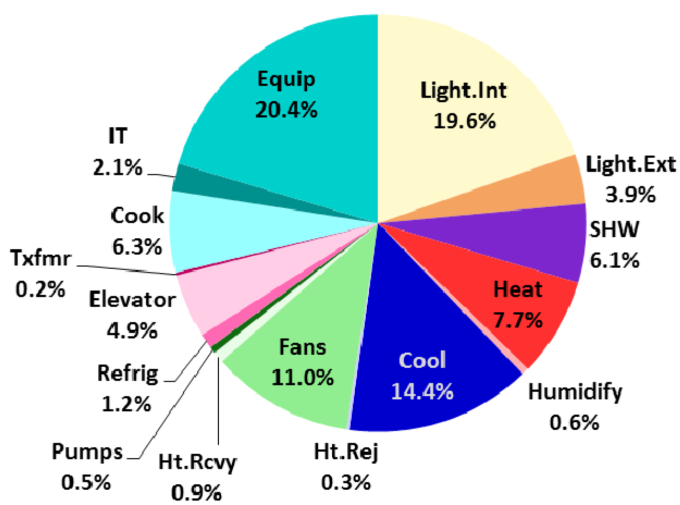


Figure 3. Detailed end-use cost for buildings in all U.S. climate zones

U.S. Weighted Cost by End Use, 2004 vs. 2013

Total U.S. weighted end-use building energy costs can be directly compared for Standards 90.1-2004 and 90.1-2013 (see Figure 4). Most categories show significant reduction; however, the cost reductions for equipment, miscellaneous, and service hot water were not significant.

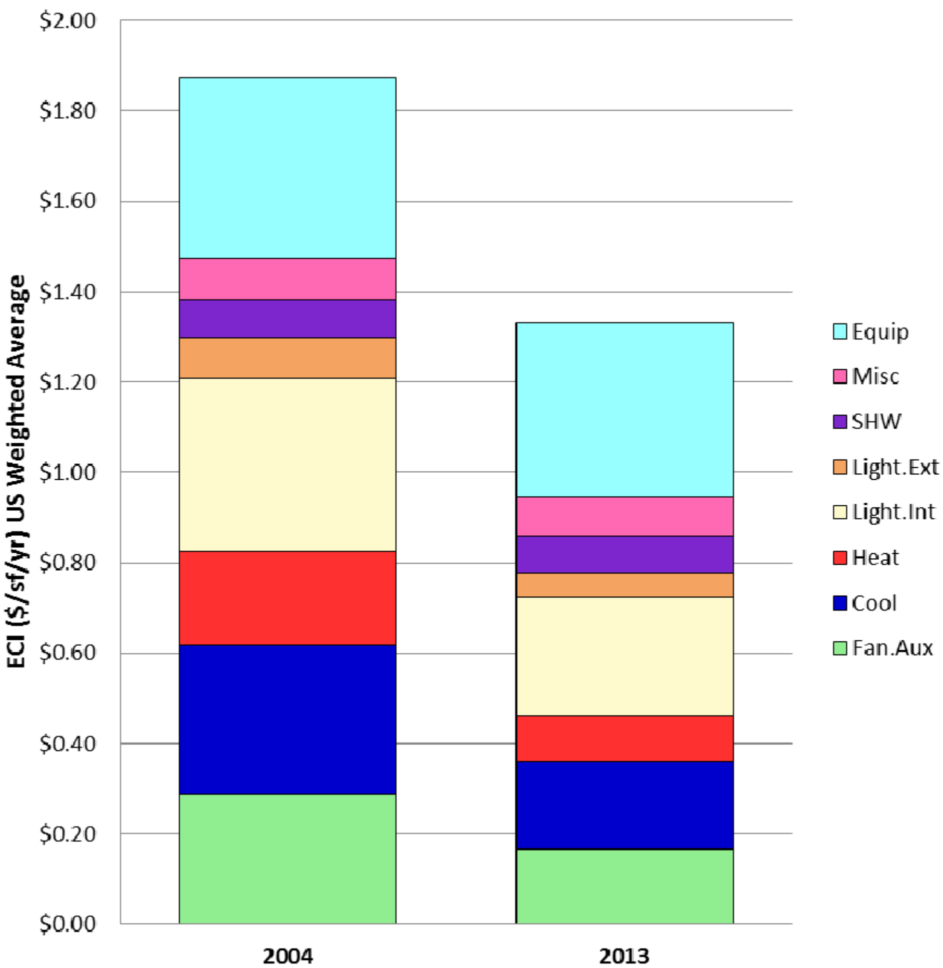


Figure 4. Standard 90.1 end-use cost improvement

U.S. Weighted Cost Impact by Building Type and End Use, 2013 Base

An examination of end-use cost data by building type is presented in this section. Figure 5 illustrates building type and energy cost impact weighted by national construction by climate zone. Prototypes are grouped by similar type. The widths of the building type (vertical) bars are scaled to represent each building type's share of impact on national building energy cost. The entire width of the plot matches national building energy use based on Standard 90.1-2013. Using the same 8.2 billion square feet of new building floor area from 2003−2007 construction data reports (Jarnagin and Bandyopadhyay 2010), the area of the plot represents a commercial new construction building energy cost of $11 billion per year.

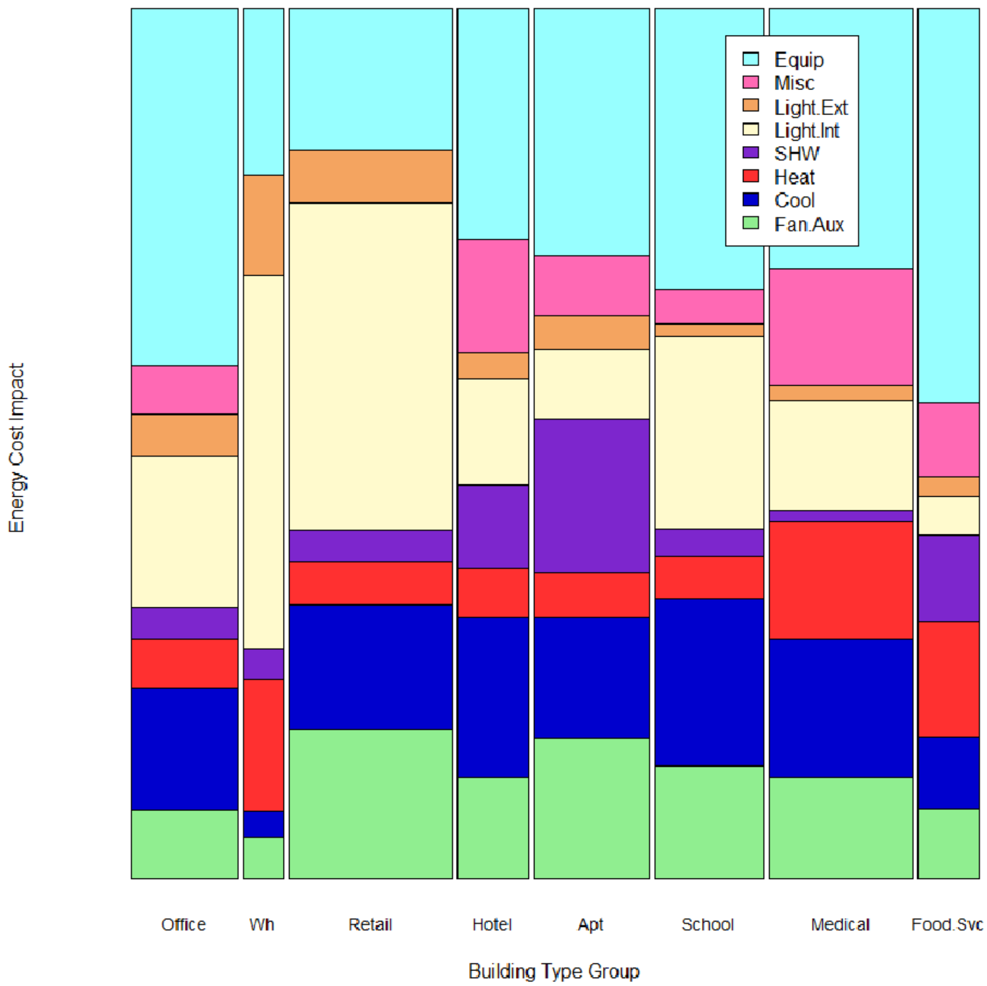


Figure 5. Commercial energy cost impact by end use U.S. weighted, after 90.1-2013

U.S. Weighted Cost Impact by Building Type and End Use, 2004 Base

Figure 6 shows the same nationally weighted results after Standard 90.1-2013 against a base of Standard 90.1-2004. Again, the widths of the building type (vertical) bars are scaled to represent each building type's share of impact on national building energy cost. The entire area of the plot matches national building energy cost based on Standard 90.1-2004, or $15.5 billion. The white savings blocks show the difference for 90.1-2013 compared to 90.1-2004, which amounts to $4.5 billion per year. So, we can see both the savings from the stable 2004 baseline and the remaining energy cost after 90.1-2013.

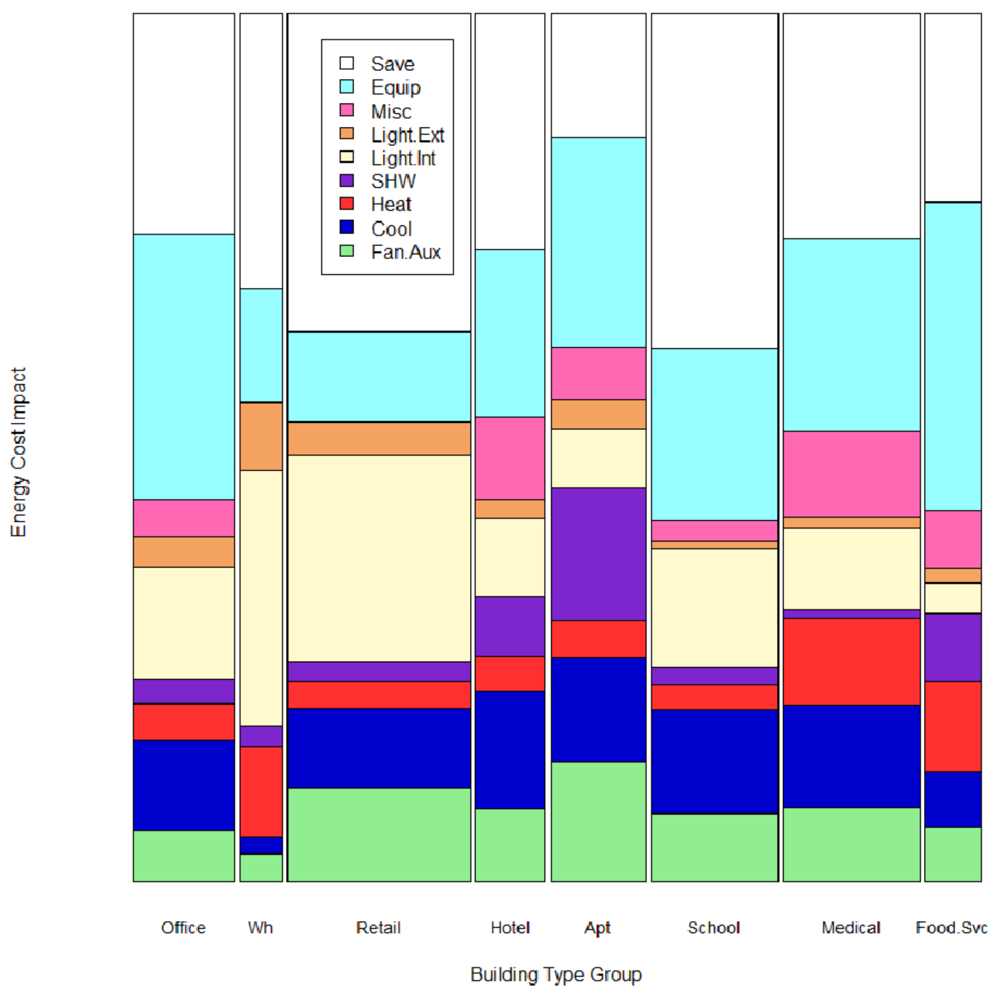


Figure 6. Commercial energy cost impact by end use U.S. weighted (90.1-2004).
White area represents savings from 90.1-2004 to 2013

U.S. Weighted End-Use Prioritization

Figure 7 shows overall progress by detailed end use, measured as cost savings from Standard 90.1-2004 to Standard 90.1-2013. The information is prioritized for end uses by national weighted building energy impact or percentage of U.S. total building use after Standard 90.1-2013.

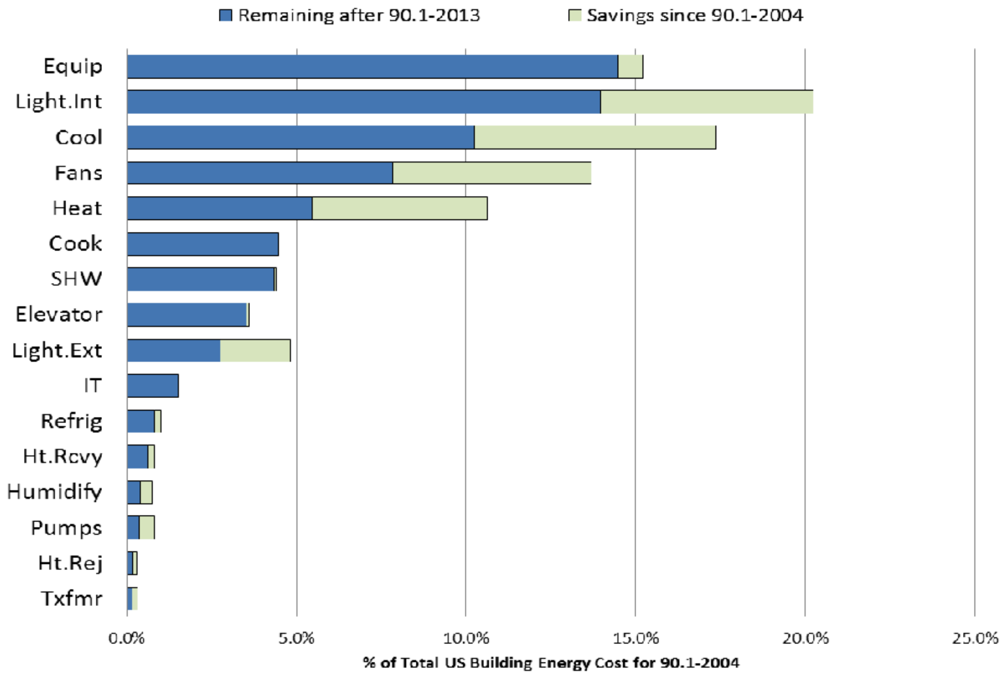


Figure 7. U.S. building energy cost by end use prioritized by post-2013 cost

Table 3 shows the breakdown by building type, with remaining energy cost after Standard 90.1-2013. Red indicates highest remaining cost impact, and white represents lowest remaining cost impact. Appendix A includes more detailed heat maps of costs and cost savings from Standard 90.1-2004 to Standard 90.1-2013.

Table 3. Impact percent of U.S. building energy cost remaining after 90.1-2013

	Light.Int	Light.Ext	SHW	Heat	Cool	Fan.Aux	Misc	Equip	Total
Office	2.3%	0.6%	0.5%	0.7%	1.8%	1.0%	0.7%	5.4%	13.1%
Warehouse	2.1%	0.6%	0.2%	0.8%	0.1%	0.2%	0.0%	0.9%	5.0%
Retail	7.6%	1.2%	0.7%	1.0%	2.9%	3.5%	0.0%	3.3%	20.2%
Hotel	1.1%	0.3%	0.8%	0.5%	1.6%	1.0%	1.1%	2.3%	8.8%
Apt	1.1%	0.6%	2.5%	0.7%	2.0%	2.3%	1.0%	4.0%	14.3%
School	3.0%	0.2%	0.4%	0.6%	2.6%	1.7%	0.5%	4.3%	13.5%
Medical	2.2%	0.3%	0.2%	2.4%	2.8%	2.1%	2.3%	5.3%	17.6%
Food.Svc	0.3%	0.2%	0.8%	1.0%	0.6%	0.6%	0.6%	3.4%	7.6%
U.S. Weighted	19.8%	3.9%	6.2%	7.7%	14.5%	12.5%	6.4%	29.0%	**100%**

Segment Graphs

Segment Graphs, ECI Weighted for Climate

The segment graphs for each building type (see Figure 8) show the relative end uses based on individual building ECI. Because they are weighted by climate zone construction, they represent national averages. The radius of each segment is proportional to the end-use ECI ($/ft^2/yr) for the building type shown, relative to the largest building end-use ECI in the data set. On this graph, most building graphs are quite small, but we can see the very high equipment, heating, and service water heating intensity in the food service sector. Following graphs show the other buildings and uses at a more readable scale.

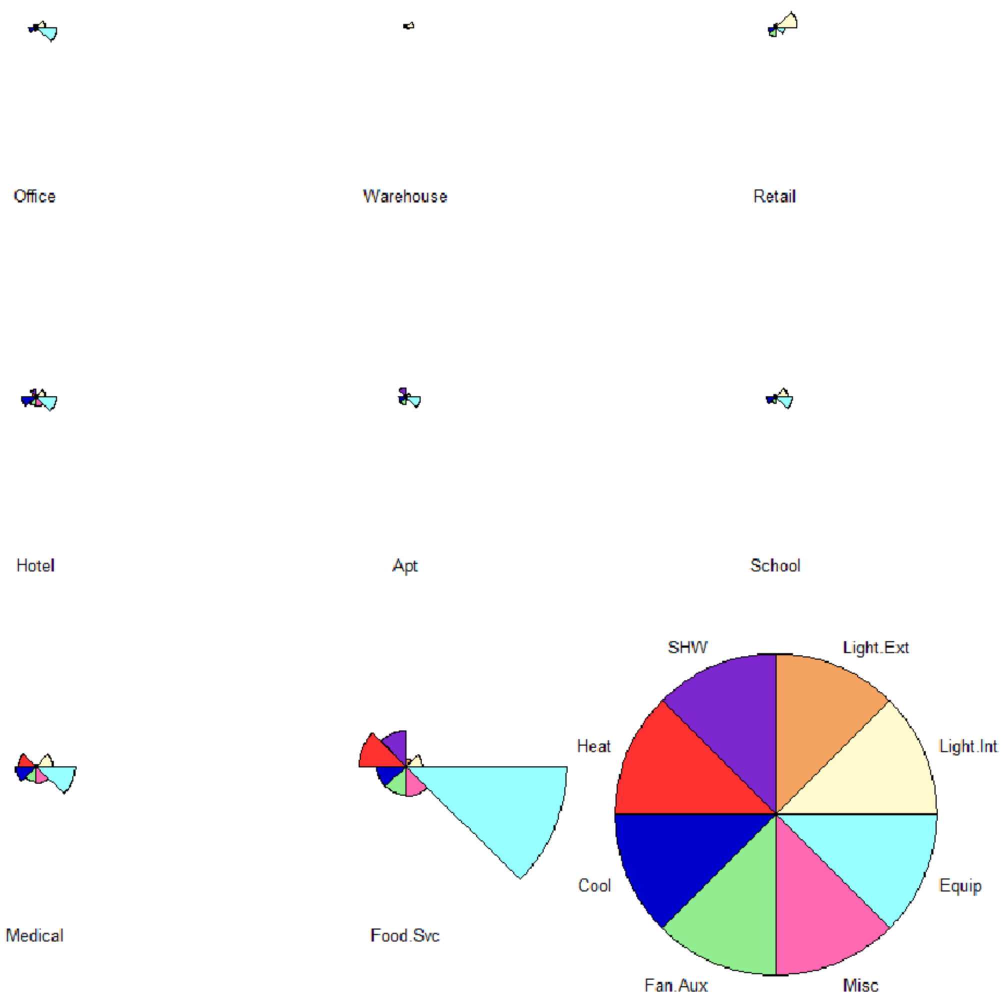


Figure 8. U.S. ECI of building end uses, after 90.1-2013

Segment Graphs, ECI by Climate with Scaled Food Equipment

Figure 9 is based on the same data as Figure 8 and shows the food service equipment (primarily cooking) at one-fourth the scale of the other segments. The radius of each segment is proportional to the end-use ECI for the building type shown, relative to the largest full-scale building end-use ECI in the data set (Food.Svc heat).

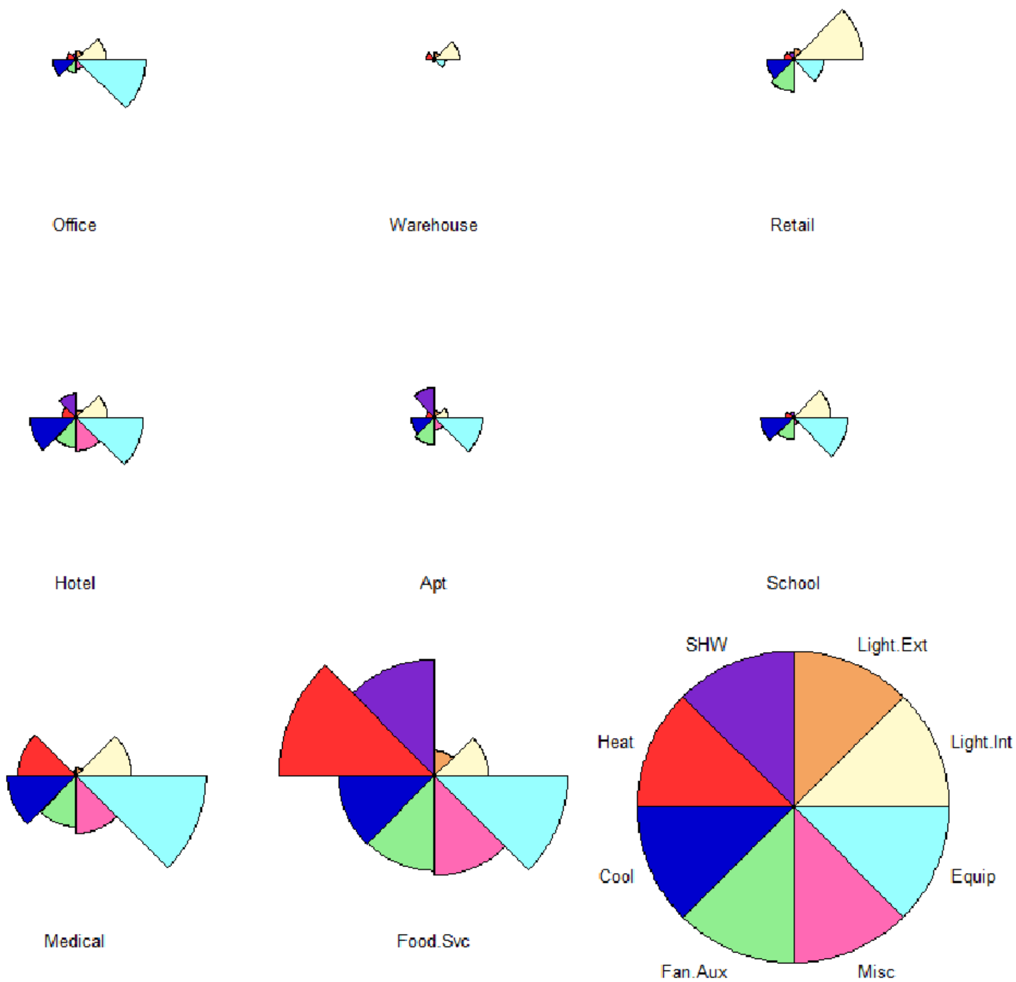


Figure 9. U.S. ECI of building end uses, after 90.1-2013 (Cooking NTS).
(Food service equipment is shown at 25% of actual scale.)

Segment Graphs, ECI Weighted for U.S. Construction

When individual building ECI results are weighted by each building's share of new construction floor area (see Figure 10), the impact on total U.S. commercial building cost by type and end use becomes apparent. This result can be referred to as the weighted building cost index (WBCI). Retail interior lighting has the largest contributing end use. Equipment dominates in most other areas; however, service water heating captures a large segment of contributing end use for apartments.

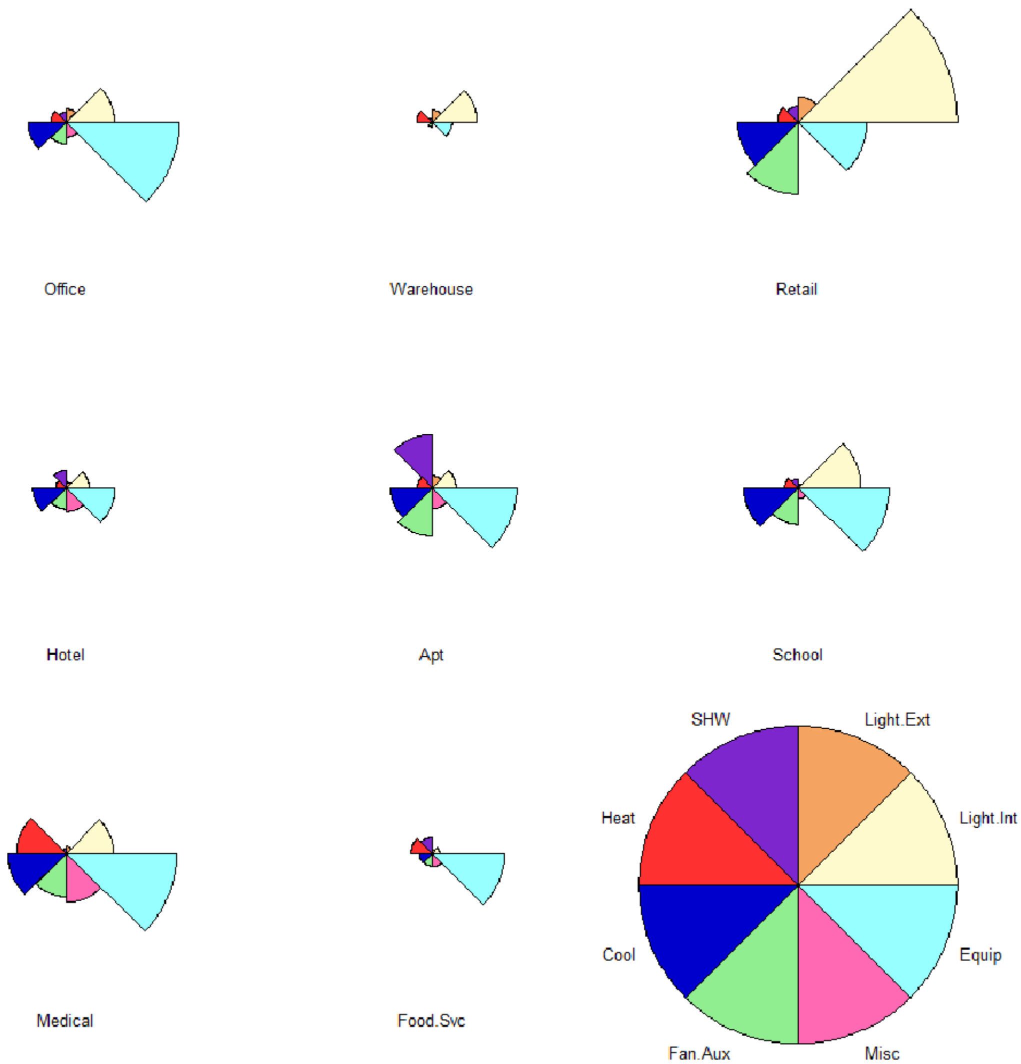


Figure 10. U.S. WBCI of building end uses, after 90.1-2013.
(WBCI = weighted building cost impact or contribution to total energy cost)

U.S. Weighted Sorted End Use ECI, with Building Splits

Figure 11 breaks down end uses based on overall weighted U.S. impact (from largest to smallest impact) and shows the breakdown in each bar by building. Separating equipment and miscellaneous (e.g., transformers, refrigeration, and elevators) helps identify which unregulated loads are impacted.

Though units are in dollars per square foot contribution to an average U.S. building (i.e., a weighted combination of all building types), it may be easier to think of this graph as showing a relative impact factor, since the results are partial. That is, the sum of all end uses shown would equal the weighted average U.S. building ECI based on total construction, or about $1.33 per square foot.

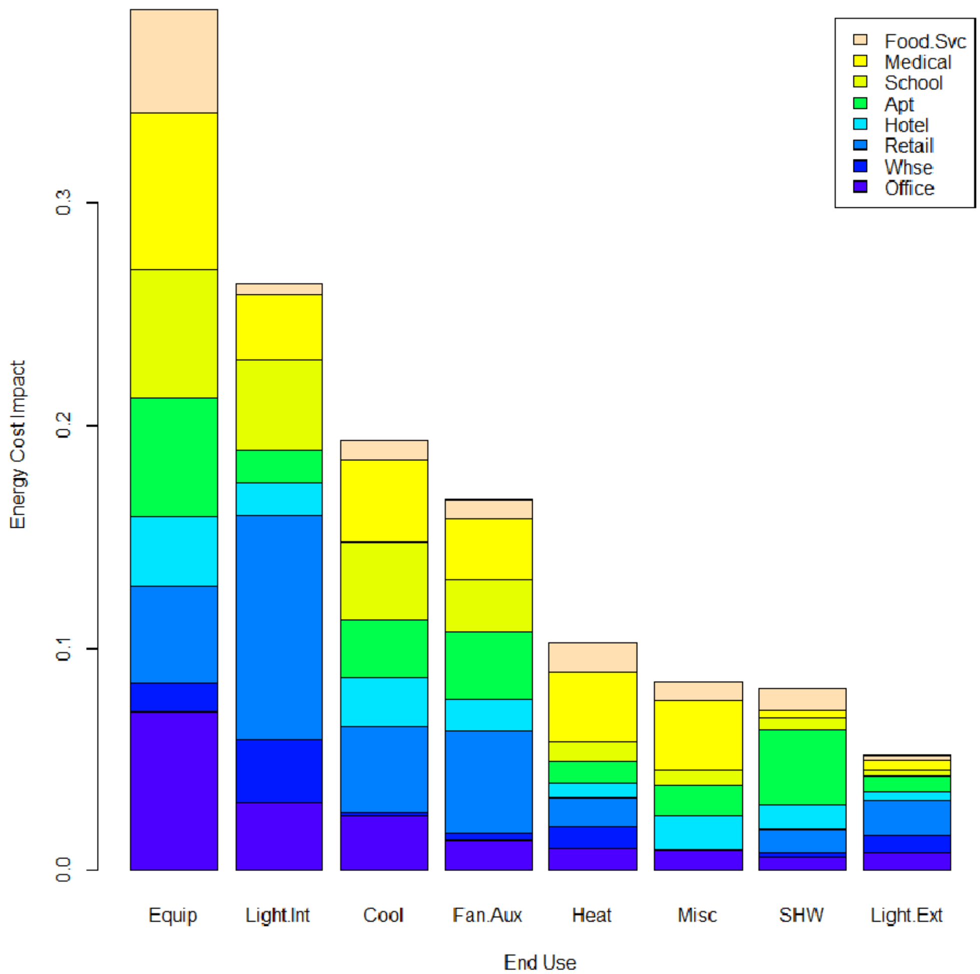


Figure 11. U.S. commercial energy cost impact by end use (weighted by new construction floor area)

Total U.S. Energy Cost by Building Type

Figure 12 shows energy costs following the implementation of Standard 90.1-2013 by building type group weighted for all climate zones. Energy cost savings from Standard 90.1-2004 vs. 90.1-2013 are also shown. Figure 12 indicates that energy cost intensity for food service is highest, based primarily on the high energy density of fast food restaurants. Medical is next, followed by hotel, retail, and office. Appendix B provides separate graphs for each end use to better illustrate the distribution of individual end-use costs by building type.

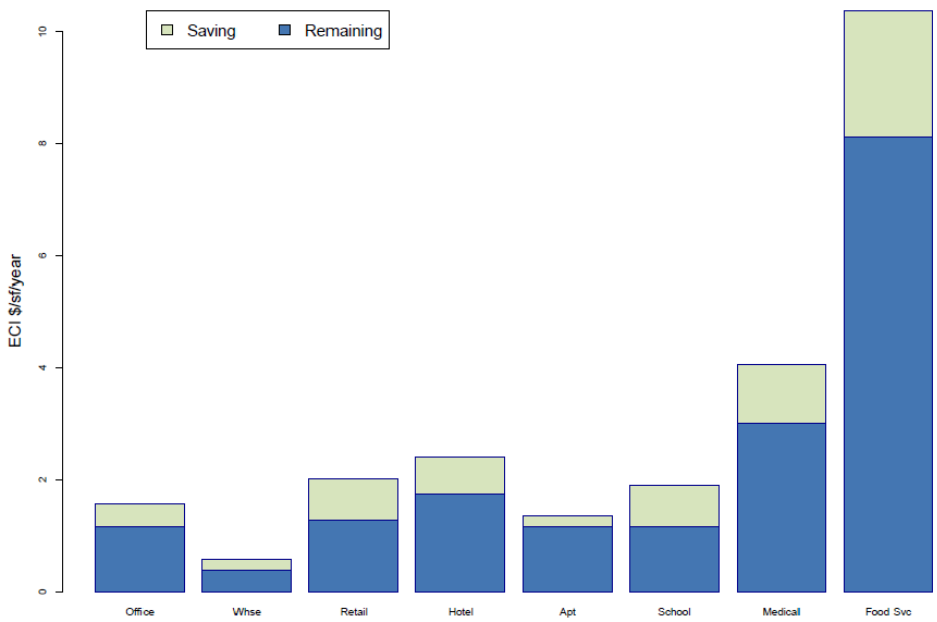


Figure 12. Total Standard 90.1-2013 vs 90.1-2004; U.S. energy cost

Focus Potential Score

The focus potential scoring method was developed, using a somewhat arbitrary numerical approach, to help focus on end uses where there may be future savings potential. While scores are simply numerical and do not include judgment about what is possible or an analysis of maximum technical potential, they provide a second look at end uses we might have dismissed. For example, the equipment end-use scores high, even though it has been considered an “unregulated” load. The focus potential scoring method combines the three factors shown in Table 4.

Table 4. Focus potential scoring method factors

Weight	Focus	Low score	High score
6	Savings from 90.1-2004 to 90.1-2013	Low (2) if high previous savings	High (6) if little previous savings
3	Individual building end-use cost (ECI)	Low (0) if building ECI low	High (3) if building ECI high
3	National end-use cost (ECI)	Low (0) if national ECI low	High (3) if national ECI high

Although the focus potential scoring approach is not perfect, it draws attention to the end uses that have not had large savings historically and that have high building-level ECI and high national weighted impact. In the heat map of focus potential scoring results (see Table 5), green indicates areas that may have high savings potential, and white indicates areas that have lower savings potential. Focus Potential Scores are rolled up at the simple end-use level and for building groups rather than the detailed level as many of the detailed uses are so small, they would score zero. Because restaurant and equipment end uses are outliers, their partial scores are capped at the maximum. The Focus Potential Scores are shown in Table 5 and charted in Figure 13 at the end-use level overall for all building types.

Table 5. Total end-use "Focus Potential Scores"

Potential	Light.Int	Light.Ext	SHW	Heat	Cool	Fan.Aux	Misc	Equip
Office	5.9	3.5	6.4	4.1	5.3	5.4	6.1	10.8
Warehouse	5.7	4.4	6.0	4.4	3.2	3.1		6.7
Retail	10.5	4.0	6.3	2.8	5.2	5.6		8.6
Hotel	5.5	4.9	7.3	3.3	6.4	4.9	7.5	9.5
Apt	6.6	4.5	8.3	4.1	6.0	6.8	6.5	9.6
School	6.1	3.2	6.3	3.0	5.3	4.4	5.3	9.5
Medical	8.2	3.5	6.3	6.0	8.0	6.9	9.2	11.0
Food.Svc	4.7	4.5	9.3	8.4	7.1	5.8	7.9	10.4
U.S. Weighted	7.1	4.0	6.7	3.8	5.3	5.2	4.1	9.2

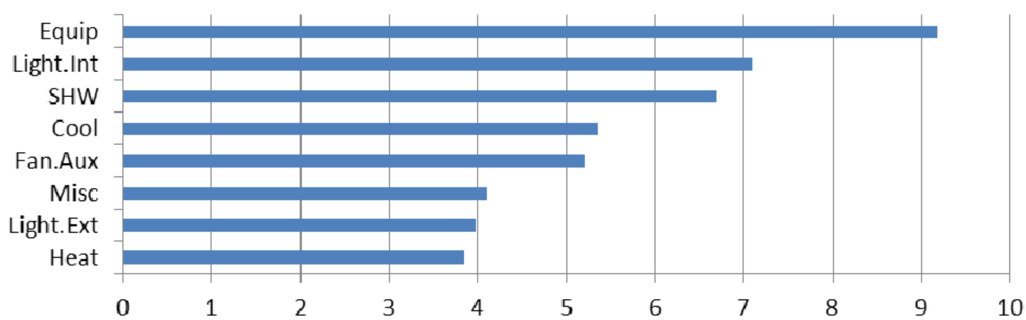


Figure 13. Total end-use "Focus Potential Scores," prioritized

HVAC by Climate Zone

The heating and cooling ECIs by climate zone (weighted by building type construction within each climate zone) are shown in Figure 14. Climate zones are grouped by moisture regime, and climate zones 1B and 5C are excluded because they have no U.S. construction. Heat rejection is included with cooling, but humidification is not included.

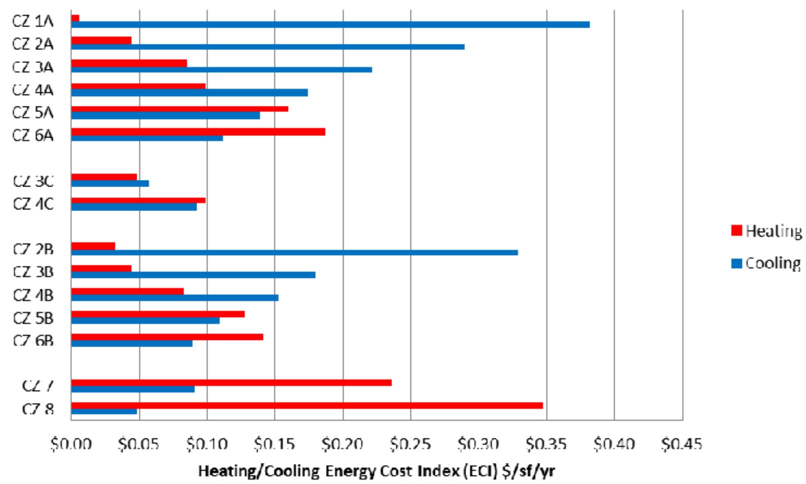


Figure 14. Building ECI heating and cooling by climate zone (CZ)

While Figure 14 shows individual climate zone ECIs, Figure 15 shows the relative contribution of each climate zone's heating and cooling to the total U.S. energy cost. This graph indicates that reducing heating in climate zone 5A is more important than reducing heating in climate zones 6, 7, or 8.

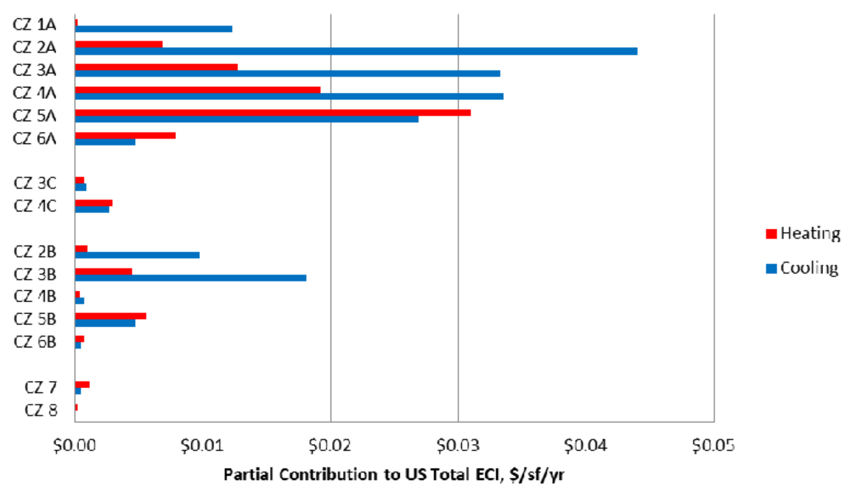


Figure 15. Weighted impact of climate zone heating and cooling on U.S. heating and cooling costs

HVAC Building ECI by Numerical Climate Zone and Space Conditioning Category

To more closely evaluate the prescriptive insulation categories in Standard 90.1, the heating and cooling data was split by building category and numerical climate zone (without moisture regimes). Climate zones 1B and 5C are not included because there are no U.S. locations. Heating and cooling energy cost indices, by climate zone, are shown in Figure 16. Apartments and hotels are grouped in the residential category, warehouses in the semi-heated category, and all other buildings in the non-residential category. Note that although some residential areas exist in hospitals, some non-residential areas can be found in large hotels, and only about half of the warehouse prototypes are semi-heated; this grouping used in Figure 16 is based on the predominant category in each individual building type. In addition, different building types have different HVAC systems and ventilation or other HVAC differences, but are not excluded from this analysis. Further, heat rejection is included with cooling, but humidification is not included.

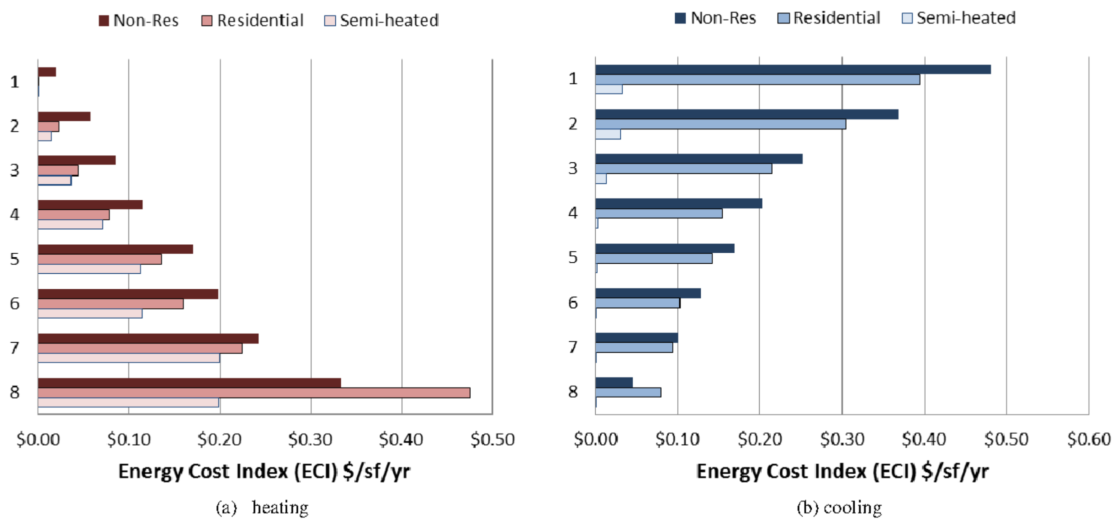
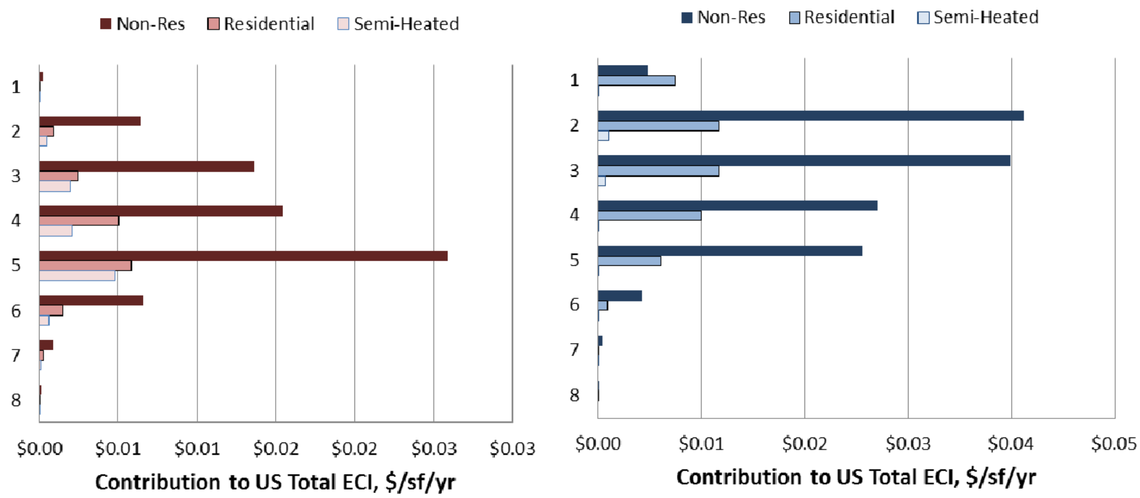


Figure 16. Total (a) heating and (b) cooling ECI by climate zone

HVAC Weighted Cost Impact by Numerical Climate Zone and Space Conditioning Category

While Figure 16 shows individual climate zone building ECIs (weighted for building type construction in each numerical climate zone), Figure 17 shows the relative contribution of each climate zone's heating and cooling to the total U.S. energy cost. Groupings for building type and climate zone are the same as in Figure 16. Figure 17 indicates the importance of reducing heating in climate zone 5 and the cooling in zones 2 and 3.



(a) heating (b) cooling

Figure 17. Weighted impacts on total U.S. (a) heating and (b) cooling costs

Heating ECI Detail by Climate Zone

A heat map (see Table 6) is used to display detailed heating ECI by climate zone. Darker red indicates a higher heating cost for the building type and climate zone. Because these values are not weighted, all climate zones are included. Heat map shading is provided separately for the medical and restaurant groups because their heating costs are much higher than the other building prototypes. Again, humidification energy is not included with heating.

Table 6. Heating ECI detail by climate zone

	Moist Climates						Marine Climates			Dry Climates						Cold	
Building	CZ 1A	CZ 2A	CZ 3A	CZ 4A	CZ 5A	CZ 6A	CZ 3C	CZ 4C	CZ 5C	CZ 1B	CZ 2B	CZ 3B	CZ 4B	CZ 5B	CZ 6B	CZ 7	CZ 8
AptH	$0.000	$0.021	$0.080	$0.089	$0.175	$0.202	$0.018	$0.059	$0.095	$0.001	$0.002	$0.016	$0.022	$0.069	$0.112	$0.270	$0.373
AptM	$0.000	$0.011	$0.043	$0.057	$0.108	$0.126	$0.010	$0.040	$0.061	$0.001	$0.002	$0.011	$0.020	$0.048	$0.079	$0.171	$0.250
HotL	$0.016	$0.059	$0.101	$0.096	$0.143	$0.167	$0.078	$0.096	$0.115	$0.031	$0.029	$0.044	$0.059	$0.101	$0.141	$0.200	$0.398
HotS	$0.001	$0.023	$0.072	$0.119	$0.211	$0.249	$0.016	$0.079	$0.106	$0.004	$0.009	$0.026	$0.057	$0.109	$0.181	$0.339	$0.547
OfcL	$0.000	$0.012	$0.042	$0.057	$0.101	$0.121	$0.004	$0.023	$0.033	$0.005	$0.004	$0.008	$0.016	$0.035	$0.089	$0.159	$0.248
OfcM	$0.004	$0.043	$0.105	$0.087	$0.160	$0.188	$0.029	$0.079	$0.108	$0.011	$0.019	$0.032	$0.039	$0.092	$0.146	$0.184	$0.342
OfcS	$0.000	$0.009	$0.030	$0.031	$0.055	$0.071	$0.007	$0.019	$0.027	$0.001	$0.003	$0.013	$0.018	$0.031	$0.056	$0.102	$0.173
RtlB	$0.002	$0.011	$0.028	$0.039	$0.069	$0.082	$0.031	$0.081	$0.114	$0.014	$0.014	$0.027	$0.050	$0.106	$0.052	$0.123	$0.255
RtlS	$0.003	$0.036	$0.095	$0.134	$0.228	$0.278	$0.039	$0.111	$0.164	$0.008	$0.015	$0.030	$0.047	$0.129	$0.206	$0.362	$0.577
SchP	$0.017	$0.058	$0.095	$0.117	$0.145	$0.172	$0.064	$0.120	$0.093	$0.018	$0.025	$0.053	$0.082	$0.130	$0.130	$0.212	$0.388
SchS	$0.001	$0.010	$0.027	$0.021	$0.039	$0.050	$0.048	$0.107	$0.049	$0.011	$0.016	$0.044	$0.076	$0.130	$0.038	$0.075	$0.228
Whse	$0.000	$0.016	$0.044	$0.073	$0.120	$0.118	$0.045	$0.062	$0.073	$0.004	$0.011	$0.026	$0.048	$0.070	$0.084	$0.199	$0.199
MedC	$0.233	$0.317	$0.394	$0.316	$0.384	$0.415	$0.225	$0.279	$0.292	$0.236	$0.220	$0.224	$0.250	$0.315	$0.381	$0.459	$0.711
MedH	$0.159	$0.222	$0.279	$0.323	$0.375	$0.412	$0.234	$0.285	$0.318	$0.189	$0.191	$0.213	$0.200	$0.321	$0.360	$0.461	$0.653
Rest	$0.052	$0.308	$0.616	$0.916	$1.333	$1.584	$0.566	$0.911	$1.093	$0.101	$0.185	$0.349	$0.586	$0.971	$1.353	$2.047	$3.119
Fast	$0.181	$0.645	$1.144	$1.530	$2.143	$2.501	$1.057	$1.478	$1.753	$0.284	$0.443	$0.773	$1.104	$1.641	$2.223	$3.193	$4.718

Cooling ECI Detail by Climate Zone

A heat map (Table 7) is also used to show detailed cooling ECI by climate zone. Darker blue indicates a higher cooling cost for the building type and climate zone. Because these values are not weighted, all climate zones are included. Heat map shading is provided separately for the medical and restaurant groups because their cooling costs are much higher than the other building prototypes.

Table 7. Cooling ECI detail by climate zone

	Moist Climates						Marine Climates			Dry Climates						Cold	
Building	CZ 1A	CZ 2A	CZ 3A	CZ 4A	CZ 5A	CZ 6A	CZ 3C	CZ 4C	CZ 5C	CZ 1B	CZ 2B	CZ 3B	CZ 4B	CZ 5B	CZ 6B	CZ 7	CZ 8
AptH	$0.381	$0.245	$0.182	$0.146	$0.113	$0.070	$0.007	$0.076	$0.040	$0.344	$0.294	$0.168	$0.157	$0.112	$0.077	$0.059	$0.055
AptM	$0.275	$0.185	$0.141	$0.108	$0.086	$0.058	$0.021	$0.060	$0.036	$0.280	$0.235	$0.132	$0.115	$0.083	$0.059	$0.045	$0.038
HotL	$0.862	$0.611	$0.464	$0.318	$0.260	$0.183	$0.116	$0.163	$0.105	$0.775	$0.603	$0.371	$0.272	$0.201	$0.142	$0.145	$0.098
HotS	$0.405	$0.299	$0.229	$0.170	$0.139	$0.106	$0.116	$0.116	$0.087	$0.364	$0.323	$0.213	$0.164	$0.124	$0.096	$0.086	$0.062
OfcL	$0.473	$0.365	$0.309	$0.268	$0.173	$0.133	$0.083	$0.118	$0.073	$0.449	$0.352	$0.250	$0.187	$0.144	$0.109	$0.103	$0.070
OfcM	$0.362	$0.270	$0.202	$0.151	$0.131	$0.088	$0.052	$0.084	$0.046	$0.359	$0.309	$0.178	$0.139	$0.098	$0.068	$0.065	$0.035
OfcS	$0.190	$0.142	$0.107	$0.083	$0.070	$0.051	$0.038	$0.051	$0.037	$0.193	$0.170	$0.105	$0.087	$0.060	$0.046	$0.040	$0.029
RtlB	$0.442	$0.279	$0.214	$0.156	$0.124	$0.079	$0.036	$0.074	$0.027	$0.515	$0.365	$0.205	$0.148	$0.104	$0.070	$0.053	$0.031
RtlS	$0.435	$0.328	$0.220	$0.147	$0.113	$0.073	$0.028	$0.073	$0.029	$0.472	$0.391	$0.185	$0.134	$0.100	$0.064	$0.048	$0.022
SchP	$0.435	$0.319	$0.242	$0.189	$0.158	$0.111	$0.070	$0.095	$0.073	$0.396	$0.350	$0.202	$0.139	$0.106	$0.086	$0.084	$0.049
SchS	$0.487	$0.356	$0.276	$0.205	$0.167	$0.113	$0.075	$0.104	$0.064	$0.452	$0.384	$0.233	$0.162	$0.128	$0.085	$0.085	$0.042
Whse	$0.033	$0.021	$0.014	$0.004	$0.002	$0.000	$0.000	$0.000	$0.000	$0.130	$0.073	$0.014	$0.004	$0.002	$0.000	$0.000	$0.000
MedC	$1.159	$0.909	$0.721	$0.546	$0.456	$0.361	$0.357	$0.341	$0.262	$0.937	$0.850	$0.577	$0.440	$0.337	$0.260	$0.303	$0.209
MedH	$0.785	$0.584	$0.449	$0.339	$0.299	$0.228	$0.158	$0.187	$0.150	$0.456	$0.425	$0.312	$0.218	$0.192	$0.145	$0.177	$0.116
Rest	$1.532	$1.077	$0.766	$0.422	$0.314	$0.173	$0.037	$0.161	$0.029	$1.528	$1.284	$0.659	$0.332	$0.239	$0.132	$0.096	$0.035
Fast	$1.932	$1.380	$0.977	$0.537	$0.396	$0.210	$0.046	$0.194	$0.032	$1.908	$1.606	$0.775	$0.425	$0.305	$0.164	$0.114	$0.038

Construction Weightings by Building Type and Climate Zone

To estimate the energy savings impact on a national scale, PNNL acquired disaggregated construction volume data from McGraw-Hill Construction (MHC) Project Starts Database. The MHC database contains the floor area of new construction in the United States for the years 2003 to 2007. PNNL analyzed this MHC database to develop detailed construction weights by climate zones, subzones, and states (Jarnagin and Bandyopadhyay 2010). These weights were used in developing a weighted national energy savings estimate for the impact of ASHRAE standards. Table 8 summarizes the percentage weights by building type and climate zone. The 16 prototypes cover 80% of new construction floor area and percentages; however, percentages in Table 8 have been normalized to result in 100% coverage. Weightings have been applied in the following three ways:

- For national results, weightings in Table 8 were applied to individual results for each building type and climate zone.
- For average building type results, normalized climate zone weightings, totaling 100% for each building type or group, were applied.
- For heating and cooling results within each climate zone, normalized building type results were applied.

Table 8. U.S. new construction weighting (basis 2003 to 2007 MHC database)

Building	Moist Climates						Marine Climates			Dry Climates						General		U.S.
Type	CZ 1A	CZ 2A	CZ 3A	CZ 4A	CZ 5A	CZ 6A	CZ 3C	CZ 4C	CZ 5C	CZ 1B	CZ 2B	CZ 3B	CZ 4B	CZ 5B	CZ 6B	CZ 7	CZ 8	All CZ
AptH	1.5%	1.5%	0.7%	2.5%	1.2%	0.1%	0.2%	0.4%	0.0%	0.0%	0.1%	0.7%	0.0%	0.1%	0.0%	0.0%	0.0%	9.0%
AptM	0.3%	1.1%	0.8%	1.7%	1.1%	0.3%	0.3%	0.4%	0.0%	0.0%	0.1%	0.9%	0.0%	0.3%	0.1%	0.0%	0.0%	7.3%
HotL	0.1%	0.6%	0.6%	1.0%	0.9%	0.2%	0.1%	0.1%	0.0%	0.0%	0.1%	0.8%	0.0%	0.2%	0.1%	0.0%	0.0%	5.0%
HotS	0.0%	0.3%	0.3%	0.3%	0.4%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	1.7%
OfcL	0.1%	0.3%	0.4%	1.1%	0.4%	0.1%	0.1%	0.2%	0.0%	0.0%	0.1%	0.3%	0.0%	0.1%	0.0%	0.0%	0.0%	3.3%
OfcM	0.1%	0.8%	0.8%	1.2%	1.1%	0.3%	0.1%	0.2%	0.0%	0.0%	0.3%	0.7%	0.0%	0.3%	0.0%	0.0%	0.0%	6.0%
OfcS	0.1%	1.1%	1.0%	0.9%	0.9%	0.2%	0.1%	0.1%	0.0%	0.0%	0.3%	0.5%	0.0%	0.3%	0.0%	0.0%	0.0%	5.6%
RtlB	0.2%	2.2%	2.4%	2.5%	3.4%	0.9%	0.2%	0.4%	0.0%	0.0%	0.5%	1.3%	0.1%	0.8%	0.1%	0.1%	0.0%	15.3%
RtlS	0.1%	1.0%	1.0%	1.0%	1.0%	0.2%	0.1%	0.1%	0.0%	0.0%	0.3%	0.6%	0.0%	0.2%	0.0%	0.0%	0.0%	5.7%
SchP	0.1%	0.9%	0.9%	0.9%	0.9%	0.2%	0.0%	0.1%	0.0%	0.0%	0.2%	0.4%	0.0%	0.2%	0.0%	0.0%	0.0%	5.0%
SchS	0.2%	1.5%	1.9%	2.0%	2.3%	0.4%	0.1%	0.2%	0.0%	0.0%	0.2%	0.8%	0.1%	0.4%	0.1%	0.1%	0.0%	10.4%
Whse	0.3%	2.6%	3.0%	2.4%	3.6%	0.5%	0.2%	0.4%	0.0%	0.0%	0.6%	2.3%	0.1%	0.7%	0.0%	0.0%	0.0%	16.7%
MedC	0.0%	0.6%	0.6%	0.8%	1.1%	0.3%	0.1%	0.2%	0.0%	0.0%	0.1%	0.3%	0.0%	0.2%	0.0%	0.0%	0.0%	4.4%
MedH	0.0%	0.5%	0.5%	0.6%	0.8%	0.2%	0.0%	0.1%	0.0%	0.0%	0.1%	0.3%	0.0%	0.2%	0.0%	0.0%	0.0%	3.4%
Rest	0.0%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%
Fast	0.0%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%
All Bldg	3.2%	15.2%	15.0%	19.3%	19.4%	4.2%	1.6%	3.0%	0.0%	0.0%	3.0%	10.1%	0.5%	4.3%	0.6%	0.5%	0.1%	100%

References

ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers). 2004. ANSI/ASHRAE/IESNA Standard 90.1-2004. *Energy Standard for Buildings Except Low-Rise Residential Buildings*. ASHRAE, Atlanta, Georgia.

ASHRAE. 2007. ANSI/ASHRAE/IESNA Standard 90.1-2007. *Energy Standard for Buildings Except Low-Rise Residential Buildings*. ASHRAE, Atlanta, Georgia.

ASHRAE. 2010. ANSI/ASHRAE/IES Standard 90.1-2010. *Energy Standard for Buildings Except Low-Rise Residential Buildings*. ASHRAE, Atlanta, Georgia.

ASHRAE. 2013. ANSI/ASHRAE/IES Standard 90.1-2013. *Energy Standard for Buildings Except Low-Rise Residential Buildings*. ASHRAE, Atlanta, Georgia.

Briggs RS, RG Lucas, and ZT Taylor. 2003. "Climate Classification for Building Energy Codes and Standards: Part 2—Zone Definitions, Maps, and Comparisons." *ASHRAE Transactions* 109(2).

DOE (U.S. Department of Energy). 2013. *Energy Plus Energy Simulation Software, Version 8.0*. U.S. Department of Energy, Washington, D.C. Available at http://apps1.eere.energy.gov/buildings/EnergyPlus/.

EIA (Energy Information Administration). 2003. *Commercial Buildings Energy Consumption Survey 2003*. Energy Information Administration of U.S. Department of Energy, Washington, D.C. Available at http://www.eia.doe.gov/emeu/cbecs/contents.html.

Jarnagin RE and GK Bandyopadhyay. 2010. *Weighting Factors for the Commercial Building Prototypes Used in the Development of ANSI/ASHRAE/IES 90.1-2010*. PNNL-19116, Pacific Northwest National Laboratory, Richland, Washington. Available at www.pnl.gov/main/publications/external/technical_reports/PNNL-19116.pdf.

PNNL. 2014a. *2013EndUseTables.xlsx*. Pacific Northwest National Laboratory, Richland, WA. Available at http://www.energycodes.gov/sites/default/files/documents/2013EndUseTables.zip.

PNNL. 2014b. *Enhancements to ASHRAE Standard 90.1 Prototype Building Models*. Pacific Northwest National Laboratory, Richland, Washington. Available at https://www.energycodes.gov/development/commercial/90.1_models.

Thornton BA, M Rosenberg, EE Richman, W Wang, Y Xie, J Zhang, H Cho, VV Mendon, RA Athalye, and B Liu. 2011. *Achieving the 30% Goal: Energy and Cost Savings Analysis of ASHRAE Standard 90.1-2010*. PNNL-20405, Pacific Northwest National Laboratory, Richland, Washington.

Appendix A

Heat Maps

Appendix A

Heat Maps

The heat maps presented in this appendix provide multiple views of prototypes by end use. The term "heat map" does not relate to the heating end use, but to a representation of relative intensity of a factor by color. Two types of heat maps (i.e., cost and savings) are used here:

- Cost heat maps: In the cost heat maps, red indicates the highest remaining cost impact and white indicates lowest remaining cost impact. Darker reds indicate higher remaining cost and, thus, a higher potential for future savings.
- Savings heat maps: In the savings heat maps, green indicates the higher cost savings from Standard 90.1-2004 to Standard 90.1-2013 and red indicates lower cost savings. Darker reds indicate a lower savings to date and, thus, a possible higher potential for future savings.

Some of the heat maps are weighted by construction and some represent individual building constructions. The weighting conditions are noted with each map. Likewise, building types and end uses presented as detailed or in groups, as noted.

Energy Cost Index by Building Type and End Use

Table A.1 shows ECI results grouped by building and end use after Standard 90.1-2013; Table A.2 shows the detailed results. Results in this section relate to the prototype independently except the last row (U.S. Weighted), which is weighted for both climate and prototype. The results are national, weighted by relative construction of each prototype in each climate zone.

Table A.1. ECI ($/ft^2/yr) remaining after 90.1-2013, by building group and end use

	Light.Int	Light.Ext	SHW	Heat	Cool	Fan.Aux	Misc	Equip	Total
Office	$0.203	$0.055	$0.043	$0.066	$0.164	$0.093	$0.065	$0.479	$1.167
Warehouse	$0.170	$0.045	$0.014	$0.060	$0.012	$0.019		$0.075	$0.395
Retail	$0.482	$0.076	$0.047	$0.063	$0.184	$0.219		$0.209	$1.281
Hotel	$0.215	$0.052	$0.166	$0.099	$0.322	$0.205	$0.229	$0.463	$1.750
Apt	$0.092	$0.046	$0.207	$0.058	$0.163	$0.189	$0.081	$0.329	$1.165
School	$0.259	$0.016	$0.037	$0.056	$0.225	$0.151	$0.046	$0.376	$1.166
Medical	$0.381	$0.054	$0.037	$0.404	$0.476	$0.352	$0.398	$0.897	$3.000
Food.Svc	$0.371	$0.175	$0.806	$1.078	$0.668	$0.656	$0.690	$3.679	$8.124
U.S. Weighted	$0.263	$0.052	$0.082	$0.103	$0.193	$0.166	$0.085	$0.386	**$1.330**

Table A.2. ECI ($/ft^2/yr) remaining after 90.1-2013, by building type and detailed end use

	Light.Int	Light.Ext	SHW	Heat	Humidfy	Cool	Ht.Rej	Fans	Ht.Rcvy	Pumps	Refrig	Elevator	Txfmr	Equip	Cook	IT	Total
Sm Office	0.238	0.064	0.094	0.029		0.100		0.104						0.252			0.880
Md Office	0.175	0.056	0.013	0.089		0.174		0.045	0.000	0.000		0.088	0.009	0.313			0.962
Lg Office	0.196	0.039	0.010	0.048	0.037	0.230	0.023	0.126	0.006	0.031		0.109	0.005	0.307		0.858	2.023
Warehouse	0.170	0.045	0.014	0.060		0.012		0.019						0.075			0.395
Retail Store	0.432	0.071	0.035	0.046		0.178		0.215	0.018					0.226			1.221
Strip Mall	0.618	0.090	0.080	0.109		0.200		0.183						0.163			1.443
Sm Hotel	0.214	0.044	0.127	0.116		0.190		0.185		0.000		0.166		0.296			1.336
Lg Hotel	0.215	0.055	0.179	0.093		0.367		0.151	0.044	0.017	0.020	0.223	0.007	0.205	0.316		1.893
Pri School	0.274	0.018	0.025	0.099		0.216		0.123	0.032	0.000	0.047		0.009	0.362	0.104		1.311
Sec School	0.252	0.016	0.042	0.035		0.229		0.111	0.032	0.007	0.026	0.009	0.006	0.259	0.073		1.096
Mid Apartment	0.094	0.034	0.322	0.049		0.121		0.171				0.106		0.328			1.226
Hi Apartment	0.091	0.055	0.113	0.065		0.187	0.009	0.186		0.017		0.054	0.007	0.330			1.115
Clinic	0.353	0.078	0.028	0.340	0.076	0.570		0.261	0.013	0.011		0.448		0.876			3.055
Hospital	0.417	0.024	0.049	0.306	0.082	0.299	0.058	0.345	0.028	0.064	0.025	0.298	0.012	0.632	0.291		2.930
Fast Food	0.371	0.177	0.673	1.373		0.751		0.762			0.977				4.469		9.553
Restaurant	0.372	0.173	0.925	0.816		0.594		0.560		0.002	0.435				2.977		6.854
U.S. Weighted	0.263	0.052	0.082	0.095	0.007	0.189	0.004	0.148	0.012	0.007	0.016	0.066	0.003	0.273	0.084	0.029	1.330

National Energy Cost Impact, by Building Type and End Use, U.S. New Construction

Table A.3 shows grouped national new construction energy cost impact results after Standard 90.1-2013; Table A.4 shows the detailed results. Results in this section are weighted by prototype and climate zone based on 8.2 billion square feet of new construction. The numerical results represent the contribution to national new construction energy cost and red shading indicates the greatest national impacts.

Table A.3. Million $/y-U.S. spend on new commercial building energy; after 90.1-2013

	Light.Int	Light.Ext	SHW	Heat	Cool	Fan.Aux	Misc	Equip	Total
Office	$252M	$69M	$53M	$81M	$202M	$115M	$80M	$593M	$1,446M
Warehouse	$235M	$63M	$19M	$83M	$16M	$26M		$104M	$546M
Retail	$834M	$132M	$82M	$109M	$318M	$380M		$361M	$2,216M
Hotel	$118M	$29M	$91M	$55M	$177M	$113M	$126M	$255M	$965M
Apt	$124M	$62M	$279M	$78M	$219M	$254M	$109M	$443M	$1,568M
School	$329M	$21M	$46M	$71M	$286M	$192M	$58M	$477M	$1,480M
Medical	$246M	$35M	$24M	$261M	$308M	$228M	$257M	$580M	$1,939M
Food.Svc	$38M	$18M	$83M	$111M	$69M	$68M	$71M	$379M	$837M
U.S. Weighted	$2,177M	$428M	$678M	$848M	$1,596M	$1,375M	$702M	$3,192M	**$10,997M**

Table A.4. Detailed million $/y-U.S. spend on new commercial building energy; after 90.1-2013

	Light.Int	Light.Ext	SHW	Heat	Humidify	Refrig	Elevator	Txfmr	Equip	Cook	IT	Cool	Ht.Rej	Fans	Ht.Rcvy	Pumps	Total
Sm Office	$110M	$30M	$43M	$13M					$117M			$46M		$48M			$408M
Md Office	$88M	$28M	$6M	$45M			$44M	$5M	$156M			$87M		$22M	$0M	$0M	$481M
Lg Office	$54M	$11M	$3M	$13M	$10M		$30M	$1M	$84M		$236M	$63M	$6M	$35M	$2M	$8M	$556M
Warehouse	$235M	$63M	$19M	$83M					$104M			$16M		$26M			$546M
Retail Store	$545M	$90M	$45M	$58M					$284M			$225M		$271M	$23M		$1,540M
Strip Mall	$290M	$42M	$37M	$51M					$77M			$94M		$86M			$676M
Sm Hotel	$30M	$6M	$18M	$16M			$24M		$42M			$27M		$26M		$0M	$190M
Lg Hotel	$88M	$23M	$73M	$38M		$8M	$91M	$3M	$84M	$129M		$150M		$62M	$18M	$7M	$775M
Pri School	$113M	$7M	$10M	$41M		$20M		$4M	$150M	$43M		$89M		$51M	$13M	$0M	$541M
Sec School	$216M	$13M	$36M	$30M		$22M	$8M	$5M	$222M	$63M		$196M		$95M	$27M	$6M	$939M
Mid Apt	$57M	$21M	$195M	$30M			$64M		$199M			$73M		$104M			$742M
Hi Apt	$67M	$41M	$84M	$48M			$40M	$5M	$245M			$139M	$7M	$138M		$12M	$827M
Clinic	$128M	$28M	$10M	$123M	$28M		$162M		$317M			$206M		$94M	$5M	$4M	$1,104M
Hospital	$119M	$7M	$14M	$87M	$23M	$7M	$85M	$3M	$180M	$83M		$85M	$17M	$98M	$8M	$18M	$835M
Fast Food	$18M	$9M	$33M	$67M		$47M				$217M		$36M		$37M			$463M
Restaurant	$20M	$9M	$50M	$45M		$24M				$162M		$32M		$31M		$0M	$374M
All Buildings	$2,177M	$428M	$678M	$787M	$61M	$128M	$547M	$26M	$2,260M	$697M	$236M	$1,566M	$30M	$1,224M	$95M	$56M	**$10,997M**

Energy Cost Savings, by Building Type and End Use

Table A.5 shows grouped results and Table A.6 shows the detailed results. These results are for savings from Standard 90.1-2004 to 2013 and are weighted by climate zone based on new construction. The percentages represent independent savings for each individual end use.

Table A.5. Percentage cost savings by end use and building type, 90.1-2004 to 90.1-2013 (% savings per individual end use)

	Light.Int	Light.Ext	SHW	Heat	Cool	Fan.Aux	Misc	Equip	Total
Office	37.1%	50.4%	0.3%	42.2%	39.5%	25.7%	10.0%	5.5%	25.4%
Warehouse	36.0%	33.1%	3.2%	36.4%	46.3%	50.6%		2.0%	31.8%
Retail	24.0%	48.0%	5.1%	64.2%	50.1%	49.9%		0.4%	36.7%
Hotel	36.6%	25.0%	0.3%	56.5%	35.7%	45.2%	5.8%	4.4%	27.2%
Apt	6.7%	32.4%	0.1%	41.3%	29.2%	21.0%	6.3%	0.3%	14.2%
School	43.0%	47.1%	0.9%	58.1%	50.0%	52.5%	19.2%	9.7%	38.5%
Medical	16.8%	47.0%	0.8%	54.8%	33.1%	33.4%	3.3%	1.5%	26.0%
Food.Svc	59.5%	43.3%	0.7%	15.9%	34.5%	55.7%	21.6%	0.0%	21.7%
U.S. Weighted	30.9%	43.2%	1.0%	50.4%	41.4%	42.5%	8.6%	3.4%	**29.0%**

Table A.6. Detailed percentage cost savings by end use and building type, 90.1-2004 to 90.1-2013 (% savings per individual end use)

	Light.Int	Light.Ext	SHW	Heat	Humidify	Cool	Ht.Rej	Fans	Ht.Rcvy	Pumps	Refrig	Elevator	Txfmr	Equip	Cook	IT	Total
Sm Office	35.6%	52.1%	0.2%	43.3%		50.2%		24.2%						8.5%			30.2%
Md Office	40.6%	53.6%	1.5%	52.0%		36.1%		30.9%		0.0%		5.5%	49.5%	8.8%			31.6%
Lg Office	33.6%	30.9%	0.2%	42.2%	-685%	31.6%	54.8%	12.9%		56.7%		2.8%	44.5%	9.1%		0.0%	14.6%
Warehouse	36.0%	33.1%	3.2%	36.4%		46.3%		50.6%						2.0%			31.8%
Retail Store	24.4%	46.7%	2.1%	73.7%		50.4%		54.4%						0.4%			38.1%
Strip Mall	23.3%	50.6%	8.3%	39.3%		49.3%		47.7%						0.4%			33.3%
Sm Hotel	35.4%	30.9%	0.1%	45.5%		30.8%		6.7%		0.0%		3.6%		7.3%			21.3%
Lg Hotel	37.0%	23.2%	0.3%	60.0%		36.5%		44.0%	59.8%	70.1%	17.5%	2.8%	45.6%	9.1%	0.0%		28.5%
Pri School	41.6%	46.0%	3.5%	42.0%		45.6%		37.1%	37.7%	2.7%	10.0%		49.6%	14.7%	0.0%		32.6%
Sec School	43.7%	47.7%	0.1%	69.6%		51.7%		55.4%	57.4%	77.9%	9.1%	13.1%	48.5%	10.2%	0.0%		41.5%
Mid Apartment	8.5%	45.0%	0.1%	38.5%		36.8%		20.2%				3.6%		0.5%			13.2%
Hi Apartment	5.1%	23.7%	0.1%	42.9%		24.7%	22.0%	20.2%		33.7%		2.8%	42.5%	0.2%			15.1%
Clinic	17.5%	51.0%	1.2%	58.6%	50.1%	31.0%		36.9%		17.7%		2.0%		0.9%			27.0%
Hospital	16.0%	21.3%	0.6%	47.0%	61.1%	38.8%	25.2%	34.6%		50.7%	21.9%	1.3%	40.6%	3.2%	0.0%		24.6%
Fast Food	56.9%	43.6%	-0.1%	8.1%		32.1%		48.4%			21.3%				0.0%		17.9%
Restaurant	61.6%	43.0%	1.2%	25.4%		37.1%		62.3%		0.0%	22.0%				0.0%		26.0%

Appendix B

End-Use Energy Cost by Building Type

Appendix B

End-Use Energy Cost by Building Type

The following figures show the energy cost (ECI, $\$/ft^2/yr$) for each end use on a separate graph with a bar for each building type group. These figures show use after Standard 90.1-2013 and are weighted for the building type across all U.S. climate zones. Energy cost savings from 90.1-2004 to 90.1-2013 are also shown to indicate which building types have the highest energy cost intensity for a particular end use. These figures also show the distribution of individual end-use costs by building type.

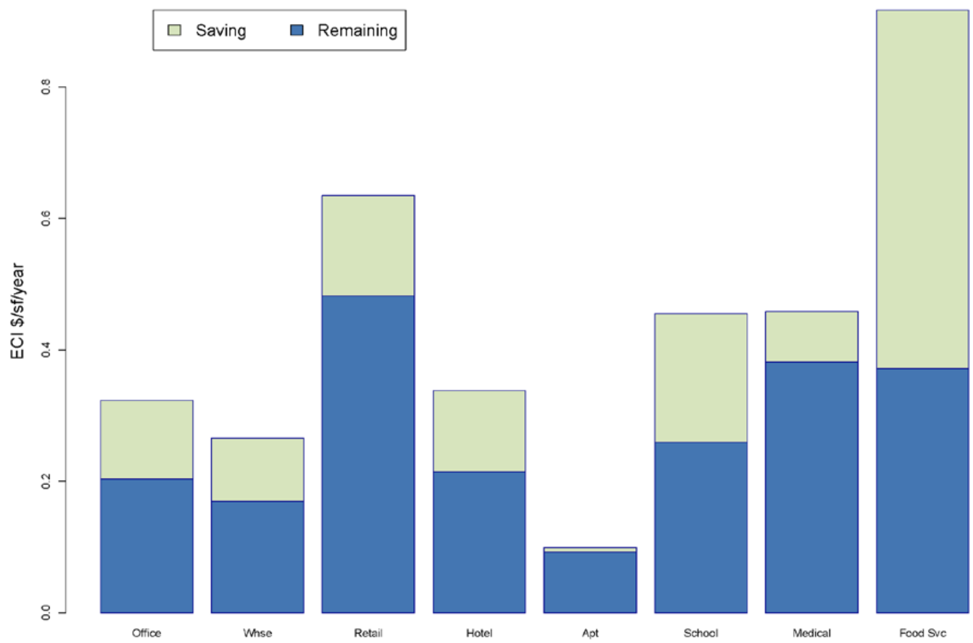


Figure B.1. Interior lighting: 90.1-2013 vs. 90.1-2004; U.S. energy cost

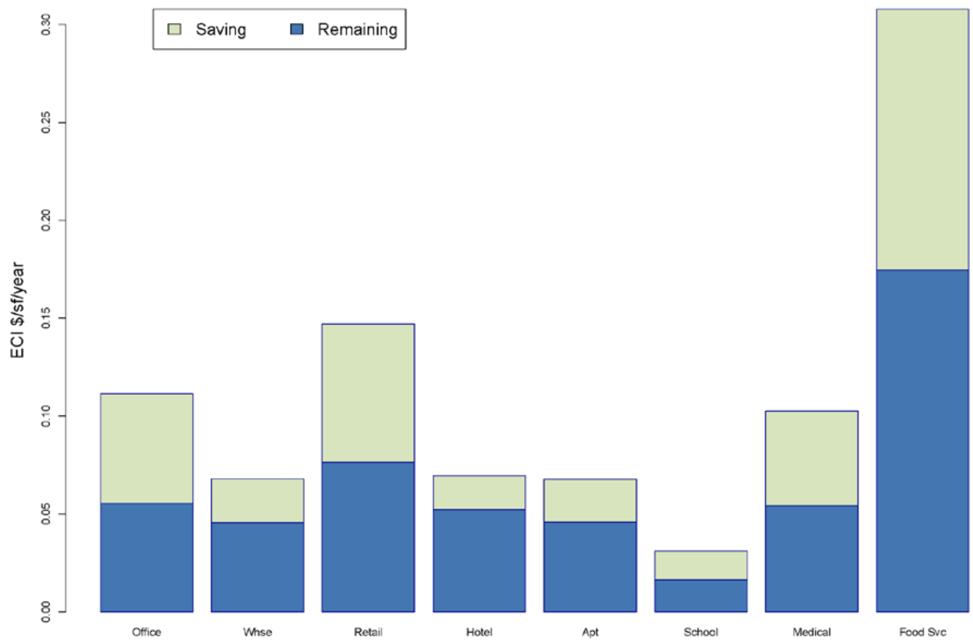


Figure B.2. Exterior lighting: 90.1-2013 vs 90.1-2004; U.S. energy cost

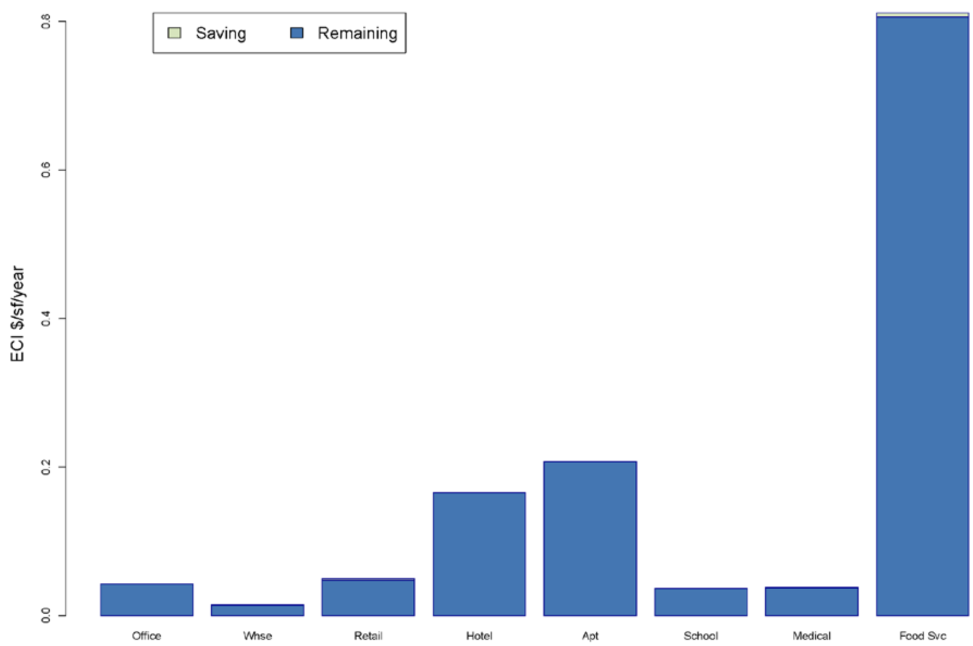


Figure B.3. Service hot water: 90.1-2013 vs. 90.1-2004; U.S. energy cost

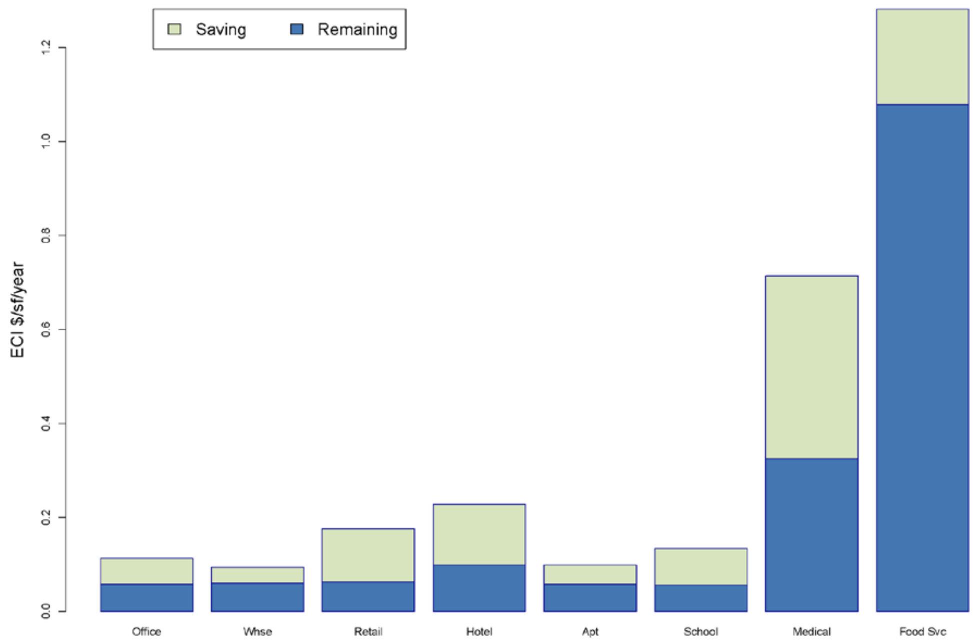


Figure B.4. Heating: 90.1-2013 vs 90.1-2004; U.S. energy cost

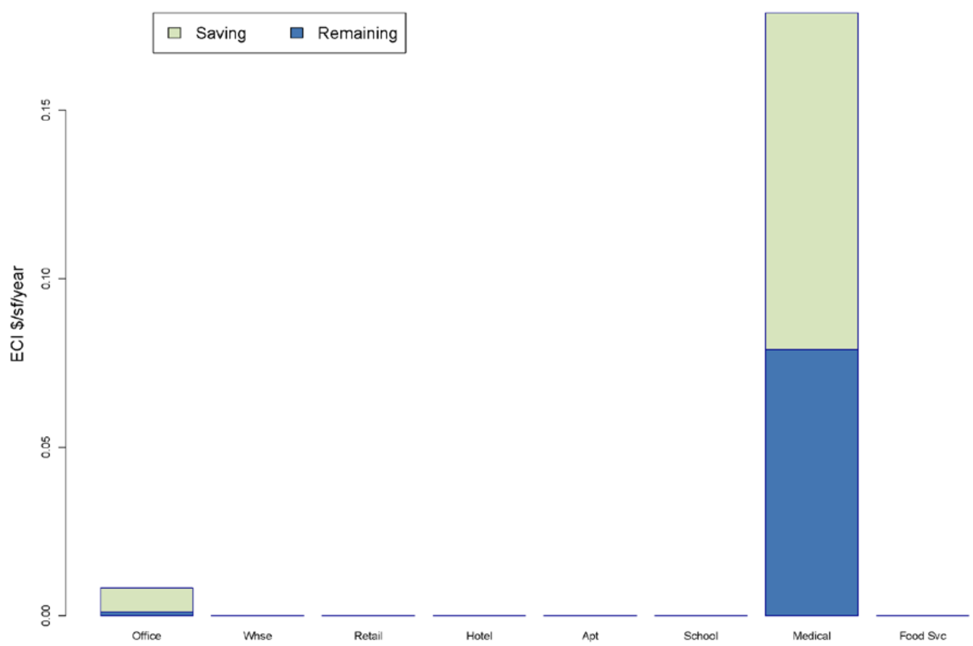


Figure B.5. Humidify: 90.1-2013 vs 90.1-2004; U.S. energy cost

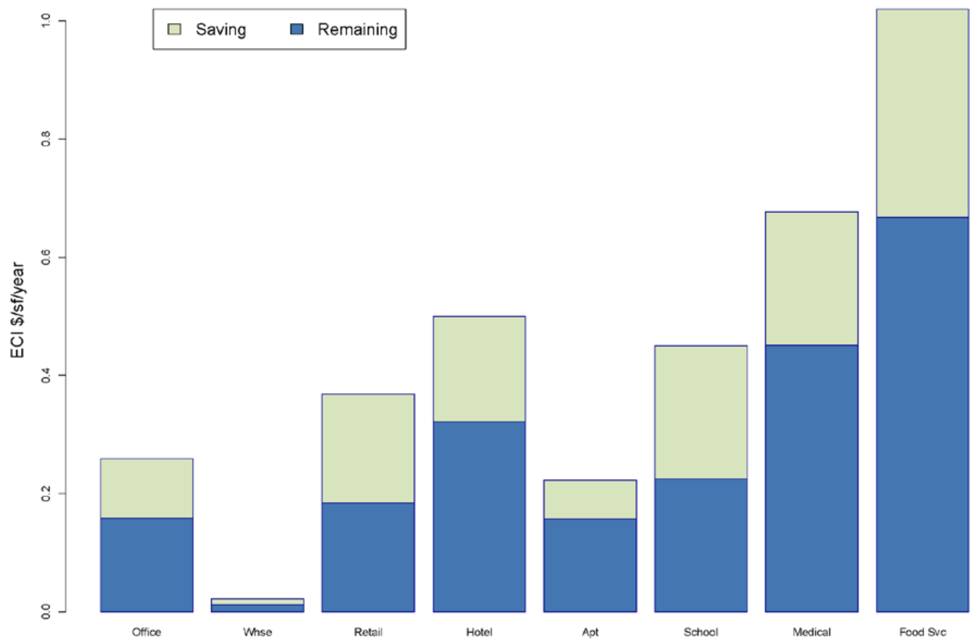


Figure B.6. Cooling: 90.1-2013 vs 90.1-2004; U.S. energy cost

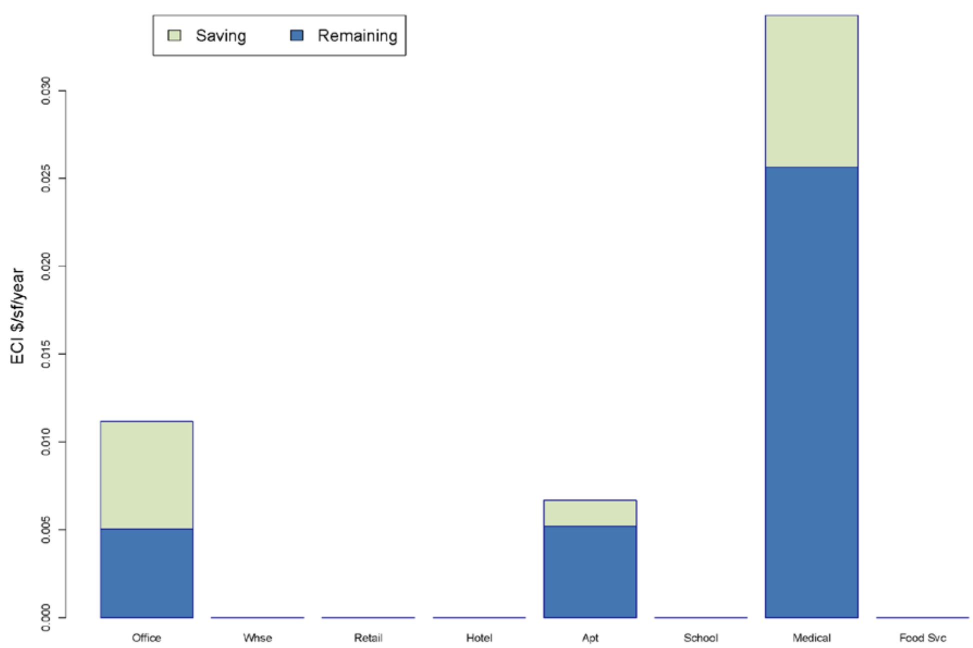


Figure B.7. Heat rejection: 90.1-2013 vs 90.1-2004; U.S. energy cost

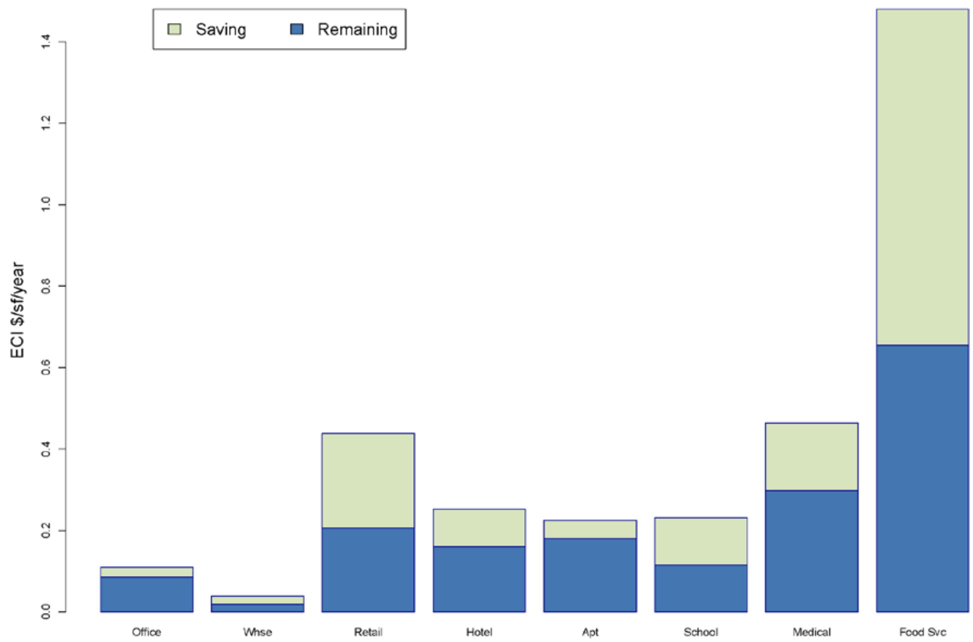


Figure B.8. Fans: 90.1-2013 vs 90.1-2004; U.S. energy cost

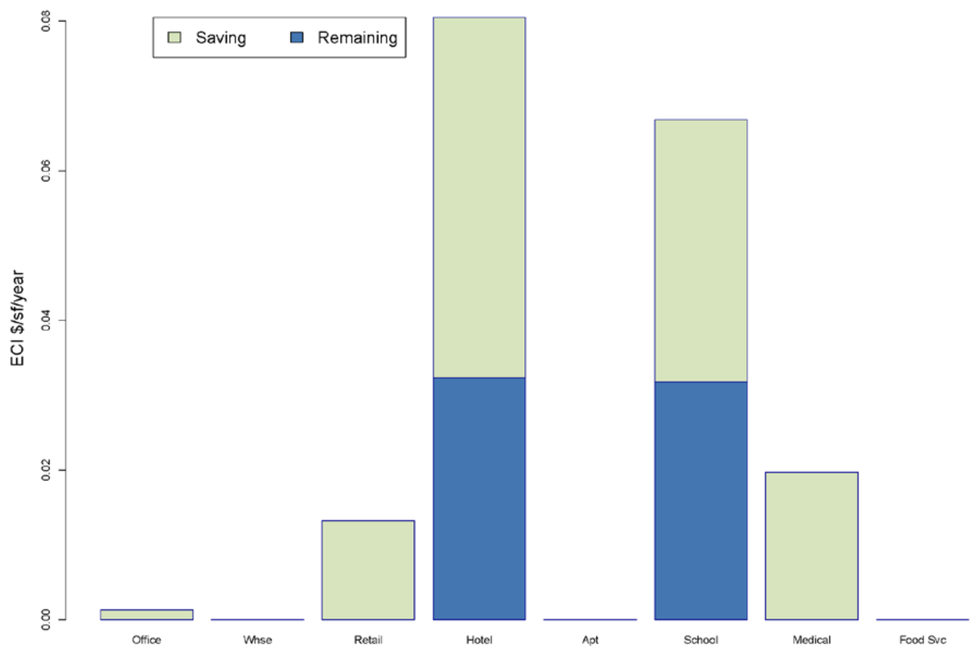


Figure B.9. Heat recovery: 90.1-2013 vs 90.1-2004; U.S. energy cost

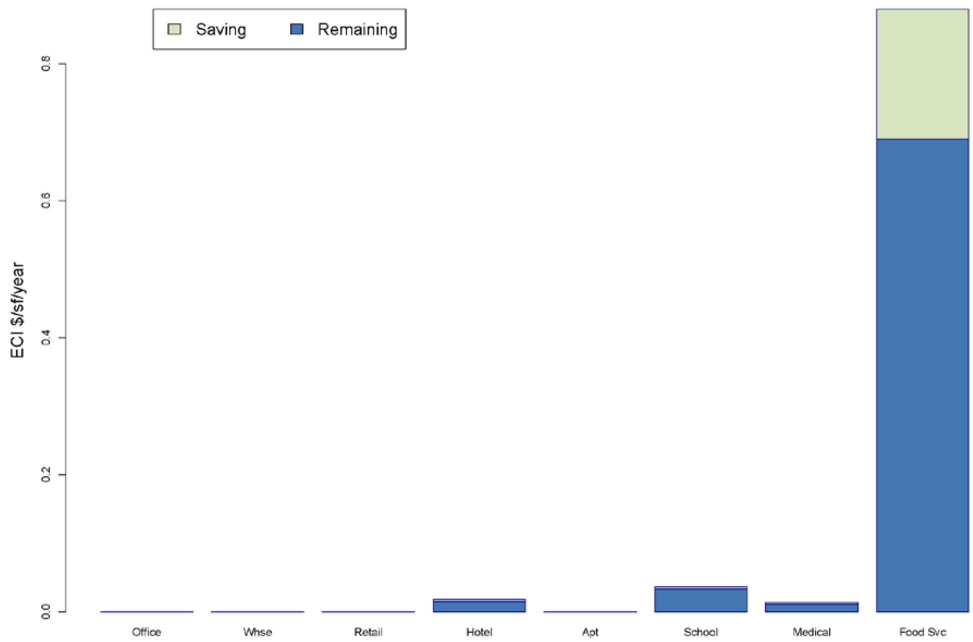


Figure B.10. Refrigeration: 90.1-2013 vs 90.1-2004; U.S. energy cost

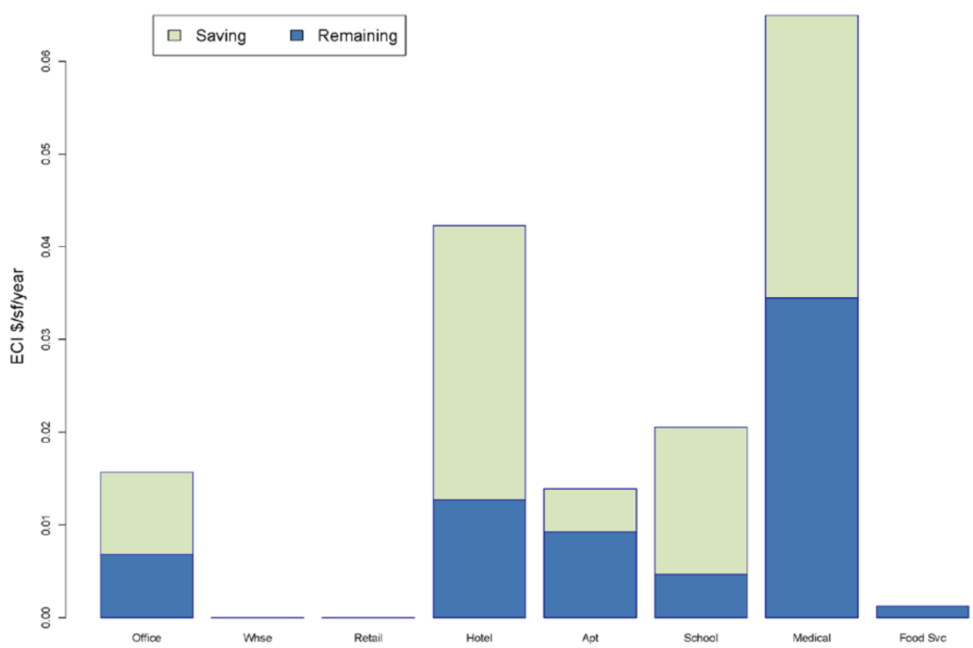


Figure B.11. Pumps: 90.1-2013 vs 90.1-2004; U.S. energy cost

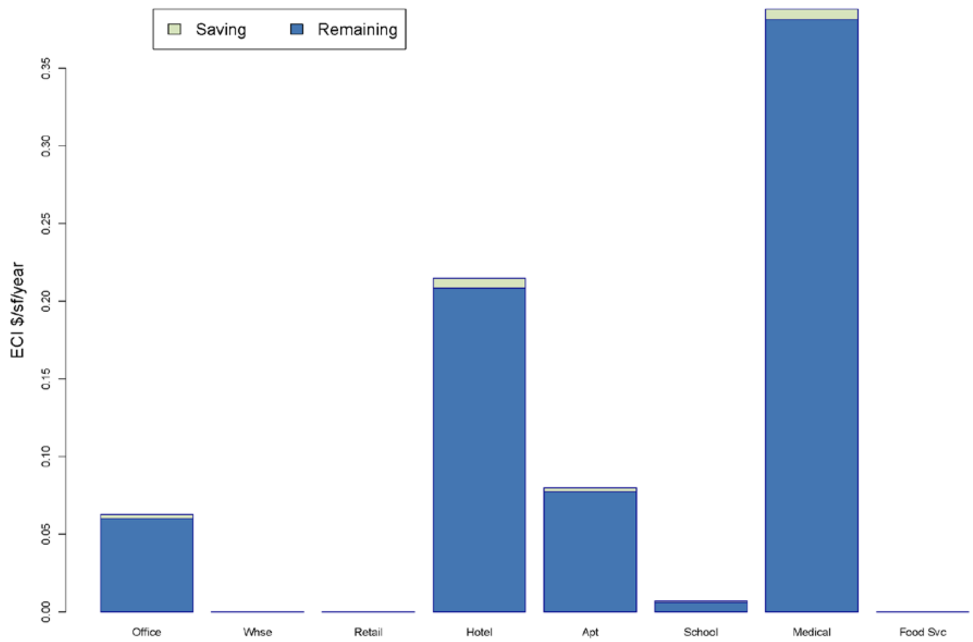


Figure B.12. Elevator: 90.1-2013 vs 90.1-2004; U.S. energy cost

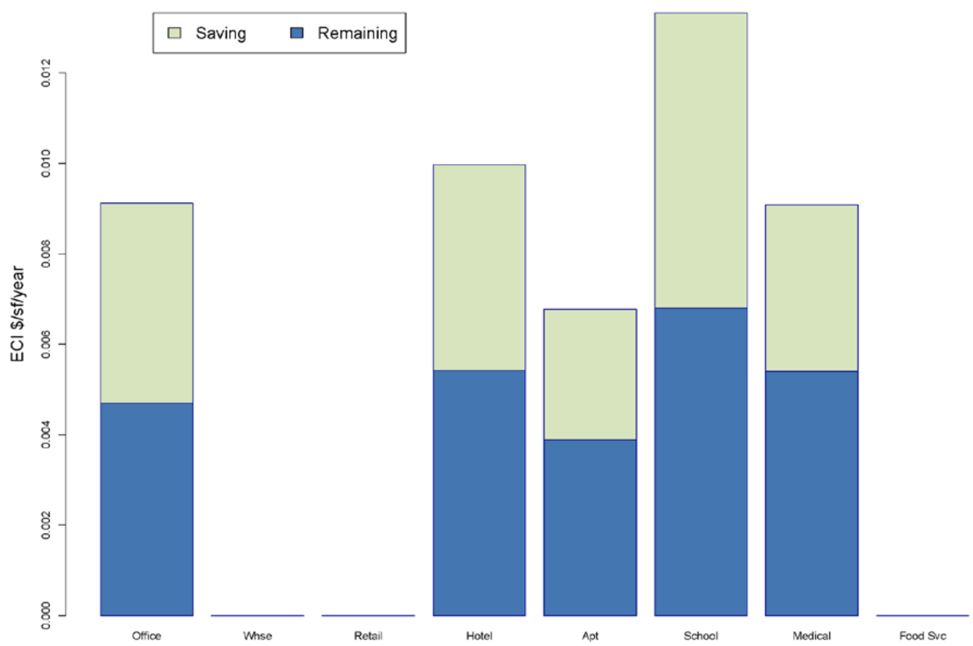


Figure B.13. Transformer loss: 90.1-2013 vs 90.1-2004; U.S. energy cost

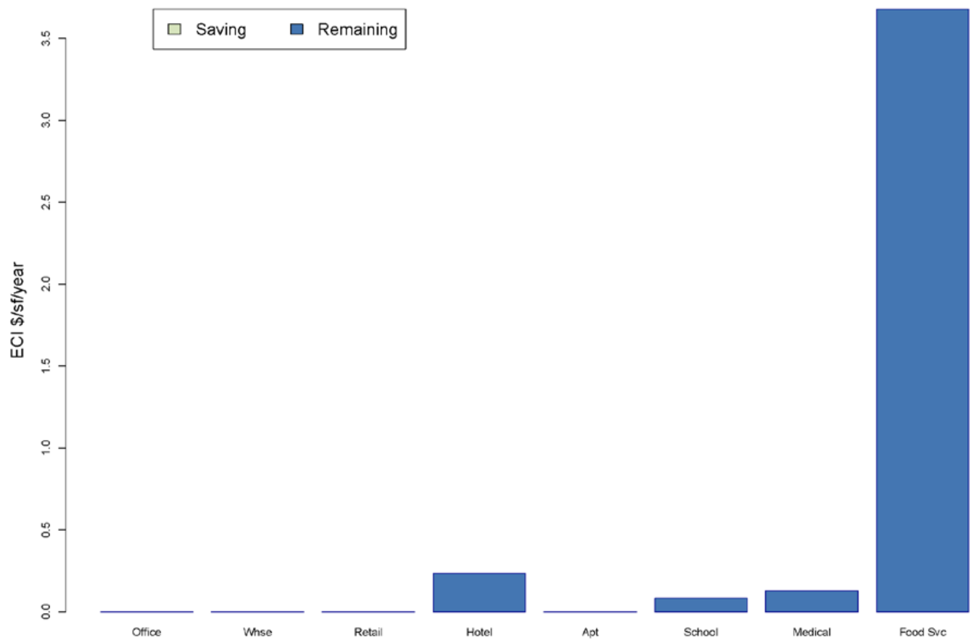


Figure B.14. Cooking: 90.1-2013 vs 90.1-2004; U.S. energy cost

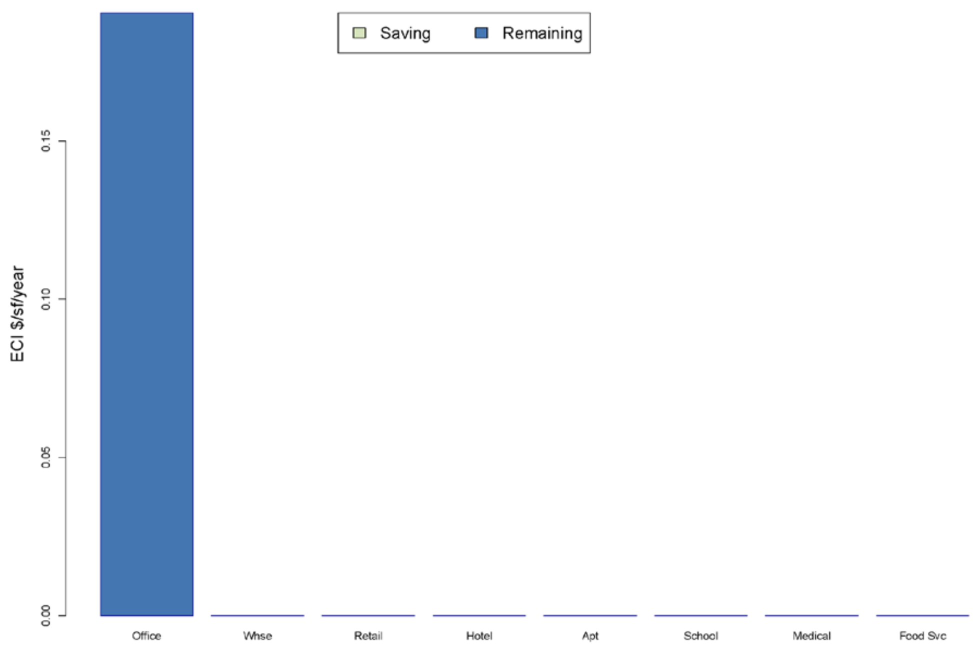


Figure B.15. IT: 90.1-2013 vs 90.1-2004; U.S. energy cost

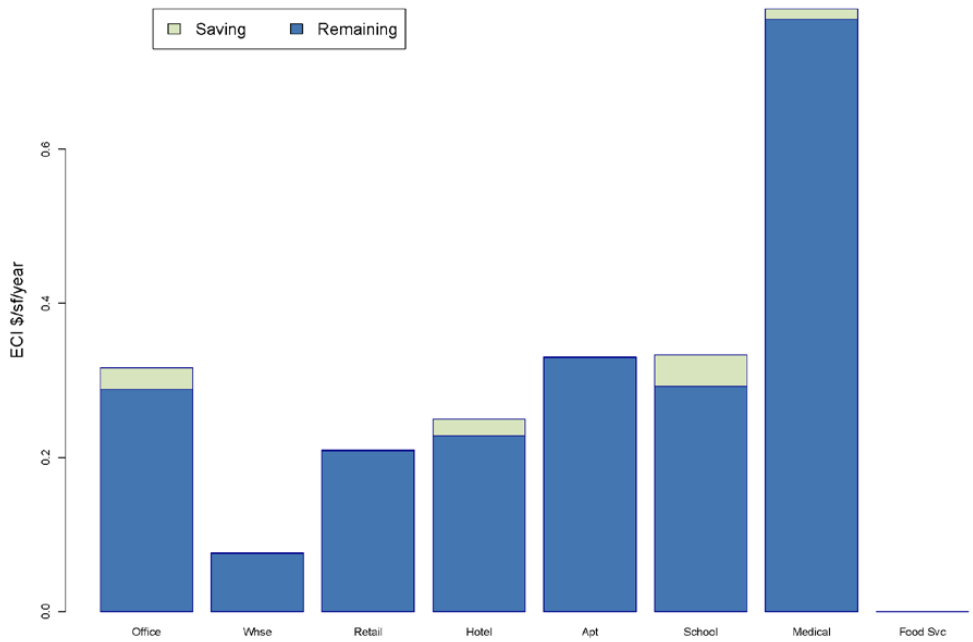


Figure B.16. Equipment: 90.1-2013 vs. 90.1-2004; U.S. energy cost

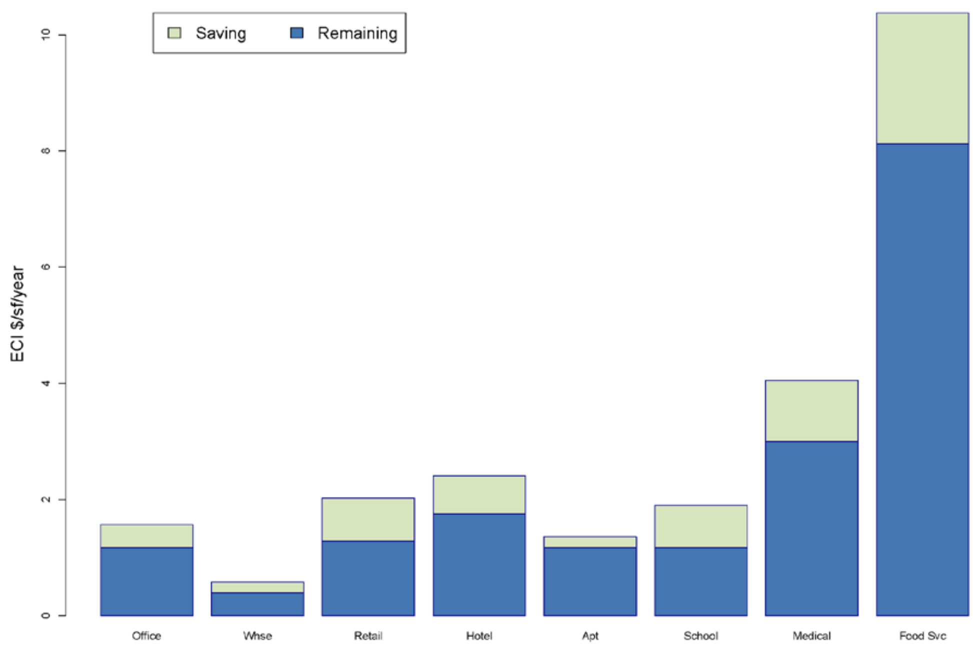


Figure B.17. Total: 90.1-2013 vs. 90.1-2004; U.S. energy cost

Pacific Northwest
NATIONAL LABORATORY

U.S. DEPARTMENT OF
ENERGY

Proudly Operated by **Battelle** *Since 1965*

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99352
1-888-375-PNNL (7665)

www.pnnl.gov

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Reducing Office Plug Loads through Simple and Inexpensive Advanced Power Strips

Preprint

I. Metzger, M. Sheppy, and D. Cutler

To be presented at the 2014 ASHRAE Annual Conference
New York City, New York
January 18-22, 2014

Produced under direction of Naval Facilities Engineering Command (NAVFAC) by the National Renewable Energy Laboratory (NREL) under Interagency Agreement IAG-11-01829 and Task No. WFK3.3070.

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC.

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Conference Paper
NREL/CP-7A40-57730
July 2013

Contract No. DE-AC36-08GO28308

NOTICE

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Available electronically at http://www.osti.gov/bridge

Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: mailto:reports@adonis.osti.gov

Available for sale to the public, in paper, from:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/help/ordermethods.aspx

Cover Photos: (left to right) photo by Pat Corkery, NREL 16416, photo from SunEdison, NREL 17423, photo by Pat Corkery, NREL 16560, photo by Dennis Schroeder, NREL 17613, photo by Dean Armstrong, NREL 17436, photo by Pat Corkery, NREL 17721.

Printed on paper containing at least 50% wastepaper, including 10% post consumer waste.

Reducing Office Plug Loads through Simple and Inexpensive Advanced Power Strips

Ian Metzger
Member ASHRAE

Michael Sheppy
Member ASHRAE

Dylan Cutler

ABSTRACT

As efficiency gains are made in building lighting and HVAC systems, plug loads become a greater percentage of building energy use and must be addressed to meet energy goals. HVAC and lighting systems are targeted because they are typically the highest energy end uses, but plug load reduction and control should be considered as part of a comprehensive approach to energy reduction. In a minimally code compliant office building, plug loads typically account for 25% of the total electrical load. In an ultra-efficient office building, plug loads are typically one of the last end uses to be considered for energy conservation and, as a result, can account for more than 50% of the total electrical load (Lobato et. al, 2011). Plug load efficiency strategies are different than other building efficiency strategies because they involve relatively small loads distributed throughout a building. These loads typically move around in the building when office configuration changes are made, so these loads may shift between circuits over time. Commercially available advanced power strips (APS) can be used to mitigate wasted energy from most plug loads and, in many cases, can have a return-on-investment of approximately two years or less. In recent technology demonstrations, data from occupancy sensors tracking plug load reductions with occupancy have shown energy-saving potential for both business and nonbusiness hours. Also, dense panel-level sub-metering has been used to quantify whole-building receptacle circuit energy consumption, energy savings, and return on investment for the whole building. Receptacle-level metering has been used to show the plug load energy consumption of individual devices and workstations. This paper documents the process (and results) of applying advanced power strips with various control approaches.

INTRODUCTION

Advanced power strips (APS) have been tested in numerous demonstration projects and wide-scale deployments. Basic mechanical schedule timers have been commercially available for a long time, while newer electronic, logic-based controls have started becoming commercially available over the past three to five years. There are an abundance of APSs that offer a variety of complexity, control strategies, data collection abilities, and costs. Some APSs come with a web-based dashboard that allows users to implement and change control strategies, as well as look at the real-time energy consumption of plug loads in their buildings. This centralized, web-based approach to plug load management is novel because conventional plug strips typically have to be configured and controlled locally.

Plug load energy savings are achieved when the device is either transitioned to a low-power state, or it is de-energized to eliminate the power draw. Both can be executed either manually or automatically. A low-power state is between a de-energized state and a ready-to-use state, such as standby, sleep, hibernate, and "off" state with parasitic power draw. A de-energized state is when electricity is not being provided to the device, such as physically disconnecting or unplugging the power cord from an electrical outlet.

Ian Metzger, Michael Sheppy, and Dylan Cutler are engineers at the U.S. Department of Energy National Renewable Energy Laboratory, Golden, Colorado.

Commercially available APSs offer a variety of control approaches, including manual control, automatic low-power state, schedule timers, load-sensing, occupancy, and vacancy. This paper describes each control approach in more detail and presents multiple case studies demonstrating plug load controls.

Manual Control

Built-in power buttons, shutdown procedures, or switched power strips are among the most common manual controls for plug loads. Switches, whether built into a device or on a power strip, provide a quick and easy manual method of powering down electronics. Other devices, such as computers, may have a shutdown procedure that users must perform to shut down the device. For some devices, manual control is the best or only method. The energy savings potential for this type of control depends entirely on user behavior.

Automatic Low-Power State Control

Built-in automatic low-power state functionality, such as standby or sleep, can often be a very effective energy saving approach. Idle time can be monitored by internal processes, causing the device to power down to a low-power state when it has been idle for a given period of time. Automatic low-power states provide limited control but are often the most accessible (and inexpensive) and effective when configured correctly. The prime example of this type of control is a computer entering a "sleep" mode. One hurdle with low-power state control is ensuring that the information services departments are enabling the appropriate settings and utilizing newly available updating techniques (such as wake-on LAN) to enable both low-power states and effective business operations.

Schedule Timer Control

Certain devices are used during the same times each day or at regular intervals, causing them to have predictable load profiles. Predictable plug loads can be effectively managed with schedule timers, which apply user-programmed schedules to de-energize and energize the device to match its pattern of usage. A schedule timer control can take multiple forms, such as electrical outlet timers, power strips, or centralized circuit controls. Schedule timer controls are generally straightforward, consistent, and reliable, but target only the energy that is wasted during nonbusiness hours.

Load Sensing Control

A device, such as a computer, may operate in conjunction with other devices, such as a monitor or other peripherals. Load-sensing control automatically energizes and de-energizes secondary devices (e.g., monitor or other peripherals) based on the "sensed" power load of the primary device (e.g., computer). If the primary device goes into a power state below a given threshold, the load-sensing control can power down the secondary devices. Load-sensing control may save more energy than scheduling control because it can reduce energy use during business and nonbusiness hours. However, it is a more complex control approach and relies on the built-in automatic low-power state functionality in the primary device.

Occupancy Control

Plug load energy savings are accomplished when devices are de-energized or transitioned into a low-power state when not in use, which for many instances, can be determined by whether or not the occupant is in the vicinity of the device. Occupancy control energizes plug loads only when users are present and de-energizes them when the space is vacant. This approach pinpoints the main source of wasted energy at workstations and has a high energy savings potential because it reduces energy use during business and nonbusiness hours. However, it is a more complex control, and depends on proper sensor placement and sensitivity.

Vacancy Control

Currently, vacancy control is not commercially available for plug loads but is commonly implemented in lighting controls because it effectively reduces energy. Vacancy control is a slight modification to occupancy control; it energizes a plug load when it receives manual input from a user and de-energizes the plug load automatically based on lack of occupancy. Plug loads that are needed only when users are present (e.g., task lights, monitors, and computers) would be good applications of vacancy control. This approach also has the highest potential for energy savings at workstations because the plug load will stay in a de-energized state until a user manually energizes the device, thus eliminating the wasted energy associated with false positives.

OCCUPACY CONTROL CASE STUDY

A demonstration project of plug load occupancy control was conducted at the U.S. Environmental Protection Agency (EPA) Region 8 Headquarters located in Denver, Colorado, from February 2011 to June 2011. This research study was undertaken in an effort to identify effective ways to reduce plug load energy. A centralized occupancy control approach was implemented on a sample of 126 occupant workstations in the building, to de-energize circuits feeding groups of six or eight cubicles. An automated energy management system de-energized the circuits when all cubicles in a group were unoccupied for a given period of time. This demonstration project also examined the influences of behavioral change on plug load energy consumption, which is not discussed in this paper.

A four-week baseline was established to quantify normal operating conditions. Occupancy controls were enabled to de-energize plug load circuits after 15 minutes of no occupancy in a group of cubicles. Energy savings of the occupancy controls were quantified by comparison to the baseline.

Energy Savings Results

The study found that the occupancy control was an effective method for reducing plug load energy consumption. Figure 1 shows workstation occupancy rates were found to be significantly less than building occupancy rates, contributing to the high energy savings potential of occupancy controls during business hours.

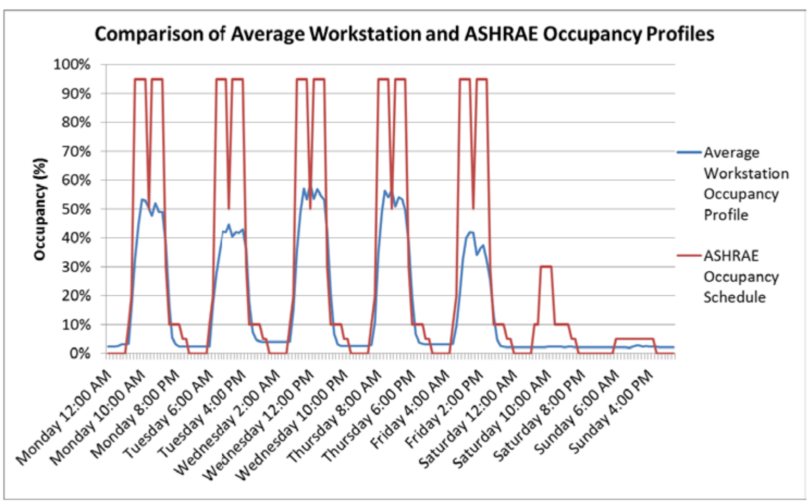


Figure 1 Comparison of the average workstation occupancy rates observed during the demonstration project compared to the ASHRAE occupancy profiles for buildings. (Credit: Ian Metzger, NREL)

The measured occupancy rates of approximately 50% during business hours confirm that control devices with the ability to track occupancy will have a higher energy saving potential at workstations. Other studies conducted by the U.S. General Services Administration (GSA) show that occupants are only at their workstations approximately 30% of the day during business hours. Energy savings for the occupant controls relative to the baseline for the 126-person test group are presented in **Table 1**.

Table 1. Occupancy Control Energy Savings Results

Plug Load Control Approach	Percent Energy Reduction from Baseline
Occupancy Control	21%

Energy savings were found to be significant during both business and nonbusiness hours. Occupancy control was found to have higher energy savings than the behavioral change methods examined in the demonstration project. It is important to note that only workstations were examined in this demonstration project. Shared equipment in common areas (e.g., kitchens, break rooms, print rooms, conference room, etc.) were not included in this study. Higher energy savings are conceivable if all office plug loads are controlled appropriately.

Lessons Learned

Collecting occupancy data can be a sensitive issue, which may require protocols to be followed that would ensure occupant anonymity could be maintained. Anonymity is typically required for field research and should be included in dashboard interfaces for displaying data.

Installation of the control and submetering system took longer and was more costly than expected. The wired installation of the control system and communications were very cumbersome and complex. Wireless communications and controls with "plug and play" installation are expected to have less complexity, are quoted at lower costs, and are currently commercially available. However, wireless communication reliability can be an issue and cyber-security at federal facilities will be a hurdle for all dashboard and data storage submetering systems. It is often more efficient to set up an independent wireless network for the submetering system.

Developing the appropriate plug load management process can have a significant influence on the success of energy reduction goals. This may include behavioral change mechanisms, control systems, or other policies. Establishing a program champion, developing a business case, benchmarking, identifying occupant needs, selecting equipment, controlling equipment schedules, institutionalizing reduction measures, and promoting occupant awareness can all be critical steps in the process.

SCHEDULE TIMER AND LOAD-SENSING CASE STUDY

A demonstration project of plug load schedule timer and load-sensing control with APS was conducted by GSA's Mid-Atlantic Region. According to several energy assessments of GSA's buildings conducted by the National Renewable Energy Laboratory (NREL), plug loads account for approximately 21% of the total electricity consumed within a standard GSA office building (Metzger et al., 2012). This project tested the effectiveness of two types of plug load control strategies: schedule timer control and load-sensing control. An APS that provided both control approaches and submetering was deployed in seven GSA field offices.

This study aimed to measure the holistic energy consumption of an office, including shared equipment and common areas, such as break rooms and print rooms. Overall, 295 devices were monitored during the study, which consisted of a baseline and two subsequent test periods, each 4 weeks long.

Energy Savings

The study found that the schedule timer control was an effective method for reducing plug load energy consumption in all space types, but most notably in the common areas, such as print rooms and break rooms. **Table 2** shows the energy savings from schedule timer controls for different space types in a typical office environment.

Table 2. Schedule Timer Control Energy Savings Results by Space Type

Space Type	Percent Energy Reduction from Baseline
Workstation	26%
Print Rooms	50%
Break Rooms	46%

Load-sensing control was only found to be moderately effective at reducing plug load energy consumption. The low energy saving results at workstations was attributed to the fact that GSA computers were being controlled by a centralized computer power management system. Computer power management is an example of automatic low-power state control. This centralized system was already putting computers and monitors into low-power states, therefore limiting the energy savings potential for this demonstration project. It should be noted that this can be a low/no-cost measure that, properly implemented, can effectively control computer power consumption. **Table 3** shows the energy savings from load-sensing control for different space types in a typical office environment.

Table 3. Load-Sensing Control Energy Savings Results by Space Type

Space Type	Percent Energy Reduction from Baseline
Workstation	4%
Print Rooms	32%
Break Rooms	N/A

Lessons Learned

Although schedule timers were found to have higher energy savings, they were only able to achieve energy savings during nonbusiness hours. In contrast, load-sensing control was able to achieve energy savings during both nonbusiness and business hours, but relied on good occupant behavior or the proper computer power settings to put the computer in sleep mode. In general, schedule timer and load-sensing controls are effective in saving energy for office equipment and can be economical if applied properly. The deployed APS had a manufacturer's suggested retail price (MSRP) of $120 per plug strip. However, there are advanced plug strips on the market that incorporate these technologies and have an MSRP of approximately $20 to $60, although these less expensive APSs typically do not provide submetering capability.

Submetering data are valuable in spotting wasted energy use, informing the future procurement of low-energy equipment, and identifying equipment that is behaving erratically (which is often a precursor to equipment failure). These data are also valuable to building energy modelers, allowing them to more accurately model plug loads in a building. However, the increased cost is typically not economical unless data are actively managed by onsite personnel. It was difficult to set the load threshold for some equipment, such as computers and monitors. The complexity of the load-sensing control resulted in instances where the equipment was being de-energized when the occupants needed them to be energized. Occupant feedback indicated a lack of training/instruction with the devices leading to limited understanding of their operation in some instances. Schedule timer controls are simple and easy to understand for users, which led to larger energy savings in this study. Load-sensing control is more complicated and difficult to understand, leading to complaints and disabling in some instances, which resulted in limited energy savings. More detailed training and maintenance could have made load-sensing control more effective.

INEXPENSIVE SCHEDULE TIMER CASE STUDY

A demonstration project of simple inexpensive schedule timer control with APS was conducted at an office building in Honolulu, Hawaii, from November 2012 through May 2013. The deployed APS could only be controlled locally, each device had to be programmed individually, and no built-in submetering capability existed. Therefore, the programmed schedule timer control was set to be more conservative to accommodate the schedules of different users. This project tested the effectiveness of schedule timer control deployed on a whole building rather than a small sample size as in other demonstration projects. APSs were deployed throughout the entire building, capturing all plug loads.

This study aimed to measure the whole building energy consumption of office plug loads using dense panel-level submetering and calculated energy savings associated with inexpensive schedule timer controls. A total of 689 plug load devices were monitored during the study, which consisted of baseline and test periods, each 4-6 weeks long.

Energy Savings

The study found that the schedule timer control is an effective method for reducing plug load energy consumption in all space types and for all occupant types. Plug loads at the demonstration building are estimated to account for approximately 22% of the whole building energy consumption. **Figure 2** shows the whole building plug load average daily usage profile, comparing the baseline to the schedule timer control. Energy savings are achieved only during nonbusiness hours. Some variation is observed during business hours, which is not attributed to the control devices but an indication that occupant behavior varied between the uncontrolled and controlled phases of the project. Occupancy and behavior are uncontrolled variables; however, occupancy data was collected and used to normalize the energy data in an attempt to remove the variability between the two phases.

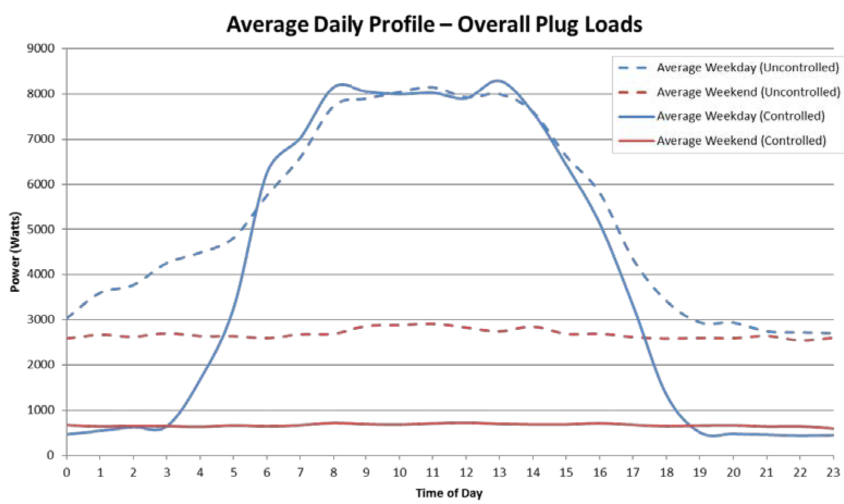


Figure 2 Baseline and APS schedule timer control plug load energy consumption profiles. (Credit: Michael Sheppy, NREL)

Energy savings were analyzed by space type to identify applications with the highest energy savings, for prioritized deployment. **Figure 3** shows the energy savings by space type. Print rooms, open offices, and hallways were found to have the highest energy savings.

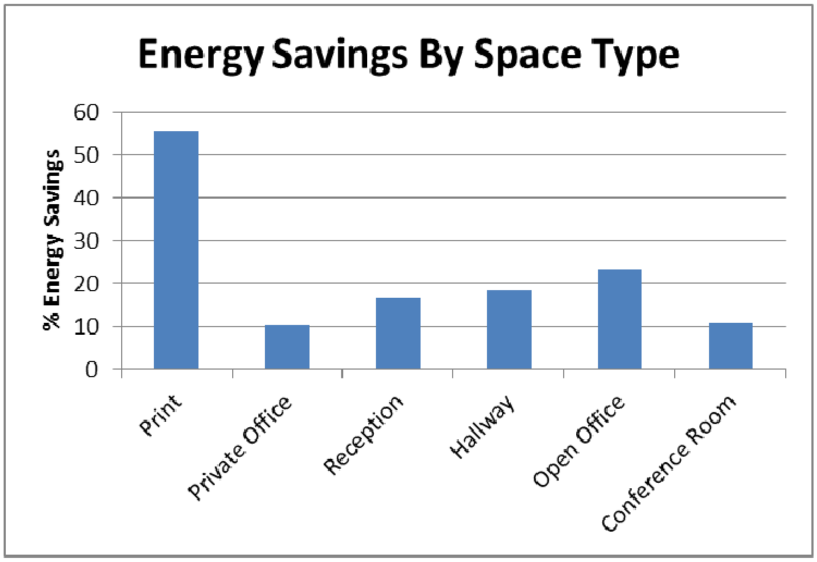


Figure 3 Energy savings by space type. (Credit: Michael Sheppy, NREL)

Measured data was extrapolated to predict annual energy savings using eQUEST energy simulation software developed by the U.S. Department of Energy. Reduction in plug load energy consumption is expected to reduce the energy required for the air conditioning system. **Table 4** shows the modeled energy savings from schedule timer controls for different energy systems.

Table 4. Schedule Timer Control Energy Savings Results by Space Type

Energy System Type	Percent Energy Reduction from Baseline
Plug Loads	28%
Air Conditioning	5%
Whole Building	***8%***

Lessons Learned

Simple and inexpensive schedule timer APSs can be effective in whole building deployments. However, schedule timers are unable to capture energy savings during business hours when occupants are not at their workstations. These devices are easy for the occupants to understand and operate, resulting in higher acceptability in wide-scale deployments. Schedule timer APSs are typically inexpensive, approximately $20 or less MSRP, and can result in payback periods of less than 2 years if applied properly.

CONCLUSION

Advanced power strips with various control approaches are commercially available and have been proven to save energy. However, selecting the appropriate control approach is critical to achieving maximum energy savings. Different equipment types require different control approaches. For example, control approaches that track occupancy, such as load-sensing, occupancy, and vacancy controls, should be applied to equipment found at workstations, such as computers, monitors, and task lights. Schedule timers should be applied to shared equipment, such as printers, coffee makers, and water coolers, but can also be effective at workstations as an alternative to automated computer power settings. However, it is also very important to understand the built-in capabilities of a device, such as automatic low-power states, and how the built-in capabilities may interact with the control approach (e.g., load-sensing). In all cases, it is important for the occupant to understand the purpose and operability of any APS. Therefore, education is paramount when considering the deployment of advanced power strips.

Potential barriers for APSs include: occupant acceptance, communications, lack of personnel time for analysis, and complex controls in some instances. These devices may require operation and maintenance to update controls, manage data, and troubleshoot incorrect operations and communication failures on a regular basis. All control strategies should provide manual override to accommodate atypical times when a plug load device would not normally be in use (e.g., using a device outside normal business hours). APSs may create a parasitic load, which must be included in the analysis of total costs savings potential.

There is the opportunity for significant energy savings through appropriate deployment of APSs. These savings can achieve very attractive returns on investment due to the low cost of certain APS devices. This has been proven with schedule based control in two case studies discussed here. There is significant opportunity for more precisely tuned control of the plug and process loads utilizing occupancy or vacancy control, but a commercially available system that accomplishes this effectively (both in effort and cost) has not been perfected.

Sub metering data are valuable in spotting wasted energy use and identifying equipment that is behaving erratically, but the increased cost is typically not economical unless data are actively managed by onsite personnel. A more effective feedback loop to the end users than the currently available web dashboard approach will be necessary to achieve higher levels of savings for submetering.

Research has been conducted on appropriate control approaches for different types of equipment and published resources are available, such as Assessing and Reducing Plug and Process Loads in Office Buildings (NREL, 2012) and Selecting a Control Strategy for Plug and Process Loads (Lobato et al, 2012). These documents provide a methodical approach to assessing and determining the appropriate control mechanism for different plug loads. Selecting the appropriate control approach and considering lessons learned from the presented case studies will help to make future deployments more effective and increase plug load energy reduction in office buildings.

REFERENCES

"Greening EPA." U.S. Environmental Protection Agency: http://www.epa.gov/greeningepa/facilities/denver-hq.htm. Accessed July 26, 2011.

Lobato, C.; Pless, S.; Sheppy, M. (2011). Reducing Plug and Process Loads for a Large Scale, Low Energy Office Building: NREL's Research Support Facility. NREL/CP-5500-49002. Golden, CO: National Renewable Energy Laboratory. Accessed June 28, 2012: http://www.nrel.gov/docs/fy11osti/49002.pdf.

Metzger, I.; Kandt, A.; Van Geet, O. (2011). Plug Load Behavioral Change Demonstration Project. NREL/TP-7A40-52248. Golden, CO: National Renewable Energy Laboratory. Accessed June 28, 2012: http://www.nrel.gov/docs/fy11osti/52248.pdf.

"Work Place Matters." U.S. General Services Administration. Accessed January 13, 2013: http://www.gsa.gov/graphics/pbs/WorkPlace_Matters_FINAL508_lowres.pdf.

"About the Mid-Atlantic Region." U.S. General Services Administration. Accessed June 27, 2012: http://www.gsa.gov/portal/category/21451.

Metzger, I.; Cutler, D.; Sheppy, M. (2012). Plug-Load Control and Behavioral Change Research in GSA Office Buildings. NREL/TP-7A40-55780. Golden, CO: National Renewable Energy Laboratory. Accessed January 12, 2013: http://www.nrel.gov/docs/fy13osti/55780.pdf.

Lobato, C.; Sheppy, M.; Brackney, L.; Pless, S.; Torcellini, P. (2012). Selecting a Control Strategy for Plug and Process Loads. NREL/TP-5500-51708. Golden, CO: National Renewable Energy Laboratory. Accessed January 12, 2013: http://www.nrel.gov/docs/fy12osti/51708.pdf.

National Renewable Energy Laboratory (2012). Assessing and Reducing Plug and Process Loads in Office Buildings. NREL/BR-5500-51199. Golden, CO: National Renewable Energy Laboratory. Accessed January 12, 2013: http://www.nrel.gov/docs/fy11osti/51199.pdf.

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Building Owners | Energy Managers

OFFICE BUILDINGS

Assessing and Reducing Plug and Process Loads in Office Buildings

Overview

Plug and process loads (PPLs) account for 33% of U.S. commercial building electricity consumption (McKenney et al. 2010). (See Figure 1.) Minimizing these loads is a significant challenge in the design and operation of an energy-efficient building. Lobato et al. (2011) and Lobato et al. (2012) define PPLs as energy loads that are not related to general lighting, heating, ventilation, cooling, and water heating, and that typically do not provide comfort to the occupants. The percentage of total building energy use from PPLs is increasing. According to the U.S. Department of Energy (DOE), by 2030, commercial building energy consumption is expected to increase by 24%; PPL energy consumption is anticipated to increase by 49% in the same time frame (DOE 2010). These trends illustrate the importance of PPL energy reduction to achieve an overall goal of reducing whole-building energy consumption.

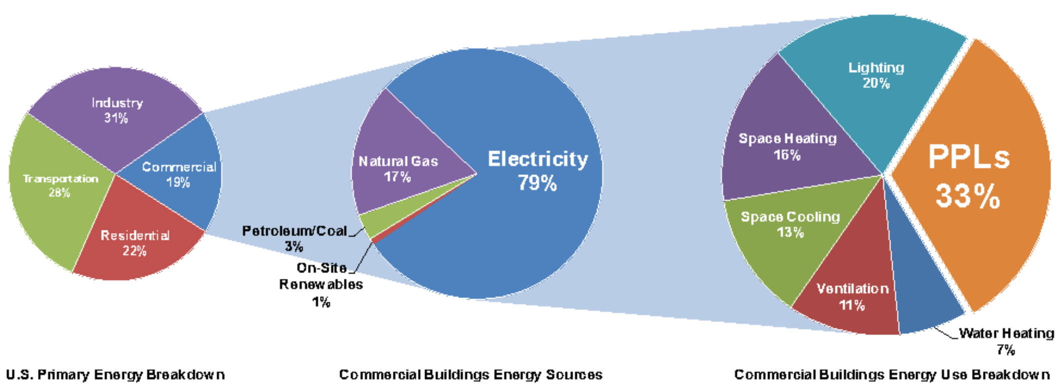


Figure 1. PPLs account for 33% of the total energy consumed by commercial buildings. *Graph by Chad Lobato, NREL; Data source: DOE (2010)*

Using the process and strategies outlined in this brochure, the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) was able to drastically reduce its PPL energy use in the Research Support Facility (RSF). NREL's previous office space PPLs used nearly 2,257,000 kWh/year; after implementing these PPL strategies, the RSF used 1,290,000 kWh/year (see Figure 2). At NREL's utility rate of $0.06/kWh, there is an annual cost saving of $58,000.

This "quick start guide" will help building owners and energy managers reduce PPL energy use in their facilities. This brochure provides an overview of PPLs in office buildings and describes the process and strategies needed to cost-effectively reduce their energy impact. It packages extensive PPL research into an easy-to-use set of instructions and provides quick references to useful tools, websites, and databases. It is also intended to guide the procurement of new equipment that incorporates strategies and technologies to significantly reduce energy consumption.

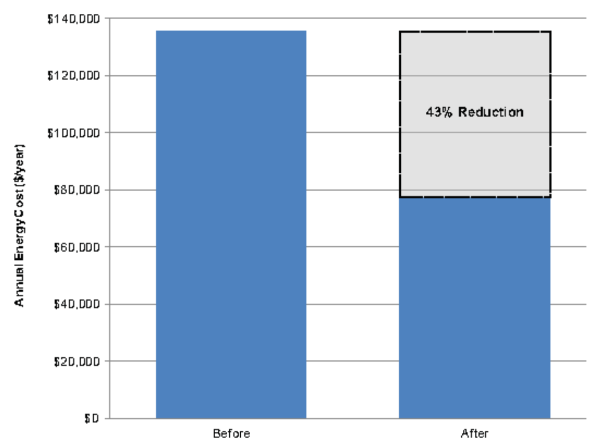


Figure 2. A 43% reduction in PPL energy use saves $58,000 annually. *Graph by Chad Lobato, NREL*

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Plug and Process Loads Reduction Process

Step 1: Establish a Plug and Process Load Champion

The first step in addressing PPLs is to establish a PPL champion (or a team of champions) to initiate and help with the process. This person needs to understand basic energy efficiency opportunities and design strategies and be able to independently and objectively apply cost justifications. He or she must be willing and able to critically evaluate, address, and influence the building's operations, institutional policies, and procurement processes.

Historically, PPLs have not been targeted as an energy consumer such as lights or HVAC, and are considered a function of the building—in some ways, something you cannot do anything about. There are huge opportunities in understanding and managing these loads. Not only do they save energy directly, but cooling energy is also saved by not removing the heat generated by PPLs. PPLs are often specified by many parties, so equipment and efficiency strategies are rarely handled by one decision maker. The champion will make sure that all decision makers are on the same page about PPLs and that their decisions save energy and integrate well with other building systems.

Step 2: Institutionalize Plug and Process Load Measures

The day-to-day energy efficiency of any building depends largely on the decisions of occupants, facility managers, and owners, all of whom play key roles in whole-building energy consumption. Therefore, one key step in reducing PPL energy use is to institutionalize PPL measures through procurement decisions and policy programs (refer to **ENERGY STAR®** for guidance). To do this, the champion must identify decision makers who can institutionalize programs based on identified PPL efficiency measures. Policies must be improved as needed to stay current with technologies.

Step 3: Benchmark Current Equipment and Operations

For a building that is representative of multiple buildings in a portfolio, the benchmarking process is required for only one building. The applicable strategies can then be implemented across the portfolio.

Step 3a: Perform a Walkthrough

A building walkthrough to identify and inventory PPLs will establish a benchmark of current equipment and operations. You can **download a workbook** to help in the inventory process and to estimate PPL energy use and costs. In this workbook, use the sheet named "Office PPL Inventory" to inventory the PPLs in your building. Use the sheet named "Office PPL Calculator" to determine which PPL strategies will offer the greatest savings in your building.

The champion will assess all PPLs, noting the various types of equipment and the quantity of each type. The champion needs to identify PPLs that are common throughout the building, and those that are present in limited quantities. At this stage, the champion will also engage the PPL users to learn how and why each device is used, and if the device is critical to health, safety, or business operations.

Frank et al. (2010) provided a detailed example of how a PPL walkthrough is conducted.

Step 3b: Develop a Metering Plan

A metering plan identifies energy-saving strategies by quantifying the energy use of PPLs. Such a plan saves time and money because only a representative sample of common items needs to be metered. For example, if every cubical has the same type of monitor, only a small sample needs to be metered. The PPLs that are present in limited quantities, that have unknown use patterns, or that are otherwise unique should all be metered if possible. The metering can be carried out, in part, with many commercially available PPL power meters. If metering is possible, the collected data can be used to understand when equipment is operated and highlight opportunities to turn off the equipment when it is not needed. If metering is not possible, either because the PPLs are hard-wired to the electrical system or because their voltage and current requirements are too great, you can **download a workbook** or refer to ASHRAE (2009), to estimate in-use power draws. You can then multiply an estimate by the hours of use to derive an estimate of actual energy use.

Another part of the metering plan is to identify PPLs that cannot be de-energized. Some PPLs cannot be de-energized because of:

- Health and safety concerns
- Interruptions to business operations
- Reductions in sales
- Shutdown procedures
- Reconfiguration requirements on startup.

If the PPL cannot be de-energized, use **the workbook** or ASHRAE (2009) to estimate the device's in-use power draw.

Step 3c: Select a Plug Load Power Meter

Many meters are commercially available to measure plug loads. A meter should have the following features:

- Ability to measure and log one week of electrical power (Watts) data. This offers a more accurate picture of energy use compared to a meter that provides only instantaneous readings.
- Sampling interval of 30 seconds
- Designed for the type of circuit to be metered (e.g., 120 Volt, 15 amp, 60 Hertz)
- Ability to accurately meter loads of 0–1800 W
- External display
- Internal clock that timestamps each data point
- Underwriters Laboratories listing
- Ability to download stored data.

Step 3d: Meter the Plug Loads

The steps to execute the metering plan for a given plug load are:

1. Assure the users that the purpose of the metering effort is to gather data about the building's energy performance, and not to monitor their personal or business activities.
2. If a business function will be interrupted by installing the meter, consider waiting until nonbusiness hours to do so.
3. If applicable, install any necessary computer software so the meter can be configured and the measured data can later be downloaded and analyzed.
4. Set up the meter to measure electrical power at a sampling interval of 30 seconds, if possible. Intervals as long as 15 minutes are acceptable. If necessary, clear the memory on the meter and go through any other initial setup, such as setting the date and time.
5. Power down and unplug the device to be metered, plug the device into the meter, plug the meter into an outlet, and power on the device.
6. Meter the device all day, every day for at least one entire work week. Time and budget permitting, meter for longer periods for more accurate annual energy use estimates and to capture seasonal use patterns.
7. Download the metered data for analysis. Calculate the average load during business and nonbusiness hours.

Step 4: Develop a Business Case for Addressing Plug and Process Loads

To gain buy-in from all parties involved, the champion must develop a business case that justifies measures to reduce PPLs.

In most projects, the initial business case is based on energy cost savings. Energy savings alone may not be sufficient to justify the most efficient PPL reduction strategy, so nonenergy benefits should be highlighted. For example, it is often difficult to justify purchasing low-energy laptop computers with energy cost savings alone. Laptops can be justified, however, because they enable users to work from home and to take their computers on travel. If mobility is not necessary, mini-desktops are available that have the efficiency of laptops without their added costs and security concerns.

Another example is centralized multifunction devices (compared to individual printers, copiers, and fax machines), which have reduced costs for maintenance and supporting unique toner cartridges. Minimizing, centralizing, and standardizing document services greatly simplify the implementation of robust standby power configurations and significantly lower service costs. Moreover, volatile organic compounds from the printer toners can be isolated to a few copy rooms with dedicated exhaust to improve indoor air quality. Depending on the building layout and function, as many as 300 printers can be replaced with as few as 20 widely distributed multifunction devices.

Step 5: Identify Occupants' True Needs

Identify occupants' and institutional true equipment needs. A true need is required to achieve a given business function; a perceived need is often based on past experience without consideration for more efficient strategies to accomplish the same function.

To reduce PPLs, the champion must understand what the occupants produce as part of their jobs and what tools they require. He or she must be diplomatic enough to help them do their jobs energy efficiently without making them feel that the purposes of their jobs are being questioned. This can be challenging, because every occupant, including those working in sensitive operations (e.g., security, information technology, upper management), should be accounted for. Determining occupant needs will reveal any nonessential equipment. A business case should be made for continued use of this equipment; otherwise, it should be removed. Exceptions can be made, especially for equipment that preserves occupant health and safety.

Certain PPLs may not be true needs, but are highly desirable. For these, the champion will need to work to meet the need with a shared, centralized piece of equipment and reduce or eliminate personal devices. For example, a shared, centralized coffee maker can meet employee demand and eliminate numerous personal coffee makers.

Step 6: Meet Needs Efficiently

Once the list of true needs is determined, each must be met as efficiently as possible. You should research the **ENERGY STAR** and **EPEAT®** databases to find energy-efficient equipment; however, these alone will not maximize cost-effective energy savings. Nonrated equipment should be researched to find the most efficient model. This will require the champion to work with equipment manufacturers and suppliers to determine the available options. Once a model is selected, it should be turned off when not in use, if possible.

A significant fraction of many PPLs' energy use is from parasitic loads, which is the power draw when a device is not performing useful work. Parasitic loads result in wasted energy, even if the equipment is energy efficient.

Step 7: Turn It All Off

Office buildings are unoccupied for two-thirds of the year. A key step in any PPL reduction program is to reduce energy use during nonbusiness hours, as it is generally wasted. Figure 3 shows a comparison between measured daily energy consumption for an **ENERGY STAR**-rated ice machine before and after timer control was implemented. Nearly $150/year was saved by installing a $20 electrical outlet timer—and the users still had all the ice they needed.

For detailed information about how to control PPLs, refer to **Lobato et al. (2012)**.

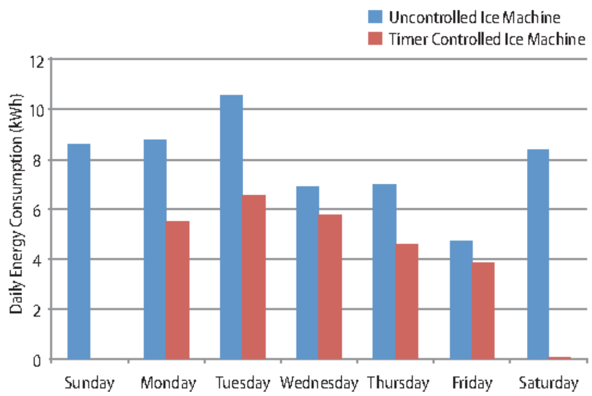


Figure 3. Ice machine daily load profile. *Graph by Chad Lobato, NREL*

Step 8: Address Unique Plug and Process Loads

Some equipment is not specified by building owners or employees. For example, outside contractors or vendors typically control food service areas, but the building owner covers their energy costs. For such situations, the owner should contractually require or provide the most efficient equipment available. Refer to **ENERGY STAR** and **EPEAT** for efficient options.

Energy-efficient gym equipment and ATMs may not be available and may be restricted from being turned off. These particular PPLs should be addressed on a case-by-case basis with the manufacturers to identify any possible solutions.

Step 9: Promote Occupant Awareness

A crucial step in reducing PPL energy use is to promote employee awareness of efficiency measures and best practices. Figure 4 is an example of a sticker that could be placed on computers and monitors to remind employees to turn off their equipment when it is not being used. Employee awareness can come in such forms as:

- Training
- Informational letters
- Emails
- Signage
- Videos
- Periodic reminders or updates.

Step 10: Address Plug and Process Loads (Design Team)

New construction and retrofit projects bring additional PPL reduction opportunities that the design team should address. The champion should work with the design team to question standard specifications, operations, and design standards that limit energy savings opportunities. One key role the design team plays in reducing PPLs is maximizing space efficiency, which increases the ratio of occupants per building area or piece of equipment. Increasing space efficiency decreases areas of dense PPLs, such as break rooms, common print areas, and cafeterias. Equipment in these areas is more efficiently used, and PPLs are reduced.

The design team has the opportunity to further reduce energy use by integrating PPL control strategies into the building's electrical system. Early in the design phase, the design team can build features into the electrical system to control the outlets at workstations and in common areas. This strategy can be as simple as installing switches, vacancy sensors, or timed disconnects for outlets, or as sophisticated as controlling outlets through the building management system.

The design team is typically responsible for specifying equipment such as elevators and transformers. The stairs should be designed to be as inviting and convenient as possible so employees want to use them. Elevators should then be carefully scrutinized to find the most efficient model. Some important features are reduced speed, occupancy-controlled lighting and ventilation, and smart scheduling.

The design team is also responsible for process cooling systems in areas with concentrated plug loads, such as information technology closets. These systems should use, where applicable, economizers, evaporative cooling, and waste heat recovery.

Figure 4. Sticker used at NREL to promote occupant awareness. *Illustration by Marjorie Schott, NREL*

Strategies ▼

The following best practices should be implemented to cost-effectively reduce PPL energy use without sacrificing functionality. When the following strategies recommend equipment replacement, refer to **ENERGY STAR** and **EPEAT** for energy-efficient options.

Note: The savings shown in the following strategies assume a utility rate of $0.10/kWh and an operating schedule of 10 business hours/day.

Strategies

Break Rooms and Kitchens

Refrigerators

For refrigerators in break rooms and kitchens, implement the following:

- ☐ Remove underused refrigerators to save $40–$80/year/refrigerator.
- ☐ Replace aging, inefficient refrigerators with the most efficient compliant refrigerators to save $40/year/refrigerator.
- ☐ Consolidate multiple mini-refrigerators into a full-size refrigerator to save $35/year/mini-refrigerator.
- ☐ Replace glass door refrigerators with similarly sized solid door refrigerators to save $60/year/glass door refrigerator.

Small Kitchen Appliances

- ☐ Upgrade items such as coffee pots, toasters, and microwaves with units that have limited parasitic loads from light-emitting diode (LED) lights or displays to save $1/year/item.
- ☐ Control these items with electrical outlet timers so they are powered down during nonbusiness hours to save $3/year/item.

Vending Machines

Vending machines have an approximate energy cost of $350/year/refrigerated machine. Implement the following strategies to reduce vending machine energy consumption:

- ☐ Remove underused machines to save $350/year/machine.
- ☐ Replace aging, inefficient vending machines with the most efficient equipment to save $150/year/machine.
- ☐ Remove the display lighting to save $65/year/machine.
- ☐ Implement a load-managing device (**Deru et al. 2003**) to save $95/year/machine.
- ☐ Set contractual requirements for vendors to use only delamped, energy-efficient vending machines that have a load-managing device preinstalled.

Drinking Fountains

- ☐ Disconnect or remove drinking fountain coolers and bottled water coolers.
- ☐ Replace aging drinking fountains and bottled water coolers with noncooled drinking fountains to save $55/year/cooler.

Workstations

Workstations represent a significant fraction of office building PPLs and overall building energy use. Figure 5 is an example of a low-energy workstation.

Computers

- ☐ Replace standard desktop computers with miniature desktop, laptop, or thin client computers to save as much as $60/year/computer.
- ☐ Disable screensavers and enable computer power management settings to save as much as $50/year/computer with use of the computer management features (**ENERGY STAR 2011**).
- ☐ Configure computers so users can manually trigger standby or sleep mode via:
  - ☐ The computer power button
  - ☐ The laptop docking station power button
  - ☐ Designated keyboard buttons
  - ☐ A standby icon on the computer desktop
  - ☐ Other external standby triggering devices.

Monitors

- ☐ Replace aging monitors with LED backlit liquid crystal display (LCD) monitors to save as much as $13/year/monitor (**Lobato et al. 2011**).

Task Lights

- ☐ Replace incandescent or fluorescent-tube task lighting with efficient compact fluorescent lamps (CFLs) or LED task lighting to save $15/year/task light.

Phones

- ☐ Replace standard phones with low-power (2-W maximum) voice over Internet protocol (VoIP) phones to save $10/year/phone.

Figure 5. Diagram of an example low-energy workstation.
Illustration by Matthew Luckwitz, NREL

Strategies

Printers, Copiers, Scanners, and Fax Machines

- Consolidate multiple personal devices into a single multifunction device to save $8/year/personal device.
- Enable the power option settings on the multifunction devices to go into standby after 15 minutes of idle time.

Parasitic Loads

- Implement power management surge protectors at work stations to reduce or eliminate the parasitic loads of equipment during nonbusiness hours.
- For detailed information about how to control PPLs, refer to Lobato et al. (2012).

Vertical Transport

Elevators

Elevator car lighting and ventilation are typically powered whether or not the car is occupied.

- Control elevator lighting and ventilation with occupancy sensors to save as much as $100/year/elevator.

Stairs

Building occupants should be encouraged to use stairs to reduce energy use and improve health.

Escalators

Escalators generally operate continuously during business hours, and in some cases continuously during nonbusiness hours.

- Control escalators so that they operate only during business hours or when needed to save as much as $900/year/escalator.

Small-Scale Food Service Areas

As with the break rooms and kitchens, replacing aging, inefficient equipment with the most efficient **ENERGY STAR** equipment will save energy. Food service areas present unique challenges because they are often outfitted and operated by outside vendors. It is important to work with the vendor to supply energy-efficient PPLs that meet their needs.

Refrigerators

- Remove underused refrigerators to save$40–$80/year/refrigerator.
- Replace aging, inefficient refrigerators with the most efficient compliant refrigerators to save $40/year/refrigerator.
- Consolidate multiple mini-refrigerators into a full-size refrigerator for a savings of $35/year/mini-refrigerator
- Replace glass-door refrigerators with similarly sized solid-door refrigerators to save $60/year/glass-door refrigerator.
- Set contractual requirements for vendors to use only the most efficient commercial refrigerators.

Nonrated Equipment

For equipment that is not rated by ENERGY STAR, or similar organizations, those responsible for specification and procurement should work directly with manufacturers to determine the most efficient option. Many manufacturers offer low-energy equipment options.

Small Kitchen Appliances

- Upgrade items such as coffee pots, toasters, and microwaves with units that have limited parasitic loads from status LED lights or displays to save $1/year/item.
- Control these items with electrical outlet timers so they are powered down during nonbusiness hours to save $3/year/item.
- Set contractual requirements for vendors to use only the most energy-efficient items.

Parasitic Loads

Food service equipment can have large parasitic loads during nonbusiness hours.

- Control equipment with electrical switches, or a similar method, to easily disconnect power to all nonessential equipment during nonbusiness hours.
- Set contractual requirements for vendors that will ensure that the equipment is disconnected and powered down during nonbusiness hours.

Strategies

Conference Room Equipment

Conference rooms are subject to varying use schedules.

- ☐ Implement controls that disconnect or turn off equipment when the space is unoccupied. Electrical outlet timers can be used to power down equipment during nonbusiness hours. Occupancy sensors can be used to disconnect power when the rooms are unoccupied during business hours.
- ☐ Outfit the space with energy-efficient equipment. LED backlit LCD televisions and energy-efficient projectors should be used for display purposes.

Server Room Equipment

- ☐ Implement an uninterruptible power supply that has the following features:
  - ☐ At least 95% energy efficiency
  - ☐ Scalable design
  - ☐ Built-in redundancy
  - ☐ End user serviceable
  - ☐ Sufficient uptime until the backup generator starts
  - ☐ Meets the efficiency guidelines of the **Server System Infrastructure** initiative, which sets open industry specifications for server power supplies and electronic bays.
- ☐ Load the uninterruptible power supply so it operates at peak efficiency.
- ☐ Use energy-efficient power distribution units.
- ☐ Use blade servers with variable-speed fans and energy-efficient power supplies.
- ☐ Implement virtualization software.
- ☐ Implement a hot aisle/cold aisle configuration.
- ☐ Implement hot aisle containment .
- ☐ Depending on climate zone, implement economizers and evaporative cooling.
- ☐ Capture waste heat from the servers for use in other areas of the building.

NREL (2013) and **Sheppy et al. (2011)** provide more details about energy reduction strategies in server rooms and data centers.

Telecommunications Room Equipment

Typical telecommunications rooms provide continuous power to all Ethernet switches and ports.

- ☐ Power these switches and ports based on occupant needs.

Additional Strategies

For office buildings that have large file storage needs, motorized compact shelving units should be replaced with manual hand crank compact shelving units to save energy.

Management policies should be implemented to address PPLs. These policies should minimize or eliminate the use of personal electronic equipment (coffee makers, fans, heaters, mini-refrigerators, decorative lighting, etc.) at the workstations. The policies should establish a standardized list of the energy-efficient equipment to be used in the building. They should provide a process for addressing atypical circumstances that may warrant what would otherwise be excessive PPL energy use.

For items that have not yet been addressed, refer to Lobato et al. (2011b) for the process required to power down PPLs when not in use. Items such as lobby displays, ice machines, and exercise equipment can be effectively controlled by commercially available control devices. The devices should be configured so the equipment is powered only during business hours.

For new construction and extensive retrofits, it is good practice to aggregate plug loads onto dedicated electrical panels. With dedicated plug load panels, the circuits can be integrated with the building control system to turn off all plug loads during nonbusiness hours. These panels also allow for easy energy submetering, which can be used to develop a building PPL energy use display system that can provide feedback to the building occupants.

Recommended Plug Load Energy Reduction Strategies for Office Buildings

Shown on the following page is a sample of the workbook available for **download** in full as an Excel file. It will help you identify potential energy savings by reducing plug loads.

For each strategy listed, answer the question "Is your building doing this?" If your response is "No" for any strategy, fill out the adjacent cells to the right to determine the total approximate savings that the given strategy could yield in your building. Strategies that are listed without savings numbers are highly variable depending on the office building being assessed.

Strategies

	Is your building doing this?			If you answered "NO," enter the quantity for each piece of equipment below to determine the approximate savings in your building.		
Strategies	**YES**	**NO**	**N/A**	**Potential Energy Savings per Piece of Equipment**	**Quantity in Your Building**	**Potential Annual Savings for Your Building (kWh)**
▸ Break Rooms and Kitchens						
Remove underused refrigerators	☐	☐	☐	**400 kWh/year** for every underused refrigerator that is removed	x___=	
Replace aging, inefficient refrigerators with one of the most efficient, full-size ENERGY STAR® refrigerators for every 60 people	☐	☐	☐	**400 kWh/year** for every inefficient refrigerator that is replaced	x___=	
Consolidate personal mini-refrigerators into a full-size shared refrigerator	☐	☐	☐	**350 kWh/year** for every mini-refrigerator that is removed	x___=	
Replace glass-door refrigerators with similarly sized solid-door refrigerators	☐	☐	☐	**600 kWh/year** for every glass-door refrigerator that is replaced	x___=	

NOTE: Potential energy savings are based on an assumption of 10 hours of operation per work day

References

ASHRAE. (2009). 2009 ASHRAE Handbook of Fundamentals, Chapter 18. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Deru, M.; Torcellini, P.; Bottom, K.; Ault, R. (2003). Analysis of NREL Cold-Drink Vending Machines for Energy Savings. Golden, CO: National Renewable Energy Laboratory. NREL/TP-550-34008. *www.nrel.gov/docs/fy03osti/34008.pdf.*

DOE. (2010). 2010 Buildings Energy Data Book. Washington, DC: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. *http://buildingsdatabook.eere.energy.gov/.*

ENERGY STAR. (2011). Power Manage Computers to Save Up to $50 Per Computer Annually. *www.energystar.gov/index.cfm?c=power_mgt.pr_power_mgt_low_carbon_join.*

Frank, S.; Lobato, C.; Long, N.; Gentile Polese, L.; Rader, E.; Sheppy, M.; Smith, J. (2010). Monitoring and Characterization of Miscellaneous Electrical Loads in a Large Retail Environment. Golden, CO: National Renewable Energy Laboratory, NREL/TP-5500-50044. Unpublished.

Lobato, C.; Pless, S.; Sheppy, M. (2011). Reducing Plug and Process Loads for a Large Scale, Low Energy Office Building: NREL's Research Support Facility. Golden, CO: National Renewable Energy Laboratory. NREL/CP-5500-49002. *www.nrel.gov/docs/fy11osti/49002.pdf.*

Lobato, C.; Sheppy, M.; Brackney, L.; Pless, S.; Torcellini, P. (2012). Selecting a Control Strategy for Plug and Process Loads. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5500-51708.

McKenney, K.; Guernsey, M.; Ponoum, R.; Rosenfeld, J. (2010). Commercial Miscellaneous Electric Loads: Energy Consumption Characterization and Savings Potential in 2008 by Building Type. Lexington, MA: TIAX LLC. May. *http://zeroenergycbc.org/pdf/2010-05-26%20TIAX%20CMELs%20Final%20Report.pdf.*

NREL. (2013). Information Technology Settings and Strategies for Energy Savings in Commercial Buildings. Golden, CO: National Renewable Energy Laboratory. NREL/FS-5500-51318. To be published.

Sheppy, M.; Lobato, C.; Van Geet, O.; Pless, S.; Donovan, K.; Powers, Chuck. (2011). Reducing Data Center Loads for a Large-Scale, Low-Energy Office Building: NREL's Research Support Facility. Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-52785. *www.nrel.gov/docs/fy12osti/52785.pdf.*

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Document Authors:
Michael Sheppy, Chad Lobato, Shanti Pless, Luigi Gentile Polese, Paul Torcellini

Email:
commercialbuildings@nrel.gov

National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

NREL/FS-5500-54175 • April 2013

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 10% post consumer waste.

LBNL-53729-Revised

After-hours Power Status of Office Equipment and Energy Use of Miscellaneous Plug-Load Equipment

Judy A. Roberson, Carrie A. Webber, Marla C. McWhinney,
Richard E. Brown, Margaret J. Pinckard, and John F. Busch

Energy Analysis Department
Environmental Energy Technologies Division
Ernest Orlando Lawrence Berkeley National Laboratory
University of California
Berkeley CA 94720, USA

May 2004

To download this paper and related data go to:
http://enduse.lbl.gov/Projects/OffEqpt.html

The work described in this paper was supported by the Office of Atmospheric Programs, Climate Protection Partnerships Division of the U.S. Environmental Protection Agency and prepared for the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

Table of Contents

List of Tables

List of Figures

Abbreviations, Acronyms, and Glossary of Terms

As Used in This Report

CRT cathode ray tube (monitor)

CPU central processing unit

ICS integrated computer system, in which computer and monitor share a power cord, (e.g., an LCD monitor powered through a computer) and may also share a housing (e.g., an Apple iMac)

ILPS in-line power supply: a type of external power supply found on the cord between the plug and the device; aka "fat snake" because it looks like the power cord swallowed a box or cylinder

LBNL Lawrence Berkeley National Laboratory (aka LBL or Berkeley Lab)

LCD liquid crystal display (monitor)

ME miscellaneous (plug-load) equipment

MFD multi-function device: a unit of digital equipment that can perform at least two of the following functions: copy, fax, print, scan

OE office equipment

OEM original equipment manufacturer

OS operating system (e.g., Windows XP or Mac OS X)

PC personal computer: a generic term that includes laptop computers, desktop computers and integrated computer systems; it includes both Apple and Intel-architecture machines

PDA personal digital assistant; a cordless (i.e., rechargeable) hand-held computer device

PIPS plug-in power supply: a type of external power supply that is incorporated into the cord's plug; aka "wall wart"

PM power management: the ability of electronic equipment to automatically enter a low power mode or turn itself off after some period of inactivity; PM rate is the percent of units *not off* that are in low power.

PM rate: the extent to which a given sample or type of equipment is *actually found* to have automatically entered a low power mode or turned itself off.

PM Enabling rate: the extent to which *settings in the user interface* of a given sample or type of equipment indicate the equipment is set to automatically enter low power or turn itself off.

XPS external power supply: a power supply external to the device that it powers; a voltage regulating device incorporated into either the power cord or the wall plug of a device

Acknowledgements

This study would not have been possible without the support of the ENERGY STAR Office Equipment and Commercial Buildings programs, as well as the cooperation of the owners and facility managers of the businesses, institutions, and organizations that participated, and whose anonymity we promised to maintain.

We would like to thank our reviewers:

Jim McMahon, Bruce Nordman, David Fridley and Steve Greenberg of LBNL;
Kent Dunn and Michael Thelander of Verdiem: Energy Efficiency for PC Networks, Seattle WA;
and Terry O'Sullivan of Energy Solutions, Oakland CA.

After-hours Power Status of Office Equipment and Energy Use of Miscellaneous Plug-Load Equipment

Judy A. Roberson, Carrie A. Webber, Marla C. McWhinney, Richard E. Brown, Margaret J. Pinckard, and John F. Busch

Abstract

This research was conducted in support of two branches of the EPA ENERGY STAR program, whose overall goal is to reduce, through voluntary market-based means, the amount of carbon dioxide emitted in the U.S. The primary objective was to collect data for the ENERGY STAR Office Equipment program on the after-hours power state of computers, monitors, printers, copiers, scanners, fax machines, and multi-function devices. We also collected data for the ENERGY STAR Commercial Buildings branch on the types and amounts of "miscellaneous" plug-load equipment, a significant and growing end use that is not usually accounted for by building energy managers. For most types of miscellaneous equipment, we also estimated typical unit energy consumption in order to estimate total energy consumption of the miscellaneous devices within our sample. This data set is the first of its kind that we know of, and is an important first step in characterizing miscellaneous plug loads in commercial buildings.

The main purpose of this study is to supplement and update previous data we collected on the extent to which electronic office equipment is turned off or automatically enters a low power state when not in active use. In addition, it provides data on numbers and types of office equipment, and helps identify trends in office equipment usage patterns. These data improve our estimates of typical unit energy consumption and savings for each equipment type, and enables the ENERGY STAR Office Equipment program to focus future effort on products with the highest energy savings potential.

This study expands our previous sample of office buildings in California and Washington DC to include education and health care facilities, and buildings in other states. We report data from sixteen commercial buildings in California, Georgia, and Pennsylvania: four education buildings, two medical buildings, two large offices (> 500 employees each), three medium offices (50-500 employees each), and five small business offices (< 50 employees each). Two buildings are in the San Francisco Bay area of California, nine (including the five small businesses) are in Pittsburgh, Pennsylvania, and five are in Atlanta, Georgia.

Introduction

Since the 1980s there has been continual growth in the market for electronic office equipment, particularly personal computers and monitors, but also printers and multi-function devices, which are replacing discrete copiers, fax machines and scanners in some office environments. According to 2003 projections by the Department of Energy, annual energy use by personal computers is expected to grow 3% per year, and energy use among other types of office equipment is expected to grow 4.2%; this growth is in spite of improvements in energy efficiency, which are expected to be offset by "continuing penetration of new technologies and greater use of office equipment" (EIA 2003).

In 1992 the US Environmental Protection Agency (EPA) launched the voluntary ENERGY STAR program, designed to curb the growth of CO_2 emissions by labeling the most energy-efficient electronic products for the mutual benefit of manufacturers, consumers, and the environment.[1] The first products to be labeled were computers and monitors; printers were added in 1993, fax machines in 1994, copiers in 1995, and scanners and multi-function devices in 1997 (EPA/DOE 2003). Continued improvement in energy savings among office equipment remains a focus of the ENERGY STAR program, which updates its product specifications as necessary to respond to changes in technology, energy consumption, and usage patterns.

ENERGY STAR labeled office equipment reduces energy use primarily through power management (PM), in which equipment is factory-enabled to automatically turn off or enter low power (any power level between off and on) after some period of inactivity, usually 15 or 30 minutes. Most office equipment is idle more often than it is active; among equipment that users tend to leave on when not in use, such as shared and networked devices, PM can save significant energy. ENERGY STAR devices have a large market share, but the percentage that actually power manage is lower for several reasons. Power management is sometimes delayed or disabled by users, administrators, or even software updates that change the factory settings in the interface; in addition, some network and computing environments (e.g., the Windows NT operating system) effectively prevent PM from functioning.

To accurately estimate energy savings attributable to the ENERGY STAR program, and target future efforts, current data are needed on the extent to which each type of office equipment is turned off or successfully enters low power mode when idle. Combined with measurements of the energy used in each power state, we can estimate typical unit energy consumption (UEC), which, combined with number of units currently in use, provides an estimate of total energy use, and program savings (Webber, Brown et al. 2002).

In our ongoing technical support of the ENERGY STAR program, the Energy Analysis Department at Lawrence Berkeley National Lab (LBNL) has conducted after-hours surveys (aka night-time audits) of office equipment in commercial buildings. Our previous series of surveys was conducted during the summer of 2000; it included nine buildings in the San Francisco Bay area and two in the Washington DC area. We recruited and surveyed a diversity of office types and documented just over 100 computers per site, on average. We collected data on the types, power states and PM delay settings of ENERGY STAR labeled office equipment (computers, monitors, copiers, fax machines, printers, scanners and multi-function devices). The methods and results of that study were reported previously (Webber, Roberson et al. 2001).

---

[1] The ENERGY STAR® program has expanded to include residential appliances and heating and cooling equipment, consumer electronics, building materials and components, refrigeration equipment, commercial buildings and new homes. Since 1996 it has been jointly administered by the U.S. EPA and DOE (http://energystar.gov/).

In that study we also recorded (but did not report) numbers of some 'miscellaneous office equipment,' such as computer speakers, external disk drives, portable fans and heaters, boomboxes, and battery chargers.

In this report, we present the results of our most recent (2003) after-hours survey of commercial buildings, which expanded on the previous study to include:

- buildings in Pittsburgh, Pennsylvania and Atlanta, Georgia,
- education buildings, health care buildings, and small offices, and
- an inventory of miscellaneous plug-load equipment.

As part of our ongoing effort to improve the accuracy of data used to evaluate the ENERGY STAR program, we wanted to capture data from a wider range of commercial building types and geographic regions. While our sample is not large enough to distinguish regional differences in equipment night-time or after-hours power status, we hope to improve the robustness of our data by increasing its geographic diversity. Also, because office equipment is not confined to offices or office buildings, we wanted to capture data from other types of commercial buildings, such as schools, which also have significant numbers of computers.

Collecting data on after-hours power status involves visiting buildings when most employees are gone. Given the difficulty of arranging after-hours access to most commercial buildings, we used this opportunity to simultaneously collect data for the ENERGY STAR Commercial Buildings program on the types and numbers of miscellaneous plug-load equipment, and to develop a taxonomy by which to categorize them. These data allow us to begin to better characterize the large 'plug-load' building energy end use category.

Methodology

The protocol used in this series of surveys changed from that of 2000 because of the need to develop a data collection protocol for miscellaneous equipment, and then integrate it with our office equipment protocol.

Building Sample

Table 1 below outlines the buildings in our sample, which are identified by a letter; for this purpose the small businesses are aggregated into one 'small office.' Appendix A describes them in more detail, but only in generic terms, to preserve the anonymity of occupants. As in 2000, our initial target was to collect data on at least 1,000 computers. In selecting types and numbers of commercial buildings to comprise that sample, we referred to data on computer densities provided by the Commercial Building Energy Consumption Survey (CBECS) (EIA/CBECS 2002). According to CBECS, in 1999, 74% of the U.S. population of computers were found among office, education, and health care buildings; therefore, our building recruitment effort focused on these three types of buildings. CBECS further characterizes offices by number of employees: 0-19 (small), 20-499 (medium), and 500+ (large).

To familiarize ourselves with what to expect (in recruitment effort and equipment found) in schools and health care buildings, we began by surveying a high school and a medical clinic in the San Francisco area. We then recruited and surveyed a variety of buildings in Pittsburgh in April, and Atlanta in June 2003.

Site recruitment is one of the most difficult and time consuming aspects of commercial building surveys. Usually it involves cold-calling from a list of prospective business or building types (e.g., high schools), briefly describing our research activity, and trying to connect with the person who is able and willing to grant after-hours access, which involves providing a key and/or escort. Most facilities have real concerns about safety, security, and privacy (e.g., of client or patient records), which of course must be addressed.

In each building, we surveyed as much area as possible in four hours or until we covered the area accessible to us, whichever came first. At two sites we surveyed a single floor, at four sites we surveyed the entire space available to us, and at the remaining six sites we surveyed portions of two or three floors. In general, the greater the density and variety of equipment found, the less area we covered in four hours. Floor areas are approximate gross square feet, based on floor plans or information from facility managers.

Table 1. Building Sample and Computer Density

site	state	building type	occupancy	in area surveyed (approximate no.)			computer density per	
				computers	ft^2	employees	1000 ft^2	employee
A	GA	education	university classroom bldg	171	28,000	n/a	6.1	n/a
B	PA	medium office	non-profit headquarters	182	55,000	128	3.3	1.42
C	GA	large office	corporate headquarters	262	28,000	120	9.4	2.18
D	CA	education	high school	112	40,000	n/a	2.8	n/a
E	GA	medium office	business consulting firm	37	22,000	70	1.7	0.53
F	PA	education	high school	248	100,000	n/a	2.5	n/a
G	CA	health care	outpatient clinic	177	45,000	n/a	3.9	n/a
H	GA	medium office	information services dept	153	24,000	76	6.4	2.01
J	PA	health care	private physicians' offices	56	26,000	n/a	2.2	n/a
K	PA	small office	5 small businesses combined	117	20,000	77	5.9	1.52
M	PA	large office	corporate headquarters	73	40,000	125	1.8	0.58
N	GA	education	university classroom bldg	95	20,000	n/a	4.8	n/a
			total	**1,683**	**448,000**	n/a = not available		

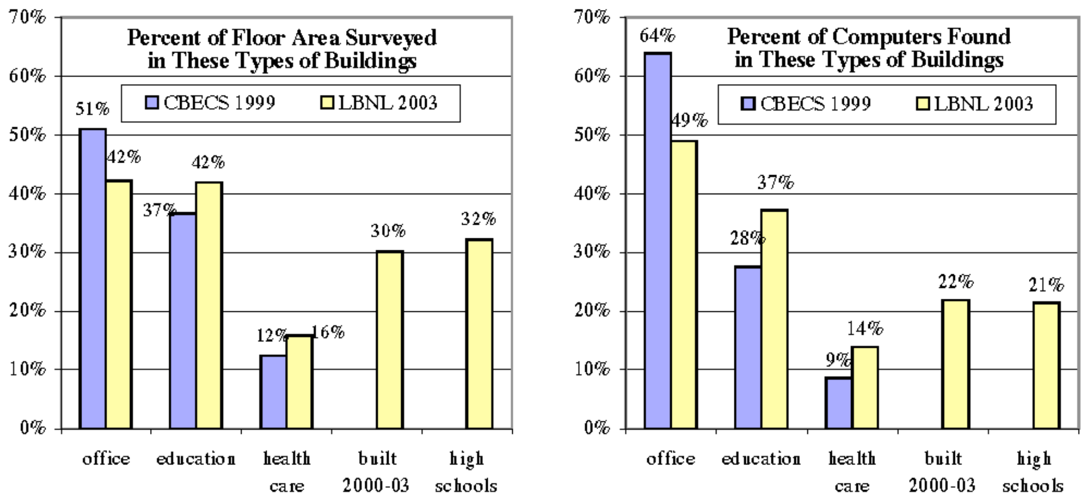
Our characterization of offices differs slightly from that of CBECS. By our definition a small office has <50 employees, a medium office has 50-500 employees, and a large office has >500 employees on site. Also, CBECS appears to classify offices by the number of employees per building, while we classify them by the number of employees per location. For example, our site E is a 'medium office' (50-500 employees) that occupies one floor of a high-rise office tower; however, CBECS might consider the same office to be part of a 'large office' (over 500 employees) that includes all offices within the entire building.

Our 'small office' is actually aggregated results for five small businesses in three different buildings: (1) a graphics and printing business, (2) an environmental consulting firm, (3) a commodity brokerage firm, (4) a software development firm, and (5) an engineering firm. Their number of employees ranged from 4 to 25, with a collective total of 77 employees.

For the six offices in our sample, Table 1 also shows the approximate density of computers by gross square feet as well as per employee. We do not have number of employees (or computer density per employee) for education and medical facilities. For high schools, where the number of students is known, equipment density per student could be a useful metric if we had surveyed the entire building, which we did not. The number of students regularly using a university classroom building, as well as the number of employees in both education and medical buildings is much more variable and difficult to determine.

Although we used the CBECS data as a starting point in our building selection and recruitment efforts, our resulting building sample does not necessarily correspond to the much larger CBECS building sample. Figure 1 below compares our building sample to CBECS, based on the sum of floor area surveyed and number of computers found among all office, education, and health care buildings in each sample. Compared to CBECS, offices are somewhat under-represented in our current sample, while education and health care buildings are somewhat over-represented. In addition, new buildings and high schools may be over-represented in our building sample, though we don't have corresponding CBECS data for comparison.

Figure 1. Comparison of LBNL and CBECS Commercial Building Samples



Survey Protocol

Each survey takes four people up to four hours to complete, and occurs on a weekday evening or weekend. We usually work in two teams of two people, with one calling out information and the other recording it. Using a floor plan, clipboard, flashlight and tape measure, we systematically record each plug-load device. The flashlight helps in tracing cords to plugs, and the tape is used to measure TV and monitor screen sizes. Our data collection is as unobtrusive as possible; we don't turn computers on or off or access any programs, settings, or files. If a workspace is occupied or obviously in use, we skip it and return later, if possible.

Office Equipment Data Collection

For our purposes in this study, office equipment includes the following equipment categories and types:

computers: desktop, laptop (notebook or mobile), server, and integrated computer system (ICS);
monitors: cathode ray tube (CRT), and liquid crystal display (LCD);
printers: impact, inkjet, laser, thermal, solid ink, and wide format;
fax machines: inkjet, laser, and thermal;
copiers;
scanners: document, flatbed, slide, and wide format; and
multi-function devices: inkjet and laser.

For each unit of office equipment, we recorded the make (brand) and model as it appears on the front or top of the unit (we did not record information from the nameplate on the bottom or back of the unit). We recorded the diagonal measurement, to the nearest inch, of monitor screens, except those of laptops (note: for CRT monitors this measurement is smaller than the nominal screen (or tube) size). For laser printers and MFDs we scrolled through the menu options available in the user interface to find the "power save delay setting," which usually ranges from 15 minutes to "never."

We tried to record each unit of office equipment that had an external power supply (XPS). These devices offer significant potential for energy efficiency improvement because they draw power even when the unit of which they are part is turned off or disconnected (e.g., when a laptop computer or cell phone is removed from its charger, which remains plugged in). We distinguish two types of external power supply: a plug-in power supply (PIPS), in which an AC/DC voltage transformer is incorporated into the plug, and an in-line power supply (ILPS), which is incorporated into and appears as an enlarged part of the power cord. We also tried to record whether or not each printer, copier, and MFD was connected to a network via cable (to the extent that networks become wireless, network connection will become more difficult to determine).

The power state of each unit was recorded as on, low, off, or unplugged (exception: we did not record units that were unplugged if it appeared they were never used). Although some office equipment, particularly copiers, may have features that enable them to turn off automatically or enter low power manually (by user action), we assume that the vast majority of units found off were turned off manually (i.e., by a user) and that units found in low power entered that state automatically (i.e., without user action).

If a monitor/computer pair were both on, we recorded the screen content; the most common occurrences are a screensaver, application, log-in or other dialog box (e.g., "It is now safe to turn off your computer"). When a monitor is off and the computer to which it is connected is not, it can be difficult to tell whether the computer is on or in low power. The method we used to determine a PC's power state is outlined in Appendix B; in short, a clampmeter is used to measure relative current in the computer power cord before and after initiating a computer wake function, such as touching the mouse or keyboard (McCarthy, 2002).

The power state of a laptop computer is usually difficult to determine, unless it is in use and obviously on. A closed laptop has few external indicators, and those that are present are often ambiguous and inconsistent (e.g., between brands or models). In terms of improving our estimates of laptop unit energy consumption, the most relevant data are the amount of time each laptop spends plugged in, and how often its battery is (re)charged. Therefore, we recorded, at a minimum, whether or not each laptop was plugged in.

In this report the term 'computer workstation' refers to any combination of computer(s) and monitor(s) physically used by one person at a time; generally, there is a workstation associated with each office chair. Workstation configurations vary widely; most common is one desktop computer connected to one monitor, but we have noticed growing numbers of other configurations, including multiple computers with one monitor, multiple (usually LCD) monitors with one computer, and laptops used with a docking station and monitor. In this series of surveys, we identified each computer workstation by a unique number; i.e., all components of each workstation were identified by the same number. We did this for two reasons: first, to facilitate subsequent analysis of the relationship between computer and monitor power states; and second, to be able to characterize the variety of workstations found. These analyses are discussed in the Results.

Miscellaneous Equipment Data Collection

'Miscellaneous equipment' (ME) refers to plug-load devices whose energy use is not usually accounted for by building energy managers because they are portable, often occupant-provided units whose number, power consumption and usage patterns are largely unknown. All ME in this report, including lighting, is plug-load, as opposed to hard-wired, although for some equipment (e.g., commercial refrigerators) we did *assume* a plug. The sheer variety of ME necessitates development of a taxonomy by which it can be categorized and summarized. Appendix C presents our current miscellaneous equipment taxonomy.

For each unit of miscellaneous equipment we recorded any information (e.g., power state or rated power) that could be used to estimate unit energy consumption. For lighting we recorded lamp type (e.g., halogen), wattage, and fixture type (desk, floor, track, etc.). For battery chargers, we noted the portable component (drill, oto-opthalmoscope, walkie-talkie. etc.) and whether the charger was empty or full. For vending machines, we recorded temperature and product (e.g., cold beverage) and any lighting. For unknown equipment we noted make and model for later determination of identity and power specifications.

As with office equipment, we noted if there was a PIPS or ILPS. We also recorded PIPSs and ILPSs that were plugged in but unattached to equipment (such as a PIPS used to charge an absent cell phone) and those whose equipment could not be identified, such as among a maze of cords in a server room. Nevertheless, we undoubtedly missed some, so our reported number of PIPSs and ILPSs is actually a conservative estimate.

Limitations of This Methodology

One advantage of conducting after-hours building walk-throughs to collect data on office equipment power status is that a good variety and number of buildings can be recruited and surveyed. On the other hand, the data collected represent a snapshot in time, and do not capture variations in user behavior over time, which would require automated long-term time series metering of equipment power state and power levels.

This is our most robust sample of buildings to date for collecting data on the after hours power status of office equipment. It includes data on 1,683 computers (including desktops, ICSs, laptops and servers) and about 448,000 ft^2 in 12 commercial buildings, including schools and health care facilities in California, Georgia, and Pennsylvania. (In comparison, our previous (2000) survey included 1,280 computers in 11 office buildings in California and Washington DC.) However, we do not suggest that this sample is representative of commercial buildings as a whole or in part (e.g., by type, size, age, or location), or that the results presented here are statistically significant. It is a record of what we found that we hope will be of use to policy makers, researchers, and building managers.

Results and Discussion

Equipment Density

Table 2 shows the number and density, per 1000 approximate gross square feet, of office equipment, miscellaneous equipment, and the sum of OE and ME in each building, and for all buildings. Our survey captured data on over 10,000 units of equipment, including almost 4,000 units of office equipment.

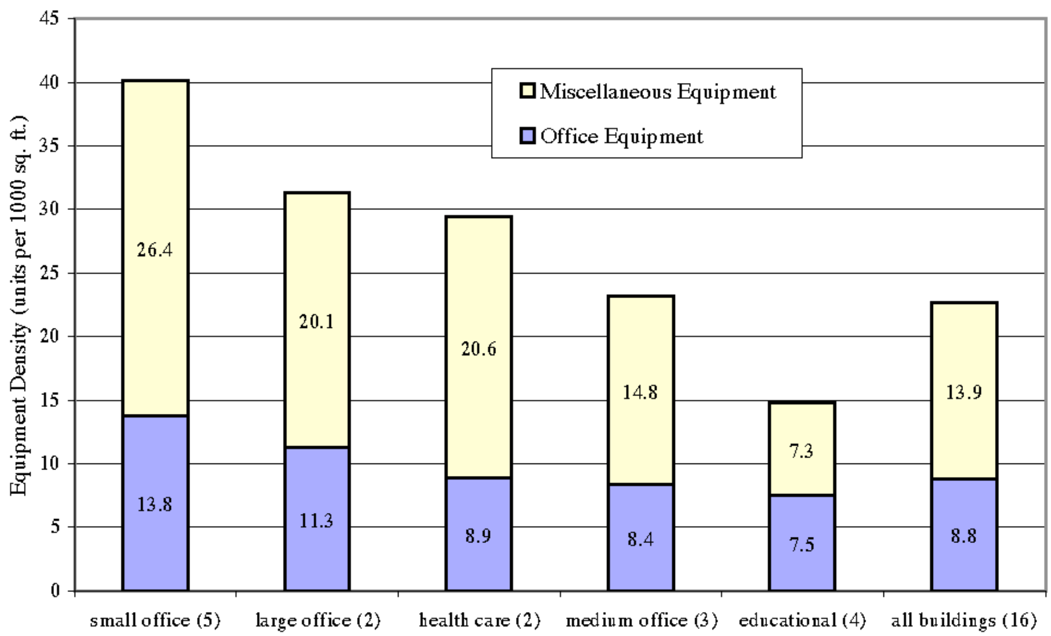
Table 2. Office and Miscellaneous Equipment: Number of Units and Density
sorted by Density of Office Equipment (units/1000 ft^2)

		Number of Units			Density (units/1000 ft^2)			Density (units/employee)		
bldg type	**site**	**OE**	**ME**	**OE+ME**	**OE**	**ME**	**OE+ME**	**OE**	**ME**	**OE+ME**
medium office	E	98	441	**539**	4.5	20.0	**24.5**	1.4	6.3	7.7
education	F	574	596	**1,170**	5.7	6.0	**11.7**			
large office	M	227	753	**980**	5.7	18.8	**24.5**	1.8	6.0	**7.8**
education	D	258	291	**549**	6.5	7.3	**13.7**			
health care	J	171	458	**629**	6.6	17.6	**24.2**			
medium office	B	410	422	**832**	7.5	7.7	**15.1**	3.2	3.3	**6.5**
education	N	204	234	**438**	10.2	11.7	**21.9**			
health care	G	460	1,002	**1,462**	10.2	22.3	**32.5**			
education	A	377	259	**636**	13.5	9.3	**22.7**			
small office	K	275	528	**803**	13.8	26.4	**40.2**	3.6	6.9	**10.4**
medium office	H	340	630	**970**	14.2	26.3	**40.4**	4.5	8.3	**12.8**
large office	C	540	612	**1,152**	19.3	21.9	**41.1**	4.5	5.1	**9.6**
all buildings		**3,934**	**6,226**	**10,160**	**8.8**	**13.9**	**22.7**	**3.2**	**5.7**	**8.9**

Note that the numbers of miscellaneous equipment units in Table 2 are lower than those in Appendix D because Table 2 does not include plug-in and in-line power supplies, while Appendix D does.

Figure 2 illustrates office and miscellaneous equipment density (per 1000 square feet), by building type.

Figure 2. Office and Miscellaneous Equipment Density, by Building Type (and number)



From Table 2 we see that the two buildings with the lowest combined equipment density are high schools, and Figure 2 shows that education buildings in our sample had the lowest equipment densities overall. Among our sample of 12 buildings, building types with the highest densities are small and large offices. We suggest that small offices may have high equipment density because every office needs certain devices (e.g., copier, fax machine, microwave oven, refrigerator), regardless of how many (or few) people share it. Medium offices exhibited a range of density (see Table 2, sites B, H), but on average their office equipment density is similar to and their miscellaneous equipment density is lower than that of health care facilities.

Closer examination of the results for each building reveals some underlying trends. For example, the only two buildings with a computer density less than 2 per 1000 ft^2 (from Table 1) were offices (one medium, one large) whose employees tend to rely on laptop computers, most of which were absent during our visit; one of these companies *requires* employees to take their laptops home or lock them up when not at work.

Office Equipment

Our sample includes data on the power state of 1,453 desktop computers (well above our target of 1,000), 1,598 monitors, 353 printers, 89 servers, 79 MFDs, 47 fax machines, 45 ICSs, 34 scanners, and 33 copiers. Among printers, our discussion of results will focus on the 158 laser and 123 inkjet printers found.

Among all buildings, computer density ranges from 1.7 to 9.4 per 1000 ft^2 gross floor area, (see Table 1). Among office buildings only, computer density ranges from 0.53 to 2.18 per employee. Office equipment density ranges from 4.5 to 19.3 units per 1000 ft^2 gross floor area, with an average of 8.8 (see Table 2). Among offices, office equipment density ranges from 1.4 to 4.5 units per employee, with an average of 3.2.

When analyzing the numbers of equipment in each power state, we are primarily interested in two values: turn-off rates and power management rates. ‘Turn-off rate’ is the percent of each equipment type that is turned off, while ‘PM rate’ is the percent of those *not off* that are in low power.

Table 3 shows the numbers of each type of office equipment, and their after-hours power state. Table 3 does not include laptop computers, units that were unplugged, or units whose power state was unknown.

Table 3. Office Equipment: After-hours Power States

Equipment		Number				Percent			
Category	**Type**	**on**	**low**	**off**	**sum**	**on**	**low**	**off**	**PM rate**
computers	desktop	869	60	524	1453	60%	4%	36%	6%
	server	87		2	89	98%	0%	2%	n/a
	ICS	7	11	27	45	16%	24%	60%	61%
monitors	CRT	259	648	422	1329	19%	49%	32%	71%
	LCD	56	164	49	269	21%	61%	18%	75%
printers	laser	53	81	24	158	34%	51%	15%	60%
	inkjet	86		37	123	70%	n/a	30%	n/a
	impact	16		6	22	73%	n/a	27%	n/a
	thermal	31		7	38	82%	n/a	18%	n/a
	wide format	2		6	8	25%	0%	75%	0%
	solid ink	1	3		4	25%	75%	0%	75%
MFDs	inkjet	9	4	3	16	56%	25%	19%	31%
	laser	36	14	13	63	57%	22%	21%	28%
copiers	all	12	5	16	33	36%	15%	48%	29%
fax machines	all	44	3		47	94%	6%	0%	6%
scanners	all	8	12	14	34	24%	35%	41%	60%

Note: “PM rate” is the percent of units *not off* that were in low power.

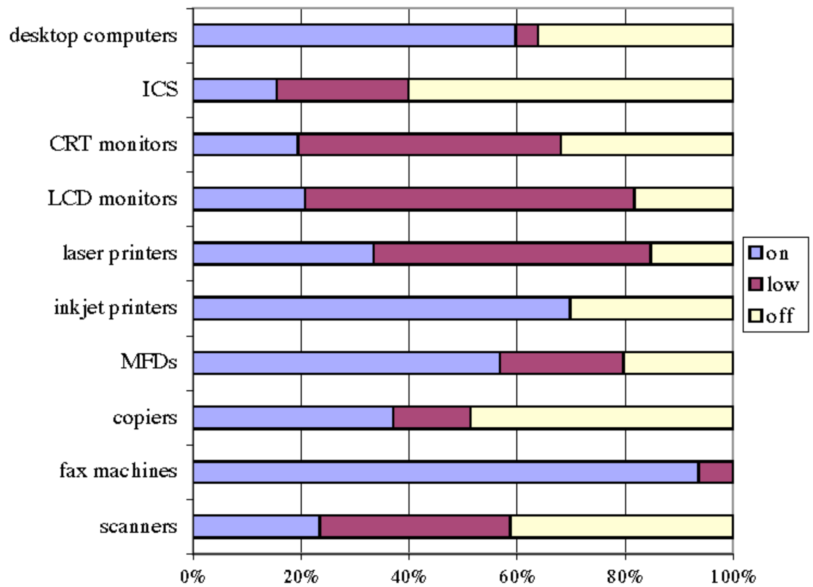
Not surprisingly, turn-off rates were lowest among fax machines and server computers. Turn-off rates were highest for integrated computer systems (60%), copiers (48%), and scanners (41%). PM rates were highest among LCD monitors (75%), CRT monitors (71%), ICSs (61%), scanners (60%), and laser printers (60%).

The lowest power management rates were among desktop computers and fax machines (6% of each). Because copiers and MFDs often have long (2-4 hour) PM delay settings that may not have elapsed at the time of our visit, PM rates in Table 3 for this equipment should be considered a minimum or lower bound. Figure 3 (below) graphically shows the breakdown by power state of each major type of office equipment.

Computers

We categorized computers as either desktop, integrated computer systems, servers, or laptops. Among 1,453 desktop computers the turn-off rate was 36%; it ranged from 5% (at Site E, medium office) to 67% (at Site B, medium office). Only 6% of all desktop computers that were not off were in low power. This PM rate is similar to the 5% rate found in a previous study (Webber, Roberson et al. 2001). Among the 45 ICSs in Table 3 the turn-off rate was 60%, and the PM rate was 61%. However, it is possible that of the 11 ICSs found in low power, only the display (but not the CPU) was in low power.

Figure 3. Office Equipment Power States



Among education buildings in our sample, the majority of the desktop computers, monitors and ICSs were found in classrooms clearly dedicated to computer-based learning. These "computer labs" typically have a 1:1 ratio between computers and chairs. Among the two high schools, 65% of desktop computers and ICSs were found in computer labs with at least 15 (and up to 77) computers each; among the two university classroom buildings, 68% of desktop computers and ICSs were found in computer labs with at least 15 (and up to 57) computers each. Because a single instructor likely controls the after-hours power status of all equipment in these rooms, and also because school buildings in general experience more 'after-hours' per year than other buildings, computer labs present a target for energy-efficiency efforts in schools.

Laptop Computers

There are 50 laptop computers in our sample, and we recorded information on the power state of 37. Of those 37, all but two (or 95%) were plugged in, either through their power cord or a docking station. Nine (or 24%) of the 37 laptops were clearly on; i.e., their display showed a desktop, application, or login screen.

Sixty percent (60%, or 21) of the 35 laptops that were plugged in were plugged into docking stations.[2] Of 107 docking stations found, 20% (21) were 'full', i.e., contained laptops, while 80% (86) were 'empty,' or without laptops. Those empty docking stations are evidence of at least 86 more laptops that were absent at the time of our visit. In addition, we found 35 power cords with ILPSs that we identified as "laptop charger, empty" (which we consider in the 'power' category of ME). Combined with 50 laptops and 86 empty docking stations found, we conclude that at least 171 laptop computers are in use among our sample of buildings. Of course, this number does not include (and we did not attempt to estimate) the number of people who take both their laptop and its power cord/battery charger home or lock them up at night.

[2] Docking stations are in our 'peripheral' miscellaneous equipment category; laptop computers are office equipment.

If we compare this minimum number of laptop computers to the total number of non-server computers in our sample, from Table 3 (1,453 desktops + 45 ICSs, + 171 laptops = 1669 total), laptops comprise approximately 10% of non-server computers found in our survey; again, this is a conservative estimate.

Some offices appear to have largely switched from desktop to laptop computers. Table 4 shows that in two (of six) offices in our sample – one large and one medium office – the sum of laptop computers, empty docking stations and empty laptop battery chargers (ILPSs) outnumbered the desktop computers found.

Table 4. Ratio of Laptop to Desktop Computers at Two Sites

Site	no. of desktop computers	number of laptop computers			
		laptops found	empty docking stations	empty laptop chargers	estimated total
E	**20**	4	11	9	**24**
M	**41**	26	40	9	**75**

Monitors

The average turn-off rate among 1,329 CRT monitors was 32%; it ranged from 17% at Site E (medium office) and N (university) to 62% at Site D (high school). 71% of CRT monitors that were not off were in low power. Among the 269 LCD monitors in Table 3 the turn-off rate was 18% and the PM rate was 75%.

Assigning a unique number to each computer/monitor workstation enabled us to analyze the relationship between computer power state and monitor power state. Table 5 shows the results of that analysis. (Note: Table 5 does not include monitors connected to more than one computer.)

Table 5. Analysis of Monitor Power Management by Computer Power State

			Monitor Power State			Monitor Power Management *	
Computer	Computer Power state	No.	Off	Low	On	Monitor PM Rate (computer is off or in low power)	PC-initiated Monitor PM Rate (computer is on)
Desktop	Off/no signal	433	184	244	5	98%	
	Low	59	4	53	2	96%	
	On	689	154	286	249		53%
Laptop **	Absent or empty docking station	55	13	42	0	100%	
	Plugged-in or in docking station	23	4	15	4	79%	
Server	On	32	14	10	8		56%

*Monitor Power Management is the percent of monitors *not off* that are in low power
** These data refer to external monitors connected to laptop computers, not to the laptop display.

Computers can initiate low power modes in ENERGY STAR monitors. Power management settings in the computer operating system (OS) control panels determine if and when the computer sends a signal to the monitor that causes the monitor to enter low power. If an ENERGY STAR monitor is attached to a computer that is on, it will enter low power only if it receives this signal. "PC-initiated monitor PM rate" refers to the share of systems in which the computer signals the monitor to initiate PM, and the monitor responds. We can infer this rate only among systems in which the computer is on and the monitor is not turned off.

An ENERGY STAR monitor can also enter low power if there is no video signal from the computer, either because the computer is off, it is in low power, or the monitor is disconnected from the computer. "Monitor PM rate" refers to the share of monitors that power manage in the absence of a signal from the computer.

Among monitors that were not turned off, those connected to computers that were off or absent had monitor power management rates of 98% (with desktop computers) and 100% (with laptops); monitors not off and connected to desktop computers that were in low power had a 96% monitor PM rate. In the remaining cases, the monitor may have been incapable of power managing (i.e., it was non-ENERGY STAR). Monitors not off and connected to desktop or server computers that were on had PC-initiated monitor PM rates that were much lower: 53% (for desktop computers) and 56% (for servers). Clearly, monitors that depended on a computer signal to initiate power management were much less likely to enter low power.

In our 2000 study we did not uniquely identify each workstation and so could not conduct this analysis. However, our 2003 monitor "PC-initiated PM rate" differs from the monitor "PM enabling rate" of another recent but unpublished study. In 2001, researchers at Energy Solutions in Oakland CA (O'Sullivan 2003) used **EZ Save** software[3] to remotely obtain (via local area networks) the PM *settings* of over 7,000 computer monitors at 17 commercial and institutional sites in the San Francisco Bay area. They found that monitor PM settings in the computer OS control panel were enabled for 44% of monitors. We would expect the share of monitors that *actually* power manage when the computer is on to be lower than the share of computers *enabled* to power manage their monitors (because some monitors may not be ENERGY STAR, there may be network interferences with PM, etc). However, our "PC-initiated PM rate" of 53% for desktop computers is higher than the 44% "PM enabling rate" found by Energy Solutions. There are several possible explanations for this:

1) Energy Solutions' 2001 sample contained significantly more computers using the Windows NT OS (which does not support PM and is no longer supported by Microsoft) than LBNL's 2003 sample,
2) Newer computers may be more successful at initiating monitor power management, and newer computer equipment (like newer buildings) may be over-represented in our 2003 sample,
3) Our PC-initiated PM rate is calculated from a subset of monitors (those left on and attached to a PC left on), while Energy Solutions' enabling rate represents all monitors. If turn-off and enabling rates are not independent (i.e., if people who leave their devices on at night are more likely to enable than those who turn their devices off), that could explain part or all of the discrepancy.
4) PC-initiated monitor PM rates actually have risen, as individuals and organizations respond to ENERGY STAR or other educational programs about the energy savings potential of monitor PM, or
5) Our 2003 sample includes a wider variety of commercial building types and locations, and so is more representative than data collected only from office buildings in California,.

In any case, the ability of computers to power manage monitors deserves further scrutiny and improvement.

In the report on our 2000 office equipment field surveys (Webber, Roberson et al. 2001) we speculated that monitors in low power might be thought by users to be off. Among buildings in this report, Site M, a large office, offers anecdotal evidence regarding user (mis)interpretation of monitor power state. According to the facility manager, this company's strict policy is that employees turn their monitors off before leaving, and security personnel turn off any monitors found left on. Our data show that only 4% of monitors were on, but only 29% were actually off; the remaining 65% were in low power mode. This confirms our field observations that if a display is black or blank, users often assume the monitor is off, even though the front panel power indicator (which is amber and/or blinking when the unit is in low power) indicates otherwise.

LCD monitors were not even mentioned in the report on our 2000 field surveys of office equipment, but in 2003, LCDs were 17% of all monitors. As shown in Table 6, at three sites (including two high schools, D and F) we found no LCD monitors, but at two sites (E, medium office; A, university building), LCD monitors outnumbered CRT monitors, and at three others (B and H, both medium offices; and J, health care) LCDs were over 25% of all monitors found.

---

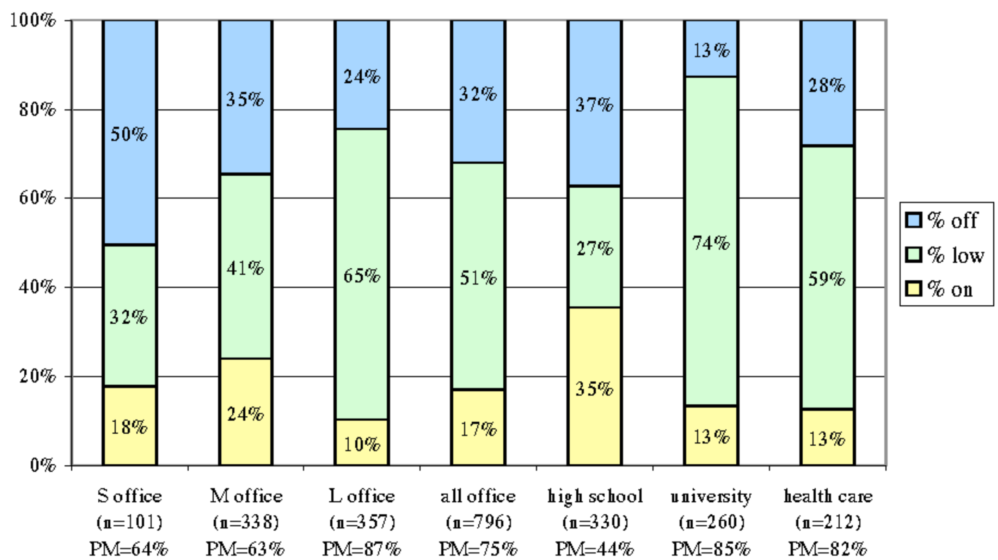
[3] **EZ Save** software was developed by the Department of Energy and adapted by the EPA ENERGY STAR program.

Table 6. Number and Percent of LCD Monitors, by Site
sorted by percent of LCD monitors

site	D	F	C	M	G	K	N	J	H	B	A	E	all
LCDs	0	0	2	4	12	14	13	18	40	66	96	21	286
CRTs	89	248	254	97	162	88	76	46	104	111	79	12	1366
total	89	248	256	101	174	102	89	64	144	177	175	33	1652
% LCDs	0%	0%	0%	4%	7%	14%	15%	28%	28%	37%	55%	64%	17%

While our building sample is not large enough to draw reliable conclusions about office equipment power management based on building type, we did some analysis within our sample. Figure 4 shows the after-hours power status of monitors (both CRT and LCD) based on building type. (A similar analysis for desktop computers and ICSs is not shown here because almost all the computers found in low power were in a single (health care) building, which may be anomalous.)

Figure 4. Monitor After-hours Power Status, by Building Type

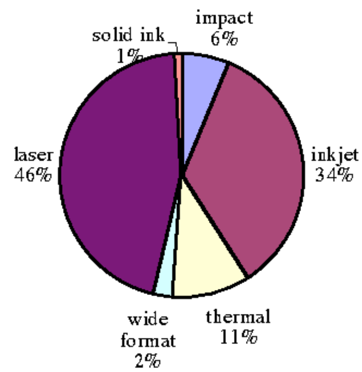


In our sample, monitor PM rates were by far the lowest in high schools (44%) and highest in university buildings (85%) and large offices (87%). Monitor turn-off rates were lowest in university buildings (13%) and highest in small offices (50%). In addition to the low monitor PM rate, a relatively high number (35%) of monitors were on in high schools, where all monitors found were CRTs, which use significantly more power when on than LCDs (Roberson, 2002). This strengthens the evidence that there is significant energy savings potential among office equipment in computer classrooms, and particularly those in high schools.

Printers

We categorize printers based on imaging technology: laser, inkjet, impact, thermal, wide format, solid ink.[4] Figure 5 shows the composition of our sample. Of 385 printers, 45% (174) were laser, 34% (132) were inkjet, 11% (41) were thermal, 6% (25) were impact, 2% (8) were wide format, and 1% (4) were solid ink.

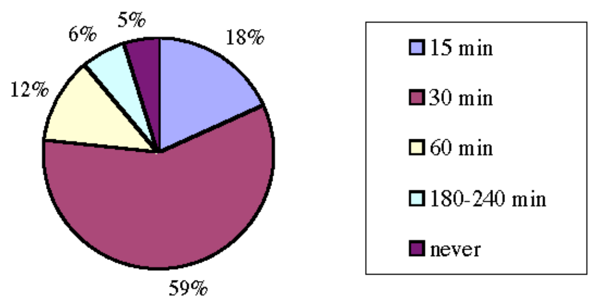
Figure 5. Printer Sample, by Technology



Of 158 laser printers in our sample, 15% were off, and 60% of those not off were in low power mode. Among the 123 inkjet printers the turn-off rate was 30%; we found no inkjet printers in low power. Of 38 thermal printers, which do not power manage, the turn-off rate was 18%. Of four solid ink printers none were off, but three (75%) were in low power.

For laser printers we tried to record "powersave" (i.e., low power) delay settings and whether or not they were networked. We did not record delay settings for laser printers that were off, or for those that did not have user interactive menus. Of 78 laser printers for which we actually recorded delay settings, 18% (14) were set to 15 minutes, 59% (46) were 30 minutes, 12% (9) were 60 minutes, 6% (5) were 180-240 minutes, and 5% (4) were set to "never" or off. Figure 6 displays this graphically.

Figure 6. Laser Printers: Powersave Delay Settings



[4] Wide-format is not an imaging technology, but rather an ENERGY STAR category for printers that accommodate 17"x 22" or larger paper. Of 8 wide format printers in our sample, 7 used inkjet, and one used impact technology.

Among printers for which we recorded the presence or absence of a network connection, 63% of laser printers but only 7% of inkjet printers were networked.

Only 60% of laser printers not off were actually found in low power (see Table 3). Not all laser printers can power manage (i.e., they are not ENERGY STAR), and so do not have powersave delay settings. Among laser printers that can power manage, there are several reasons they might be found on during our survey: (1) the printer has a long (3-4 hour) powersave delay setting, which had not elapsed, (2) the printer was recently used, and (3) the printer is in error mode, which effectively prevents it from entering low power.

Multi-Function Devices

The ENERGY STAR Office Equipment program distinguishes 'digital copier-based MFDs,' which are covered by their MFD program, from printer- and fax-based MFDs, which are covered by their printer program. In this study, we identify any multi-function device as an MFD, and distinguish between them on the basis of imaging technology (inkjet or laser), which we think is most relevant to power consumption.

Many units of office equipment that we identified in the field as copiers, fax machines, or printers turned out, on later examination of their specifications, to actually be multi-function devices. Among the 80 MFDs eventually identified, 80% (64) used laser technology, and the remaining 20% (16) were inkjets. Turn-off and PM rates were similar for laser and inkjet MFDs. Of 63 laser MFDs in Table 3 the turn-off rate was 21%, and 28% of those that were not off were in low power. Of 16 inkjet MFDs (at least some of which can power manage) the turn-off rate was 19%, and 31% of those not off were in low power.

Copiers

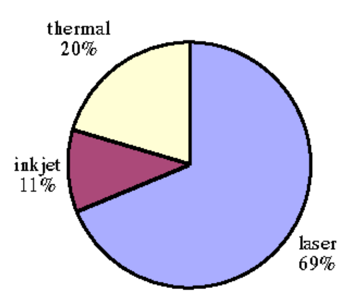
Of the 33 copy machines in Table 3, 48% were off and 29% of those that were not off were in low power. This low PM rate may be due in part to the fact that copiers often have powersave delay settings of two hours or more, and some of the copiers that we found on would eventually have entered low power.

Our 2000 field surveys of office equipment included 34 copiers and 11 'digital copier-based MFDs,' which yields a copier to 'digital copier-based MFD' ratio of 3:1. Our current sample includes 33 copiers and 64 laser or 'digital copier-based MFDs,' which yields a 2003 copier to 'digital copier-based MFD' ratio of 0.5:1. These numbers confirm our field observations that MFDs are replacing copiers in the marketplace.

Fax Machines

It can be difficult to tell whether a fax machine is on or in low power. Also, many units meet ENERGY STAR's low power requirement when on but idle or 'ready', and so do not need a separate low power mode. In this study, unless a fax machine gave a visual indication that it was in low power, we recorded it as being on. Of the 47 units in our sample and in Table 3, none were off and 6% (3) were in low power. Of the 44 fax machines whose technology we were able to determine, 69% (30) were laser, 20% (9) were thermal, and 11% (5) were inkjet. Figure 7 displays this graphically.

Figure 7. Fax Machine Technology



Scanners

Of the 34 scanners in Table 3, 41% were off and 60% of those that were not off were in low power. Of the total 37 scanners in our sample, 76% (28) were flatbed scanners, 14% (5) were specialized document scanners, 5% (2) were wide format, and 5% (2) were slide scanners. Among flatbed scanners only, 18% (5) were on, 43% (18) were in low power, 29% (8) were off, and 11% (3) were unplugged. All five document scanners were off; both wide format scanners were found in the same room, and were on.

Office Equipment: Comparison of 2000 and 2003 Turn-off and PM Rates

A primary goal of this study is to update information on office equipment turn-off and power management rates from previous studies, and to broaden the range of buildings in which this data is collected. Table 7 compares the office equipment turn-off and PM rates from this series of surveys to those from our 2000 field surveys of office buildings in California (Webber, Roberson et al. 2001).

In most cases, our 2003 field data yield turn off and PM rates that are virtually the same as those found in 2000. Notable exceptions are that monitor PM rates were higher (72% in 2003 c.f. 56% in 2000) and MFD PM rates were much lower in 2003 than in 2000 (29% in 2003 c.f. 56% in 2000). Also, copier and scanner turn-off rates were higher in 2003 than in 2000.

Table 7. Office Equipment Turn-off and Power Management Rates

			Turn-off Rate		**PM Rate**	
Category	**Type**	**no. in 2003**	**2000**	**2003**	**2000**	**2003**
computers	desktop + ICS	1,498	44%	37%	5%	7%
	desktop	**1,453**		**36%**		**6%**
	ICS	45		60%		61%
monitors	**all**	**1,598**	**32%**	**29%**	**56%**	**72%**
	CRT	1,329		32%		71%
	LCD	269		18%		75%
printers	all	353	25%	23%	44%	31%
	monochrome laser		24%		53%	
	high-end color		15%		61%	
	laser	**158**		**15%**		**60%**
	inkjet	**123**	**31%**	**30%**	**3%**	**0%**
	impact	22	31%	27%	0%	0%
	thermal	38		18%		0%
	wide format	8	57%	75%	32%	0%
	solid ink	4		0%		75%
MFDs	**all**	**79**	**18%**	**20%**	**56%**	**29%**
	inkjet	16		19%		31%
	laser	63		21%		28%
copiers	all	33	18%	49%	32%	28%
fax machines	all	47	2%	0%		6%
scanners	all	34	29%	41%		60%

For computers, the 2003 PM rate of 6% is similar to the estimated 2000 rate of 5%, but the 2003 turn-off rate of 36% for desktop computers is lower than the 2000 turn-off rate of 44% for all computers.

The 2003 turn-off rate of 32% for CRTs matches the 2000 turn-off rate for all monitors, but the 2003 turn-off rate of 18% for LCD monitors is much lower. In 2003 we found a much higher PM rate for both CRT and LCD monitors (71% and 75%, respectively) than the 56% PM rate reported for all monitors in 2000.

For all laser printers (of which <2% are color) our 2003 turn-off rate of 15% is lower than the 2000 rate of 24% for monochrome laser printers. The 2003 turn-off rates for inkjet (30%) and impact (27%) printers are similar to the 2000 rates for both (31%). Among our small sample of 8 wide format printers in 2003, the 75% turn-off rate is significantly higher than the 57% reported in 2000. The 2003 turn-off rate of 0% for (a sample of four) solid ink printers is lower than the 2000 turn-off rate of 15% for high-end color printers.

The 2003 PM rate of 60% for laser printers is similar to the 2000 rate of 61% for "high end color" printers. In 2000 some inkjet and wide-format printers were in low power, but in 2003 we found none.

The 2000 study did not report on thermal or solid ink printers, probably because few or none were found. Solid ink is not a widespread printer technology; in 2003 we found four, all in the same building. Of 41 thermal printers in our 2003 sample, only 15% were found in offices; another 15% were in education buildings, but 70% were found in health care buildings. For thermal printers the 2003 turn-off rate is 18%; for solid ink printers it is 0%. The 2003 PM rate for thermal printers is 0%; for solid ink it's 75%.

In 2003 we distinguish between laser and inkjet MFDs, but their turn-off rates (19 and 21%, respectively) are similar to the 2000 rate of 18% for all MFDs. However, in 2003 the PM rate for both inkjet and laser MFDs (31 and 28%, respectively) are significantly lower than the 2000 rate of 56% for all MFDs.

Copiers had a much higher turn-off rate in 2003 (49%) than in 2000 (18%), but their PM rate in 2003 (28%) is slightly lower than in 2000 (32%). Because of confusion about fax machine power state, no PM rate was reported in 2000; however, in 2003, at least 6% of fax machines were in low power. For scanners, the turn-off rate rose from 29% in 2000 to 41% in 2003; the 2003 PM rate was 60%.

Miscellaneous Equipment

Miscellaneous Equipment: Numbers and Density

Miscellaneous equipment outnumbered office equipment in all buildings except one (a university, site A); at one medium office (site E), the ratio of miscellaneous equipment to office equipment exceeded 4:1. For all buildings combined, if external power supplies are included as miscellaneous equipment, the ratio of miscellaneous equipment units (7,668, Appendix D) to office equipment (3,934, Table 2) is almost 2:1.

For all buildings combined, the most numerous equipment types in each ME category are as follows:

audio/visual:	television (27% of audio/visual category), VCR (23%), overhead projector (14%)
food/beverage:	microwave oven (16%), undercabinet refrigerator (15%), coffee maker (12%)
portable hvac:	8-16" diameter fan (35%), heater (21%), < 8" diameter fan (20%)
laboratory:	scale (24%), spectrophotometer (18%), tabletop centrifuge (13%)
lighting:	fluorescent undercabinet lamp (60%), 13W compact fluorescent lamp (15%)
medical:	oto-opthalmoscope charger (25%), exam light (18%), x-ray light box (12%)
networking:	switch (30%), hub (22%), modem (14%)
office misc.:	clock and/or radio (22%), compact audio system (18%), pencil sharpener (17%)
peripheral:	computer speaker pair (52%), laptop docking station (12%), PDA dock (11%)
power:	lighted power strip (36%), plug-in power supply (35%), in-line power supply (8%)
telephony:	powered phone (42%), headset with network box (13%), conference phone (11%)
maintenance:	vacuum cleaner (21%), floor polisher (14%), clothes washer or dryer (12%).

Appendix D lists the number of miscellaneous equipment units, by category, found in each building. For all sites combined, the most numerous miscellaneous equipment categories are power (including external power supplies, which are discussed in the following section), lighting, and computer peripherals. The least numerous categories of plug-load miscellaneous equipment are money exchange and security. Figure 8 shows the relative numbers of each category of miscellaneous equipment, by type of building, and Figure 9 shows the density of each equipment category, in number of units per 1000 ft^2 of floor area surveyed.

Figure 8. Miscellaneous Equipment Numbers, by Category and Building Type

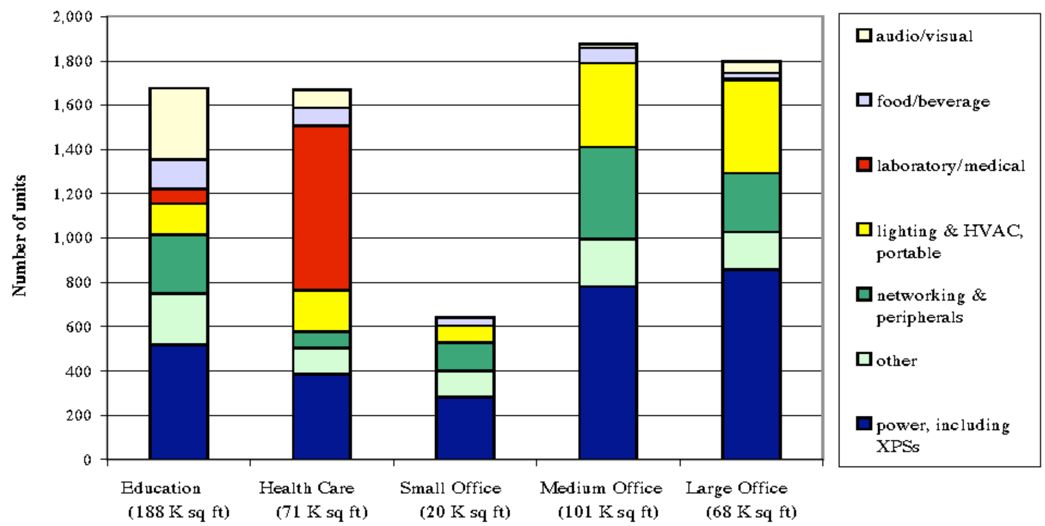
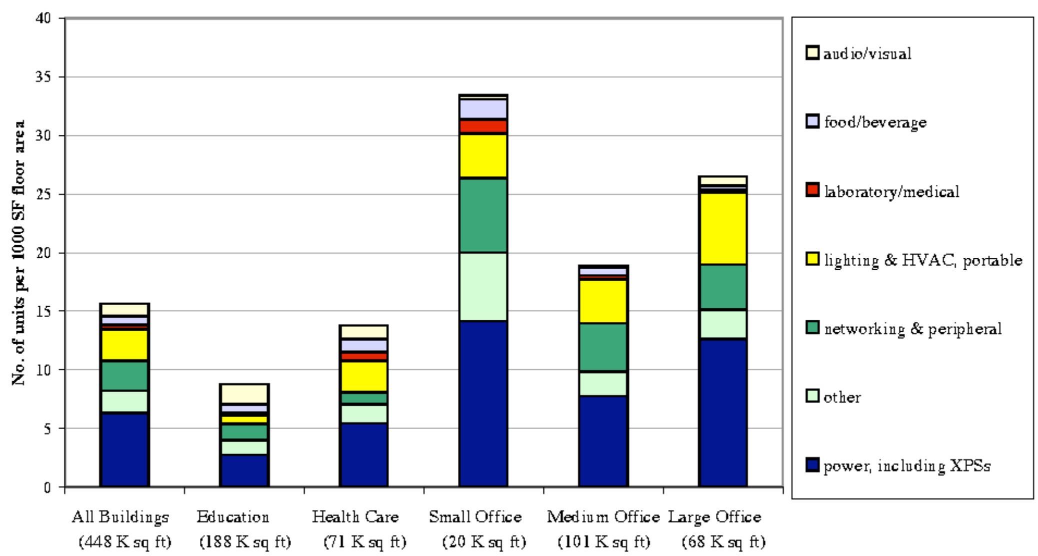


Figure 9. Miscellaneous Equipment Density, per 1000 ft^2 Floor Area



In Figures 8-11, some miscellaneous equipment categories have been combined for easier comparison. Specifically, we combined laboratory with medical and medical specialty, portable lighting with portable HVAC, and networking equipment with computer peripherals; 'other' combines the categories of money exchange, office miscellany, security, telephony, and utility/maintenance.

Not surprisingly, laboratory and medical equipment is the largest miscellaneous equipment category (in terms of number of units) in health care buildings, and audio/visual equipment is a significant category in education buildings. Networking equipment appears to be a smaller category in large offices; however, this result may be because we did not have access to network closets in the two large offices in our sample.

Miscellaneous Equipment: Relative Energy Consumption

An inventory is a necessary starting point, but does not reveal the relative total energy consumption (TEC) of ME found in our survey. For that we must first estimate the typical UEC of each type of equipment, which, when multiplied by number of units found, yields an estimate of TEC. We were able to estimate the UEC and TEC for over 70% (230 of 321 types) of ME found among buildings in this survey.

Typical unit energy consumption is the sum of the products of the power consumed in each power state (unplugged, off, on, active) and the likely number of hours per year (or percent time) spent in each state. We used data from previous metering projects and other available sources to estimate both parameters. In some cases we found UEC estimates in the literature. To estimate power consumed in each power state, we relied primarily on metering data by LBNL and others, online and published sources, and comparison to similar devices for which we have data (AD Little 1996, Cadmus 2000, USDOE 1995, Wenzel 1997).

In all cases, for both power levels and usage patterns, we recorded the basis of our estimates in order to facilitate subsequent evaluation and revision of our estimates based on new information or assumptions. To estimate the portion of time each type of miscellaneous equipment typically spends in each power state, we used data on as-found power states collected in this survey, supplemented by educated guesswork and personal experience. Here are some examples:

- we assumed that refrigerators, freezers, and refrigerated vending machines are always on,
- we estimated that microwave ovens in office lunchrooms are used 5 hours/week on average,
- 80% of VCRs found were on; we assume they are always on and estimated additional 10% usage,
- 60% of over 450 computer speaker pairs in our survey were found on; we used that data without adjustment, assuming that speakers found off during our survey were virtually always off.

Of course, for each type of equipment, usage and UEC may vary depending on the setting in which it is found. For example, a TV in a high school classroom is likely to be used less often that it would in a home. Similarly, a coffee maker is likely to be used more often in a typical office than it would in a typical home. Our UEC estimates apply to the buildings that we surveyed and do not necessarily apply in other situations.

We prioritized the considerable effort of estimating UECs by focusing on the most numerous and most energy-intensive equipment types. Miscellaneous equipment for which we do *not* have UEC (and therefore TEC) estimates include some specialized medical equipment and other equipment we could not meter and for which we could find no power specifications. That we do not have estimates of power use for some equipment does not mean that their consumption is insignificant, only that we were unable to estimate it at this time. Examples of equipment for which we have no estimate (with the number of them found) are:

- audio/visual category: video switch (9), power distribution & lighting system (5),
- food & beverage category: hot beverage dispenser (4), steam trays (3),
- peripheral category: keyboard/video/mouse (KVM) switch (27), pen tablet (17)
- power category: battery backup system (3), power amplifier (2)

For the 230 types of miscellaneous equipment for which we have estimates of both power consumption and time spent in each power mode, it is a simple matter to calculate typical unit energy consumption and (multiplying UEC by the number of units found) to calculate their total energy consumption. Obviously, any error in the UEC estimate is compounded (multiplied) by the number of units found. Also, the more power consumed and the more time spent on, the larger the potential error in our (absolute kWh) estimates.

Our UEC estimates ranged from 1 kWh/yr for pencil sharpeners to 7,008 kWh/yr for kilns; TEC estimates ranged from 1 kWh/yr (e.g., for one shaver) to almost 80,000 kWh/yr for 24 refrigerated vending machines.

Networking equipment in our survey, primarily ethernet hubs and switches, ranged from 1 to 80 ports each. Our inventory distinguishes these equipment by the number of ports (e.g., we list the number of 12-, 16-, 24-, 48-, and 80-port hubs separately), but our estimates of UEC and TEC are based on the sum of all ports, regardless of unit configuration. We found a total 2,120 ethernet switch ports and 451 ethernet hub ports.

Of the miscellaneous equipment for which we have UEC and TEC estimates, Table 8 shows the total energy consumption of miscellaneous equipment according to our categories. The top 50 in unit energy consumption are listed in Table 9 and the top 50 in total energy consumption are listed in Table 10.

The food & beverage category appears to dominate miscellaneous equipment in terms of *unit energy consumption*; eleven of the top 15 equipment types in terms of UEC are in the food & beverage category, which are shaded in Tables 9 and 10. The food & beverage category also dominates in terms of *total energy consumption*, accounting for half (50%) of total energy consumed. Table 10 shows that among our survey of commercial buildings the top ten types of food & beverage equipment in terms of TEC are:

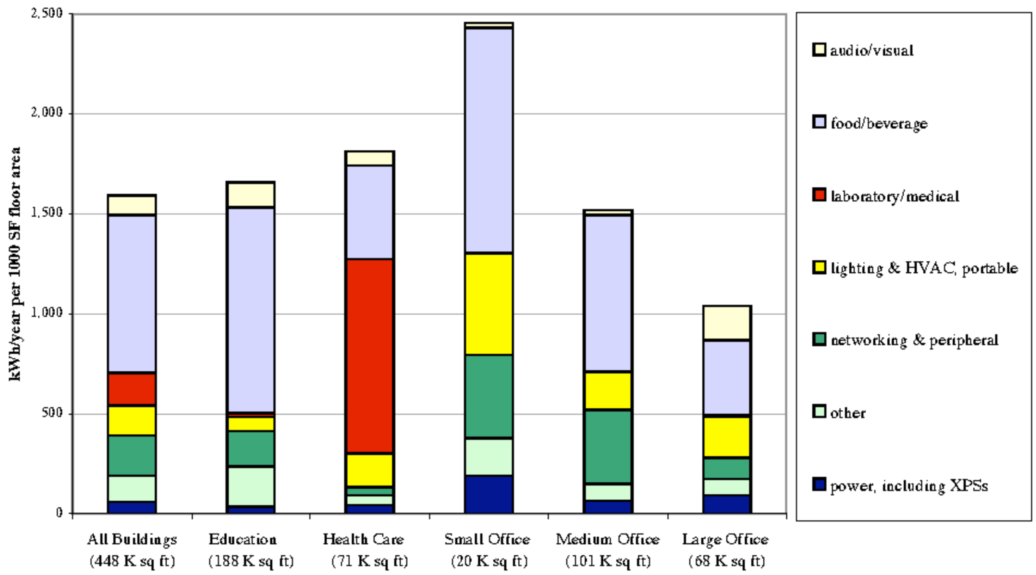
1) refrigerated vending machines
2) commercial refrigerators
3) commercial freezers
4) microwave ovens
5) coffee makers, commercial or specialty
6) hot food cabinets
7) coffee makers, residential models
8) small (undercabinet) refrigerators
9) room temperature vending machines
10) visi-coolers

While each ethernet switch port has a UEC of just 17 kWh/yr, the over 2,000 units have a collective TEC of over 35,000 kWh/year, which suggests this equipment is a good target for energy efficiency measures. We estimate that computer speaker pairs collectively account for almost 10,000 kWh/yr in these buildings; because these units are seldom used, their consumption represents a considerable energy savings potential.

Table 8. Total Energy Consumption of Miscellaneous Equipment, by Category

Miscellaneous Equipment Category	TEC (kWh/yr)	% of Sum
food/beverage	354,406	50%
laboratory/medical	72,583	10%
networking	53,775	8%
audio/visual	43,036	6%
lighting, portable	42,417	6%
computer peripherals	35,549	5%
other (money exchange, security, specialty, utility/maintenance)	38,285	5%
hvac, portable	26,731	4%
power, including XPSs	26,079	4%
office miscellany	13,114	2%
telephony	7,616	1%
All Miscellaneous Equipment Found in Survey	**713,591**	**100%**

Figure 10. TEC of Miscellaneous Equipment, Normalized by Floor Area (kWh/yr per 1000 ft²)



Figures 8-10 show that although small offices have the lowest numbers of miscellaneous equipment, they have the highest *density*, in both numbers and TEC, in all categories except audio/visual. This is consistent with Figure 2, in which small offices have the highest density of both office and miscellaneous equipment.

Figure 11. TEC of Miscellaneous Equipment, as Percent of Building Type

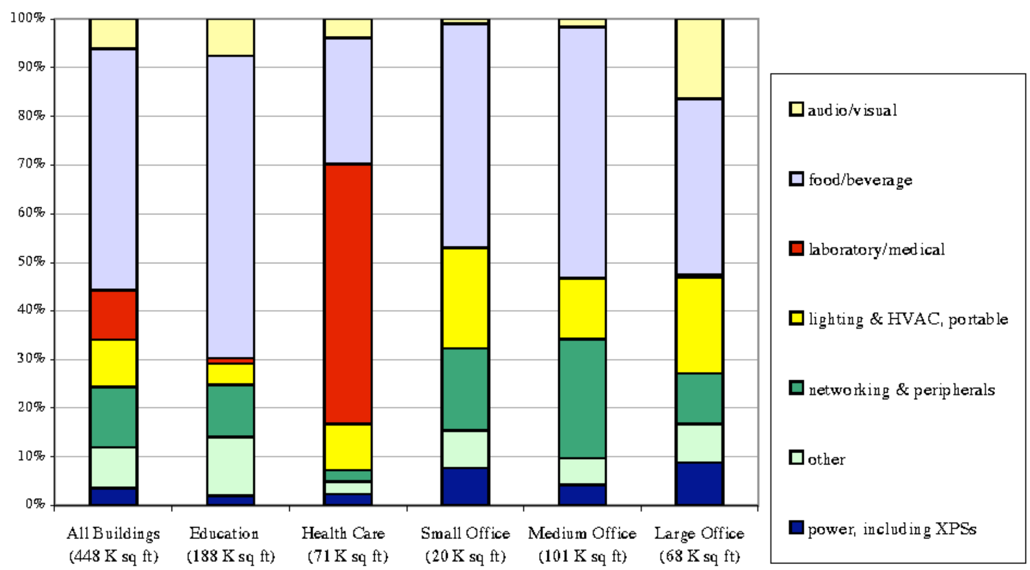


Table 9. Top 50 Miscellaneous Equipment Types, by Unit Energy Consumption

Note: Shading indicates equipment in the food & beverage category
Note: * indicates equipment for which we found and used published UEC values.

	Miscellaneous Equipment		Power Use (W)		Estimated Usage (percent time)			Unit Energy Consumption (UEC) kWh/yr
	Category	Type	On	Off	On	Off	Unplugged	
1	specialty	kiln	8000		10%	0%	90%	7,008
2	food & beverage	fryer						* 5,884
3	food & beverage	freezer, commercial						* 5,200
4	food & beverage	hot food cabinet						* 4,700
5	food & beverage	refrigerator, commercial						* 4,300
6	laboratory	autoclave	1500	0	30%	50%	20%	3,942
7	food & beverage	visi-cooler						* 3,900
8	food & beverage	vending machine, cold beverage						* 3,318
9	food & beverage	ice maker						* 2,167
10	food & beverage	vending machine, room T snack	205		100%	0%	0%	1,796
11	food & beverage	coffee maker, commercial or specialty	2595		6%	74%	20%	1,349
12	laboratory	drying oven or steam incubator	300	0	50%	50%	0%	1,314
13	food & beverage	refrigerated case						* 1,214
14	audio/visual	LED display sign, networked	135	15	100%	0%	0%	1,183
15	food & beverage	soda fountain pump or smoothie maker	100	0	100%	0%	0%	876
16	networking	switch, fiberoptic, 24 port	96		100%	0%	0%	841
17	food & beverage	bottled water tap, hot & cold						* 799
18	food & beverage	water cooler, hot & cold						* 799
19	HVAC, portable	air cleaner						* 761
20	utility/maintenance	clothes washer						* 704
21	food & beverage	refrigerator, L (full-size)						* 701
22	food & beverage	refrigerator/freezer						* 701
23	peripheral	external drive, tape backup	100		80%	10%	10%	701
24	audio/visual	system control, rack-mount	79	5	100%	0%	0%	692
25	audio/visual	power/volume controller	79	5	100%	0%	0%	692
26	HVAC, portable	room air conditioner						* 630
27	utility/maintenance	clothes dryer						* 622
28	specialty	bookshelves, mobile	70	0	100%	0%	0%	613
29	utility/maintenance	pump, water treatment chemical	70	0	100%	0%	0%	613
30	food & beverage	refrigerator, M (apt-size)						* 567
31	utility/maintenance	exhaust fan, industrial	125	0	50%	50%	0%	548
32	laboratory	refrigerator, S	60	0	100%	0%	0%	526
33	laboratory	freezer	60	0	100%	0%	0%	526
34	lighting, portable	incandescent tracklight, 50 lamps each	2000	0	3%	97%	0%	520
35	telephony	phone/PBX centrex system	55.5		100%	0%	0%	486
36	food & beverage	coffee maker, residential model	865	0	6%	69%	25%	450
37	food & beverage	microwave oven	1620	3	3%	97%	0%	447
38	medical specialty	charger, suction pump	50	3	100%	0%	0%	438
39	peripheral	disk array	50		100%	0%	0%	438
40	networking	tape drive	100		50%	50%	0%	438
41	medical specialty	sterilizer, hot bead	90		50%	50%	0%	394
42	audio/visual	digital video camera	70	3	60%	40%	0%	378
43	networking	router	40		100%	0%	0%	350
44	peripheral	external drive, other	50		80%	20%	0%	350
45	medical specialty	charger, defibrillator	50	3	75%	25%	0%	335
46	HVAC, portable	heater	750		5%	48%	48%	329
47	peripheral	external drive, hard disk	50		67%	25%	8%	292
48	food & beverage	refrigerator, S (undercabinet)						* 277
49	networking	video processor, rack-mount	30		100%	0%	0%	263
50	lighting, portable	incandescent studio lamp, 500W	500	0	6%	94%	0%	260

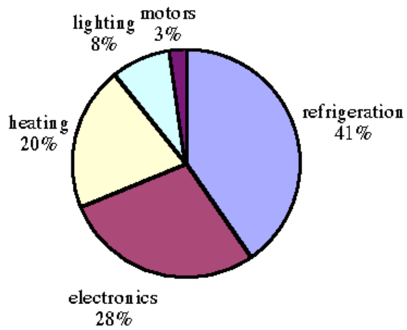
Finally, we characterized the top 50 miscellaneous equipment types in Table 10 according to these broader end-use or technology categories: electronics, heating, lighting, motors, and refrigeration. For equipment that could belong in more than one of these categories, we categorized it based on its primary technology or consumption. For example, refrigerated vending machines are a 'refrigeration' end use, while room temperature vending machines are 'lighting;' microwave ovens and computer projectors are categorized as 'electronics' although they might alternatively be categorized as 'heating' and 'lighting,' respectively. Figure 12 shows the relative consumption of equipment in Table 10 according to these end-use categories.

Table 10. Top 50 Miscellaneous Equipment Types, by Total Energy Consumption

Note: Shading indicates equipment in the food & beverage category

	Miscellaneous Equipment		number	Energy Consumption, kWh/yr	
	Category	Type	found	per Unit	Total
1	food & beverage	vending machine, cold beverage	24	3,318	79,632
2	food & beverage	refrigerator, commercial	18	4,300	77,400
3	networking	switch, ethernet, total no. of ports	2120	17	35,285
4	food & beverage	freezer, commercial	5	5,200	26,000
5	food & beverage	microwave oven	53	447	23,675
6	specialty	kiln	3	7,008	21,024
7	lighting, portable	fluorescent undercabinet lamp, ave 24"	626	33	20,833
8	food & beverage	coffee maker, commercial or specialty	15	1,349	20,241
9	laboratory	autoclave	5	3,942	19,710
10	food & beverage	hot food cabinet	4	4,700	18,800
11	food & beverage	coffee maker, residential model	39	450	17,542
12	food & beverage	refrigerator, small (undercabinet)	50	277	13,860
13	food & beverage	vending machine, room T snack	7	1,796	12,571
14	food & beverage	visi-cooler	3	3,900	11,700
15	HVAC, portable	heater	33	329	10,841
16	power	plug-in power supply (PIPS), attached	878	11	9,999
17	peripheral	computer speakers (pair)	464	21	9,836
18	food & beverage	refrigerator, M (apt-size)	17	567	9,641
19	food & beverage	bottled water tap, hot & cold	12	799	9,588
20	food & beverage	ice maker	4	2,167	8,668
21	HVAC, portable	air cleaner	11	761	8,371
22	networking	router	23	350	8,059
23	lighting, portable	incandescent desk/table lamp, 75W ave	99	78	7,722
24	peripheral	external drive, tape backup	11	701	7,709
25	audio/visual	VCR	113	64	7,214
26	audio/visual	LED display sign, networked	6	1,183	7,096
27	medical specialty	charger, defibrillator	21	335	7,036
28	audio/visual	TV (all sizes)	130	53	6,941
29	audio/visual	projector, overhead	68	96	6,524
30	peripheral	projector, computer	32	204	6,523
31	food & beverage	fryer	1	5,884	5,884
32	laboratory	refrigerator, S	11	526	5,782
33	power	UPS (uninterruptible power supply)	137	36	4,983
34	medical	exam table w/ heated drawer	38	130	4,940
35	networking	hub, ethernet, all sizes, total no. ports	451	11	4,938
36	office miscellany	adding machine	81	58	4,730
37	medical	charger, oto/opthalmoscope	116	39	4,573
38	telephony	phone, powered	98	42	4,116
39	peripheral	external drive, hard disk	13	292	3,796
40	office miscellany	typewriter	32	116	3,700
41	medical specialty	vital signs monitor	24	153	3,679
42	specialty	bookshelves, mobile	6	613	3,679
43	HVAC, portable	fan, medium (8-16" diam)	56	62	3,495
44	audio/visual	system control, rack-mount	5	692	3,460
45	food & beverage	refrigerator, L (full-size)	4	701	2,803
46	medical specialty	sterilizer, hot bead	7	394	2,759
47	medical	exam light	87	31	2,714
48	networking	video processor, rack-mount	10	263	2,628
49	laboratory	drying oven or steam incubator	2	1,314	2,628
50	peripheral	external drive, other	7	350	2,450
				SUM	**607,780**

Figure 12. End-Use Breakdown of Top 50 Miscellaneous Equipment Types, by TEC

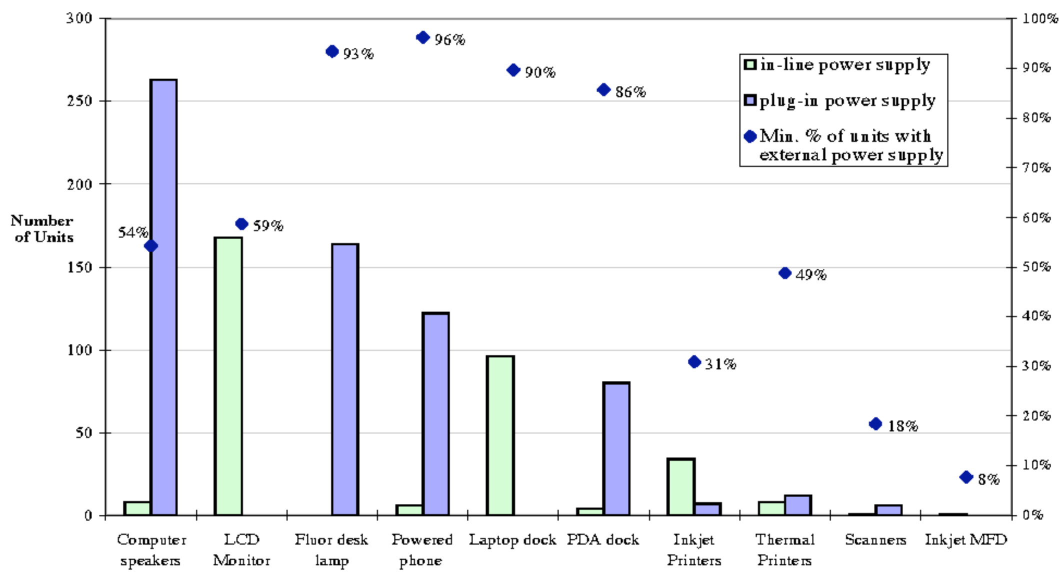


External Power Supplies

Figure 13 shows the types of equipment we found with external power supplies, the number of units of each equipment type that had an XPS, the type of power supply (ILPS or PIPS), and the minimum percent of each equipment category that had an XPS. It is a minimum value because although we tried to record every occurrence of an XPS, we did not capture all of them.

The most numerous XPSs were among computer speakers, LCD monitors, fluorescent desk lamps (whose PIPS included a magnetic ballast), powered phones (including conference and speaker phones), laptop and PDA docking stations. The highest percentage of units with XPSs were among powered phones, fluorescent desk lamps, laptop and PDA docking stations. ILPSs were prevalent among LCD monitors and laptop docking stations, while PIPSs prevailed among computer speakers, fluorescent desk lamps, powered phones and PDA docks. Equipment among which we found both ILPSs and PIPSs (though not on the same unit) were computer speakers, powered phones, PDA docks, inkjet printers, thermal printers, and scanners.

Figure 13. External Power Supplies: Number, Type and Frequency



Conclusions

For all buildings combined, the average plug-load equipment density in *units per 1000 gross ft^2*, was about 9 for office equipment and 14 for miscellaneous equipment, for a sum of about 23 units per 1000 gross ft^2. Educational buildings, where large floor areas are devoted to classrooms, had the lowest density of both office and miscellaneous equipment. However, two-thirds of computers and monitors found in educational buildings (and thus most of the energy savings potential) were concentrated in computer-based classrooms.

Among offices only (for which we were able to estimate number of employees, or occupants), the average equipment density, in *units per employee*, was approximately 3 units of office equipment and 6 units of miscellaneous equipment per employee, for a sum of about 9 electrical plug-load devices per employee; note that this includes equipment found in common areas such as kitchens, print centers, and utility closets. Because we have not attempted to estimate equipment density before, these data represent a baseline for reference and comparison with future data.

Office Equipment

A good overview of our results regarding office equipment power states is provided by Figure 3 (page 10), which allows a visual comparison of the percent of units found on, in low power, or off, by equipment type. Power management, indicated by the middle segment of each bar, is most successful among monitors and laser printers; and least successful among desktop computers, inkjet printers, copiers, and fax machines. Turn-off rates, indicated by the right segment of each bar, are highest (≥ 40%) among integrated computer systems, copiers, and scanners; and lowest (≤ 20%) among laser printers, LCD monitors, and MFDs.

This is the first field study in which we analyzed the effect of computer power state on monitor power state. Only 6% of desktop computers in this study of commercial buildings were found in low power, and only 53% of those that were on successfully initiated power management in monitors. Computers in homes (where fewer are networked) may have higher enabling rates, but we have no data from residences. Clearly there is significant room for improvement in power management of computers, and more data are needed to identify the parameters that affect the ability of computers to power manage themselves and their monitors.

In contrast, 96-98% of monitors connected to computers that were not on were found in low power, so a very high proportion of monitors are ENERGY STAR compliant, or capable of power managing themselves.

This report presents evidence of the growing use of laptop computers. Because of their inherent portability, accounting for laptops is difficult, especially during an after-hours survey, but our conservative estimate is that laptops comprise at least 10% of the non-server computers in our sample. We also estimate that laptops outnumbered desktop computers at two sites: one medium and one large office. To the extent that relatively energy-efficient laptops are replacing desktop computers, significant electrical energy is saved. However, more work is needed to characterize laptop usage patterns and energy consumption, which can vary widely depending on how often they are used when plugged in and how often the battery is charged. Laptop power state data from this survey can be useful in developing a typical unit energy consumption for laptop computers, but needs to be supplemented by data not available from after-hours surveys.

LCD monitors, which use significantly less energy when on than CRT monitors, are also penetrating the market. They outnumbered CRT monitors at two of the twelve sites in our sample: a medium office and a university classroom building. In contrast, we found no LCD monitors at three sites: two high schools and a large office. We expect the market share of LCD monitors to continue to grow as older CRT monitors are replaced and LCD monitor technology improves and becomes more affordable due to economies of scale.

For both types of education buildings in our sample (high schools and university classroom buildings), two-thirds of computers and monitors found were in "computer labs," or classrooms with a 1:1 ratio between computer workstations and chairs.[5] Some university computer labs had LCD monitors, but all the high school computer labs we visited had CRT monitors, many of which were found on after-hours. With so many workstations located in one room, and (presumably) controlled by one or very few instructor(s), we suggest efficiency efforts in high schools focus on reducing power consumed by equipment in these rooms.

Among our sample of printers, 46% were laser and 34% were inkjet. The turn-off rate was twice as high (30%) for inkjet printers as for laser printers (15%); inkjet printers are more likely to be turned off than laser printers because they are much less likely to be networked. Among laser printers, 77% had power management delay settings of 30 minutes or less, and only 5% were disabled (i.e., set to "never"). This indicates a high market penetration for ENERGY STAR laser printers; however, for reasons discussed above (including error messages and after-hours network use), the actual PM rate for laser printers is lower than indicated by PM delay settings. Nevertheless, the 2003 PM rate of 60% for laser printers is higher than the 2000 PM rate of 53% for monochrome laser printers, suggesting improvement in actual PM rates.

Eighty percent (80%) of multi-function devices that we found used laser imaging technology; the other 20% were inkjet. For both types, the average turn-off rate was about 20%, and the average PM rate was 30%, significantly lower than the 56% PM rate for MFDs observed in 2000. Power management rates among MFDs are important because MFDs appear to be replacing copiers in the workplace; the ratio of digital copier-based MFDs to copiers rose from 1:3 in our 2000 survey of office equipment to 2:1 in the 2003 survey reported here. However, while most MFDs can also fax, print, and scan, we did not observe a corresponding decrease in the relative number of fax machines, printers and scanners.

Miscellaneous Equipment

The inventory and energy consumption estimates of miscellaneous plug-load equipment presented in this report represent a first step toward characterizing the electrical demand of this large end-use category. Miscellaneous equipment outnumbered office equipment in our sample by a factor of almost two to one. While some energy-intensive devices, such as commercial refrigeration equipment, have been the target of efficiency efforts, including ENERGY STAR labeling, other less consumptive but more numerous devices, such as networking equipment and external power supplies, may offer significant energy savings potential.

According to our system of taxonomy, by far the most numerous category of miscellaneous plug-load equipment was 'power,' including power strips, surge suppressors, and external power supplies. The second most numerous category was 'lighting,' particularly undercabinet and compact fluorescent lamps, and the next most numerous category was computer 'peripherals,' 52% of which were computer speaker pairs. However, the numbers of each type of equipment do not necessarily reflect their relative energy intensity. The next step was to estimate typical unit energy consumption for the most common types of miscellaneous equipment, and begin to sort out their relative contribution to plug-load end use.

We were able to derive UEC estimates and calculate TEC for just over 70% of the types of ME found in our survey. Among miscellaneous equipment for which we have TEC estimates, equipment types with the top 50 TEC account for 85% of the total TEC—about 608K of 714K kWh/year, respectively. The food & beverage category accounts for 50% of the estimated (714K kWh/yr) TEC for all miscellaneous equipment devices. This category includes refrigeration equipment (freezers, refrigerators, vending machines) that are always on, as well as ubiquitous and frequently-used devices such as coffee makers and microwave ovens.

[5] We do not necessarily assume a 1:1 ratio between chairs and people; occupancy rates may vary between classes.

Future Work

The low rate of power management in desktop computers causes concern and deserves further investigation to ascertain barriers to computer power management as well as the most effective ways to mitigate them. One possibility would be to conduct more in-depth case studies in several types of buildings to identify specific institutional or technological impediments and evaluate the efficacy of various counter measures. Increasing power management among PCs would yield significant savings in both computers and monitors.

The increasing use of laptop computers makes it important to characterize their unit energy consumption. This would likely involve visiting offices during working hours and asking laptop users about their usage patterns, including how often the laptop is powered from a wall outlet and how often the battery is charged. It would also be useful to estimate the extent to which laptops are used in addition to or instead of desktops.

Results of this study point to the savings potential among computers and monitors in computer classrooms. We should improve our assessment of computer usage patterns in schools and develop effective strategies for realizing these savings. It would then be possible to implement prospective energy-saving measures in several computer classrooms and schools, and conduct follow-up surveys to evaluate their relative efficacy.

It would be useful to supplement these survey results with automated, network-based collection of data regarding usage patterns and power management settings of computers, printers, fax machines, and MFDs. While the former provides more detail, the latter yields significantly more data over longer periods of time.

Now that we have UECs for most common types of miscellaneous equipment, it would be possible to calculate their relative energy intensity among all buildings in our sample, or between types of buildings. Given utility bills for an individual building, we could work with building managers to estimate the portion of building energy load attributable to miscellaneous plug-load and to identify energy saving opportunities.

Additional after-hours building surveys could improve our understanding of office equipment usage and miscellaneous plug loads. Surveying a single building more than once (e.g., at weekly, monthly intervals) would help us to assess the robustness of the results from a single survey. The representativeness of our office equipment sample would be improved (compared to CBECS, for example) by visiting more large offices, and the completeness of our miscellaneous equipment inventory could be improved by ensuring that we survey their common or service areas such as network, phone and other utility closets. Furthermore, now that we have a baseline inventory of miscellaneous equipment, additional surveys and device metering would enable us to track changes in numbers and types of miscellaneous equipment, as well as their after-hours power status, and begin to characterize the typical ‘plug-load profile’ for various types of buildings.

References

AD Little. 1996. *Energy Savings Potential for Commercial Refrigeration Equipment.*

Cadmus. 2000. *Product Testing and Analysis of Water Dispensers.* Memo prepared for EPA's Energy Star Program. February.

EIA. 2003. *Annual Energy Outlook 2003 with Projections to 2025,* Dept of Energy, Energy Information Administration, Washington DC.

EIA/CBECS. 2002. *Computers and Photocopiers in Commercial Buildings.* Energy Information Agency, Commercial Building Energy Consumption Survey. US Dept of Energy (DOE), Washington DC.

EPA/DOE. 2003. *History of Energy Star.* http://208.254.22.7/index.cfm?c=about.ab_history

McCarthy, Kathryn, and R.E. Brown. 2002. (Draft) *A Field Method to Quickly Detect Power State in Plug-in Devices.* LBNL-54169. Lawrence Berkeley National Laboratory, Berkeley CA.

O'Sullivan, Terry, of Energy Solutions, Oakland CA. 2003. *Personal Communication,* November 30: Monitor power management enabling rates determined by EZ Save software.

Roberson, Judy A., G.K. Homan, A. Mahajan, B. Nordman, C.A. Webber, R.E. Brown, M. McWhinney, J.G. Koomey. 2002. *Energy Use and Power Levels in New Monitors and Personal Computers.* LBNL-48581. Lawrence Berkeley Lab, Berkeley CA. 36 pgs. http://enduse.lbl.gov/Info/Pubs.html

Rosen, K. and A. Meier. 1999. *Energy Use of Televisions and Videocassette Recorders in the U.S.* LBNL-42393. March. Lawrence Berkeley National Laboratory, Berkeley CA.

Roth, Kurt, Goldstein, Kleinman. 2002. *Energy Consumption by Office and Telecommunication Equipment in Commercial Buildings Volume 1: Energy Consumption Baseline.* Arthur D Little Reference No. 72895-00. US DOE

US DOE. 2003. *Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications.* Office of Energy Efficiency and Renewable Energy, Building Technologies Program. November.

US DOE. 1995. *Technical Support Document: Energy Efficiency Standards for Consumer Products: Refrigerators, Refrigerator-Freezers & Freezers.* DOE/EE-0064.

Webber, Carrie A., R.E. Brown, A. Mahajan, J.G. Koomey. 2002. *Savings Estimates for the Energy Star Voluntary Labeling Program: 2001 Status Report.* LBNL-48496. Lawrence Berkeley National Laboratory, Berkeley CA. 29 pgs.

Webber, Carrie A., J.A. Roberson, R.E. Brown, C.T. Payne, B. Nordman, J.G. Koomey. 2001. *Field Surveys of Office Equipment Operating Patterns.* LBNL-46930. Lawrence Berkeley National Laboratory, Berkeley CA http://enduse.lbl.gov/Info/Pubs.html

Wenzel et al. 1997. *Energy Data Sourcebook for the U.S. Residential Sector.* LBNL-40297. Lawrence Berkeley National Lab, Berkeley CA.

Appendix A: Building Descriptions

Site A

University classroom building, Atlanta GA
Urban, downtown campus; 4-story, circa 1970
Area surveyed includes chemistry and computer laboratory/classrooms, faculty offices, lecture hall, lobby, and storage.

Site B

Medium office, Pittsburgh PA
Headquarters of a national non-profit organization
Suburban office park, 3-story, new in 2002
Area surveyed includes computer lab/shop, conference, cubicles, custodial, kitchen, lounge, network closet, offices, print/copy centers, reception, server room, shipping & receiving.

Site C

Large office, Atlanta GA
National headquarters of an internet company
Midtown office building, 8-story, circa 1970s
Area surveyed includes customer call center, computer classrooms, break room, conference, cubicles, .offices, and print/copy centers.

Site D

Urban high school, CA
3-story main building, new in 2001
Area surveyed includes administrative offices, audio/visual studio, bookroom, classrooms, computer classrooms, conference, library, teachers lounge, network closet, print/copy center, utility/mechanical. Most computers are found in a few rooms, including computer classrooms and the library.

Site E

Medium office, Atlanta GA
Branch office of an international consulting firm
One floor of a 1990s suburban office tower
Area surveyed includes break room, conference, cubicles, lounge, offices, print/copy centers, server room. This office had a high percentage of laptop computers, which must be locked up or taken home at night. Only administrative staff have desktop computers, which are left on at night for backups and updates.

Site F

Urban high school, Pittsburgh PA
3-story main building, remodeled in 1990s
Area surveyed includes auditorium, cafeteria, classrooms (including art, band, language, computer classrooms, conference, library, teachers lounge, network closet, offices, storage, and A/V workroom. Most computers are found in a few classrooms and the library.

Site G

Outpatient clinic, San Francisco CA
10-story urban medical campus building
Area surveyed includes conference, cubicles medical labs, library, lounges, exam rooms (including E/N/T, general medicine, ophthalmology, pediatric), nurses stations, offices, patient registration, phone bank, medical utility, treatment rooms, and waiting. Each exam and treatment room had a computer/monitor.

Site H

Medium office, Atlanta GA
Information services department of a university
6-story urban campus building, circa 1970s
Area surveyed includes break room, conference, copy/print center, cubicles, custodial, lounge, network closet, offices, server room , and utility/mechanical.

Site J

Medical office building, Pittsburgh PA
Suites of physicians in private practice
5-story suburban building,
Area surveyed includes break room, conference, exam rooms (including cardiology, E/N/T, endocrinology, ophthalmology, sleep disorders, urology), kitchen, labs, offices, server room, storage, utility, and waiting.

Site K

Small office, Pittsburgh PA
5 small businesses in 3 different suburban buildings
Area surveyed includes break room, conference, copy/print center, cubicles, electronics shop, network closet, offices, server room , and storage.

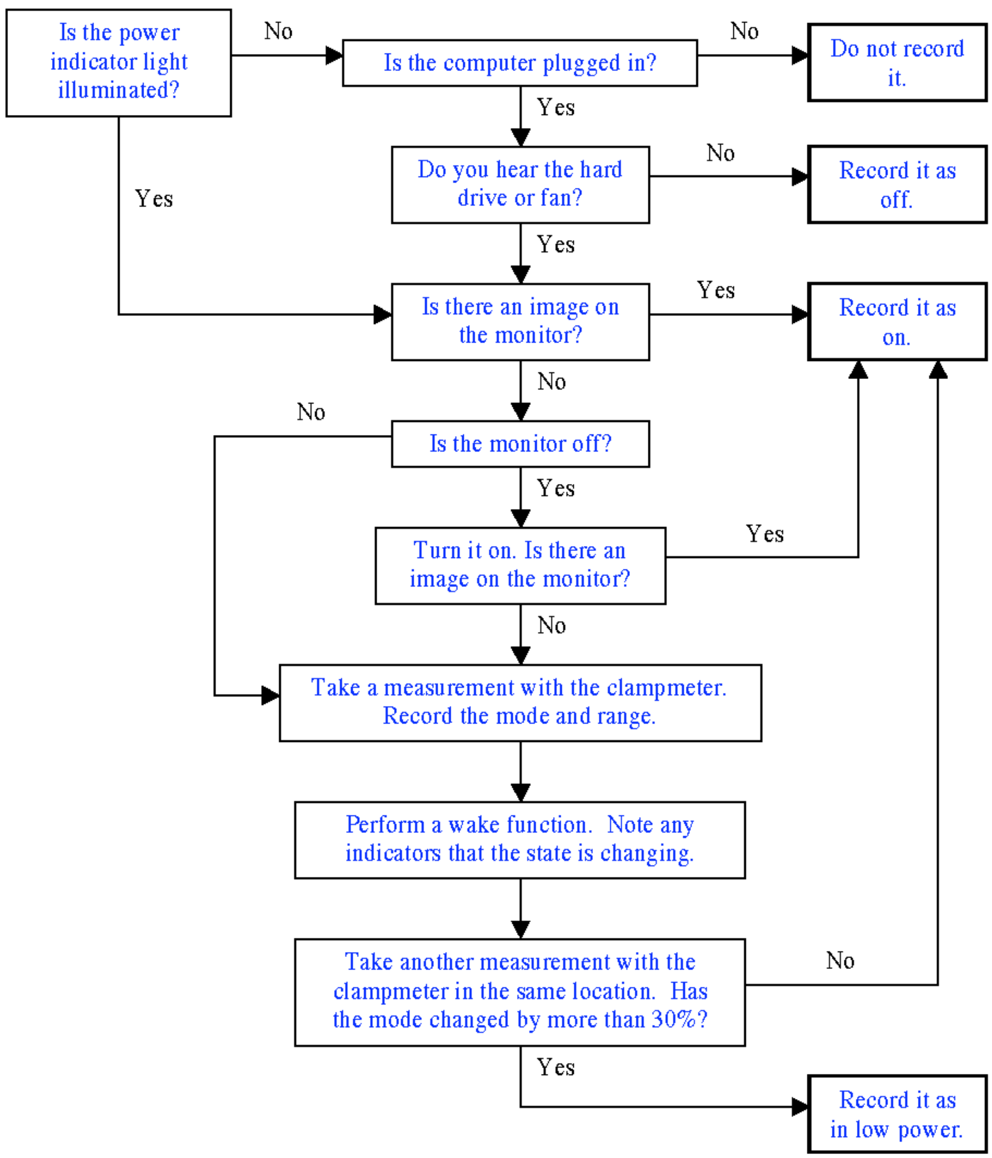
Site M

Large office, Pittsburgh PA
Corporate headquarters of a major manufacturer
Urban downtown office building, 6-story, new in 2001
Area surveyed includes conference, copy/print centers, cubicles, kitchen, lounge, health center, offices. Many employees in this office use laptop computers. Company policy is to turn monitors off at night (to prevent fires); special permission is required to bring in or use small appliances (fans, heaters, lamps, etc).

Site N

University classroom building, Atlanta GA
Urban, downtown campus; 4-story, circa 1960
The area surveyed included computer laboratories and classrooms, other classrooms, and offices of faculty, staff, and graduate students.

Appendix B: Flowchart for Auditing Desktop Computer Power State



Appendix C: Miscellaneous Equipment Taxonomy

Category	Equipment Type (not an exhaustive list)
audio/visual	television, video cassette player/recorder, overhead projector, audio amplifier, compact disk audio device, digital video disk device, slide projector, video monitor, audio mixer, audio tape device, LED display sign, receiver, speaker, tuner, digital video camera, video conferencing device, microfilm viewer, scan converter, public address system, set-top box
food & beverage	microwave oven, refrigerator (all sizes), coffee maker, toaster/toaster oven, vending machine, hot/cold bottled water tap, hot pot/kettle, water cooler, freezer, hot beverage dispenser, hot food cabinet, ice maker, coffee grinder, drinking fountain, fryer/griddle, steam trays, visi-cooler, meat slicer, mixer, soda fountain pump, blender, refrigerated case
hvac, portable	fan, heater, air cleaner, room air conditioner
laboratory	scale, spectrophotometer, tabletop centrifuge, temperature monitor, lab refrigerator, microscope, autoclave, shaker/stirrer, lab freezer, hot plate/warmer, drying oven, timer
lighting	fluorescent undercabinet lamp (by size), desk/table/floor lamp (by lamp type and power use), incandescent spotlight or studio lamp, decorative lamp, strand or cable lights, fluorescent light box, incandescent or halogen track light or recessed lamp, exterior fluorescent sign
medical	oto-opthalmoscope charger, exam light or headlamp, x-ray light box, exam chair or table, body scale, hospital bed, utensil sterilizer, blood pressure monitor, IV cart
medical specialty	vital signs monitor, respirator, defibrillator charger, EKG machine & accessories, pulse oxymeter, eye chart projector, lensmeter, glucometer charger, hot bead sterilizer, suction pump charger, hearing test device, retinal scanner, fundus camera, hyfrecator, sonoscope
money exchange	credit card reader, cash register, bar code scanner, change or stamp vending machine
networking	modem, router, hub, printer hub, switch, print controller/server, video processor, wireless access point, audio/video modulator, tape drive, broadband distribution amplifier, driver
office miscellany	clock and/or radio, boombox or compact audio system, pencil sharpener, adding machine, shredder, typewriter, stapler, postage meter or scale, hole punch, laminator, time stamper, binding machine, microfiche reader
peripheral	computer speakers (pair), laptop docking station, personal digital assistant dock, computer projector, keyboard/video/mouse switch, external drive (CD, zip, hard disk, tape backup), pen tablet, digital whiteboard,
power	power strip, surge protector, PIPS, ILPS, uninterruptible power supply, charger (for laptop computer, cell or cordless phone, power tool), power conditioner, battery backup system
security	badge reader, book demagnetizer, shoplifting sensor, article surveillance system
specialty	pottery wheel, mobile bookshelves, oscilloscope, shrinkwrapper, bench wheel, soldering iron
telephony	conference or speaker phone, answering machine, intercom, phone switch, phone jack or box, dictation machine, PBX phone line converter, voice control box, switchboard phone, integrated voice server
utility/maintenance	vacuum cleaner, floor polisher, dishwasher, ultrasonic cleaner, water purifier, clothes washer or dryer

Appendix D: Miscellaneous Equipment Numbers, by Category and Site

Sorted in descending order

site code	**G**	**M**	**C**	**H**	**F**	**K**	**E**	**J**	**B**	**A**	**D**	**N**	**All**
bldg type	medical	L office	L office	M office	school	S office	M office	medical	M office	school	school	school	
ME Category													**sum**
power	114	220	205	174	57	167	87	64	139	36	44	86	**1393**
lighting	85	226	179	158	70	52	172	51	15	8	10	20	**1046**
plug-in power supply	92	123	221	111	34	84	76	35	88	60	24	42	**990**
peripheral	13	104	150	125	85	82	87	9	118	36	30	44	**883**
audio/visual	58	28	24	8	144	7	8	27	2	65	90	23	**484**
office miscellany	28	68	6	34	38	86	18	56	86	9	33	19	**481**
medical	393	5						76					**474**
in-line power supply	25	72	16	69	27	32	29	56	10	95		13	**444**
food/beverage	29	9	15	31	71	33	14	51	24	19	30	14	**340**
networking	27	8	8	48	43	46	31	21	6	4	11	11	**264**
telephony	5	76	15	26	49	10	20	8	12	3	1	8	**233**
medical specialty	149	3			2			70					**224**
hvac, portable	41	1	13	24	7	24	5	11	6	3	20	4	**159**
laboratory	44	1						10		63			**118**
utility/maintenance	3			2	14	4	2	2	4	9	8	4	**52**
specialty	1	2			13	14			3	1	9	1	**44**
money exchange	12	1			3	3		2	6	3	3		**33**
security		1	1		1				1		2		**6**
sum	**1119**	**948**	**853**	**810**	**658**	**644**	**549**	**549**	**520**	**414**	**315**	**289**	**7668**

Note; Plug-in and in-line power supplies are listed separately, but are actually part of the power category

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Energy Efficiency in Separate Tenant Spaces – A Feasibility Study

APRIL 2016

ENERGY.GOV

Table of Contents

1. Executive Summary

Commercial buildings account for 20% of energy used in the United States economy,[1] with leased spaces representing approximately 50% of all commercial building energy use.[2] Increasingly, market pressures such as rising energy costs, new requirements to publicly disclose energy usage, and increased attention on energy efficiency as a means to combat climate change are motivating tenants, building owners, and other commercial building stakeholders to explore new ways to reduce energy consumption.

Traditionally, efforts to encourage energy efficiency in commercial buildings have focused on building owners rather than tenants. While building owners generally have control over building systems and operations, tenants play a critical role in achieving lasting reductions in energy intensity. In recognition of this collaborative role, the Energy Efficiency Improvement Act of 2015 mandated the development of a voluntary tenant space recognition system similar to the successful ENERGY STAR® buildings program. Additionally, the legislation mandated a feasibility analysis, presented here, regarding the implementation of tenant-specific energy efficiency measures. In response, this paper presents best practices, resources, and policies that could serve as the backbone for future tenant energy efficiency programs.

The energy consumption at a representative large, multi-tenant building can be partitioned into energy attributable to common areas (such as atriums, lobbies and garages), shared mechanical systems (such as central heating, fans, and cooling towers), and tenant spaces. In a typical arrangement, certain segments are clearly controlled by the owner, such as the garage lighting. Other segments are clearly controlled by the tenant, such as plug loads in tenant spaces. However, ultimate responsibility for managing the energy consumed in a multi-tenant space is often balanced between tenants and owners. Circumstances differ based on lease structure, but in a typical arrangement, neither owner nor tenant has complete control.[3] Instead, the energy usage and associated emissions are under the joint control of the owner and tenant, and the significant reductions in energy consumption require collaboration between the two parties.

Achieving greater levels of energy efficiency in tenant spaces is feasible through the use of technologies that exist in the market today. However, historic challenges have prevented wide-spread adoption of separate space efficiency measures. First, the timing and process of leasing - characterized by infrequent design windows, multiple stakeholders, design and budget constraints, and the dynamics of fluctuating negotiating leverage between owners and tenants - have largely prevented rapid advancement of energy efficiency in separate tenant spaces. Second, many owners, tenants, and brokers remain unaware or uninterested in the financial benefits and opportunities afforded by energy efficiency within leased spaces. Third, the majority of tenants in the market are small, disparate, and hard to reach with overarching energy efficiency strategies. Fourth, owners and tenants are hesitant to invest in tenant space energy efficiency measures due to the "split-incentive" problem. This "split-incentive" refers to the financial disconnect of investments in energy efficiency that can result from how costs and benefits of energy efficiency are allocated to different parties. And fifth, the inability to collect tenant-specific energy data from whole building consumption, in order to validate the benefits of energy efficiency investments, limits owners and tenant insight into the value of energy efficiency, further dampening interest.

1 U.S. Energy Information Administration. (2006). 2003 CBECS Detailed Tables – Table C4A: Expenditures for Sum of Major Fuels for All Buildings. https://www.eia.gov/consumption/commercial/data/archive/cbecs/cbecs2003/detailed_tables_2003/2003set14/2003html/c4a.html

2 NRDC. (2013). High Performance Tenant Demonstration Project. http://www.josre.org/wp-content/uploads/2013/02/CMI-PPT-on-Tenant-Energy-Performance.pdf

3 As an example, while the owner may select and maintain the central heating system, the tenant may have control over the thermostat controlling the leased space and the adjoining common corridor. Together, the choices made by the owner and tenant determine the energy consumption at the building.

Increased education and awareness materials, collection of tenant-specific energy consumption data, and a re-alignment of leasing cost structures targeted toward building owners, tenants, and brokers, may help overcome these challenges and encourage widespread uptake of tenant space energy efficiency measures. This paper highlights a variety of potential ways to address these needs including:

Submetering of tenant spaces – Metering tenant-specific energy use offers the ability to separate out individual tenant-level energy usage from common area usage. This "submetering" helps ensure that each tenant pays for their own energy consumption, and receives the full benefit of energy cost reductions on their part.

Easy comparison of energy efficient technologies – Technologies exist to increase the energy efficiency of tenant spaces. However, understanding the costs and benefits of utilizing such technologies is often complicated and time consuming, requiring tenants to understand not only the energy saving attributes of individual products, but also interactive effects between technologies. Improving the ability to readily compare packages of technologies through interactive tools or build-out guidance checklists is one potential way to increase the uptake of energy efficient technology in tenant spaces.

Recognizing the business case for energy efficiency – Many businesses recognize the ways in which energy efficiency can improve their bottom line. There are opportunities to help even more businesses see these benefits, including the role of energy efficiency in reducing total cost of occupancy, making spaces more comfortable and attractive, contributing to improved worker performance, and increasing asset value at time of sale. Even in lease structures with a split incentive for energy efficiency, building owners can benefit from increased energy efficiency through market differentiation – and in certain markets command higher rents and longer tenures. A growing body of research has shown that energy efficient buildings rent for an average premium of 2-6%,[4] can sell for a premium of as much as 16%,[5] attract high-quality tenants,[6] and have lower default rates for commercial mortgages.[7]

Low-cost energy simulation models for tenant spaces – Tenants can compare different energy efficiency measures through energy simulations and decide which options are most appropriate for the individual space. Energy modeling is most often used today in large spaces (greater than 20,000 square feet) where the return on investment from energy efficiency measures more than covers the upfront costs of modeling. Continued investments in both guidance and software to make advanced modeling more accessible and targeted at tenant spaces will help smaller tenant applications (less than 20,000 square feet) to use designs that benefit from energy modeling.

Improving leasing language and broker engagement – energy efficiency-aligned language can be added to traditional building leases to create "green leases" that mitigate the landlord-tenant split-incentive problem. To increase the use of green leases, which in turn can help tenants realize financial benefits, industry trade organizations can continue to highlight examples of successful green leases, collect and publish best practices, and create case studies that illustrate the benefits and market opportunity for green leasing strategies. Education that increases energy efficiency literacy among real estate brokers will help them to better respond to tenant requests for energy efficient spaces and leases.

4 Eichholtz, P., Kok, N., & Yonder, E. (2012). Portfolio greenness and the financial performance of REITs. Journal of International Money and Finance, 31(7), 1911-1929. http://www.fir-pri-awards.org/wp-content/uploads/Article-Eichhiltz-Kok-Yonder.pdf

5 Eichholtz, P., Kok, N., & Yonder, E . (2010). Doing Well by Doing Good? American Economic Review. http://urbanpolicy.berkeley.edu/pdf/AER_Revised_Proof_101910.pdf

6 Eichholtz, P., Kok, N., & Quigley, J. M. (2009). Why do companies rent green? Real property and corporate social responsibility. Real Property and Corporate Social Responsibility (August 20, 2009). Program on Housing and Urban Policy Working Paper, (W09-004). http://www.ucei.berkeley.edu/PDF/EPE_024.pdf.

7 An, X., & Pivo, G. Default Risk of Securitized Commercial Mortgages: Do Sustainability Property Features Matter? (2015). http://capla.arizona.edu/sites/default/files/faculty_papers/Default%20Risk%20of%20Securitized%20Commercial%20Mortgages%20and%20Sustainability%20Features%2C%202015.pdf

Creation of a federal tenant space recognition system – By allowing for direct peer-to-peer comparison of buildings based on energy or sustainability performance, recognition systems provide the market with greater insight to evaluate building performance. This can help owners, tenants, and brokers to broadcast the value of energy efficiency measures, and distinguish high-performance buildings from the rest of the market. Simplifying efficiency to an accessible metric can give market participants a "scorecard" to measure higher levels of performance, and often drives activity across the industry as a whole through competitive forces and peer comparison. There will be several possible ways to design a recognition program for leased spaces. Options range from recognition based on outcome-focused gross metrics like those used by the Australian government (energy use intensity), to detailed metrics focused on design and operational inputs like the government in Singapore (lighting level, temperature ranges) to energy simulation-based approaches or simpler checklist-based approaches. Further research is warranted to assess the metrics, structure, and market viability of a potential system to best support the U.S. market.

2. Introduction, Definition of Scope and Existing Efforts

2.1 Introduction and Legislative Mandate

Over the past 20 years, many of the energy efficiency gains in commercial buildings in the United States have occurred as a result of a focus on improved technologies and owner-oriented tactics, while tenants have so far received relatively little pressure or support to improve energy efficiency measures within their spaces. As such, congress passed the Energy Efficiency Improvement Act of 2015 on April 23, 2015 to foster greater attention and collaboration on tenant space energy management.

The Energy Efficiency Improvement Act requires completion of this study to determine the feasibility of: (1) significantly improving energy efficiency in commercial buildings through the design and construction of separate spaces with high-performance energy efficiency measures, and (2) encouraging owners and tenants to implement such measures in separate spaces. The legislation also requires the Secretary to publish this study on the website of the Department of Energy (DOE).

2.2 Definition of Scope

This study investigates the feasibility of significantly improving energy efficiency in commercial buildings through the design and construction, by owners and tenants, of separate spaces with high-performance energy efficiency measures. For the purposes of this study: "significant improvement" is defined as an excess of 20% improvement, "separate spaces" are spaces that tenants are leasing, and "high-performance energy efficiency measures" are combinations of tools, practices, and technologies that when applied drive energy efficiency improvements in excess of 20%, either separately or in combination.

In addition, this study investigates the feasibility of encouraging owners and tenants to implement high-performance energy efficiency measures in separate spaces. For the purposes of this study: "encouraging" is the development, distribution, and adoption of tools, resources and policies that enable owners and tenants to implement energy efficiency measures.

3. Benefits of Achieving Energy Efficiency in Tenant Spaces

Reducing the energy used in tenant spaces would provide significant benefits to the economy and environment of the United States. Fundamentally, both owners and tenants affect the energy consumed and resulting emissions from leased spaces, and as a result, this section discusses the energy and emissions of the commercial real estate sector accordingly.

3.1 Energy and Emissions in Tenant Spaces

The energy consumption at a representative large, multi-tenant building can be partitioned into energy attributable to common areas (such as atriums, lobbies and garages), shared mechanical systems (such as central heating, fans, and cooling towers), and tenant spaces. In a typical arrangement, certain of these segments are clearly controlled by the owner, such as the garage lighting. Other segments are clearly controlled by the tenant, such as plug loads in tenant spaces. However, ultimate responsibility for managing the energy consumed in a multi-tenant space is often balanced between tenants and owners. Circumstances differ based on lease structure, but in a typical arrangement, neither owner nor tenant has complete control.[8] Instead, the energy and associated emissions are under the joint control of the owner and tenants, and significant reductions in energy costs can best be captured through their collaboration.

For purposes of scale, this section quantifies the total energy consumed by office, retail, and flex (a mix of office, warehouse, and light industrial) spaces. While multifamily spaces are also leased, they typically are not designed and constructed for each new tenant, and have a different set of considerations that are outside the scope of this report.

As a whole, commercial buildings account for 20% of the energy used in the United States Economy.[9] Of this number, office, warehouse, and retail spaces in the United States occupy 26.5 billion square feet of space, consume 4,700 trillion Btu of energy (major fuels and electricity), and spend $25 billion annually on energy costs. The office, retail, and warehouse sectors produce over 970 million metric tons (MMT) of carbon dioxide equivalent emissions (CO2e).[10] While these estimates encompass all office and retail space, leased space accounts for more than 50% of an office building's total energy use.[11] Making a conservative assumption that energy use associated with retail and warehouse leased space is also 50% of total building energy use, leased spaces account for more than 490 MMT of emissions, and 2,350 trillion Btu of energy consumption annually.

8 As an example, while the owner may select and maintain the central heating system, the tenant may have control over the thermostat controlling the leased space and the adjoining common corridor. Together, the choices made by the owner and tenants determine the energy consumption at the building.

9 U.S. Energy Information Administration. (2006). 2003 CBECS Detailed Tables – Table C4A: Expenditures for Sum of Major Fuels for All Buildings. https://www.eia.gov/consumption/commercial/data/archive/cbecs/cbecs2003/detailed_tables_2003/2003set14/2003html/c4a.html

10 EIA. (2003). Commercial Buildings Energy Consumption Survey (CBECS) – 2003 CBECS Survey Data. CBECS website http://www.eia.gov/consumption/commercial/data/2003/

11 NRDC. (n.d.). High Performance Tenant Demonstration Project. http://www.josre.org/wp-content/uploads/2013/02/CMI-PPT-on-Tenant-Energy-Performance.pdf

3.2 Potential Benefits

There are quantifiable financial and environmental benefits associated with increasing energy efficiency. As a quick estimate of benefits, if current energy use in retail, warehouse, and office space was reduced by 20%, the country could save:

- 940 trillion Btu of energy, roughly the quantity of electricity consumed by Mexico.[12]
- $5 billion in annual expenditures.
- 190 MMT of CO2e, or the emissions from 370 billion miles of automobile travel.

3.3 Effects of Energy Efficiency on Employment

A recent literature review and analysis by the Pacific Northwest National Laboratory (PNNL) evaluates the impact of improved energy efficiency on employment and the economy.[13] [14] The study evaluated two primary vectors of energy efficiency job creation:

1. Long-run, economy-wide job creation due to energy efficiency freeing up money that would otherwise have been spent on energy. The study concluded that spending money made available by reducing energy expenditures for alternative goods and services generates a net gain of about 8 jobs per million dollars of consumer bill savings.
2. Immediate, sector-specific job creation due to investments in energy efficiency. The study concluded that initial investments in energy efficiency generate about 11 jobs per million dollars of investment. These activities include the purchasing and installing of measures for retrofit or for new construction and also jobs in other sectors "induced" by this economic activity.

Common Types of Lease Structures

While there are many lease structures, a few of the most common are briefly described below, in order to illustrate the ranges of responsibility:

- In a triple-net lease, the costs of maintenance, insurance, taxes, and utilities are borne by the tenant. In this case, the owner has little control or financial interest in the energy consumption of the leased area.
- In a gross lease, the costs of maintenance, insurance, taxes, and sometimes utilities are paid by the owner. The tenant pays a flat fee covering these expenses. In this case, the owner has more control and financial interest in the energy consumption of the leased area.
- In a pro rata share scenario, tenants are responsible for a percentage of total utility bills proportional to the percentage of the building's area which they occupy, and are billed through a monthly recovery fee.
- The vast majority of lease structures resemble one of these three models, with tenants directly or indirectly covering energy usage costs associated with their use (such as plug loads), and paying proportionally for the use of shared systems or energy costs for common area spaces, lobbies, etc.

12 EIA. (2014). Total Petroleum and Other Liquids Production – 2014. http://www.eia.gov/beta/international/

13 Anderson, D. M., Belzer, D. B., Livingston, O. V., & Scott, M. J. (2014). Assessing National Employment Impacts of Investment in Residential and Commercial Sector Energy Efficiency: Review and Example Analysis (No. PNNL-23402). PNNL, Richland, WA (US). http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23402.pdf

14 Further explanation of the PNNL study methodologies and results are referenced in section 5.1 of the appendix.

4. Feasibility of Achieving Energy Efficiency in Tenant Spaces

The technologies exist to improve energy performance in separate spaces; however, historic challenges have prevented wide-spread adoption of separate space efficiency measures. While challenges do exist, there are a variety of opportunities that mitigate these barriers and encourage the uptake of energy efficiency in tenant spaces. The following discussion summarizes current research and strategies to improve tenant spaces energy efficiency.

4.1 Challenges

While the potential benefits of energy efficiency in separate tenant spaces were described in Section 3, several challenges have historically prevented large-scale adoption of such measures. These systemic barriers discourage the implementation of energy efficient technologies during design and construction. Broadly speaking, these challenges can be categorized as issues of Timing and Process, Education and Awareness, Tenant Market Demographics, Cost Structures, and Data Availability.

4.1.1 *Timing & Process*

As background, the energy efficiency of a tenant space is determined primarily during two time windows:

- Design and fit-out, or the time leading up to and including construction of the tenant space.
- Occupancy, or the time in which tenants occupy the space.

Major tenant improvements are relatively infrequent – tied to the lease cycle, the time in-between can typically be 3-7 years or more – and as such the opportunity to influence the design and selection of major systems and technologies in the space are limited to these intermittent windows.[15] While some energy efficiency strategies are available during occupancy, the largest-scale gains are typically achievable in the infrequent design window, with moderate additional energy savings obtainable during occupancy. Generally speaking, these gains apply to office, retail and warehouse buildings, whereas other space types such as data centers and manufacturing have an entirely different relationship where the operational energy in the space is much greater than that of the building. Figure 1 below provides a generalized overview of the leasing and tenant improvement process, noting the sequence of these "windows" in a typical project:

15 The greatest opportunity to implement energy efficiency in separate tenant spaces is during the new construction process and in particular, during a build-to-suit development. During new construction, the greatest systemic changes can be implemented, including customized design of the HVAC system, metering schema, and building envelope. While the opportunities are greater during this stage, the considerations are highly similar to those discussed in this section.

FIGURE 2 – THE TENANT IMPROVEMENT PROCESS

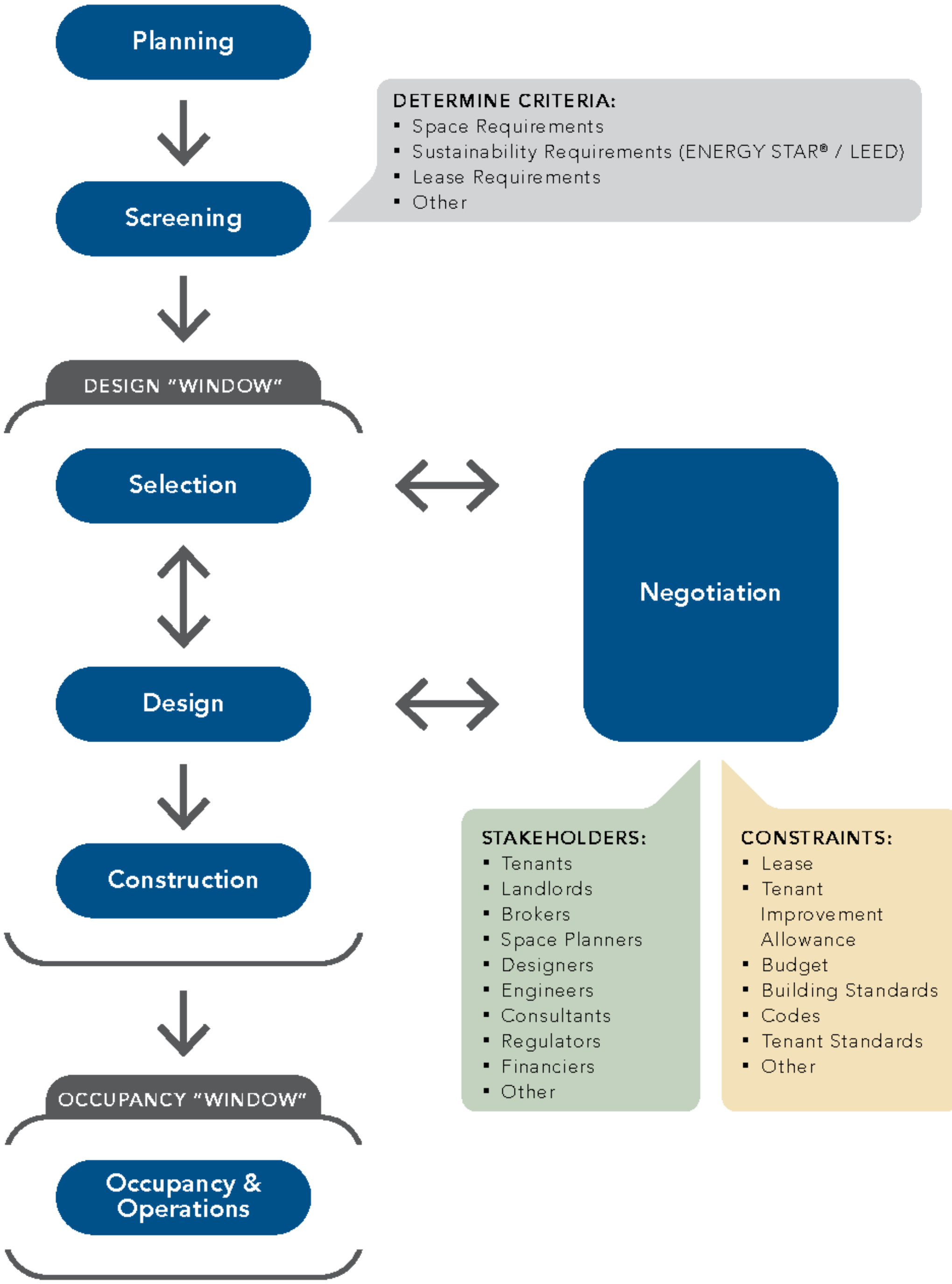


Table 1 details each of the steps shown in Figure 1, noting key activities and processes that can influence the implementation of energy efficiency initiatives throughout the tenant improvement process:

TABLE 1 – THE KEY PHASES OF THE TENANT IMPROVEMENT PROCESS

PHASE:	DESCRIPTION AND ACTIVITIES:
Planning	▪ Decision that new space is needed ▪ Criteria development ▪ Office search and design team formation, can include: tenant representative (broker), designer, architects, and space planners
Screening	▪ Initial review of candidate properties ▪ Preliminary matching against space criteria ▪ Development of a "short list" of properties for initial negotiations
Selection	▪ Final decision on property, depending on outcome of negotiations and design
Negotiations	▪ Finalizing lease terms, conditions, rental rates, tenant improvement allowances, length, and other considerations
Design	▪ Space planning ▪ Aesthetic and functional design of tenant suite
Construction	▪ Build-out, furnishing, and commissioning of infrastructure, systems, and equipment
Occupancy & Operations	▪ Building operations and maintenance ▪ Tenant business operations

The energy performance of tenant spaces is influenced in multiple ways across each of the above phases. Factors including owner attitudes, financial situation, and negotiating position can foster or inhibit energy performance considerations in decision-making. For example, in the planning phase, tenants can establish environmental and energy performance targets for their space, guiding which buildings become eligible through the screening process. As a result, tenants may screen building ownership for their sustainability practices and attitudes, or limit their searches to LEED or ENERGY STAR® certified spaces in an effort to find a collaborative partner for saving energy. These, and other decisions at earlier stages of the tenant improvement process, can have significant influence on the ultimate efficiency of the space.

The Design Window

The design window consists of three phases (2): selection, negotiation, and design. Depending on the market, the size of the leased space, the sophistication of the parties, and the specifics of the project, these phases can occur simultaneously or sequentially.[16] Through the three stages parties iteratively negotiate, examining proposals and counter-proposals, evaluating competing bids, and revising financial projections. Timing pressure and budget constraints are intense components of this process, as owners and tenants both wish to avoid lost revenues or unnecessary costs due to a long leasing process. As such, energy efficiency measures may be rushed or dropped altogether, as the parties often perceive that they have more pressing considerations.

While the three phase design window is the process used by many tenants, other tenants may go through a simpler process. In its simplest form the process may involve identifying a nearby space (avoiding the selection phase), negotiating terms directly with the owner (avoiding the broker), and moving in with little fit-out. Again, energy efficiency may be de-prioritized as tangential in this process.

Throughout this entire design window, multiple stakeholders (and motivations) come into play, each with varying levels of influence depending on the situation:

The Deep-Retrofit "Window"

In addition to the design and occupancy windows described here, a major opportunity to improve energy performance arises through a "Deep Retrofit." Defined as an integrated, whole-building modernization program, Deep Retrofits can reduce energy consumption by 40% or more by enacting a holistic set of energy efficiency strategies across both common areas and tenant spaces.

Deep Retrofits often make sense when real estate owners, developers, and investors seek to "reposition" an older, dated property to be more competitive in the market, when significant tenant turnover is expected, or when large centralized systems such as a chiller or window glazing need to be replaced. By acting on this Deep Retrofit window - and integrating energy performance strategies throughout tenant spaces and building common areas - building owners can achieve a multiplier effect in terms of energy savings potential. However, these windows are infrequent, often 20-50 years apart.

- Brokers, motivated by commissions, often leave out energy efficiency topics in negotiations as they often seek quick and simple deal closure, and try to eliminate any extraneous factors from complicating negotiations.
- Tenants, often facing "sticker shock" at the expenses involved in leasing space or dealing with day-to-day business requirements, are faced with adding additional up front expenses of incorporating energy efficiency measures into their operations.
- Designers, consultants, and engineers all must keep abreast of negotiations and budgets in addition to client energy efficiency demands, and translate tenant criteria and space constraints into a workable plan.[17] Energy efficiency can be pushed aside relative to other client priorities.

16 Critically, tenants often will enter into negotiations with multiple building owners at the same time, attempting to achieve pricing leverage or to examine multiple options or locations. Designers often must look at the available space and produce a "test fit" preliminary design to ensure that the tenant requirements could be met by a particular property, and to check the impacts to the tenant improvement budget. Building owners put forward an initial proposal at this stage including rental rates, terms, and tenant improvement allowances.

17 Constraints also guide the ultimate space design. Large, national tenants or chains and franchisees may have brand standards and design criteria, specifying lighting technologies, illumination levels, or other aesthetic requirements that may compete with energy efficiency strategies. Building codes, project budgets, or unique leasing terms regarding maintenance practices may all combine to limit designers. Further, building ownership may have tenant improvement guidelines or building standards that specify systems, technologies, or operational constraints that impact energy performance opportunities. Each of these options needs to be evaluated by the parties in the transaction, and resolved through negotiations and by designers.

- Building owners, in a highly competitive market, have a valuable product and may suspend complex negotiations involving energy efficiency when a more attractive tenant - with simpler demands - appears.

Once design of a tenant space begins in earnest, timing considerations add pressure to decision making. At this juncture, both tenants and owners likely have financial and other resources committed to the deal, and any delays can result in additional costs:

- Tenants and owners often forego energy efficiency analyses - such as engineering studies, energy modeling, or technical pilots –so as to not disrupt the project's timing.
- Tenants may not be able to justify the financial and time costs of analysis by consultants, engineers, or other design professionals in comparison to the amount of energy costs that may be saved, particularly in smaller spaces.
- Owners often avoid perceived risks of "new" or "different" requirements are included, as this adds further complexity and uncertainty to the deal.
- In many cases, the initial costs of more efficient lighting, HVAC, or other equipment exceed that of standard technologies, further burden project financing and strain negotiations.

Ultimately, what gets installed and built in a tenant improvement project can depend on negotiating leverage. In a high-vacancy, tenant friendly market, a national credit-worthy tenant can demand and often receive significant concessions from property owners. Alternatively, in a low-vacancy, owner friendly market, building owners may provide minimal tenant improvement allowances (if any) or charge rent premiums. Such a market discourages the inclusion of energy efficient measures due to the ability of owners to easily identify alternative, less-demanding tenants.

Given these process related aspects – the phases of the design window, the multiple stakeholders and design constraints, and the dynamics of fluctuating negotiating leverage – significant advancements in achieving energy efficiency in separate tenant spaces has been slow to materialize.

When energy efficient technologies are implemented in the tenant improvement process, the most common improvements are items localized to the separate space, such as interior lighting upgrades and/or enhancements, efficient power supplies, efficient data center power and cooling systems, and tenant-specific HVAC systems that may or may not interact with central building systems. In larger leases, where a tenant has leverage through potential occupancy of a significant portion of a building, tenant improvements and leasing requirements may also include envelope enhancements, specify operating hours and practices by building management, set expectations on sustainability certifications such as LEED or ENERGY STAR®, or control other operational aspects.

The Occupancy Window

Once a tenant begins occupancy, some potential for significant energy savings diminishes. Tenants have limited control over central systems and in-suite equipment to improve efficiency, and only control limited building operations, if any. Owners, having secured the tenant for the life of the lease and having financed all or part of the cost of the tenant improvement, are hesitant to consider additional upgrades while mid-stream in the lease. Likewise, tenants in a shorter lease or mid-stream in their lease will resist spending resources on energy efficiency projects as they will not be able to fully benefit from the generated cost savings by the time their lease is up. At this point, the utility costs are paid by either the tenant or the owner as designated in the lease, and any cost savings achieved through energy efficiency may not be realized by the party that is making the investment. Further, the business needs and requirements of a tenant may preclude changes in technology or system operations for the purposes of energy efficiency – for example, while one might typically try to restrict operating system use during traditional business hours, tenant operations might require extended operations of HVAC equipment.[18] Owners are also reluctant to conduct large-scale energy efficiency upgrades that may disrupt tenants due to construction activities. As a result, both the owner and tenants may have limited appetite to pursue major energy savings projects during occupancy.

During occupancy, owners are generally operating and maintaining shared building systems, such as HVAC, exterior lighting, elevators, and building amenities. Depending on the leasing arrangements, the owner may also be maintaining select equipment within tenant spaces, such as replacing lights, or operating dedicated HVAC systems. Yet doing so still requires significant coordination between building ownership and tenants. The ultimate result is that during occupancy, most owners focus energy efficiency efforts on shared building systems under their purview, while tenants implement plug-load and behavior change strategies within their own spaces, if they act at all.

4.1.2 *Education, Awareness, and the Role of the Broker*

While timing pressures during the lease negotiation process decrease the prioritization of energy efficiency, the challenge is compounded by the fact that for many in the industry, energy efficiency in tenant spaces is not yet a common topic of discussion. While leading property owners and managers have become increasingly aware of the financial and competitive benefits of energy-efficient buildings, the owner has historically been the main driver of energy efficiency in commercial real estate. As discussed earlier in this section, the leasing terms have typically allowed the owner to dictate energy efficiency measures.

As a result, a vast number of potential tenants remain unaware or uninterested in the financial benefits and opportunities afforded by energy efficiency within leased spaces. Market inertia, competing priorities, information overload, and financial concerns can crowd out the "mindspace" of a potential tenant, leaving little time to investigate energy efficiency opportunities. For example, when examining a new space for lease, most tenants are primarily focused on location, rent, space suitability, and amenities. Energy efficiency is a distant fifth or lower on the list of priorities. This is reinforced by the relative costs of energy and rent. At a typical major city office building, energy will cost between $2 and $4 per SF. By contrast, rent may be as much as:

18 An example of necessary extended operating system hours could be an accounting firm requesting HVAC services for after hours during tax season.

TABLE 2 – RENT IN MAJOR MARKETS

CITY:	AVERAGE CLASS A OFFICE ANNUAL RENT ($/SF)
Manhattan, NY	$77 [A]
New York, NY (City Average)	$49 [B]
Washington, DC	$45 [C]
Austin, TX	$43 [D]
Denver, CO	$34 [E]
Tulsa, OK	$16 [F]

A Mashayekhi, R. (2015). Manhattan office vacancy rate hits six-year low. The Real Deal. http://therealdeal.com/2015/07/21/manhattan-office-vacancy-rate-hits-six-year-low/

B LoopNet. (2015). New York, NY Market Trends. http://www.loopnet.com/New-York_New-York_Market-Trends/?Trends=AskingRentsFL,NumberOfListingsFL,ProfileViewsFL,TotalSFAvailableFL,DaysOnMarketFL&PropertyTypes=Multifamily,Office,Industrial,Retail

C LoopNet. (2015). Washington, DC Market Trends. http://www.loopnet.com/Washington_District-of-Columbia_Market-Trends?Trends=AskingRentsFL,NumberOfListingsFL,ProfileViewsFL,TotalSFAvailableFL,DaysOnMarketFL&PropertyTypes=Multifamily,Office,Industrial,Retail

D Davidson, C. (2015). Austin Office Market Report – Q1 2015. The Tenant Advisor. http://www.coydavidson.com/office/austin-office-market-report-q1-2015/

E API Global. (2015). High Lease Rates and Low Vacancies a Hard Pill to Swallow for Tenants. Denver Metropolitan Commercial Real Estate Update. http://sg-realty.com/wp-content/uploads/2010/03/news-mid-year-20155.pdf

F CBRE. (2015). Tulsa Office MarketView H1 2015. Market Reports USA Tulsa/Oklahoma. http://www.cbre.us/o/tulsa/Pages/market-reports.aspx

One potential barrier to raising awareness is the role of the real estate advisor or brokerage community. Brokers "…hold the keys to what gets negotiated in the lease and what interests are being represented."[19] Working primarily for a commission based on the total rent and length of the lease, brokers facilitate negotiations covering terms, conditions, cost structures, tenant improvement allowances, and other logistical details.[20] When and if energy cost arrangements are discussed, they often constitute a minor element of negotiations, given the scale of energy costs in comparison to rent and other considerations. These same advisors are typically compensated when a deal is completed and have little incentive to complicate the transaction with discussions of sustainability. Thus, many tenants remain unaware of the relative efficiency of the tenant spaces they are considering.

Various real estate advisors – brokers, designers, property managers – play a particularly prominent role because the average tenant improvement project is driven by a non-real estate professional. The typical small to medium business owner who is seeking new space will designate a member of the staff to manage the process. Often, a human resources manager, business executive, or the owner themselves will act as project champion. Their leasing experience may represent the only time they engage in this type of transaction, resulting in a heavy reliance on their leasing representative and prospective owners for information and guidance.

It then falls to the real estate advisors to inform prospective tenants on the value of energy efficiency improvements. Brokers in particular play a critical role in interpreting, explaining, and advising their clients on the lease terms. But many real estate advisors will not take the time to educate tenants unless energy efficiency or sustainability is a goal expressed in preliminary discussions by the prospective tenant. Likewise, many tenants simply do not know what questions to ask related to energy efficiency. Unless an active effort is made by the tenant or owner sides to introduce energy efficiency and sustainability into leasing discussions, many projects will continue to move ahead without capitalizing on the opportunities.

4.1.3 *Tenant Market Demographics*

The tenant space market is comprised of a minority of national tenants with the ability to implement portfolio-wide energy efficiency changes. Conversely, the majority of tenants in the market are small, disparate, and hard to reach with overarching energy efficiency strategies. The National Association of Realtors and CoStar Group provide visualization of these market demographics:

- "In terms of inventory, commercial real estate markets are bifurcated, with the majority of buildings (81%) being relatively small, while the bulk of commercial space (71%) is concentrated in larger buildings."[21]
- Tenant demand is strongest for small leased properties of 5,000 square feet (SF) or less - these properties represent 75% of all leased properties in the United States. While demand for large spaces of 50,000 SF and above represent less than 15% of leased properties (Figure 2).[21]
- The average office lease for class A, B and C office buildings are about 8,000 sf, 3,500 sf, and 1,600 sf, respectively.[22]

19 Regulations.gov. (2015). Comment response to the published Request for Information (RFI). Shorenstein Realty Services. http://www.regulations.gov/#!documentDetail;D=EERE-2015-BT-BLDG-0012-0005

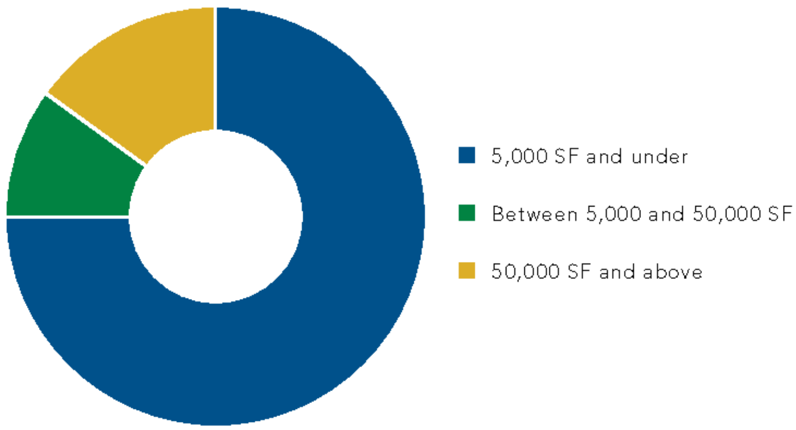
20 Brokers may also cover energy related items such as sustainability certifications, special HVAC cooling needs due to data centers or other unique equipment, operating hours, or energy and power source requirements due to intensive plug loads.

21 This number includes retail, office, and multifamily, and industrial space data. National Association of Realtors® Research Division. (2016). Commercial Real Estate Market Trends: Q4.2015. http://www.realtor.org/reports/2015-q4-commercial-real-estate-market-survey

22 Ponsen, A. (2015). Trends in Square Feet per Office Employee. Commercial Real Estate Development Association. http://www.naiop.org/en/Magazine/2015/Spring-2015/Business-Trends/Trends-in-Square-Feet-per-Office-Employee.aspx

- Lease terms of 36 and 60-months are most predominant in the market (59%).[21]
- Average lease prices vary with class A offices, class B and C offices, class A retail spaces, and class B and C retail spaces averaging $129/SF, $98/SF, $124/SF, and $91/Sf, respectively.[21]

FIGURE 2 – TENANT DEMAND FOR LEASED PROPERTIES REPRESENTED AS A PERCENTAGE OF THE U.S. MARKET.[21]



Efforts or programs targeting tenants will have an uphill battle due to the fragmented and diverse nature of the tenant population. These trends necessitate the creation, production, and distribution of resources and tools that can be effectively disseminated and communicated to tenants despite such variabilities.

4.1.4 *Cost Structures*

One of the most commonly cited barriers to the adoption of energy efficiency strategies in shared spaces remains the "split-incentive" problem. In a commercial building lease, all operational and maintenance costs associated with a building are paid by the owner, the tenant, or some combination thereof. These costs may include utilities, property taxes, security, insurance, janitorial services and more, and the lease legally defines who is responsible for these costs and any methodologies for cost-sharing or reimbursements.

In this context, the "split-incentive" refers to the accrual of costs and benefits of energy efficiency to different parties based on the separation of responsibilities for capital improvements and paying energy bills, or other bills associated with benefit streams such as operations and maintenance and worker salaries. In one typical scenario, capital costs are the responsibility of the owner, but operational costs are borne by the tenant. As an example, if a building owner invests in a more efficient lighting technology, the financial benefits of reduced energy consumption will flow partially or in whole to the tenant, depending on the lease structure. Likewise, tenants who will only occupy a building for a few years are hesitant to invest in a building system that lasts beyond that time horizon, or that ultimately becomes the building owner's property. Another form of the split-incentive can be found in space that is not submetered, but energy is included in the lease. With this structure, energy saving behavior by one tenant doesn't necessarily benefit that tenant – instead, the bill reduction is split across all tenants.

Numerous scenarios exist that determine to what extent, if any, owners or tenants both have a financial interest in reducing energy consumption. Specific lease types such as gross, net, fixed-base, or various permutations have different mechanisms for allocating energy costs. Gross leases typically specify that owners are responsible for energy costs, while net leases place that responsibility on the tenant. Various other approaches utilize mathematical formulas, cost ratios, common area maintenance (CAM) methodologies, or energy submeters to determine the timing, proportion, and ultimate responsibility for energy costs. Further, different property types traditionally use different methodologies – with industrial or retail properties, the tenant is typically responsible for all utilities, while office properties are typically have terms that reflect local norms.

In many leases, owners have the right to pass-through costs of upgrades to the building, *if that investment will lead to a financial benefit to the tenant.*[23] For example, if a lighting retrofit would cost $2,000, and as a result the tenant would receive energy cost savings of $200 a year, then the owner could approach the tenant and pass the $2,000 through to them, assuming the tenant would be in the space for over 10 years and would "break-even" at a minimum. Of course, both parties would need to agree to this course of action and the specifics of the lighting project, subject to the terms and conditions of the lease. Understandably, many tenants are hesitant to agree to these relatively unplanned costs – effectively a rent increase - as they are trying to manage their total cost of occupancy in the building as part of their business expenses. Likewise, owners may be unwilling or unable to effectively discuss these types of energy efficiency investments with tenants, due to the complexity of the cost allocations, a fear of potentially upsetting or losing the tenant, or simply because the perceived benefits are minimal.

The "split-incentive" market barrier is not new, and has been identified and acted on by a number of organizations, with some limited progress. BOMA released its Green Lease Guide in 2008[24] and has made several updates since

The Distinction between Value and Cost-Savings

The benefits of energy efficiency and sustainability in commercial buildings can take many forms, and an important distinction should be made between cost-savings and value. In the book Value beyond Cost Savings and through numerous other publications, Scott Muldavin, the Rocky Mountain Institute (RMI), and many others have articulated the numerous real estate, business, and corporate enterprise benefits that result from energy efficient, green, or sustainable buildings. These benefits include improved competitiveness, increased asset value, increased worker productivity, reduced risks, improved corporate image and branding, employee attraction and retention – all can directly or indirectly result from improved energy performance, and provide building owners, business enterprises, and tenants with tangible value.

To a large extent, these benefits are not subject to the split-incentive in the same manner as cost-savings, as the owner and tenant each directly benefits from these attributes. For example, an owner will benefit from increased asset value, while a tenant would benefit from increased productivity.

In viewing the larger value considerations beyond basic cost savings, more-compelling business cases and new, opportunities can emerge. As market participants – owners, investors, tenants, and businesses – become aware of and act on the greater value benefits beyond strict cost savings, investments in energy efficiency and sustainability may accelerate, and circumvent many of the market barriers and challenges described herein.

23 This is often referred to as a tenant cost recovery clause.

24 BOMA. (2010). Commercial Lease: Guide to Sustainable and Energy Efficient Leasing for High-Performance Buildings. BOMA website http://store.boma.org/products/commercial-lease-guide-to-sustainable-and-energy-efficent-leasing-for-high-performance-buildings

then. The Green Lease Guide and subsequent publications provide model leasing language and practices for optimizing lease language in a manner that, among other things, aligns owner and tenant interests in energy efficiency and sustainability initiatives. The Natural Resources Defense Council's (NRDC) Center for Market Innovation has also published Energy Efficiency Lease Guidance, and is participating with the City of New York Mayor's Office of Long-Term Planning and Sustainability to disseminate and craft model energy aligned lease language within the New York real estate market. Additionally, a tenant space energy efficiency program managed by the Urban Land Institute (ULI) seeks to deliver a replicable process that integrates energy efficiency into office tenant space design and construction within the tenant improvement cycle window (refer to section 4.2 below for more details on this program).

The Institute of Market Transformation (IMT) has launched several tools, resources, and programs promoting "green leasing" practices, most notably the Green Lease Leaders recognition program.[25] Over the past several years, the Rocky Mountain Institute (RMI), the General Services Administration (GSA), the Northwest Energy Efficiency Alliance (NEEA), the Penn State Consortium for Building Energy Innovation, the California Sustainability Alliance, and numerous other regional and national groups have developed tools and programs targeting leasing and "split-incentive" cost structure barriers in the commercial real estate market.[26] [27] [28] [29] [30]

4.1.5 *Data Availability*

Another major challenge in improving the energy efficiency of separate spaces is segregating the energy consumed by a particular tenant from the whole building's energy consumption. This inability to collect tenant-specific energy data hinders efficiency for two primary reasons:

- As discussed, owners hesitate to invest in energy efficiency improvements of shared systems as only the tenant benefits from reduced utility costs of such endeavors.
- Second, lack of individualized data results in a common-pool resource issue[31] as tenants have no incentive to reduce energy use if they are not held financially accountable for their actions. Changes in their personal energy consumption would be distributed across all tenants.

Metering tenant-specific energy use, a process known as submetering, serves as one potential solution to this data availability problem. Submetering is needed to ensure that each tenant pays for what they use and receives the full benefit of energy they save.

Comments from USGBC are illuminating about the prevalence of tenant space submetering. The 2009 LEED-CI rating system has credit language that rewards the measurement and verification of tenant spaces which includes the installation of submetering equipment to measure and record energy use within tenant spaces. USGBC data show that 54% or 1,900 projects certified under the 2009 LEED-CI rating system have achieved credits dealing with measurement and verification, of which submetering is among several compliance options. This achievement rate demonstrates that submetering is achievable in the tenant space but is not an industry norm.

25 Green Lease Library. (2015). Green Lease Leaders. http://www.greenleaselibrary.com/green-lease-leaders.html

26 Rocky Mountain Institute. (n.d.). Built Environment: Tools and Resources. http://www.rmi.org/tools_and_resources

27 GSA. (n.d.). Green Lease Policies and Procedures. http://www.gsa.gov/portal/category/108551

28 Northwest Energy Efficiency Alliance. (2009). Solving the Energy Efficiency Puzzle: Achieving Bigger Savings in the Pacific Northwest. http://www.nwenergy.org/data/NWEC_Solving-the-EE-Puzzle.pdf

29 Consortium for Building Energy Innovation. (n.d.). http://cbei.psu.edu/

30 California Sustainability Alliance. (n.d.). Green Leases Toolkit. http://sustainca.org/green_leases_toolkit

31 The tragedy of the commons denotes a situation where individuals acting independently and rationally according to each other's self-interest behave contrary to the best interests of the whole group by depleting some common resource.

As a matter of current practice, few buildings and markets in the country measure tenant-level energy use through submetering. Where submetering strategies are employed, meters are most commonly installed for the primary function of lease administration, or the proper billing of tenants for energy use. The vast majority of these installations are typically for the purposes of monitoring spaces characterized by above-average energy use, such as data centers, and separating out this use from total building energy consumption.

Submeters are usually installed as a single entity or as a small group of manually-read meters. Their measurement is typically restricted to electricity use of lighting and plug loads. Energy use from HVAC and other shared systems is not included in these measurements; it is instead billed to the tenant by the owner on a pro rata basis.

Building owners often utilize less sophisticated meters over utility-grade meters. These meters are less expensive and "get the job done" when it comes to simple and consistent measurement of energy use from a single space. These basic meters provide a simple number of kWh used by a separate space over a given period of time. Under this scenario, facilities staff or contractors read the submeter's energy use and apply appropriate multipliers to this number in order to subtract this usage from that of the whole building's demand-charged utility bill.

These same meters can be installed with technical options allowing electricity measurements to tie into systems mimicking utility tariff standards. Such sophisticated options are used for heightened accuracy of tenant energy use billback.

Installing permanent submeters is expensive, with prices often ranging from $700 to almost $5,000 depending on the type and number of meters installed.[32] [33] These costs discourage many owners and tenants from purchasing meters as an energy monitoring tool. While lower-cost wireless meters exist, they currently lack the ability to measure energy use over an extended period of time. Rather, they are most commonly used to temporarily monitor the energy use of a space in order to justify permanent submetering of above-average energy use spaces.

In the absence of nationwide regulation, the presence of submetering is influenced primarily by tenant profile, with large corporate renters, energy-intensive users, sustainability conscious tenants, and tenants vying for LEED-CI certification occasionally requiring submetering during lease negotiations. This disparity can often lead to a varied presence of submetering within markets and buildings, making it difficult to uniformly collect energy use data for individual tenant spaces.

Building owners such as Shorenstein Realty have emphasized the "all or none" problem with billing tenants for energy use.[34] In order to separate out common area usage from tenant usage for billback, owners need to understand the energy consumption of each tenant in the building. Distinguishing common area usage from tenant energy usage can only be accomplished by submetering every tenant in the building. The submetering of just one tenant does not solve this issue as the owner is left with the problem of partitioning the remaining energy use between tenants and common area usage.

32 National Science and Technology Council Committee on Technology. (2011). Submetering of Building Energy and Water Usage. https://www.whitehouse.gov/sites/default/files/microsites/ostp/submetering_of_building_energy_and_water_usage.pdf

33 GSA. (2012). Submetering Business Case: How to calculate cost-effective solutions in the building context. http://www.gsa.gov/portal/mediaId/156791/fileName/Energy_Submetering_Finance_Paper_Knetwork_2012_11_269(508).action

34 Regulations.gov. (2015). Comment response to the published Request for Information (RFI). Shorenstein Realty Services. Regulations.gov website http://www.regulations.gov/#!documentDetail;D=EERE-2015-BT-BLDG-0012-0005

4.2 Technical Opportunities to Improve Energy Efficiency in Tenant Spaces

Despite the variety of challenges to achieving energy efficiency goals in tenant spaces, the technologies exist to significantly improve energy efficiency in these spaces. Case studies and cost benefit analyses of many proven technologies clearly demonstrate the feasibility of improving the energy efficiency in tenant spaces under a variety of different space and use conditions.

Efficient technologies are traditionally considered on an individual basis by which an owner or tenant can choose between simple investment options, such as whether or not to install LED lighting or lighting controls, in order to increase the efficiency of their space. Through this process, the decision maker can draw a straight line from cost of investment to energy savings as only one, or a few, efficiency upgrades are implemented at a time.

It is becoming increasingly important to consider energy efficiency technologies as a package of solutions rather than individual entities during a tenant fit out. This is because high efficiency technologies oftentimes complement the energy reductions of one another (such as HVAC equipment selection and advanced monitoring and controls) and owners often make decisions on more than one type of technology at a time during a fit out. As such, an owner or whole-building tenant may consider their investment holistically during construction.

Choosing between packages of energy efficiency technologies becomes difficult to manage as the number of variables involved increases. In addition, the costs and benefits of technologies can vary significantly depending on the geography, construction, and operations of the building. As a result, owners and tenants sometimes rely on energy modeling and technical consultants to assist with the decision-making process. As such, there is a clear market need for user-friendly, inexpensive tools that allow for decisions to be made without additional burden of technical considerations. Such tools could come in the form of an excel based program, a simple download, or an application that would allow owners and tenants to input specifics about their property (location, size, layout and use), select packages of efficient technologies, and compare results of packages based on financial metrics (incremental cost, payback period, and return on investment).

Several resources which provide broad return on investment (ROI) estimates of recommended energy efficiency packages are available to the public, including the Advanced Energy Retrofit Guide for Office Buildings prepared for the U.S. DOE and case studies produced by the Tenant Energy Analysis and Metrics program. The results of these case studies demonstrate the feasibility of significantly improving the energy efficiency of tenant spaces.

The Advanced Energy Retrofit Guide (AERG) for Office Buildings prepared for the U.S. DOE by PNNL provides several insightful case studies illustrating the implementation of different energy efficiency packages in different locations and the associated financial benefits of the project results.

One AERG case study highlighted the GUND Partnership's 2008 Cambridge, MA office renovation project and attainment of LEED Gold for Commercial Interiors certification (LEED-CI). Specific measures in the selected energy efficiency technology package included: lighting retrofits and the installation of ENERGY STAR® computers, printers, and office equipment. The project's costs totaled $4,400, estimated annual electricity savings were calculated to be $3,000, and the simple payback period was 1.5 years.[35]

An additional AERG case study focused on the 2009 energy efficiency retrofit of the Wilson Blvd. Building in Arlington, VA. Key energy efficiency measures included in the efficiency technology package

35 Thornton, B.A., Wang, W., Lane, M.D., Rosenberg, M.I., and Liu B. (2011). Advanced Energy Retrofit Guides Office Buildings. http://www.pnnl.gov/main/publications/external/technical_reports/pnnl-20761.pdf

included: alternate HVAC rooftop units, upgraded pneumatic HVAC controls and air handler system compressors, the installation of LED downlights, and the promotion of a tenant energy awareness strategy. Project costs totaled $1,140,000, while estimated annual energy savings were calculated to be $250,000, and the simple payback period for the project was 3.9 years.[35]

The Tenant Energy Analysis and Metrics program (referred to as "the program" or "the process") seeks to deliver a replicable process to integrate energy efficiency into office tenant space design and construction within the tenant improvement cycle window.[36] The program, developed in partnership with the NRDC, now resides at and is managed by the Urban Land Institute (ULI). The Tenant Energy Analysis and Metrics approach outlines a 10-step process to guide tenants through the leasing, design, modeling, analysis, execution, and measurement and verification stages of their build-out and occupancy:

- Step 1: select an office space.
- Step 2: select a project team (architects, engineers, and contractors tasked to help with the build-out).
- Step 3: set energy performance goals and create a list of energy efficiency technologies and strategies.
- Step 4: create packages of energy efficiency technologies and model their projected energy performance.
- Step 5: review the incremental costs of the energy efficiency packages and available incentives to specific energy efficiency technologies.
- Step 6: conduct a financial analysis including the calculation of return on investment (ROI) and payback period for each package of energy efficiency measures.
- Step 7: review financial analyses and choose a package of energy efficiency measures.
- Step 8: build out the space with chosen package of energy efficiency measures.
- Step 9: measure and verify the actual energy performance of the space.
- Step 10: share the results on an ongoing basis.

This process is further supported through guidance documents which detail in-depth instructions to complete each of the 10-steps discussed above.

The program documented ten case studies of tenants using the 10-step process to choose between packages of energy efficiency solutions, and the results they observed. These case studies are described in brief below. Energy and cost savings projections detailed in these summaries are based on actual energy performance and delivered savings. Case study participants verified savings numbers by measuring the operational energy use of their space upon completion of the build-out.

Bloomberg LP, a leading provider of global business information, rented space in Manhattan's 120 Park Avenue. Bloomberg partnered with the program for the design and construction of their new office. The company selected the following package of high efficiency measures for their build-out: mechanical duct bridging, high-efficiency lighting, daylight harvesting, and NightWatchman Software (plug load management). Combined, these efficiency measures totaled $3.06/square foot in incremental implementation costs.[37] Over the course of Bloomberg's lease, the project is estimated to reduce electricity use by 10.5% and save more than $173 thousand in electricity costs with a ROI of 140% and a payback period of 2.5 years (Table 3).

36 Information related to the ULI tenant space energy efficiency program and the case study summaries discussed below will be hosted at http://uli.org/.

37 The incremental implementation cost includes deductions from rebates and incentives.

COTY Inc., a global leader in beauty products, designed a tenant space build-out for floors 16 and 17 of their Empire State Building headquarters in Midtown Manhattan. Using the 10-step process, COTY chose the following package of high efficiency technologies for their planned build-out: a LED lighting system, daylight controls, variable air volume (VAV) air handling units, demand control ventilation, elimination of noise traps on air handling units, and plug and process load reduction through the installation of ENERGY STAR® equipment. In total, these efficiency measures amounted to $0.71/square foot in incremental implementation costs.43 Over the course of COTY's 17-year-lease, this project is estimated to reduce electricity use by 30.7% and save more than $716 thousand in electricity costs with a ROI of 328% and a payback period of 2.7 years (Table 3).

Cushman & Wakefield, a global commercial real estate services company, rented space in the newly constructed One World Trade Center in 2015. The company chose to use the program to guide the design and construction of their office. Cushman & Wakefield selected the following efficiency measures for their build-out: LED lighting; daylight harvesting; no humidity control, raising of temperature set points, and allowing independent distribution facility (IDF) room ventilation to cycle off; high-efficiency tenant HVAC and motors; ENERGY STAR® office equipment; server power management; and temperature set points (77° cooling and 70° heating). All in all, incremental implementation costs for these efficiency measures totaled $3.25/square foot.43 Over the course of Cushman & Wakefield's 10-year-lease, this project is estimated to reduce electricity use by 47.5% and save more than $87 thousand43 in electricity costs with a ROI of 359% and a payback period of 1.7 years (Table 3).

The Estee Lauder Companies, a leading manufacturer and marketer of cosmetics, leased 10,000 square feet at 110 East 59th Street in Manhattan. Through their partnership with the program, the company selected a package of energy efficiency measures for their build-out, which included: high efficiency lighting (0.7 and 0.9 Watts/square foot), daylight harvesting, occupancy sensor lighting, ENERGY STAR® equipment, and plug loads shutdown (master shutoff switch). This package of energy efficiency measures totaled $1.29/square foot in incremental implementation costs.43 Over the course of The Estee Lauder Companies' 6-year-lease, this project is estimated to reduce electricity use by 12.1% and save more than $15 thousand in electricity costs with a ROI of 42% and a payback period of 3.7 years (Table 3).

Global Brands Group Holding Ltd. leased 137,000 square feet on Floors 7, 8, and 9 of the Empire State Building in Midtown Manhattan and used the program to guide the design and construction of their new office space. The company selected the following package of energy efficiency measures for their build-out: daylight harvesting lighting controls, high-efficiency lighting, optimized HVAC units, demand-controlled ventilation (CO2 sensors), low-velocity air handler units (AHUs), and plug load management. The project totaled $0.98/square foot in incremental implementation costs.43 Over the course of Global Brands' 15-year-lease, this package of efficiency measures is estimated to reduce electricity use by 11.8% and save more than $438 thousand in electricity costs with a ROI of 126% and a payback period of 4.6 years (Table 3).

LinkedIn Corp, the world's largest online professional network, leased 36,000 square feet on Floor 22 of the Empire State Building in Midtown Manhattan. The company partnered with the program to guide the build-out of their office. LinkedIn chose the following energy efficiency measures to be incorporated into their new space: high-efficiency lighting, advance lighting (daylight harvesting and occupancy sensors), no humidification and increased temperature set points in IDF, optimized air handlers, demand-controlled ventilation, ENERGY STAR® equipment, and occupancy sensor plug strips. The incremental implementation cost for this project totaled $2.63/square foot.43 Over the course of LinkedIn's 10-year-lease, this package of efficiency measures is estimated to reduce electricity use by 31.3% and save more than $153 thousand in electricity costs with a ROI of 23% and a payback period of 6.4 years (Table 3).

The New York State Energy Research and Development Authority (NYSERDA), a state agency that helps New Yorkers increase energy efficiency, leased office space at 1359 Broadway in Manhattan. The agency partnered with the program for their planned build-out. NYSERDA chose the following energy efficiency measures to be included in the design and construction of their new space: high-efficiency lighting, daylight harvesting, ENERGY STAR® equipment, computer shutoff software, energy recovery ventilator, natural ventilation, and a variable refrigerant flow (VRF) system. Project incremental implementation costs totaled $2.43/square foot.43 Over the course of NYSERDA's 14-year-lease, this package of efficiency measures is estimated to reduce electricity use by 39.0% and save more than $188 thousand in electricity costs with a ROI of 179% and a payback period of 3.6 years (Table 3).

Reed Smith, a leading international law firm, moved into their office in Philadelphia's Three Logan Square in 2014. The company utilized the 10-step process and chose the following energy efficiency measures for their new office space: energy efficient lighting design (0.84 Watts/square foot), daylight harvesting controls, bi-level lighting control, dimmable switching controls, ENERGY STAR® equipment, occupancy sensor power strips, manually controlled quad outlets, after-hours outlet control, and high-efficiency motors and variable frequency drives on air handling units (AHUs). Incremental implementation costs for this project totaled $1.31/square foot.43 Over the course of Reed Smith's 16-year-lease, this package of efficiency measures is estimated to reduce electricity use by 44.5% and save more than $1 million in electricity costs with a ROI of 410% and a payback period of 2.2 years (Table 3).

Shutterstock, a global provider of high-quality licensed media, leased approximately 60,000 square feet at the Empire State building in Midtown, Manhattan. The company applied the 10-step process to their office build-out. Shutterstock selected the following energy efficiency measures for their new space: as-designed lighting (0.986 Watts/square foot), daylight harvesting, local occupancy sensors, economization of data center space, demand-controlled ventilation, and a chilled water data center cooling unit. Project incremental implementation costs totaled $2.63/square foot.43 Over the course of Shutterstock's 11-year-lease, this project is estimated to reduce electricity use by 22.9% and save more than $369 thousand in electricity costs with a ROI of 40% and a payback period of 6.1 years (Table 3).

In 2013, TPG Architecture, an architecture and interior design firm, signed a lease for 40,000 square feet of office space in Midtown Manhattan's 31 Penn Plaza. TPG worked with program partners to identify key energy efficiency measures in the design of their office space. The company selected the following energy efficiency package in their tenant space build out: as-designed lighting (1.08 Watts/square foot), daylight harvesting, local lighting occupancy sensors, ENERGY STAR® equipment, demand-controlled ventilation, no humidification in the office data center, computer shut-off software, occupancy sensor plug strips, and high-efficiency lighting (0.8 Watts/square foot). In total, incremental implementation costs for the package were estimated to be $2.01/square foot.43 Over the course of TPG's 11-year-lease, this project is estimated to reduce electricity use by 21.6% and save more than $275 thousand in electricity costs with a ROI of 162% and a payback period of 3.2 years (Table 3).

TABLE 3 – ULI TENANT SPACE ENERGY EFFICIENCY PROGRAM CASE STUDY RESULTS[A]

COMPANY	LOCATION	LEASED AREA	INCREMENTAL IMPLEMENTATION COST ($ / SQ FT)	PHASE*	ENERGY REDUCTION	TOTAL ELECTRICITY SAVINGS OVER LEASE TERM	ROI	PAYBACK PERIOD
Bloomberg LP	120 Park Avenue, Manhattan	20,000 ft²	$3.06 / sq ft	Modeled Savings	10.9%	$182,208	152%	2.4 years
				Verified Savings	10.5%	$173,880	140%	2.5 years
COTY Inc.[B]	350 Fifth Avenue, Manhattan	80,000 ft²	$0.71 / sq ft	Modeled Savings	32.0%	$548,317	227%	3.5 years
				Verified Savings	30.7%	$716,148	328%	2.7 years
Cushman & Wakefield	One World Trade Center, Manhattan	7,500 ft²	$3.25 / sq ft	Modeled Savings	52.6%	$95,663	404%	2.2 years
				Verified Savings	47.5%	$87,862	359%	1.7 years
Estee Lauder Companies[C]	110 E. 59th St., Manhattan	10,000 ft²	$1.29 / sq ft	Modeled Savings	10.8%	$23,069	106%	2.5 years
				Verified Savings	12.1%	$15,862	42%	3.7 years
Global Brands Group	350 Fifth Avenue, Manhattan	137,000 ft²	$0.98 / sq ft	Modeled Savings	25.5%	$546,983	189%	3.7 years
				Verified Savings	11.8%	$438,090	126%	4.6 years
LinkedIn Corp.	350 Fifth Avenue, Manhattan	36,000 ft²	$2.63 / sq ft	Modeled Savings	34.2%	$284,195	129%	3.4 years
				Verified Savings	31.3%	$153,000	23%	6.4 years
NYSERDA	1359 Broadway, Manhattan	15,200 ft²	$2.43 / sq ft	Modeled Savings	34.2%	$180,277	168%	3.8 years
				Verified Savings	39.0%	$188,017	179%	3.6 years
Reed Smith	Three Logan Square, Philadelphia	117,000 ft²	$1.31 / sq ft	Modeled Savings	34.3%	$1,800,986	715%	1.4 years
				Verified Savings	44.5%	$1,126,498	410%	2.2 years
Shutterstock Inc.	350 Fifth Avenue, Manhattan	58,600 ft²	$2.63 / sq ft	Modeled Savings	23.5%	$354,861	34%	6.3 years
				Verified Savings	22.9%	$369,897	40%	6.1 years
TPG Architecture LLP	31 Penn Plaza, Manhattan	40,000 ft²	$2.01 / sq ft	Modeled Savings	20.2%	$188,447	79%	4.7 years
				Verified Savings	21.6%	$275,372	162%	3.2 years

* "Modeled Savings" numbers represent original project savings estimates (step 4 of the 10-step process) while "Verified Savings" numbers represent verified project savings estimates (step 9 of the 10-step process).

A The numbers outlined above are the results of the Tenant Analysis and Metrics program which documented ten case studies of tenants using the 10-step process to choose between packages of energy efficiency solutions.

B Differences in modeled savings and verified savings energy reductions may be attributed to baseline and assumption adjustments and actual energy use documented during the measurement and verification process.

C Differences in modeled electricity savings is usually due to a discovered underestimation or overestimation of energy use in the measurement and verification process.

4.2.1 *Analysis of High Efficiency Technologies*

The technologies, outlined below, and their associated cost benefit analyses clearly demonstrate the feasibility of improving the energy efficiency in tenant spaces under a variety of different space and use conditions. This analysis of high efficiency technologies, discussed in the appendix, provides insight into major energy efficiency opportunities in separate spaces, simple cost-benefit analyses, and links to additional information.[38] This collection of technologies is reflective of the general opportunities and classes of technology that can be used in improving energy efficiency in a separate tenant space, but should not be considered a comprehensive list.

The following technologies are discussed in the appendix:

4.3 Market Opportunities to Improve Energy Efficiency in Tenant Spaces

In addition to technology, there are market-based opportunities to increase energy efficiency through processes, programs, and policies oriented to encourage the uptake of energy efficiency in tenant spaces. This section offers a list of high performance energy efficiency market-based opportunities with the intention of illustrating the variety of approaches available. These energy efficiency approaches are broken out into two categories, processes and programs.

4.3.1 *Processes*

This section discusses the market processes that currently influence the level of energy efficiency within a tenant space, explains how a tenant might navigate these processes, and investigates how these processes might be improved to drive additional energy efficiency across the market.

4.3.1.1 *Analyzing Opportunities*

Within the design and construction process, both tenants and owners have a role in determining the efficiency of the tenant space. As discussed, building owners traditionally control the building shell, shared equipment such as HVAC systems, and any global operational controls. By contrast, tenants

38 The High Impact Technology Catalyst: Technology Deployment Strategies paper prepared by Navigant Consulting for the U.S. DOE is one of the primary additional information resources and provides a list of building technologies with large savings potential.

control the installation of efficient equipment (lighting and plug-loads), and more directly manage energy use behavior.

Depending on the size and characteristics of the space, the tenant may choose to use conventional methods and checklist approaches to determine energy efficiency strategy in the build-out of the space, or employ estimates and energy modeling for a more detailed perspective and to maximize return on investment.

Conventional Methods and Checklist Approaches

Under a conventional fit-out process, driven by a tenant, the tenant may work with architects, engineers, and the owner to outfit the space. This team may rely upon guidelines, rules of thumb, or prior experiences in order to select technologies for meeting their pre-determined energy efficiency goals. Choices can be driven at one extreme by the legal codes and standards (minimum applicable requirements), and at the other by certification standards (ratable standards for design and construction such as LEED and Green Globes). Most fit-outs will fall somewhere in the middle, where decisions to incorporate energy efficiency projects above and beyond minimum applicable requirements are made absent of a coherent efficiency plan.

For many owners and tenants in this middle-ground scenario, checklist approaches may be sufficient to determine their energy efficient technology needs. While checklist approaches may not maximize potential energy savings, these methods may provide easy-to-implement guidance applicable to a variety of space types that align with a clearly defined energy efficiency result. This guidance can be incorporated cost-effectively, particularly in the case of smaller projects.

The industry has taken steps towards providing such guidance checklists. However, the current scope of these checklists falls short in accommodating the industry-wide need for a comprehensive set of guidelines that offer specification language customizable to the variety of tenant spaces that exist (such as a large versus small space or a retail versus office space). Additionally, the industry has not widely publicized these materials, leading to a lack of awareness on their existence and proper usage.

The Saving Energy in Leased Spaces (SELS) training and information website, created by the Consortium for Building Energy Innovation,[39] is one example of an existing online toolkit. The SELS website provides three toolkits focusing on saving energy in: existing leases, new leases, and during tenant improvement projects. Each toolkit provides users with: an online course on energy reduction; tools and checklists to track plug loads and calculate estimated energy savings; and a resource library of reference materials.[40] While the SELS website exhibits some best practices, including specification language for several types of tenant space improvements and options for users in different phases of the leasing cycle, it does not provide customization for different purposes (retail versus office) or sizes (small or large) of leased spaces.

The DOE's Technology & System Specifications represents another example of a collection of best practice guidelines. These specifications are designed to guide building owners and tenants through the process of obtaining quotes for energy efficient purchases.[41] While this collection offers a variety of specifications, users are required to determine which specifications apply to their leased space and to further customize chosen specifications to fit their space's attributes.

The Chartered Institution of Building Services Engineers' "Energy Efficient Refurbishment of Retail

39 The Energy Efficient Buildings Hub (EEBHUB) has been rebranded as the Consortium for Building Energy Innovation, however the SELS website still uses EEBHUB branding.

40 Energy Efficient Buildings Hub. (n.d.). Saving Energy in Leased Spaces (SELS) training and information website. http://savingenergyinleasedspace.com/

41 DOE Better Buildings. (n.d.). Technology & Systems Specifications. https://www4.eere.energy.gov/alliance/activities/specifications

Buildings" document provides guidance specific to retail space fit-outs. However, this document does not include specification language.

RMI is currently developing the Commercial Energy+ Initiative, which aims to rapidly increase the scale of building retrofits by providing a platform to provide accessible and inexpensive energy efficiency solutions for commercial buildings with tenant spaces. RMI reports that this initiative will supply a package of efficiency measures and technologies that can be scaled to specific building attributes and directly increase the efficiency of the space.[42]

Estimates and Energy Models

In scenarios where a tenant chooses to go beyond the minimum code requirements, but not pursue a formal guidance checklist, the tenant or service provider can estimate the value of an energy efficiency measure in a tenant space by calculating upfront costs, lifecycle costs, annual savings, and returns on investment. Tenants can also use energy modeling to help determine the energy efficiency opportunities of a space. With modeling, the tenant can compare different energy efficiency measures and decide which options are most appropriate for the individual space.

One example of such modeling programs is the EnergyPlus energy simulation software, DOE's free and open-source, whole building energy modeling engine that allows users to estimate energy consumption from a variety of sources including: plug and process loads, heating, cooling, and lighting.[43] A companion product is OpenStudio, a free and open-source graphical application for model development, parametric analysis and optimization using EnergyPlus. Commercial, proprietary front ends to EnergyPlus offer additional functionality.

While energy models provide the benefit of assessing energy efficiency measures in detail before their implementation, the effort required to use them has historically prevented such tools from wide-spread market uptake. Energy modeling often requires specialized consultants, and some additional time, both of which can strain project budgets. Modeling guidance for tenant space is also lacking – e.g. there may be confusion over whether central HVAC systems need to be modeled, or how to model adjacent tenant spaces. Clear modeling guidelines for tenant space are needed to ensure consistency and avoid confusion.

Organizations are beginning to develop tools to help translate modeling results to be applicable to tenant spaces. As an example, the ULI Tenant Energy Analysis and Metrics program aims to create a process to assist tenants achieve 30 to 50 percent energy savings with a payback period of 3-5 years through a 10-step process that relies on energy modeling.[44] The program's Excel-based Value Analysis Tool that allows for the comparison of energy efficiency measures grouped into "Good," "Better," and "Best" packages in order for the tenant to decide which options are the most appropriate for their goals and budget – an analysis that can also be useful in traditional non-modeling approaches.

Given the current levels of effort required, energy modeling is most beneficial to large spaces where the return on investment from energy efficiency measures covers the additional upfront costs of modeling. In order to make this process financially feasible for small tenant applications, continued investments in both guidance and turnkey wrappers that make modeling and modeling results more accessible are necessary.[45] Specifically, development of a layman's user interface for comparing simple tenant energy efficiency measures could make robust analysis available to a broad set of tenant spaces.

42 DOE. (n.d.). EnergyPlus Energy Simulation Software. http://energyplus.net/

43 2015-09-30 Comment response to the published RFI: High Performance Tenant Optimization Guide. ID #: EERE-2015-BLDG-0012-0011. http://www.regulations.gov/#!documentDetail;D=EERE-2015-BT-BLDG-0012-0011

44 The popularity of the miles per gallon (MPG) comparison tools at FuelEconomy.gov offers a glimpse of potential for such low-cost software.

45 2015-09-30 Comment response to the published RFI: High Performance Tenant Optimization Guide. ID #: EERE-2015-BLDG-0012-0011. http://www.regulations.gov/#!documentDetail;D=EERE-2015-BT-BLDG-0012-0011

4.3.1.2 *Leasing*

Traditional lease language does not typically directly address the energy efficiency of the tenant space. As discussed in section 4.1 above, a conventional lease might allocate utility expenses to tenants proportionally based on leased area and create a split incentive between tenants and owners with regard to energy efficiency measures. As such, neither owners nor tenants may be financially motivated to reduce energy use. However, in recent years the "green lease" has become an option for owners and tenants to re-align energy efficiency incentives through changes to leasing language.

While there are no formal standards for a "green lease", recent initiatives have articulated best practices and provided templates, including the BOMA Green Lease Guide, and the Green Lease library, maintained by the Institute for Market Transformation (IMT). The requirements for the Green Lease Leader recognition program lend a useful set of criteria for defining a green lease, which should contain:

- **A tenant cost recovery clause** that can be used for energy efficiency-related improvements. Tenant cost recovery clauses, which allow the owner to recover the cost of capital on infrastructure investments through a specified amortization schedule, have been included in most commercial leases for the last 10-15 years. That said, these clauses have not typically been used for energy efficiency improvements. When this clause is used for green leasing, owners are incentivized to invest in energy efficiency improvements as they will be able to recoup their costs.[46]
- **Stipulations for best practices in energy management** that can include: installation of submeters for tenants, minimum standards for tenant energy efficiency improvements (such as equipment specifications or available watts per square foot), payment of services to periodically adjust or calibrate equipment to ensure efficiency, and requirements for tenant disclosure of monthly utility data for building benchmarking purposes.53
- **Guidance on sustainable operations and maintenance** that should cover the restriction of individual tenant space heaters, requests for extensions of normal leasing hours such as weekends, and ensuring janitorial services occur during daytime hours.53

As discussed in Section 4.1.1, energy efficiency remains a relatively minor consideration in larger leasing negotiations. However, even in situations where energy efficiency is a priority, several challenges exist to implementing a green lease:

- **Lease diversity.** Tenants in the same building can have leases that look vastly different from one another as their priorities and negotiating power likely differ.
- **Tenant size.** With smaller or less sophisticated tenants, leasing language is often driven by building ownership. In these cases, owners have greater control over leasing language and may not be responsive to a tenant's requests for modification. With large tenants that have greater purchasing power and mandates for green leasing - such as the General Service Administration, Walmart, Target and others - owners may be more willing to incorporate client-specific mandates within leasing language.

46 Green Lease Library. (n.d.). Program Requirements. http://www.greenleaselibrary.com/program-requirements.html

- **Owner size.** Only owners with significant market power can implement aggressive energy efficiency lease clauses. These large owners may have the ability to retain tenant demand for their buildings despite changes in conventional leasing structures, unlike smaller tenants with less market power. As an example, Pyramid Companies (the largest privately owned developer of shopping centers in the Northeast United States), expanded its Carousel Center retail complex to include a 1.3-million-square-foot LEED Gold certified project for Core & Shell Development in the United States. As part of this development, Pyramid modified its standard lease to require that all 100 tenant spaces achieve LEED for LEED-CI certification.[47]
- **Lack of incentive for brokers to advocate for a green lease.** Real estate brokers are motivated by their commission to close deals quickly and often view green leasing stipulations as an added layer of complexity in a deal.

To continue advancing green leases, which in turn will advance high performance spaces, industry organizations can continue to collect and publish best practices, and create case studies to illustrate the benefits and market opportunity for green leasing strategies. However, providing resources is not enough.

First and foremost, brokers need to become actively motivated to implement green leases. Both owners and tenants can accomplish this by directing their brokers to include key green lease features as their default leasing language in leasing negotiations. Brokers will be driven to accommodate these requests in order to close real estate deals.

Additionally, a broker engagement strategy, which would align incentives so that brokers actively facilitate green leases, would also improve the adoption of green leases. A broker engagement strategy might include the following components:

- Developing a coalition of brokers to encourage and educate existing brokers and brokerage firms about green leasing. NAIOP (the Commercial Real Estate Development Association), SIOR (the Society of Industrial and Office Realtors), National Association of Realtors, or other organizations could play a leadership role.
- Working with the coalition of brokers to develop potential updates to the licensure exam, or additional certifications that could be leveraged as a marketing differentiator. This may require a gradual approach since licensing requirements for commercial real estate brokers often differ depending on the state.
- Basing an ongoing green certification for brokers on the completion of a minimum number of green leases per year (meeting the Green Lease Leader criteria).
- Working with Green Lease Leaders and other programs to communicate the benefits of using an efficiency-certified broker.

Similar steps are currently being taken by industry members. As an example, CBRE developed and launched a training platform for its more than 2,900 U.S. brokerage professionals. The platform includes a broker training video and a resource center that helps brokers understand and communicate the sustainable features of commercial properties helping to connect sustainability conscious tenants with high performing space that meets their needs. This training program does not go as far as a certification, but is a large step towards recognizing and responding to current needs.

By engaging brokers, communicating the value of an "efficiency-certified" broker, and requiring on-going completion of green leases to maintain certification, green leases can be more commonly harnessed to drive efficiency.

47 DOE. (n.d.). Pyramid Companies Implements Green Leasing to Promote Energy Efficiency in Tenant Retail Space. Building Technologies Program. http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/pyramid_case_study_10-15-12.pdf

4.3.2 *Programs*

Improvements in energy efficiency can also be encouraged through programs that target specific market challenges or opportunities unique to tenant spaces, including: expanding the business case for energy efficiency; rating systems; reporting frameworks; leasing language; voluntary initiatives; regulation; and education, awareness, and behavioral change.

4.3.2.1 *Expanding the business case*

One key reason leading to historic under-emphasis on energy efficiency in the design and construction of tenant spaces are the weak financial incentives to each party (brokers, designers, building owners, and tenants, as discussed in section 4.1). As discussed in section 4.1.2, utility costs are typically small in comparison to rent and other costs associated with the transaction, and often fade from prominence during the negotiation of the lease. However, a growing body of research quantifies the financial benefits of increasing energy efficiency of tenants' spaces to owners, tenants, designers, and brokers alike.

Even in lease structures with a split incentive for energy efficiency, building owners can benefit from increased energy efficiency through market differentiation – and attract higher rents and longer tenures. Research shows that energy efficient buildings rent for an average premium of 2-6%,[48] sell for a premium of as much as 16%,[49] attract high-quality tenants,[50] and have lower default rates for commercial mortgages (Figure 3).[51] According to a 2010 study,[52] lease-up rates for green certified spaces can range from average to 20% above average market rates for conventional spaces. A 2012 study examining the San Diego real estate market showed that the overall vacancy rate for green buildings was 4% lower than for non-green properties and LEED-certified buildings routinely commanded the highest rents, and an increased asset value of their buildings.[53] Significantly, more than 62% of buildings nationally over 500,000 square feet were green certified, representing 76% of all area in those buildings.[54] In such a market, not receiving a green certification actually leads to a competitive disadvantage. Additionally, a recent study found that commercial properties with ENERGY STAR® labels were 20% less likely to default on mortgage loans than those without labels;[52] supporting the conception that buildings with energy efficient features are better financial investments.

48 Eichholtz, P., Kok, N., & Yonder, E. (2012). Portfolio greenness and the financial performance of REITs. Journal of International Money and Finance, 31(7), 1911-1929. http://www.fir-pri-awards.org/wp-content/uploads/Article-Eichhiltz-Kok-Yonder.pdf

49 Eichholtz, P., Kok, N., & Yonder, E. (2010). Doing Well by Doing Good? American Economic Review. http://urbanpolicy.berkeley.edu/pdf/AER_Revised_Proof_101910.pdf

50 Eichholtz, P., Kok, N., & Quigley, J. M. (2009). Why do companies rent green? Real property and corporate social responsibility. Real Property and Corporate Social Responsibility. Program on Housing and Urban Policy Working Paper, (W09-004). http://www.ucei.berkeley.edu/PDF/EPE_024.pdf

51 An, X. & Pivo, G. (2015). Default Risk of Securitized Commercial Mortgages: Do Sustainability Property Features Matter? http://capla.arizona.edu/sites/default/files/faculty_papers/Default%20Risk%20of%20Securitized%20Commercial%20Mortgages%20and%20Sustainability%20Features%2C%202015.pdf

52 Miller, N. (2010). Does Green Still Pay Off? http://www.normmiller.net/wp-content/uploads/2012/08/Does-Green-Still-Pay-Off.docx

53 CBRE Global Research and Consulting (2012). Global Market View - Q2 2012.

54 CBRE. (2015). Green Adoption Index 2015. http://www.cbre.com/~/media/files/corporate%20responsibility/green-building-adoption-index-2015.pdf?la=en

FIGURE 3 – FINANCIAL BENEFITS OF ENERGY EFFICIENCY-CERTIFIED BUILDINGS

Tenants can realize a wide variety of benefits from the implementation of energy efficiency projects in their leased spaces. The most direct benefit of energy efficiency is the decrease in utility costs. However, a number of other benefits can also be attributed to energy efficient spaces such as increased worker productivity,[55 56] attracting and retaining employees,[57] and increasing brand value. Changing social norms, recognition of these benefits, and increased awareness of the "brand" value of green space can drive demand for high performing tenant spaces.

Engineers, architects, and interior designers can also profit from energy efficient tenant spaces. Each of these design professionals wants to remain competitive within their respective industries. Potential clients such as GSA,[58] TD Banknorth, and Capital One now require energy efficiency within their lease terms and will only work with designers who can fulfill such requests.[59]

Broker incentives for energy efficiency remain one of the most challenging open issues holding back energy efficient separate spaces. One recent initiative has been the Green Lease Leader program, which recognizes brokers for successfully implementing green lease language into new or existing leases. As discussed earlier, the broker plays a key role in matching owners and tenants. Providing a powerful incentive for brokers to preferentially consider energy efficient spaces would significantly encourage owners and tenants to implement energy efficiency measures. If brokers adopt practices, language, and processes centered on the leasing of efficient buildings, it could result in a competitive advantage. However, brokers remain unaware or unmotivated to adopt such practices, because the market has not demanded such service.

55 Delmas, M & Pekovic, S. (2012). Environmental standards and labor productivity: Understanding the mechanisms that sustain sustainability. Journal of Organizational Behavior. Pages 34, 230-252. 2012

56 Allen, J., MacNaughton, P., Satish, U., Santanam, S., Vallarino, J., & Spengler, D. (2015). Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers: A Controlled Exposure Study of Green and Conventional Office Environments. Environmental Health Perspectives. http://ehp.niehs.nih.gov/15-10037/

57 CBRE. (2015). National Green Building Adoption Index, "Houston", CBRE, Page 16.

58 GSA. (n.d.). Green Lease Policies and Procedures. http://www.gsa.gov/portal/category/108551

59 Green Lease Library. (2015). Green Lease Leaders. http://www.greenleaselibrary.com/2015-awardees.html

Efforts to raise awareness of these financial benefits are necessary to increase emphasis on energy efficiency in the design and construction of tenant spaces. Policy makers, owners, and tenants can all participate in these efforts:

- Policy makers can support programs that illustrate and communicate the quantitative link between increased energy efficiency and increased competitiveness to the commercial real estate market can drive change as industry participants become aware of the business benefits of energy efficiency. In a market where high performing tenant spaces are expected, owners would be inclined to implement energy efficiency measures as a way to preserve and increase the value of their investments.
- Owners can advertise the decreased operational costs and increased employee retention, worker productivity, and brand value associated with the energy-efficient aspects of their building to potential tenants.
- Tenants and owners can articulate their demand to brokers for energy efficient buildings and green leasing structures.
- Tenants and owners can implement requirements that push designers to attain certifications and offer services to meet the demand for energy efficient tenant spaces, thus driving energy efficiency through competition.

4.3.2.2 *Rating systems*

By allowing for direct peer-to-peer comparison of buildings based on energy performance, rating systems provide the market with greater insight to evaluate building performance, broadcast the value of energy efficiency measures, and distinguish high-performance buildings from the rest of the market. Simplifying efficiency to an accessible metric gives market participants a "scorecard" to measure higher levels of performance, and often drives activity across the industry as a whole through competitive forces and peer comparison. Whole building rating systems, such as ENERGY STAR® and LEED have histories spanning decades,[60] and have driven energy efficiency demand by providing owners and tenants with broad information about building performance.

However, there are few applicable rating systems in the U.S. that focus on design and operations at the tenant space level. The additional resolution provided by rating systems focused on separate spaces has the potential to provide substantial value if designed in a way that cost-effectively provides the market with unique information about a space.

60 ENERGY STAR®. (n.d.). The value of the ENERGY STAR® certification. http://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/learn-benefits/value-energy-star-certification

Whole Building Rating Systems

Three prominent examples of whole building energy rating systems include:

ENERGY STAR®, a voluntary program managed by the Environmental Protection Agency (EPA) and DOE, has encouraged building operators to benchmark energy use, implement energy management practices, cut operational costs, and earn recognition for performance. The ENERGY STAR® ranking system provides a 1-100 score for buildings that directly coincides with performance compared to peer buildings of a similar type. Since 1999, over 27 thousand buildings and plants representing 3.9 billion square feet[61] throughout the United States have earned the ENERGY STAR® certification. The EPA reports that the ENERGY STAR® building initiative saves more than 9 billion dollars and prevents nearly 135 MMT of greenhouse gas emissions each year.[62]

"Designed To Earn ENERGY STAR®" is the ENERGY STAR® design designation through which Architects can help their clients reduce their carbon footprints and energy costs by designing buildings to earn the ENERGY STAR®. These buildings are designed to perform in the top 25% of similar buildings nationwide, and are recognized for their design (and predicted ENERGY STAR® score), rather than operational performance. Many buildings go on to receive the ENERGY STAR® certification.[63]

The U.S. DOE's Building Energy Asset Score is a more recent national standardized tool for assessing the physical and structural energy efficiency of commercial and multifamily residential buildings. The Asset Score generates a simple energy efficiency rating that enables comparison among buildings, and identifies opportunities to invest in energy efficiency upgrades. Unlike an ENERGY STAR® score, which enables the comparison of buildings based on their energy consumption, the Asset Score reflects the energy efficiency of a building based on its design, construction, and energy systems.

The Leadership in Energy and Environmental Design (LEED) rating systems, voluntary frameworks developed by the U.S. Green Building Council (USGBC), guides building owners and operators through the process of achieving green building design, construction, operations, and maintenance solutions. While both LEED and ENERGY STAR® focus on energy efficiency, LEED also incorporates a broader set of performance categories focusing on non-energy related items. Buildings can earn points by demonstrating their ability to address environmental impacts and human benefits through six categories: sustainable sites, water efficiency, energy & atmosphere, materials & resources, indoor environmental quality, and innovation in design. Within the United States alone, more than 25 thousand projects representing about 3.2 billion square feet of building space are LEED-certified.[64]

These LEED and ENERGY STAR® systems have driven market change by demonstrating value to owners, managers, and leaseholders. However, while these systems provide significant value, they don't attribute responsibility to individual actors within a multi-tenant space, with the exception of LEED for Commercial Interiors (LEED-CI) which is discussed below.[65]

61 ENERGY STAR®. (n.d.). Certified Buildings and Plants. https://www.energystar.gov/index.cfm?fuseaction=labeled_buildings.locator

62 ENERGY STAR®. (n.d.). Buildings & Plants: https://www.energystar.gov/buildings?s=mega

63 ENERGY STAR®. (2015). Projects and architects to achieve Designed to Earn the ENERGY STAR®. https://www.energystar.gov/buildings/service-providers/design/step-step-process/apply-designed-earn-energy-star/architects-and-projects

64 USGBC. (2016). Country Market Brief: United States. http://www.usgbc.org/advocacy/country-market-brief

65 LEED has Core and Shell, New Construction, and Existing Building and Maintenance programs, focused on the whole building –the Commercial Interiors program, which does have a tenant component, is discussed in the next section.

Tenant Space Rating Systems

While a tenant space rating system could lead to a significant increase in the energy efficiency of separate spaces, several barriers, discussed in Section 4.1, have hindered emergence of a widely adopted tenant space rating system in the United States:

- Market research hasn't demonstrated strong demand for an additional set of voluntary building rating systems.
- Lack of submetering for energy used in tenant space has prevented measurement of tenant energy use.
- Tenant space rating systems will likely be implemented in buildings that already participate in whole-building rating systems such as LEED or ENERGY STAR®. Therefore, the costs associated with such tenant space rating systems would likely be additive to the costs associated with existing whole-building rating systems.

The most common tenant space rating system in the United States is LEED for Commercial Interiors, a variant of the voluntary LEED system managed by USGBC. However, participation within this LEED rating system and other similar tenant space rating systems in the United States remains small and inconsistent. For example, there are currently 8,000 certified LEED-CI projects representing about 380 thousand square feet of space,[66] these certified spaces equate to less than 0.01% of U.S. commercial real estate floor space.[67] This lack of market uptake and consistency leads to consumer confusion and, as a result, these rating systems have largely not driven significant market change. By contrast, both Australia and Singapore have implemented universal tenant space rating systems that show the potential of a single dominant rating system to propel industry-wide energy efficiency improvements.

LEED for Commercial Interiors

LEED for Commercial Interiors (LEED-CI) addresses the specifics of tenant spaces primarily in office, retail, and institutional buildings. Tenants who lease their space or do not occupy the entire building are eligible. Over 12,000 projects have certified or have declared intent to certify with the LEED-CI.[68]

A primary barrier to LEED-CI is cost, as the program typically involves consultants to guide the project team through the process of certification and documentation. Regardless of the size of the space, all LEED-CI prospects are required to undergo the same process and documentation. This fixed cost is especially challenging for tenants with smaller spaces. Tenants who do use the LEED-CI process tend to be those with a large rental area for which the cost of certification is not prohibitive, or those with corporate guidelines mandating building performance certifications for rental spaces.

LEED-CI is not a universally prevalent scheme in the United States, and thus does not fulfill the full potential of a tenant space-rating scheme to drive energy efficiency. By contrast, the NABERs system in Australia has become prevalent throughout the market, and as a result is used as a common comparison scheme to drive the adoption of energy efficient technologies.

66 USGBC. (2016). Country Market Brief: United States. http://www.usgbc.org/advocacy/country-market-brief

67 EIA. (2003). Commercial Buildings Energy Consumption Survey (CBECS) – 2003 CBECS Survey Data. CBECS website http://www.eia.gov/consumption/commercial/data/2003/

68 Opitz, M. (2008). From Single Commercial Buildings to Portfolios: Streamlining LEED® Documentation for Volume Customers. USGBC. http://aceee.org/files/proceedings/2008/data/papers/4_199.pdf

International Programs: National Australian Built Environment Rating System (Australia and New Zealand)[69]

The National Australian Built Environment Rating System (NABERS) was originally established as in 1998, by the government of the Australian state of New South Wales. At its founding, three building rating systems were developed: whole building, base building (excluding leasable square footage), and tenant spaces. In a critical move, in 2009, the Council of Australian Governments mandated disclosure of energy efficiency of commercial buildings.[70]

In developing its tenancy energy ratings, NABERS has benefited from the fact that, in the Australian states of New South Wales (NSW) and Victoria, the law forbids owners to pass electricity costs through to their tenants. Thus, unlike in the United States, the law has compelled tenant spaces to be individually metered. The typical metering divisions in Australian buildings allocate heating, air conditioning, elevators, and common area HVAC and lighting to the base building meters. The NABERS tenancy rating thus covers the other loads typically on the tenancy distribution board, including lighting within the tenancy, tenant equipment, and supplementary tenant air conditioning.

As a consequence, the NABERs system benefited from two advantages that are not currently available for tenant space ratings in the U.S.

- In Australia, energy data was readily available for tenant spaces.
- The use of the rating system was mandated.

Critical to driving energy efficiency, tenant space ratings are mandated to occur before the point of the real estate transaction. When the owner or manager intends to advertise the space for let, they must engage a NABERS assessor to conduct an assessment, to result in a star rating (1-6) to be used in promotional literature, advertisements, and on the publically posted signage connected to tenant spaces.

Within the NABERS, a rating of 2.5-3 stars is considered market average building performance, 5 stars is considered excellent building performance, and 6 stars is considered to be market-leading building performance. Originally the ratings only went up to five stars, with the sixth star being added four or five years ago after realization that some buildings were achieving five stars and beyond. When NABERS was first being developed, 4 stars was considered "not easily achievable" and 5 stars achievable only through "exceptional design and operation." This held true for some time, as even in 2006, only 5% to 15% of rated buildings achieved 4 stars or higher. However, in more recent years, those ratings have become more prevalent; out of the 1,422 buildings rated using NABERS Energy in 2012/13, the median result was 4 stars with more than 20% achieving 5 stars or higher.[71] A rating is determined by comparing consumption use of the space against spaces of the same type and is valid for one year.

69 Much of the material in this section is drawn from EPA ENERGY STAR® Task Order 306, Technical Direction #1: Memorandum, Case Studies of Government-Sponsored Tenant Energy Performance Programs Based On Measured Energy Data.

70 At present NABERS is administered by an internal government team of 18 full-time staff, drawing on a network of around 600 accredited NABERS assessors who perform the majority of the work required to determine ratings. Most of the funding for the NABERS program (around 80%) comes from fees associated with ratings, including fees for registering a rating with NABERS, as well as accreditation and training fees for assessors. The remaining 20% of funding comes from state and territory representatives that pay a fee to participate in the national steering committee. NABERS is looking to shift to a full cost recovery model, either by increasing fees or streamlining internal costs.

71 The Office of Environmental Heritage. (2014). The Key Principles and Defining Features of NAMBERS Version 1.0. http://www.nabers.gov.au/public/WebPages/DocumentHandler.ashx?docType=3&id=134&attId=0

International Programs: Green Mark for Office Interiors (Singapore)

Singapore's Building and Construction Authority (BCA) launched the voluntary BCA Green Mark Scheme in January 2005. There are several different "schemes," which apply to different space types, including one for office interiors, whose criteria were first developed in May 2009 and revised in November 2012. The criteria for office interiors can be applied to new offices, existing operating offices, as well as existing offices undergoing renovation.

Singapore's regulations require that all new buildings, building additions, or major retrofits to existing buildings of 2000 square meters (21,530 sf) or greater, achieve a sustainability standard equal to Green Mark Certified level. Tenancy ratings for spaces within existing buildings not undergoing build-out or major renovation are voluntary. Certified buildings are required to be re-assessed every three years in order to maintain their Green Mark status.

Unlike a performance based systems, there are specific operational criteria to Singapore's program. As an example, office interiors pursuing Green Mark certification at any level must meet the prerequisite requiring that the office's temperature setting is no lower than 24 degrees Celsius. Those seeking a $Gold^{Plus}$ rating must have an energy efficiency index (EEI) not exceeding 80 $kWh/m^2/year$ (or 7.43 $kWh/ft^2/year$) and a lighting power budget of 11 W/m2 (or 1.02 W/ft^2) or lower.

Additionally, the plan puts forward new awards to recognize buildings that have adopted green leases and achieved certification for at least 50% of their tenant spaces.

Opportunities for a U.S. Tenant Recognition Systems to Drive Energy Efficiency

As seen above, rating systems can help achieve improved efficiency in the design and construction of tenant spaces. As shown by the examples in the U.S., Singapore, and Australia, data availability and a critical focus on simple comprehensive metrics are key to designing an effective, equitable, and widely accepted rating system.

With wide acceptance, energy ratings could make their way into more transactional decisions in real estate. Such programs could include the incorporation of building energy performance data within commonly used real estate platforms, serving to match tenants seeking energy efficient spaces with owners who have available efficient space. In Australia and Singapore, where these ratings are near universal, tenants and owners each have the ability to weigh energy efficiency in their leasing and purchasing decisions. In these markets it is clear:

- When the rating system is universal, the information can be more easily included as part of the transaction, regardless of broker incentives.
- The on-going need to renew ratings can drive competitive energy efficiency improvements.
- If market demand for the voluntary rating system is high, it can cause owners to install the metering equipment necessary to participate.

A Federal Tenant Space Recognition System

The U.S. is exploring a government recognized recognition system. The Energy Efficiency Improvement Act of 2015 mandates the establishment of a voluntary tenant space recognition system in the United States. Administered by the EPA, developing this program will require access to several new data sets, and will also need to confront the same challenges regarding participation and information barriers.

In establishing this system, EPA will have the option of many approaches, each with their own inherent challenges. Options range from gross metrics focused on outcomes like those used by Australia (EUI), to detailed metrics focused on design and operational inputs like Singapore (lighting level, temperature ranges). This paper and other efforts will further assess the market viability, metrics, and structure of a potential system to best accommodate the U.S. market.

4.3.2.3 *Reporting Frameworks*

Investors, owners, tenants, regulators and other stakeholders are increasingly asking for greater levels of transparency with respect to environmental issues. This demand for disclosure on the sustainability performance of property companies and fund managers is broadly driving energy efficiency across portfolios. An increasing number of investors now incorporate such information directly into their investment strategies.[72] Consequently, comprehensive reporting frameworks provide market benchmarks, compare peers, force respondents to monitor and act on energy performance, and encourage improvement through competitive public rankings.

Examples of these reporting frameworks include the following:

- **The Global Real Estate Sustainability Benchmark (GRESB)** is a benchmark used by institutional investors to assess sustainability performance of real estate at the portfolio level. As of 2014, the benchmark included 637 survey participants representing 56,000 assets covered, and $5.5 trillion in institutional capital.[73] Annual survey results are analyzed and turned into portfolio benchmarks and rankings across a number of environmental, social, and governance dimensions.
- **The Carbon Disclosure Project (CDP)** works with public companies to improve their disclosure of environmental impacts and risks. Similar to the use of GRESB survey results, CDP survey respondents can use this information to market their environmental performance and advertise to investors that they comply with voluntary environmental performance disclosure standards. As of 2014, over 5,000 companies respond to the CDP survey each year.[74]

Other reporting frameworks include those organized by the Urban Land Institute's Greenprint Program, the National Council for Real Estate Investment Fiduciaries (NCREIF) collection of sustainability data, and the International Council of Shopping Centers (ICSC) scorecard.

72 GRESB. (2015). 2015 GRESB Report. https://www.gresb.com/results2015/introduction

73 GRESB. (2014). 2014 GRESB Report. http://www.corporate-engagement.com/files/file/2014%20GRESB%20Report.pdf

74 CDP. (2014). Climate Change Program. https://www.cdp.net/respond

These frameworks could be modified and leveraged as a mechanism to encourage owners to implement high performance energy efficiency measures in separate spaces. In particular, frameworks could begin to include tenant specific metrics such as:

- Average tenant space rating (when available).
- Ratio of (sub) meters to leases.
- Cost sharing and how the company handles the split incentive.
- Tenant incentives offered during design and construction or occupancy to encourage energy efficiency.

By expanding these frameworks to recognize those investors who have specifically taken action to significantly improving energy efficiency in commercial buildings through the design and construction of separate spaces, these competitive frameworks can serve as a catalyst to the more rapid adoption of high-performance measures.

4.3.2.4 *Voluntary Initiatives and Professional Certifications*

Voluntary initiatives encourage energy efficiency by fostering peer-to-peer competition and by providing tools and resources to further industry improvement and education. A voluntary initiative specifically focused on tenant spaces would be a powerful mechanism toward driving energy efficiency, by providing a single source for tools, resources, and expertise to drive the market. Voluntary initiatives can range from building-specific, to corporate, to local, to national in scale and they can also take the form of professional certifications.

Better Buildings Initiative and Green Lease Leaders

One successful voluntary initiative, albeit one that focuses on both large institutions and whole-building energy performance, is the DOE's Better Buildings Initiative. As of 2015, more than 250 organizations, representing over 3.5 billion square feet, 650 manufacturing plants, and $5.5 billion in financing investments, have committed to improving their energy efficiency by 20% or more over 10 years[75] through their participation in this voluntary initiative. In addition to an energy savings pledge, organizations also commit to: conduct an energy efficiency assessment of their building portfolio, showcase an energy efficiency project with long-lasting results, and publically report on their progress by sharing their successful methods for energy efficiency.

The Better Buildings Initiative has created: a searchable database for understanding trends in building performance, a dictionary of building characteristics and energy use terms, compiled financing solutions for energy efficiency initiatives, and a building energy asset scoring tool, in addition to a variety of other educational resources. The program has also developed partnerships with large commercial organizations such as Wal-Mart, Best Buy, Macy's, and others, fostering a competition of well-known brands in the public spotlight that will drive further interest and participation in these programs.

Under the Better Building Alliance affiliate program, non-profits, efficiency NGOs, and trade organizations that represent sectors covered by the Alliance, including Commercial Real Estate, Hospitality, Retail, Food Service, Grocery, Healthcare, and Higher Education, are eligible to join the alliance as program affiliates. The affiliates then use their membership resources to advance joint initiatives relating to energy efficiency.

The Green Lease Leaders program provides a number of support pieces that are similar to the Better

75 Better Buildings Solutions Center. (n.d.). About the Better Buildings Challenge. DOE. http://betterbuildingssolutioncenter.energy.gov/about-better-buildings-challenge

Buildings Initiative, including a library of resources, webinars, and a method for contacting an expert. Reflecting the fragmented state of the tenant market, the Green Lease Leaders program does not have the proactive outreach and networking component of the Better Buildings Initiative. The average tenant is seeking turn-key resources when they need to negotiate a lease and fit-out a space, and therefore does not necessarily want to commit to long-term membership in an energy efficiency initiative.

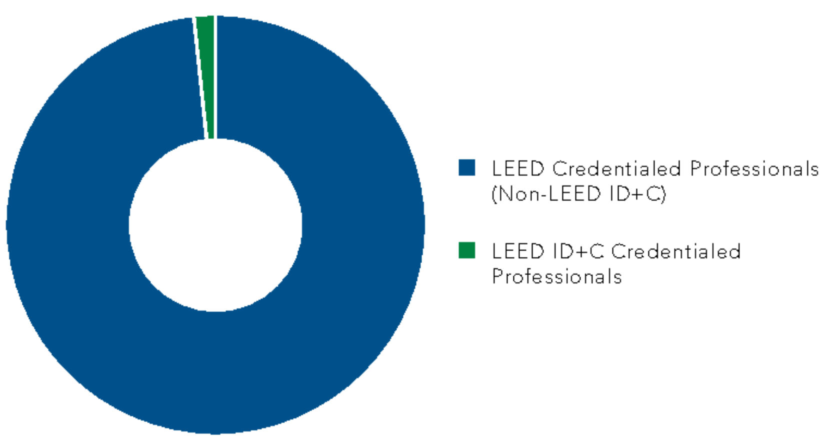
Critically, for many smaller tenants, lease negotiation is an infrequent occurrence, and they only need support at certain discrete points in the business cycle. While the suite of tools and resources produced by the Green Lease Leaders program provides a model to partially replicate for tenant spaces, the on-going support is not necessarily sufficient for the needs of smaller tenants.

Professional Certification Programs

A different tact for creating positive voluntary action is to address personnel, rather than real estate portfolios. While many popular professional certifications exist that relate to energy management, ranging from the certified energy managers (CEM) program to the LEED Accredited Professional (AP), the industry has taken its first steps to extend existing accreditations to explicitly include a curriculum around energy efficient tenant spaces. Ideally, these credentials will begin to improve the ability for designers and other professionals to market their credentials. With such programs, energy-efficiency conscious tenants can begin to choose qualified personnel to assist them in modifying their rental space to fit their needs aesthetically and environmentally.

The USGBC has created such a tenant space certification within their LEED AP Interior Design and Construction (ID+C) specialization. This certification "serves participants in the design, construction and improvement of commercial interiors and tenant spaces that offer a healthy, sustainable and productive work environment."[76] However, LEED ID+C professionals (about 2,500 credential holders) currently represent a small minority, or 1.4%, of LEED credentialed professionals (about 175,000 credential holders) (Figure 4).[77]

FIGURE 4 – LEED ID+C CREDENTIALED PROFESSIONALS AS A PERCENT OF TOTAL LEED CREDENTIALED PROFESSIONALS



76 USGBC. (2016). Distinguish your Expertise. http://www.usgbc.org/credentials#ap

77 USGBC. (2016). County Market Brief: United States. http://www.usgbc.org/advocacy/country-market-brief

Additionally, the Better Buildings Initiative is collaborating with industry practitioners and the National Institute of Building Sciences to maintain voluntary national workforce guidelines that improve the quality and consistency of commercial buildings workforce credentials for energy-related jobs.[78] During 2015, DOE released four Job Task Analyses and Schemes: Energy Manager, Energy Auditor, Building Operator, and Commissioning Professional and announced the corresponding Better Buildings Workforce Guidance (BBWG) recognition program for certification bodies. In late 2015, the Certified Energy Manager certification from the Association of Energy Engineers (AEE) became the first BBWG recognized certification program and others are expected to follow. Building owners and managers can use these guidelines when hiring or procuring services in these four job areas by requesting that individuals hold credentials that are recognized by DOE as aligned with the Better Buildings Workforce Guidelines.

Once these credentials are available, a tenant space focused guideline and certification could be a potential next step in defining and recognizing such skillsets.

While the industry is just beginning to create tenant space professional certification programs, participation and awareness of these programs among energy professionals remains low. As such, there is a market need for the increased support and creation of awareness materials to encourage the further development of, and interest in, such certifications.

4.2.3.5 *Incentives, Policies, and Regulation*

Utility policy, equipment and performance incentives, information disclosure policies, and regulation are additional options to accelerate the adoption of energy efficiency measures in tenant spaces.

Utility Policy and Incentives

The American Council for an Energy-Efficient Economy's State Energy Efficiency Scorecard tracks and evaluates state and local energy efficiency policies, and provides a valuable resource on local utility incentives, as does the DOE's Database of State Incentives for Renewables & Efficiency (DSIRE) program and Energy Incentive Programs listing.[79] [80]

Most states have implemented pre-qualified incentives for existing building energy efficiency initiatives. As an example, under its Existing Facilities Program, the New York State Energy Research and Development Authority (NYSERDA) offers facility owners, management companies, and tenants incentives to help offset the costs of implementing energy efficiency improvements. Applicants can receive up to $30,000 for pre-qualified simple equipment updates including lighting, HVAC, chillers, variable frequency drives, and commercial refrigeration. Larger improvements that save at least 250,000 kWh and/or 2,000 MMBtu per year are eligible for performance-based incentives of up to $500,000.[81]

These types of utility rebates have historically been oriented around pre-qualified (or prescriptive) savings estimates or on engineering studies and modeling estimates to determine the size and nature of the incentive. However, most historical programs have not been designed to tie to measured performance at the meter (kWh reduced below a baseline). Performance based incentives are more complicated to validate, and can be more challenging to implement for applicants who have no guarantee of payment.

78 DOE. (n.d.). Better Buildings. http://energy.gov/eere/better-buildings

79 DOE. (n.d.). Energy Incentive Programs. http://energy.gov/eere/femp/energy-incentive-programs

80 DSIRE. (n.d.). Database of State Incentives for Renewables & Efficiency. http://www.dsireusa.org/

81 Typically, and as a consequence of regulation, utility rebates are awarded for technologies that directly reduce energy usage. As a consequence, rebates are not typically available for submeters. If rebates could be awarded for submeters, this might be a powerful, although expensive, method for increasing the penetration of submeters.

Irrespective of these challenges, the 2015 passage of SB-350 in California "authorize[s] pay for performance programs that link incentives directly to measured energy savings. As part of pay for performance programs authorized by the [State Energy Resources Conservation and Development] commission, customers should be reasonably compensated for developing and implementing an energy efficiency plan, with a portion of their incentive reserved pending post project measurement results." SB 350 later states that "incentive payments shall be based on measured results."

A performance based utility incentive that requires normalized energy consumption to decrease as compared to a baseline could be a technology neutral driver of significant savings. It is notable to mention that this type of incentive can best be captured by tenants if their energy usages are separately metered. Such performance based programs that are explicitly designed for separate spaces and provide concrete energy use data could help to move the market toward greater efficiency. Submetering can be employed to determine accurate energy usage and utility billing of tenant spaces. Clarification of state rules that explicitly allow building owners to submeter tenants would be useful in states where these actions have been in question.

Building Codes and Design Standards

Building codes provide regulated minimum energy efficiency standards at the federal, state, and local level. Most building energy codes are implemented at the local level in the United States.

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) and the International Code Council (ICC) are tasked with the development and administration of the two model commercial building energy codes used in the United States: the ASHRAE 90.1 ("Energy Standard for Buildings Except Low-Rise Residential Buildings") and the International Energy Conservation Code (IECC), respectively. Both codes are updated through a revision process that includes submissions of proposed changes, stakeholder participation, public hearing opportunities, and committee review. New editions of the ASHRAE 90.1 and IECC are published every three years and reflect changes gathered through the revision process. States and local jurisdictions can adopt codes through direct legislative action or through specialized regulatory agencies. Upon approval, the building energy code becomes the law within that state or jurisdiction. Unlike federal laws or regulations, energy codes can be changed relatively frequently, and relatively quickly.

Due to the frequent revisions, energy codes can be an effective way to dictate minimum standards for energy efficiency. In fact, the U.S. DOE estimates the ASHRAE 90.1-2010 standard yields 23% energy savings relative to the 2004 edition.[82] Codes adapted to tenant space needs could yield a similar efficiency effect. Adoption can be accomplished by incorporating tenant space measures into existing codes or creating entirely new codes specific to tenant spaces. Specific measures could include prescriptive policies such as: requiring LED lighting, specifying thermostat settings within given ranges, installing automated lighting control technologies; or, efficiency performance specifications such as requiring specific energy use intensity based on the size and function of a tenant space. Tenant space energy codes could serve to set minimum efficiency requirements and impact every tenant improvement project in the state or locality where it is established.

82 DOE. (2014). Saving Energy and Money with Building Energy Codes in the United States. http://energy.gov/sites/prod/files/2014/05/f15/saving_with_building_energy_codes.pdf

Tax Policies

Federal

Federal tax policies can be used as an effective tool to drive energy efficiency. While requiring an act of congress, they can provide a broad financial incentive for increasing efficiency. Previous actions have generally focused on tax incentives for the purchase of equipment meeting energy efficiency standards. Past examples include the American Recovery and reinvestment Act of 2009, which offered tax credits for homeowners purchasing energy efficient equipment for their properties,[83] and the Energy Policy Act of 2005, which established the 179D tax deduction for energy-efficient equipment in commercial buildings.[84]

Any new policies could consider the following options for tenants:

- Offering tax deductions based on achieved energy use intensity.
- Accelerating the depreciation of systems and equipment installed as part of a tenant fit-out.[85]
- Incentivizing the purchasing of energy efficient equipment.
- Removing sales tax on energy efficient equipment.[86]
- Lowering import duties on energy efficient equipment.[87]
- Reducing real estate tax for spaces that have achieved a targeted energy reduction.

Of these ideas, the most common tax incentives are consumer rebates based on equipment installation. However, more recent federal efforts have focused on providing financial incentives to a small amount of manufacturers rather than a large number of consumers.[88]

While any of these incentives could be targeted toward tenant fit-out, focusing on the performance (achieved EUI) offers the most guaranteed benefit, but also requires metering to demonstrate achieved EUI. Incentives not requiring metering would parallel those that have been previously executed – such as offering direct tax credits for energy efficient equipment, or creating a parallel to the 179D deduction and allowing its use for tenant spaces.

83 DOE. (2012). Success of the Recovery Act. http://www.energy.gov/recovery-act

84 Businesses can take a tax deduction for new or renovated buildings by reducing the energy costs associated with three components—lighting system; building envelope; and heating, cooling and water heating equipment. Buildings must meet the ASHRAE 90.1-2001 standard and be placed in service between January 1, 2006 and December 31, 2013 in order to be eligible.

85 Example: The Tax Relief, Unemployment Insurance Reauthorization and Job Creation Act of 2010 provides businesses with 100 percent bonus depreciation for certain capital investments placed in service between September 8, 2010 and December 31, 2011. As an example, outdoor energy efficient LED lighting qualifies for a 100% deduction under the new bonus depreciation rules. http://www.boston.com/business/personalfinance/managingyourmoney/archives/2011/03/tax_opportuniti.html

86 Example: Tax free weekends on ENERGY STAR® equipment are currently offered by Alabama, Florida, Georgia, Louisiana, Maryland, Missouri, Texas and Virginia. http://www.houselogic.com/blog/taxes-incentives/state-sales-tax-holidays/

87 Example: In 2006 the Thai government introduced tax incentives for energy efficiency projects. The tax incentives include: Exemption of the import duties for energy efficiency / renewable energy equipment, exemption of corporate income tax for 8 years for energy efficiency equipment and renewable energy manufacturers and ESCO companies, reduction of the corporate income tax for companies that improve their energy efficiency or develop renewable energy projects. http://iepd.iipnetwork.org/policy/tax-incentives

88 Doris, E., Cochran, J. & Vorum, M. (2009). Energy Efficiency Policy in the United States: Overview of Trends at Different Levels of Government. National Renewable Energy Laboratory Technical Report. http://www.nrel.gov/docs/fy10osti/46532.pdf

Additionally, good tax policy design would ensure that even entities without tax liabilities can still benefit from the tax incentive for an efficiency fit-out. For example if a Real Estate Investment Trust (REIT) that does not receive tax burden, is eligible for an efficiency fit-out tax incentive, they should be allowed to assign (or trade) it to an entity with tax liability (such as the tenant or the engineering firm doing the work).

State and Local

Many states also provide financial incentives to support energy efficiency. [91] [89] One example is found in Oregon, which has offered a Business Energy Tax Credit (BETC) since 1979, which includes a tax credit of 35% towards the purchase of conservation technologies, and includes a Pass-through Option, which allows entities that do not pay a sufficient amount in taxes to receive a lump-sum payment. The options for designing the tax incentive are similar at the state, local, and federal level – however the path to enacting the tax incentive varies by jurisdiction.

4.3.2.6 *Education, Awareness, and Behavioral Change*

The overarching goal of each of the initiatives discussed above, from financial incentives, to rating systems, reporting frameworks, leasing language, voluntary initiatives, and regulation is to drive behavioral change and give people opportunities and incentives to select more energy efficient choices. One additional opportunity is to explicitly educate occupants in order to change the way they interact with the building. Recent scientific studies have drawn a clear link between energy savings education and awareness and behavioral change resulting in reduced energy consumption. For example, a 2013 meta-analysis of 156 energy conservation field studies found that behavioral strategies yielded an average of a 7.4% improvement in energy conservation.[90] [91] Energy conservation behavioral strategies can include:

- Disclosing information such as a building's current energy demand in the lobby or through other tenant communications.
- Adding educational signs that encourage resource conservation and education, such as "turn off the lights when you leave the room."
- Displaying energy efficiency awards (such as LEED certification and ENERGY STAR® plaques) in building common areas to increase awareness.
- Hosting educational training programs or providing tips and fact sheets that train building occupants on energy conservation strategies.
- Encouraging people toward energy-saving behavior through building aesthetics (making stairwells easy to access, pleasant, etc.).
- Energy conservation competitions and recognition of top performers.

89 The same report has a useful chart of all government incentives (non-research and development) that are targeted toward energy efficiency.

90 Although, the same study noted that conservation decreased with relative study rigor.

91 Delmas, M., Fischlein, M. & Asensio, O. (2013). Information Strategies and Energy Conservation Behavior: A Meta-Analysis of Experimental Studies from 1975 to 2012. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2273850

While most of these initiatives are directly applicable to tenant spaces, there are tools that could be better leveraged to maximize their impact. One option is to maximize the availability of these educational resources through:

- Advertising at public forums that reach general audiences, such as construction trade association meetings, local business associations, chambers of commerce and other events.
- Creating websites with educational toolkits catered specifically to tenants and building owners of separate spaces. ENERGY STAR® "Bring Your Green to Work" is a good example of a current toolkit,[92] as is the Better Buildings Implementation Model for Shorenstein Realty LLC.[93]

One further option is to include such measures as part of the fit-out phase, by incorporating specific requirements (such as educational signs or displays of building energy use). One example might be to install "please shut off the light stickers" next to each switch. Some rating systems, such as LEED, already allocate points within their recognition systems for the inclusion of this type of awareness building.

Stanford University's Precourt Energy Efficiency Center provides several resources on driving energy efficiency through behavioral science. These include a series of foundational readings,[94] as well as a series of tools, such as resources for program design and evaluation, and key behavior and energy questions as identified by sector leaders.

92 ENERGY STAR®. (n.d.). Bring Your Green to Work with ENERGY STAR®. https://www.energystar.gov/buildings/about-us/how-can-we-help-you/communicate/energy-star-communications-toolkit/bring-your-green-work

93 Better Buildings Solutions Center. (n.d.) Implementation Model: "Flip the Switch" Tenant Engagement Program. http://betterbuildingssolutioncenter.energy.gov/implementation-models/%E2%80%9Cflip-switch%E2%80%9D-tenant-engagement-program

94 Precourt Energy Efficiency Center, (n.d.). Stanford University. Foundational Readings. http://peec.stanford.edu/behavior/foundational_readings.php

4.4 Measurement & Verification

4.4.1 *Current Application of Feasibility of M&V in Tenant Spaces*

Measurement and Verification (M&V) is the process for quantifying savings delivered by energy efficiency measures. M&V programs are utilized for a variety of reasons:

- **Tenants and Owners** may have a need to validate a return on their investments. As an example, some tenants and owners invest in efficiency only when they can recover their investment from their reduction in utility costs. In other cases, M&V may be required to demonstrate a return to a rebate issuing third party.
- **Vendors** can use M&V to validate their energy efficiency offerings, and demonstrate the value of their product.
- **Utilities** may require M&V to meet regulatory requirements, to demonstrate savings, or to validate energy rebates.

An M&V platform typically consists of systems to gather, analyze, and manage data. In typical scenarios, an M&V platform can be used to (a) measure actual energy use derived from base consumption and compare it to consumption under energy efficiency measures, and (b) determine whether the implemented measures generate the savings intended in the initial design and construction of the separate spaces.

As M&V platforms differ, decisions can be made as to whether the system will include the whole building or a specific space, incorporate data in real time or at regular intervals, and include shared systems or just local loads. In most cases, data and collection is technically feasible; the main consideration is cost relative to potential return.[95] At the data collection level, there are a number of factors affecting cost:

- While most buildings will have total ("whole-building") utility usage data from a master meter, not all buildings have submeters to isolate separate spaces within a building, nor will all buildings have "smart" meters to support real-time analysis.
- Some M&V projects will require current transformers to apportion energy from shared systems such as cooling towers or shared HVAC.
- In some cases, building management systems can automatically collect energy consumption data via smart meters, data loggers, and network controllers.
- To minimize costs, an M&V system should be designed to work in conjunction with the design of the tenant space, as well as the central systems.

95 In a small space, while feasible, the potential energy savings may not justify significant additional data collection costs. By contrast, in a larger space, M&V can be more easily absorbed in the energy savings.

A major step toward reducing the costs of M&V are the class of technologies considered collectively as, Measurement & Verification (M&V) 2.0. A M&V 2.0 system builds upon energy information technology advancements, such as measurement software, embedded equipment sensors, advanced metering infrastructure and data analytics to calculate energy savings accurately and quickly. Where submetering is in place at the level of a tenant space, these tools can provide a rapid and cost-effective way to track results from energy-saving activities and provide warnings when energy performance begins to degrade.

There are a wide variety of software tools that can be used to construct an M&V program, and which integrate this new technology to varying degrees. These tools track energy usage at greater temporal (daily, hourly, or minute-by-minute) and spatial (space or equipment specific) resolution to match the sub- and smart metering of the building. Based on this data, sophisticated models can be developed to predict and avoid inefficient energy usage.

In addition to tools, guides such as the International Performance Measurement and Verification Protocol, compile best practice techniques for the measurement and verification of energy use data. These resources allow practitioners to use tools consistently and allow for relevant comparisons of energy efficiency data.

The best of the M&V 2.0 tool sets can help eliminate the "night-time walkthrough" or the need to survey the space outside of operating hours to identify equipment that is operating unnecessarily. Instead, the sensors and system can help identify the issues in real time, improve efficiency, and drive down operational costs.

4.4.2 *M&V Gaps & Needs*

Within the M&V 2.0 ecosystem, hardware such as sensors and submeters, analytic software, and the technician time to provide analyses of performance can be expensive.

- While costs are dropping, the most prevalent submetering technologies remain expensive and can be limited in their data collection.
  - A submeter is able to track energy use from plug loads (such as appliances, computers, printers, etc.) but cannot monitor individual use of shared systems such as HVAC units.
  - The installation of submeters and sensors can be complex. If tenants move or reconfigure office space, then submetering systems must be reconfigured accordingly.
- While modern analytic software often simplifies trend analysis, a specialist (consultant) is often required to recommend a course of action.

One major step toward further use of M&V 2.0 is the emerging technology of "smart" devices that can report their own real-time performance to an energy management and information system (EMIS). These devices have the opportunity to transform the M&V process, and are being supported by major industry vendors. Lower costs, easier installation, and high configurability are the keys to future adoption.

5. Acknowledgements

This report was prepared by JDM Associates with contributions from Deborah Cloutier, Jack Davis, Hannah Tillmann, and Kirk Vizzier, under the oversight of Cody Taylor and Jason Hartke at the U.S. Department of Energy. The authors of this report would like to express their gratitude to all report reviewers, especially Michael Zatz and Cindy Jacobs from the U.S. Environmental Protection Agency. We would also like to thank all individuals and organizations who submitted comments to the Department of Energy's public request for information. And, finally we would like to thank the Urban Land Institute and the Natural Resources Defense Council for sharing and discussing their tenant space energy efficiency materials.

6. Appendix

6.1 Energy Efficiency Employment Impact Multipliers[96]

The PNNL paper concludes that energy efficiency results in positive economic impacts including overall levels of employment. Greater energy efficiency means households and businesses are able to maintain or increase the levels of service (e.g., comfortable indoor temperatures, illumination, and hot water) from their buildings or equipment while consuming less energy. Over the lifetime of energy efficiency measures, the money saved on energy becomes available to be spent on other goods and services. Typically, the number of jobs required to produce these other goods and services are greater per dollar of output than the number of jobs needed to produce the same dollars' worth of energy. Based on the results of a number of studies, spending money made available by reducing energy expenditures for these alternative goods and services generates a net gain of about 8 jobs per million dollars of consumer bill savings.

Distinct from the effects of bill savings, the PNNL study concludes that initial investments in energy efficiency generate about 11 jobs per million dollars of investment. These activities include the purchasing and installing of measures for retrofit or for new construction and also jobs in other sectors "induced" by this economic activity. This impact occurs in years when these investments occur. Results using this approach are comparable to typical industry-specific estimates of the job creation from spending targeted at specific sectors.

6.1.1 *Modeled Energy Efficiency Scenarios*

PNNL modeled the 2030 employment impacts of a national initiative to accelerate residential and commercial energy efficiency trends under both 15% and 10% electricity savings cases. In the 15% case, efficiency activities save about 15% of Annual Energy Outlook (AEO) Reference Case commercial and residential electricity consumption by 2030.[97] [98]

The analysis of the 15% case indicates that by 2030 nearly 320,000 new jobs likely would result from energy efficiency. To achieve this level of new jobs in 2030 would require an annual average of more than 60,000 jobs in prior years directly supporting the manufacturing, installation, and maintenance of energy efficiency measures and practices.

These are new energy efficiency jobs resulting initially from the investment associated with the construction of more energy-efficient new buildings or the retrofit of existing buildings, and would be sustained for as long as the investment continues. Based on what is known about the current level

96 This text draws heavily from: Anderson, D. M., Belzer, D. B., Livingston, O. V., & Scott, M. J. (2014). Assessing National Employment Impacts of Investment in Residential and Commercial Sector Energy Efficiency: Review and Example Analysis (No. PNNL-23402). PNNL, Richland, WA (US). http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23402.pdf

97 Significantly, the PNNL study does not consider the impacts of energy efficiency on all fuels, but focuses on electricity. In 2014, electricity generation consumed 40% of the energy in the United States, while residential and commercial fuel consumption accounted approximately another 12%. As the potential energy efficiency gains in separate spaces would likely also reduce fuel consumption, the PNNL paper likely underestimates the total potential employment gains.

98 The 15% case assumed that the additional energy savings in both the residential and commercial sectors due to the scenario begin in 2015 at zero, then increase in an S-shaped market penetration curve, with the level of savings equaling about 7.0 percent of the AEO 2014 U.S. national residential and commercial electricity consumption saved by 2020, 14.8 percent by 2025 and 15 percent by 2030. The 10% case assumes the additional savings due to the scenario begin at zero in 2015, increase to 3.8 percent in 2020, 9.8 percent by 2025 and, 10 percent of the AEO reference case value by 2030.

of building-sector energy efficiency jobs, this would represent an increase of more than 13% from the current estimated level of over 450,000 such jobs. The more significant and longer-lasting effect comes from redirecting energy bill savings to the purchase of other goods and services in the general economy. This example analysis utilized PNNL's ImSET model, a modeling framework that PNNL has used over the past two decades to assess the economic impacts of DOE's energy efficiency programs in the buildings sector.

The PNNL study focuses principally on the economic effects arising from increased levels of energy efficiency in the buildings (both residential and commercial). As the present discussion focuses solely on commercial real estate (and in fact on the office, retail, and industrial subset of the that sector), we can approximate the impacts from an improvement in commercial building energy efficiency by parsing out the electricity consumption in the residential and commercial sectors – the paper attributes approximately 50% of the electricity usage to the commercial sector. As a consequence, perhaps 160,000 net new jobs could be attributed to a 15% reduction in energy consumption in the commercial sector.

6.1.2 *Further Sources*

The employment analysis presented in this paper is largely in line with other similar studies conducted over the past ten years, including papers presented by the American Council for an Energy Efficient Economy (ACEEE),[99] Cambridge Econometrics,[100] the Economic Policy Institute,[101] as well as many of the dozens of peer-reviewed and white papers reviewed in the PNNL paper excerpted above.[102] Investment in energy efficiency has consistently shown a positive multiplier effect – where investments consistently yield increases in employment.

99 American Council for an Energy-Efficient Economy. (n.d). How Does Energy Efficiency Create Jobs? http://aceee.org/files/pdf/fact-sheet/ee-job-creation.pdf.

100 Cambridge Econometrics. (2015). Assessing the Employment and Social Impact of Energy Efficiency. https://ec.europa.eu/energy/sites/ener/files/documents/CE_EE_Jobs_main%2018Nov2015.pdf.

101 Bivens, JoshJ. (2015). A Comprehensive Analysis of the Employment Impacts of the EPA's Proposed Clean Power Plan. http://www.epi.org/publication/employment-analysis-epa-clean-power-plan/./

102 Anderson, D. M., Belzer, D. B., Livingston, O. V., & Scott, M. J. (2014). Assessing National Employment Impacts of Investment in Residential and Commercial Sector Energy Efficiency: Review and Example Analysis (No. PNNL-23402). PNNL, Richland, WA (US). http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-+-23402.pdf.

6.2 Analysis of High Efficiency Technologies Continued

6.2.1 *High Efficiency Lighting*

Lighting accounts for approximately 30-40% of commercial building energy consumption.[103] Installing high efficiency lighting technologies (e.g., LED, high efficiency linear fluorescent, and compact fluorescent lamps) can reduce tenant space lighting energy consumption by up to 30-60%.[104] For example, LED lamps use at least 75% less energy and last 25 times longer than incandescent lighting,[105] which reduces ongoing maintenance and lamp replacement costs. Additionally, high efficiency T8 linear fluorescent lamps, a standard lighting technology in tenant spaces, use 20-35% less energy than standard efficiency linear fluorescent lamps. Finally, LED technologies incorporated in to the most common commercial lighting fixtures, recessed lighting troffers (representing an estimated 50% of commercial lighting fixtures), can provide energy savings up to 60%.[106]

Cost/Benefit analysis for a typical use or uses

High efficiency lighting technologies can reduce tenant space lighting energy consumption by up to 30-60% with a typical payback ranging from 1-3 years.[107] Costs vary considerably with type of upgrade and project size but the average cost is roughly $5/square foot.[108]

More Information

- Interior Lighting Campaign. US DOE Better Buildings. Link.
- LED lighting. US DOE. Link.
- LED Lighting: The New Low-hanging Fruit in a Lighting (R)evolution. CLEAResult. Link.
- Upgrading Troffer Luminaries to LED. US DOE. Link.
- Certified Products. ENERGY STAR®. Link.

6.2.2 *Lighting control technologies*

A variety of cost-effective lighting control technologies can be employed in tenant spaces to reduce lighting energy consumption including vacancy sensors, bi-level switching, timers, and daylight sensors.

- Vacancy sensors require occupants to manually turn the lighting on and then automatically turn the lighting off when motion is not detected for a period of time.
- Bi-level switching enables the control of a lighting system in groups of fixtures or lamps. For example, bi-level switching allows you to turn off half of the lights in a room off when full illumination is not required.

103 Regulations.gov. (2015). This is a Comment on the Energy Efficiency and Renewable Energy Office (EERE) Notice: 2015-07-31 Request for Information (RFI) for High-Performance Energy Efficiency Measures in Separate Spaces. http://www.regulations.gov/#!documentDetail;D=EERE-2015-BT-BLDG-0012-0010.

104 Nelson, DavidD. (2014). Energy Efficient Lighting. Whole Building Design Guide. https://www.wbdg.org/resources/efficientlighting.php.

105 DOE. LED Lighting. DOE Energy Saver. http://energy.gov/energysaver/led-lighting

106 Navigant Consulting for DOE. (2015). High Impact Technology Catalyst: Technology Deployment Strategies. http://energy.gov/sites/prod/files/2015/09/f26/CBI%20HIT%20Deployment%20Strategy.pdf.

107 Nelson, DavidD. (2014). Energy Efficient Lighting. Whole Building Design Guide. https://www.wbdg.org/resources/efficientlighting.php.

108 Benson et al. (2011). Retrofitting Commercial Real Estate: Current Trends and Challenges in Increasing Building Energy Efficiency. http://www.environment.ucla.edu/media/files/Retrofitting-Commercial-Real-Estate-30-mlg.pdf.

- Timers turn lights on or off at pre-determined periods of the day to ensure lighting is activated only when needed.
- Daylight sensors dim lighting when sufficient daylight is available, saving energy and money.[109]

Proper commissioning of such technologies is needed to ensure that sensors and controls are performing as intended.

Cost/Benefit analysis for a typical use or uses

Lighting controls can reduce tenant space lighting energy consumption by 24-38% with a typical payback of less than 3 years.[110] [111] Costs vary considerably with type of strategy and project size but average costs of roughly $2/square foot have been achieved in the industry.[112] Bundling lighting controls with lamp upgrades can maximize the savings opportunity by lowering purchase costs, as it is less expensive to install lighting controls and lamp upgrades at the same time compared to separate installations, and creating higher returns on investment.

More Information

- ENERGY STAR® Building Upgrade Manual. ENERGY STAR®. Link.
- Energy Savings Tips for Small Businesses: Offices- Owners and Tenants. ENERGY STAR®. Link.

6.2.3 *Daylighting*

Daylighting is the controlled introduction of natural light into an interior space to reduce lighting energy consumption. An effective daylighting strategy is integrated with conventional lighting design strategies and appropriately illuminates the tenant space without subjecting occupants to glare or major variations in light levels, which can impact comfort and productivity.[113] Various design strategies can be employed to maximize daylighting in a tenant space, including exterior shades or light shelves that redirect sunlight deep into the space,[114] window films that reduce solar heat gain and improve lighting distribution, light-colored reflective ceiling and wall finishes, window shades on the lower portions of the windows, low wall partitions or translucent panels to allow deep daylight penetration, locating private offices on the interior of the floor to maintain open space along the perimeter walls, and installing daylighting controls to turn off or dim interior lighting when natural lighting is sufficient. Additionally, improving daylighting in a tenant space can lead to increased employee productivity, improved health, and improved mood and reduced absenteeism.[115]

109 ENERGY STAR®. Energy Savings Tips for Small Businesses: Office – Owners and Tenants. http://www.energystar.gov/sites/default/files/tools/Small_Business_Offices_0.pdf.

110 Williams, Alison;A., Atkinson, Barbara;B., Garbesi, Karina;K., & Rubinstein, FrancisF. (2012). Quantifying National Energy Savings Potential of Lighting Controls in Commercial Buildings. Ernest Orlando Lawrence Berkeley National Laboratory. http://eetd.lbl.gov/sites/all/files/quantifying_national_energy_savings_potential_of_lighting_controls_in_commercial_buildings_lbnl-5895e.pdf

111 Kanellos, MichaelM. (2010). Payback for Lighting Controls: Less than Three Years. GreenTechMedia. http://www.greentechmedia.com/articles/read/payback-for-lighting-controls-less-than-three-years

112 Berkeley Lab Energy Technologies Area (ETA). (2013). Lighting Control Testbeds at the General Services Administration Showing Promise for Lighting Energy Reductions. (2013). http://eetd.lbl.gov/news/article/56664/lighting-control-testbeds-at-th.

113 http://www.gsa.gov/portal/mediaId/211239/fileName/Lighting_and_Daylighting_Two_Pager_508_compliant_2-9-15.action GSA. GSA. (n.d.). Saving Energy through Lighting and Daylighting Strategies. http://www.gsa.gov/portal/mediaId/211239/fileName/Lighting_and_Daylighting_Two_Pager_508_compliant_2-9-15.action

114 http://www.wbdg.org/resources/daylighting.php Ander, Gregg DG. (2014). Whole Building Design Guide. Daylighting. http://www.wbdg.org/resources/daylighting.php

115 https://www.portlandoregon.gov/bps/article/285215 City of Portland Bureau of Planning and Sustainability. (n.d.). Creating a High Performance Workplace. https://www.portlandoregon.gov/bps/article/285215

Cost/Benefit analysis for a typical use or uses

An effective daylighting strategy can reduce tenant space lighting energy consumption by 20-80%[116] and has a cost premium of ≤ $5/square foot.[117]

More Information

- Creating a High Performance Workspace. Portland's Green Tenant Improvement Guide. Link.
- Daylighting. Whole Building Design Guide. Link.
- Saving Energy through Lighting and Daylighting Strategies. GSA. Link.

6.2.4 *ENERGY STAR® Certified Appliances and Office Equipment*

ENERGY STAR® certified appliances and office equipment are highly energy efficient and use 10-40% less energy than standard models. They often include higher quality components that can result in fewer mechanical problems, longer equipment life, and extended warranties. Appliances and office equipment with the ENERGY STAR® certification include refrigerators, freezers, dishwashers, vending machines, coffee makers, computers, external displays, printers, and data center storage units.[118]

Cost/Benefit analysis for a typical use or uses

ENERGY STAR® certified appliances and office equipment use 10-40% less energy than standard efficiency models and although there can be a cost premium in the range of $50 - $200; ENERGY STAR®-certified appliances typically provide a payback period of 1-3 years.[119] [120]

More Information

- Certified Products. ENERGY STAR®. Link.

116 http://news.mit.edu/2007/techtalk51-26.pdf MIT. MIT. (2007). Tech Talk. Daylight device lightens electricity cost. http://news.mit.edu/2007/techtalk51-26.pdf

117 http://energy.gov/sites/prod/files/2014/02/f8/BTO_windows_and_envelope_report_3.pdf DOE. DOE. (2014). Windows and Building Envelope Research and Development: Roadmap for Emerging Technologies. http://energy.gov/sites/prod/files/2014/02/f8/BTO_windows_and_envelope_report_3.pdf

118 https://www.energystar.gov/ia/new_homes/features/Appliances_062906.pdf ENERGY STAR®. ENERGY STAR®. (n.d.). ENERGY STAR® Qualified Appliances. https://www.energystar.gov/ia/new_homes/features/Appliances_062906.pdf

119 ENERGY STAR®. (n.d.). Certified Products. https://www.energystar.gov/products

120 Green Building Advisor. (2010). Are Energy-Efficient Appliances Worth it? http://www.greenbuildingadvisor.com/blogs/dept/green-communities/are-energy-efficient-appliances-worth-it

6.2.5 *Plug and Process load (PPL) inventory and reduction strategies*

"Plug and process loads" (PPLs), or the energy consumed by the equipment connected to electrical outlets, account for 30% of the electricity consumption in office buildings.[121] In a commercial building, PPLs include computers, printers, networking equipment, task lighting, kitchen appliances, etc.[122] Performing a plug load inventory and implementing a load reduction strategy can reduce unnecessary tenant space plug loads by up to 20-50%.[123] Effective strategies for tenant spaces include utilizing wireless devices to control specific receptacles, wiring separate electrical zones to enable occupancy sensor or timer control of the PPLs, and end-user dashboard-based feedback technology and smart sub-metering that prompts end-users to power off equipment.

Cost/Benefit analysis for a typical use or uses

A plug load reduction strategy can reduce unnecessary plug load energy use by up to 20-50%.[124] In a National Renewable Energy Laboratory (NREL) study, a $20 electrical outlet timer was installed on an ENERGY STAR® ice maker and saved $150 per year.[125]

More Information

- Assessing and Reducing Plug and Process Loads in Office Buildings. NREL. Link.
- Plug Load Reduction Checklist. GSA. Link.
- Decision Guides for Plug and Process Load Controls. DOE. Link.

High efficiency HVAC units for above-standard operations

Installing high efficiency, ENERGY STAR® certified, supplemental HVAC equipment for tenant spaces with above standard operating hours or heating and cooling needs (e.g., data centers, server rooms, call centers, etc.) can reduce HVAC energy consumption by 5-20%[126] when compared to standard efficiency units. Specifying ENERGY STAR® certified HVAC units with variable speed compressors, fans, and pumps that are appropriately sized for the heating and cooling loads of the space can lead to significant energy saving over less efficient equipment. Where feasible, water-cooled HVAC equipment should be specified that can be tied into the base building condenser water loop. Water-cooled HVAC equipment is typically 10-20% more efficient than air-cooled equipment. Additionally, energy consumption associated with the supplemental HVAC equipment should be submetered.[127]

121 http://www.gsa.gov/portal/mediaId/178935/fileName/PlugLoad_Checklist_Form_Fields_508 GSA. GSA. (n.d). Plug Load Reduction Checklist. http://www.gsa.gov/portal/mediaId/178935/fileName/PlugLoad_Checklist_Form_Fields_508

122 https://www4.eere.energy.gov/alliance/activities/technology-solutions-teams/plug-process-loads Better Buildings, DOE. Better Buildings, DOE. (n.d.). Plug & Process Loads. https://www4.eere.energy.gov/alliance/activities/technology-solutions-teams/plug-process-loads

123 http://www.regulations.gov/#!documentDetail;D=EERE-2015-BT-BLDG-0012-0010 Regulations.gov. Regulations.gov. (2015). 2015-09-30 Comment response to the published Request for Information (RFI). NEMA Comments - DOE RFI on Energy Efficiency in Separate Spaces. http://www.regulations.gov/#!documentDetail;D=EERE-2015-BT-BLDG-0012-0010

124 http://www.regulations.gov/#!documentDetail;D=EERE-2015-BT-BLDG-0012-0010 Regulations.gov. Regulations.gov. (2015). 2015-09-30 Comment response to the published Request for Information (RFI). NEMA Comments - DOE RFI on Energy Efficiency in Separate Spaces. http://www.regulations.gov/#!documentDetail;D=EERE-2015-BT-BLDG-0012-0010

125 Sheppy; Michael,M., Lobato, Chad;C., Pless, Shanti;S., Polese, Luigi;L., & Torcellini, Paul.P. (2013). NREL. Assessing and Reducing Plug and Process Loads in Office Buildings. (2013). http://www.nrel.gov/docs/fy13osti/54175.pdf.

126 https://www.energystar.gov/products/certified-products?s=mega ENERGY STAR®. (n.d.). Certified Products. https://www.energystar.gov/products/certified-products?s=mega

127 https://www.energystar.gov/sites/default/files/buildings/tools/EPA_BUM_Full.pdf ENERGY STAR®. (2008). Building Upgrade Manual. https://www.energystar.gov/sites/default/files/buildings/tools/EPA_BUM_Full.pdf

Cost/Benefit analysis for a typical use or uses

High efficiency, ENERGY STAR® certified, supplemental HVAC equipment is 5-20% more efficient than standard efficiency units and on average have a cost premium of $100 – 180 per ton compared to standard efficiency models.[128] [129]

More Information

- ENERGY STAR® Building Upgrade Manual. ENERGY STAR®. Link.
- Certified Products. ENERGY STAR®. Link.

6.2.6 *Point-of-use domestic water heating*

Electric point-of-use (i.e., tankless) water heaters are typically the most cost-effective domestic water heating technology installed in tenant spaces and can reduce domestic hot water energy consumption by 27-50%. Unlike storage tank water heaters, point-of-use water heaters are installed at each hot water outlet and do not require water distribution piping. They save energy by providing hot water on-demand.[130] Properly maintaining the temperature at the DOE recommended setpoint (120°F) will ensure energy efficiency and safety.[131] [132]

Cost/Benefit analysis for a typical use or uses

Point-of-use water heaters cost on average $200 and can reduce domestic hot water energy consumption by 27-50%, when compared to storage tank water heaters.[133] [134]

More Information

- Tankless of Demand-Type Water Heaters. US DOE. Link.
- Point of Use (POU) Water Heaters. ENERGY STAR®. Link.

128 ENERGY STAR®. (n.d.). Certified Products. https://www.energystar.gov/products/certified-products?s=mega

129 EPA. (n.d.). State and Local Climate and Energy Program. Rules of Thumb. http://www3.epa.gov/statelocalclimate/documents/pdf/table_rules_of_thumb.pdf.

130 http://energy.gov/energysaver/tankless-or-demand-type-water-heaters DOE. DOE. (n.d.). Tankless or Demand-Type Water Heaters. http://energy.gov/energysaver/tankless-or-demand-type-water-heaters

131 https://www.energystar.gov/sites/default/files/buildings/tools/DataTrends_Savings_20121002.pdf http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/ElectricTanklessCompetitiveAssessment.pdf ENERGY STAR® Portfolio Manager®. (2011). Benchmarking and Energy Savings. https://www.energystar.gov/sites/default/files/buildings/tools/DataTrends_Savings_20121002.pdf

132 R. Milward, R. (2005). EPRI Retail Technology Application Centers. Electric Tankless Water Heating: Competitive Assessment. http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/ElectricTanklessCompetitiveAssessment.pdf

133 DOE. (n.d.).Estimating Costs and Efficiency of Storage, Demand, and Heat Pump Water Heaters. http://energy.gov/energysaver/estimating-costs-and-efficiency-storage-demand-and-heat-pump-water-heaters.

134 DOE. (n.d.). Tankless or Demand-Type Water Heaters. http://energy.gov/energysaver/tankless-or-demand-type-water-heaters

6.2.7 *Energy management and information systems (EMIS)*

Energy Management and Information Systems (EMIS) comprise a broad family of tools and services to manage commercial building energy use. While EMIS technologies are typically implemented at the building-level, they can be applied to individual tenant spaces to improve energy performance. These technologies include energy information systems (EIS), equipment-specific fault detection and diagnostic systems, benchmarking and utility tracking tools, and building automation systems (BAS).[135] A BAS is a computer-based control system that controls and monitors building mechanical and electrical equipment, including heating and cooling, ventilation, lighting, fire control systems, and security systems. Integrating tenant space HVAC and lighting controls into a well-programmed central BAS can lead to significant energy savings by automatically controlling tenant space operations using advanced control strategies. Benchmarking and monitoring the utility performance of submetered tenant spaces enables the tracking of savings associated with energy conservation measures and the identification of operational anomalies that can improve energy performance when addressed.

Cost/Benefit analysis for a typical use or uses

Benchmarking or closely monitoring tenant space energy consumption can lead to annual energy savings of 2-3%.[136] Integrating the control of tenant space mechanical and electrical systems into a well-programmed BAS can reduce energy consumption by 10-15%.[137] Proper installation and use of EMIS systems can lead up to 16% energy savings and average $0.30/square foot cost with a 1.1 year payback period for existing buildings and 13% energy savings and average $1.16/square foot with a 4.2 year payback in new construction.[138]

More Information

- Energy Management and Information Systems. DOE Better Buildings Alliance. Link.
- Energy Information Systems (EIS): Technology Costs, Benefit, and Best Practice Uses. Lawrence Berkeley National Laboratory. Link.

135 DOE. (n.d.) EMIS Technology Classification Framework. https://www4.eere.energy.gov/alliance/sites/default/files/uploaded-files/emis-technology-classification-framework.pdf

136 Better Buildings Alliance. (n.d.). Energy Management and Information Systems. https://www4.eere.energy.gov/alliance/activities/technology-solutions-teams/energy-management-information-systems

137 Granderson, Jessica;J., Lin, Guanjing;G., & Hult, ErinE. (2013). EMIS: Crash Course. Better Buildings. http://eis.lbl.gov/pubs/emis-crash-course.pdf

138 Mills, Evan. (2009). Building Commissioning A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions. Report Prepared for: California Energy Commission Public Interest Energy Research (PIER). http://cx.lbl.gov/documents/2009-assessment/lbnl-cx-cost-benefit.pdf

6.2.8 *Optimization of outside air volumes according to tenant occupancy*

Properly ventilated tenant spaces require the HVAC system to deliver adequate amounts of clean, fresh air to building occupants. This fresh air replaces stale air that has become polluted with airborne contaminants from occupant and equipment activities. These airborne pollutants include odors, CO2 (from breathing), equipment emissions (ozone and particulates from copiers and printers), moisture, dirt, dust, mold and various other airborne chemicals.[139] Sensing and control technologies can be employed to deliver fresh air on demand, based on indoor CO2 levels detected by sensors in individual areas within a tenant space. During the design process, the tenant should coordinate with the mechanical designer or building engineering team to ensure that outside air volumes delivered to the tenant space are optimized for the anticipated occupancy. Providing excessive volumes of outside air will increase HVAC system energy consumption, while lower levels of outside air will negatively impact indoor air quality. Additionally, emerging approaches to ventilation systems include scrubbing pollutants directly out of indoor air to reduce the requirement to condition outside air.

Cost/Benefit analysis for a typical use or uses

Optimizing outside air volumes according to tenant occupancy can save $0.05 to over $1.00 per square foot and can range in cost from $300 to $1,000 per HVAC zone.[140] [141] Although it is difficult to apply a specific rule of thumb for savings, studies show that large spaces that have significant variations in occupancy provide the best opportunity to achieve energy savings through optimizing outside air volumes.[142]

More Information

- Creating a High Performance Workspace. Portland's Green Tenant Improvement Guide. Link.

139 https://www.portlandoregon.gov/bps/article/285215 City of Portland Planning and Sustainability. (n.d.). Creating a High Performance Workplace. https://www.portlandoregon.gov/bps/article/285215

140 Oregon Office of Energy. (2003). Northwest Energy Efficiency Alliance. Demand-Controlled Ventilation: A Design Guide. http://www.oregon.gov/energy/cons/bus/dcv/docs/dcvguide.pdf.

141 Sand, James.J. (2004). DOE Federal Energy Management Program. Demand Controlled Ventilation Using CO2 Sensors. (2004). http://infohouse.p2ric.org/ref/43/42844.pdf.

142 Energy Design Resources. (2007). Design Brief: Demand-Controlled Ventilation. https://energydesignresources.com/media/1705/EDR_DesignBriefs_demandcontrolledventilation.pdf?tracked=true.

6.2.9 *Data centers and IT server room best practices*

Data centers and server rooms and are one of the most energy-intensive spaces in commercial buildings, consuming 10 to 50 times the energy per floor area of a typical commercial office building. Collectively, these spaces account for approximately 2% of the total U.S. electricity use, and as use of information technology grows, data center and server energy use is expected to grow too. There are many opportunities to reduce energy use in server closets and data centers,[143] including consolidating servers, decommissioning servers that are not in service, consolidating and organizing stored data to eliminate unnecessary redundancy, installing ENERGY STAR® qualified servers, arranging of server racks and isolating air flows to create hot/cold aisles that prevent the mixing of warm and cool air, adjusting the temperature set points and managing humidity levels, and utilizing air- and water-side economizers when weather conditions permit.[144] Building engineers can play a role in reviewing data center design and providing building-specific recommendations to optimize the performance of the data center.

Cost/Benefit analysis for a typical use or uses

Implementing design and operational strategies to improve energy performance can reduce data centers and server closet energy consumption by up to 80%.[145] A Lawrence Berkeley National Laboratory test on three data centers varying in size, design and energy load showed estimated costs to implement energy efficiency measures from $276,000 - $770,000 with an average payback of approximately 2 years.[146]

More Information

- Top 12 Ways to Decrease the Energy Consumption of your Data Center. ENERGY STAR®. Link.
- Energy Efficiency in Small Server Rooms: Field Surveys and Findings. Lawrence Berkeley National Laboratory. Link.

6.2.10 *Improving Building Envelope Performance*

Improving building envelope performance in tenant spaces is most cost-effective when evaluated during the design phase of new construction projects, as the incremental cost premium for upgrading the building envelope when designing new buildings is significantly lower than when retrofitting existing buildings. Opportunities for improving building envelope performance for new buildings include installing high-efficiency windows and glazing systems, operable windows that provide natural ventilation and increase occupant comfort, exterior shading systems, properly insulating pipes and ducts in perimeter walls, and increasing wall and roof insulation levels. Various strategies can be implemented to improve building envelope performance in existing buildings, which include installing high efficiency window films, interior window shading devices, reducing air infiltration through exterior doors, properly sealing the perimeter walls and openings, and installing a radiant barrier on the

143 http://energy.gov/eere/buildings/data-centers-and-servers DOE. DOE. Data Centers and Services. http://energy.gov/eere/buildings/data-centers-and-servers

144 http://www.energystar.gov/ia/products/power_mgt/downloads/DataCenter-Top12-Brochure-Final.pdf?d63b-c2a9 ENERGY STAR®. ENERGY STAR®. (n.d.). Top 12 Ways to Decrease the Energy Consumption of Your Data Center. http://www.energystar.gov/ia/products/power_mgt/downloads/DataCenter-Top12-Brochure-Final.pdf?d63b-c2a9

145 http://www.energystar.gov/ia/products/power_mgt/ES_Data_Center_Utility_Guide.pdf?ff29-42fa ENERGY STAR®. ENERGY STAR®. (2012). Understanding and Designing Energy-Efficiency Programs for Data Centers. http://www.energystar.gov/ia/products/power_mgt/ES_Data_Center_Utility_Guide.pdf?ff29-42fa

146 Mahdavi, Rod.R. (2014). Prepared for the US DOE's Federal Energy Management Program by the Lawrence Berkeley National Laboratory. Case Study: Opportunities to Improve Energy Efficiency in Three Federal Data Centers. (2014). http://energy.gov/sites/prod/files/2014/06/f16/casestudy_3federaldatacenters_0.pdf.

perimeter walls.[147] For tenant spaces in both new and existing buildings, it is essential to coordinate with the design and building management teams early in the design process to identify opportunities and limitations for improving building envelope performance.[148]

Cost/Benefit analysis for a typical use or uses

Envelope performance can have a wide range of costs and benefits, ranging from the trivial (minor caulking) to transformative (replacement of façade, new windows, comprehensive air sealing). As an example, in multiunit buildings, caulking has been estimated to save 3-12% on energy for conditioning, at a cost of less than $0.31/ft^2.[149] Additionally, a study of non-residential buildings in Canada found that a 40% to 70% decrease in air infiltration resulted in "a 9% to 15% reduction in overall energy expenditure, with a payback period of less than 2 years."[152] By contrast, replacing the panes on a major office tower can yield significant energy savings with a correspondingly high cost. Envelope improvements at this scale are typically completed as part of a repositioning upgrade and need to be individually evaluated.[150] [151]

More Information

- High-Performance Tenant Build-Out: A Primer for Tenants. Institute for Building Efficiency. Link.
- Tenant Energy Performance in Commercial Office Buildings. Real Estate Roundtable. Link.

147 http://www.institutebe.com/InstituteBE/media/Library/Resources/Existing%20Building%20Retrofits/Primer_Tenant_Build_Outs.pdf Institute for Building Efficiency. (2011). High-Performance Tenant Build-Out: A Primer For Tenants. http://www.institutebe.com/InstituteBE/media/Library/Resources/Existing%20Building%20Retrofits/Primer_Tenant_Build_Outs.pdf

148 http://www.josre.org/wp-content/uploads/2013/02/CMI-PPT-on-Tenant-Energy-Performance.pdf NRDC. NRDC. (2013). Tenant Energy Performance in Commercial Office Buildings. NRDC Center for Market Innovation High Performance Tenant Demonstration Project. http://www.josre.org/wp-content/uploads/2013/02/CMI-PPT-on-Tenant-Energy-Performance.pdf

149 Dentz, J., Conlin, F., Podorson, D. (2012). Case Study of Envelope Sealing in Existing Multiunit Structures. NREL. http://www.nrel.gov/docs/fy13osti/54787.pdf

150 Hampson, R. (2010). Empire State Building goes green, one window at a time. USA Today. http://usatoday30.usatoday.com/news/nation/environment/2010-07-12-empire-state-building-windows-green_N.htm

151 Guevarra, L. (2010). A Tall Order: Serious Materials to Retrofit Empire State Building's Windows. GreenBiz. http://www.greenbiz.com/news/2010/03/03/tall-order-serious-materials-retrofit-empire-state-buildings-windows

6.2.11 *HVAC zoning*

Creating separate HVAC zones to align with hours of operation, occupancy, and unique heating and cooling requirements of tenant spaces will improve the comfort of building occupants and reduce HVAC energy consumption. When a tenant space is properly zoned, heating and cooling is provided based on the temperature requirements of each HVAC zone. For example, a conference room with a high occupant density will require more cooling than an infrequently occupied tenant break room. An effective strategy for HVAC zoning in tenant spaces is organizing the interior layout to create zones with similar needs for heating and/or cooling based on function, level of activity, exposure to the sun or wind, schedules and location in the building. Additionally, utilizing variable air volume (VAV) systems and providing separate thermostats for each zone to precisely control the temperature and volume of the air delivered will further reduce HVAC energy consumption in tenant spaces.

Cost/Benefit analysis for a typical use or uses

Increasing the number of HVAC zones in a space can cost an additional $3/square foot to $6/square foot on top of typical mechanical system costs.[152] Retrofitting a constant volume system to a VAV system can cost between $1/square foot and $4/square foot and can achieve a payback of 10 months to 12.1 years depending on available rebates.[153]

More Information

- Creating a High Performance Workspace. Portland's Green Tenant Improvement Guide. Link.
- Los Alamos National Laboratory Sustainable Design Guide. Chapter 5- Lighting, HVAC, and Plumbing. Link.

152 California Energy Commission. (2003). Advanced Variable Air Volume System Design Guide. http://www.energy.ca.gov/2003publications/CEC-500-2003-082/CEC-500-2003-082-A-11.PDF.

153 ENERGY STAR®. (2008). Building Upgrade Manual: Air Distribution Systems. https://www.energystar.gov/ia/.../EPA_BUM_CH8_AirDistSystems.pdf.

6.2.12 *Window attachments*

Window attachments are a cost-effective means of improving the energy efficiency of a tenant space by reducing solar heat gain and improving light distribution.

Window films:

- High-reflectivity films help reduce solar heat gain and cooling costs during the summer.
- Prismatic films redirect sunlight towards the ceiling to provide more natural light in tenant spaces, reducing lighting energy consumption when daylight sensors are utilized to control electric lighting.[154]
- Window films with a low-e coating provide the benefits of year-round energy savings by improving window insulating performance and helping to keep the heat in during the winter and out during the summer.

Awnings, low-cost shades, and roof overhangs provide a physical barrier from strong midday sunlight while allowing soft light in the early or late hours. The exterior nature of awnings and roof overhangs may be difficult for tenants in high-rise structures, but can prove useful for retail tenants with first floor rental space. In addition to conserving energy, window attachments can reduce glare, improve occupant health and productivity, improve access to daylight and views, and improve thermal comfort.[155]

Cost/Benefit analysis for a typical use or uses

Window films can reduce tenant space energy consumption by 5-17% and typically have a cost premium of ≤ $2/square foot, when compared to standard window systems.[156] [157]

Exterior window attachments, such as awnings, can reduce summertime solar heat gain between 65 and 77%.[158]

More Information

- Energy efficient window treatments. US DOE. Link.
- Windows and Building Envelope Research and Development: Roadmap for Emerging Technologies. US DOE. Link.
- Reducing Supplemental Loads. ENERGY STAR®. Link.

154 Thanachareonkit, Anothai;A., Lee, Elanor;E., & McNeil, AndrewA. (2013). Empirical assessment of a prismatic daylight-redirecting window film in a full-scale office testbed. http://eetd.lbl.gov/daylight/daylight-field-test.pdf

155 Regulations.gov. (2015). 2015-09-23 Comment response to the published Request for Information (RFI). EastmanChemicalCompanyCommentEERE2015BTBLDG0012. http://www.regulations.gov/#!documentDetail;D=EERE-2015-BT-BLDG-0012-0008

156 DOE. (2014). Windows and Building Envelope Research and Development: Roadmap for Emerging Technologies. http://energy.gov/sites/prod/files/2014/02/f8/BTO_windows_and_envelope_report_3.pdf

157 International Window Film Association (IWFA). Enegy Analysis for Window Films Applications in New and Existing Homes and Offices. http://www.iwfa.com/Portals/0/PDFDocs/IWFA%20Energy%20Study%20FINAL.pdf

158 DOE. (n.d.). Energy Efficient Window Treatments. http://energy.gov/energysaver/articles/energy-efficient-window-treatments

6.2.13 *Utility Metering and Submetering*

While submetering provides the opportunity for additional energy savings, it does not, in of itself, save energy. Submetering provides tenants and property management teams an additional level of insight into the energy performance of their space or sub-spaces. Data gathered through a well-designed submetering plan can greatly inform and influence the development of energy management strategies and can highlight the specific impact of energy efficiency projects, providing data-driven evidence of program effectiveness. Submeters also provide more accurate billing for energy usage in a specific tenant space when building operating expenses are normally billed pro rata. Submeters can be applied to measure large (entire building floors) or small scale (circuit-level or outlet-level) energy usage within a tenant space.

As discussed in section 4.1.5, building owners tend to favor less sophisticated meters over utility-grade meters. These meters are less expensive and "get the job done" when it comes to simple and consistent measurement of energy use from a single space. These same meters can be installed with technical options allowing electricity measurements to tie into systems mimicking utility tariff standards. Such sophisticated options are used for heightened accuracy of tenant energy use billback.

Installing permanent submeters is expensive. These costs discourage many owners and tenants from purchasing meters as an energy monitoring tool. While lower-cost wireless meters exist, they currently lack the ability to measure energy use over an extended period of time. Rather, they are most commonly used to temporarily monitor the energy use of a space in order to justify permanent submetering of above-average energy use spaces.

Cost/Benefit analysis for a typical use or uses

Submeters can cost between $700 and $5,000 and less robust models are available at a lower cost.[159] [160]

More Information

- Submetering Business Case: How to calculate cost-effectiveness solutions in the building context. GSA. Link.
- Submetering of Building Energy and Water Usage. National Science and Technology Council Committee on Technology. Link.

159 National Science and Technology Council Committee on Technology. (2011). Submetering of Building Energy and Water Usage. https://www.whitehouse.gov/sites/default/files/microsites/ostp/submetering_of_building_energy_and_water_usage.pdf

160 GSA. (2012). Submetering Business Case: How to calculate cost-effective solutions in the building context. http://www.gsa.gov/portal/mediaId/156791/fileName/Energy_Submetering_Finance_Paper_Knetwork_2012_11_269(508).action

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10086

19

Date Submitted	02/15/2022	**Section**	403.2.12.6	**Proponent**	Amanda Hickman
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

none

Summary of Modification

LDCF and CFEI

Rationale

This proposal adds the minimum energy efficiency requirements from 42 U.S.C. 6295(ff)(6)(C)(ii) for large-diameter ceiling fans to the Florida Energy Code and is consistent with the federal standards. On January 19, 2017, the U.S. Department of Energy (DOE) completed a rulemaking and published a final rule establishing new federal minimum energy efficiency standards for ceiling fans. In doing so, it established the LDCF product class, which are ceiling fans with a blade span greater than 2.13 m (84 in.) and a corresponding efficiency metric of cubic feet per minute per Watt, or CFM/W.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Yes. This modification will make Federal requirements easier to enforce.

Impact to building and property owners relative to cost of compliance with code

No. This modification is consistent with existing Federal requirements.

Impact to industry relative to the cost of compliance with code

No. This modification is consistent with existing Federal requirements.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes. This modification is consistent with Federal requirements, which will lead to energy savings and lower GHG emissions.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes. This modification eases applications of Federal requirements.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

No. This modification is consistent with Federal requirements.

Does not degrade the effectiveness of the code

No. This modification improves the effectiveness of the code by making it consistent with Federal requirements.

Chapter 2 [CE] - Add new definition:

LARGE DIAMETER CEILING FAN. A ceiling fan that is greater than or equal to 84.5 inches (2.15 meters) in diameter. These fans are sometimes referred to as High-Volume, Low-Speed (HVLS) fans.

Add new text as follows:

C403.2.12.6 Large-diameter ceiling fans. Where provided, large-diameter ceiling fans shall be tested and labeled in accordance with AMCA 230 and shall meet the efficiency requirements of Table C403.2.12.6 and Section C403.2.12.6.1.

Add new text as follows:

TABLE C403.2.12.6 CEILING FAN EFFICIENCY REQUIREMENTS[a]

EQUIPMENT TYPE	MINIMUM EFFICIENCY[b,c]	TEST PROCEDURE
Large-diameter ceiling fan for applications outside the U.S.[c]	CFEI = 1.00 at high (maximum) speed CFEI = 1.31 at 40% of high speed or the nearest speed that is not less than 40% of high speed	10 CFR 430 Appendix U or AMCA Standard 230 and AMCA Standard 208 (for FEI calculations)
Large-diameter ceiling fan	CFEI = 1.00 at high (maximum) speed; and CFEI = 1.31 at 40% of high speed or the nearest speed that is not less than 40% of high speed	10 CFR 430 Appendix U

a. The minimum efficiency requirements at both high speed and 40% of maximum speed shall be met or exceeded to comply with this code.

b. Ceiling fans are regulated as consumer products by 10 CFR 430.

c. Chapter 6 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

C403.2.12.6.1 Ceiling Fan Energy Index (CFEI). The Ceiling Fan Energy Index shall be calculated as the ratio of the electric input power of a reference large-diameter ceiling fan to the electric input power of the actual large-diameter ceiling fan as calculated in accordance with AMCA 208 with the following modifications to the calculations for the reference fan: using an airflow constant (Q) of 26,500 cfm (12.507 m^3/s), a pressure constant (P) of 0.0027 in. of water (0.6719 Pa), and fan efficiency constant (?) of 42%.

Add new standard(s) as follows:

230—15 with errata Laboratory Methods of Testing Air Circulating Fans for Rating and Certification

AMCA Air Movement and Control Association International 30 West University Drive Arlington Heights IL 60004-1806

10 CFR, Part 430, App U Uniform Test Method for Measuring the Energy Consumption of Ceiling Fans

DOE US Department of Energy c/o Superintendent of Documents 1000 Independence Avenue SW Washington DC 20585

ANSI/AMCA Standard 230-15

Laboratory Methods of Testing Air Circulating Fans for Rating and Certification

Air Movement and Control Association International
30 W. University Drive
Arlington Heights, Illinois
60004

AMCA Publications

Authority AMCA Standard 230-15 was adopted by the membership of the Air Movement and Control Association International Inc. on September 4, 2015, and approved by the American National Standards Institute on October 16, 2015.

Objections Air Movement and Control Association International Inc. will consider and take action upon all written complaints regarding its standards, certification programs or interpretations thereof. For information on procedures for submitting and handling complaints, write to

Air Movement and Control Association International
30 West University Drive
Arlington Heights, IL 60004-1893 U.S.A.
AMCA International Incorporated

European AMCA
Avenue des Arts, numéro 46
à Bruxelles (1000 Bruxelles)

Asia AMCA Sdn Bhd
No. 7, Jalan SiLC 1/6,
Kawasan Perindustrian SiLC Nusajaya,
Mukim Jelutong, 79200 Nusajaya, Johor
Malaysia

Disclaimer AMCA uses its best efforts to produce publications for the benefit of the industry and the public in light of available information and accepted industry practices. However, AMCA does not guarantee, certify or assure the safety or performance of any products, components or systems tested, designed, installed or operated in accordance with AMCA publications or that any tests conducted under its publications will be non-hazardous or free from risk.

Review Committee

John Cermak	ACME Engineering and Manufacturing Corp.
John Fox	Air King Ventilation Products
Vasanthi Iyer	Air Movement Solution
Christian Avedon	Airius, LLC
Jay Fizer	Big Ass Solutions
Christian Taber	Big Ass Solutions
Armin Hauer	ebm-papst Inc.
Luis Carlos Mendes Dos Santos Nior	Equilibrio Balanceamentos Industriais Ltda
Fernando A. Ruiz C., P.E., M.A.	Equipos Electromecánicos, S.A. de C.V.
Justin Meyer	Hartzell Air Movement
Bill Walker	Hunter Fan Company
Tom Breeden	Hunter Fan Company
Terry Lyons	J&D Manufacturing
Jonathan Hollist	MacroAir
Michael Danielsson	MacroAir
Jesse Jensen	PennBarry
Edoardo Capello	Termotecnica Pericoli Srl
James Quinn	Triangle Engineering of Arkansas Inc.
Tim Orris	AMCA Staff

Related AMCA Documents

Related Publications	AMCA Publication 11, *Certified Ratings Program — Operating Manual*
	AMCA Publication 211, *Certified Ratings Program — Product Rating Manual for Fan Air Performance*
	AMCA Publication 311, *Certified Ratings Program — Product Rating Manual for Fan Sound Performance*
Related Standards	ANSI/AMCA Standard 300, *Reverberant Room Method for Sound Testing of Fans*
	ANSI/AMCA Standard 210, *Laboratory Methods of Testing Fans for Aerodynamic Performance Rating*

Contents

Laboratory Methods of Testing Air Circulating Fans for Rating and Certification

1. Purpose

The purpose of this standard is to establish uniform methods for laboratory testing of air circulating fans to determine performance (forward or reverse flow) in terms of airflow rate for rating, certification or guarantee purposes.

2. Scope

This standard shall be used as the basis for testing air circulating fan heads, ceiling fans, box fans, table fans, portable personnel coolers or other air circulating devices when air is used as the test gas. The diameter of the fan being tested shall be limited by the minimum dimensions as shown in the applicable test figures.

Blowers, exhausters, compressors, positive displacement machines and positive pressure ventilators are not within the scope of this standard.

The parties to a test for guarantee purposes shall agree on exceptions to this standard in writing prior to the test. However, only tests which do not violate any mandatory requirements of this standard shall be designated as tests conducted in accordance with this standard.

3. Units of Measurement

3.1 System of units

SI units (The International System of Units, *Le Systéme International d'Unités*) [1] are the primary units employed in this standard, with I-P units (inch-pound) given as the secondary reference. SI units are based on the fundamental values of the International Bureau of Weights and Measures [1], and I-P values are based on the values of the National Institute of Standards and Technology, which are in turn based on the values of the International Bureau.

3.2 Basic units

The SI unit of length is the meter (m) or the millimeter (mm); the I-P unit of length is the foot (ft) or the inch (in.). The SI unit of mass is the kilogram (kg); the I-P unit of mass is the pound mass (lbm). The unit of time is either the minute (min) or the second (s). The SI unit of temperature is either the Kelvin (K) or the degree Celsius (°C); the I-P unit of temperature is either the degree Fahrenheit (°F) or the degree Rankine (°R). The SI unit of force is the newton (N); the I-P unit of force is the pound force (lbf).

3.3 Velocity

The SI unit of velocity is the meter per second (m/s); the I-P unit of velocity is the foot per minute (fpm).

3.4 Thrust

The SI unit of thrust is the newton (N); the I-P unit is the pound force (lbf).

3.5 Pressure

The SI unit of pressure is the pascal (Pa). The I-P unit of pressure is either the inch water gauge (in. wg) or the inch mercury (in. Hg). Values in mm Hg or in in. Hg shall be used only for barometric pressure measurements.

The in. wg shall be based on a one-inch column of distilled water at 68 °F under standard gravity and a gas column balancing effect based on standard air. The in. Hg shall be based on a one-inch column of mercury at 32 °F under standard gravity in a vacuum. The mm Hg shall be based on a one-millimeter column of mercury at 0 °C under standard gravity in a vacuum.

3.6 Power

The unit of input power is the watt (W).

3.7 Speed

The unit of rotational speed is the revolution per minute (rpm).

3.8 Gas properties

The SI unit of density is the kilogram per cubic meter (kg/m^3); the I-P unit of density is the pound mass per cubic foot (lbm/ft^3). The SI unit of viscosity is the pascal-second, (Pa-s); the I-P unit of viscosity is the pound mass per foot-second (lbm/ft-s). The SI unit of gas constant is the joule per kilogram-kelvin (J/kg-K); the I-P unit of gas constant is the foot-pound force per pound-mass-degree Rankine (ft-lb/(lbm•°R)).

3.9 Dimensionless groups

Various dimensionless quantities appear in the text. Any consistent system of units may be employed to evaluate these quantities unless a numerical factor is included, in which case units must be as specified.

3.10 Physical constants

The SI value of standard gravitational acceleration shall be taken as 9.80665 m/s^2, which corresponds to mean sea level at 45° latitude; the I-P value of standard gravitational acceleration is 32.1740 ft/s^2, which corresponds to mean sea level at 45° latitude [1]. The SI density of distilled water at saturation pressure shall be taken as 998.278 kg/m^3 at 20°C; the I-P value is 62.3205 lbm/ft^3 at 68 °F [2]. The density of mercury at saturation pressure shall be taken as 13595.1 kg/m^3 at 0 °C; the I-P value is 848.714 lbm/ft^3 at 32°F [2]. The specific weights in kg/m^3 (lbm/ft^3) of these fluids in vacuum under standard gravity are numerically equal to their densities at corresponding temperatures.

4. Symbols and Subscripts

See Table 1.

5. Definitions

5.1 Air circulating fan

A non-ducted fan used for the general circulation of air within a confined space. Various types of air circulating fans are defined below.

5.1.1 Air circulating fan head
An assembly consisting of a motor, impeller and guard for mounting on a pedestal having a base and column, wall mount bracket, ceiling mount bracket, I-beam bracket or other commonly accepted mounting means.

5.1.2 Ceiling fan
A fan which is mounted to the ceiling or overhead structure of a building, usually with the fan shaft oriented vertically. The impeller may or may not be guarded.

5.1.3 Personnel cooler
A fan used in shops, factories, etc. Generally supplied with wheels or casters on the housing or frame to aid in portability, and with motor and impeller enclosed in a common guard and shroud.

5.1.4 Box fan
A fan used in an office or residential application and having the motor and impeller enclosed in an approximately square box frame having a handle.

5.1.5 Table fan
A fan intended for use on a desk, table or countertop. The fan may also be provided with the means for mounting to a wall.

5.2 Psychrometrics

5.2.1 Dry-bulb temperature
The air temperature measured by a dry temperature sensor.

5.2.2 Wet-bulb temperature
The temperature measured by a temperature sensor covered by a water-moistened wick and exposed to air in motion. When properly measured, it is a close approximation of the temperature of adiabatic saturation.

5.2.3 Wet-bulb depression
The difference between the dry-bulb and wet-bulb temperatures at the same location.

5.2.4 Air density
The mass per unit volume of the air.

5.2.5 Standard air
Air with a density of 1.2 kg/m^3 (0.075 lbm/ft^3), a ratio of specific heats of 1.4, a viscosity of 1.8185 × 10^{-5} Pa•s (1.222 × 10^{-5} lbm•s). Air at 20 °C (68 °F), 50% relative humidity and 101.325 kPa (29.92 in. Hg) barometric pressure has these properties, approximately.

5.3 Pressure

5.3.1 Pressure
Pressure is force per unit area. This corresponds to energy per unit volume of fluid.

5.3.2 Absolute pressure
The value of a pressure when the datum pressure is absolute zero. It is always positive.

5.3.3 Barometric pressure
The absolute pressure exerted by the atmosphere.

5.4 Force

5.4.1 Load differential
The difference in measured force, using either standard weights or a load cell, when the fan is energized and when it is not energized.

5.5 Fan performance variables

5.5.1 Fan thrust
The reaction force due to the momentum change of the mass flow through the device.

5.5.2 Fan speed
The rotational speed of the impeller.

5.5.3 Power input
The electrical power required to drive the fan and any elements in the drive train which are considered a part of the fan.

Table 1
Symbols and Subscripts

Symbol	Description	SI Unit	I-P Unit
A	Discharge area	m^2	ft^2
D	Diameter	m	ft
E	Voltage	V	V
Eff_{circ}	Efficacy of a circulating fan	$(m^3/s)/W$	cfm/W
F_t	Force due to thrust	N	lbf
ΔF	Load differential	N	lbf
η_o	Overall efficiency	dimensionless	
I	System input current	A	A
L_1	Lever arm length	mm	in.
L_2	Lever arm length	mm	in.
N	Fan speed	rpm	rpm
p_b	Corrected barometric pressure	Pa	in. Hg
p_e	Saturated vapor pressure	Pa	in. Hg
p_p	Partial vapor pressure	Pa	in. Hg
Q_0	Airflow rate	m^3/s	cfm
R	Gas constant	J/(kg•K)	ft-lb/(lbm•°R)
ρ_0	Ambient air density	kg/m^3	lbm/ft^3
ρ_{std}	Standard air density	kg/m^3	lbm/ft^3
t_{d0}	Ambient dry-bulb temperature	°C	°F
t_{w0}	Ambient wet-bulb temperature	°C	°F
t_t	Total temperature	°C	°F
V	Air velocity	m/s	fpm
W_E	Electrical input power	W	W

5.5.4 Discharge area
Area of a circle having a diameter equal to the blade tip diameter.

5.6 Miscellaneous

5.6.1 Shall and should
The word *shall* is to be understood as mandatory, the word *should* as advisory.

5.6.2 Determination
A complete set of measurements for the free-air operation of an air circulator fan. A determination shall, at a minimum, include the following measurements:

Ambient dry bulb temperature in °C (°F)
Ambient wet bulb temperature in °C (°F)
Barometric pressure in mm Hg (in. Hg)
Diameter in meters (feet)
Electrical input voltage in volts
System input current in amps
Electrical input power input in watts
Fan speed in rpm
Load differential in newtons (pounds force)

5.6.3 Test
A series of determinations for one or more points of operation of a fan, e.g., various fan speeds, voltages or frequencies.

6. Instruments and Methods of Measurement

6.1 Accuracy

The specifications for instruments and methods of measurement that follow include both accuracy requirements and specific examples of equipment that are capable of meeting those requirements. Equipment other than the examples cited may be used provided the accuracy requirements are met or exceeded [3].

6.1.1 Instrument accuracy
The specifications regarding accuracy correspond to two standard deviations based on an assumed normal distribution. This is frequently how instrument suppliers identify accuracy, but that should be verified. The calibration procedures, which are specified below, shall be employed to minimize errors. In any calibration process, the large systematic error of the instrument is exchanged for the

smaller combination of the systematic error of the standard instrument and the random error of the comparison. Instruments shall be set up, calibrated and read by qualified personnel trained to minimize errors.

6.1.2 Measurement uncertainty
It is axiomatic that every test measurement contains some error and that the true value cannot be known because the magnitude of the error cannot be determined exactly. However, it is possible to perform an uncertainties analysis to identify a range of values within which the true value probably lies. A probability of 95% has been chosen as acceptable for this standard.

The standard deviation of random errors can be determined by statistical analysis of repeated measurements. No statistical means are available to evaluate systematic errors, so these must be estimated. The estimated upper limit of a systematic error is called the systematic uncertainty and, if properly estimated, it will contain the true value 99% of the time. The two standard deviation limit of a random error has been selected as the random uncertainty. Two standard deviations yield 95% probability for random errors.

6.1.3 Uncertainty of a result
The results of a fan test are the various fan performance variables listed in Section 5.5. Each result is based on one or more measurements. The uncertainty in any result can be determined from the uncertainties in the measurement. It is best to determine the systematic uncertainty of the result and then the random uncertainty of the result before combining them into the total uncertainty of the result. This may provide clues on how to reduce the total uncertainty. When the systematic uncertainty is combined in quadrature with the random uncertainty, the total uncertainty will give 95% coverage. In most test situations, it is wise to perform a pre-test uncertainties analysis to identify potential problems. A pre-test uncertainties analysis is not required for each test covered by this standard because it is recognized that most laboratory tests for rating are conducted in facilities where similar tests are repeatedly run. Nevertheless, a pre-test analysis is recommended as is a post-test analysis. The simplest form of analysis is a verification that all accuracy and calibration specifications have been met. The most elaborate analysis would consider all the elemental sources of error including those due to calibration, data acquisition, data reduction, calculation assumptions, environmental effects and operational steadiness.

6.2 Airflow rate

6.2.1 Airflow rate
Airflow rate shall be calculated from the thrust, standard density and physical diameter of the fan using equations Eq. 9.6 SI or Eq. 9.6 I-P (see Section 9.4).

6.2.2 Thrust
The thrust shall be calculated from the measured load differential, ambient air density and physical dimensions of the test setup. Load differential shall be determined using either standard weights or a load cell.

6.2.2.1 Standard weights
Standard weights shall be accurate within ± 0.5%. Weights shall be added to the test apparatus to balance the apparatus (see figures) prior to energizing the fan. After the fan is energized, additional weights are added to balance the fixture. Load differential is the difference between these two weights.

6.2.2.2 Load cell
Load cell measurements shall be accurate within ± 0.5% of the measured value. Load cell measurements shall be recorded at a minimum of one-second intervals through a 120-second period of test, and the mean of the measured values reported.

6.2.3 Dimensional measurements

6.2.3.1 Lever arm lengths
Lever arm lengths, L_1 and L_2, shall be measured to within ± 0.5% of the actual value (See Test Figures 2A, 2B1 and 2B2).

6.2.3.2 Diameter
Diameter, D, is the outermost impeller blade tip diameter. It shall be measured to within ± 0.5% of the actual value (See Test Figures 1, 2A, 2B1, 2B2, 3A and 3B).

6.3 Power

Input power shall be determined from the measurement of active (real) power in all phases simultaneously by an electric meter.

6.3.1 Meters
Electrical meters shall have certified accuracies of ± 1% of observed reading.

6.3.2 Calibration
Each voltmeter, ammeter and wattmeter shall be calibrated over the range of values to be encountered during testing against a meter with a calibration that is traceable to the National Institute of Standards and Technology (NIST) or other national physical measures recognized as equivalent by NIST.

All electrical equipment used to measure fan performance shall be calibrated with uncertainties by an ISO 17025 accredited calibration laboratory.

6.3.3 Averaging

The power required by a fan is never strictly steady; therefore, to obtain a true reading, either the instrument must be damped or the readings must be averaged in a suitable manner. The power measurement shall be recorded at a minimum of one-second intervals through a 120-second period of test and the mean of the measured values reported. Multipoint or continuous record averaging can be accomplished with instruments and analyzers designed for this purpose.

6.4 Speed

The speed measurement shall be recorded at a minimum of one-second intervals through a 120-second period of test and the mean of the measured values reported. Speed shall be measured with a revolution counter and chronometer, a stroboscope and chronometer, a precision instantaneous tachometer, an electronic counter-timer or any other device which has a demonstrated accuracy of ± 0.5% of the value being measured.

6.4.1 Strobe

A stroboscopic device triggered by the line frequency of a public utility is considered a primary instrument and need not be calibrated if it is maintained in good condition.

6.4.2 Chronometer

A watch with a sweep second hand or digital display that keeps time within five seconds per day is considered a primary instrument.

6.4.3 Other Devices

The combination of a line frequency strobe and chronometer shall be used to calibrate all other speed measuring devices. Any speed measurement device that affects fan operating speed shall not be used.

6.5 Air density

Air density shall be calculated from measurements of wet-bulb temperature, dry-bulb temperature, and barometric pressure. Other parameters may be measured and used if the maximum error in the calculated density does not exceed 0.5%.

6.5.1 Thermometers

Both wet and dry-bulb temperatures shall be measured with thermometers or other instruments with demonstrated accuracies ± 1 °C (± 2 °F) and resolution of 0.5 °C (1 °F) or finer.

6.5.1.1 Calibration

Thermometers shall be calibrated with uncertainties over the range of temperatures to be encountered during testing against a thermometer with a calibration by an ISO 17025 accredited calibration laboratory that is traceable to NIST or other national physical measures recognized as equivalent by NIST.

6.5.1.2 Wet-bulb

The wet-bulb thermometer shall have an air velocity over the water-moistened wick-covered bulb of 3.5 to 10 m/s (700 to 2000 fpm) [4]. The dry-bulb thermometer shall be mounted upstream of the wet-bulb thermometer so its reading will not be depressed.

6.5.2 Barometers

The barometric pressure shall be measured with a mercury column barometer or other instrument with a demonstrated accuracy ± 1.25 mm Hg. (± 0.05 in. Hg) and readable to 0.25 mm Hg (0.01 in. Hg) or finer.

6.5.2.1 Calibration

Barometers shall be calibrated against a mercury column barometer with a calibration that is traceable to the NIST or other national physical measures recognized as equivalent by NIST. A permanently mounted mercury column barometer should hold its calibration well enough so that comparisons every three months should be sufficient. Transducer type barometers shall be calibrated for each test. Barometers shall be maintained in good condition.

All equipment used to measure psychometric data shall be calibrated with uncertainties by an ISO 17025 accredited calibration laboratory.

6.5.2.2 Corrections

Barometric readings shall be corrected for any difference in mercury density from standard or any change in length of the graduated scale due to temperature. Refer to manufacturer's instructions.

7. Equipment and Setups

7.1 Allowable test setups

Six setups are diagrammed in Test Figures 1, 2 and 3. The following shall be used as a guide to the selection of a proper setup.

- Test Figure 1 shall be used for ceiling fans only.
- Test Figures 2A, 2B1 and 2B2 may be used for air circulating fan heads and table fans.
- Test Figures 3A and 3B may be used for personnel coolers and box fans.

7.2 Load cell orientation

In Test Figures 1, 3A and 3B the axis of the load cell shall be parallel to the axis of the unit under test. In all other setups the axis of the load cell shall be perpendicular to the axis of the unit under test. In all cases, the test apparatus shall provide the means of isolating the load cell from torque loading.

8. Observations and Conduct of Test

8.1 General test requirements

8.1.1 Equilibrium
Equilibrium conditions shall be established before each measurement. To test for equilibrium, trial observations shall be made until steady readings are obtained.

8.1.2 Extraneous airflow
Air velocity in the test room not generated by the test circulator fan shall not exceed 0.25 m/s (50 fpm) prior to, during and after the test. Velocity measurements shall be taken immediately before and immediately after the test to ensure that this condition is met.

Location of extraneous airflow measurement shall be directly under the center of the fan at an elevation of 1701.8 mm (67 in.) above floor.

8.2 Data to be recorded

8.2.1 Test unit
The description of the test unit and its nameplate data shall be recorded.

8.2.2 Test setup
The description of the test setup including specific dimensions shall be recorded and included in the final report. Reference shall be made to the test figures in this standard. Alternatively, a drawing or annotated photograph of the setup may be attached to the data.

8.2.3 Instruments
The instruments and apparatus used in the test shall be listed. Names, model numbers, serial numbers, scale ranges and calibration information shall be recorded.

8.2.4 Test data
Test data for each determination shall be recorded. Readings shall be made simultaneously whenever possible. For all tests, ambient dry-bulb temperature (t_{d0}), ambient wet-bulb temperature (t_{w0}), ambient barometric pressure (p_b), fan diameter (D), load differential (ΔF), fan speed (N), electrical input power (W_E), voltage input (E), date, digital readout, calibration, resolution, units of force and system input current (I) shall be recorded.

For fans with variable speed, performance data shall be captured and reported in five speeds (20, 40, 60, 80 and 100 percent of maximum speed) evenly spaced throughout the speed range. If there are less than five speeds available, the performance of all speeds shall be measured.

8.2.5 Personnel
The names of test personnel shall be listed with the data for which they are responsible.

9. Calculations

9.1 Calibration correction

Calibration corrections, when required, shall be applied to individual readings before averaging or other calculations. Calibration corrections need not be made if the correction is smaller than one half the maximum allowable error as specified in Section 6.

9.2 Ambient air density

The density of ambient air (ρ_0) shall be determined from measurements, taken at the time of testing in the general test area, of dry-bulb temperature (t_{d0}), wet-bulb temperature (t_{w0}), and barometric pressure (p_b) using the following formulae [5].

$$p_e = 3.25t_{w0}^2 + 18.6t_{w0} + 692 \quad \text{Eq. 9.1 SI}$$

$$p_e = \left(2.96\times10^{-4}\right)t_{w0}^2 - \left(1.59\times10^{-2}\right)t_{w0} + 0.41 \quad \text{Eq. 9.1 I-P}$$

$$p_p = p_e - p_b\left(\frac{t_{d0} - t_{w0}}{1500}\right) \quad \text{Eq. 9.2 SI}$$

$$p_p = p_e - p_b\left(\frac{t_{d0} - t_{w0}}{2700}\right) \quad \text{Eq. 9.2 I-P}$$

$$\rho_0 = \left(\frac{p_b - 0.378p_p}{R(t_{d0} - 273.15)}\right) \quad \text{Eq. 9.3 SI}$$

$$\rho_0 = 70.73\left(\frac{p_b - 0.378p_p}{R(t_{d0} + 459.67)}\right) \quad \text{Eq. 9.3 I-P}$$

Equation 9.1 is approximately correct for p_e for a range of t_{w0} between 4 °C and 32 °C (40 °F and 90 °F). More precise values of p_e can be obtained from the ASHRAE Handbook of Fundamentals [6]. The gas constant (R) may be taken as 287 J/(kg•K) (53.35 ft lb/(lbm•°R) for air.

9.3 Thrust

Thrust shall be calculated according to the following:
For Test Figures 1, 3A and 3B:

$$F_t = \Delta F\left(\frac{\rho_{std}}{\rho_0}\right) \quad \text{Eq. 9.4}$$

For Test Figures 2A, 2B1 and 2B2:

$$F_t = \Delta F\left(\frac{L_2}{L_1}\right)\left(\frac{\rho_{std}}{\rho_0}\right) \qquad \text{Eq. 9.5}$$

Where:

F_t = Force due to thrust, N (lbf)
L_1 = Lever arm length, mm (in.)
L_2 = Lever arm length, mm (in.)
ΔF = Load differential, N (lbf)
ρ_0 = Ambient air density, kg/m^3 (lbm/ft^3)
ρ_{std} = Standard air density, 1.2 kg/m^3 (0.075 lbm/ft^3)

9.4 Airflow rate

The velocity distribution downstream of a circulator fan is determined by a variety of factors, including the aerodynamic design of the fan. It is beyond the scope of this standard to measure, predict or describe details of this velocity distribution. The airflow rate associated with the calculated thrust shall also be calculated as:

$$Q_0 = \sqrt{\frac{AF_t}{\rho_{std}}} \qquad \text{Eq. 9.6 SI}$$

$$Q_0 = 340.3\sqrt{\frac{AF_t}{\rho_{std}}} \qquad \text{Eq. 9.6 I-P}$$

Where:

Q_0 = Airflow rate, m^3/s (cfm)
F_t = Thrust, N (lb)
A = $\pi(D/2)^2$, m^2 (ft^2)
ρ_{std} = Standard air density, 1.2 kg/m^3 (0.075 lbm/ft^3)

9.5 Fan overall efficiency

9.5.1 Overall efficiency

The overall efficiency, η_o, shall be calculated from the calculated thrust, F_t, and input electrical power, W_E, using the following equations:

$$\eta_o = \frac{\frac{1}{2}\frac{\rho_0}{\rho_{std}}\sqrt{\frac{F_t^3}{A\rho_{std}}}}{W_E} \qquad \text{Eq. 9.7 SI}$$

$$\eta_o = \frac{3.845\frac{\rho_0}{\rho_{std}}\sqrt{\frac{F_t^3}{A\rho_{std}}}}{W_E} \qquad \text{Eq. 9.7 I-P}$$

Where:

F_t = Thrust, N (lbf)
A = Discharge area, m^2 (ft^2)
W_E = Electrical input power, watt
ρ_0 = Ambient air density, kg/m^3 (lbm/ ft^3)
ρ_{std} = Standard air density, 1.2 kg/m^3 (0.075 lbm/ft^3)

9.6 Circulator fan efficacy

9.6.1 Efficacy

The efficacy of a circulator fan shall be expressed in cubic meters per second per watt [(m^3/s)/W] or cubic feet per minute per watt (cfm/W).

$$Eff_{circ} = \frac{Q_0}{W_E} \qquad \text{Eq. 9.8}$$

Where:

Q_0 = Fan airflow rate m^3/s (cfm)
W_E = Electrical input power, watt

10. Report and Results of Test

The report of a laboratory test of a fan shall include object, results, test data, and descriptions of the test fan, test instruments and personnel as outlined in Section 8. At a minimum, the report shall include the following items:

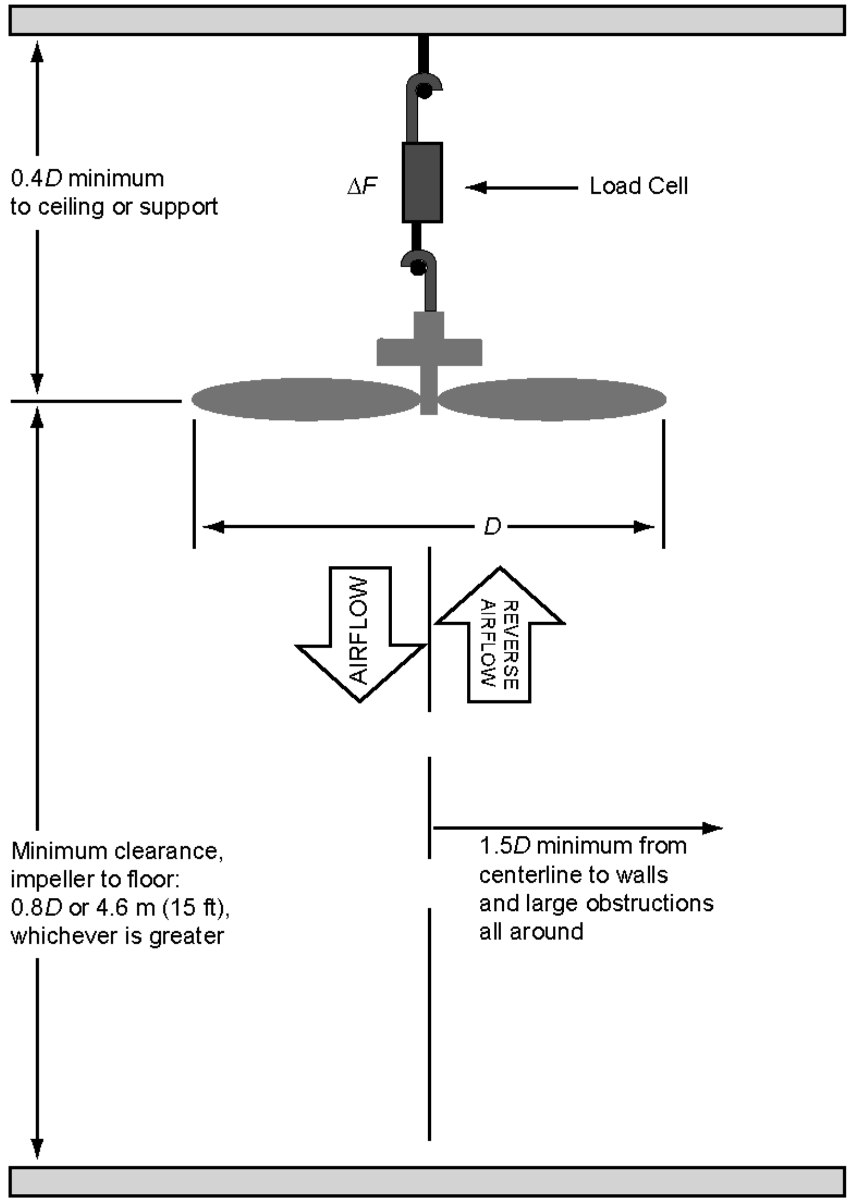
General Test Information:
Laboratory name
Laboratory address
Date of testing
Test number
Personnel performing testing
Air circulating fan type
Test setup (test figure number)
Room dimensions
Minimum clearances to walls, floor, and ceiling or support (per applicable test figure)
Lever arm length 1 (if applicable)
Lever arm length 2 (if applicable)
Fan diameter
Fan model number
Fan serial number
Motor model number
Motor serial number
Motor nameplate data
VSD model number (if applicable)
VSD serial number (if applicable)

Data at test conditions:
Ambient dry bulb temperature
Ambient wet bulb temperature
Ambient barometric pressure
Extraneous airflow before test

Extraneous airflow after test
System input voltage
System input current
System input power
Fan speed
Direction of operation (forward or reverse flow)
Load differential

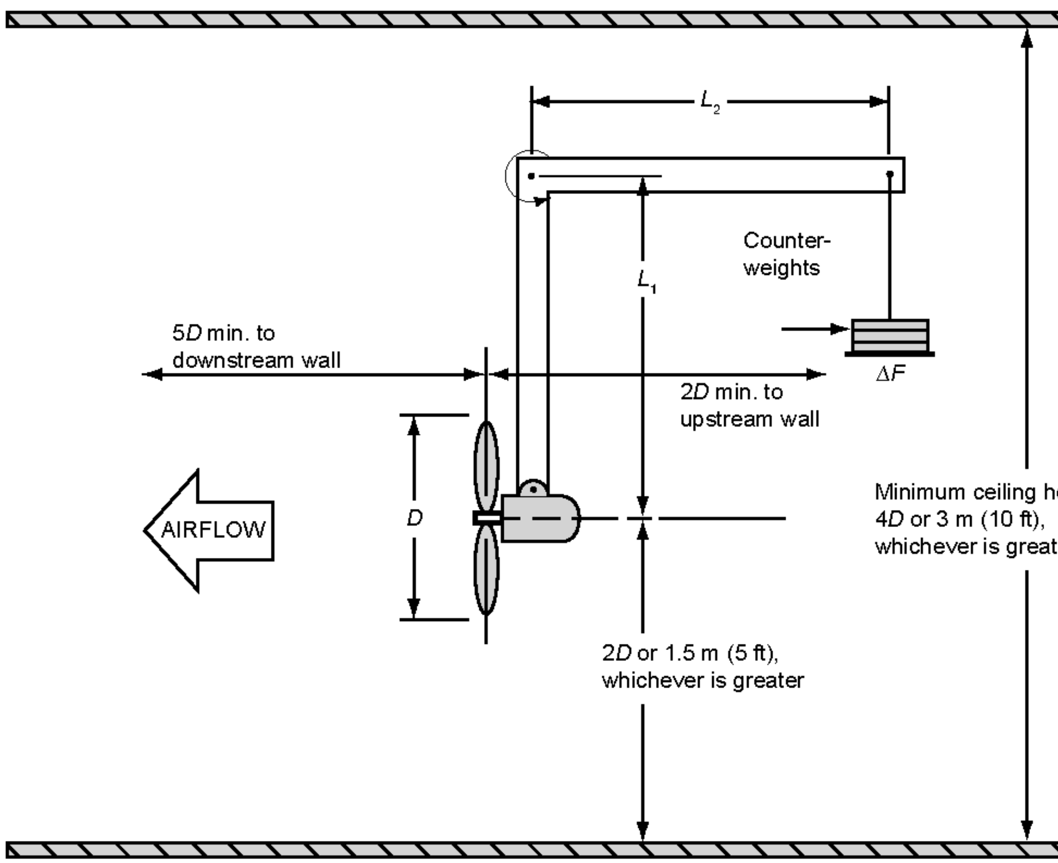
Calculated values:
Fan discharge area
Ambient air density
Percent of maximum fan speed
Thrust at standard conditions
Airflow rate
Overall efficiency at ambient conditions
Efficacy at ambient conditions

Calibration information (per instrument):
Manufacturer
Model number
Serial number
Scale range
ISO 17025 calibration laboratory
Date of last calibration
Date of next required or scheduled calibration



Note:
The vertical centerline through the test setup shall be kept vertical within ± 1° during testing.

Test Figure 1
Vertical Airflow Setup with Load Cell
(Ceiling Fans)

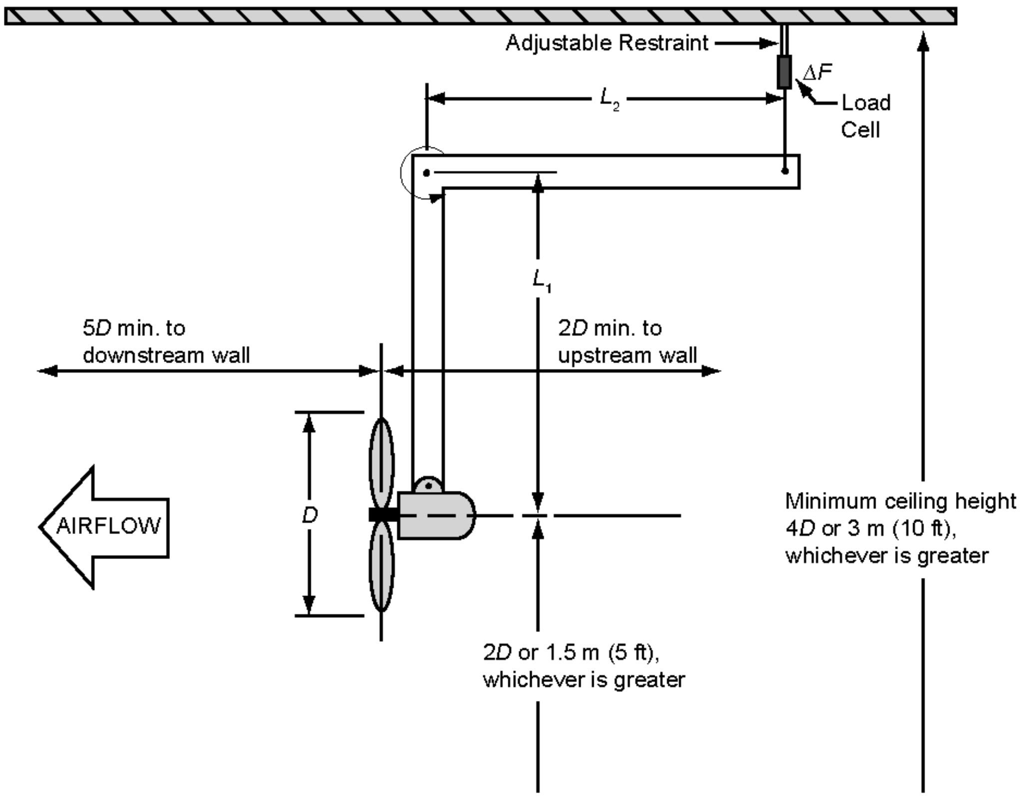


SIDE ELEVATION

Notes:

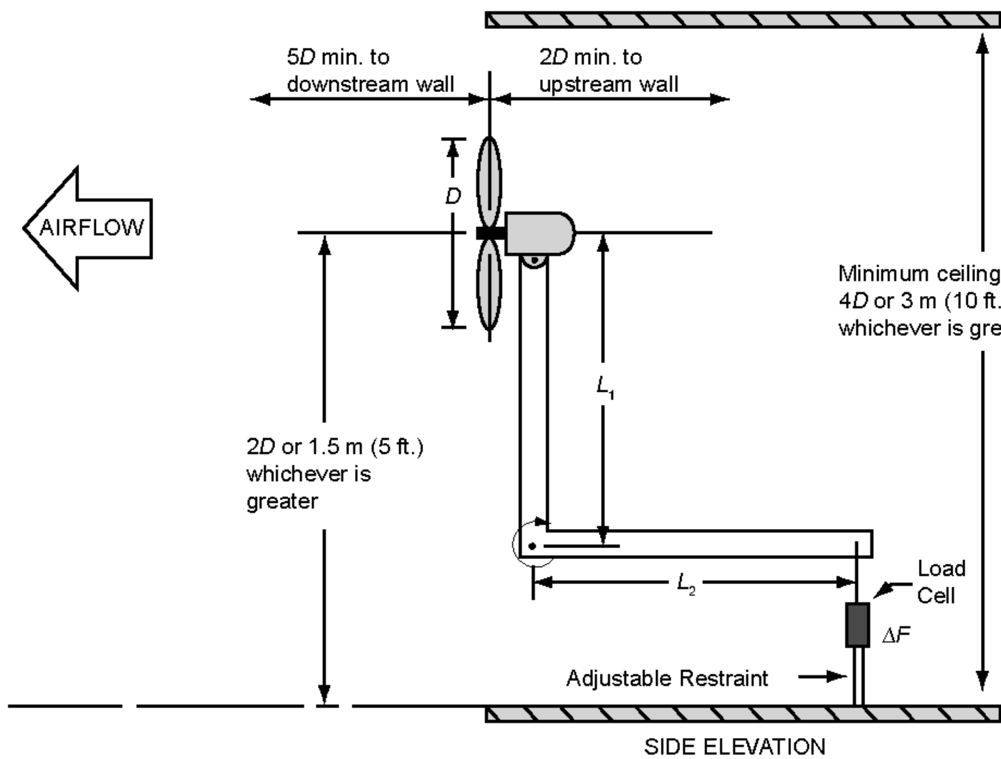
1. The horizontal centerline through the test setup shall be kept horizontal within ± 1° during testing.
2. 2D minimum to walls and large obstructions on sides of test unit.

Test Figure 2A
Horizontal Airflow Setup with Counterweights Pivot Above Test Subject
(Air Circulating Fan Heads and Table Fans)



Notes:
1. The horizontal centerline through the test setup shall be kept horizontal within ± 1° during testing.
2. 2*D* minimum to walls and large obstructions on sides of test unit.

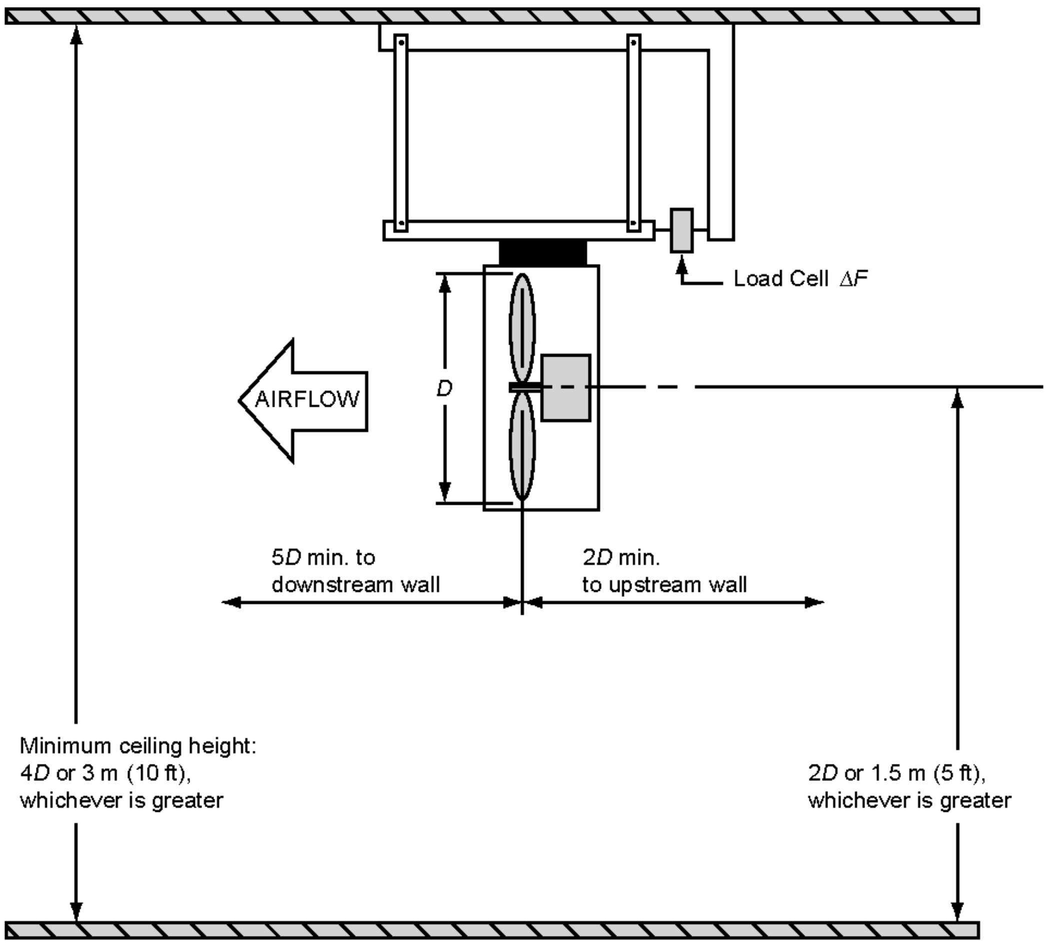
Test Figure 2B1
Horizontal Airflow Setup with Load Cell
(Air Circulating Fan Heads and Table Fans)



Notes:

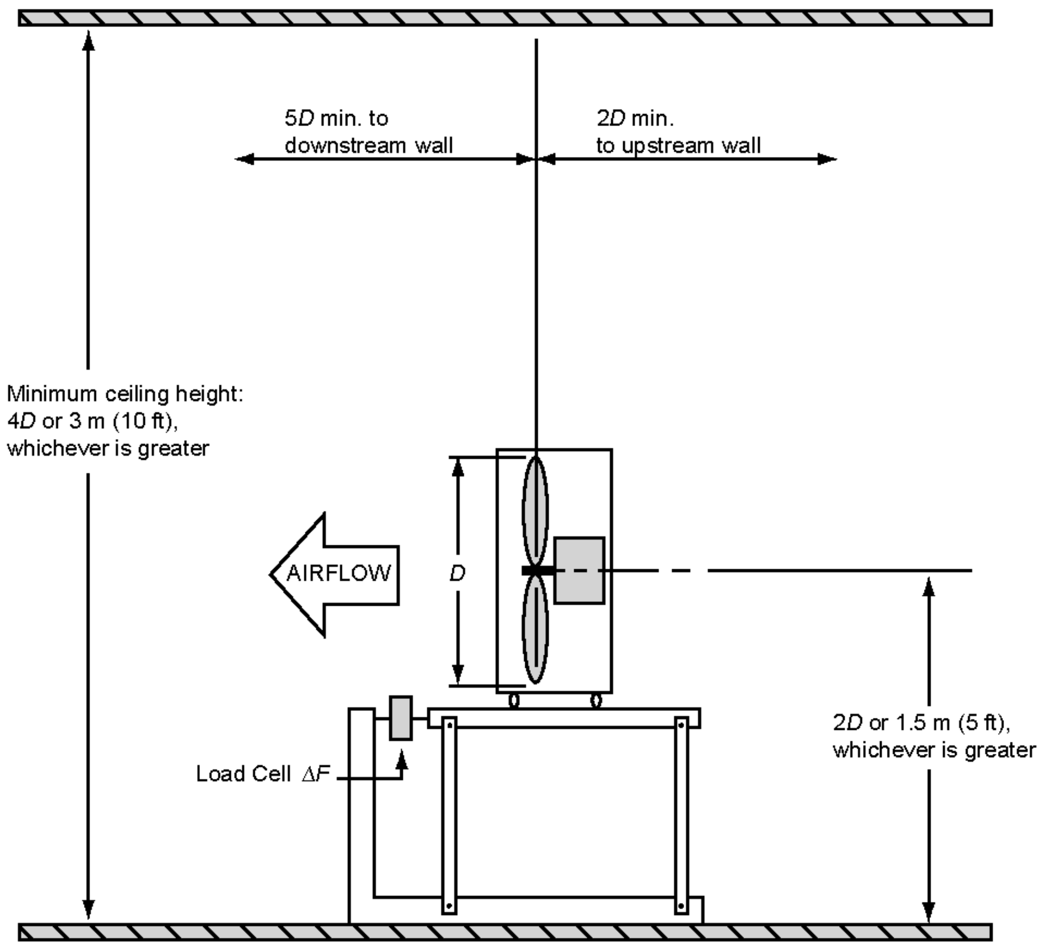
1. The horizontal centerline through the test setup shall be kept horizontal within ± 1° during testing.
2. 2*D* minimum to walls and large obstructions on sides of test unit.

Test Figure 2B2
Horizontal Airflow Setup with Load Cell Pivot Below Test Subject
(Air Circulating Fan Heads and Table Fans)



Note:
2*D* minimum to walls and large obstructions on sides of test unit.

Test Figure 3A
Horizontal Airflow Setup with Load Cell
(Box Fan or Personnel Cooler Fan)

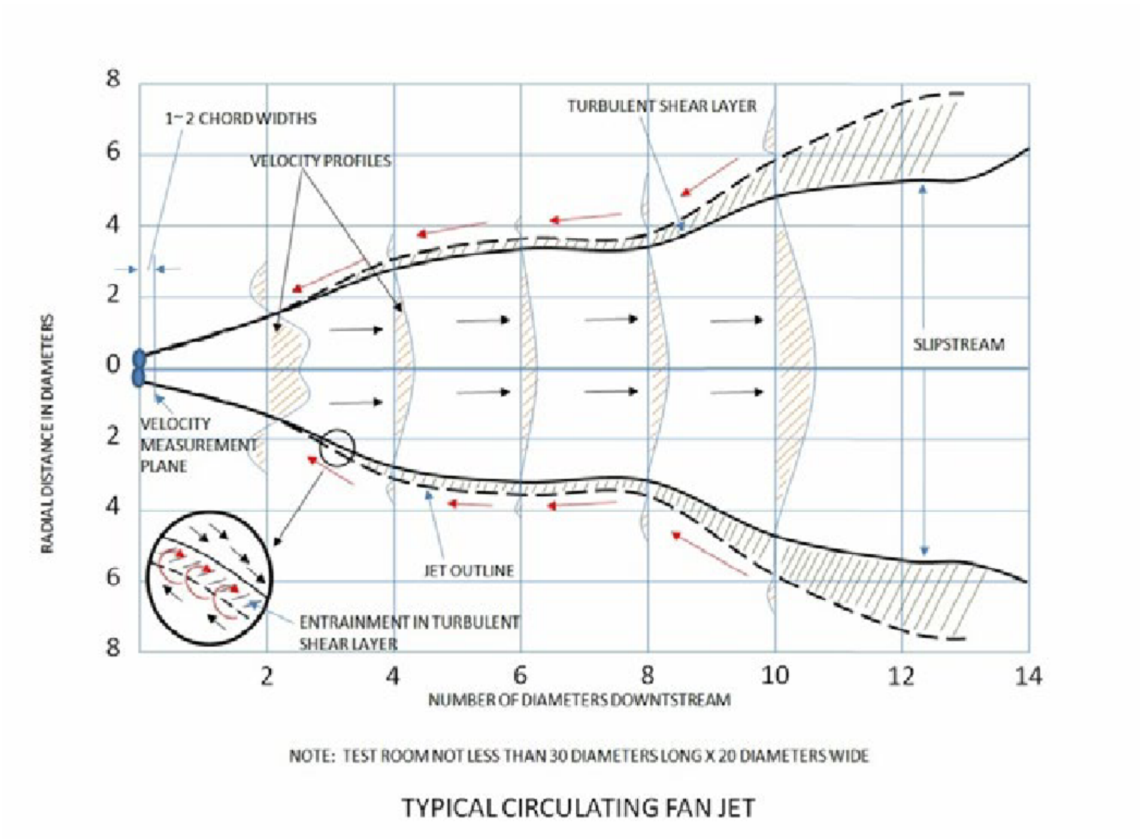


Note:
2*D* minimum to walls and large obstructions on sides of test unit.

Test Figure 3B
Horizontal Airflow Setup with Load Cell
(Box Fan or Personnel Cooler Fan)

Annex A
Circulating Fans and Their Relationship to Airflow and Velocity (Informative)

The measurement of thrust and power consumption serves as simple means to characterize and compare performance of air circulating fans. A more accurate determination of the flow through the fan requires additional measurements. Typically, this is done by measuring and integrating a velocity profile in the primary jet of the fan. Care must be taken with this type of measurement since the primary jet downstream of a circulator fan will entrain additional air from the surroundings. Consequently, the velocity profile should be obtained in a plane normal to the fan axis located about one or two chord lengths downstream in order to minimize the influence of air entrainment. In addition, the measurement must be able to accurately distinguish the axial component of the resultant velocity vector since radial and swirl components are also present. Specialized thermal or laser anemometers are the most accurate instruments capable of these measurements, but five- and seven-hole pressure probes can be used with reasonable accuracy.



Note:
Test room not less than 30*D* long x 20*D* wide.

Figure A.1
Typical Circulating Fan Jet
Adapted from *Axial Flow Fans and Ducts* [7]

Annex B
References (Informative)

[1] NBS Special Publication 330. *The International System of Units (SI)*. Taylor, Barry and Ambler Thompson, eds. Gaithersburg, MD: NIST, 2008.

[2] *Steam Tables*. New York: ASME, 1967.

[3] ASHRAE Standard 41. *Standard Measurement Guide*. Atlanta: ASHRAE, 1975. p. 5-75.

[4] ASHRAE Standard 41. p. 1-86.

[5] Helander, L. "Psychrometric Equations for the Partial Vapor Pressure and Density of Moist Air." Report to AMCA Standard 210/ASHRAE 51P Committee. Nov. 1, 1974

[6] *Handbook of Fundamentals*. Atlanta: ASHRAE, 1993

[7] Wallis, R. Allen. *Axial Flow Fans and Ducts*. New York: Wiley-Interscience, 1983.

TECHNICAL ERRATA SHEET FOR
ANSI/AMCA STANDARD 230-15
Density Corrections

The corrections listed in this errata sheet apply to all copies of ANSI/AMCA Standard 230-15, *Laboratory Methods of Testing Air Circulating Fans for Rating and Certification*.

The corrections are not part of the approved, published document because they did not undergo the rigorous process of consensus development required by the American National Standards Institute (ANSI).

In Section 9, measured fan thrust is converted to standard air density, but the power does not include a density correction. This technical erratum addresses that omission.

In Table 1, add the following variable:

Symbol	Description	SI Unit	IP Unit
W_0	Measured electrical input power	W	W

In Section 8.2.4, replace "W_E" with "W_0".

Insert a new section after Section 9.4:

9.4a Power

The electrical input power, W_E, shall be calculated from the measured electrical input power, W_0, using the following equation:

$$W_E = W_0\left(\frac{\rho_{std}}{\rho_0}\right)$$

In Section 9.5.1, replace all instances of "W_E" with "W_0", including in Equation 9.7.

In Section 10, include "Measured electrical input power" in "Data at test conditions" and "Electrical input power" in "Calculated values."

conducted in accordance with the test requirements specified in section 6.5, Flow Capacity Test, of the ASME/ANSI Standard A112.18.1M–1996 (see §430.22). Measurements shall be recorded at the resolution of the test instrumentation. Calculations shall be rounded off to the same number of significant digits as the previous step. The final water consumption value shall be rounded to one decimal place for non-metered faucets, or two decimal places for metered faucets.

b. Showerheads—The test conditions to measure the water flow rate for showerheads, expressed in gallons per minute (gpm) and liters per minute (L/min), shall be conducted in accordance with the test requirements specified in section 6.5, Flow Capacity Test, of the ASME/ANSI Standard A112.18.1M–1996 (see §430.22). Measurements shall be recorded at the resolution of the test instrumentation. Calculations shall be rounded off to the same number of significant digits as the previous step. The final water consumption value shall be rounded to one decimal place.

[63 FR 13316, Mar. 18, 1998]

Appendix T to Subpart B of Part 430—Uniform Test Method for Measuring the Water Consumption of Water Closets and Urinals

1. *Scope:* This Appendix covers the test requirements used to measure the hydraulic performances of water closets and urinals.

2. *Test Apparatus and General Instructions:*

a. The test apparatus and instructions for testing water closets shall conform to the requirements specified in section 7.1.2, Test Apparatus and General Requirements, subsections 7.1.2.1, 7.1.2.2, and 7.1.2.3 of the ASME/ANSI Standard A112.19.6–1995 (see §430.22). Measurements shall be recorded at the resolution of the test instrumentation. Calculations shall be rounded off to the same number of significant digits as the previous step. The final water consumption value shall be rounded to one decimal place.

b. The test apparatus and instructions for testing urinals shall conform to the requirements specified in section 8.2, Test Apparatus and General Requirements, subsections 8.2.1, 8.2.2, and 8.2.3 of the ASME/ANSI Standard A112.19.6–1995 (see §430.22). Measurements shall be recorded at the resolution of the test instrumentation. Calculations shall be rounded off to the same number of significant digits as the previous step. The final water consumption value shall be rounded to one decimal place.

3. *Test Measurement:*

a. Water closets—The measurement of the water flush volume for water closets, expressed in gallons per flush (gpf) and liters per flush (Lpf), shall be conducted in accordance with the test requirements specified in section 7.1.6, Water Consumption and Hydraulic Characteristics, of the ASME/ANSI Standard A112.19.6–1995 (see §430.22).

b. Urinals—The measurement of water flush volume for urinals, expressed in gallons per flush (gpf) and liters per flush (Lpf), shall be conducted in accordance with the test requirements specified in section 8.5, Water Consumption, of the ASME/ANSI Standard A112.19.6–1995 (see §430.22).

[63 FR 13317, Mar. 18, 1998]

Appendix U to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Ceiling Fans

1. *Scope.* This appendix covers the test requirements used to measure the energy performance of ceiling fans.

2. *Definitions:*

a. *Airflow* means the rate of air movement at a specific fan-speed setting expressed in cubic feet per minute (CFM).

b. *Airflow efficiency* means the ratio of airflow divided by power at a specific ceiling fan-speed setting expressed in CFM per watt (CFM/watt).

3. *Test Apparatus and General Instructions:* The test apparatus and instructions for testing ceiling fans shall conform to the requirements specified in Chapter 3, "Air-Delivery Room Construction and Preparation," Chapter 4, "Equipment Set-up and Test Procedure," and Chapter 6, "Definitions and Acronyms," of the EPA's "ENERGY STAR Testing Facility Guidance Manual: Building a Testing Facility and Performing the Solid State Test Method for ENERGY STAR Qualified Ceiling Fans," Version 1.1, December 9, 2002 (Incorporated by reference, see §430.22). Record measurements at the resolution of the test instrumentation. Round off calculations to the same number of significant digits as the previous step. Round the final energy consumption value to the nearest whole number as follows:

(i) A fractional number at or above the midpoint between the two consecutive whole numbers shall be rounded up to the higher of the two whole numbers; or

(ii) A fractional number below the midpoint between the two consecutive whole numbers shall be rounded down to the lower of the two whole numbers.

4. *Test Measurement:* Measure the airflow and airflow efficiency for ceiling fans, expressed in cubic feet per minute (CFM) and CFM per watt (CFM/watt), in accordance with the test requirements specified in Chapter 4, "Equipment Setup and Test Procedure,"

of the EPA's "ENERGY STAR Testing Facility Guidance Manual: Building a Testing Facility and Performing the Solid State Test Method for ENERGY STAR Qualified Ceiling Fans," Version 1.1, December 9, 2002 (Incorporated by reference, see §430.22). In performing the airflow test, measure ceiling fan power using a RMS sensor capable of measuring power with an accuracy of ±1 %. Prior to using the sensor and sensor software it has selected, the test laboratory shall verify performance of the sensor and sensor software. Measure power input at a point that includes all power consuming components of the ceiling fan (but without any attached light kit energized). Measure power at the rated voltage that represents normal operation continuously over the time period for which the airflow test is conducted, and report the average value of the power measurement in watts (W). Use the average value of power input to calculate the airflow efficiency in CFM/W.

[71 FR 71366, Dec. 8, 2006]

APPENDIX V TO SUBPART B OF PART 430—UNIFORM TEST METHOD FOR MEASURING THE ENERGY CONSUMPTION OF CEILING FAN LIGHT KITS

1. *Scope:* This appendix covers the test requirements used to measure the energy performance of ceiling fan light kits.

2. *Definitions:*

a. *Input power* means the actual total power used by all lamp(s) and ballast(s) of the light kit during operation, expressed in watts (W) and measured using the lamp and ballast packaged with the kit.

b. *Lamp ballast platform* means a pairing of one ballast with one or more lamps that can operate simultaneously on that ballast. A unique platform is defined by the manufacturer and model number of the ballast and lamp(s) and the quantity of lamps that operate on the ballast.

c. *Lamp lumens* means a measurement of luminous flux expressed in lumens and measured using the lamp and ballast shipped with the fixture.

d. *System efficacy per lamp ballast platform* means the ratio of measured lamp lumens expressed in lumens and measured input power expressed in watts (W).

3. *Test Apparatus and General Instructions:*

(a) The test apparatus and instruction for testing screw base lamps packaged with ceiling fan light kits that have medium screw base sockets shall conform to the requirements specified in section 2, "Definitions," section 3, "Referenced Standards," and section 4, "CFL Requirements for Testing" of DOE's "ENERGY STAR Program Requirements for [Compact Fluorescent Lamps] CFLs," Version 3.0, (Incorporated by reference, see §430.22). Record measurements at the resolution of the test instrumentation. Round off calculations to the same number of significant digits as the previous step. Round off the final energy consumption value to a whole number as follows:

(i) A fractional number at or above the midpoint between the two consecutive whole numbers shall be rounded up to the higher of the two whole numbers; or

(ii) A fractional number below the midpoint between the two consecutive whole numbers shall be rounded down to the lower of the two whole numbers.

(b) The test apparatus and instruction for testing pin-based fluorescent lamps packaged with ceiling fan light kits that have pin-based sockets shall conform to the requirements specified in section 1, "Definitions," and section 3, "Energy Efficiency Specifications for Qualifying Products" of the EPA's "ENERGY STAR Program Requirements for Residential Light Fixtures," Version 4.0, (Incorporated by reference, see §430.22). Record measurements at the resolution of the test instrumentation. Round off calculations to the same number of significant digits as the previous step. The final energy consumption value shall be rounded to a whole number as follows:

(i) A fractional number at or above the midpoint between the two consecutive whole numbers shall be rounded up to the higher of the two whole numbers; or

(ii) A fractional number below the midpoint between the two consecutive whole numbers shall be rounded down to the lower of the two whole numbers.

4. *Test Measurement:*

(a) For screw base compact fluorescent lamps packaged with ceiling fan light kits that have medium screw base sockets, measure the efficacy, expressed in lumens per watt, in accordance with the test requirements specified in section 4, "CFL Requirements for Testing," of the "ENERGY STAR Program Requirements for Compact Fluorescent Lamps," Version 3.0 (Incorporated by reference, see §430.22).

(b) For pin-based compact fluorescent lamps packaged with ceiling fan light kits that have pin-based sockets, measure the efficacy, expressed in lumens per watt, in accordance with the test requirements specified in section 3, "Energy-Efficiency Specifications for Qualifying Products" and Table 3 in section 4, "Qualification Process, Testing Facilities, Standards, and Documentation," of the "ENERGY STAR Program Requirements for Residential Light Fixtures," Version 4.0 (Incorporated by reference, see §430.22).

[71 FR 71366, Dec. 8, 2006]

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10088

20

Date Submitted	02/04/2022	**Section**	405.9	**Proponent**	Bryan Holland
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

This proposed modification adds requirements for energy monitoring to the code.

Rationale

The investment made for the infrastructure of a building in order to comply with the energy code is significant. The assumption that is currently made upon commissioning a facility is that energy efficiency measures will not degrade, or go out of calibration, over time and their energy consumption will not increase as time passes from the time they were commissioned. Such an assumption is completely inaccurate, and any payback assumed for energy efficient infrastructure investments will be lengthened, thereby reducing the ROI and increasing the payback period. The only means to retain the energy performance of a building is to continuously monitor energy consumption levels of various energy consuming systems and compare them to previous levels. Monitoring sub-systems provides key indications when changes have been made or systems are not operating to specification, which increases energy consumption.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposed modification will require the local entity to confirm the design and installation of energy monitoring at time of plan review and inspection.

Impact to building and property owners relative to cost of compliance with code

This proposed modification will increase the cost of compliance with the code but will give the building and property owners the ability to monitor their energy consumption as a means of continuous commissioning of the various systems to ensure ROI and promised energy savings.

Impact to industry relative to the cost of compliance with code

This proposed modification will increase the cost of compliance with the code for industry. Energy monitoring software and hardware are readily available in the marketplace, however these systems do require installers and users to receive specialized training.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposed modification will improve the health and welfare of the general public by improving the effect use of energy and energy conservation.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposed modification improves the code and meets the mandate outlined in F.S. 553.886 that states; "the Florida Building Code must facilitate and promote the use of cost-effective energy conservation, energy-demand management, and renewable energy technologies in buildings.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposed modification does not discriminate against any materials, methods, or systems of constructions.

Does not degrade the effectiveness of the code

This proposed modification improves the effectiveness of the code.

1st Comment Period History

EN10088-G1

Proponent Muthusamy Swami Submitted 4/17/2022 12:58:48 PM Attachments No

Comment:

This proposed code change is going to a new provision for 2023 FBCEC (also new to the 2021 IECC) but the same code exits in ASHRAE 90.1-2019. We have commented in EN1007 (item #1) why we should support this code requirement. FSEC has demonstrated that this proposed code change is cost-effectiveness and determined that the saving to investment ratio (SIR) was 3.44 – 14.01 range. Note that this code change impacts buildings floor size larger than 25,000 square foot. FSEC encourages adoption of this proposed code change.

C405.9 Energy monitoring. New buildings with a gross conditioned floor area of 25,000 square feet (2322 m2) or larger shall be equipped to measure, monitor, record and report energy consumption data in compliance with Sections C405.9.1 through C405.9.5.

Exception: R-2 occupancies and individual tenant spaces are not required to comply with this section provided that the space has its own utility services and meters and has less than 5,000 square feet (464.5 m2) of conditioned floor area.

C405.9.1 Electrical energy metering. For all electrical energy supplied to the building and its associated site, including but not limited to site lighting, parking, recreational facilities and other areas that serve the building and its occupants, meters or other measurement devices shall be provided to collect energy consumption data for each end-use category required by Section C405.9.2.

C405.9.2 End-use metering categories. Meters or other approved measurement devices shall be provided to collect energy use data for each end-use category indicated in Table C405.9.2. Where multiple meters are used to measure any end-use category, the data acquisition system shall total all of the energy used by that category. Not more than 5 percent of the measured load for each of the end-use categories indicated in Table C405.9.2 shall be permitted to be from a load that is not within that category.

Exceptions:

1. HVAC and water heating equipment serving only an individual dwelling unit shall not require end-use metering.

2. End-use metering shall not be required for fire pumps, stairwell pressurization fans or any system that operates only during testing or emergency.

3. End-use metering shall not be required for an individual tenant space having a floor area not greater than 2,500 square feet (232 m2) where a dedicated source meter complying with Section C405.9.3 is provided.

TABLE C405.9.2

ENERGY USE CATEGORIES

LOAD CATEGORY	DESCRIPTION OF ENERGY USE
Total HVAC System	Heating, cooling, and ventilation, including but not limited to fans, pumps, boilers, chillers and water heating. Energy used by 120-volt equipment, or by 208/120-volt equipment that is located in a building where the main service is 480/277-volt power, is permitted to be excluded from the total HVAC system energy use.
Interior lighting	Lighting systems located within the building
Exterior lighting	Lighting systems located on the building site but not within the building.
Plug loads	Devices, appliances, and equipment connected to convenience receptacle outlets.
Process loads	Any single load that is not included in an HVAC, lighting or plug load category and that exceed 5 percent of the peak connected load of the whole building , including but not limited to data centers, manufacturing equipment and commercial kitchens.
Building operations and other miscellaneous loads	The remaining loads not included elsewhere in this table, including but not limited to vertical transportation systems, ornamental fountains, ornamental fireplaces, swimming pools, in-ground spas and snow-melt systems.

C405.9.3 Meters. Meters or other measurement devices required by this section shall be configured to automatically communicate energy consumption data to the data acquisition system required by Section C405.9.4. Source meters shall be allowed to be any digital-type meter. Lighting, HVAC or other building systems that can monitor their energy consumption shall be permitted instead of meters. Current sensors shall be permitted, provided that they have a tested accuracy of ±2 percent. Required metering systems and equipment shall have the capability to provide at least hourly data that is fully integrated into the data acquisition system and graphical energy report in accordance with Sections C405.9.4 and C405.9.5.

C405.9.4 Data acquisition system. A data acquisition system shall have the capability to store the data from the required meters and other sensing devices for a minimum of 36 months. The data acquisition system shall have the capability to store real-time energy consumption data and provide hourly, daily, monthly and yearly logged data for each end-use category required by Section C405.9.2.

C405.9.5 Graphical energy report. A permanent and readily accessible reporting mechanism shall be provided in the building that is accessible by building operation and management personnel. The reporting mechanism shall have the capability to graphically provide the energy consumption for each end-use category required by Section C405.9.2 at least every hour, day, month and year for the previous 36 months.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

21

EN10089

Date Submitted	02/04/2022	**Section**	406	**Proponent**	Bryan Holland
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

This proposed modification adds two additional efficiency package options and will now require two of the seven options to be selected for compliance.

Rationale

To help improve energy conservation of commercial buildings, this proposal will require a second efficiency package to be selected from the list of options. This essentially doubles the energy efficiency impact of Section C406. Additionally, two new options have been added to allow the installation of energy monitoring and/or FDD in a building not required by C405.9 and C403.2.15, respectfully, to count towards the additional efficiency package requirement. These two options reward the building owner for installation of energy conservation systems not required by the code.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposed modification will require the local entity to confirm a second efficiency package has been designed and installed at time of plan review and inspection.

Impact to building and property owners relative to cost of compliance with code

This proposed modification will increase the cost of compliance with the code but will result immediate energy savings to the building and property owners.

Impact to industry relative to the cost of compliance with code

This proposed modification will increase the cost of compliance with the code for industry by requiring a second efficiency package to be designed and installed.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposed modification will improve the health and welfare of the general public by essentially doubling the energy efficiency impact of C406.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposed modification improves the code and meets the mandate outlined in F.S. 553.886 that states; "the Florida Building Code must facilitate and promote the use of cost-effective energy conservation, energy-demand management, and renewable energy technologies in buildings.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposed modification does not discriminate against any materials, methods, or systems of constructions.

Does not degrade the effectiveness of the code

This proposed modification improves the effectiveness of the code.

1st Comment Period History

EN10089-G1

Proponent	Muthusamy Swami	Submitted	4/17/2022 1:00:50 PM	Attachments	No

Comment:

The proposed code change provides design flexibility. However, one cannot have these options available unless code change EN9993 (item#2) and EN10088 (item #6) are adopted. FSEC encourages adoption of proposed code changes: EN9993, EN10088, and EN10089.

C406.1 Requirements.

Buildings shall comply with at least ~~one~~ two of the following:

1. More efficient HVAC performance in accordance with Section C406.2.

2. Reduced lighting power density system in accordance with Section C406.3.

3. Enhanced lighting controls in accordance with Section C406.4.

4. On-site supply of renewable energy in accordance with Section C406.5.

5. Provision of a dedicated outdoor air system for certain HVAC equipment in accordance with Section C406.6.

6. High-efficiency service water heating in accordance with Section C406.7.

7. Where not required by Section C405.9, include an energy monitoring system in accordance with Section C405.9.

10. Where not required by Section C403.2.15 include a fault detection and diagnostics (FDD) system in accordance with Section C403.2.15

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10112

22

Date Submitted	02/08/2022	**Section**	403.2	**Proponent**	Abbott Mikah
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

EC R403.7.1.1 NEW Associating Residential Cooling Equipment Sizing Practices with [CE] C403.2.1

Summary of Modification

This modification clarifies [CE] C403.2.2. Previous section CE 403.2.2 does not include reference to the characterization of “Living Spaces” in commercial settings. Update language of [CE] C403.2.2 to “shall comply with R403.7.1.1” listed as Exception 3.

Rationale

In the existing code's current language, there is no mathematical clarification (% of BTUH Load) for under sizing of cooling equipment in "living spaces" for commercial buildings. There only exists limitations on oversizing of cooling equipment. Buidling Departments need mathematical clarification in the code that allows them to regulate the under sizing of cooling equipment. By associating the residential cooling equipment sizing practices to "living spaces" in commercial buildings, designers will be required to size the mechanical equipment such that it is "not less than the calculated total load but not more than 1.15 times greater than the total load calculated in Section 403.7". All Exceptions found in R403.7.1.1 shall be applied in this manner as well.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No additional work is required from building department. This proposed code modification will allow building officials to enforce mathematically, the proper sizing of cooling equipment associated with "living spaces" in commercial buildings.

Impact to building and property owners relative to cost of compliance with code

There will be no impact on the cost to building and property owners to install PROPERLY sized equipment.

Impact to industry relative to the cost of compliance with code

There will be no impact on the cost of compliance to industry.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Proper sizing ensures that the installed cooling systems have the ability to effectively remove humidity from these "living spaces". This helps mitigate the opportunity for mold activity to encroach in the space.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposed modification adds clarity to a prior applicable lack of definition in cooling system sizing for "living spaces" in commercial buildings. It delineates between livable and tenable spaces within commercial applications.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposal does not discriminate against any of the listed items.

Does not degrade the effectiveness of the code

This proposed modification does not degrade the effectiveness of the code. It adds clarity to a previously non delineated section of commercial spaces.

1st Comment Period History

EN10112-G1

Proponent	Timothy de Carion	Submitted	3/7/2022 2:03:13 PM	Attachments	No

Comment:

I agree with this code modification. The code must address undersizing equipment also.

C403.2.2 Equipment Sizing

The output capacity of heating and cooling equipment shall be not greater than the loads calculated in accordance with Section C403.2.1. A single piece of equipment providing both heating and cooling shall satisfy this provision for one function with the capacity for the other function as small as possible, within available equipment options.

Exceptions:

1. Required standby equipment and systems provided with controls and devices that allow such systems or equipment to operate automatically only when the primary equipment is not operating.

2. Multiple units of the same equipment type with combined capacities exceeding the design load and provided with controls that have the capability to sequence the operation of each unit based on load.

3. "Living Spaces" in Commercial Buildings shall be sized in accordance with R403.7.1.1 and its exceptions.

Pompano Beach Building Department Case Study Summary of Ruling

In this case study, the heat load BTUH's calculation provided showed a requirement of 28,800 BTUH's, while the provided equipment selection showed a capacity of 24,000 BTUH's. This heat load and equipment selection was brought to the Broward County Board of Rules & Appeals. The ruling concluded that the designer **did** follow the code in C403.2.1 because the equipment BTUH's available are "not greater than" the loads calculated. This ruling was set due to the lack of clarity defining how low the design professional can go when selecting the equipment.

The problem remains that the unit by current definition satisfies the code requirements, but in reality will struggle to remove the humidity from the space. This, in turn, could potentially lead to a "sick building" in the form of mold development due to the lack of proper moisture removal capacity.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10123

23

Date Submitted	02/15/2022	**Section**	408.2.1	**Proponent**	Douglas Baggett
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

10251 10245 10445

Summary of Modification

This proposed modification will serve to keep requirements and verbiage consistent with proposed modifications 10245, 10251 and 10445

Rationale

It is important to keep verbiage and requirements consistent throughout the energy codes in order to prevent confusion and misunderstanding.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

There will be no impact - this would just be a verbiage and clarification modification

Impact to building and property owners relative to cost of compliance with code

There will be no impact - this would just be a verbiage and clarification modification

Impact to industry relative to the cost of compliance with code

There will be no impact - this would just be a verbiage and clarification modification

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The health, safety and welfare of the general public will be by ensuring the building codes are consistent and by ensuring properly trained and certified individuals commission the mechanical systems

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposed modification will improve the code by allowing for clear and consistent requirements for commissioning systems

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposed modification does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not degrade the effectiveness of the code

This proposed modification does not degrade the effectiveness of the code, it enhances it.

408.2.1. Commissioning Plan. A commissioning plan shall be developed by a certified third-party commissioning agent that meet the requirements set forth in C104.4.1 ~~licensed design professional, electrical engineer, mechanical engineer or approved agency~~ and shall include the following items:

1. A narrative description of the activities that will be accomplished during each phase of commissioning, including the personnel intended to accomplish each of the activities.
2. A listing of the specific equipment, appliances or systems to be tested and a description of the tests to be performed.
3. Functions to be tested including, but not limited to, calibrations and economizer controls.
4. Conditions under which the test will be performed. Testing shall affirm winter and summer design conditions and full outside air conditions.
5. Measurable criteria for performance.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10212

24

Date Submitted	02/11/2022	**Section**	403.2.3	**Proponent**	Bereket Nigusse
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Editorial changes to Table C403.2.3(5) Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers

Rationale

Updates footnotes and adds text to table C403.2.3(5) for clarification. If adapted this modification adds clarity to the residential application of boilers and makes it consistent with that of the 2019 ASHRAE Standard 90.1.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The proposed modification will not impact the local entity relative to code enforcement.

Impact to building and property owners relative to cost of compliance with code

The proposed modification will not impact the building and property owners cost.

Impact to industry relative to the cost of compliance with code

The proposed modification will not change the cost of compliance.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The proposed modification does not impact the health, safety, and welfare of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The proposed modification improves and strengthens the code by clarifying the section on enforcement.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The proposed modification does not discriminate against materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

The proposed modification enhances the effectiveness of code by adding clarifications.

See attached documents for the updated table C403.2.3(5).

TABLE C403.2.3(5)
MINIMUM EFFICIENCY REQUIREMENTS: GAS- AND OIL-FIRED BOILERS

EQUIPMENT TYPE[a]	SUBCATEGORY ORRATING CONDITION	SIZE CATEGORY (INPUT)	MINIMUM EFFICIENCY[d, eg, f]	TEST PROCEDURE
Boilers, hot water	Gas-fired	< 300,000 Btu/h[f, gg, h] US Residential Application	84% AFUE	10 CFR Part 430
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[bc]	80% E_t	10 CFR Part 431
		> 2,500,000 Btu/h[eb]	82% E_c	
	Oil-fired[ed]	< 300,000 Btu/h[gg, h] US Residential Application	86% AFUE	10 CFR Part 430
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[bc]	82% E_t	10 CFR Part 431
		> 2,500,000 Btu/h[eb]	84% E_c	
Boilers, steam	Gas-fired	< 300,000 Btu/h[fg] US Residential Application	82% AFUE	10 CFR Part 430
	Gas-fired—all, except natural draft	≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[bc]	79% E_t	10 CFR Part 431
		> 2,500,000 Btu/h[eb]	79% E_t	
	Gas-fired—natural draft	≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[bc]	77% E_t 79% E_t effective March 2, 2022	
		> 2,500,000 Btu/h[eb]	77% E_t 79% E_t effective March 2, 2022	
	Oil-fired[ed]	< 300,000 Btu/h[g] US Residential Application	85% AFUE	10 CFR Part 430
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[bc]	81% E_t	10 CFR Part 431
		> 2,500,000 Btu/h[eb]	81% E_t	

For SI: 1 British thermal unit per hour = 0.2931 W.

a. Chapter 6 contains a complete specification of the referenced standards, which include test procedure, including the reference year version of the test procedure.

b. These requirements apply to boilers with rated input of 8,000,000 Btu/h or less that are not packaged boilers and to all packaged boilers. Minimum efficiency requirements for boilers cover all capacities of packaged boilers.

c. Maximum capacity – minimum and maximum ratings as provided for and allowed by the unit's controls.

d. Includes oil-fired (residual).

e. E_c = Combustion efficiency (100 percent less flue losses).

f. E_t = Thermal efficiency. See referenced standard for detailed information.

g. Boilers shall not be equipped with a constant burning ignition pilot.

h. A boiler not equipped with a tankless domestic water heating coil shall be equipped with an automatic means for adjusting the temperature of the water such that an incremental change in inferred heat load produces a corresponding incremental change in the temperature of the water supplied.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10213

25

Date Submitted	02/11/2022	**Section**	403.2.3	**Proponent**	Bereket Nigusse
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Updates Table C403.2.3(1) Minimum Efficiency Requirements: Electrically Operated Unitary Air Conditioners and Condensing Units

Rationale

The proposed modification updates minimum efficiency requirements of Unitary Air Conditioners and Condensing Units based on federal minimum standards. If adapted this change makes the 2023 FBC-Energy Conservation minimum efficiency requirements of unitary air conditioners and condensing units consistent with that of the 2019 ASHRAE Standard 90.1.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The proposed modification will not impact the local entity relative to code enforcement.

Impact to building and property owners relative to cost of compliance with code

The proposed modification may slightly impact the building and property owners cost.

Impact to industry relative to the cost of compliance with code

The proposed modification will not change the cost of compliance.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The proposed modification does not impact the health, safety, and welfare of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The proposed modification improves and strengthens the code by providing efficient unitary air conditioners and condensing units.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The proposed modification does not discriminate against materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

The proposed modification enhances the effectiveness of code enforcement due to added clarifications.

See attached documents for the updated table C403.2.3(1).

TABLE C403.2.3(1)
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS[c]

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
Air conditioners, air cooled	< ~~6~~45,000 Btu/h[b]	All	Split System, three phase and applications outside US single phase[b]	14.0 SEER before 1/1/2023 14.3 SEER2 after 1/1/2023	AHRI 210/240 – 2017 before 1/1/2023 AHRI 210/240 – 2023 after 1/1/2023
	≥ 45,000 Btu/h[b] and < 65,000 Btu/h[b]			14.0 SEER before 1/1/2023 13.8 SEER2 after 1/1/2023	
	< 65,000 Btu/h[b]		Single Package, three phase and applications outside US single phase[b]	14.0 SEER[c] before 1/1/2023 13.4 SEER2 after 1/1/2023	
Through-the-wall (air cooled)	≤ 30,000 Btu/h[b]	All	Split system, three phase and applications outside US single phase[b]	12.0 SEER before 1/1/2023 11.7 SEER2 after 1/1/2023	
			Single Package, three phase and applications outside US single phase[b]	12.0 SEER before 1/1/2023 11.7 SEER2 after 1/1/2023	
Small-duct high-velocity(air cooled)	< 65,000 Btu/h[b]	All	Split system, three phase and applications outside US single phase[b]	12.0 SEER before 1/1/2023 12.0 SEER2 after 1/1/2023	
Air conditioners, air cooled	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.2 EER 12.9 IEER before 1/1/2023 14.8 IEER after 1/1/2023	AHRI 340/360
		All other	Split System and Single Package	11.0 EER 12.7 IEER before 1/1/2023 14.6 IEER after 1/1/2023	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 12.4 IEER before 1/1/2023 14.2 IEER after 1/1/2023	
		All other	Split System and Single Package	10.8 EER 12.2 IEER before 1/1/2023 14.0 IEER after 1/1/2023	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 11.6 IEER before 1/1/2023 13.2 IEER after 1/1/2023	
		All other	Split System and Single Package	9.8 EER 11.4 IEER before 1/1/2023 13.0 IEER after 1/1/2023	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER 11.2 IEER before 1/1/2023 12.5 IEER after 1/1/2023	

		All other	Split System andSingle Package	9.5 EER 11.0 IEER before 1/1/2023 12.3 IEER after 1/1/2023	

(continued)

TABLE C403.2.3(1)—continued
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS[c]

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUB-CATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
Air conditioners, water cooled	< 65,000 Btu/h[b]	All	Split System and Single Package	12.1 EER 12.3 IEER	AHRI 210/240
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.1 EER 13.9 IEER	AHRI 340/360
		All other	Split System and Single Package	11.9 EER 13.7 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.5 EER 13.9 IEER	
		All other	Split System and Single Package	12.3 EER 13.7 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.4 EER 13.6 IEER	
		All other	Split System and Single Package	12.2 EER 13.4 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.2 EER 13.5 IEER	
		All other	Split System and Single Package	12.0 EER 13.3 IEER	
Air conditioners, evaporatively cooled	< 65,000 Btu/h[b]	All	Split System and Single Package	12.1 EER 12.3 IEER	AHRI 210/240
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.1 EER 12.3 IEER	AHRI 340/360
		All other	Split System and Single Package	11.9 EER 12.1 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.0 EER 12.2 IEER	
		All other	Split System and Single Package	11.8 EER 12.0 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.9 EER 12.1 IEER	
		All other	Split System and Single Package	11.7 EER 11.9 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.7 EER 11.9 IEER	
		All other	Split System and Single Package	11.5 EER 11.7 IEER	
Condensing units, air cooled	≥ 135,000 Btu/h			10.5 EER 11.8 IEER	AHRI 340/360
Condensing units, water cooled	≥ 135,000 Btu/h			13.5 EER 14.0 IEER	
Condensing units, evaporatively cooled	≥ 135,000 Btu/h			13.5 EER 14.0 IEER	

For SI: 1 British thermal unit per hour = 0.2931 W.

a. Chapter 6 contains a complete specification of the referenced standards, which include test procedure, including the reference year version of the test procedure.

b. Single-phase, US air-cooled air conditioners less than 65,000 Btu/h are regulated ~~by NAECA~~as consumer products by the US Department of Energy Code of Federal Regulations DOE 10 CFR 430. SEER and SEER2 values for single-phase products are set by the US Department of Energy~~SEER values are those set by NAECA.~~

c. DOE 10 CFR 430 Subpart B Appendix M1 includes the test procedure updates effective 1/1/2023 that will be incorporated in AHRI 210/240 – 2023.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10214

26

Date Submitted	02/11/2022	**Section**	403.2.3	**Proponent**	Bereket Nigusse
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Updates Table C403.2.3(2) Minimum Efficiency Requirements: Electrically Operated Unitary and Applied Heat Pump.

Rationale

The proposed modification updates minimum efficiency requirements of electrically operated unitary and applied heat pumps based on federal minimum standards. If adapted this change makes the 2023 FBC-Energy Conservation heat pumps minimum efficiency requirement consistent with that of the 2019 ASHRAE Standard 90.1.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The proposed modification will not impact the local entity relative to code enforcement.

Impact to building and property owners relative to cost of compliance with code

The proposed modification may slightly impact the building and property owners cost.

Impact to industry relative to the cost of compliance with code

The proposed modification will not change the cost of compliance.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The proposed modification does not impact the health, safety, and welfare of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The proposed modification improves and strengthens the code by specifying efficient products.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The proposed modification does not discriminate against materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

The proposed modification enhances the effectiveness of code by adding clarifications based on product capacity and applicability. Moves the water-source heat pumps to new Table C403.2.3(16) for clarity.

See attached documents for the updated table C403.2.3(2). The modification deleted and moved water-source heat pumps to a new table C403.2.3(16).

TABLE C403.2.3(2)
MINIMUM EFFICIENCY REQUIREMENTS: ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS~~[c, d]~~

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
Air cooled (cooling mode)	< 65,000 Btu/h[b]	All	Split System, three phase and applications outside US single phase[b]	14.0 SEER before 1/1/2023 14.3 SEER2 after 1/1/2023	~~AHRI 210/240~~ AHRI 210/240 – 2017 before 1/1/2023 AHRI 210/240 – 2023 after 1/1/2023
			Single Package, three phase and applications outside US single phase[b]	14.0 SEER before 1/1/2023 13.4 SEER2 after 1/1/2023	
Through-the-wall, air cooled	≤ 30,000 Btu/h[b]	All	Split System, three phase and applications outside US single phase[b]	12.0 SEER before 1/1/2023 11.9 SEER2 after 1/1/2023	
			Single Package, three phase and applications outside US single phase[b]	12.0 SEER before 1/1/2023 11.9 SEER2 after 1/1/2023	
Single-duct high-velocity air cooled	< 65,000 Btu/h[b]	All	Split System, three phase and applications outside US single phase[b]	12.0 SEER before 1/1/2023 12.0 SEER2 after 1/1/2023	
Air cooled (cooling mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 12.2~~0~~ IEER before 1/1/2023 14.1 IEER after 1/1/2023	AHRI 340/360
		All other		10.8 EER 12.0~~11.8~~ IEER before 1/1/2023 13.9 IEER after 1/1/2023	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)		10.6 EER 11.6 IEER before 1/1/2023 13.5 IEER after 1/1/2023	
		All other		10.4 EER 11.4 IEER before 1/1/2023 13.3 IEER after 1/1/2023	
	≥ 240,000 Btu/h	Electric Resistance (or None)		9.5 EER 10.6 IEER before 1/1/2023 12.5 IEER after 1/1/2023	
		All other		9.3 EER 10.4 IEER before 1/1/2023 12.3 IEER after 1/1/2023	

(continued)

TABLE C403.2.3(2) —continued
MINIMUM EFFICIENCY REQUIREMENTS: ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE*
Water to Air: Water Loop(cooling mode)	< 17,000 Btu/h	All	86°F entering water	12.2 EER	ISO 13256-1
	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86°F entering water	13.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86°F entering water	13.0 EER	
Water to Air: Ground Water (cooling mode)	< 135,000 Btu/h	All	59°F entering water	18.0 EER	ISO 13256-1
Brine to Air: Ground Loop(cooling mode)	< 135,000 Btu/h	All	77°F entering water	14.1 EER	ISO 13256-1
Water to Water: Water Loop(cooling mode)	< 135,000 Btu/h	All	86°F entering water	10.6 EER	ISO 13256-2
Water to Water: Ground Water (cooling mode)	< 135,000 Btu/h	All	59°F entering water	16.3 EER	
Brine to Water: Ground Loop (cooling mode)	< 135,000 Btu/h	All	77°F entering fluid	12.1 EER	

TABLE C403.2.3(2)—continued
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS[c, d]

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
Air cooled (heating mode)	< 65,000 Btu/h[b]	—	Split System, three phase and applications outside US single phase[b]	8.2 HSPF before 1/1/2023 7.5 HSPF2 after 1/1/2023	~~AHRI 210/240~~ AHRI 210/240 – 2017 before 1/1/2023 AHRI 210/240 – 2023 after 1/1/2023
		—	Single Package, three phase and applications outside US single phase[b]	8.0 HSPF before 1/1/2023 6.7 HSPF2 after 1/1/2023	
Through-the-wall, (air cooled, heating mode)	≤ 30,000 Btu/h[b] (cooling capacity)	—	Split System, three phase and applications outside US single phase[b]	7.4 HSPF before 1/1/2023 6.3 HSPF2 after 1/1/2023	
		—	Single Package, three phase and applications outside US single phase[b]	7.4 HSPF before 1/1/2023 6.3 HSPF2 after 1/1/2023	
Small-duct high velocity (air cooled, heating mode)	< 65,000 Btu/h[b]	—	Split System, three phase and applications outside US single phase[b]	7.2 HSPF before 1/1/2023 6.1 HSPF2 after 1/1/2023	
Air cooled (heating mode)	≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity)	—	47°F db/43°F wb outdoor air	3.3 COP_H before 1/1/2023 3.4 COP_H after 1/1/2023	AHRI 340/360
			17°F db/15°F wb outdoor air	2.25 COP	
	≥ 135,000 Btu/h and < 240,000 Btu/h (cooling capacity)	—	47°F db/43°F wb outdoor air	3.2 COP_H before 1/1/2023 3.3 COP_H after 1/1/2023	
			17°F db/15°F wb outdoor air	2.05 COP_H	
	≥ 240,000 Btu/h (cooling capacity)	—	47°F db/43°F wb outdoor air	3.2 COP_H	
			17°F db/15°F wb outdoor air	2.05 COP_H	
~~Water to Air: Water Loop(heating mode)~~	~~< 135,000 Btu/h (cooling capacity)~~	—	~~68°F entering water~~	~~4.3 COP_H~~	~~ISO 13256-1~~
~~Water to Air: Ground Water(heating mode)~~	~~< 135,000 Btu/h (cooling capacity)~~	—	~~50°F entering water~~	~~3.7 COP_H~~	
~~Brine to Air: Ground Loop(heating mode)~~	~~< 135,000 Btu/h (cooling capacity)~~	—	~~32°F entering fluid~~	~~3.2 COP~~	
~~Water to Water: Water Loop(heating mode)~~	~~< 135,000 Btu/h (cooling capacity)~~	—	~~68°F entering water~~	~~3.7 COP~~	~~ISO 13256-2~~
~~Water to Water: Ground Water(heating mode)~~	~~< 135,000 Btu/h (cooling capacity)~~	—	~~50°F entering water~~	~~3.1 COP~~	
~~Brine to Water: Ground Loop(heating mode)~~	~~< 135,000 Btu/h (cooling capacity)~~	—	~~32°F entering fluid~~	~~2.5 COP~~	

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8.

a. Chapter 6 contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.

b. Single-phase, US air-cooled air conditioners less than 65,000 Btu/h are regulated ~~by NAECA~~as consumer products by the US Department of Energy Code of Federal Regulations DOE 10 CFR 430. SEER and SEER2 values for single-phase products are set by the US Department of Energy. ~~SEER values are those set by NAECA.~~

c. DOE 10 CFR 430 Subpart B Appendix M1 includes the test procedure updates effective 1/1/2023 that will be incorporated in AHRI 210/240 – 2023.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

27

EN10216

Date Submitted	02/11/2022	**Section**	403.2.3	**Proponent**	Bereket Nigusse
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Updates Table C403.2.3(3) Minimum Efficiency Requirements: Electrically Operated PTACs, PTHPs, Single-Package Vertical Air-Conditioners, Single-Package Vertical Heat Pumps, Room Air Conditioners and Room Air-Conditioners and Room Air-Conditioners Heat Pumps.

Rationale

The proposed modification updates minimum efficiency requirements for electrically operated PTACs, PTHPs, SPVACs, SPVHPs, Room ACs and Room HPs based on federal minimum standards (CFR 431.97). If adapted this modification makes the 2023 FBC-Energy Conservation minimum efficiency requirements consistent with that of the 2019 ASHRAE Standard 90.1.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The proposed modification will not impact the local entity relative to code enforcement.

Impact to building and property owners relative to cost of compliance with code

The proposed modification may slightly impact the building and property owners cost.

Impact to industry relative to the cost of compliance with code

The proposed modification will not change the cost of compliance.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The proposed modification does not impact the health, safety, and welfare of the general public

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The proposed modification improves and strengthens the code by specifying energy efficient products.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The proposed modification does not discriminate against materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

The proposed modification enhances the effectiveness of code enforcement by adding clarifications.

See attached documents for the updated table C403.2.3(3).

TABLE C403.2.3(3)
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED PACKAGED TERMINAL AIR CONDITIONERS, PACKAGED TERMINAL HEAT PUMPS, SINGLE-PACKAGE VERTICAL AIR CONDITIONERS, SINGLE-PACKAGE VERTICAL HEAT PUMPS, ROOM AIR CONDITIONERS AND ROOM AIR-CONDITIONER HEAT PUMPS

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY[d]	TEST PROCEDURE[a]
PTAC (cooling mode) ~~new construction~~ standard size	~~All Capacities~~ <7,000 Btu/h	95°F db/ 75°F wb outdoor air	11.9 EER	AHRI 310/380
	≥7,000 Btu/h and ≤15,000 Btu/h		14.0 – (0.300 × Cap/1000) EER	
	>15,000 Btu/h		9.5 EER	
PTAC (cooling mode) ~~replacements[b]~~ nonstandard size[b]	~~All Capacities~~ <7,000 Btu/h	95°F db/ 75°F wb outdoor air	9.4 EER	
	≥7,000 Btu/h and ≤15,000 Btu/h		10.9 - (0.213 × Cap/1000) EER	
	>15,000 Btu/h		7.7 EER	
PTHP (cooling mode) ~~new construction~~ standard size	~~All Capacities~~ <7,000 Btu/h	95°F db/ 75°F wb outdoor air	11.9 EER	
	≥7,000 Btu/h and ≤15,000 Btu/h		14.0 - (0.300 × Cap/1000) EER	
	>15,000 Btu/h		9.5 EER	
PTHP (cooling mode) ~~replacements[b]~~ nonstandard size[b]	~~All Capacities~~ <7,000 Btu/h	95°F db/ 75°F wb outdoor air	9.3 EER	
	≥7,000 Btu/h and ≤15,000 Btu/h		10.8 - (0.213 × Cap/1000) EER	
	>15,000 Btu/h		7.6 EER	
PTHP (heating mode) ~~new construction~~ standard size	~~All Capacities~~ <7,000 Btu/h	95°F db/ 75°F wb outdoor air—	3.3 COP_H	
	≥7,000 Btu/h and ≤15,000 Btu/h		3.7 - (0.052 × Cap/1000) COP_H	
	>15,000 Btu/h		2.9 COP_H	
PTHP (heating mode) ~~replacements~~ Nonstandard size[b]	~~All Capacities~~ <7,000 Btu/h	95°F db/ 75°F wb outdoor air—	2.7 COP_H	
	≥7,000 Btu/h and ≤15,000 Btu/h		2.9 - (0.026 × Cap/1000) COP_H	
	>15,000 Btu/h		2.5 COP_H	
SPVAC (cooling mode)	< 65,000 Btu/h	95°F db/ 75°F wb outdoor air	11.0 EER	AHRI 390
	≥ 65,000 Btu/h and < 135,000 Btu/h	95°F db/ 75°F wb outdoor air	10.0 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	95°F db/ 75°F wb outdoor air	10.0 EER	
SPVHP (cooling mode)	< 65,000 Btu/h	95°F db/ 75°F wb outdoor air	11.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	95°F db/ 75°F wb outdoor air	10.0 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	95°F db/ 75°F wb outdoor air	10.0 EER	
SPVHP (heating mode)	< 65,000 Btu/h	47°F db/ 43°F wb outdoor air	3.3 COP_H	AHRI 390
	≥ 65,000 Btu/h and < 135,000 Btu/h	47°F db/ 43°F wb outdoor air	3.0 COP_H	
	≥ 135,000 Btu/h and < 240,000 Btu/h	47°F db/ 75°F wb outdoor air	3.0 COP_H	

(continued)

TABLE C403.2.3(3)—continued
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED PACKAGED TERMINAL AIR CONDITIONERS,
PACKAGED TERMINAL HEAT PUMPS, SINGLE-PACKAGE VERTICAL AIR CONDITIONERS,
SINGLE-PACKAGE VERTICAL HEAT PUMPS, ROOM AIR CONDITIONERS AND ROOM AIR-CONDITIONER HEAT PUMPS

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY ORRATING CONDITION	MINIMUM EFFICIENCY[d]	TEST PROCEDURE[a]
Room air conditioners without reverse cycles, with louvered sides for applications outside US	< 6,000 Btu/h	—	11.0 CEER	ANSI/AHAM RAC-1
	≥ 6,000 Btu/h and < 8,000 Btu/h	—	11.0 CEER	
	≥ 8,000 Btu/h and < 14,000 Btu/h	—	10.9 CEER	
	≥ 14,000 Btu/h and < 20,000 Btu/h	—	10.7 CEER	
	≥ 20,000 Btu/h and < 2528,000 Btu/h	—	9.4 CEER	
	≥ 2528,000 Btu/h	—	9.0 CEER	
Room air conditioners, without louvered sides	< 6,000 Btu/h	—	10.0 CEER	ANSI/AHAM RAC-1
	≥ 6,000 Btu/h and < 8,000 Btu/h	—	10.0 CEER	
	≥ 8,000 Btu/h and < 11,000 Btu/h	—	9.6 CEER	
	≥ 11,000 Btu/h and < 14,000 Btu/h	—	9.5 CEER	
	≥ 14,000 Btu/h and < 20,000 Btu/h	—	9.3 CEER	
	≥ 20,000 Btu/h	—	9.4 CEER	
Room air-conditioner with reverse cycleheat pumps withlouvered sides for applications outside US	< 20,000 Btu/h	—	9.8 CEER	ANSI/ AHAM RAC-1
	≥ 20,000 Btu/h	—	9.3 CEER	
Room air-conditioner heat pumps without louvered sides for applications outside US	< 14,000 Btu/h	—	9.3 CEER	
	≥ 14,000 Btu/h	—	8.7 CEER	
Room air conditioner casement only for applications outside US	All capacities	—	9.5 CEER	ANSI/ AHAM RAC-1
Room air conditioner casement-slider for applications outside US	All capacities	—	10.4 CEER	

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8, wb = wet bulb, db = dry bulb.

"Cap" = The rated cooling capacity of the project in Btu/h. Where the unit's capacity is less than 7,000 Btu/h, use 7,000 Btu/h in the calculation. Where the unit's capacity is greater than 15,000 Btu/h, use 15,000 Btu/h in the calculations.

a. Chapter 6 contains a complete specification of the referenced, which includes test procedures, including the referenceed year version of the test procedure.

b. Replacement Nonstandard size unit shallmust be factory labeled as follows: "MANUFACTURED FOR REPLACEMENTNONSTANDARD APPLICATIONS ONLY: NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS." ReplacementNonstandard size efficiencies apply only to units with existing sleeves having an external wall opening of less than 16 inches (406 mm) highin height and or less than 42 inches (1067 mm) widein width and less than 670 square inches (0.43 m²).

c. The cooling-mode wet bulb temperature requirement only applies for units that reject condensate to the condenser coil.

d. "Cap" in EER and COP_H equations for PTACs and PTHPs means cooling capacity in Btu/h at 95°F outdoor dry-bulb temperature.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10218

28

Date Submitted	02/11/2022	**Section**	403.2.3	**Proponent**	Bereket Nigusse
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Updates Table C403.2.3(4) Warm Air Furnaces and Combination Warm Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces and Unit Heaters, Minimum Efficiency Requirements

Rationale

The proposed modification updates table C403.2.3(4) minimum efficiency requirements of warm-air furnaces based on federal minimum standards. If adapted this modification makes the 2023 FBC-Energy Conservation minimum efficiency requirement of warm-air furnaces consistent with that of the 2019 ASHRAE Standard 90.1.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The proposed modification will not impact the local entity relative to code enforcement.

Impact to building and property owners relative to cost of compliance with code

The proposed modification may slightly impact the building and property owners cost.

Impact to industry relative to the cost of compliance with code

The proposed modification will not change the cost of compliance.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The proposed modification does not impact the health, safety, and welfare of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The proposed modification improves and strengthens the code by specifying energy efficient warm-air furnaces.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The proposed modification does not discriminate against materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

The proposed modification enhances the effectiveness of code enforcement by adding application details and footnotes for clarification.

See attached documents for the updated table C403.2.3(4).

TABLE 403.2.3(4)
WARM AIR FURNACES AND COMBINATION WARM AIR FURNACES/AIR-CONDITIONING UNITS, WARM-AIR DUCT FURNACES AND UNIT HEATERS, MINIMUM EFFICIENCY REQUIREMENTS

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY[d, e]	TEST PROCEDURE[a]
Warm air furnaces, gas fired Non-weatherized	< 225,000 Btu/h	—	80% AFUE or 80% E_t[c] 81% AFUE	DOE 10 CFR, Part 430 or Section 2.39, Thermal Efficiency of ANSI Z 21.47
Weatherized gas furnace	≥ 225,000 Btu/h	Maximum capacity[c]	80% E_t[f]	Section 2.39, Thermal Efficiency of ANSI Z21.47
Warm air furnaces, oil fired Non-weatherized Weatherized oil fired furnace	< 225,000 Btu/h	—	83% AFUE or 80% E_t[c] 78% AFUE	DOE 10 CFR, Part 430 or Section 42, Combustion, of UL 727
	≥ 225,000 Btu/h	Maximum capacity[b]	81% E_t[g]	Section 42, Combustion, of UL 727
Warm air duct furnaces, gas fired	All capacities	Maximum capacity[b]	80% E_c	Section 2.10, Efficiency of ANSI Z83.8
Warm air unit heaters, gas fired	All capacities	Maximum capacity[b]	80% E_c	Section 2.10, Efficiency of ANSI Z83.8
Warm air unit heaters, oil fired	All capacities	Maximum capacity[b]	80% E_c	Section 40, Combustion, of UL 731
Mobile home furnace, gas fired	< 225,000 Btu/h	—	80% AFUE	DOE 10 CFR, Part 430
Mobile home furnace, oil fired	< 225,000 Btu/h	—	75% AFUE	DOE 10 CFR, Part 430

For SI: 1 British thermal unit per hour = 0.2931 W.

a. Chapter 6, Referenced Standards, contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

b. Minimum and maximum ratings as provided for and allowed by the unit's controls.

c. Combination units not covered by the National Appliance Energy Conservation Act of 1987 (NAECA) (3-phase power or cooling capacity greater than or equal to 65,000 Btu/h [19 kW]) shall comply with either rating.

d. E_t = Thermal efficiency. See test procedure for detailed discussion.

e. E_c = Combustion efficiency (100% less flue losses). See test procedure for detailed discussion.

f. E_c = Combustion efficiency. Units shall also include an IID, have jackets not exceeding 0.75 percent of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.

g. E_t = Thermal efficiency. Units shall also include an IID, have jacket losses not exceeding 0.75 percent of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.

TABLE 403.2.3(4)
WARM AIR FURNACES AND COMBINATION WARM AIR FURNACES/AIR-CONDITIONING UNITS, WARM-AIR DUCT FURNACES AND UNIT HEATERS, MINIMUM EFFICIENCY REQUIREMENTS

EQUIPMENT TYPE	SIZE CATEGORY(INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
Warm air furnaces, gas fired for US Residential Application	< 225,000 Btu/h	Nonweatherized excluding mobile home	80% AFUE	DOE 10 CFR, Part 430 Appendix N
		Nonweatherized excluding mobile home	80% AFUE	
		Weatherized	81% AFUE	
Warm air furnaces, gas fired for application outside the US	< 225,000 Btu/h	Maximum capacity[c]	80% AFUE (nonweatherized) or 81% AFUE (weatherized) or $80\%E_t$[b, d]	DOE 10 CFR, Part 430 Appendix N or Section 2.39, Thermal Efficiencyof ANSI Z 21.47
Warm air furnaces, gas-fired	≥ 225,000 Btu/h	Maximum capacity[c]	$80\%E_t$[b, d] before 1/1/2023 $81\%E_t$[d] after 1/1/2023	Section 2.39, Thermal Efficiency of ANSI Z21.47
Warm air furnaces, oil-fired for US Residential Application	< 225,000 Btu/h	Nonweatherized excluding mobile home	83% AFUE	DOE 10 CFR, Part 430 Appendix N
		Nonweatherized excluding mobile home	75% AFUE	
		Weatherized	78% AFUE	
Warm air furnaces, oil-fired for application outside the US	< 225,000 Btu/h	Maximum capacity[c]	83% AFUE (nonweatherized) or 78% AFUE (weatherized) or $80\%E_t$[b, d]	DOE 10 CFR, Part 430 Appendix N or Section 42, Combustion, UL 727
Warm air furnaces, oil-fired	≥ 225,000 Btu/h	Maximum capacity[c]	$81\%E_t$ before 1/1/2023 $82\%E_t$ after 1/1/2023	Section 42, Combustion, UL 727
Electric furnaces for US Residential Application	< 225,000 Btu/h	All	78% AFUE	DOE 10 CFR, Part 430 Appendix N
Electric furnaces for application outside the US	< 225,000 Btu/h	All	96% AFUE	DOE 10 CFR, Part 430 Appendix N
Warm air duct furnaces, gas-fired	All capacities	Maximum capacity[c]	$80\%E_c$[e]	Section 2.10, Efficiency of ANSI Z83.8
Warm air unit heaters, gas-fired	All capacities	Maximum capacity[c]	$80\%E_c$[e, f]	Section 2.10, Efficiency of ANSI Z83.8
Warm air unit heaters, oil-fired	All capacities	Maximum capacity[c]	$80\%E_c$[e, f]	Section 40, Combustion, of UL 731
Mobile home furnace, gas-fired	< 225,000 Btu/h	—	80% AFUE	DOE 10 CFR, Part 430
Mobile home furnace, oil-fired	< 225,000 Btu/h	—	75% AFUE	DOE 10 CFR, Part 430

For SI: 1 British thermal unit per hour = 0.2931 W.

a. Chapter 6 contains a complete specification of the referenced standards, which include test procedure, including the reference year version of the test procedure.

b. Combination units (i.e., furnaces contained within the same cabinet as an air conditioner) not covered by 10 CFR 430 (i.e., three-phase power or with cooling capacity greater than or equal to 65,000 Btu/h) may comply with either rating. All other units less than 225,000 Btu/h sold in the U.S. must meet the AFUE standards for consumer products and test using USDOE's AFUE test procedure at 10 CFR 430, Subpart B, Appendix N.

c. Compliance of multiple firing rate units shall be at the maximum firing rate.

d. E_t = Thermal efficiency. See test procedure for detailed discussion. Units shall also include an IID, have jackets not exceeding 0.75 percent of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.

e. E_C = Combustion efficiency (100% less flue losses). See test procedure for detailed discussion.

f. Units must also include an interrupted or intermittent ignition device (IID) and either power venting or an automatic flue damper.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10219

29

Date Submitted	02/11/2022	**Section**	403.2.3	**Proponent**	Bereket Nigusse
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Editorial changes to Table C403.2.3(7) Water Chilling Packages - Efficiency Requirements.

Rationale

Editorial changes to the Table C403.2.3(7) for clarification and deleting obsolete requirements. If adapted this modification makes the table the same as the 2019 ASHRAE Standard 90.1. No change to minimum efficiency requirements.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The proposed modification will not impact the local entity relative to code enforcement.

Impact to building and property owners relative to cost of compliance with code

The proposed modification will not impact the building and property owners cost.

Impact to industry relative to the cost of compliance with code

The proposed modification will not change the cost of compliance.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The proposed modification does not impact the health, safety, and welfare of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The proposed modification has no impact on the product quality or methods.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The proposed modification does not discriminate against materials, products, methods, or systems of construction

Does not degrade the effectiveness of the code

The proposed modification enhances effectiveness of the code by removing obsolete sections.

See attached documents for the updated Table C403.2.3(7).

TABLE C403.2.3(7)
WATER CHILLING PACKAGES – EFFICIENCY REQUIREMENTS[a, b, e]

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	~~BEFORE 1/1/2015~~		~~AFTER 1/1/2015~~		TEST PROCEDURE[c]
			~~Path A~~	~~Path B~~	Path A	Path B	
Air-cooled chillers	< 150 tons	EER (Btu/W)	~~≥ 9.562 FL~~	~~NA[c]~~	≥ 10.100 FL	≥ 9.700 FL	AHRI 550/590
			~~≥ 12.500 IPLV~~		≥ 13.700 IPLV	≥ 15.800 IPLV.IP	
	≥ 150 tons		~~≥ 9.562 FL~~	~~NA[c]~~	≥ 10.100 FL	≥ 9.700 FL	
			~~≥ 12.500 IPLV~~		≥ 14.000 IPLV	≥ 16.100 IPLV.IP	
Air cooled without condenser, electrically operated	All capacities	EER (Btu/W)			Air-cooled chillers without condenser shall be rated with matching condensers and complying with air-cooled chiller efficiency requirements		
Water cooled, electrically operated positive displacement	< 75 tons	kW/ton	~~≤ 0.780 FL~~	~~≤ 0.800 FL~~	≤ 0.750 FL	≤ 0.780 FL	
			~~≤ 0.630 IPLV~~	~~≤ 0.600 IPLV~~	≤ 0.600 IPLV	≤ 0.500 IPLV.IP	
	≥ 75 tons and < 150 tons		~~≤ 0.775 FL~~	~~≤ 0.790 FL~~	≤ 0.720 FL	≤ 0.750 FL	
			~~≤ 0.615 IPLV~~	~~≤ 0.586 IPLV~~	≤ 0.560 IPLV	≤ 0.490 IPLV.IP	
	≥ 150 tons and < 300 tons		~~≤ 0.680 FL~~	~~≤ 0.718 FL~~	≤ 0.660 FL	≤ 0.680 FL	
			~~≤ 0.580 IPLV~~	~~≤ 0.540 IPLV~~	≤ 0.540 IPLV	≤ 0.440 IPLV.IP	
	≥ 300 tons and < 600 tons		~~≤ 0.620 FL~~	~~≤ 0.639 FL~~	≤ 0.610 FL	≤ 0.625 FL	
			~~≤ 0.540 IPLV~~	~~≤ 0.490 IPLV~~	≤ 0.520 IPLV	≤ 0.410 IPLV.IP	
	≥ 600 tons		~~≤ 0.620 FL~~	~~≤ 0.639 FL~~	≤ 0.560 FL	≤ 0.585 FL	
			~~≤ 0.540 IPLV~~	~~≤ 0.490 IPLV~~	≤ 0.500 IPLV	≤ 0.380 IPLV.IP	
Water cooled, electrically operated centrifugal	< 150 tons	kW/ton	~~≤ 0.634 FL~~	~~≤ 0.639 FL~~	≤ 0.610 FL	≤ 0.695 FL	
			~~≤ 0.596 IPLV~~	~~≤ 0.450 IPLV~~	≤ 0.550 IPLV	≤ 0.440 IPLV.IP	
	≥ 150 tons and < 300 tons		~~≤ 0.634 FL~~	~~≤ 0.639 FL~~	≤ 0.610 FL	≤ 0.635 FL	
			~~≤ 0.596 IPLV~~	~~≤ 0.450 IPLV~~	≤ 0.550 IPLV	≤ 0.400 IPLV.IP	
	≥ 300 tons and < 400 tons		~~≤ 0.576 FL~~	~~≤ 0.600 FL~~	≤ 0.560 FL	≤ 0.595 FL	
			~~≤ 0.549 IPLV~~	~~≤ 0.400 IPLV~~	≤ 0.520 IPLV	≤ 0.390 IPLV.IP	
	≥ 400 tons and < 600 tons		~~≤ 0.576 FL~~	~~≤ 0.600 FL~~	≤ 0.560 FL	≤ 0.585 FL	
			~~≤ 0.549 IPLV~~	~~≤ 0.400 IPLV~~	≤ 0.500 IPLV	≤ 0.380 IPLV.IP	
	≥ 600 tons		~~≤ 0.570 FL~~	~~≤ 0.590 FL~~	≤ 0.560 FL	≤ 0.585 FL	
			~~≤ 0.539 IPLV~~	~~≤ 0.400 IPLV~~	≤ 0.500 IPLV	≤ 0.380 IPLV.IP	
Air cooled, absorption, single effect	All capacities	COP (W/W)	~~≥ 0.600 FL~~	~~NA[c]~~	≥ 0.600 FL	NA[d]	AHRI 560
Water cooled absorption, single effect	All capacities	COP (W/W)	~~≥ 0.700 FL~~	~~NA[c]~~	≥ 0.700 FL	NA[d]	
Absorption, double effect, indirect fired	All capacities	COP (W/W)	~~≥ 1.000 FL~~	~~NA[c]~~	≥ 1.000 FL	NA[d]	
			~~≥ 1.050 IPLV~~		≥ 1.050 IPLV		
Absorption double effect direct fired	All capacities	COP (W/W)	~~≥ 1.000 FL~~	~~NA[c]~~	≥ 1.000 FL	NA[d]	
			~~≥ 1.000 IPLV~~		≥ 1.050 IPLV		

a. Chapter 6 contains a complete specification of the reference standards, which include test procedures, including the reference year version of the procedure

b. The requirements for centrifugal chiller shall be adjusted for nonstandard rating conditions in accordance with Section C403.2.3.1 and are only applicable for the range of conditions listed in Section C403.2.3.1. The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the reference test procedure.

c. Both the full-load and IPLV.IP requirements shall be met or exceeded to comply with this standard. Where there is a Path B, compliance can be with either PathA or Path B for any application.

d. NA means the requirements are not applicable for Path B and only Path A can be used for compliance.

e. FL represents the full-load performance requirements and IPLV.IP the part-load performance requirements.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

30

EN10221

Date Submitted	02/11/2022	**Section**	403.2.3	**Proponent**	Bereket Nigusse
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Updates Table C403.2.3(8) Performance Requirements for Heat Rejection Equipment - Minimum Efficiency Requirements

Rationale

The proposed modification updates minimum efficiency requirements for selected heat rejection equipment and adds a new equipment category. If adapted this change makes the 2023 FBC-Energy Conservation minimum efficiency requirement of heat rejection equipment consistent with that of the 2019 ASHRAE Standard 90.1.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The proposed modification will not impact the local entity relative to code enforcement.

Impact to building and property owners relative to cost of compliance with code

The proposed modification will not impact the building and property owners cost.

Impact to industry relative to the cost of compliance with code

The proposed modification will not change the cost of compliance.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The proposed modification does not impact the health, safety, and welfare of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The proposed modification improves and strengthens the code by updating to current heat rejection product technologies.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The proposed modification does not discriminate against materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

The proposed modification enhances effectiveness of the code by adding new heat rejection equipment category.

See attached documents for the updated Table C403.2.3(8).

TABLE C403.2.3(8)
~~MINIMUM EFFICIENCY REQUIREMENTS:~~PERFORMANCE REQUIREMENTS FOR HEAT REJECTION EQUIPMENT–MINIMUM EFFICIENCY REQUIREMENTS

EQUIPMENT TYPE[a]	TOTAL SYSTEM HEAT REJECTION CAPACITY AT RATED CONDITIONS	SUBCATEGORY ORRATING CONDITION[i]	PERFORMANCE REQUIRED[b, c, d, g, h]	TEST PROCEDURE[e, f]
Propeller or axial fanopen-circuit cooling towers	All	95°F entering water 85°F leaving water75°F entering wb	≥ 40.2 gpm/hp	CTI ATC-105 andCTI STD-201
Centrifugal fan open-circuit coolingtowers	All	95°F entering water 85°F leaving water75°F entering wb	≥ 20.0 gpm/hp	CTI ATC-105 andCTI STD-201
Propeller or axial fanclosed-circuit coolingtowers	All	102°F entering water 90°F leaving water 75°F entering wb	≥ 16.1 gpm/hp	CTI ATC-105S andCTI STD-201
Centrifugal fan closed-circuit cooling towers	All	102°F entering water 90°F leaving water 75°F entering wb	≥ 7.0 gpm/hp	CTI ATC-105S andCTI STD-201
Propeller or axial fan dry coolers (air-cooled fluid coolers)	All	115°F entering water 105°F leaving water 95°F entering wb	≥ 4.5 gpm/hp	CTI ATC-105DS
Propeller or axial fan evaporative condensers	All	Ammonia Test Fluid 140°F entering gas temperature96.3°F condensing temperature 75°F entering wb	≥ 134,000 Btu/h·hp	CTI ATC-106
Centrifugal fan evaporative condensers	All	Ammonia Test Fluid 140°F entering gas temperature 96.3°F condensing temperature 75°F entering wb	≥110,000 Btu/h·hp	CTI ATC-106
Propeller or axial fan evaporative condensers	All	~~R-507A~~R-448A Test Fluid 165°F entering gas temperature105°F condensing temperature 75°F entering wb	~~≥157,000 Btu/h·hp~~ ≥ 160,000 Btu/h·hp	CTI ATC-106
Centrifugal fan evaporative condensers	All	~~R-507A~~R-448A Test Fluid 165°F entering gas temperature105°F condensing temperature 75°F entering wb	~~≥135,000 Btu/h·hp~~ ≥ 137,000 Btu/h·hp	CTI ATC-106
Air-cooled condensers	All	125°F Condensing Temperature 190°F Entering Gas Temperature 15°F subcooling 95°F entering db	≥ 176,000 Btu/h·hp	AHRI 460

For SI: °C = [(°F)-32]/1.8, L/s · kW = (gpm/hp)/(11.83), COP = (Btu/h · hp)/(2550.7),
db = dry bulb temperature, °F, wb = wet bulb temperature, °F.

a. The efficiencies and test procedures for both open- and closed-circuit cooling towers are not applicable to hybrid cooling towers that contain a combination of wet and dry heat exchange sections.

b. For purposes of this table, open circuit cooling tower performance is defined as the water flow rating of the tower at the thermal rating condition listed in Table 403.2.3(8) divided by the fan nameplate-rated motor power.

c. For purposes of this table, closed-circuit cooling tower performance is defined as the water flow rating of the tower at the thermal rating condition listed in Table 403.2.3(8) divided by the sum of the fan nameplate-rated motor power and the spray pump nameplate-rated motor power.

d. For purposes of this table, air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the fan nameplate-rated motor power.

e. Chapter 6 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure. The certification requirements do not apply to field-erected cooling towers.

f. Where a certification program exists for a covered product and it includes provisions for verification and challenge of equipment efficiency ratings, then the product shall be listed in the certification program; or, where a certification program exists for a covered product, and it includes provisions for verification and challenge of equipment efficiency ratings, but the product is not listed in the existing certification program, the ratings shall be verified by an independent laboratory test report.

g. Cooling towers shall comply with the minimum efficiency listed in the table for that specific type of tower with the capacity effect of any project-specific accessories and/or options included in the capacity of the cooling tower.

h. For purposes of this table, evaporative condenser performance is defined as the heat rejected at the specified rating condition in the table divided by the sum of the fan motor nameplate power and the integral spray pump nameplate power.

i. Requirements for evaporative condensers are listed with ammonia (R-717) and ~~R-507A~~R-448A as test fluids in the table. Evaporative condensers intended for use with halocarbon refrigerants other than ~~R-507A~~R-448A shall meet the minimum efficiency requirements listed in this table with ~~R-507A~~ R-448A as the test fluid. For ammonia, the condensing temperature is defined as the saturation temperature corresponding to the refrigerant pressure at the condenser entrance. For R-448A, which is a zeotropic refrigerant, the condensing temperature is defined as the arithmetic average of the dew point and the bubble point temperatures corresponding to the refrigerant pressure at the condenser entrance.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10222

31

Date Submitted	02/11/2022	**Section**	403.2.3	**Proponent**	Bereket Nigusse
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Updates Table C403.2.3(9) Floor-Mounted Air Conditioners and Condensing Units Serving Computer Rooms-Minimum Efficiency Requirements

Rationale

The proposed modification updates minimum efficiency requirements for floor-mounted air conditioners and condensing units serving computer rooms and re-arranges the minimum efficiency requirements of each standard model category by capacity range. If adapted this modification makes the 2023 FBC-Energy Conservation minimum efficiency requirement consistent with that of the 2019 ASHRAE Standard 90.1.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The proposed modification will not impact the local entity relative to code enforcement.

Impact to building and property owners relative to cost of compliance with code

The proposed modification may slightly impact the building and property owners cost.

Impact to industry relative to the cost of compliance with code

The proposed modification will not change the cost of compliance.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The proposed modification does not impact the health, safety, and welfare of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The proposed modification improves and strengthens the code by adding clarity and specifying energy efficiency products.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The proposed modification does not discriminate against materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

The proposed modification enhances the effectiveness of the code by re-arranging the table for clarity.

See attached documents for the updated table C403.2.3(9).

TABLE C403.2.3(9)
MINIMUM EFFICIENCY AIR CONDITIONERS AND CONDENSING UNITS SERVING COMPUTER ROOMS

Equipment Type	Net Sensible Cooling Capacity[a]	Standard Model	Minimum Net Sensible COP[b] (NSCOP) Return Air Dry-Bulb Temperature / Dew-Point Temperature			Test Procedure
			Class 1	Class 2	Class 3	
Air cooled	< 65,000 Btu/h	Downflow unit		2.30		AHRI 1360
		Upflow unit—ducted		2.10		
		Upflow unit—nonducted	2.09			
		Horizontal-flow unit			2.45	
	≥ 65,000 and < 240,000 Btu/h	Downflow unit		2.20		
		Upflow unit—ducted		2.05		
		Upflow unit—nonducted	1.99			
		Horizontal-flow unit			2.35	
	≥ 240,000 Btu/h	Downflow unit		2.00		
		Upflow unit—ducted		1.85		
		Upflow unit—nonducted	1.79			
		Horizontal-flow unit			2.15	
Water cooled	< 65,000 Btu/h	Downflow unit		2.50		AHRI 1360
		Upflow unit—ducted		2.30		
		Upflow unit—nonducted	2.25			
		Horizontal-flow unit			2.70	
	≥ 65,000 and < 240,000 Btu/h	Downflow unit		2.40		
		Upflow unit—ducted		2.20		
		Upflow unit—nonducted	2.15			
		Horizontal-flow unit			2.60	
	≥ 240,000 Btu/h	Downflow unit		2.25		
		Upflow unit—ducted		2.10		
		Upflow unit—nonducted	2.05			
		Horizontal-flow unit			2.45	
Water cooled with *fluid economizer*	< 65,000 Btu/h	Downflow unit		2.45		AHRI 1360
		Upflow unit—ducted		2.25		
		Upflow unit—nonducted	2.20			
		Horizontal-flow unit			2.60	
	≥ 65,000 and < 240,000 Btu/h	Downflow unit		2.35		
		Upflow unit—ducted		2.15		
		Upflow unit—nonducted	2.10			
		Horizontal-flow unit			2.55	
	≥ 240,000 Btu/h	Downflow unit		2.20		
		Upflow unit—ducted		2.05		
		Upflow unit—nonducted	2.00			
		Horizontal-flow unit			2.40	

(continued)

TABLE C403.2.3(9)—continued
MINIMUM EFFICIENCY AIR CONDITIONERS AND CONDENSING UNITS SERVING COMPUTER ROOMS

Equipment Type	Net Sensible Cooling Capacity[a]	Standard Model	Minimum Net Sensible COP[b] (NSCOP) Return Air Dry-Bulb Temperature / Dew-Point Temperature Class 1	Class 2	Class 3	Test Procedure
Glycol cooled	< 65,000 Btu/h	Downflow unit		2.30		AHRI 1360
		Upflow unit—ducted		2.10		
		Upflow unit—nonducted	2.00			
		Horizontal-flow unit			2.40	
	≥ 65,000 and < 240,000 Btu/h	Downflow unit		2.05		
		Upflow unit—ducted		1.85		
		Upflow unit—nonducted	1.85			
		Horizontal-flow unit			2.15	
	≥ 240,000 Btu/h	Downflow unit		1.95		
		Upflow unit—ducted		1.80		
		Upflow unit—nonducted	1.75			
		Horizontal-flow unit			2.10	
Glycol cooled with *fluid economizer*	< 65,000 Btu/h	Downflow unit		2.25		AHRI 1360
		Upflow unit—ducted		2.10		
		Upflow unit—nonducted	2.00			
		Horizontal-flow unit			2.35	
	≥ 65,000 and < 240,000 Btu/h	Downflow unit		1.95		
		Upflow unit—ducted		1.80		
		Upflow unit—nonducted	1.75			
		Horizontal-flow unit			2.10	
	≥ 240,000 Btu/h	Downflow unit		1.90		
		Upflow unit—ducted		1.80		
		Upflow unit—nonducted	1.70			
		Horizontal-flow unit			2.10	

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) − 32]/1.8

a. Net Sensible Cooling Capacity. The rate, expressed in Btu/h and/or kW, at which the equipment removes sensible heat from the air passing through it under specified conditions of operation, including the fan energy dissipated into the conditioned space.

b. Net Sensible Coefficient of Performance (NSCOP). A ratio of the Net Sensible Cooling Capacity in kilowatts to the total power input in kilowatts (excluding reheaters and humidifiers) at any given set of Rating Conditions defined in AHRI Standard 1360.

TABLE C403.2.3(9)
FLOOR-MOUNTED AIR CONDITIONERS AND CONDENSING UNITS SERVING COMPUTER ROOMS–MINIMUM EFFICIENCY REQUIREMENTS

Equipment Type	Standard Model	Net Sensible Cooling Capacity[b]	Minimum Net Sensible COP[c]	Rating Conditions Return Air (dry bulb /dew point)	Test Procedure[a]
Air cooled	Downflow	< 80,000 Btu/h	2.70	85°F/52°F (Class 2)	AHRI 1360
		≥80,000 Btu/h and < 295,000 Btu/h	2.58		
		≥ 295,000 Btu/h	2.36		
	Upflow–ducted	< 80,000 Btu/h	2.67		
		≥80,000 Btu/h and < 295,000 Btu/h	2.55		
		≥ 295,000 Btu/h	2.33		
	Upflow–nonducted	< 65,000 Btu/h	2.16	75°F/52°F (Class 1)	
		≥65,000 Btu/h and < 240,000 Btu/h	2.04		
		≥ 240,000 Btu/h	1.89		
	Horizontal	< 65,000 Btu/h	2.65	95°F/52°F (Class 3)	
		≥65,000 Btu/h and < 240,000 Btu/h	2.55		
		≥ 240,000 Btu/h	2.47		
Air cooled with fluid economizer	Downflow	< 80,000 Btu/h	2.70	85°F/52°F (Class 2)	AHRI 1360
		≥80,000 Btu/h and < 295,000 Btu/h	2.58		
		≥ 295,000 Btu/h	2.36		
	Upflow–ducted	< 80,000 Btu/h	2.67		
		≥80,000 Btu/h and < 295,000 Btu/h	2.55		
		≥ 295,000 Btu/h	2.33		
	Upflow–nonducted	< 65,000 Btu/h	2.09	75°F/52°F (Class 1)	
		≥65,000 Btu/h and < 240,000 Btu/h	1.99		
		≥ 240,000 Btu/h	1.81		
	Horizontal	< 65,000 Btu/h	2.65	95°F/52°F (Class 3)	
		≥65,000 Btu/h and < 240,000 Btu/h	2.55		
		≥ 240,000 Btu/h	2.47		
Water cooled	Downflow	< 80,000 Btu/h	2.82	85°F/52°F (Class 2)	AHRI 1360
		≥80,000 Btu/h and < 295,000 Btu/h	2.73		
		≥ 295,000 Btu/h	2.67		
	Upflow–ducted	< 80,000 Btu/h	2.79		
		≥80,000 Btu/h and < 295,000 Btu/h	2.70		
		≥ 295,000 Btu/h	2.64		
	Upflow–nonducted	< 65,000 Btu/h	2.43	75°F/52°F (Class 1)	
		≥65,000 Btu/h and < 240,000 Btu/h	2.32		
		≥ 240,000 Btu/h	2.20		
	Horizontal	< 65,000 Btu/h	2.79	95°F/52°F (Class 3)	
		≥65,000 Btu/h and < 240,000 Btu/h	2.68		
		≥ 240,000 Btu/h	2.60		

(continued)

TABLE C403.2.3(9)–continued
FLOOR-MOUNTED AIR CONDITIONERS AND CONDENSING UNITS SERVING COMPUTER ROOMS–MINIMUM EFFICIENCY REQUIREMENTS

Equipment Type	Standard Model	Net Sensible Cooling Capacity[b]	Minimum Net Sensible COP[c]	Rating Conditions Return Air (dry bulb /dew point)	Test Procedure[a]
Water cooled with fluid economizer	Downflow	< 80,000 Btu/h	2.77	85°F/52°F (Class 2)	AHRI 1360
		≥80,000 Btu/h and < 295,000 Btu/h	2.68		
		≥ 295,000 Btu/h	2.61		
	Upflow–ducted	< 80,000 Btu/h	2.74		
		≥80,000 Btu/h and < 295,000 Btu/h	2.65		
		≥ 295,000 Btu/h	2.58		
	Upflow–nonducted	< 65,000 Btu/h	2.35	75°F/52°F (Class 1)	
		≥65,000 Btu/h and < 240,000 Btu/h	2.24		
		≥ 240,000 Btu/h	2.12		
	Horizontal	< 65,000 Btu/h	2.71	95°F/52°F (Class 3)	
		≥65,000 Btu/h and < 240,000 Btu/h	2.60		
		≥ 240,000 Btu/h	2.54		
Glycol cooled	Downflow	< 80,000 Btu/h	2.56	85°F/52°F (Class 2)	AHRI 1360
		≥80,000 Btu/h and < 295,000 Btu/h	2.24		
		≥ 295,000 Btu/h	2.21		
	Upflow–ducted	< 80,000 Btu/h	2.53		
		≥80,000 Btu/h and < 295,000 Btu/h	2.21		
		≥ 295,000 Btu/h	2.18		
	Upflow–nonducted	< 65,000 Btu/h	2.08	75°F/52°F (Class 1)	
		≥65,000 Btu/h and < 240,000 Btu/h	1.90		
		≥ 240,000 Btu/h	1.81		
	Horizontal	< 65,000 Btu/h	2.48	95°F/52°F (Class 3)	
		≥65,000 Btu/h and < 240,000 Btu/h	2.18		
		≥ 240,000 Btu/h	2.18		
Glycol cooled with fluid economizer	Downflow	< 80,000 Btu/h	2.51	85°F/52°F (Class 2)	AHRI 1360
		≥80,000 Btu/h and < 295,000 Btu/h	2.19		
		≥ 295,000 Btu/h	2.15		
	Upflow–ducted	< 80,000 Btu/h	2.48		
		≥80,000 Btu/h and < 295,000 Btu/h	2.16		
		≥ 295,000 Btu/h	2.12		
	Upflow–nonducted	< 65,000 Btu/h	2.00	75°F/52°F (Class 1)	
		≥65,000 Btu/h and < 240,000 Btu/h	1.82		
		≥ 240,000 Btu/h	1.73		
	Horizontal	< 65,000 Btu/h	2.44	95°F/52°F (Class 3)	
		≥65,000 Btu/h and < 240,000 Btu/h	2.10		
		≥ 240,000 Btu/h	2.10		

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) – 32]/1.8

a. Chapter 6 contains a complete specification of the referenced standards, which includes the test procedures, including the referenced year version of the test procedure.

b. Net Sensible Cooling Capacity. The rate, expressed in Btu/h and/or kW, at which the equipment removes sensible heat from the air passing through it under specified conditions of operation, including the fan energy dissipated into the conditioned space.

c. Net Sensible Coefficient of Performance. A ratio of the Net Sensible Cooling Capacity in kilowatts to the total power input in kilowatts (excluding reheaters and humidifiers) at any given set of Rating Conditions defined in AHRI Standard 1360.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10223

32

Date Submitted	02/11/2022	**Section**	403.2.3	**Proponent**	Bereket Nigusse
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Updates Table C403.2.3(11) Electrically Operated Variable Refrigerant Flow Multi-Split Air Conditioners-Minimum Efficiency Requirements. This table is a replica of ASHRAE 90.1 Table 6.8.1-8 Electrically Operated Variable-Refrigerant-Flow Air Conditioners–Minimum Efficiency Requirements

Rationale

The proposed modification updates minimum efficiency requirements of electrically operated Variable Refrigerant Flow (VRF) multi-split air-conditioners. The current table C403.2.3(11) is split into VRF air-conditioners (table C403.2.3(11)) and a new table for VRF heat pump (table C403.2.3(12)). Also adds IEER as an additional efficiency metric for VRF air-conditioners for size categories larger than 65 kBtu/h. If adapted this modification makes the 2023 FBC-Energy Conservation minimum efficiency requirement of the VRF air-conditioners table consistent with that of the 2019 ASHRAE Standard 90.1.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The proposed modification will not impact the local entity relative to code enforcement.

Impact to building and property owners relative to cost of compliance with code

The proposed modification will not impact the building and property owners cost.

Impact to industry relative to the cost of compliance with code

The proposed modification will not change the cost of compliance.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The proposed modification does not impact the health, safety, and welfare of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The proposed modification improves and strengthens the code by re-arranging the table and products category for clarity.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The proposed modification does not discriminate against materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

The proposed modification enhances effectiveness of the code enforcement by simplifying the table.

See attached documents for the updated table C403.2.3(11).

TABLE C403.2.3(11)
MINIMUM EFFICIENCY REQUIREMENTS
VARIABLE REFRIGERANT FLOW MULTI-SPLIT AIR CONDITIONERS AND HEAT PUMPS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING TYPE[a]	MINIMUM EFFICIENCY	TEST PROCEDURE[b]
VRF Multi split Air Conditioners (Air cooled)	< 65,000 Btu/h	All	13.0 SEER	AHRI 1230 (omit Sections 5.1.2 and 6.6)
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric resistance (or none)	11.2 EER	
		All other	11.0 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric resistance (or none)	11.0 EER	
		All other	10.8 EER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric resistance (or none)	10.0 EER	
		All other	9.8 EER	
VRF Multi split Heat Pumps (Air cooled)	< 65,000 Btu/h	All	13.0 SEER 7.7 HSPF	
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric resistance (or none)	11.0 EER 3.3 COP	
		All other	10.8 EER 3.3 COP	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric resistance (or none)	10.6 EER 3.2 COP	
		All other	10.4 EER 3.2 COP	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric resistance (or none)	9.5 EER 3.2 COP	
		All other	9.3 EER 3.2 COP	
VRF Multi split Air Conditioners (Water source)	< 17,000 Btu/h	Without heat recovery	12.0 EER 4.3 COP	
		With heat recovery	11.8 EER 4.3 COP	
	≥ 17,000 Btu/h and < 65,000 Btu/h	All	12.0 EER 4.3 COP	
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	12.0 EER 4.3 COP	
	≥ 135,000 Btu/h and < 760,000 Btu/h	Without heat recovery	10.0 EER 4.0 COP	
		With heat recovery	9.8 EER 4.0 COP	

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) – 32]/1.8

a. VRAF Multi split Heat Pumps (air cooled) with heat recovery fall under the category of "All Other Types of Heating" unless they also have electric resistance heating, in which case it falls under the category for "No Heating or Electric Resistance Heating."

b. Chapter 6, Referenced Standards, contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.

TABLE C403.2.3(11)
ELECTRICALLY OPERATED VARIABLE REFRIGERANT FLOW MULTI-SPLIT AIR CONDITIONERS—MINIMUM EFFICIENCY REQUIREMENTS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE[a]	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
VRF air conditioners, air-cooled	< 65,000 Btu/h	All	VRF multisplit system	13.0 SEER	AHRI 1230
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric resistance (or none)	VRF multisplit system	11.0 EER 15.5 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric resistance (or none)	VRF multisplit system	11.0 EER 14.9 IEER	
	≥ 240,000 Btu/h	Electric resistance (or none)	VRF multisplit system	10.0 EER 13.9 IEER	

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) – 32]/1.8

a. Chapter 6, Referenced Standards, contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10224

Date Submitted	02/11/2022	**Section**	403.2.3	**Proponent**	Bereket Nigusse
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Adds a new Table C403.2.3(12) Electrically Operated Variable-Refrigerant-Flow and Applied Heat Pumps-Minimum Efficiency Requirements. This table was created from current table C403.2.3(11) and added ground source VRF multi-split heat pumps category from the 2019 ASHRAE Standard 90.1.

Rationale

The proposed modification adds a new Table C403.2.3(12) minimum efficiency requirements for electrically operated Variable-Refrigerant-Flow (VRF) applied heat pumps based on federal minimum and the 2019 ASHRAE Standard 90.1. This new table is created by moving the heat pumps section from current table C403.2.3(11). This modification also adds IEER as an additional efficiency metric for VRF heat pumps in cooling mode for size categories larger than 65 kBtu/h. If adapted this modification makes the 2023 FBC-Energy Conservation minimum efficiency requirement of the VRF heat pumps table consistent with that of the 2019 ASHARE Standard 90.1.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The proposed modification will not impact the local entity relative to code enforcement.

Impact to building and property owners relative to cost of compliance with code

The proposed modification will not impact the building and property owners cost.

Impact to industry relative to the cost of compliance with code

The proposed modification will not change the cost of compliance.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The proposed modification does not impact the health, safety, and welfare of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The proposed modification improves and strengthens the code by re-arranging the table and adds new products category.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The proposed modification does not discriminate against materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

The proposed modification enhances effectiveness of the code by expanding the table to include ground source VRF heat pump category.

See attached documents for the new table C403.2.3(12).

New Table C403.2.3(12). This new table substitutes heat pump part of variable refrigerant flow products listed in Table C403.2.3(11) of the 2020 FBC-EC code.

TABLE C403.2.3(12)
ELECTRICALLY OPERATED VARIABLE REFRIGERANT FLOW AND APPLIED HEAT PUMPS—MINIMUM EFFICIENCY REQUIREMENTS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE[a]	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
VRF air cooled (cooling mode)	< 65,000 Btu/h	All	VRF multisplit system	13.0 SEER	AHRI 1230
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric resistance (or none)	VRF multisplit system	11.0 EER 14.6 IEER	
			VRF multisplit system with heat recovery	10.8 EER 14.4 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h		VRF multisplit system	10.6 EER 13.9 IEER	
			VRF multisplit system with heat recovery	10.4 EER 13.7 IEER	
	≥ 240,000 Btu/h		VRF multisplit system	9.5 EER 12.7 IEER	
			VRF multisplit system with heat recovery	9.3 EER 12.5 IEER	
VRF water source (cooling mode)	< 65,000 Btu/h	All	VRF multisplit system 86°F entering water	12.0 EER 16.0 IEER	AHRI 1230
			VRF multisplit system with heat recovery 86°F entering water	11.8 EER 15.8 IEER	
	≥ 65,000 Btu/h and < 135,000 Btu/h		VRF multisplit system 86°F entering water	12.0 EER 16.0 IEER	
			VRF multisplit system with heat recovery 86°F entering water	11.8 EER 15.8 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h		VRF multisplit system 86°F entering water	10.0 EER 14.0 IEER	
			VRF multisplit system with heat recovery 86°F entering water	9.8 EER 13.8 IEER	
	≥ 240,000 Btu/h		VRF multisplit system 86°F entering water	10.0 EER 12.0 IEER	
			VRF multisplit system with heat recovery 86°F entering water	9.8 EER 11.8 IEER	
VRF groundwater source (cooling mode)	< 135,000 Btu/h	All	VRF multisplit system 59°F entering water	16.2 EER	AHRI 1230
			VRF multisplit system with heat recovery 59°F entering water	16.0 EER	
	≥ 135,000 Btu/h		VRF multisplit system 59°F entering water	13.8 EER	
			VRF multisplit system with heat recovery 59°F entering water	13.6 EER	

(continued)

TABLE C403.2.3(12)—continued
ELECTRICALLY OPERATED VARIABLE REFRIGERANT FLOW AND APPLIED HEAT PUMPS—MINIMUM EFFICIENCY REQUIREMENTS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE[a]	Subcategory or Rating Condition	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
VRF ground source (cooling mode)	< 135,000 Btu/h	All	VRF multisplit system 77°F entering water	13.4 EER	AHRI 1230
			VRF multisplit system with heat recovery 77°F entering water	13.2 EER	
	≥ 135,000 Btu/h		VRF multisplit system 77°F entering water	11.0 EER	
			VRF multisplit system with heat recovery 77°F entering water	10.8 EER	
VRF air cooled (heating mode)	< 65,000 Btu/h (cooling mode)	—	VRF multisplit system	7.7 HSPF	AHRI 1230
	≥ 65,000 Btu/h and < 135,000 Btu/h (cooling mode)		VRF multisplit system 47°F db/43°F wb outdoor air	3.3 COP_H	
			VRF multisplit system 17°F db/15°F wb outdoor air	2.25 COP_H	
	≥ 135,000 Btu/h (cooling mode)		VRF multisplit system 47°F db/43°F wb outdoor air	3.2 COP_H	
			VRF multisplit system 17°F db/15°F wb outdoor air	2.05 COP_H	
VRF water source (heating mode)	< 65,000 Btu/h (cooling mode)	—	VRF multisplit system 68°F entering water	4.3 COP_H	AHRI 1230
	≥ 65,000 Btu/h and < 135,000 Btu/h (cooling mode)		VRF multisplit system 68°F entering water	4.3 COP_H	
	≥ 135,000 Btu/h and < 240,000 Btu/h (cooling mode)		VRF multisplit system 68°F entering water	4.0 COP_H	
	≥ 240,000 Btu/h (cooling mode)		VRF multisplit system 68°F entering water	3.9 COP_H	
VRF groundwater source (heating mode)	< 135,000 Btu/h (cooling mode)	—	VRF multisplit system 50°F entering water	3.6 COP_H	AHRI 1230
	≥ 135,000 Btu/h (cooling mode)		VRF multisplit system 50°F entering water	3.3 COP_H	
VRF ground source (heating mode)	< 135,000 Btu/h (cooling mode)	—	VRF multisplit system 32°F entering water	3.1 COP_H	AHRI 1230
	≥ 135,000 Btu/h (cooling mode)		VRF multisplit system 32°F entering water	2.8 COP_H	

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) – 32]/1.8

a. Chapter 6, Referenced Standards, contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10225

Date Submitted	02/14/2022	**Section**	403.2.3	**Proponent**	Bereket Nigusse
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Adds a new Table C403.2.3(13) Vapor-Compression-Based Indoor Pool Dehumidifiers–Minimum Efficiency Requirements. This is a new table in the 2021-IECC and is a replica of ASHRAE 90.1 Table 6.8.1-12 Vapor-Compression-Based Pool Dehumidifiers–Minimum Efficiency Requirements.

Rationale

The proposed modification adds a new Table C403.2.3(13) minimum efficiency requirements for vapor-compression-based indoor pool dehumidifiers. Currently, there is no minimum efficiency requirement for this product in the 2020 FBC- Energy Conservation (FBC-EC). If adapted this modification makes the 2023 FBC-EC code minimum efficiency requirement for vapor-compression-based indoor pool dehumidifiers consistent with that of the 2019 ASHRAE Standard 90.1.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The proposed modification will not impact the local entity relative to code enforcement.

Impact to building and property owners relative to cost of compliance with code

The proposed modification may slightly impact the building and property owners cost by requiring more energy efficient product category.

Impact to industry relative to the cost of compliance with code

The proposed modification will not change the cost of compliance.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The proposed modification does not impact the health, safety, and welfare of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The proposed modification improves and strengthens the code by allowing better products that are not currently supported.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The proposed modification does not discriminate against materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

The proposed modification enhances the effectiveness of the code by allowing energy efficient products.

See attached documents for the new table C403.2.3(13).

COMMERCIAL ENERGY EFFICIENCY

New Table C403.2.3(13)

TABLE C403.2.3(13)
VAPOR-COMPRESSION-BASED INDOOR POOL DEHUMIDIFIERS–MINIMUM EFFICIENCY REQUIREMENTS

EQUIPMENT TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
Single package indoor (with or without economizer)	Rating Conditions: A or C	3.5 MRE	AHRI 910
Single package indoor water cooled (with or without economizer)	Rating Conditions: A, B or C	3.5 MRE	
Single package indoor air cooled (with or without economizer)	Rating Conditions: A, B or C	3.5 MRE	
Split system indoor air cooled (with or without economizer)	Rating Conditions: A, B or C	3.5 MRE	

a. Chapter 6 contains a complete specification of the referenced standards, which includes the test procedures, including the referenced year version of the test procedure.

b. MRE is moisture removal efficiency, defined as a ratio of the moisture removal capacity in lb of moisture/h to the power input values in kW at any given set of Rating Conditions expressed in lb of moisture/kWh.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10226

35

Date Submitted	02/14/2022	**Section**	403.2.3	**Proponent**	Bereket Nigusse
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Adds a new Table C403.2.3(14) Electrically Operated DX-DOAS Units, Single-Package and Remote Condenser, without Energy Recover–Minimum Efficiency Requirements. This is a new table in the 2021-IECC and is a replica of ASHRAE 90.1 Table 6.8.1-13 Electrically Operated DX-DOAS Units.

Rationale

The proposed modification adds a new Table C403.2.3(14) minimum efficiency requirements for electrically operated DX-DOAS Units, single-package and remote condenser, without Energy Recovery. Currently, there is no minimum efficiency requirement for this product category in the 2020 FBC- Energy Conservation (FBC-EC). If adapted this modification makes the 2023 FBC-EC code minimum efficiency requirement for electrically operated DX-DOAS units match that of the 2019 ASHARE Standard 90.1.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The proposed modification will not impact the local entity relative to code enforcement.

Impact to building and property owners relative to cost of compliance with code

The proposed modification may slightly impact the building and property owners cost by requiring energy efficient product category.

Impact to industry relative to the cost of compliance with code

The proposed modification will not change the cost of compliance.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The proposed modification does not impact the health, safety, and welfare of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The proposed modification improves and strengthens the code by allowing better products.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The proposed modification does not discriminate against materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

The proposed modification enhances the effectiveness of the code by allowing energy efficient products that are not supported in the current code.

See attached documents for the new table C403.2.3(14).

COMMERCIAL ENERGY EFFICIENCY

New Table C403.2.3(14)

TABLE C403.2.3(14)
ELECTRICALLY OPERATED DX-DOAS UNITS, SINGLE-PACKAGE AND REMOTE CONDENSER, WITHOUT ENERGY RECOVERY–MINIMUM EFFICIENCY REQUIREMENTS[b]

EQUIPMENT TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
Air cooled (dehumidification mode)	–	4.0 ISMRE	AHRI 920
Air-source heat pump (dehumidification mode)	–	4.0 ISMRE	AHRI 920
Water cooled (dehumidification mode)	Cooling tower condenser water	4.9 ISMRE	AHRI 920
	Chilled water	6.0 ISMRE	
Air-source heat pump (heating mode)		2.7 ISCOP	AHRI 920
Water-source heat pump (dehumidification mode)	Ground source, closed loop	4.8 ISMRE	AHRI 920
	Ground-water source	5.0 ISMRE	
	Water source	4.0 ISMRE	
Water-source heat pump (heating mode)	Ground source, closed loop	2.0 ISCOP	AHRI 920
	Ground-water source	3.2 ISCOP	
	Water source	3.5 ISCOP	

a. Chapter 6 contains a complete specification of the referenced standards, which includes the test procedures, including the referenced year version of the test procedure.

b. This table is a replica of ASHRAE 90.1 Table 6.8.1-13 Electrically Operated DX-DOAS Units, Single-Package and Remote Condenser, without Energy Recovery–Minimum Efficiency Requirements

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10227

36

Date Submitted	02/14/2022	**Section**	403.2.3	**Proponent**	Bereket Nigusse
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Adds a new Table C403.2.3(15) Electrically Operated DX-DOAS Units, Single-Package and Remote Condenser, with Energy Recover–Minimum Efficiency Requirements. This is a new table in the 2021-IECC and is a replica of ASHRAE 90.1 Table 6.8.1-14 Electrically Operated DX-DOAS Units with energy recovery.

Rationale

The proposed modification adds a new Table C403.2.3(15) minimum efficiency requirements for electrically operated DX-DOAS Units, single-package and remote condenser, with Energy Recovery. Currently, there is no minimum efficiency requirement for this product category in the 2020 FBC- Energy Conservation (FBC-EC). If adapted this modification makes the 2023 FBC-EC code minimum efficiency requirement for electrically operated DX-DOAS units with energy recovery match that of the 2019 ASHRAE Standard 90.1

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The proposed modification will not impact the local entity relative to code enforcement.

Impact to building and property owners relative to cost of compliance with code

The proposed modification may slightly impact the building and property owners cost by requiring energy efficient product category.

Impact to industry relative to the cost of compliance with code

The proposed modification will not change the cost of compliance.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The proposed modification does not impact the health, safety, and welfare of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The proposed modification improves and strengthens the code by allowing energy efficient products.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The proposed modification does not discriminate against materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

The proposed modification enhances the effectiveness of the code by allowing energy efficient products that are not in the code currently.

See attached documents for the new table C403.2.3(15).

New Table C403.2.3(15)

TABLE C403.2.3(15)
ELECTRICALLY OPERATED DX-DOAS UNITS, SINGLE-PACKAGE AND REMOTE CONDENSER, WITH ENERGY RECOVERY–MINIMUM EFFICIENCY REQUIREMENTS

EQUIPMENT TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
Air cooled (dehumidification mode)	–	5.2 ISMRE	AHRI 920
Air-source heat pump (dehumidification mode)	–	5.2 ISMRE	AHRI 920
Water cooled (dehumidification mode)	Cooling tower condenser water	5.3 ISMRE	AHRI 920
	Chilled water	6.6 ISMRE	
Air-source heat pump (heating mode)	–	3.3 ISCOP	AHRI 920
Water-source heat pump (dehumidification mode)	Ground source, closed loop	5.2 ISMRE	AHRI 920
	Ground-water source	5.8 ISMRE	
	Water source	4.8 ISMRE	
Water-source heat pump (heating mode)	Ground source, closed loop	3.8 ISCOP	AHRI 920
	Ground-water source	4.0 ISCOP	
	Water source	4.8 ISCOP	

a. Chapter 6 contains a complete specification of the referenced standards, which includes the test procedures, including the referenced year version of the test procedure.

b. ISMRE is Integrated Seasonal Moisture Removal Efficiency expressed in lb of moisture/kW-h.

c. ISCOP is Integrated Seasonal Coefficient of Performance (ISCOP) expressed in W/W.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10228

37

Date Submitted	02/14/2022	**Section**	403.2.3	**Proponent**	Bereket Nigusse
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Adds a new Table C403.2.3(16) Electrically Operated Water-Source Heat Pumps-Minimum Efficiency Requirement as a substitute for waster-source heat pumps deleted from table C403.2.3(2).

Rationale

The proposed modification adds a new Table C403.2.3(16) minimum efficiency requirements for electrically operated water-source heat pumps as a substitute for deleted section of Table C403.2.3(2). If adapted this modification makes the 2023 FBC-Energy Conservation (FBC-EC) minimum efficiency requirement of the water-source heat pump consistent with that of the 2019 ASHRAE Standard 90.1.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The proposed modification will not impact the local entity relative to code enforcement.

Impact to building and property owners relative to cost of compliance with code

The proposed modification will not impact the building and property owners cost.

Impact to industry relative to the cost of compliance with code

The proposed modification will not change the cost of compliance.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The proposed modification does not impact the health, safety, and welfare of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The proposed modification improves and strengthens the code by providing a dedicated table for water source-heat pump products.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The proposed modification does not discriminate against materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

The proposed modification enhances the clarity of the code by providing a separate table for water-source and ground-source heat pumps.

See attached documents for a new table C403.2.3(16).

COMMERCIAL ENERGY EFFICIENCY

New Table C403.2.3(16)

TABLE C403.2.3(16)
ELECTRICALLY OPERATED WATER-SOURCE HEAT PUMPS–MINIMUM EFFICIENCY REQUIREMENTS[b]

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
Water-to-air, water loop (cooling mode)	< 17,000 Btu/h	All	86°F entering air	12.2 EER	ISO-13256-1
	≥ 17,000 Btu/h and < 65,000 Btu/h			13.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h			13.0 EER	
Water-to-air, groundwater (cooling mode)	< 135,000 Btu/h	All	59°F entering air	18.0 EER	ISO-13256-1
Brine-to-air, ground loop (cooling mode)	< 135,000 Btu/h	All	77°F entering air	14.1 EER	ISO-13256-1
Water-to-water, water loop (cooling mode)	< 135,000 Btu/h	All	86°F entering air	10.6 EER	ISO-13256-2
Water-to-water, groundwater (cooling mode)	< 135,000 Btu/h	All	59°F entering air	16.3 EER	ISO-13256-2
Brine-to-water, ground loop (cooling mode)	< 135,000 Btu/h	All	77°F entering air	12.1 EER	ISO-13256-2
Water-to-air, water loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering air	4.3 COP_H	ISO-13256-1
Water-to-air, groundwater (heating mode)	< 135,000 Btu/h (cooling capacity)	—	50°F entering air	3.7 COP_H	ISO-13256-1
Brine-to-air, ground loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering air	3.2 COP_H	ISO-13256-1
Water-to-water, water loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering air	3.7 COP_H	ISO-13256-2
Water-to-water, groundwater (heating mode)	< 135,000 Btu/h (cooling capacity)	—	50°F entering air	3.1 COP_H	ISO-13256-2
Brine-to-water, ground loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering air	2.5 COP_H	ISO-13256-2

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) – 32]/1.8

a. Chapter 6 contains a complete specification of the referenced standards, which includes the test procedures, including the referenced year version of the test procedure.

b. This Single-phase, U.S. air-cooled heat pumps <19 kW are regulated as consumer products by 10 CFR 430. SCOPC, SCOP2C, SCOPH and SCOP2H values for single-phase products are set by the USDOE

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10233

38

Date Submitted	02/14/2022	**Section**	403.2.3	**Proponent**	Bereket Nigusse
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Adds a new Table C403.2.3(18) Ceiling-Mounted Computer-Room Air Conditioners–Minimum Efficiency Requirements. This is a new table in the 2021-IECC and is a replica of ASHRAE 90.1 Table 6.8.1-17 Ceiling-Mounted Computer-Room Air Conditioners–Minimum Efficiency Requirements.

Rationale

The proposed modification adds a new Table C403.2.3(18) minimum efficiency requirements for ceiling-mounted computer-room air-conditioners. Currently, there is no minimum efficiency requirement for ceiling mounted computer room air-conditioners in the 2020 FBC-Energy Conservation (FBC-EC). If adapted this modification makes the 2023 FBC-EC code minimum efficiency requirement of ceiling-mounted computer-room air-conditioners match that of the 2019 ASHRAE Standard 90.1 and provides design flexibility.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The proposed modification will not impact the local entity relative to code enforcement.

Impact to building and property owners relative to cost of compliance with code

The proposed modification will not impact the building and property owners cost

Impact to industry relative to the cost of compliance with code

The proposed modification will not change the cost of compliance but provides design flexibility.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The proposed modification does not impact the health, safety, and welfare of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The proposed modification improves and strengthens the code by allowing better products and encourages design flexibility.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The proposed modification does not discriminate against materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

The proposed modification enhances the effectiveness of the code by specifying energy efficient products that is not supported in the current code.

See attached documents for the new table C403.2.3(18).

COMMERCIAL ENERGY EFFICIENCY

New Table C403.2.3(18)

TABLE C403.2.3(18)
CEILING-MOUNTED COMPUTER-ROOM AIR CONDITIONERS–MINIMUM EFFICIENCY REQUIREMENTS

EQUIPMENT TYPE	STANDARD MODEL	NET SENSIBLE COOLING CAPACITY[b]	MINIMUM NET SENSIBLE COP[c]	RATING CONDITIONS RETURN AIR (dry bulb /dew point)	TEST PROCEDURE[a]
Air cooled with free air discharge condenser	Ducted	< 29,000 Btu/h	2.05	75°F/52°F (Class 1)	AHRI 1360
		≥29,000 Btu/h and < 65,000 Btu/h	2.02		
		≥ 65,000 Btu/h	1.92		
	Nonducted	< 29,000 Btu/h	2.08		
		≥29,000 Btu/h and < 65,000 Btu/h	2.05		
		≥ 65,000 Btu/h	1.94		
Air cooled with free air discharge condenser with fluid economizer	Ducted	< 29,000 Btu/h	2.01	75°F/52°F (Class 1)	AHRI 1360
		≥29,000 Btu/h and < 65,000 Btu/h	1.97		
		≥ 65,000 Btu/h	1.87		
	Nonducted	< 29,000 Btu/h	2.04		
		≥29,000 Btu/h and < 65,000 Btu/h	2.00		
		≥ 65,000 Btu/h	1.89		
Air cooled with ducted condenser	Ducted	< 29,000 Btu/h	1.86	75°F/52°F (Class 1)	AHRI 1360
		≥29,000 Btu/h and < 65,000 Btu/h	1.83		
		≥ 65,000 Btu/h	1.73		
	Nonducted	< 29,000 Btu/h	1.89		
		≥29,000 Btu/h and < 65,000 Btu/h	1.86		
		≥ 65,000 Btu/h	1.75		
Air cooled with fluid economizer and ducted condenser	Ducted	< 29,000 Btu/h	1.82	75°F/52°F (Class 1)	AHRI 1360
		≥29,000 Btu/h and < 65,000 Btu/h	1.78		
		≥ 65,000 Btu/h	1.68		
	Nonducted	< 29,000 Btu/h	1.85		
		≥29,000 Btu/h and < 65,000 Btu/h	1.81		
		≥ 65,000 Btu/h	1.70		
Water cooled	Ducted	< 29,000 Btu/h	2.38	75°F/52°F (Class 1)	AHRI 1360
		≥29,000 Btu/h and < 65,000 Btu/h	2.28		
		≥ 65,000 Btu/h	2.18		
	Nonducted	< 29,000 Btu/h	2.41		
		≥29,000 Btu/h and < 65,000 Btu/h	2.31		
		≥ 65,000 Btu/h	2.20		

(continued)

100928663

TABLE C403.2.3(18)—continued
CEILING-MOUNTED COMPUTER-ROOM AIR CONDITIONERS—MINIMUM EFFICIENCY REQUIREMENTS

EQUIPMENT TYPE	STANDARD MODEL	NET SENSIBLE COOLING CAPACITY[b]	MINIMUM NET SENSIBLE COP[c]	RATING CONDITIONS RETURN AIR (dry bulb /dew point)	TEST PROCEDURE[a]
Water cooled with fluid economizer	Ducted	< 29,000 Btu/h	2.33	75°F/52°F (Class 1)	AHRI 1360
		≥29,000 Btu/h and < 65,000 Btu/h	2.23		
		≥ 65,000 Btu/h	2.13		
	Nonducted	< 29,000 Btu/h	2.36		
		≥29,000 Btu/h and < 65,000 Btu/h	2.26		
		≥ 65,000 Btu/h	2.16		
Glycol cooled	Ducted	< 29,000 Btu/h	1.97	75°F/52°F (Class 1)	AHRI 1360
		≥29,000 Btu/h and < 65,000 Btu/h	1.93		
		≥ 65,000 Btu/h	1.78		
	Nonducted	< 29,000 Btu/h	2.00		
		≥29,000 Btu/h and < 65,000 Btu/h	1.98		
		≥ 65,000 Btu/h	1.81		
Glycol cooled with fluid economizer	Ducted	< 29,000 Btu/h	1.92	75°F/52°F (Class 1)	AHRI 1360
		≥29,000 Btu/h and < 65,000 Btu/h	1.88		
		≥ 65,000 Btu/h	1.73		
	Nonducted	< 29,000 Btu/h	1.95		
		≥29,000 Btu/h and < 65,000 Btu/h	1.93		
		≥ 65,000 Btu/h	1.76		

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) – 32]/1.8

a. Chapter 6 contains a complete specification of the referenced standards, which includes the test procedures, including the referenced year version of the test procedure.

b. Net Sensible Cooling Capacity. The rate, expressed in Btu/h and/or kW, at which the equipment removes sensible heat from the air passing through it under specified conditions of operation, including the fan energy dissipated into the conditioned space.

c. Net Sensible Coefficient of Performance. A ratio of the Net Sensible Cooling Capacity in kilowatts to the total power input in kilowatts (excluding reheaters and humidifiers) at any given set of Rating Conditions defined in AHRI Standard 1360.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10234

39

Date Submitted	02/14/2022	**Section**	403.2.3	**Proponent**	Bereket Nigusse
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Updates Table C404.2 Table C404.2 Minimum Performance of Water-Heating Equipment. This modification applies to instantaneous electric water heater capacity greater than 58.6 kW.

Rationale

The proposed modification clarifies that instantaneous electric water heater capacity greater than 58.6 kW has no minimum efficiency requirements. If adapted this modification makes the 2023 FBC-EC code minimum efficiency requirement of this product consistent with that of the 2019 ASHRAE Standard 90.1.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The proposed modification will not impact the local entity relative to code enforcement.

Impact to building and property owners relative to cost of compliance with code

The proposed modification will not impact the building and property owners cost.

Impact to industry relative to the cost of compliance with code

The proposed modification will not change the cost of compliance.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The proposed modification does not impact the health, safety, and welfare of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The proposed modification improves and strengthens the code by adding clarity.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The proposed modification does not discriminate against materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

The proposed modification enhances the code clarity.

1st Comment Period History

EN10234-G1

Proponent	Timothy de Carion	Submitted	3/28/2022 11:01:47 AM	Attachments	No

Comment:

I agree with this code modification

See attached documents for updated table C404.2.

TABLE C404.2
MINIMUM PERFORMANCE OF WATER-HEATING EQUIPMENT

EQUIPMENT TYPE	SIZE CATEGORY (input)	SUBCATEGORY OR RATING CONDITION	DRAW PATTERN	PERFORMANCE REQUIRED[a, b, g]	TEST PROCEDURE
Storage water heaters, electric	≤ 12 kW[d]	Tabletop,[e] ≥ 20 gallons and ≤ 120 gallons	Very small Low Medium High	0.6323 - (0.0058 × V), UEF 0.9188 - (0.0031 × V), UEF 0.9577 - (0.0023 × V), UEF 0.9884 - (0.0016 × V), UEF	DOE 10 CFR Part 430
		≥ 20 gallons and ≤ 55 gallons	Very small Low Medium High	0.8808 - (0.0008 × V), UEF 0.9254 - (0.0003 × V), UEF 0.9307 - (0.0002 × V), UEF 0.9349 - (0.0001 × V), UEF	
		> 55 gallons and ≤ 120 gallons	Very small Low Medium High	1.9236 - (0.0011 × V), UEF 2.0440 - (0.0011 × V), UEF 2.1171 - (0.0011 × V), UEF 2.2418 - (0.0011 × V), UEF	
		Grid-enabled[f] > 75 gallons	Very small Low Medium High	1.0136 - (0.0028 × V), UEF 0.9984 - (0.0014 × V), UEF 0.9853 - (0.0010 × V), UEF 0.9720 - (0.0007 × V), UEF	
	> 12 kW	All		$(0.3 + 27/V_m)$, SL, %/h	DOE 10 CFR Part 431
Instantaneous water heaters, electric		< 2 gal	Very small Low Medium High	0.91, UEF 0.91, UEF 0.91, UEF 0.92, UEF	DOE 10 CFR Part 430
	> 12 kW and ≤ 58.6 kW	Residential-duty commercial ≤ 2 gal	Very small Low Medium High	0.80, UEF 0.80, UEF 0.80, UEF 0.80, UEF	DOE 10 CFR Part 431
	> 58.6 kW	≥ 4,000 Btu/h/gal and < 10 gal		No Requirement	
		≥ 4,000 Btu/h/gal and ≥ 10 gal			
Storage water heaters, gas	≤ 75,000 Btu/h	≥ 20 gallons and ≤ 55 gallons	Very small Low Medium High	0.3456 - (0.0020 × V), UEF 0.5982 - (0.0019 × V), UEF 0.6483 - (0.0017 × V), UEF 0.6920 - (0.0013 × V), UEF	DOE 10 CFR Part 430
		> 55 gallons and ≤ 100 gallons	Very small Low Medium High	0.6470 - (0.0006 × V), UEF 0.7689 - (0.0005 × V), UEF 0.7897 - (0.0004 × V), UEF 0.8072 - (0.0003 × V), UEF	
	> 75,000 Btu/h	< 4,000 Btu/h/gal		80% E_t $(Q/800 + 110\sqrt{V})$, SL, Btu/h	DOE 10 CFR Part 431
	> 75,000 Btu/h and ≤ 105,000 Btu/h	Residential-duty commercial ≤ 120 gal	Very small Low Medium High	0.2674 - (0.0009 × V), UEF 0.5362 - (0.0012 × V), UEF 0.6002 - (0.0011 × V), UEF 0.6597 - (0.0009 × V), UEF	
Instantaneous water heaters, gas	> 50,000 Btu/h and ≤ 200,000 Btu/h[c]	≥ 4,000 Btu/h/gal and < 2 gal	Very small Low Medium High	0.80, UEF 0.81, UEF 0.81, UEF 0.81, UEF	DOE 10 CFR Part 430
	> 200,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal		80% E_t	DOE 10 CFR Part 431
	> 200,000 Btu/h	≥ 4,000 Btu/h/gal and ≥ 10 gal		80% E_t $(Q/800 + 110\sqrt{V})$, SL, Btu/h	

(continued)

TABLE C404.2—continued
MINIMUM PERFORMANCE OF WATER-HEATING EQUIPMENT

EQUIPMENT TYPE	SIZE CATEGORY (input)	SUBCATEGORY OR RATING CONDITION	DRAW PATTERN	PERFORMANCE REQUIRED[a, b, g]	TEST PROCEDURE
Storage water heaters, oil	≤ 105,000 Btu/h	≥ 20 gal ≤ 50 gallons	Very small Low Medium High	0.2509 - (0.0012 × V), UEF 0.5330 - (0.0016 × V), UEF 0.6078 - (0.0016 × V), UEF 0.6815 - (0.0014 × V), UEF	DOE 10 CFR Part 430
	> 105,000 Btu/h	< 4,000 Btu/h/gal		80% E_t $(Q/800 + 110\sqrt{V})$, SL, Btu/h	ANSI Z21.10.3
	> 105,000 Btu/h and ≤ 140,000 Btu/h	Residential-duty commercial ≤ 120 gal	Very small Low Medium High	0.2932 - (0.0015 × V), UEF 0.5596 - (0.0018 × V), UEF 0.6194 - (0.0016 × V), UEF 0.6740 - (0.0013 × V), UEF	DOE 10 CFR Part 431
Instantaneous water heaters, oil	≤ 210,000 Btu/h	≥ 4,000 Btu/h/gal and < 2 gal		0.59 - 0.0019V, EF	DOE 10 CFR Part 430
	> 210,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal		80% E_t	DOE 10 CFR Part 431
	> 210,000 Btu/h	≥ 4,000 Btu/h/gal and ≥ 10 gal		78% E_t $(Q/800 + 110\sqrt{V})$, SL, Btu/h	
Hot water supply boilers, gas and oil	≥ 300,000 Btu/h and < 12,500,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal		80% E_t	DOE 10 CFR Part 431
Hot water supply boilers, gas	≥ 300,000 Btu/h and < 12,500,000 Btu/h	≥ 4,000 Btu/h/gal and ≥ 10 gal		80% E_t $(Q/800 + 110\sqrt{V})$, SL, Btu/h	
Hot water supply boilers, oil	> 300,000 Btu/h and < 12,500,000 Btu/h	> 4,000 Btu/h/gal and ≥ 10 gal		78% E_t $(Q/800 + 110\sqrt{V})$, SL, Btu/h	
Pool heaters, gas and oil	All	—		82% E_t	ASHRAE 146
Heat pump pool heaters	All	—		4.0 COP At low air temperature	AHRI 1160[h, i]
Unfired storage tanks	All	—		Minimum insulation requirement R-12.5 (h · ft² · °F)/Btu	DOE 10 CFR Part 431

For SI: °C = [(°F) - 32]/1.8, 1 British thermal unit per hour = 0.2931 W, 1 gallon = 3.785 L, 1 British thermal unit per hour per gallon = 0.078 W/L.

a. Energy factor (EF), uniform energy factor (UEF) and thermal efficiency (E_t) are minimum requirements. In the EF and UEF equations, V is the rated volume in gallons.

b. Standby loss (SL) is the maximum Btu/h based on a nominal 70°F temperature difference between stored water and ambient requirements. In the SL equation, Q is the nameplate input rate in Btu/h. In the equations for electric water heaters, V is the rated volume in gallons and V_m is the measured volume in gallons. In the SL equation for oil and gas water heaters and boilers, V is the rated volume in gallons.

c. Instantaneous water heaters with input rates below 200,000 Btu/h shall comply with these requirements where the water heater is designed to heat water to temperatures 180°F or higher.

d. Electric water heaters with an input rating of 12 kW (40,950 Btu/h) or less that are designed to heat water to temperatures of 180°F or greater shall comply with the requirements for electric water heaters that have an input rating greater than 12 kW (40,950 Btu/h).

e. A tabletop water heater is a water heater that is enclosed in a rectangular cabinet with a flat top surface not more than 3 feet (0.91 m) in height.

f. A grid-enabled water heater is an electric resistance water heater that meets all of the following:

1. Has a rated storage tank volume of more than 75 gallons.
2. Is manufactured on or after April 16, 2015.
3. Is equipped at the point of manufacture with an activation lock.
4. Bears a permanent label applied by the manufacturer that complies with all of the following:
   - 4.1. Is made of material not adversely affected by water.
   - 4.2. Is attached by means of non-water-soluble adhesive.
   - 4.3. Advises purchasers and end-users of the intended and appropriate use of the product with the following notice printed in 16.5 point Arial Narrow Bold font: "IMPORTANT INFORMATION: This water heater is intended only for use as part of an electric thermal storage or demand response program. It will not provide adequate hot water unless enrolled in such a program and activated by your utility company or another program operator. Confirm the availability of a program in your local area before purchasing or installing this product."

g. Water heaters and hot water supply boilers having more than 140 gallons of storage capacity need not meet the standby loss requirement if: (1) The tank surface area is thermally insulated to R-12.5 or more; (2) a standing pilot light is not used; and (3) for gas or oil-fired storage water heaters, they have a fire damper or fan-assisted combustion.

h. Test report from independent laboratory is required to verify procedure compliance.

i. Geothermal swimming pool heat pumps are not required to meet this standard.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

40

EN10364

Date Submitted	02/13/2022	**Section**	408.2	**Proponent**	Joseph Belcher
Chapter	4	**Affects HVHZ**	Yes	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

This is a series of changes to correlate with the change to C104.2.6.

Summary of Modification

This is a series of changes to subsections of 408.2 requiring documentation to be submitted to the code official.

Rationale

C408.2 It has been reported that many projects do not request commissioning because the local building department does not request the documentation. The code change is necessary to enhance enforcement of the commissioning provisions of the FBC-EC. Requiring documentation to be submitted to the building official as well as the owner will ensure the building department is kept advised of the project and the progress of the commissioning process and will lead to improved enforcement. C408.2 Exception: The change excepts individual systems serving dwelling units or sleeping units because these are separate systems, which do create a large system serving other than the dwelling or sleeping units. C408.2.4.1The deletion of provisions related to “a letter of transmittal” to the code official and requiring providing the code official with the Preliminary Commissioning Report before the final inspection will enhance enforcement of the provisions. C408.2.4.2 Requiring the submission of the Preliminary Commissioning Report to the code official for review will enhance enforcement of the code. C408.2.5 Documentation Requirements. Providing the construction documents to the code official will enhance enforcement and create a record for future use. C408.3. 2 Documentation requirements. Providing the construction documents to the code official will enhance enforcement and create a record for future use.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact as the changes merely require providing the documentation to the code official.

Impact to building and property owners relative to cost of compliance with code

No impact as the changes merely require providing the documentation to the code official.

Impact to industry relative to the cost of compliance with code

No impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The proposal has a reasonable and positive impact on the health, safety, and welfare of the public by enhancing enforcement of the code.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The proposal strengthens the code by enhancing enforcement of the commissioning provisions of the code.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The change does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities.

Does not degrade the effectiveness of the code

The proposed change does not degrade the effectiveness of the code and improves the effectiveness of the code.

1st Comment Period History

EN10364-G1

Proponent	Timothy de Carion	Submitted	3/28/2022 11:33:52 AM	Attachments	No

Comment:

I agree with this code modification

C408.1 General – No change.

C408.1.1 Building operation and Maintenance information. – No Change.

C408.2 Mechanical systems and service water-heating systems commissioning and completion requirements.

Prior to the final mechanical and plumbing inspections, the licensed design professional, electrical engineer, mechanical engineer or *approved agency* shall provide evidence of mechanical systems *commissioning* and completion in accordance with the provisions of this section.

Construction document notes shall clearly indicate provisions for *commissioning* and completion requirements in accordance with this section and are permitted to refer to specifications for further requirements. Copies of all documentation shall be given to the owner or owner's authorized agent and ~~made available~~ provided to the *code official* ~~upon request~~ in accordance with Sections C408.2.4 and C408.2.5.

Exceptions: The following systems are exempt:

1. Mechanical systems and service water heater systems in buildings where the total mechanical equipment capacity is less than 480,000 Btu/h (140.7 kW) cooling capacity and 600,000 Btu/h (175.8 kW) combined service water-heating and space-heating capacity. Capacities of individual systems serving dwelling units or sleeping units shall not be counted in determining the total mechanical and/or water heating system's capacity for the whole building.
2. Systems included in Section C403.3 that serve individual *dwelling units* and *sleeping units*.

No changes to intervening sections.

C408.2.4.1 Acceptance of report.

Buildings, or portions thereof, shall not be considered acceptable for a final inspection pursuant to Section C104.3 until the *code official* has received ~~a letter of transmittal from the building owner acknowledging that the building owner or owner's authorized agent has received~~ the Preliminary Commissioning Report.

C408.2.4.2 Copy of report.

The *code official* shall ~~be permitted to~~ require that a copy of the Preliminary Commissioning Report be made available for review by the *code official*.

C408.2.5 Documentation requirements.

The *construction documents* shall specify that the documents described in this section be provided to the building owner or owner's authorized agent and provided to the code official within 90 days of the date of receipt of the *certificate of occupancy*.

No changes in intervening sections.

C408.3.2 Documentation requirements.

The construction documents shall specify that the documents described in this section be provided to the building owner or owner's authorized agent <u>and provided to the code official</u> within 90 days of the date of receipt of the *certificate of occupancy*.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10401

41

Date Submitted	02/14/2022	**Section**	408.2	**Proponent**	Dominique Flickinger
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

408.2.1 408.3.1

Summary of Modification

Change wording on who should provide commissioning services to eliminate loopholes of firms providing commissioning on their own work and thereby circumventing the intent of this code.

Rationale

The above proposed change would bring the code into line with the specifications on federal projects. It would also conform to recommendations made by professional associations such as ASHRAE, AEE, BCxA and the USGBC to hire an independent third party to provide commissioning services. This change would eliminate the loopholes some contractors and engineers are using to sign off on their own work. Although some firms are policing themselves appropriately many are not. Some examples of issues discovered include engineering firms not including sequence of operations on their mechanical drawings thereby not allowing a third party to bid on the work, engineers informing their clients that commissioning wasn't required although the equipment size met or exceeded the code, commissioning specifications being omitted from the specifications for a project altogether, and specifications that state the EOR will perform the commissioning. This has led to Owners not receiving the project they requested, mechanical drawings not being completed 100% at construction and being modified "on the fly" to meet commissioning requirements, and errors in engineering that the Owner would not be made aware of.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

There should be no additional construction costs for this change as commissioning should already be included in the cost of a project to comply with the code. The above change would only affect how the code is applied.

Impact to building and property owners relative to cost of compliance with code

There should be no additional construction costs for this change as commissioning should already be included in the cost of a project to comply with the code. The above change would only affect how the code is applied.

Impact to industry relative to the cost of compliance with code

There should be no additional construction costs for this change as commissioning should already be included in the cost of a project to comply with the code. The above change would only affect how the code is applied.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This change will help to ensure the intent of the code is being enforced to help with energy savings.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This change will improve this code by closing loopholes and ensuring the intent of the code is enforced with regards to energy conservation and proper equipment installation and function.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

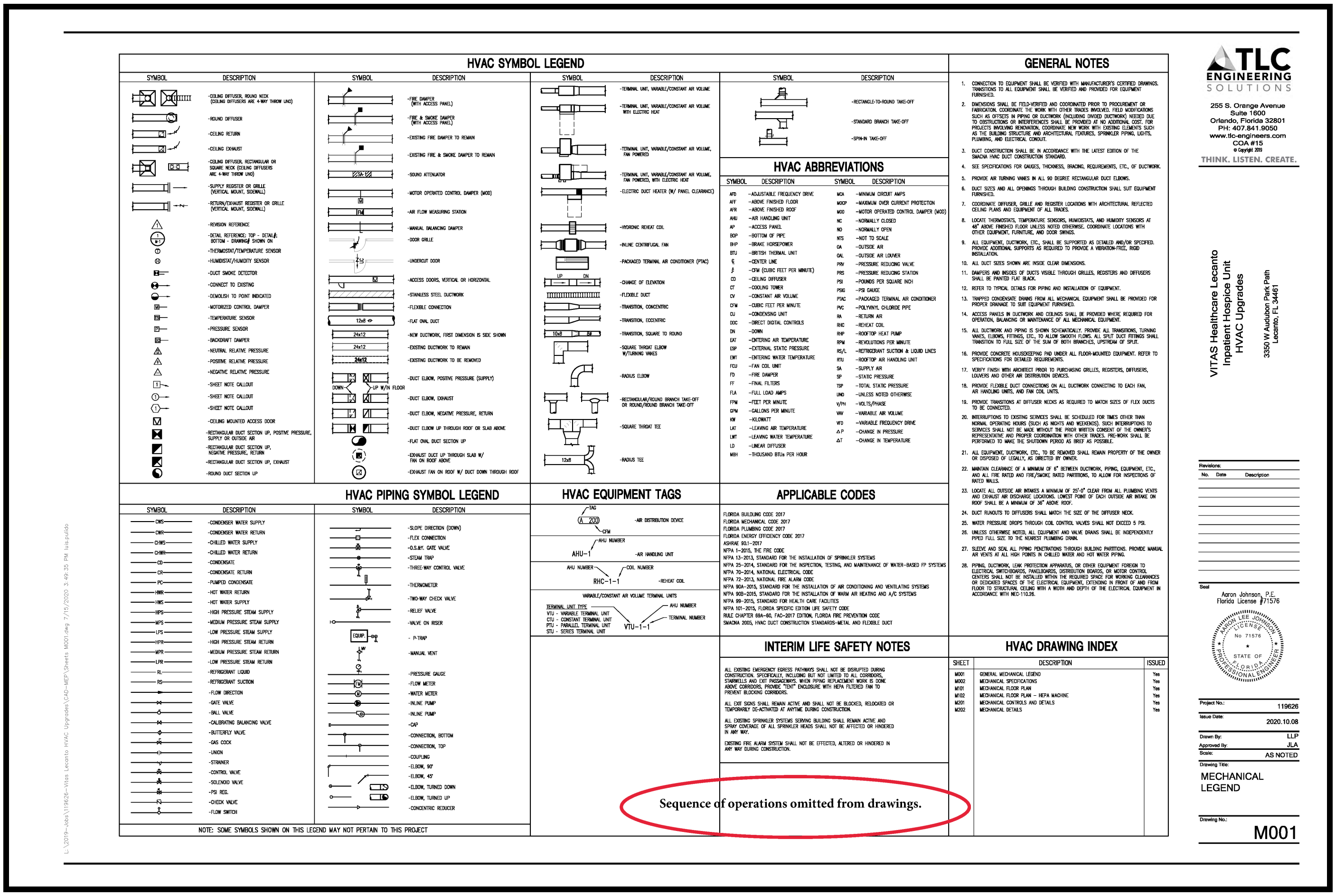
This change does not discriminate against anything or anyone with the exception of unscrupulous contractors who are disregarding the intent of the current code.

Does not degrade the effectiveness of the code

This change will not degrade the effectiveness of the code. It will strengthen the code.

Prior to the final mechanical and plumbing inspections, ~~the licensed design professional, electrical engineer, mechanical engineer, or approved agency~~ an independent commissioning firm that is a 1st tier subcontractor of the General or Prime Contractor or Owner and is financially and corporately independent of all other subcontractors including any Design or Engineering firms, shall provide evidence of mechanical systems commissioning and completion in accordance with the provisions of this section.

EN10401Rationale



Page: 1

Mod_10401_Rationale_VITAS - Lecanto mechanicals Example.pdf

EN10401Rationale

23 00 10 – BASIC MECHANICAL REQUIREMENTS

1.06 RECORD DRAWINGS

A. PRODUCTION: MAINTAIN ONE SET OF BLACK OR BLUE LINE ON WHITE PROJECT RECORD "AS-BUILT" DRAWINGS AT THE SITE. AT ALL TIMES THE SET SHALL BE ACCURATE, CLEAR, AND COMPLETE, INDICATING THE ACTUAL INSTALLATION. RECORD DRAWINGS SHALL BE UPDATED WEEKLY TO RECORD THE PRESENT STAGE OF PROGRESS. THESE DRAWINGS SHALL BE AVAILABLE TO THE ARCHITECT AT ALL TIMES. EQUIPMENT SCHEDULES, CONTROL DIAGRAMS, SEQUENCES OF OPERATION SHALL ALSO BE UPDATED.

B. COMPLETION: PRIOR TO SUBSTANTIAL COMPLETION, TRANSFER ONTO AN UNMARKED SECOND SET OF DRAWINGS ALL CHANGES, MARKED IN COLORED PENCIL, AND SUBMIT THEM TO THE ARCHITECT. UPON COMPLETION OF ALL PUNCH LISTS, TRANSFER ALL "AS-BUILT" CONDITIONS TO THE AUTOCAD DRAWING FILES, PACKAGE THREE (3) PRINT SETS OF FULL SIZE DRAWINGS AND TWO (2) CDS OF THE AUTOCAD DRAWING FILES WITH ASSOCIATED REFERENCE FILES AND SUBMIT THEM TO THE ARCHITECT FOR REVIEW AND APPROVAL.

1.07 SUBMITTAL

A. GENERAL: THE PROVISIONS OF THIS SECTION ARE SUPPLEMENTAL TO THE REQUIREMENTS IN DIVISION 1, AND ONLY APPLY TO THE MATERIAL AND EQUIPMENT COVERED IN DIVISION 23.

B. TIME: SUBMIT MANUFACTURER'S LITERATURE, PERFORMANCE DATA AND INSTALLATION INSTRUCTIONS COVERED IN EACH SECTION OF DIVISION 23 UNDER AN INDIVIDUAL LETTER OF TRANSMITTAL WITHIN 30 DAYS AFTER NOTICE TO PROCEED UNLESS OTHERWISE INDICATED.

C. SUBMITTER'S REVIEW: ALL ITEMS REQUIRED FOR EACH SECTION SHALL BE REVIEWED BEFORE SUBMITTAL. SUBMITTAL INFORMATION FOR EACH ITEM SHALL BEAR A REVIEW STAMP OF APPROVAL, INDICATING THE NAME OF THE CONTRACTOR AND SUBCONTRACTOR (WHERE APPLICABLE), THE MATERIAL SUPPLIERS, THE INITIALS OF SUBMITTER AND DATE CHECKED. RESPONSIBILITY FOR ERRORS OR OMISSIONS IN SUBMITTALS SHALL NOT BE RELIEVED BY THE ARCHITECT'S REVIEW OF SUBMITTALS. RESPONSIBILITY FOR SUBMITTALS CANNOT BE SUBROGATED TO MATERIAL SUPPLIERS BY CONTRACTORS OR SUBCONTRACTORS.

1. REVIEW OF THE SUBMITTAL DATA, WHETHER INDICATED WITH "APPROVED" OR WITH REVIEW COMMENTS, DOES NOT CONSTITUTE AUTHORIZATION FOR OR ACCEPTANCE OF A CHANGE IN THE CONTRACT PRICE.

D. ARCHITECT'S REVIEW: THE SUBMITTAL DATA SHALL BE REVIEWED ONLY FOR GENERAL CONFORMANCE WITH THE DESIGN CONCEPT OF THE PROJECT AND FOR GENERAL COMPLIANCE WITH THE CONTRACT DOCUMENTS. ANY ACTION INDICATED IS SUBJECT TO THE REQUIREMENTS OF THE CONTRACT DOCUMENTS. REVIEWS OF SUBMITTAL DATA REVIEW SHALL NOT INCLUDE QUANTITIES; DIMENSIONS (WHICH SHALL BE CONFIRMED AND CORRELATED AT THE JOB SITE); FABRICATION PROCESSES; TECHNIQUES OF CONSTRUCTION; AND CO-ORDINATION OF THE SUBMITTAL DATA WITH ALL OTHER TRADES. COPIES OF THE SUBMITTAL DATA WILL BE RETURNED MARKED "ACCEPTED AS SUBMITTED", "ACCEPTED AS NOTED", "REVISED AS NOTED AND RESUBMIT", "REJECTED, REVISED AS NOTED AND RESUBMIT".

E. SUBMITTAL ITEMS: SUBMITTAL ITEMS SHALL BE INSERTED IN A TECHNICAL INFORMATION BROCHURE. MARK THE APPROPRIATE SPECIFICATION SECTION OR DRAWING REFERENCE NUMBER IN THE RIGHT HAND CORNER OF EACH ITEM. ALL TYPEWRITTEN PAGES SHALL BE ON THE PRODUCT OR EQUIPMENT MANUFACTURER'S PRINTED LETTERHEAD.

1. MANUFACTURER'S LITERATURE: WHERE INDICATED, INCLUDE THE MANUFACTURER'S PRINTED LITERATURE. LITERATURE SHALL BE CLEARLY MARKED TO INDICATE THE ITEM INTENDED FOR USE.

2. PERFORMANCE DATA: PROVIDE PERFORMANCE DATA, WIRING AND CONTROL DIAGRAMS AND SCALE DRAWINGS WHICH SHOW THAT PROPOSED EQUIPMENT WILL FIT INTO ALLOTTED SPACE (INDICATE AREAS REQUIRED FOR SERVICE ACCESS, CONNECTIONS, ETC.), AND OTHER DATA REQUIRED FOR THE ARCHITECT TO DETERMINE THAT THE EQUIPMENT COMPLIES WITH THE CONTRACT DOCUMENTS. WHERE NOTED, PERFORMANCE DATA SHALL BE CERTIFIED BY THE MANUFACTURER AT THE DESIGN RATING POINTS.

3. INSTALLATION INSTRUCTIONS: WHERE REQUESTED, EACH PRODUCT SUBMITTAL SHALL INCLUDE THE MANUFACTURER'S INSTALLATION INSTRUCTIONS. GENERIC INSTALLATION INSTRUCTIONS ARE NOT ACCEPTABLE. INSTRUCTIONS SHALL BE THE SAME AS THOSE INCLUDED WITH THE PRODUCT WHEN IT IS SHIPPED FROM THE FACTORY.

4. WRITTEN OPERATING INSTRUCTIONS: INSTRUCTIONS SHALL BE THE MANUFACTURER'S WRITTEN OPERATING INSTRUCTIONS FOR THE SPECIFIED PRODUCT. IF THE INSTRUCTIONS COVER MORE THAN ONE MODEL OR TYPE OF PRODUCT THEY SHALL BE CLEARLY MARKED TO IDENTIFY THE INSTRUCTIONS THAT COVER THE PRODUCT DELIVERED TO THE PROJECT. OPERATING INSTRUCTIONS SHALL BE SUBMITTED IMMEDIATELY AFTER THE PRODUCT OR EQUIPMENT SUBMITTAL HAS BEEN RETURNED FROM THE ARCHITECT MARKED "APPROVED" OR "APPROVED AS NOTED".

5. MAINTENANCE INSTRUCTIONS: INFORMATION SHALL BE THE MANUFACTURER'S PRINTED INSTRUCTIONS AND PARTS LISTS FOR THE EQUIPMENT FURNISHED. IF THE INSTRUCTIONS COVER MORE THAN ONE MODEL OR TYPE OF EQUIPMENT THEY SHALL BE MARKED TO IDENTIFY THE INSTRUCTIONS FOR THE FURNISHED PRODUCT. SUBMIT MAINTENANCE INSTRUCTIONS IMMEDIATELY AFTER THE PRODUCT OR EQUIPMENT SUBMITTAL HAS BEEN RETURNED FROM THE ARCHITECT MARKED "APPROVED" OR "APPROVED AS NOTED".

F. SUBSTITUTIONS:

1. GENERAL: REFER TO DIVISION 1. SUBSTITUTIONS MAY BE CONSIDERED FOR ANY PRODUCT OR EQUIPMENT OF A MANUFACTURER. SEE PARAGRAPH ENTITLED "MANUFACTURER" IN THIS SECTION. ANY PRODUCT OR EQUIPMENT MAY BE SUBMITTED FOR REVIEW; HOWEVER, ONLY ONE SUBSTITUTION PER ITEM WILL BE CONSIDERED. IF A SUBSTITUTED PRODUCT OR EQUIPMENT ITEM IS REJECTED, PROVIDE THE SPECIFIED PRODUCT OR EQUIPMENT.

A. SUBMITTAL SHALL INCLUDE THE NAME OF THE MATERIAL OR EQUIPMENT TO BE SUBSTITUTED, EQUIPMENT MODEL NUMBERS, DRAWINGS, CATALOG CUTS, PERFORMANCE AND TEST DATA AND ANY OTHER DATA OR INFORMATION NECESSARY FOR THE ARCHITECT TO DETERMINE THAT THE EQUIPMENT MEETS THE SPECIFICATION REQUIREMENTS. IF THE ARCHITECT ACCEPTS ANY PROPOSED SUBSTITUTIONS, SUCH ACCEPTANCE WILL BE SET FORTH IN WRITING.

B. SUBSTITUTED EQUIPMENT WITH ALL ACCESSORIES INSTALLED OR OPTIONAL EQUIPMENT WHERE PERMITTED AND FOUND ACCEPTABLE, MUST CONFORM TO SPACE REQUIREMENTS. SUBSTITUTED EQUIPMENT THAT CANNOT MEET SPACE REQUIREMENTS, WHETHER ACCEPTED OR NOT, SHALL BE REPLACED AT NO ADDITIONAL EXPENSE TO THE OWNER. IF THE SUBSTITUTED ITEM AFFECTS THE WORK OF OTHER TRADES, THE REQUEST FOR SUBSTITUTION FORM SHALL INCLUDE A LIST OF THE NECESSARY MODIFICATIONS.

23 00 10 – BASIC MECHANICAL REQUIREMENTS

2. DEVIATIONS: THE REQUEST FOR SUBSTITUTION FORM SHALL INCLUDE A COMPLETE LIST OF DEVIATIONS FROM THE SCHEDULED ITEM STATING BOTH THE FEATURES AND FUNCTIONS OF THE SCHEDULED ITEM AND THE COMPARABLE FEATURES AND FUNCTIONS OF THE PROPOSED SUBSTITUTION.

A. ANY DEVIATION NOT INDICATED IN WRITING WILL BE ASSUMED TO BE IDENTICAL TO THE SPECIFIED ITEM EVEN IF IT IS SHOWN OTHERWISE ON THE SUBMITTAL DATA.

B. IF A DEVIATION NOT LISTED IS FOUND ANYTIME AFTER REVIEW AND ACCEPTANCE BY THE ARCHITECT AND THAT DEVIATION, IN THE OPINION OF THE ARCHITECT, RENDERS THE SUBSTITUTED ITEM AS UNACCEPTABLE, THE ITEM SHALL BE REMOVED AND REPLACED BY THE SCHEDULED ITEM AT NO ADDITIONAL COST TO THE OWNER.

C. THE ARCHITECT SHALL RETAIN THE RIGHT TO SPECIFY MODIFICATIONS TO THE SUBSTITUTED ITEM, CORRECTING OR ADJUSTING FOR THE DEVIATION, IF THE ARCHITECT DEEMS IT TO BE IN THE BEST INTEREST OF THE OWNER.

3. SCHEDULED ITEM: A SCHEDULED ITEM IS A PRODUCT OR ITEM OF EQUIPMENT INDICATED IN THE CONTRACT DOCUMENTS BY MANUFACTURER'S NAME AND MODEL NUMBER IDENTIFYING A SINGLE ITEM. THE MANUFACTURER'S TRADE NAME FOR A GROUP OF PRODUCTS THAT DOES NOT SIGNIFY A SINGLE ITEM INCLUDING TYPE, STYLE, QUALITY, PERFORMANCE, AND SOUND RATING SHALL NOT BE CLASSIFIED AS A SCHEDULED ITEM. WHERE MORE THAN ONE MANUFACTURER AND PRODUCT MODEL NUMBER ARE INDICATED, EACH SHALL BE CONSIDERED AS A SCHEDULED ITEM.

4. REJECTION: SUBSTITUTED PRODUCTS OR EQUIPMENT WILL BE REJECTED IF, IN THE OPINION OF THE ARCHITECT, THE SUBMITTAL DOES NOT MEET ANY ONE OF THE FOLLOWING CONDITIONS OR REQUIREMENTS:

A. THE SUBMITTAL DATA IS INSUFFICIENT OR NOT CLEARLY IDENTIFIED. THE ARCHITECT MAY OR MAY NOT REQUEST ADDITIONAL INFORMATION.

B. THE PRODUCT OR EQUIPMENT WILL NOT FIT THE SPACE AVAILABLE AND STILL PROVIDE THE MANUFACTURERS PUBLISHED SERVICE AREA REQUIREMENTS.

C. THE PRODUCT OR EQUIPMENT SUBMITTED IS NOT EQUIVALENT TO OR BETTER THAN THE SPECIFIED ITEM. PRODUCTS OR EQUIPMENT OF LESSER QUALITY MAY BE CONSIDERED PROVIDED AN EQUITABLE FINANCIAL REBATE, SATISFACTORY TO THE ARCHITECT, IS TO BE RETURNED TO THE OWNER.

D. THE PRODUCT OR EQUIPMENT SUBMITTED HAS LESS CAPACITY, EFFICIENCY AND SAFETY PROVISIONS THAN THE SPECIFIED ITEM.

E. THE PRODUCT OR EQUIPMENT SUBMITTED DOES NOT HAVE WARRANTY, SERVICE AND FACTORY REPRESENTATION EQUIVALENT TO THAT SPECIFIED.

F. THE OWNER PREFERS NOT TO ACCEPT THE SUBMITTED PRODUCT.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. SPECIFIED PRODUCTS: MANUFACTURER'S NAMES AND PRODUCT MODEL NUMBERS INDICATED ON THE DRAWINGS AND IN THESE SPECIFICATIONS ESTABLISH THE TYPE, STYLE, QUALITY, PERFORMANCE, AND SOUND RATING OF THE DESIRED PRODUCT. LISTING OF OTHER MANUFACTURERS INDICATES THAT THEIR EQUIVALENT PRODUCTS WOULD BE ACCEPTABLE IF THEY MEET THE SPECIFICATION REQUIREMENTS, THE SPECIFIC USE AND INSTALLATION SHOWN ON THE DRAWINGS, INCLUDING SPACE AND CLEARANCE REQUIREMENTS, AND THE ENERGY CONSUMPTION AND EFFICIENCY OF THE SPECIFIED PRODUCT. THE LISTING OF ADDITIONAL MANUFACTURERS IN NO WAY INDICATES THAT THE MANUFACTURER CAN PROVIDE AN ACCEPTABLE PRODUCT.

B. SPACE REQUIREMENTS: ALL MANUFACTURED PRODUCTS FURNISHED ON THIS PROJECT MUST HAVE THE REQUIRED SPACE AND SERVICE AREAS INDICATED IN THE MANUFACTURER'S PRINTED LITERATURE OR SHOWN ON THEIR SHOP DRAWING. WHEN THE MANUFACTURER DOES NOT INDICATE THE SPACE REQUIRED FOR SERVICING THE EQUIPMENT, THE SPACE SHOWN ON THE DRAWINGS OR AS REQUIRED BY THE ARCHITECT MUST BE PROVIDED.

PART 3 - EXECUTION

3.01 WORKMANSHIP

A. GENERAL: THE INSTALLATION OF MATERIALS AND EQUIPMENT SHALL BE DONE IN A NEAT, WORKMANLIKE AND TIMELY MANNER BY AN ADEQUATE NUMBER OF CRAFTSMEN KNOWLEDGEABLE OF THE REQUIREMENTS OF THE CONTRACT DOCUMENTS. THEY SHALL BE SKILLED IN THE METHODS AND CRAFTSMANSHIP NEEDED TO PRODUCE A FIRST-QUALITY INSTALLATION. PERSONNEL WHO INSTALL MATERIALS AND EQUIPMENT SHALL BE QUALIFIED BY TRAINING AND EXPERIENCE TO PERFORM THEIR ASSIGNED TASKS. ALL MATERIALS AND EQUIPMENT SHALL BE INSTALLED PER THE MANUFACTURER'S WRITTEN REQUIREMENTS.

B. ACCEPTABLE WORKMANSHIP: ACCEPTABLE WORKMANSHIP IS CHARACTERIZED BY FIRST-QUALITY APPEARANCE AND FUNCTION WHICH CONFORMS TO APPLICABLE STANDARDS OF BUILDING SYSTEM CONSTRUCTION AND EXHIBITS A DEGREE OF QUALITY AND PROFICIENCY WHICH IS JUDGED BY THE ARCHITECT AS EQUIVALENT OR BETTER THAN THAT ORDINARILY PRODUCED BY QUALIFIED INDUSTRY TRADESMEN.

C. PERFORMANCE: PERSONNEL SHALL NOT BE USED IN THE PERFORMANCE OF THE INSTALLATION OF MATERIAL AND EQUIPMENT WHO, IN THE OPINION OF THE ARCHITECT, ARE DEEMED TO BE CARELESS OR UNQUALIFIED TO PERFORM THE ASSIGNED TASKS. MATERIAL AND EQUIPMENT INSTALLATIONS NOT IN COMPLIANCE WITH THE CONTRACT DOCUMENTS, OR INSTALLED WITH SUBSTANDARD WORKMANSHIP IN THE OPINION OF THE ARCHITECT, SHALL BE REMOVED AND REINSTALLED BY QUALIFIED CRAFTSMEN AT NO CHANGE IN THE CONTRACT PRICE.

3.02 CORRECTION OF WORK

A. GENERAL: AT NO ADDITIONAL COST TO THE OWNER, RECTIFY DISCREPANCIES BETWEEN THE ACTUAL INSTALLATION AND CONTRACT DOCUMENTS WHEN IN THE OPINION OF THE T&B AGENCY OR THE ARCHITECT THE DISCREPANCIES WILL AFFECT SYSTEM BALANCE AND PERFORMANCE.

B. DRIVE CHANGES: INCLUDE THE COST OF ALL PULLEY, BELT, AND DRIVE CHANGES, AS WELL AS BALANCING DAMPERS, VALVES AND FITTINGS, AND ACCESS PANELS TO ACHIEVE PROPER SYSTEM BALANCE RECOMMENDED BY THE T&B AGENCY.

3.03 COORDINATION AND ASSISTANCE

A. GENERAL: PROVIDE ALL LABOR, EQUIPMENT, TOOLS AND MATERIAL REQUIRED TO OPERATE THE EQUIPMENT AND SYSTEMS NECESSARY FOR THE TESTING AND BALANCING OF THE SYSTEMS AND FOR THE ADJUSTMENT, CALIBRATION OR REPAIR OF ALL ELECTRIC OR PNEUMATIC AUTOMATED CONTROL DEVICES AND COMPONENTS. THESE SERVICES SHALL BE AVAILABLE ON EACH WORKING DAY DURING THE PERIOD OF FINAL TESTING AND BALANCING.

B. DRAWINGS AND SPECIFICATIONS: PROVIDE TO THE T&B AGENCY A COMPLETE SET OF PROJECT RECORD DRAWINGS AND SPECIFICATIONS AND AN APPROVED COPY OF ALL HVAC SHOP DRAWINGS AND EQUIPMENT SUBMITTALS. THE T&B AGENCY SHALL BE INFORMED OF ALL CHANGES MADE TO THE SYSTEM DURING CONSTRUCTION, INCLUDING APPLICABLE CHANGE ORDERS.

C. COORDINATION: COORDINATE THE WORK OF ALL TRADES AND EQUIPMENT SUPPLIERS TO COMPLETE THE MODIFICATIONS RECOMMENDED BY THE T&B AGENCY AND ACCEPTED BY THE ARCHITECT. CUT OR DRILL HOLES FOR THE INSERTION OF AIR MEASURING DEVICES AS DIRECTED FOR TEST PURPOSES; REPAIR TO AS-NEW CONDITION, INSERTING PLASTIC CAPS OR COVERS TO PREVENT AIR LEAKAGE. REPAIR OR REPLACE INSULATION AND RE-ESTABLISH THE INTEGRITY OF THE VAPOR RETARDANT.

3.04 ACCEPTANCE TESTING PROCEDURE

GENERAL: EACH HVAC SYSTEM SHALL BE TESTED TO CONFIRM PROPER OPERATION AND FUNCTION IN ACCORDANCE WITH THE CONSTRUCTION DOCUMENTS AND CONTROL SEQUENCE OF OPERATIONS.

A. THE ENCLOSED CHECKLISTS SHALL BE COMPLETED FOR EACH SYSTEM AND SIGNED OFF BY THE MECHANICAL SUB-CONTRACTOR PROJECT REPRESENTATIVE, THEN VERIFIED AND SIGNED-OFF BY THE MECHANICAL SUB-CONTRACTOR PROJECT SUPERVISOR AND THE CONSTRUCTION MANAGER SYSTEMS ENGINEER. ALL CHECKLISTS SHALL BE INCORPORATED INTO THE PROJECT'S CLOSE-OUT MANUALS SUBMITTED FOR OWNER RECORD.

B. ON-SITE TESTING BY THE ARCHITECT AND ENGINEER SHALL BE PERFORMED AT THE DISCRETION OF THE ARCHITECT/ENGINEER FOR ANY OR ALL SYSTEMS TO CONFIRM TEST RESULTS AND SYSTEM FUNCTION.

C. THE CONTRACTOR IS RESPONSIBLE TO PROVIDE ADEQUATE TIME IN THE COMPLETION OF THE CONSTRUCTION TO PERFORM THESE SYSTEM TESTS PRIOR TO THE FINAL INSPECTIONS IN THE AFFECTED AREAS/SYSTEMS.

D. THE CONTRACTOR IS RESPONSIBLE FOR ENSURING ALL REQUIRED SYSTEM TESTS ARE CONDUCTED SUCCESSFULLY AND RECORDING ASSOCIATED TEST DATA AND RESULTS.

E. THE CONTRACTOR IS RESPONSIBLE FOR CONTACTING THE ARCHITECT AND ENGINEER AT LEAST TWO WEEKS PRIOR TO SYSTEM TEST AVAILABILITY AND SCHEDULE ACCEPTABLE TO ARCHITECT/ENGINEER FOR ON-SITE TESTING.

F. IF, IN THE ARCHITECT'S AND ENGINEER'S OPINION, THE TEST RESULTS INDICATE THAT THE SYSTEMS' INSTALLATION IS NOT ADEQUATELY COMPLETE FOR TESTING, THE TESTING SHALL BE RE-SCHEDULED AND THE CONTRACTOR SHALL BE RESPONSIBLE TO PREPARE FOR SUCH RE-TEST.

G. PRIOR TO OWNER OCCUPANCY, ALL SYSTEM TESTING SHALL BE COMPLETED AND APPROVED.

3.05 PROTECTION OF MATERIALS AND EQUIPMENT

A. REPLACEMENT OF DAMAGED STORED MATERIAL AND EQUIPMENT: ANY MATERIAL AND EQUIPMENT THAT HAS BEEN WET OR OTHERWISE DAMAGED PRIOR TO INSTALLATION, IN THE OPINION OF THE ARCHITECT, SHALL BE REPLACED WITH NEW MATERIAL REGARDLESS OF THE CONDITION OF THE MATERIAL AND EQUIPMENT AT THE TIME OF INSTALLATION.

B. REPAIR OF DAMAGED INSTALLED MATERIAL AND EQUIPMENT: AFTER INSTALLATION CORRECT OR REPAIR DENTS, SCRATCHES AND OTHER VISIBLE BLEMISHES. AT THE DIRECTION OF ARCHITECT REPLACE OR REPAIR TO "AS NEW" CONDITION EQUIPMENT WHICH HAS BEEN DAMAGED DURING CONSTRUCTION.

C. DURING CONSTRUCTION, ALL PIPING AND DUCTWORK SYSTEM OPENINGS SHALL BE CAPPED WITH AT LEAST TWO LAYERS OF POLYETHYLENE FILM, FASTENED TIGHTLY IN PLACE WITH BANDING MATERIAL OR FOIL TAPE UNTIL CONNECTION OF THE CONTINUATION OF SUCH PIPING OR DUCTWORK IS OCCURRING.

3.06 COORDINATION OF SERVICES

A. GENERAL: COORDINATE INTERRUPTION OF SERVICES TO OWNER-OCCUPIED AREAS IN WRITING IN ADVANCE WITH THE ARCHITECT. SHUTDOWN TIME AND DURATION OF SERVICES INTERRUPTION SHALL BE DECIDED BY THE OWNER. PROVIDE SHUTOFF VALVES AT POINTS OF INTERCONNECTION TO MINIMIZE DOWNTIME. PROCEDURES INCIDENTAL TO THE OUTAGE SHALL BE PREPARED IN ADVANCE TO MINIMIZE DOWNTIME.

B. GENERAL: COORDINATE INTERRUPTION OF EXISTING SERVICES IN WRITING AT LEAST 1 WEEK IN ADVANCE WITH THE ARCHITECT. SHUTDOWN TIME AND DURATION OF SERVICES INTERRUPTION SHALL BE DECIDED BY THE OWNER. PROVIDE SHUTOFF VALVES AT POINTS OF INTERCONNECTION TO MINIMIZE DOWNTIME. PROCEDURES INCIDENTAL TO THE OUTAGE SHALL BE PREPARED IN ADVANCE TO MINIMIZE DOWNTIME.

23 21 13 – REFRIGERANT PIPING

TLC ENGINEERING SOLUTIONS
255 S. Orange Avenue
Suite 1600
Orlando, Florida 32801
PH: 407.841.9050
www.tlc-engineers.com
COA #15

THINK. LISTEN. CREATE.

VITAS Healthcare Lecanto
Inpatient Hospice Unit
HVAC Upgrades
3350 W Audubon Park Path
Lecanto, FL 34461

Aaron Johnson, P.E.
Florida License #71576

Project No.:	119626
Issue Date:	2020.10.08
Drawn By:	LLP
Approved By:	JLA
Scale:	AS NOTED
Drawing Title:	MECHANICAL SPECIFICATIONS
Drawing No.:	M002

Mod_10401_Rationale_VITAS - Lecanto mechanicals Example.pdf Page: 2

FAN COILS AND CONDENSING UNIT

PLAN MARK	MODEL NO.	TOTAL COOLING CAPACITY (BTU/H)	TOTAL HEATING CAPACITY (BTU/H)	ELECTRICAL DATA				WEIGHT (LBS)	LOCATION
				VOLT/ PHASE	AMPS	MCA	MOP		
FCU-8	S-09MK2U6	9,600	11,000	208/1	0.25	15	15	20	BEDROOM 8
FCU-6	S-09MK2U6	9,600	11,000	208/1	0.25	15	15	20	BEDROOM 6
FCU-29	S-09MK2U6	9,600	11,000	208/1	0.25	15	15	20	FAMILY LOUNGE
FCU-4	S-09MK2U6	9,600	11,000	208/1	0.25	15	15	20	BEDROOM 4
FCU-2	S-09MK2U6	9,600	11,000	208/1	0.25	15	15	20	BEDROOM 2
FCU-28	S-07MY2U6	7,500	8,500	208/1	0.32	15	15	40	CORRIDOR
FCU-33	S-07MY2U6	7,500	8,500	208/1	0.32	15	15	40	STORAGE
MCU-1	U-52LE1U6	52,900	60,000	208/1	23.5	29	50	229	OUTSIDE
FCU-1	S-09MK2U6	9,600	11,000	208/1	0.25	15	15	20	BEDROOM 1
FCU-3	S-09MK2U6	9,600	11,000	208/1	0.25	15	15	20	BEDROOM 3
FCU-7	S-09MK2U6	9,600	11,000	208/1	0.25	15	15	20	BEDROOM 7
FCU-5	S-09MK2U6	9,600	11,000	208/1	0.25	15	15	20	BEDROOM 5
FCU-26	S-07MK2U6	7,500	8,500	208/1	0.23	15	15	20	NURSE
FCU-27	S-07MK2U6	7,500	8,500	208/1	0.23	15	15	20	MEDS
FCU-25	S-07MY2U6	7,500	8,500	208/1	0.32	15	15	40	CORRIDOR
MCU-2	U-52LE1U6	52,900	60,000	208/1	23.5	29	50	229	OUTSIDE
FCU-10	S-09MK2U6	9,600	11,000	208/1	0.25	15	15	20	BEDROOM 10
FCU-12	S-09MK2U6	9,600	11,000	208/1	0.25	15	15	20	BEDROOM 12
FCU-20	S-07MY2U6	7,500	8,500	208/1	0.32	15	15	20	CORRIDOR
FCU-14	S-07MK2U6	7,500	8,500	208/1	0.23	15	15	20	BEDROOM 14
FCU-16	S-09MK2U6	9,600	11,000	208/1	0.25	15	15	20	BEDROOM 16
FCU-32	S-07MY2U6	7,500	8,500	208/1	0.32	15	15	20	BREAKROOM
MCU-3	U-52LE1U6	52,900	60,000	208/1	23.5	29	50	229	OUTSIDE

NOTES:
1. BASIS OF DESIGN: PANASONIC
2. ECO-FRIENDLY R410A REFRIGERANT
3. PROVIDE WITH CURB/EQUIPMENT SUPPORTS.
4. CONDENSING UNITS DESIGNED FOR OUTDOOR AIR TEMPERATURE AT 95F.
5. PROVIDE LOW AMBIENT OPERATION TO 35'F.
6. ROUTE AND SIZE REFRIGERANT PIPING PER MANUFACTURER'S GUIDELINES.
7. PROVIDE EQUIPMENT SUPPORTS WITH ISOLATORS FOR EACH CONDENSING UNIT.
8. PROVIDE ANTI-SHORT CYCLE TIMER AND SEACOAST KIT.
9. PROVIDE 3/4" CONDENSATE PVC PIPE, EXTEND TO OUTSIDE. INCLUDE 1" ADAPTER.
10. FOUR-WAY CEILING CASSETTE 24"x24"
11. OUTDOOR UNIT: HEAT PUMP, VRF, INVERTER TYPE COMPRESSOR; HIGH PRESSURE SWITCH.
12. EACH INTERIOR UNIT WILL ELECTRONIC EXPANSION VALVE FOR ACCURATE REFRIGERANT CONTROL.
13. FINAL LOCATION OF ALL INDOOR AND OUTDOOR EQUIPMENT SHALL BE COORDINATED WITH OWNER.
14. REFRIGERANT PIPING/TUBING SIZE SHALL BE COORDINATED WITH EQUIPMENT REP BASED ON FINAL EQUIPMENT LOCATION AND LINE ROUTING. FOR THIS PURPOSE CONTRACTOR SHALL TRACE ON FIELD THE BEST SUITABLE ROUTING PRIOR TO INSTALLING ANY PIPE.
15. ALL CONTROL WIRING SHALL BE INSTALLED AS PER MANUFACTURER GUIDELINES.
16. ALL CONDENSATE DRAIN LINES ABOVE CEILING SHALL RUN WITH ADEQUATE SLOPE TO ALLOW PROPER DRAINAGE.

FAN COILS AND CONDENSING UNIT

PLAN MARK	MODEL NO.	TOTAL COOLING CAPACITY (BTU/H)	TOTAL HEATING CAPACITY (BTU/H)	ELECTRICAL DATA				WEIGHT (LBS)	LOCATION
				VOLT/ PHASE	AMPS	MCA	MOP		
FCU-11	S-09MK2U6	9,600	11,000	208/1	0.25	15	15	20	BEDROOM 11
FCU-13	S-09MK2U6	9,600	11,000	208/1	0.25	15	15	20	BEDROOM 13
FCU-15	S-09MK2U6	9,600	11,000	208/1	0.25	15	15	20	BEDROOM 15
FCU-17	S-07MY2U6	7,500	8,500	208/1	0.32	15	15	20	CORRIDOR
FCU-18	S-07MK2U6	7,500	8,500	208/1	0.23	15	15	20	NURSE
FCU-19	S-07MK2U6	7,500	8,500	208/1	0.23	15	15	20	MEDS
MCU-4	U-52LE1U6	52,900	60,000	208/1	23.5	29	50	229	OUTSIDE
FCU-31	S-07MY2U6	7,500	8,500	208/1	0.32	15	15	20	OFFICE
FCU-9	S-09MK2U6	9,600	11,000	208/1	0.25	15	15	20	BEDROOM 9
FCU-22	S-09MK2U6	9,600	11,000	208/1	0.25	15	15	20	LIVING
FCU-21	S-07MK2U6	7,500	8,500	208/1	0.23	15	15	20	CHAPEL
FCU-30	S-07MY2U6	7,500	8,500	208/1	0.32	15	15	20	CORRIDOR
FCU-24	S-07MK2U6	7,500	8,500	208/1	0.23	15	15	20	FAMILY ROOM
FCU-23	S-09MK2U6	9,600	11,000	208/1	0.25	15	15	20	RECEPTION
MCU-5	U-52LE1U6	52,900	60,000	208/1	23.5	29	50	229	OUTSIDE

NOTES:
17. COORDINATE NEW EQUIPMENT INSTALLATION WITH EXISTING HVAC DUCTWORK.
18. ALL REFRIGERANT PIPING SHALL BE PROTECTED FROM PHYSICAL DAMAGE.
19. OUTDOOR UNIT SHALL BE PROPERLY FIXED TO BASE; CLEARANCE AS PER MANUFACTURER REQUIREMENTS.
20. LIQUID/GAS REFRIGERANT PIPES SHALL BE INDIVIDUALLY INSULATED; 3/4" MINIMUM THICKNESS.
21. PRESSURE TEST AND EVACUATE SYSTEM AS PER MANUFACTURER GUIDELINES.
22. COMPLETE ALL TRIAL OPERATION TESTING AS PER MANUFACTURER GUIDELINES.
23. COORDINATE WITH PROJECT ARCHITECT REQUIRED DETAILS FOR CUTTING/PATCHING/PAINTING OF CEILING AND WALLS.
24. WALL MOUNTED UNITS IN AN INTERIOR WALL SHALL HAVE A CONDENSATE DRAIN PUMP TO BE PROVIDED BY SYSTEM VENDOR.

EQUIPMENT LEGEND

Symbol	Description
⊠	CEILING MOUNTED (WITH BUILT IN DRAIN PUMP)
▯	WALL MOUNTED (* PROVIDE DRAIN PUMP)
Ⓣ	TEMPERATURE SENSOR (CZ-CSRC3)
Ⓜ	MAIN SYSTEM CONTROLLER (CZ-64ESMC2U)

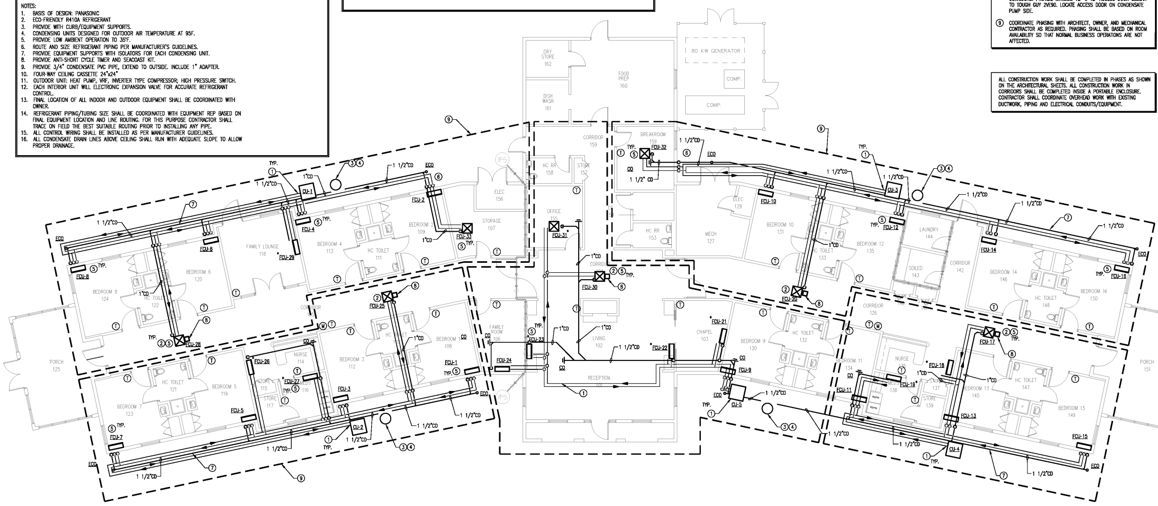
GENERAL NOTES:

- ALL OUTDOOR CONDENSATE PIPING SHALL BE 1 1/2"UNLESS OTHERWISE NOTED.
- ALL INDOOR CONDENSATE BRANCH PIPING SHALL BE 3/4"UNLESS OTHERWISE NOTED.
- ALL INDOOR CONDENSATE AND REFRIGERANT PIPING SHALL BE INSULATED.
- ALL CONTROL WIRING SHALL BE INSTALLED AS PER MANUFACTURER GUIDELINES.

PLAN KEY NOTES:

1. REFRIGERANT PIPE SIZE AND LOCATION SHALL BE COORDINATED WITH EQUIPMENT MANUFACTURER.
2. PORTABLE DUST ENCLOSURE TO BE USED DURING THE CONNECTION IN THE CORRIDOR.
3. DRYWELL EQUAL TO NDS FLOW WELL MODEL #FWAS24WH. CONTRACTOR TO FIELD COORDINATE EXACT LOCATION AND PIPING CONFIGURATION.
4. 1 1/2" CONDENSATE DRAINAGE PIPE BELOW GRADE TO DISCHARGE TO DRYWELL WITH A 45 DEGREE FITTING AND AIRGAP.
5. PROVIDE 3/4" CONDENSATE DRAIN TO EACH FCU, PROVIDE P-TRAP AND ALL ASSOCIATED FITTINGS TO COMPLETE INSTALLATION PER MANUFACTURER RECOMMENDATIONS.
6. COORDINATE PIPE ROUTING WITH EXISTING ELECTRICAL EQUIPMENT IN THIS AREA. ALL PIPING SHALL NOT RUN OVER ELECTRICAL EQUIPMENT.
7. RUN NEW REFRIGERANT DRAIN LINES UNDERGROUND (TYP.) COORDINATE WITH EXISTING UNDERGROUND UTILITIES.
8. PROVIDE LIGHTWEIGHT INSULATED ALUMINUM ACCESS DOOR TO PROVIDE ACCESS TO CEILING MOUNTED CASSETTE UNITS IN CORRIDORS. PROVIDE MINIMUM 12" x 12" ACCESS DOOR SIMILAR TO TOUGH GUY 2VE90. LOCATE ACCESS DOOR ON CONDENSATE PUMP SIDE.
9. COORDINATE PHASING WITH ARCHITECT, OWNER, AND MECHANICAL CONTRACTOR AS REQUIRED. PHASING SHALL BE BASED ON ROOM AVAILABILITY SO THAT NORMAL BUSINESS OPERATIONS ARE NOT AFFECTED.

ALL CONSTRUCTION WORK SHALL BE COMPLETED IN PHASES AS SHOWN ON THE ARCHITECTURAL SHEETS. ALL CONSTRUCTION WORK IN CORRIDORS SHALL BE COMPLETED INSIDE A PORTABLE ENCLOSURE. CONTRACTOR SHALL COORDINATE OVERHEAD WORK WITH EXISTING DUCTWORK, PIPING AND ELECTRICAL CONDUITS/EQUIPMENT.



MECHANICAL FLOOR PLAN
SCALE: 1/8" = 1'-0"

TLC ENGINEERING SOLUTIONS
255 S. Orange Avenue
Suite 1600
Orlando, Florida 32801
PH: 407.841.9050
www.tlc-engineers.com
COA #15

THINK. LISTEN. CREATE.

VITAS Healthcare Lecanto
Inpatient Hospice Unit
HVAC Upgrades

3350 W Audubon Park Path
Lecanto, FL 34461

Revisions:

No.	Date	Description

Seal
Aaron Johnson, P.E.
Florida License #71576
AARON LEE JOHNSON LICENSE No 71576 STATE OF FLORIDA PROFESSIONAL ENGINEER

Project No.:	119626
Issue Date:	2020.10.08
Drawn By:	LLP
Approved By:	JLA
Scale:	AS NOTED

Drawing Title:
MECHANICAL FLOOR PLAN

Drawing No.:
M101

EN10401Rationale

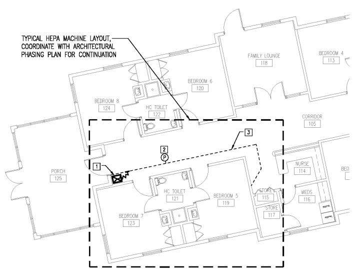
DEMOLITION KEY NOTES:

1. PROVIDE A TEMPORARY HEPA FILTERED NEGATIVE AIR FAN FOR CONSTRUCTION AREA. MAINTAIN A MINIMUM 0.03" NEGATIVE PRESSURE IN THIS AREA RELATIVE TO THE ADJACENT SPACES. PROVIDE VISUAL DISPLAY OF AIRFLOW DIRECTION. PROVIDE ADDITIONAL NEGATIVE AIR MACHINES AS REQUIRED TO ACHIEVE MINIMUM NEGATIVE PRESSURE. PROVIDE TEMPORARY DUST BARRIER PARTITIONS. ALL EXISTING RETURN REGISTERS AND OPENINGS LOCATED WITHIN THE RENOVATION AREA SHALL BE SHUT AND TAPED CLOSED, ISOLATING THE RENOVATION AREA FROM THE AIR HANDLER SYSTEM. ALL EXISTING EXHAUST REGISTERS LOCATED WITHIN THE RENOVATION AREA SHALL BE PROVIDED WITH TEMPORARY CONSTRUCTION FILTERS. ROUTE TEMPORARY 12ø FLEXIBLE DUCT FROM DISCHARGE OF HEPA UNIT TO OUTSIDE OF CONSTURCTION AREA. PROVIDE 2 SETS OF HEPA FILTERS - ONE HEPA FILTER AT NEGATIVE AIR FAN, AND ONE HEPA FILTER AT DISCHARGE INTO CLEAN CORRIDOR.

   FAN CRITERIA:
   MODEL - HEPA-AIRE MODEL PAS2400HC
   CFM - 700-2100 CFM
   HP/V/P - 1.5/120/1
   RELOCATE HEPA UNIT FOR EACH SUBSEQUENT PHASE. PROVIDE WITH DISCONNECTIVE MEANS AND FAN GUARDS.

2. PROVIDE AN INCLINED MANOMETER, DIFFERENTIAL PRESSURE TYPE, WITH WHITE FACE GAUGE AND BLACK LETTERS WITH MAXIMUM PRESSURE RANGE OF 0.1" W.G. THIS SHALL BE USED BY THE CONTRACTOR TO RECORD, ON A DAILY BASIS, THE NEGATIVE PRESSURE IN THE RENOVATION AREA RELATIVE TO THE ADJACENT SPACES. COORDINATE EXACT LOCATION WITH TEMPORARY CONSTRUCTION WALLS.

3. PROVIDE TEMPORARY CONSTRUCTION BARRIER AS SHOWN IN ARCHITECTURAL DRAWINGS.



MECHANICAL FLOOR PLAN-HEPA MACHINE
SCALE: 1/8" = 1'-0"

TLC ENGINEERING SOLUTIONS
255 S. Orange Avenue
Suite 1600
Orlando, Florida 32801
PH: 407.841.9050
www.tlc-engineers.com
COA #15

THINK. LISTEN. CREATE.

VITAS Healthcare Lecanto
Inpatient Hospice Unit
HVAC Upgrades

3350 W Audubon Park Path
Lecanto, FL 34461

Revisions:

No.	Date	Description

Seal
Aaron Johnson, P.E.
Florida License #71576

AARON LEE JOHNSON LICENSE No 71576 STATE OF FLORIDA PROFESSIONAL ENGINEER

Project No.:	119626
Issue Date:	2020.10.08
Drawn By:	LLP
Approved By:	JLA
Scale:	X=X

Drawing Title:
MECHANICAL FLOOR PLAN - HEPA MACHINE

Drawing No.: M102

Mod_10401_Rationale_VITAS - Lecanto mechanicals Example.pdf Page: 4

EN10401Rationale

INFECTION CONTROL RISK ASSESSMENT (ICRA)

ALL WORK SHALL CONFORM WITH THE OWNER'S INFECTION CONTROL AND CONSTRUCTION POLICIES, PROCESSES AND OWNER'S PROJECT-SPECIFIC INFECTION CONTROL RISK ASSESSMENT PLAN.

ICRA MATRIX

IC RISK LEVEL	CONSTRUCTION ACTIVITY TYPE			
	TYPE A	TYPE B	TYPE C	TYPE D
GROUP 1	CLASS I	CLASS II	CLASS II	CLASS III/IV
GROUP 2	CLASS I	CLASS II	CLASS III	CLASS IV
GROUP 3	CLASS I	CLASS III	CLASS III/IV	CLASS IV
GROUP 4	CLASS III	CLASS III/IV	CLASS III/IV	CLASS IV

INFECTION CONTROL RISK LEVELS

GROUP 1 LOWEST	GROUP 2 MEDIUM	GROUP 3 MEDIUM HIGH	GROUP 4 HIGHEST
OFFICE AREAS	ALL PATIENT CARE UNITS	EMERGENCY ROOM	TRANSPLANT CLINIC
CONFERENCE ROOMS	WAITING ROOMS*	RADIOLOGY AREAS	SURGERY SUITES
PUBLIC BATHROOMS		ROCP	RECOVERY ROOMS
WAITING ROOMS*		LABOR AND DELIVERY	LABOR & DELIVERY ORs
		NURSERIES	CARDIAC CATH / ANGIO
		PEDIATRICS	CVICU
		RIO SURGERY	OUTPATIENT UNITS
		ALL INTENSIVE CARE AREAS	DIALYSIS AND TRANSPLANT
		NUCLEAR MEDICINE	ONCOLOGY / BONE MARROW
		ADMISSION / DISCHARGE AREA	CARDIOLOGY
		PHYSICAL THERAPY TANK AREA	HYPERBARIC MEDICINE
		CAFETERIA	ENDOSCOPY
		ECHOCARDIOGRAPHY	PHARMACY ADMIXTURE
		LABORATORIES	
		PHARMACY	

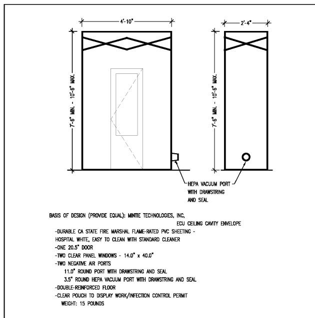
* DEPENDENT ON LOCATION

CONSTRUCTION ACTIVITY TYPES

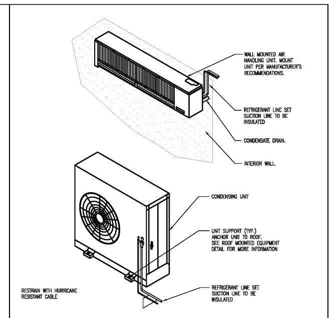
TYPE A	INSPECTIONS AND NON-INVASIVE ACTIVITIES. INCLUDES, BUT IS NOT LIMITED TO, REMOVAL OF CEILING TILES FOR VISUAL INSPECTION LIMITED TO 1 TILE PER 50 SQUARE FEET, PAINTING (BUT NOT SANDING) WALL COVERING, ELECTRICAL TRIM WORK, MINOR PLUMBING, AND ACTIVITIES WHICH DO NOT GENERATE DUST OR REQUIRE CUTTING OF WALLS OR ACCESS TO CEILINGS OTHER THAN FOR VISUAL INSPECTION.
TYPE B	SMALL SCALE, SHORT DURATION ACTIVITIES WHICH CREATE MINIMAL DUST. INCLUDES, BUT IS NOT LIMITED TO, INSTALLATION OF TELEPHONE AND COMPUTER CABLING, ACCESS TO CHASE SPACES, CUTTING OF WALLS OR CEILING WHERE DUST MIGRATION CAN BE CONTROLLED.
TYPE C	ANY WORK WHICH GENERATES A MODERATE TO HIGH LEVEL OF DUST OR REQUIRES DEMOLITION OR REMOVAL OF ANY FIXED BUILDING COMPONENTS OR ASSEMBLIES. INCLUDES, BUT IS NOT LIMITED TO, SANDING OF WALL FOR PAINTING OR WALL COVERING, REMOVAL OF FLOOR COVERINGS, CEILING TILES AND CASEWORK, NEW WALL CONSTRUCTION, MINOR DUCTWORK OR ELECTRICAL WORK ABOVE CEILINGS, MAJOR CABLING ACTIVITIES, AND ANY ACTIVITY WHICH CANNOT BE COMPLETED WITHIN A SINGLE WORKSHIFT.
TYPE D	MAJOR DEMOLITION AND CONSTRUCTION PROJECTS. INCLUDES, BUT IS NOT LIMITED TO, ACTIVITIES WHICH REQUIRE CONSECUTIVE WORK SHIFTS, REQUIRE HEAVY DEMOLITION OR REMOVAL OF A COMPLETE CEILING SYSTEM, AND NEW CONSTRUCTION.

ICRA CLASSIFICATION SCHEDULE

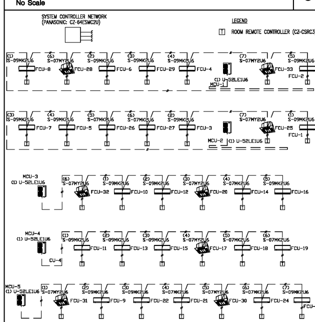
CLASS I ☐	1. EXECUTE WORK BY METHODS TO MINIMIZE RAISING DUST FROM CONSTRUCTION OPERATIONS. 2. IMMEDIATELY REPLACE ANY CEILING TILE DISPLACED FOR VISUAL INSPECTION. 3. MINOR DEMOLITION FOR REMODELING.
CLASS II ☑	1. PROVIDES ACTIVE MEANS TO PREVENT AIRBORNE DUST FROM DISPERSING INTO ATMOSPHERE. 2. WATER MIST WORK SURFACES TO CONTROL DUST WHILE CUTTING. 3. SEAL UNUSED DOORS WITH DUCT TAPE. 4. BLOCK OFF AND SEAL AIR VENTS. 5. WIPE SURFACES WITH DISINFECTANT. 6. CONTAIN CONSTRUCTION WASTE BEFORE TRANSPORT IN TIGHTLY COVERED CONTAINERS. 7. WET MOP AND/OR VACUUM WITH HEPA FILTERED VACUUM BEFORE LEAVING WORK AREA. 8. PLACE DUST MAT AT ENTRANCE AND EXIT OF WORK AREA. 9. REMOVE OR ISOLATE HVAC SYSTEM IN AREAS WHERE WORK IS BEING PERFORMED.
CLASS III ☐	1. OBTAIN INFECTION CONTROL PERMIT BEFORE CONSTRUCTION BEGINS. 2. ISOLATE HVAC SYSTEM IN AREA WHERE WORK IS BEING DONE TO PREVENT CONTAMINATION OF THE DUCT SYSTEM. 3. COMPLETE ALL CRITICAL BARRIERS OR IMPLEMENT CONTROL CUBE METHOD BEFORE CONSTRUCTION BEGINS. 4. MAINTAIN NEGATIVE AIR PRESSURE WITHIN WORK SITE UTILIZING HEPA EQUIPPED AIR FILTRATION UNITS AND MONITOR WITH MAGNEHELIC GAUGES. 5. DO NOT REMOVE BARRIERS FROM WORK AREA UNTIL COMPLETE PROJECT IS THOROUGHLY CLEANED BY ENVIRONMENTAL SERVICES DEPARTMENT. 6. VACUUM WORK WITH HEPA FILTERED VACUUMS. 7. WET MOP WITH DISINFECTANT. 8. REMOVE BARRIER MATERIALS CAREFULLY TO MINIMIZE SPREADING OF DIRT AND DEBRIS ASSOCIATED WITH CONSTRUCTION. 9. CONTAIN CONSTRUCTION WASTE BEFORE TRANSPORT IN TIGHTLY COVERED CONTAINERS. 10. COVER TRANSPORT RECEPTACLES OR CARTS. TAPE COVERING. 11. REMOVE OR ISOLATE HVAC SYSTEM IN AREAS WHERE WORK IS BEING PERFORMED.
CLASS IV ☐	1. OBTAIN INFECTION CONTROL PERMIT BEFORE CONSTRUCTION BEGINS. 2. ISOLATE HVAC SYSTEM IN AREA WHERE WORK IS BEING DONE TO PREVENT CONTAMINATION OF THE DUCT SYSTEM. 3. COMPLETE ALL CRITICAL BARRIERS OR IMPLEMENT CONTROL CUBE METHOD BEFORE CONSTRUCTION BEGINS. 4. MAINTAIN NEGATIVE AIR PRESSURE WITHIN WORK SITE UTILIZING HEPA EQUIPPED AIR FILTRATION UNITS AND MONITOR WITH MAGNEHELIC GAUGES. 5. SEAL HOLES, PIPES, CONDUITS, AND PUNCTURES APPROPRIATELY. 6. CONSTRUCT ANTEROOM AND REQUIRE ALL PERSONNEL TO PASS THROUGH THIS ROOM SO THEY CAN BE VACUUMED USING A HEPA VACUUM CLEANER BEFORE LEAVING WORK SITE OR THEY CAN WEAR CLOTH OR PAPER COVERALLS THAT ARE REMOVED EACH TIME THEY LEAVE THE WORK SITE. 7. ALL PERSONNEL ENTERING WORK SITE ARE REQUIRED TO WEAR SHOE COVERS. 8. DO NOT REMOVE BARRIERS FROM WORK AREA UNTIL COMPLETED PROJECT IS THOROUGHLY CLEANED BY THE ENVIRONMENTAL SERVICES DEPARTMENT AND RELEASED BY SAFETY AND INFECTION CONTROL. 9. VACUUM WORK AREA WITH HEPA FILTERED VACUUMS. 10. WET MOP WITH DISINFECTANT. 11. REMOVE BARRIER MATERIALS CAREFULLY TO MINIMIZE SPREADING OF DIRT AND DEBRIS ASSOCIATED WITH CONSTRUCTION. 12. CONTAIN CONSTRUCTION WASTE BEFORE TRANSPORT IN TIGHTLY COVERED CONTAINERS. 13. COVER TRANSPORT RECEPTACLES OR CARTS. TAPE COVERING. 14. REMOVE OR ISOLATE HVAC SYSTEM IN AREAS WHERE CONSTRUCTION IS BEING DONE.



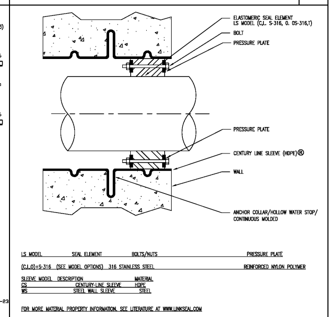
PORTABLE DUST ENCLOSURE 3
No Scale



DUCTLESS DX SPLIT SYSTEMS 1



WIRING DIAGRAMS 4
No Scale



LINK SEAL PENETRATION DETAIL 2
No Scale

TLC ENGINEERING SOLUTIONS

255 S. Orange Avenue
Suite 1600
Orlando, Florida 32801
PH: 407.841.9050
www.tlc-engineers.com
COA #15

THINK. LISTEN. CREATE.

VITAS Healthcare Lecanto
Inpatient Hospice Unit
HVAC Upgrades

3350 W Audubon Park Path
Lecanto, FL 34461

Revisions:

No.	Date	Description

Seal
Aaron Johnson, P.E.
Florida License #71576

Project No.:	119626
Issue Date:	2020.10.08
Drawn By:	LLP
Approved By:	JLA
Scale:	AS NOTED

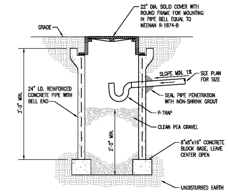
Drawing Title:
MECHANICAL CONTROLS AND DETAILS

Drawing No.:
M201

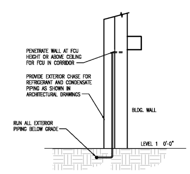
Page: 5

Mod_10401_Rationale_VITAS - Lecanto mechanicals Example.pdf

EN10401Rationale



DRY WELL 1
No Scale



PIPE WALL PENETRATION 2
No Scale

TLC ENGINEERING SOLUTIONS
255 S. Orange Avenue
Suite 1600
Orlando, Florida 32801
PH: 407.841.9050
www.tlc-engineers.com
COA #15

THINK. LISTEN. CREATE.

VITAS Healthcare Lecanto
Inpatient Hospice Unit
HVAC Upgrades

3350 W Audubon Park Path
Lecanto, FL 34461

Revisions:

No.	Date	Description

Seal
Aaron Johnson, P.E.
Florida License #71576

Project No.: 119626
Issue Date: 2020.10.08
Drawn By: LLP
Approved By: JLA
Scale: X=X
Drawing Title: MECHANICAL DETAILS
Drawing No.: M202

Page: 6

Mod_10401_Rationale_VITAS - Lecanto mechanicals Example.pdf

See page 8 of this pdf.

The Strategic Guide to Commissioning

Report from the ASHRAE Presidential Ad-Hoc Committee
Building Performance Alliance on Commissioning

Presented to ASHRAE Board of Directors
June 24, 2014

ASHRAE

The Building Performance Alliance Committee on Commissioning

The Strategic Guide to Commissioning

Committee Roster (2012–2014)

ASHRAE President William P. Bahnfleth, PhD., P.E. (2013–14)

ASHRAE President Thomas E. Watson, P.E. (2012–13)

Ross D. Montgomery, P.E., CPMP, CxA, Chairman 2013–14: Vice-chairman 2012–13: Quality Systems and Technology Inc.
Hugh F. Crowther, Chairman 2012–13: Price Mechanical.
Ray Bert: AABC Commissioning Group; ACG
James W. Bochat: Commissioning Concepts; NEBB
Hoy R. Bohanon, Jr, P.E..: Working Buildings
Ron Burton: PTW Advisors, LLC; BOMA
Michael Chelednik: URS Corporation; AIA
Michael F. DeSantiago, P.E.: Primera Engineers, Ltd.; CAMEE
James E. Feeney, P.E.: Manager Cx Group, Primera Engineers, Ltd.
James R. Fields: Superior Mechanical Services
Liz Fischer, BCA Building Commissioning Association
Eli P. Howard, III: SMACNA Sheet Metal and A/C Contractors Association
Earle Kennett: National Institute of Building Sciences NIBS
Gerald J. Kettler: Air Engineering & Testing Inc.
Michael J. King: ARCOM Master Systems
James I. Magee: Facility Commissioning Group
Thomas R. Meyer: National Environmental Balancing Bureau NEBB
Mark F. Miller: Strategic Building Solutions; BCA
Davor Novosel: National Center for Energy Management and Building Technology
Brendan Owens: USGBC United States Green Building Council
James Page: NEMIC National Energy Management Institute Committee
Thomas H. Phoenix, P.E.: Moser Mayer Phoenix Assoc. PA
Richard M. Rose: Mechanical Technology Inc.
Ginger Scoggins, P.E., LEED-AP: Engineered Designs, Inc.
Dominic Sims: ICC International Code Council
David Underwood, P. Eng. (retired), ASHRAE
Timothy G. Wentz, P.E.: University of Nebraska
Claire Ramspeck: ASHRAE staff; Director of Technology
Denise Latham: ASHRAE staff; Administrative Assistant to the Director of Technology

Table of Contents

Foreword

This is the first edition of the Strategic Guide to Commissioning produced by the Building Performance Alliance committee on Commissioning. BPA began as a Presidential Ad Hoc committee appointed by ASHRAE President Thomas E. Watson, and completed under the direction of ASHRAE President William P. Bahnfleth. Its charge was to "meet with interested and affected parties in the commissioning industry and identify ways to improve the commissioning process through working together".

This guide was developed in collaboration with twenty-eight ASHRAE members with direct representatives from fourteen major commissioning related organizations and stakeholders ("BPA team") that can best represent the common needs of the commissioning industry. The "Roadmap", or outline, was created during its 2012–13 term (Figure 2); this guide was created during its 2013–14 term, based on that "Roadmap".

The BPA team collaborated with industry leaders to develop a strategic document that communicates over-arching commissioning goals and objectives. This effort will lead to improving overall building and system performance, as well as protecting the existing and established industry interests and processes/procedures.

This guide serves as a quality-focused, high level strategic commissioning document that provides stakeholders with a basis for understanding enhanced delivery of new and existing building projects. It describes the value, benefits and rationale for verifying and documenting that all of the commissioned systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the Owner's Project Requirements (OPR) for new buildings and/or major renovations, and the Current Facility Requirements (CFR) for existing buildings.

Key users of this guide are anyone involved in design, construction, optimizing and operating buildings, including:

- Owners
- Facility Managers
- Maintenance and Operations Personnel
- Architects and Engineers
- Commissioning Authorities and Providers (Certified)
- Facility Design Engineers
- Building Controls Contractors
- General Contractors
- Design-Build Contractors
- Construction Managers
- Subcontractors
- Utility Operators and Providers
- Inspectors and Code Officials (Authorities Having Jurisdiction, or AHJ's)Developers
- Occupants, Users, and Visitors

Types of Commissioning (Figure 1) addressed by this guide include, but are not limited to::

Site Development and Land Use

Construction, Demolition, and Renovation Waste Management

Enclosure (including Roofing, Exterior Walls, Openings and Ground Floor)

Building Pressurization (including Thermography and Air Tightness testing),

Interior Systems (including Architectural Walls, Ceilings, Floors/ Interior Doors, Windows, Openings)

Structural

Heating, Ventilation, Air Conditioning and Refrigeration

Energy Systems (including renewables)

Indoor Environmental Quality (IEQ)

Electrical Systems and Emergency Power/Generation, Smoke Control, Fire Protection, Fire Suppression, Fire Alarm, Lighting Systems

Specialty Processes

Vertical Conveyances (including Elevators, Hoist Ways, and Escalators)

Plumbing, Domestic Water, and non-potable Systems

Security Systems

Telecommunications, IT, Audio Visual

Figure 1: Commissioning Types

This guide is intended to have far-reaching impact on the Industry to establish and maintain consistent high level goals and objectives, including performance, cost effectiveness, consistency, and best practice.

Section 1: Introduction

The Building Performance Alliance Roadmap, Figure 2 – *next page*, was developed through a cooperative process by a wide spectrum of building performance stakeholders. The twenty eight members and fourteen organizations that participated in the development of the Roadmap and this guide over the course of two years are bound together in the belief that our industry, and ultimately our clients, are evolving to expect a higher level of performance from their buildings. Evidence of this evolution is seen in the emergence of performance benchmarking and energy reduction incentives from both public and private sources. The Roadmap is a tangible commitment to prepare the users of this guide for a future where building performance and functionality is the baseline foundation and a fundamental need of our industry.

Section 2: Strategic Overview

Buildings often do not perform as expected, in spite of the best efforts put forth by the parties involved in the process. In order for a building to meet its true performance potential, all facets of the planning, design, construction, maintenance and operation must work holistically, focused on common goals for the building's performance.

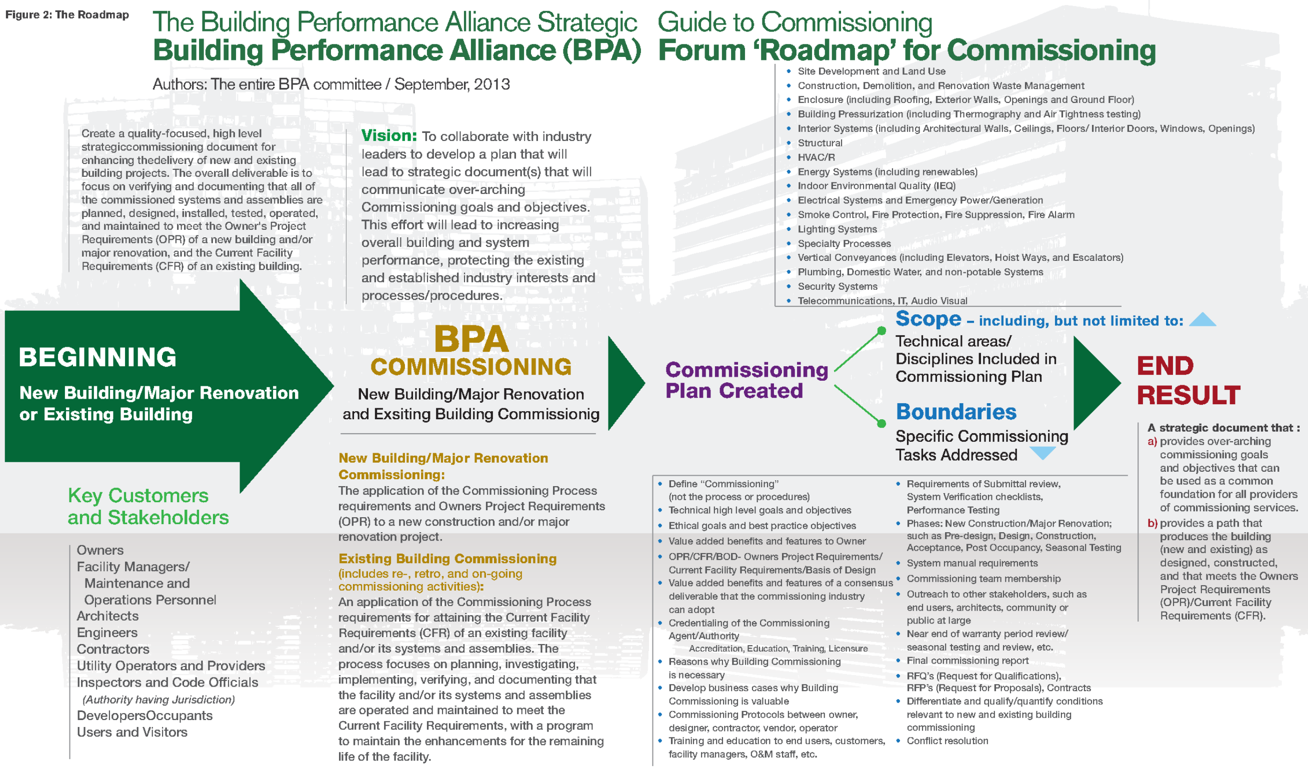
The reasons that many buildings do not perform properly are sometimes complex. Historically, the building industry has not placed enough importance about addressing building performance early in the project development. Waiting too long to engage the commissioning process at project inception can result in "fixing" problems and delivering performance at the end of the project in lieu of preventing them from happening from the beginning. At times in the past the process has been approached in a very prescriptive manner with segregated duties and responsibilities, resulting in performance expectations that may not be communicated well enough and thus are sometimes not met. This guide choses an all-inclusive path by concentrating on building performance as the priority outcome.

Interpretation of the OPR or CFR is a shared responsibility of the Commissioning Authority, owner/client, and designer, and is a sensitive area for all participants in the commissioning process. It is valuable to consider that a commissioned project must have the cooperation and collaboration of all parties in the facility planning, design and construction efforts.

Consistently achieving high levels of building performance, given the current state of the design, construction and facilities management professions, is difficult and complicated, but obtainable.

continued on page 10

Figure 2: The Roadmap



This guide:

- Demonstrates that the commissioning process is a good tool to begin efforts to achieve consistently higher building capabilities according to intent, which can provide the most direct path to improving building performance.
- Provides a strategic outline and vision for commissioning new and existing projects by providing a common foundation for use by all providers of commissioning services.
- Assists and informs building project participants on how to produce and sustain high-quality buildings by ensuring that all of the commissioning systems and assemblies are planned, designed, installed, tested, operated and maintained to meet the Owner's Project Requirements (OPR) for a new building and the Current Facility Requirements (CFR) for an existing building.

Section 3: The Commissioning Process

Building Commissioning is a process, defined as "a quality-focused process for enhancing the delivery of a new and existing building project. The overall process focuses upon verifying and documenting that all of the commissioned systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the Owner's Project Requirements (OPR) of a new building and/or major renovation, and the Current Facility Requirements (CFR) of an existing building."

It is recognized that specific and detailed commissioning procedural methods and means may differ slightly from organization to organization, and we have agreed these variations are outside the scope of this high level strategic document.

In terms of building performance, the commissioning process helps owners and project teams achieve quality performance in new and existing buildings. Post-occupancy on-going commissioning can also contribute to sustaining optimal performance over time, delivering energy efficiency and operational savings.

The commissioning process includes defined activities and deliverables that are accomplished throughout the pre-design, design, construction and operations of the building. The commissioning actions and documents provide the plans, procedures, coordination, verification, and project records that will produce high performing buildings.

Special systems and assembly commissioning expertise, such as building enclosure commissioning (BECx), is often required for commercial facilities due to the complex nature and interface of enclosure materials and assemblies.

The new building construction commissioning (NCx) process differs from existingbuilding commissioning (EBCx), because the forensic (investigative) components of EBCx are unnecessary for new projects. EBCx is also variously known as retro commissioning (RCx), and recommissioning.

On-going commissioning is a process of continuously testing and/or tuning building systems to maintain building performance as expected, in keeping with the OPR/CFR.

Refer to Appendix A for definitions of terms.

Refer to Appendix B for a description of the commissioning process activities and deliverables.

Refer to Appendix C for commissioning resources.

Section 4: Value and Benefits

Commissioning provides value and benefits to the owner, the project design and construction team, and ultimately the occupants and building operators in many ways as described herein.

The added value and many benefits to the owner by commissioning a building are manifested in higher-performing buildings that efficiently serve the occupants and, by extension, the economies they serve.

Our Appendix C has many examples and resources that explain in great detail how commissioning can be credibly proven to be valuable and useful, but perhaps is best expressed by the author of resource #8 citing, "16% median whole-building energy savings in existing buildings and 13% in new construction, with payback times of 1.1 years and 4.2 years, respectively. Median benefit-cost ratios of 4.5 and 1.1, and cash-on-cash returns of 91% and 23% were achieved"; and goes on to say that "commissioning is arguably the single most cost effective strategy for reducing energy, costs, and greenhouse gas emissions in buildings today".

Buildings are as diverse as the people who utilize them. The value and benefits of the commissioning process can be demonstrated in direct proportion to the cost and advantages of performing commissioning weighed against the cost and risks of not performing commissioning. The design and construction process is enhanced by the expertise and facilitation of the commissioning authority in integrating its multi-faceted levels and phases in order to obtain its maximum potentials.

Facilitation of the design and construction phases, and review from phase to phase, add value to the process and the building performance outcome. These activities are performed by a commissioning authority that is an experienced professional using industry "standards of care" and accepted best practices. Issues and their resolutions are facilitated and documented with communication to all members of the commissioning team. The Owner can then receive the design and construction results at the scheduled time period, and within its budget. All of this provides a direct path toward informed and good practices during maintenance & operations.

Commissioning documentation and verification can lead to obtaining various energy, comfort, IAQ, and IEQ, and high performing building awards, while enhancing the learning experience, and helping to perpetuate the buildings' sustainability aspects.

4.1 Value and Benefits: Owner's Project Requirements/Current Facility Requirements (OPR/CFR)

The process of developing the OPR/CFR, updating, and validating fulfillment of the OPR/CFR from conception through occupancy and operation, keeps the owner, design team, and construction team focused on the delivery of the end product. The commissioning authority focuses on the OPR/CFR at every stage of project delivery, diminishing or eliminating undocumented changes in design requirements.

The commissioning authority monitors, and reports the metrics of performance and operation for the commissioning process, creating the path that produces the building as designed and constructed to meet the Owners OPR and/or CFR.

4.2 Value and Benefits: Process

The commissioning process streamlines and accelerates the work flow of the project from start to finish. Scheduling and meeting milestones are enhanced by monitoring and intervention/facilitation by the commissioning authority. For example:

- Design and submittal reviews assure compliance with OPR/CFR and plans and specifications, as well as prequalification of equipment, systems, personnel, and code/standards compliance.
- Checklists are issued and documented, establishing prerequisites for timely provision of equipment and systems installation.
- Performance testing assures compliance with design objectives and requirements.
- Start-ups are performed as an integral part of the process and documented before any performance testing is started.
- Training is facilitated to ensure continued operations.

4.3 Value and Benefits: Project Team (Planning, Design, Construction)

As a result of the commissioning process, the owner, designer, contractor, and operator realize fewer costs due to downtime, delays, change orders, clarifications, and requests for extension of time for completion. Owners, designers and contractors realize that the commissioning authority is working in their best interests to assist in facilitating and executing the project schedule and milestones based on unbiased execution of the OPR and/or CFR.

Designers benefit by commissioning review due to commissioning diligence by verifying the design works properly and is provided in accordance with the OPR/CFR. Designers experience reduced requests for clarification, information, and questions about system design and its intended operations.

The commissioning process, including testing, identification of premature equipment failures, and due diligence, benefits contractors, equipment vendors and subcontractors by reducing material and labor costs, punch lists, callbacks, and warranty work.

Performance testing and any re-testing of poor results assure that the project works in compliance with the project requirements. The construction team, vendors and product manufacturers realize the benefit of concentrating on products and activities that meet the OPR/CFR as a guideline, forefront in everyone's mind, which can reduce product substitutions and value engineering. Vendors and material providers benefit from proper equipment start-ups, performance testing, and operation/maintenance training to verify compliance with contract documents which accelerates the successful project turnover process. Finally, warranty claims, completion delays, call-backs, and building down-time due to repairs are reduced because the systems are tested and performance is verified prior to occupancy.

4.4 Value and Benefits: Performance and Operation Outcomes

The operational outcomes in terms of minimizing costs and maximizing building performance are many. Results include, for example:

- Training is facilitated and enhanced by requiring a plan and curriculum followed by monitoring and documentation of results.
- O&M staffs are provided with comprehensive systems manuals and O&M documentation that allows seamless transfer of knowledge base about its equipment and systems understanding.
- Users and occupants of facilities benefit from having a working or living environment in which conditions are designed, constructed, and efficiently and sustainably operated with their specific uses in mind.

Section 5: Performance Requirements

Commissioning performance requirements are a function of the specific project. The performance requirements document goals, expectations, values, and benefits that will be achieved in a successful project. Performance requirements will be different for a new building as opposed to an existing building. Both new and existing types of buildings can benefit from the commissioning process.

In general, these requirements are intended to maximize the effective performance of the building by allowing people to optimize their productivity as the facility operates properly, and mandating that the building meets performance thresholds determined by established metrics and specific owner's needs.

The OPR or CFR must clearly define the expected building performance and outcomes from the commissioning process. These documents will require considerable effort from the owner or project manager and the Commissioning Authority working collaboratively. These define the project criteria to be used in developing an appropriate commissioning plan for systems that are to be commissioned. The purpose of the facility, activities performed, and operator's ability must be some of the many items to be included in the commissioning plan.

Commissioning can be used to document and achieve these goals without jeopardizing other performance requirements such as indoor environmental quality. The commissioning process can be utilized to assure that the goals of technology integration, interoperability, sustainability, and coordination are achieved while, at the same time, minimizing effects of unintended consequences.

5.1 The Owner's Project Requirements should contain performance requirements for the building, such as:

- Performance requirements needed to achieve a high performance energy rating/label in an energy rating system.
- The performance requirements needed to prove compliance with energy codes and statutes.
- Certain requirements with regard to indoor environmental quality (IEQ), building envelope performance, or other requirements specific to the new building.
- Adequate scoping to explicitly list the inclusion of "green" building commissioning as a subset of the total building commissioning scope.

5.2 Existing facilities may have a wide variety of requirements. These requirements may differ from the original project requirements when the building was originally designed and built due to a number of reasons, such as:

- The building, or parts of the building, may be used for a different purpose.
- Some changes in occupancy type may differ from the way the building was being used for the same purpose.
- Technology enhancements with respect to better performing equipment and systems may be available.
- New regulations or codes may impose new requirements and/or energy goals.
- The owner may want to include additional "green" building requirements, in the change, retrofit, or upgrade.

Section 6: Commissioning Authority Characteristics

The Commissioning Authority is in charge of the commissioning process and makes the final recommendations to the owner regarding functional and practical performance of the commissioned building systems. In the selection of a commissioning authority it is important that it be based on the qualifications and experience of the proposed candidate. For each project, the commissioning purpose and scope should be clearly defined in the Commissioning Authority's contract for services. There are many key skills, characteristics, and ethics required to perform successful and effective commissioning, as discussed herein.

The Commissioning Authority is an objective and independent advocate for the owner. The Commissioning Authority should work directly for the owner, keeping the owner's objectives and best interests as the top priority. The Commissioning Authority does not provide peer review, but ensures that OPR/CFR is being met by all parties involved in the project. The Commissioning Authority is to facilitate the process, to insure that all parties provide good communication, demonstrate good judgment and professionalism, resolve issues as a team approach, and document performance.

In addition to having good written and verbal communication skills, the Commissioning Authority should have current engineering knowledge, with extensive and relevant hands-on field experience in the area of expertise of their commissioning discipline. The commissioning authority should be credentialed and certified by a reliable, nationally recognized, and credible professional association/organization specializing in the commissioning business.

The Commissioning Authority recommends clearly defined roles and scope for all members of the design and construction teams for the execution of the commissioning process; this allows for each team member to have a better understanding of the commissioning process. Additionally, it helps to identify and resolve problems in the process, and document the performance of the building. Since the commissioning authority provides constructive input for the resolution of system problems and deficiencies, diplomacy and consensus building during these discussions are critical. However, this role does not give the Commissioning Authority any rights or responsibilities to overrule and/or perform the specific work of this team of professionals.

The Commissioning Authority must also know how to interview building staff on their knowledge of the systems they maintain to determine the appropriate level of training once the project is complete. Training and mentoring the building staff during the turnover phase combines the Commissioning Authority's technical skills with communication skills which are critical to the long term success of the building.

A conflict of interest may exist if the Commissioning Authority's firm has other project responsibilities or function, and/or is not under direct contract to the owner. The commissioning authority needs to be a provider without any financial or business interests or potential conflicts of interest that would interfere with the faithful execution of his/her duties. Wherever this occurs the Commissioning Authority should disclose, in writing, the nature of the conflict and the means by which the conflict shall be managed.

Situations may arise during many of the decision-making points in the commissioning process that may require that the Commissioning Authority address some difficult decisions, deliberations, and/or conversations; these should be handled with the utmost professionalism and ethics.

Quality assurance and optimization are essential elements of any commissioning effort, including efforts to improve energy efficiency, indoor environmental quality, comfort, and operations.

Section 7: Commissioning Expectations

Utilizing the commissioning process as outlined in this Strategic Guide to Commissioning will result in better buildings and building systems. It will support a quality focused mutually acceptable commissioning process and procedure. The ultimate intent is to make the owner confident and satisfied that "they got what they paid for," reduced risk, and met/exceeded their scheduling targets and financial goals.

The strategic commissioning suggestions outlined herein will provide benefits to the key customers and stakeholders of buildings, most importantly being the owner. Commissioning has been proven to save time and costs for the owner, designer, and contracting team members. Studies and resources listed in this guide have provided results and research that has concluded that commissioning is beneficial and should be used as much as possible.

It is expected that this guide will provide principles of commissioning for a broad audience of users of the building commissioning verification approach to improving building performance and the built environment. These principles can be used to enhance building performance at many levels, such as benchmarking, exploring opportunities for increased efficiencies, achieving goals and objectives of management, exploring alternatives, and promoting best practices. With the use of these principles and methodologies, the benefits of better building performance, enhanced maintenance and operations, improved occupant comfort, and energy efficiency/reduction can be achieved

Effective commissioning provides opportunities for enhanced integrated design, improved and timely construction procedures, lower warranty costs, and proper operator training which all lead to satisfied building occupants. The systems that the owner decides to commission on each project may differ.

Commissioning is the most reliable path and process to produce properly performing building systems and assemblies that are as planned, designed, installed and operated.

It is intended that this guide can be used to communicate over-arching commissioning goals and objectives that can be used as a common foundation for all providers of commissioning services. A fully utilized commissioning process and procedure from project inception through to building testing and occupancy is the best and most cost effective way to improve building performance and operation.

APPENDIX A: Definitions[1]

Acceptance: A formal action, taken by a person with appropriate authority (which may or may not be contractually defined) to declare that some aspect of the project meets defined requirements, thus permitting subsequent activities to proceed.

Basis of Design (BOD): A document that records the concepts, calculations, decisions, and product selections used to meet the Owner's Project Requirements and to satisfy applicable regulatory requirements, standards, and guidelines. The document includes both narrative descriptions and lists of individual items that support the design process.

Checklists: Project and element-specific checklists that are developed and used during all phases of the commissioning process to verify that the Owner's Project Requirements or Current Facility Requirements (CFR) are being achieved. Checklists are used for general evaluation, testing, training, and other design and construction requirements.

Commissioning Authority (or Agent): An entity identified by the Owner who leads, plans, schedules, and coordinates the commissioning team to implement the Commissioning Process.

Commissioning Plan: A document that outlines the organization, schedule, allocation of resources, and documentation requirements of the Commissioning Process.

Commissioning Process: A quality process for enhancing the delivery of new and existing building projects. It focuses on verifying and documenting that all of the commissioned systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the Owner's Project Requirements (OPR) of a new building and/or major renovation, and the Current Facility Requirements (CFR) of an existing building.

Commissioning Progress Report: A written document that details activities completed as part of the Commissioning Process and significant findings from those activities, and is continuously updated during the course of a project.

Commissioning Team: The individuals and agencies, which through coordinated actions, are responsible for implementing the Commissioning Process.

Commissioning Testing: The evaluation and documentation of the equipment and assemblies: delivery and condition; installation; proper function according to the manufacturer's specifications, and project documentation to meet the criteria in the Owner's Project Requirements or Current Facility Requirements (CFR).

Commissioning: New Building/Major Renovation: The application of the Commissioning Process requirements and Owners Project Requirements (OPR) to a new construction and/or major renovation project.

Commissioning: Existing Building: (includes re-, retro, and on-going commissioning activities): An application of the Commissioning Process requirements for attaining the Current Facility Requirements (CFR) of an existing facility and/or its systems and assemblies. The process focuses on planning, investigating, implementing, verifying, and documenting that the facility and/or its systems and assemblies are operated and maintained to meet the Current Facility Requirements, with a program to maintain the enhancements for the remaining life of the facility. Re-commissioning refers to commissioning performed on an existing building that had commissioning performed when it was new. Retro-commissioning methodology is identical to that for re-commissioning, except that it occurs when the building was not commissioned when new, and is being commissioned for the first time. On-going commissioning is a process of continuously testing and/or tuning building systems to maintain building performance as expected and previously commissioned.

Construction Documents: This includes a wide range of documents, which will vary from project to project, and with the Owner's needs and regulations, laws, and jurisdictional requirements. Construction documents usually include the project manual (specifications), plans (drawings), and General Terms and Conditions of the contract.

Contract Documents: This includes a wide range of documents, which will vary from project to project and with the Owner's needs, regulations, laws, and jurisdictional requirements. Contract Documents frequently include price agreements, construction management process, sub-contractor agreements or requirements, requirements and procedures for submittals, changes, and other construction requirements, timeline for completion, and the Construction Documents.

Coordination Drawings: Drawings showing the work of all trades to illustrate that equipment can be installed in the space allocated without compromising equipment function or access for maintenance and replacement. These drawings graphically illustrate and dimension manufacturers' recommended maintenance clearances.

Current Facility Requirements (CFR): A written document that details the current functional requirements of an existing facility and the expectations of how it should be used and operated. This includes goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information to meet the requirements of occupants, users, and owners of the facility.

Design Checklist: A form developed by the commissioning team to verify that elements of the design are in compliance with the Owner's Project Requirements.

Design Review – PEER: An independent and objective technical review of the design of the Project or a part thereof, conducted at specified stages of design completion by one or more qualified professionals, for the purpose of enhancing the quality of the design.

Design Review – Constructability: The review of effective and timely integration of construction knowledge into the conceptual planning, design, construction and field operation of a project to achieve project objectives efficiently and accurately at the most cost effective levels to reduce or prevent errors, delays and cost overruns.

Design Review – Code or Regulatory: A review of a document conducted by staff or designated entity of an Authority Having Jurisdiction to determine whether the content of the document complies with regulations, codes, or other standards administered by the Jurisdiction.

Design Review – Commissioning: A review of the design documents to determine compliance with the Owner's Project Requirements, including coordination between systems and assemblies being commissioned, features and access for testing, commissioning and maintenance, and other reviews required by the OPR and commissioning plan.

Existing building commissioning: An application of the Commissioning Process requirements for attaining the Current Facility Requirements (CFR) of an existing facility and/or its systems and assemblies. The process focuses on planning, investigating, implementing, verifying, and documenting that the facility and/or its systems and assemblies are operated and maintained to meet the Current Facility Requirements, with a program to maintain the enhancements for the remaining life of the facility.

Evaluation: The process by which specific documents, components, equipment, assemblies, systems, and interfaces among systems and their performance are confirmed with respect to the criteria required in the Owner's Project Requirements and/or the Current Facility Requirements (CFR).

Facility Guide: A basic building systems description and operating plan with general procedures and confirmed facility operating conditions, set points, schedules, and operating procedures for use by facility operations to properly operate the facility.

Final Commissioning Report: A document that records the activities and results of the Commissioning Process and is developed from the final Commissioning Plan with all of its attached appendices.

Issues and Resolution Log: A formal and on-going record of problems or concerns and their resolutions that have been raised by members of the Commissioning Team during the course of the Commissioning Process.

New building commissioning: the application of the commissioning process requirements and owners project requirements to a new construction and/or major renovation project.

Owner's Project Requirements (OPR): A written document that details the requirements of a project and the expectations of how it will be used and operated. This includes project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information.

Performance Test (PT): Performance Testing is the process of verifying that a material, product, assembly, or system meets defined performance criteria. The methods and conditions under which performance is verified are described in one or more test protocols.

Record Documents: (the term "as-builts" have been previously used): Documents prepared by the architect, engineer, and/or contractor that reflect on-site changes the contractor noted in the as-built drawings. They are often compiled as a set of on-site changes made for the owner per the contract requirements.

Systems Manual: A system-focused composite document that includes the design and construction documentation, facility guide and operation manual, maintenance information, training information, commissioning process records, and additional information of use to the Owner during occupancy and operations.

Test Procedure: A written protocol that defines methods, personnel, and expectations for tests conducted on components, equipment, assemblies, systems, and interfaces among systems to verify compliance with the Owner's Project Requirements.

Training Plan: A written document that details the expectations, schedule, duration and deliverables of Commissioning Process activities related to training of project operating and maintenance personnel, users, and occupants.

---

[1] These definitions are taken directly from the BPA "Roadmap", and ASHRAE Standard 202–2013.

APPENDIX B: Commissioning Process Activities and Deliverables.

The Commissioning Process is defined as a quality-focused process for enhancing the delivery of a new and existing building project. The overall process focuses upon verifying and documenting that all of the commissioned systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the Owner's Project Requirements (OPR).

The commissioning process has a series of actions and schedules for proper completion. Each action has specific deliverables. These define the building and commissioning requirements, the documentation of the performance results, training for the systems, and assemblies commissioned. The actions in the commissioning process shall be:

1. The owner initiates the Commissioning Process and retains the commissioning authority at the beginning of the project. The roles and responsibilities of the project and commissioning teams are determined. Procedures and contracts are prepared and executed.
2. Project requirements are then determined and documented, including not only the site and building scope and use but also the performance, training, commissioning and documentation requirements. The deliverable for this action is the Owner's Project Requirements (OPR) document, which is the guiding instruction for the project, and is updated throughout the project.
3. The initial Commissioning Plan is developed in the next step showing the commissioning scope, roles and responsibilities, communication procedures, and design and construction requirements for providing and integrating commissioning into the project. This Commissioning Plan is updated throughout the project with checklists, functional, and performance testing protocols and procedures, schedules and documentation details.
4. The design team then determines and documents the design approach to meet the Owner's Project Requirements. The commissioning authority reviews this Basis of Design (BOD) for conformance to the OPR.
5. During the design phase, the contractor commissioning requirements are determined for each commissioned system, and commissioning specifications are included in the construction documents package.
6. Also in the design phase, the commissioning authority reviews the design documents for conformance to the OPR, and provides the design review report.
7. Early in the project construction, the commissioning team reviews the materials and equipment submittals for conformance to the OPR and construction documents. Discrepancies, problems or inadequacies should be reported. This submittal review and report provides familiarity with the building systems for development of testing and commissioning requirements.
8. As the project is constructed, the commissioning team observes and verifies the installation and witnesses the equipment start up and testing. At system completion, performance testing is conducted and documented in checklists, logs and reports to verify performance compliance with the OPR and design documents.
9. One of the main functions and benefits of commissioning process is the identification and resolution of project issues, in both the design and construction phases, using the Issues and Resolution Log and project team collaboration. The design team and contractors should provide responses to the issues.
10. During design and construction the project documents are assembled into the systems manual that provides the details and history of the design and construction of the building, and information needed to properly operate the building. The systems manual is used in the training of the operations and facility staff and occupants, and is updated throughout the life of the building.
11. In order to operate the building in accordance with the OPR and design capabilities. The building operations, maintenance, and facility staff should be trained on the installed and commissioned equipment and systems. The training plans and records are retained and updated for use in later training.
    - Commissioning logs and interim reports are collected throughout the project and distributed as required by the commissioning plan.
    - At the completion of the project, the commissioning report is assembled and provided to the owner and others as required by the OPR, project documents, and local jurisdiction requirements.

Existing building commissioning processes involve planning, development of Current Facility Requirements (CFR), investigating, testing, project selection and implementation followed by system testing, commissioning, training and final documentation.

To maintain building performance, an on-going commissioning plan is developed and documented during the commissioning process for the use of building staff and occupants.

APPENDIX C: Commissioning Resources

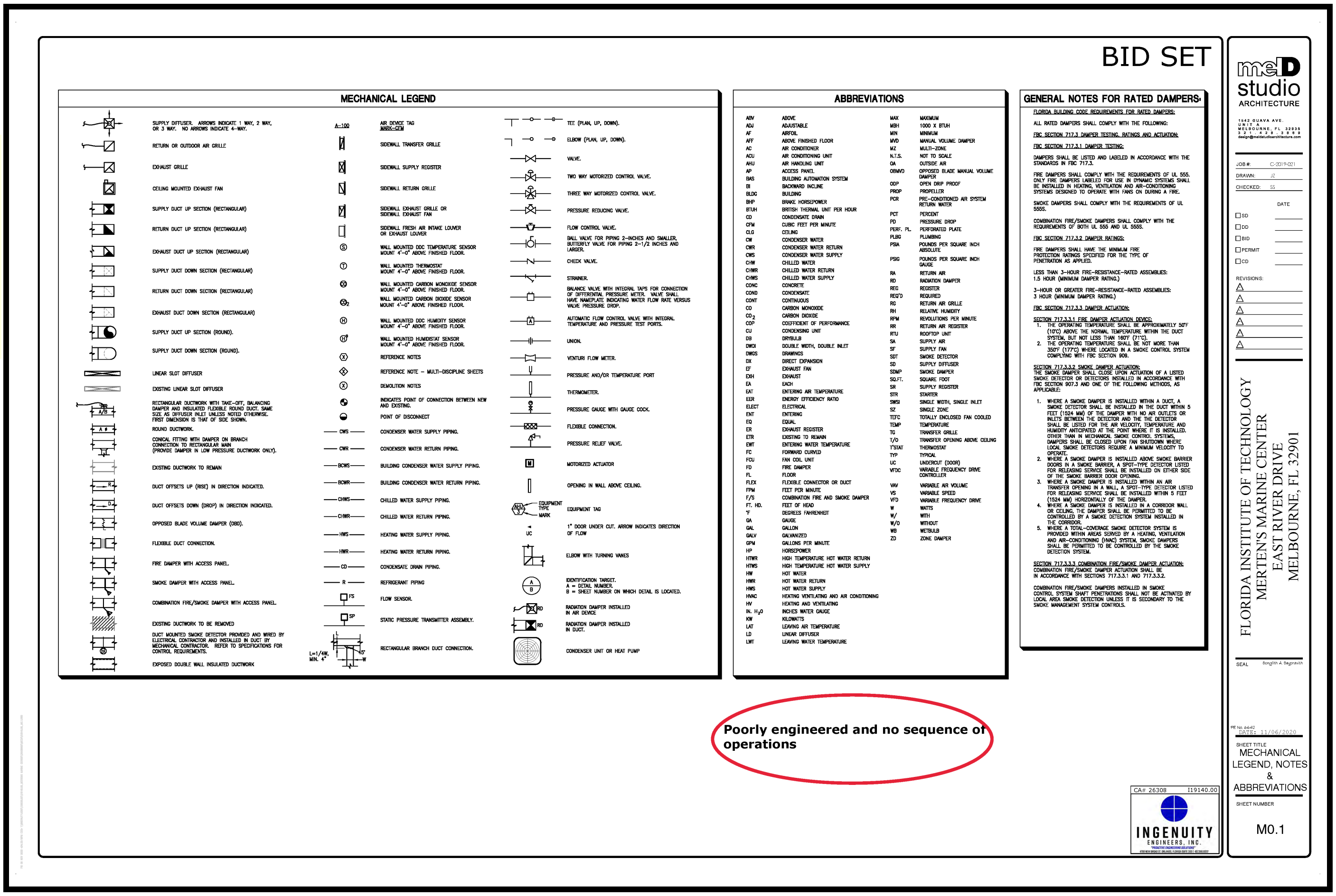
This list of commissioning resources and providers, either published by or recommended by this committee, is intended to provide the user of this guide where to find the best sources of information about the commissioning Industry and practices, procedures, means and methods from credentialed and reliable sources.

1. ACG Commissioning Guideline for Building Owners, Design Professionals and Commissioning Service Providers, 2nd Edition, AABC Commissioning Group (ACG), 2005.
2. ASHRAE Guideline 0-2013: The Commissioning Process Guideline.
3. ASHRAE Guideline 1.1, The HVAC Commissioning Process Guideline
4. ASHRAE Standard 202-2013 -- Commissioning Process for Buildings and Systems
5. ASTM E2813 – 12 Standard Practices for Building Enclosure Commissioning
6. Building Commissioning Association (BCA): New Construction Building Commissioning Best Practice
7. Building Commissioning Association (BCA): Best Practices in Commissioning Existing Buildings
8. "Building Commissioning; A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions", Evan Mills, Ph.D., Lawrence Berkeley National Laboratory; July 21, 2009
9. California Commissioning Guide, 2006
10. Canadian Commissioning Manual, 2006
11. DOE Commissioning Guide, 2011
12. GSA Commissioning Guide, 2005
13. ICC G4- 2012 Guideline for Commissioning
14. ICC/IAS AC 476 Accreditation Criteria for Organizations Providing Training and/or Certification of Commissioning Personnel
15. ICC 1000 – 201X Standard for Commissioning
16. IECC (various commissioning requirements), 2012
17. IgCC (various commissioning requirements), 2012
18. IESNA, The Commissioning Process Applied to Lighting and Control Systems; 2011
19. NAVFAC Design Build Commissioning Manual, 2009
20. NECA 90-2009 Standard for Commissioning Building Electrical Systems.
21. NEBB; Procedural Standards for Whole Building Systems Technical Commissioning for New Construction, National Environmental Balancing Bureau (NEBB), 2014.
22. NEBB; Procedural Standards for the Technical Retro-Commissioning of Existing Building Systems, National Environmental Balancing Bureau (NEBB), 2014.
23. NIBS Guideline 3-2012 Building Enclosure Commissioning Process BECx, National Institute of Building Sciences, 2012.
24. NFPA Commissioning Fire Protection Systems. David R. Hague., 2005
25. SMACNA/ANSI HVAC Systems Commissioning Manual.
26. The Building Commissioning Guide, U.S. General Services Administration, 2005.
27. VA Commissioning Manual, 2010

This guide was developed by a BPA team consisting of twenty-eight ASHRAE members and direct representation by fourteen organizations who are major stakeholders in the commissioning industry. This collaborative effort will lead to improved overall building and system performance while maintaining established industry interests and practices which has led to continuing advances in its technology.

AIA
National Institute of BUILDING SCIENCES
ASHRAE
BCxA Building Commissioning Association
USGBC
CAMEE Council of American Mechanical and Electrical Engineers
acg AABC Commissioning Group
NEMIC NATIONAL ENERGY MANAGEMENT INSTITUTE COMMITTEE
ICC INTERNATIONAL CODE COUNCIL
NEBB
BOMA International
SMACNA
ARCOM The leader in specifications

EN10401Rationale



Poorly engineered and no sequence of operations

Page: 1

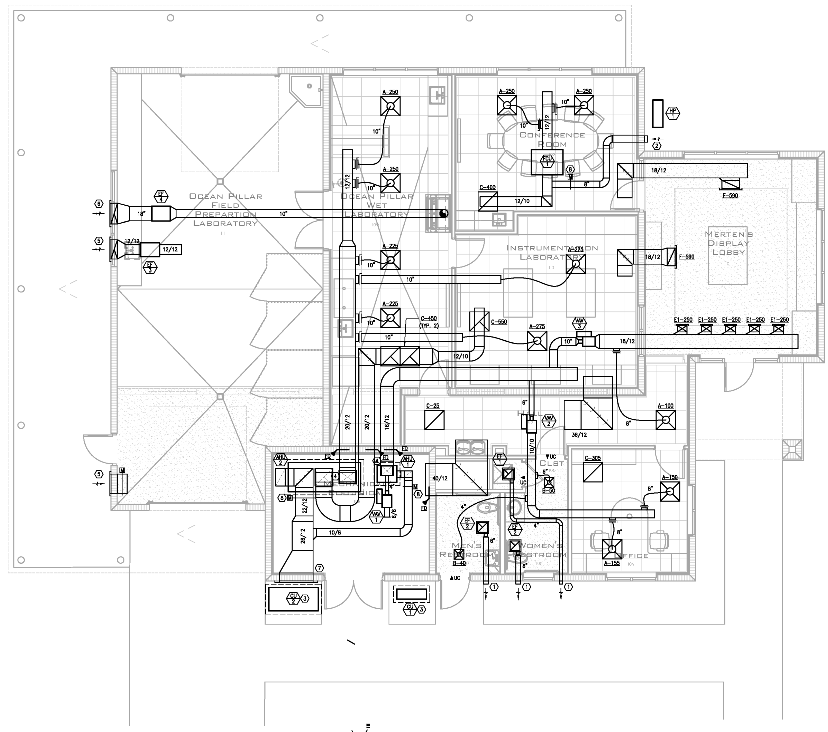
Mod_10401_Rationale_Florida_Tech_Mertens_Marine_Center_Bid_Set Example.pdf

EN10401Rationale

BID SET

REFERENCE NOTES

1. MINIMUM 26 GAUGE GALVANIZED EXHAUST DUCT SIZED PER PLAN. TERMINATE WITH WALL CAP AND INTEGRAL BACKDRAFT DAMPER PER DETAIL. SEE DETAIL FOR MORE INFORMATION. PRIME COAT AND PAINT WALL CAP TO MATCH BUILDING COLOR.
2. INTAKE WALL CAP. PROVIDE BIRD SCREEN. PAINT TO MATCH BUILDING COLOR. MAINTAIN 10 FT. OR MORE FROM ANY EXHAUST INTAKE.
3. CONDENSING UNIT ON GRADE. SEE DETAILS FOR MORE INFORMATION.
4. SUPPLY/EXHAUST AIR UP. TRANSITION TO FULL SIZE OF UNIT CONNECTION.
5. 24/20 GREENHECK EHV-550D LOUVER.
6. 26/20 GREENHECK EHV-550D LOUVER.
7. 42/28 GREENHECK EHV-550D LOUVER.
8. 24V AUTOMATIC CLOSING DAMPER.



Mechanical Ground Floor Plan

CA# 26308 I19140.00

INGENUITY ENGINEERS, INC.

meD studio ARCHITECTURE
1542 GUAVA AVE. UNIT A
MELBOURNE, FL 32935
321.428.3869
design@meldstudioarchitecture.com

JOB #: C-2019-021
DRAWN: JZ
CHECKED: SS

DATE
☐ SD
☐ DD
☐ BID
☐ PERMIT
☐ CD

REVISIONS:

FLORIDA INSTITUTE OF TECHNOLOGY
MERTEN'S MARINE CENTER
EAST RIVER DRIVE
MELBOURNE, FL 32901

SEAL Songlith A. Sayprasith

PE No. 66412
DATE: 11/06/2020

SHEET TITLE
MECHANICAL GROUND FLOOR PLAN

SHEET NUMBER
M2.0

Page: 2

Mod_10401_Rationale_Florida_Tech_Mertens_Marine_Center_Bid_Set Example.pdf

BID SET

AIR DEVICE SCHEDULE

MARK	DESCRIPTION	FACE SIZE	NECK	MATERIAL	BASIS OF DESIGN MANUFACTURER/MODEL #	DAMPER	NOTES
A	LOUVERED FACE 2 CONE ADJUSTABLE SUPPLY DIFFUSER	24"x24"	SEE TABLE BELOW	ALUMINUM	METAL AIRE 5700-AL	Y	1, 2, 3
B	LOUVERED FACE 2 CONE ADJUSTABLE SUPPLY DIFFUSER	12"x12"	SEE TABLE BELOW	ALUMINUM	METAL AIRE 5700-AL	Y	1, 2, 3
C	EGGCRATE RET./EXH. GRILLE (1/2"x1/2"x1/2")	24"x24"	22"X22"	ALUMINUM	METAL AIRE CC-5	Y	1, 2
D	EGGCRATE RET./EXH. GRILLE (1/2"x1/2"x1/2")	12"x12"	10"X10"	ALUMINUM	METAL AIRE CC-5	Y	1, 2
E1	SIDEWALL SINGLE DEFLECTION SUPPLY GRILLE	NOTE 4	SEE TABLE BELOW	ALUMINUM	METAL AIRE H4002	Y	1,7
E2	SIDEWALL DOUBLE DEFLECTION SUPPLY GRILLE	NOTE 4	SEE TABLE BELOW	ALUMINUM	METAL AIRE H4004	Y	1,7
F	SIDEWALL/CEILING 45° DEFLECTION RETURN GRILLE	NOTE 4	SEE TABLE BELOW	ALUMINUM	METAL AIRE RH	Y	1, 2, 7
G1	CEILING SINGLE DEFLECTION SUPPLY GRILLE – 1 WAY	NOTE 4	SEE TABLE BELOW	ALUMINUM	METAL AIRE L-1	Y	1, 2, 7
G2	CEILING SINGLE DEFLECTION SUPPLY GRILLE – 2 WAY	NOTE 4	SEE TABLE BELOW	ALUMINUM	METAL AIRE LT-1	Y	1, 2, 7
G3	CEILING SINGLE DEFLECTION SUPPLY GRILLE – 3 WAY	NOTE 4	SEE TABLE BELOW	ALUMINUM	METAL AIRE LS3-1	Y	1, 2, 7
G4	CEILING SINGLE DEFLECTION SUPPLY GRILLE – 4 WAY	NOTE 4	SEE TABLE BELOW	ALUMINUM	METAL AIRE LS4-1	Y	1, 2, 7
H	CURVED SIDEWALL DOUBLE DEFLECTION SUPPLY GRILLE	NOTE 4	SEE TABLE BELOW	ALUMINUM	METAL AIRE 4004P	Y	1, 2
J	LINEAR SLOT RETURN	SEE PLANS	SEE TABLE BELOW	ALUMINUM	METAL AIRE 6600R	Y	1, 2, 3, 5
K	PERFORATED FLUSH FACE CEILING SUPPLY (KITCHEN)	24"x24"	SEE TABLE BELOW	ALUMINUM	METAL AIRE 7500R-AL	Y	1, 2, 3
L	LINEAR SLOT SUPPLY DIFFUSER	SEE PLANS	SEE TABLE BELOW	ALUMINUM	METAL AIRE 6600	Y	1, 2, 3, 6
T	SIDEWALL/CEILING 45° DEFLECTION TRANSFER GRILLE	NOTE 8	SEE TABLE BELOW	ALUMINUM	METAL AIRE RH	Y	1, 2, 7, 8

NOTES:

1. COORDINATE COLOR AND SURFACE FINISHES WITH ARCHITECTURAL DRAWINGS.
2. PROVIDE RAPID MOUNT T-BAR FRAME FOR PLASTER AND SHEET ROCK CEILINGS.
3. SUPPLY COMPLETE WITH FACTORY INSTALLED 1/2" THICK FOIL BACKED INSULATION.
4. FACE SIZE DEPENDENT UPON NECK SIZE.
5. FOR NON-DUCTED RETURN, PROVIDE LIGHT SHIELD. FOR DUCTED RETURN PROVIDE FACTORY INSTALLED PLENUM BOX WITH ½" THICK FOIL BACKED INSULATION.
6. PROVIDE WITH FACTORY INSTALLED PLENUM BOX WITH ½" THICK FOIL BACKED INSULATION FOR NOISE REDUCTION AND EXTERNALLY INSULATE PER SPECIFICATIONS.
7. PROVIDE STEEL GRILLE WHEN USED IN ACCORDANCE WITH U.L. APPROVED PENETRATION DETAIL.
8. GRILLES SIZED FOR 50 SQUARE INCHES PER 100 CFM OF TRANSFER AIR.

A-CFM

CFM RANGE	NECK SIZE
0 – 95	6"Ø
96 – 205	8"Ø
206 – 375	10"Ø
376 – 605	12"Ø
606 – 850	14"Ø

B-CFM

CFM RANGE	NECK SIZE
0 – 40	4"Ø
41 – 60	5"Ø
61 – 95	6"Ø
96 – 145	7"Ø
146 – 205	8"Ø

C-CFM

CFM RANGE	NECK SIZE
0 – 2500	22"X22"

D-CFM

CFM RANGE	NECK SIZE
0 – 550	10"X10"

E1-2, G1-4, H-CFM

CFM RANGE	NECK SIZE
0 – 75	6"x6"
76 – 150	10"x6"
151 – 200	12"x6"
201 –250	12"x8"
251 – 300	14"x8"

E1-2, G1-4, H-CFM (CONT)

CFM RANGE	NECK SIZE
301-350	16"x8"
351-400	18"x8"
401-500	24"x8"
501-575	22"x10"
576-650	24"x10"

F-CFM

CFM RANGE	NECK SIZE
0 – 75	6"x6"
76 – 150	8"x6"
151 – 200	10"x6"
201 –235	12"x6"
236 – 275	14"x6"

F-CFM (CONT)

CFM RANGE	NECK SIZE
276 – 450	12"x12"
451 – 535	18"x10"
536 – 590	14"x14"
591 – 670	22"x10"
671 – 875	24"x12"

F-CFM (CONT)

CFM RANGE	NECK SIZE
876 – 1000	20"x16"
1001 – 1200	24"x16"
1201 – 1300	24"x18"
1301 – 1500	24"x20"
1501 – 1800	28"x20"

J-CFM

CFM RANGE	NECK SIZE
0 – 95	6"Ø
96 – 205	8"Ø
206 – 300	10"Ø
301 – 390	12"Ø
395 – 450	14"Ø
451 – 500	15"Ø

K-CFM

CFM RANGE	NECK SIZE
0 – 80	6"Ø
81 – 175	8"Ø
176 – 320	10"Ø
321 – 520	12"Ø
521 – 780	14"Ø
781 – 1120	16"Ø

T-CFM

CFM RANGE	NECK SIZE
0 – 75	8"x6"
76 – 140	12"x6"
141 – 190	16"x6"/12"x8"
191 – 235	12"x10"/20"x6"
236 – 285	24"x6"/12"x12"
286 – 360	18"x10"/30"x6"

T-CFM (CONT)

CFM RANGE	NECK SIZE
361 – 430	18"x12"/36"x6"
431 – 500	18"x14"/42"x6"
501 – 575	18"x16"/24"x12"
576 – 720	30"x12"
721 – 860	24"x18"/36"x12"
861 – 1000	36"x14"/42"x12"

T-CFM (CONT)

CFM RANGE	NECK SIZE
1001 – 1150	48"x12"/24"x24"
1151 – 1290	36"x18"
1291 – 1440	36"x20"/30"x24"
1441 – 1580	36"x22"
1581 – 1725	48"x18"/36"x24"
1726 – 2300	48"x24"/36"x32"

EXHAUST FAN SCHEDULE

MARK	AREA SERVED	TYPE	CFM	DRIVE TYPE	E.S.P.	WATTS/HP	R.P.M.	VOLTS/PH	SONES	MANUFACTURER	MODEL NO.	NOTES
EF-1	CLOSET	CABINET	50	DIRECT	0.4	4.0 WATTS	---	120/1Ø	0.3	BROAN	LP50100DC	1,2
EF-2	BATHROOM	CABINET	80	DIRECT	0.4	6.3 WATTS	---	120/1Ø	0.6	BROAN	LP50100DC	1,2
EF-3	PREP. LAB.	INLINE	600	BELT	0.5	1/4 HP	1725	120/1Ø	10.3	GREENHECK	BSQ-90-4	–
EF-4	FUME HOOD	INLINE	750	BELT	1.5	1/2 HP	1725	120/1Ø	–	GREENHECK	TCB-1-09-5	–

NOTES:

1. PROVIDE COMPLETE WITH FUSED DISCONNECT SWITCH, DESIGNER GRILLE, FACTORY SOLID STATE SPEED CONTROLLER, FACTORY BACKDRAFT DAMPER, AND FACTORY HANGING VIBRATION ISOLATOR KIT.
2. INTERLOCK WITH ROOM LIGHT/OCCUPANCY SENSOR.

DX AIR HANDIING UNIT SCHEDULE

TAG NO.	AREA SERVED	FAN DATA: SUPPLY AIR CFM	FAN DATA: E.S.P.	FAN DATA: MOTOR HP	FAN DATA: FAN RPM	COOLING COIL DATA: TOTAL MBH	COOLING COIL DATA: SENSIBLE MBH	AIR TEMP. °F: E.D.B.	AIR TEMP. °F: E.W.B.	AIR TEMP. °F: L.D.B.	AIR TEMP. °F: L.W.B.	ELECTRIC HEAT COIL: STAGES	ELECTRIC HEAT COIL: RATING KW	ELECTRIC HEAT COIL: E.D.B.	ELECTRIC HEAT COIL: L.D.B.	ELECTRICAL DATA: VOLT/PHASE	ELECTRICAL DATA: MCA	ELECTRICAL DATA: MOCP	GAS REHEAT COIL: INPUT RATING (MBTUH)	GAS REHEAT COIL: OUTPUT RATING (MBTUH)	GAS REHEAT COIL: L.D.B.	GAS REHEAT COIL: L.W.B.	BASIS OF DESIGN MANUFACTURER/MODEL#	NOTES
AHU-1	OFFICES/GENERAL	1,850	1.0	3/4	–	54	–	78.5	66.5	56.0	55.0	–	–	–	–	208/1	6.5	15	–	–	–	–	DAIKIN / DV60FECD14	1,2
AHU-2	LABORATORIES	1,500	1.0	1.34 x2	2580	64.6	40.05	92.0	77.0	53.5	53.39	1	5.6	63.9	75.7	208/3	27	30	–	30	72.00	60.54	AAON /V3BRB8A161C5NS	1,2,3

NOTES:

1. PROVIDE COMPLETE WITH DISCONNECT SWITCH, VIBRATION ISOLATION RAIL, FACTORY MOUNTED MICROPROCESSOR CONTROLS AND UNIT MOUNTED SERVICE RECEPTACLE.
2. PROVIDE COMPLETE WITH TIME DELAY RELAY AND ANTI-SHORT CYCLE TIMER AND VARIABLE SPEED DRIVE FOR BOTH FANS. VFD'S ARE PROVIDED BY DIV 23.
3. PROVIDE DIRTY FILTER SENSOR FOR BOTH OA/EA FILTERS, MERV 13 FILTERS FOR OA AND EA, AND VAV CONTROL WITH FACTORY MOUNTED CONTROLS.

AIR COOLED CONDENSING UNIT SCHEDULE

MARK	LOCATION	NOMINAL COOLING (MBH)	COMPRESSOR: OUTDOOR DESIGN TEMP. (F°)	COMPRESSOR: QTY.	ELECTRICAL: VOLTAGE/PHASE	ELECTRICAL: MCA	ELECTRICAL: MOCP	UNIT INFORMATION: UNIT SIZE L x W x H	UNIT INFORMATION: OPERATING WEIGHT (LBS)	UNIT INFORMATION: MANUFACTURER	UNIT INFORMATION: MODEL NUMBER	MINIMUM SEER	NOTES
CU-1	ON GRADE	54	95	1	208/1	35.5	40	37" x 12.6" x 39"	181	DAIKIN	DX17VSS601AA	14	1,2,3,4
CU-2	ON GRADE	68.1	95	1	208/3	28	45	61.5" x 29.25" x 56.25"	474	AAON	CFA-007-A-A-8-DC0EH	14	1,2,3,4

NOTES:

1. PROVIDE COMPLETE WITH R410-A REFRIGERANT, SCROLL COMPRESSOR, FIELD INSTALLED FILTER/DRIER, FRONT SEATING SERVICE VALVES, INTERNAL PRESSURE RELIEF VALVE, INTERNAL THERMAL OVERLOAD, LONG LINE CAPABILITY, LOW AMBIENT CAPABILITY/KIT (WHERE REQUIRED), ACCUMULATOR, HIGH PRESSURE CUTOUT SWITCH, AND LOSS OF CHARGE SWITCH.
2. PROVIDE WITH THESE FACTORY OPTIONS: ANTI-SHORT CYCLE RELAY, TIME DELAY RELAY (TO MEET ARI RATING WHERE INDOOR UNIT IS NOT EQUIPPED), ANTI-SHORT CYCLE TIMER, EVAPORATOR FREEZE THERMOSTAT & ISOLATION RELAY (WHEN LOW AMBIENT KIT USED), LIQUID LINE SOLENOID VALVE, AND BI-FLOW TXV LOW AMBIENT CONDENSER FAN MOTOR SPEED CONTROLLER.
3. CONTRACTOR TO PROVIDE CODE APPROVED RACK FOR CONDENSER UNITS TO BE MOUNTED ON. TIE-DOWN RACKS PER HURRICANE EQUIPMENT TIE-DOWN DETAILS ON SHEET XXXX.
4. SIZE REFRIGERANT PIPING BASED ON MANUFACTURER'S INSTALLATION INSTRUCTIONS.

DX FAN COIL UNIT SCHEDULE

MARK	SERVICE	FAN: TOTAL AIR FLOW (CFM)	FAN: OUTSIDE AIR FLOW (CFM)	FAN: E.S.P. (IN.WG.)	FAN: DRIVE TYPE	FAN: BLOWER SPEED TAP	FAN: HP	COOLING COIL: ENTERING AIR TEMP. (°F DB/WB)	COOLING COIL: LEAVING AIR TEMP. (°F DB/WB)	COOLING COIL: TOTAL CAPACITY (MBH)	COOLING COIL: SENSIBLE CAPACITY (MBH)	HEATING CAPACITY (MBH @ 17°F)	AUXILIARY ELECTRIC HEATER @208V	ELECTRICAL: VOLTAGE/PHASE	ELECTRICAL: MCA	ELECTRICAL: MOCP	UNIT INFORMATION: DIMENSIONS (WxDxH)	UNIT INFORMATION: OPERATING WEIGHT (LBS)	UNIT INFORMATION: MANUFACTURER	UNIT INFORMATION: MODEL NUMBER	UNIT INFORMATION: NOMINAL TONS	NOTES
FCU-1	CONFERENCE	516	100	0.60	DIRECT	(HIGH)	–	78/65	55.3/54.9	14.4	–	11	–	208/1	–	–	39.375"x31.5"x9.625"	77	DAIKIN	FDMQ15RVJU	1.5	1,2,3,4,5,6,7

NOTES:

1. PROVIDE COMPLETE WITH SINGLE POINT WIRING, 1" THICK CABINET FOIL FACED INSULATION, AND FUSED DISCONNECT.
2. CONTRACTOR SHALL INSTALL MANUFACTURER'S RECOMMENDED 7-DAY PROGRAMMABLE DIGITAL THERMOSTAT IN SPACE AS INDICATED ON UNIT PLANS. STAT SHALL BE CAPABLE OF CONTROLLING MOTOR SPEED TO MAINTAIN TEMPERATURE.
3. ELECTRIC HEATER SHALL BE ENABLED WHEN HEAT PUMP COMPRESSOR HAS BEEN DISABLED.
4. 12 YEAR PARTS WARRANTY (ONLINE REGISTRATION REQUIRED) SEE MANUFACTURER'S POLICY FOR DETAILS.
5. CONTRACTOR SHALL PROVIDE COMPLETE WITH TXV, AND ECM MOTOR.
6. SIZE REFRIGERANT PIPING BASED ON MANUFACTURER'S INSTALLATION INSTRUCTIONS.
7. CONTRACTOR SHALL INSTALL MANUFACTURER'S RECOMMENDED DAIKIN ONE+ SMART THERMOSTAT OR EQUIVALENT IN SPACE AS INDICATED ON UNIT PLANS. STAT SHALL BE CAPABLE OF CONTROLLING MOTOR SPEED TO MAINTAIN SPACE TEMPERATURE AND CAPABLE OF OVERCOOLING TO MAINTAIN HUMIDITY SETPOINT (ADJ.)

AIR COOLED HEAT PUMP UNIT SCHEDULE

MARK	LOCATION	NOMINAL COOLING (MBH @ ARI)	HEATING (MBH @ 47°F/17°F)	COMPRESSOR: OUTDOOR DESIGN TEMP. (F°)	COMPRESSOR: QTY.	ELECTRICAL: VOLTAGE/PHASE	ELECTRICAL: MCA	ELECTRICAL: MOCP	UNIT INFORMATION: UNIT SIZE L x W x H	UNIT INFORMATION: OPERATING WEIGHT (LBS)	UNIT INFORMATION: MANUFACTURER	UNIT INFORMATION: MODEL NUMBER	MINIMUM SEER	MINIMUM HSPF	NOTES
HP-1	GRADE	14.4	18/11	95	1	208/1	9.7	15	34.25"x12.625"x29"	97	DAIKIN	RX15RMVJU	15	8.2	1,2,3,4,5,6

NOTES:

1. PROVIDE COMPLETE WITH R410-A REFRIGERANT, SCROLL COMPRESSOR, FIELD INSTALLED FILTER/DRIER, FRONT SEATING SERVICE VALVES, INTERNAL PRESSURE RELIEF VALVE, INTERNAL THERMAL OVERLOAD, LONG LINE CAPABILITY, LOW AMBIENT CAPABILITY/KIT (WHERE REQUIRED), ACCUMULATOR, AND HIGH PRESSURE CUTOUT SWITCH AND LOSS OF CHARGE SWITCH.
2. PROVIDE WITH THESE FACTORY OPTIONS: ANTI-SHORT CYCLE RELAY, TIME DELAY RELAY (TO MEET ARI RATING WHERE INDOOR IS NOT EQUIPPED), ANTI-SHORT CYCLE TIMER, COMPRESSOR START ASSIST CAPACITOR AND RELAY, CRANKCASE HEATER, EVAPORATOR FREEZE THERMOSTAT & ISOLATION RELAY (WHEN LOW AMBIENT KIT IS USED), LIQUID LINE SOLENOID VALVE, LOW AMBIENT PRESSURE SWITCH KIT, LOW AMBIENT CONDENSER FAN MOTOR SPEED CONTROLLER, REVERSING VALVE AND BI-FLOW TXV.
3. CONTRACTOR TO PROVIDE CODE APPROVED RACK FOR CONDENSER UNITS TO BE MOUNTED ON. TIE-DOWN RACKS PER HURRICANE EQUIPMENT TIE-DOWN DETAILS.
4. HEAT PUMP COMPRESSOR SHALL NOT OPERATE SIMULTANEOUSLY WITH EMERGENCY ELECTRIC HEATER IN FAN COIL UNIT.
5. SIZE REFRIGERANT PIPING BASED ON MANUFACTURER'S INSTALLATION INSTRUCTIONS.
6. 6 YEAR UNIT REPLACEMENT, 12 YEAR PARTS WARRANTY (ONLINE REGISTRATION REQUIRED). SEE MANUFACTURER'S POLICY FOR DETAILS.

VAV BOX SCHEDULE

MARK	LOCATION	AIR DATA: DESIGN CFM	AIR DATA: MINIMUM CFM	AIR DATA: MAXIMUM CFM	INLET SIZE DIA. INCHES	E.S.P. (IN. W.G.)	MAX. N.C.	WEIGHT (LBS.)	HEATING DATA: HEATING CFM	HEATING DATA: EAT/LAT (°F)	HEATING DATA: KW	HEATING DATA: STAGES	V/Ø/HZ	MANUFACTURER	MODEL NUMBER	UNIT L"xW"xH"	NOTES
VAV-1	–	95	0	225	4	–	–	–	–	–/–	–	–	208/1/60	TITUS	DESV-04	18 X 12 X 8	1,2,3
VAV-2	–	395	0	500	6	–	–	–	200	74.6/90	2.5	–	208/1/60	TITUS	DESV-06	18 X 12 X 10	1,2,3
VAV-3	–	1350	0	1400	10	–	–	–	880	74.6/90	5.0	–	208/1/60	TITUS	DESV-10	18 X 16 X 15	1,2,3

NOTES:

1. PROVIDE ELECTRONIC ROOM THERMOSTAT WITH DIGITAL DISPLAY, ADJUSTABLE SETPOINT AND NIGHT SET-BACK OVERRIDE AND CANCEL BUTTONS.
2. PROVIDE FUSED CONTROL POWER TRANSFORMER.
3. PROVIDE PRESSURE INDEPENDENT TYPE. PROVIDE ALL NECESSARY EQUIPMENT TO ALLOW COMMUNICATION WITH BUILDING MANAGEMENT SYSTEM (BMS)

CA# 26308 I19140.00

INGENUITY ENGINEERS, INC.
"PROACTIVE ENGINEERING SOLUTIONS"
4799 NEW BROAD ST. ORLANDO, FLORIDA SUITE 200 | 407.398.9007

meD studio ARCHITECTURE
1542 GUAVA AVE. UNIT A
MELBOURNE, FL 32935
321.428.3889
design@meldstudioarchitecture.com

JOB #: C-2019-021
DRAWN: JZ
CHECKED: SS

DATE

- ☐ SD
- ☐ DD
- ☐ BID
- ☐ PERMIT
- ☐ CD

REVISIONS:

FLORIDA INSTITUTE OF TECHNOLOGY
MERTEN'S MARINE CENTER
EAST RIVER DRIVE
MELBOURNE, FL 32901

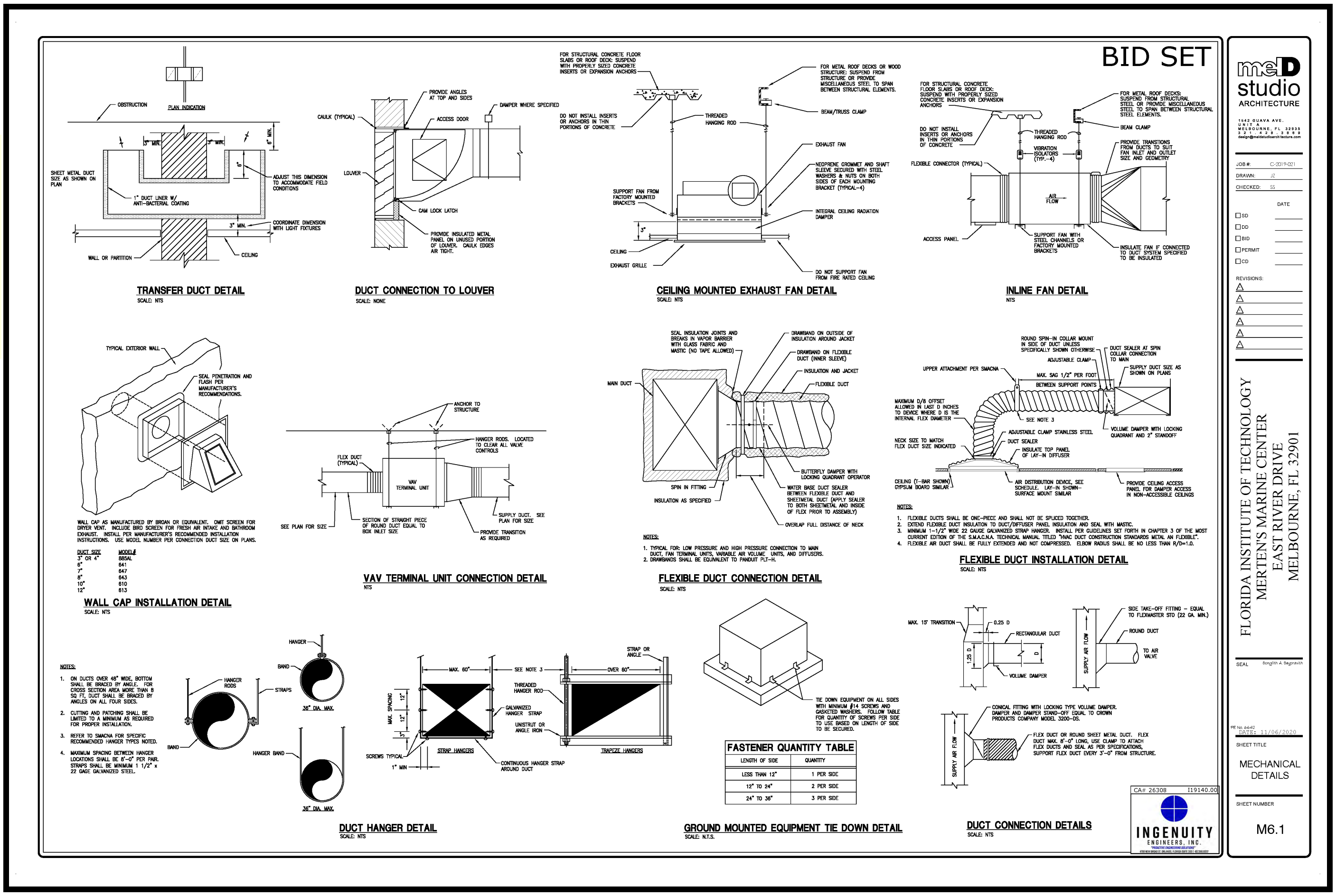
SEAL Songlith A. Sayprasith

PE No. 66412
DATE: 11/06/2020

SHEET TITLE
MECHANICAL SCHEDULES

SHEET NUMBER
M5.1

EN10401Rationale



Page: 4

Mod_10401_Rationale_Florida_Tech_Mertens_Marine_Center_Bid_Set Example.pdf

BID SET

ELECTRICAL SYMBOLS LEGEND

LIGHTING (SEE LIGHTING FIXTURE SCHEDULE)

- 2'X 2' LED LIGHTING FIXTURE
- 2' x 2' EMERGENCY LED LIGHTING FIXTURE WITH EMERGENCY BALLAST INTEGRAL LUMEN.
- 2' X 4' LED LIGHTING FIXTURE
- 2' x 4' EMERGENCY LED LIGHTING FIXTURE WITH EMERGENCY BALLAST INTEGRAL LUMEN.
- 1'X 4' LED LIGHTING FIXTURE CONNECTED TO EMERGENCY BALLAST.
- 1'X 4' EMERGENCY LED LIGHTING FIXTURE WITH EMERGENCY BALLAST INTEGRAL LUMEN.
- FAN WITH LIGHT KIT
- LED STRIP LIGHTING
- LED EMERGENCY STRIP LIGHTING WITH EMERGENCY BALLAST INTEGRAL 1400 LUMEN.
- LIGHTING FIXTURE
- LIGHTING FIXTURE – WALL MOUNTED
- WALL WASH / ACCENT FIXTURE – CEILING MOUNTED
- EMERGENCY LIGHTING FIXTURE WITH EMERGENCY BALLAST INTEGRAL 1400 LUMEN.
- EMERGENCY LIGHTING FIXTURE – WALL MOUNTED WITH EMERGENCY BALLAST INTEGRAL 1400 LUMEN.
- EXIT SIGN – SINGLE FACE ARROW INDICATES DIRECTION– CEILING MOUNTED
- EXIT SIGN – SINGLE FACE ARROW INDICATES DIRECTION– WALL MOUNTED
- EXIT SIGN – DOUBLE FACE – ARROW INDICATES DIRECTION – CEILING MOUNTED
- EMERGENCY LIGHT WITH INTEGRAL BATTERY PACK – DUAL HEAD
- PARKING LOT LUMINARE – POLE MOUNTED
- DECORATIVE PENDANT
- LIGHT TRACK – CEILING MOUNTED.

FIRE ALARM

- F — MANUAL PULL STATION
- F — COMBINATION AUDIBLE/VISUAL SIGNALING UNIT– HORN/FLASHING "FIRE" LIGHT WALL MOUNTED 80" AFF UNLESS OTHERWISE NOTED. WP=WEATHER PROOF. A=AUDIBLE ONLY. 75 CANDELA UNLESS NOTED OTHERWISE.
- F — VISUAL SIGNALING UNIT, WALL MOUNTED– FLASHING "FIRE" LIGHT ONLY (NO AUDIO DEVICE) 75 CANDELA UNLESS NOTED OTHERWISE.
- R / S — PHOTOELECTRIC DUCT SMOKE DETECTOR R=RETURN S=SUPPLY
- R — FIRE ALARM SHUTDOWN OR CONTROL RELAY
- RTI — DUCT DETECTOR REMOTE TROUBLE INDICATOR. MOUNT ADJACENT TO UNIT.
- H 2 — FIRE ALARM HEAT DETECTOR. (2) INDICATES TO PROVIDE DUAL CONVERTIBLE CONTACTS.
- 2 — CEILING MOUNTED SMOKE DETECTOR. (2) INDICATES PROVIDE DUAL CONTACT.
- 120 — CEILING OR WALL MOUNTED 120 VOLT RATED RESIDENTIAL SELF CONTAINED SMOKE DETECTOR. ALL UNITS SHALL BE ELECTRICALLY TIED TOGETHER AND ALARM ALL AT ONE TIME WITHIN UNIT.
- CM — CEILING OR WALL MOUNTED 120 VOLT RATED RESIDENTIAL SELF CONTAINED CARBON MONOXIDE SENSOR. ALL UNITS SHALL BE ELECTRICALLY TIED TOGETHER AND ALARM ALL AT ONE TIME WITHIN UNIT.
- DH — MAGNETIC DOOR HOLDER
- "FACP" — FIRE ALARM CONTROL PANEL. FLUSH MOUNTED.
- FAJB — FIRE ALARM JUNCTION BOX.
- FAAP — REMOTE FIRE ALARM ANNUNCIATOR PANEL, FLUSHED MOUNTED.
- TS — SPRINKLER TAMPER SWITCH CONNECTION
- S — FIRE ALARM SYSTEM, RESIDENTIAL UNIT MINI–HORN. LOW FREQUENCY SOUND CAPABLE, 520 HZ.
- WL — "DO NOT USE" ELEVATOR WARNING LIGHT.
- CR — CARD READER. TO BE TIED INTO FIRE ALARM SYSTEM TO UNLOCK ON ALARM INITIATION WHEN IN EGRESS PATH.

SWITCHES

- S — SINGLE POLE SWITCH – TOGGLE TYPE. SEE ELECTRICAL SPECIFICATIONS FOR MOUNTING HEIGHTS.
  - (3) 3 WAY
  - (4) 4 WAY
  - (2) DOUBLE POLE
  - (P) WITH PILOT LIGHT INDICATION
  - (K) KEY OPERATED
  - (OS) OCCUPANCY SENSOR
- S_M — MOTOR RATED SWITCH – 1 POLE OR 2 POLE 30 AMP WITH INTEGRAL THERMAL OVERLOADS

POWER — SEE ELECTRICAL SPECIFICATIONS FOR MOUNTING HEIGHTS.

- DUPLEX RECEPTACLE – SEE ELECTRICAL SPECIFICATIONS FOR MOUNTING HEIGHTS.
  - (WP) WEATHERPROOF
  - (H) HORIZONTALLY MOUNTED
  - (G) CEILING MOUNTED
  - (USB) REC/USB COMBINATION
- DOUBLE DUPLEX RECEPTACLE
- "GFI" DUPLEX RECEPTACLE/GROUND FAULT INTERRUPTING
- WP — "GFI" DUPLEX RECEPTACLE/GROUND FAULT INTERRUPTING/WEATHERPROOF COVER
- "GFI" DOUBLE DUPLEX RECEPTACLE/GROUND FAULT INTERRUPTING
- "GFI" DOUBLE DUPLEX RECEPTACLE/GROUND FAULT INTERRUPTING, COUNTER HEIGHT
- DUPLEX RECEPTACLE – TOP HALF SWITCHED – MOUNT 18" AFF
- DUPLEX RECEPTACLE
- DOUBLE DUPLEX RECEPTACLE
- DUPLEX RECEPTACLE, COMMUNICATIONS AND COMPUTER OUTLETS MOUNTED TOGETHER IN A FLUSH MOUNTED FLOOR BOX.
- DUPLEX RECEPTACLE – FLUSH MOUNTED IN FLOOR BOX.
- DOUBLE DUPLEX RECEPTACLE MOUNTED TOGETHER IN A FLUSH MOUNTED FLOOR BOX.
- 50 — SPECIAL PURPOSE OUTLET – COORDINATE EXACT NEMA CONFIGURATION AMPACITY RATING AS INDICATED.
- 30 F J — CEILING FAN JUNCTION BOX (SIZE AS REQUIRED PER N.E.C.).
- J — WALL MOUNTED JUNCTION BOX (SIZE AS REQUIRED PER N.E.C.).
- EF — MOTOR (EF) EXHAUST FAN (AHU) AIR HANDLING UNIT
- P — PHOTO CELL
- C — LIGHTING CONTACTOR
- T — TIME CLOCK
- M — METER SOCKET
- WP — ELECTRICAL SERVICE SHUNT TRIP BREAK GLASS STATION SQUARE "D" CLASS#900 1–K15 W/ CLASS 9001–K25 STAINLESS STEEL COVER PLATE. ENGRAVE "SERVICE DISCONNECT" MOUNT 7'–0" AFF./WEATHERPROOF HOUSING

DATA/COMM

- WH — DATA/COMM OUTLET WITH FLUSH MOUNTED 4" SQUARE SINGLE GANG JUNCTION BOX. PROVIDE BLANK STAINLESS STEEL COVER PLATE. EXTEND 1" CONCEALED CONDUIT TO ABOVE ACCESSIBLE CEILING AND STUB–OUT WITH PLASTIC BUSHING. OR AS NOTED. INSTALL PULL WIRE. WH= WALL MOUNTED. C= 6" ABOVE COUNTER BACK SPLASH.
- DATA/COMM OUTLET FLUSH MOUNTED IN FLOOR.
- TV — TELEVISION OUTLET. MOUNT 18 " ABOVE FINISHED FLOOR.
- "SMC" — STRUCTURED MEDIA COMPONENT FLUSH MTD. BOX FOR RESIDENTIAL USE PROVIDED AND INSTALLED BY CONTRACTOR. MOUNT 48" ABOVE FINISH FLOOR TO BOARD.
- TELEPHONE TERMINAL BOARD

SERVICE AND DISTRIBUTION

- BRANCH CIRCUIT PANELBOARD, UNDER 250 VOLTS, SURFACE MOUNTED.
- 3 30 * — FUSED DISCONNECT SWITCH.3–POLE, 30AMP ASTERISK INDICATES TO FUSE ACCORDING TO MANUFACTURERS RECOMMENDATIONS. NEMA 1 RATED INDOORS, NEMA 3R RATED OUTDOORS.
- 3 30 * — COMBINATION STARTER/DISCONNECT SWITCH 3–POLE, 30AMP, FUSED. NEMA SIZE 1 NEMA RATED INDOORS, NEMA 3R RATED OUTDOORS.
- UTILITY TRANSFORMER
- TVSS — TRANSIENT VOLTAGE SURGE SUPPRESSOR. (TVSS)

ABBREVIATIONS

A	AMPERES	EMT	ELECTRICAL METALLIC TUBING	KCMIL	THOUSAND CIRCULAR MILLS	P	POLE
A/C	AIR CONDITIONING	EF	EXHAUST FAN	KVA	KILOVOLT–AMPERES	PNL	PANELBOARD
AC	ALTERNATING CURRENT	EWC	ELECTRIC WATER COOLER	KW	KILOWATT	PVC	POLYVINYL CHLORIDE
AFF	ABOVE FINISHED FLOOR	EX	EXISTING	LTG	LIGHTING	RGS	RIGID GALVANIZED STEEL
AFG	ABOVE FINISHED GRADE	FA	FIRE ALARM	MCM	THOUSANDS OF CIRCULAR MILS	RM	ROOM
AHU	AIR HANDLING UNIT	FACP	FIRE ALARM CONTROL PANEL	MCP	MOTOR CIRCUIT PROTECTION	SPEC	SPECIFICATION
AWG	AMERICAN WIRE GAUGE	G	GROUND	MCU	MASTER CONTROL UNIT	SS	STAINLESS STEEL
C	CONDUIT	GFI	GROUND FAULT INTERRUPTER	MH	MOUNTING HEIGHT	TVSS	TRANSIENT VOLTAGE SURGE SUPPRESSION
CFL	COMPACT FLUORESCENT LAMP	GND	GROUND	N	NEUTRAL	TYP	TYPICAL
CH	COUNTER HEIGHT	GRC	GALVANIZED RIGID CONDUIT	NA	NOT APPLICABLE	UON	UNLESS OTHERWISE NOTED
CONC	CONCRETE	HVAC	HEATING, VENTILATING AND AIR CONDITIONING	NEC	NATIONAL ELECTRICAL CODE	V	VOLTS
COND	CONDUIT	IWH	INSTANTANEOUS WATER HEATER	NEMA	NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION	W	WIRE
CU	COPPER	IBC	INTERNATIONAL BUILDING CODE	NFPA	NATIONAL FIRE PROTECTION ASSOCIATION	WP	WEATHERPROOF
DISC	DISCONNECT	H.I.D.	HIGH INTENSITY DISCHARGE	NF	NON–FUSED		
ECB	ENCLOSED CIRCUIT BREAKER	I.G.	ISOLATED GROUND	NIC	NOT IN CONTRACT		
ELEC	ELECTRICAL	J	JUNCTION	NL	NIGHT LIGHT		
EM	EMERGENCY	KAIC	(THOUSAND) AMPERE INTERRUPTING CAPACITY	O.C.	ON CENTER		
EMS	ENERGY MANAGEMENT SYSTEM						

BUILDING LIGHTING FIXTURE SCHEDULE

TYPE	MANUFACTURER & CATALOG NO.	DESCRIPTION	LAMPS	VOLTS	OR APPROVED EQUALS BY
A	CREE LIGHTING: KR620L40K120V10V	6" LED DOWNLIGHT.	25W LED	120	AS APPROVED BY OWNER
B	CREE LIGHTING: ZR2220L84010V5UNV	2' X 2' SURFACE TROFFER LIGHT	15W LED	120	AS APPROVED BY OWNER
C	CREE LIGHTING: LSQ40L40K10V	1' X 4' LED STRIP FIXTURE	40 W LED	120	AS APPROVED BY OWNER
D	CREE LIGHTING: ST3SI08LM40KL10V04AGR	1' X 8' SUSPENDED CONF ROOM FIXTURE	86 W LED	120	AS APPROVED BY OWNER
E	CREE LIGHTING: XSPW–B–WM–2ME–2L–30K–UL–BK	EXTERIOR WALL PACK	20W LED	120	AS APPROVED BY OWNER
F	TASK LIGHTING: L–VK4Z4A–65–30	COVE LIGHTING FOR DISPLAY AREA	(2.8W)/FT LED	120	AS APPROVED BY OWNER
EM	LIGHT ALARMS: 2MGRA1LD2M	TWIN HEAD EMERGENCY LIGHT–SURFACE	5(2.5W) LED	120	AS APPROVED BY OWNER
EX	LIGHT ALARMS: 6UEARM10	EMERGENCY EXIT LIGHTING FIXTURE	3W LED	120	AS APPROVED BY OWNER
H	CREE LIGHTING: F2533–80–LED	BATHROOM VANITY FIXTURE	24W	120	AS APPROVED BY OWNER

GENERAL NOTE:

THESE PLANS HAVE BEEN DESIGNED IN ACCORDANCE WITH THE 2014 NATIONAL ELECTRICAL CODE.

VOLTAGE DROP

THIS PROJECT IS IN COMPLIANCE WITH 2017 FBC-ENERGY CONSERVATION C405.8.3 AND NEC 210.19 WITH REGARDS TO VOLTAGE DROP (5%).

CA# 26308 I19140.00

INGENUITY ENGINEERS, INC.

meD studio ARCHITECTURE
1542 GUAVA AVE. UNIT A
MELBOURNE, FL 32935
321.428.3869
design@meldstudioarchitecture.com

JOB #: C-2019-021
DRAWN: FK
CHECKED: JBH

DATE
☐ SD
☐ DD
☐ BID
☐ PERMIT
☐ CD

REVISIONS:

FLORIDA INSTITUTE OF TECHNOLOGY
MERTEN'S MARINE CENTER
EAST RIVER DRIVE
MELBOURNE, FL 32901

SEAL Joseph B. Harrill

PE No. 73015
DATE: 11/06/2020

SHEET TITLE
ELECTRICAL LEGEND, NOTES & ABBREVIATIONS

SHEET NUMBER
E0.1

BID SET

SITE ELECTRICAL UTILITY LEGEND

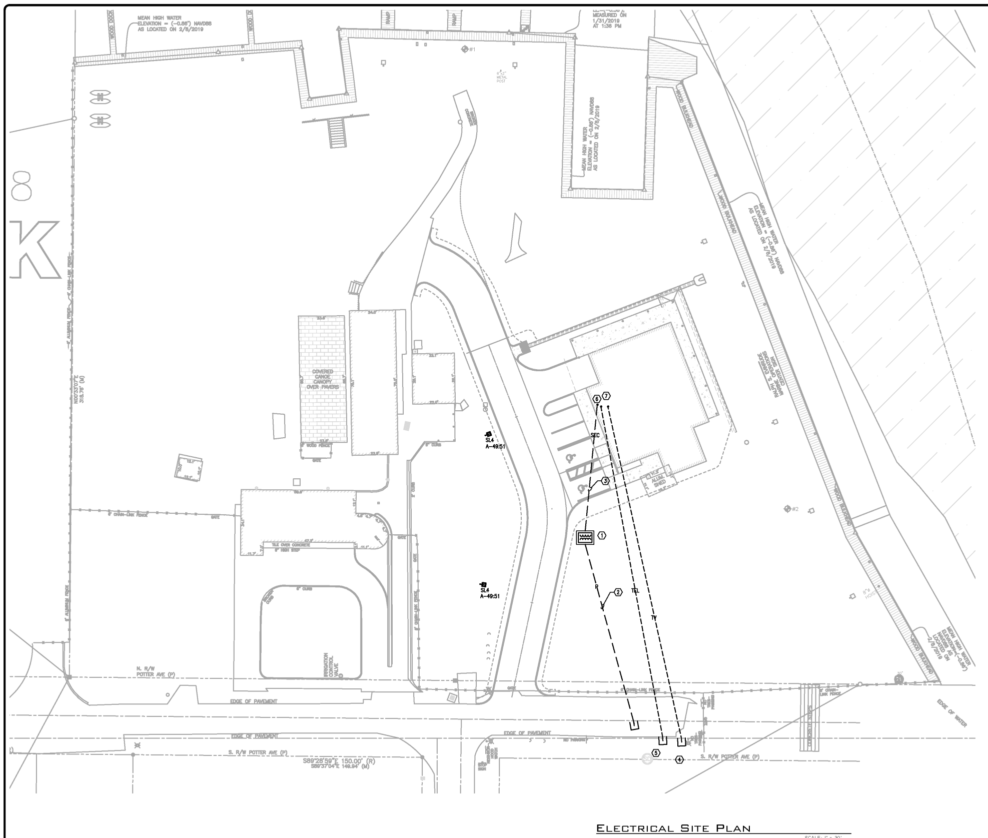
1. THIS PROJECT IS IN COMPLIANCE WITH 2017 FBC–ENERGY CONSERVATION C405.6.3 AND NEC 210.19 WITH REGARDS TO VOLTAGE DROP FOR BOTH DISTRIBUTION PANEL (5%).

SITE ELECTRICAL UTILITY LEGEND

– – – – P – – –	PRIMARY U.G. SERVICE ENTRANCE CONDUITS
– – – SEC – – –	UNDERGROUND SECONDARY SERVICE ENTRANCE FEEDERS.
– – – – – – – –	U.G. FEEDER AND CONDUIT
– – – TV – – –	U.G. SERVICE ENTRANCE TELEPHONE CONDUITS U.H. INSTALLED AT 30" BELOW FINISHED GRADE.
– – – TEL – – –	U.G. TELEVISION CONDUITS INSTALLED AT 30" BELOW FINISHED GRADE.

REFERENCE NOTES.

1. 120/208V, 3ø, 4W UTILITY TRANSFORMER. PROVIDE PAD PER UTILITY COMPANY REQUIREMENTS. CONTACT LOCAL UTILITY COMPANY
2. UNDERGROUND PRIMARY SERVICE ENTRANCE CONDUITS. (2) 6" UNDERGROUND SCHEDULE 40 PVC CONDUIT TO PROPERTY LINE WITH PULL WIRE AND CAP. INSTALL MARKER. UTILIZE LONG RADIUS ELBOWS. TERMINATE AT PAD MOUNTED TRANSFORMER. FIELD VERIFY EXACT FINAL LOCATION WITH UTILITY COMPANY PRIOR TO INSTALLATION OF CONDUITS.
3. UNDERGROUND 120/208V 3ø 4W ELECTRICAL SECONDARY SERVICE ENTRANCE. SEE ONE–LINE ELECTRICAL RISER DIAGRAM DRAWING. FIELD COORDINATE THE EXACT ROUTING AND TERMINATION POINT PRIOR TO BIDDING.
4. (3)4" UNDERGROUND CONDUITS BURIED 30" B.F.G. TO PROPERTY LINE FOR TELEVISION SERVICE ENTRANCE. UTILIZE LONG RADIUS ELBOWS. INSTALL PULLWIRE. TERMINATE AT PROPERTY LINE. CAP CONDUIT AND INSTALL MARKER.
5. (3)4", AND (2)2" SPARE, UNDERGROUND CONDUITS BURIED 30" B.F.G. TO PROPERTY LINE FOR TELEPHONE SERVICE ENTRANCE. UTILIZE LONG RADIUS ELBOWS. INSTALL PULLWIRE. TERMINATE AT PROPERTY LINE. CAP CONDUIT AND INSTALL MARKER.
6. APPROXIMATE LOCATION OF MAIN TELEPHONE, TELEVISION TERMINAL BOARD. SEE FLOOR PLANS FOR EXACT TERMINATION LOCATION AND DETAILS.
7. APPROXIMATE LOCATION OF MAIN ELECTRICAL DISTRIBUTION EQUIPMENT. (SEE POWER FLOOR PLANS FOR EXACT LOCATION).



ELECTRICAL SITE PLAN

SCALE: 1" = 20'

CA# 26308 I19140.00

INGENUITY ENGINEERS, INC.

meD studio ARCHITECTURE

1542 GUAVA AVE. UNIT A MELBOURNE, FL 32935 321.428.3869 design@meldstudioarchitecture.com

JOB #: C-2019-021

DRAWN: FK

CHECKED: JBH

DATE

☐ SD
☐ DD
☐ BID
☐ PERMIT
☐ CD

REVISIONS:

FLORIDA INSTITUTE OF TECHNOLOGY
MERTEN'S MARINE CENTER
EAST RIVER DRIVE
MELBOURNE, FL 32901

SEAL Joseph B. Harrill

PE No. 73018

DATE: 11/06/2020

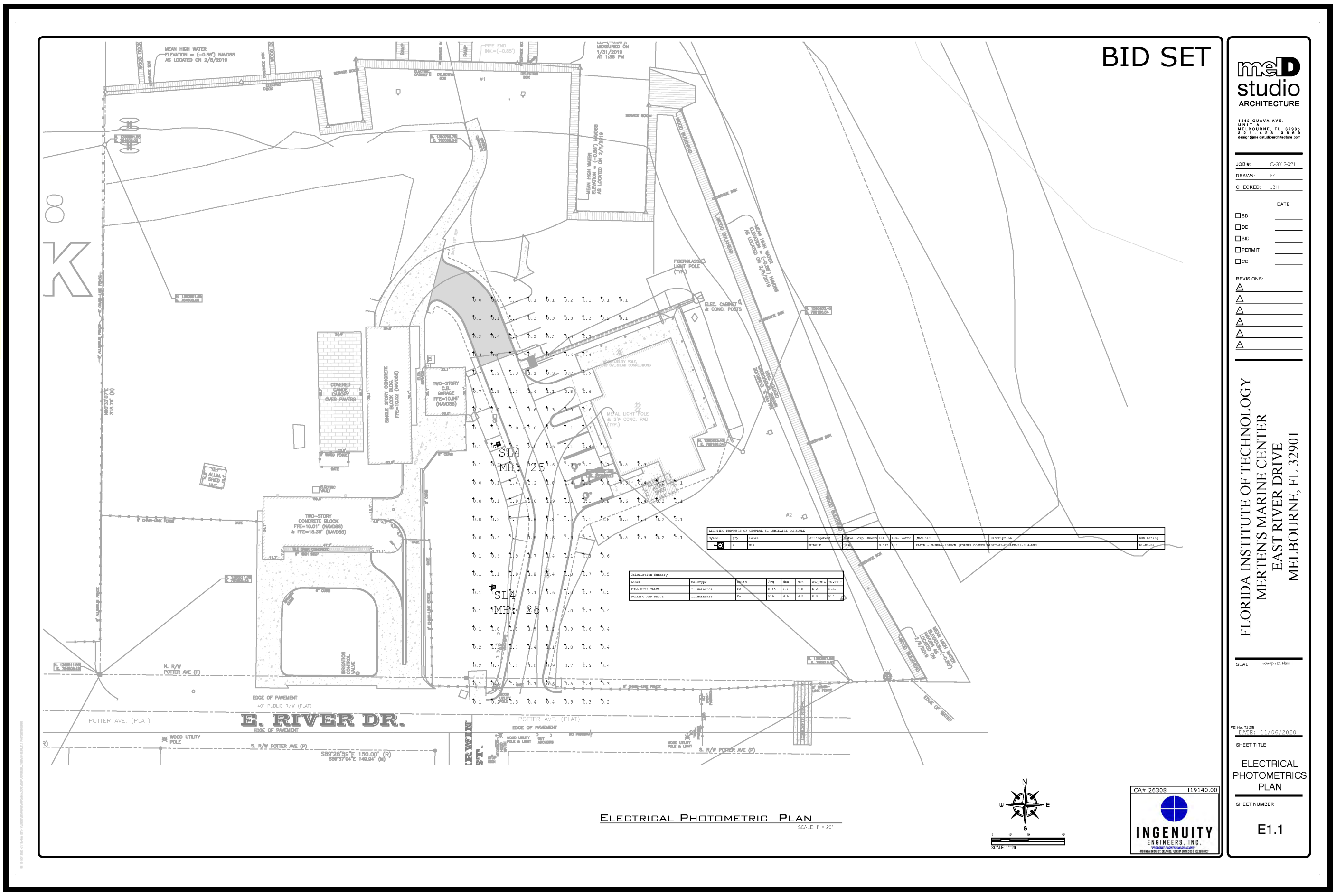
SHEET TITLE

ELECTRICAL SITE PLAN

SHEET NUMBER

E1.0

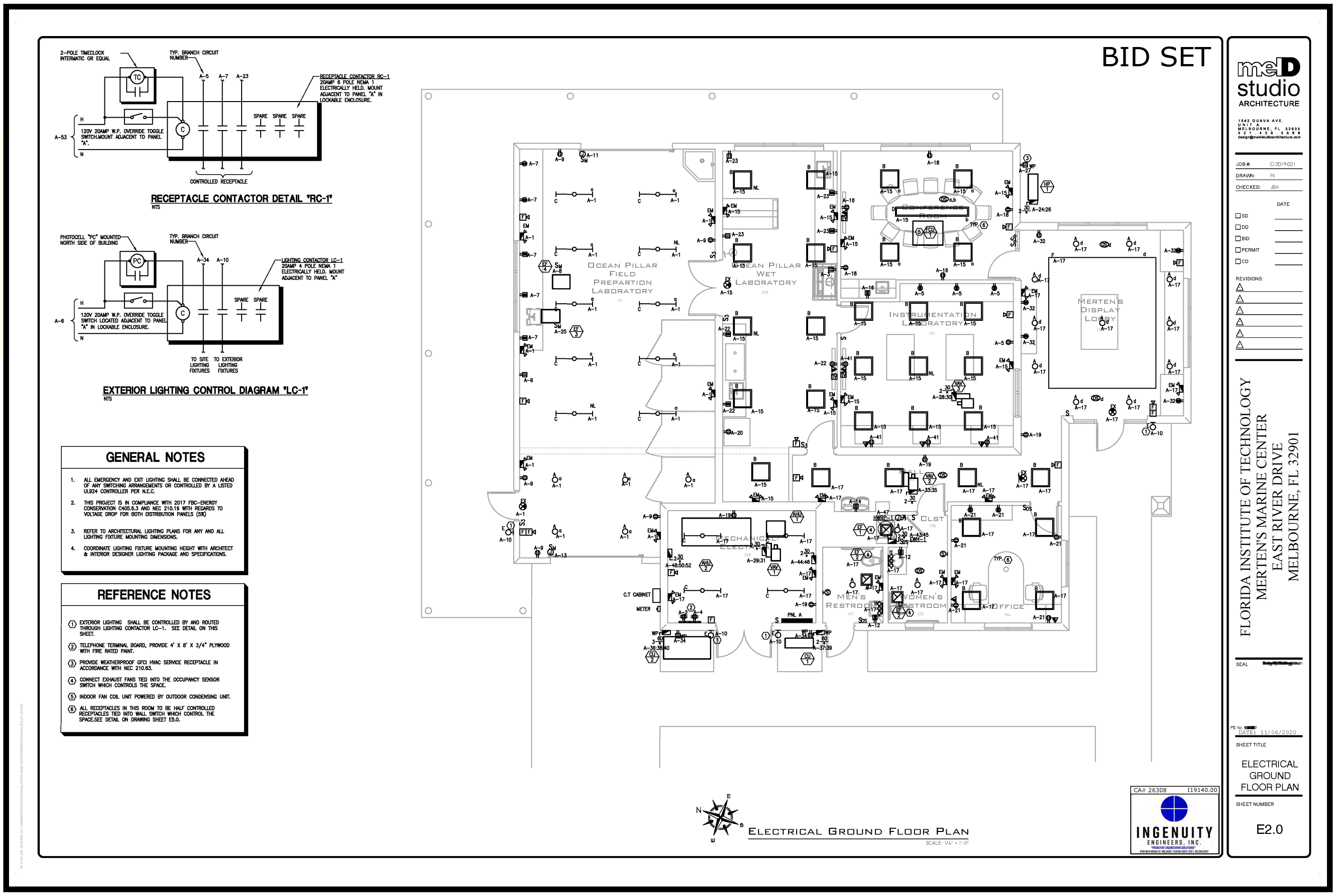
EN10401Rationale



Page: 7

Mod_10401_Rationale_Florida_Tech_Mertens_Marine_Center_Bid_Set Example.pdf

EN10401Rationale



Mod_10401_Rationale_Florida_Tech_Mertens_Marine_Center_Bid_Set Example.pdf Page: 8

EN10401Rationale

BID SET

PANEL A — SECTION 1

RATING: 400 AMP M.C.B. | SERVICE: 120/208V, 3Ø, 4 WIRE | LUG LOCATION: BOTTOM | MOUNTING: SURFACE | AIC: 22KAIC | TYPE: SQUARE D

CKT NO.	EQUIPMENT SERVED	-LD TYP	KVA	CKT. BKR. POLE	CKT. BKR. TR	BRANCH CIRCUIT Ø	NEUT	GND	COND	Ø	CKT NO.	EQUIPMENT SERVED	-LD TYP	KVA	CKT. BKR. POLE	CKT. BKR. TR	BRANCH CIRCUIT Ø	NEUT	GND	COND
1	LTG FIELD PREP AREA	L	0.90	1	20	12	12	12	1/2"	A	2	TTB	R	0.36	1	20	12	12	12	1/2"
3	LAB MACHINE *	R	0.90	1	20	12	12	12	1/2"	B	4	TTB	R	0.36	1	20	12	12	12	1/2"
5	RECEPT	R	0.72	1	20	12	12	12	1/2"	C	6	LC-1	R	0.50	1	20	12	12	12	1/2"
7	RECEPT	R	0.90	1	20	12	12	12	1/2"	A	8	EF-4	A	1.20	1	20	12	12	12	1/2"
9	RECEPT	R	0.90	1	20	12	12	12	1/2"	B	10	EXT. LTG	R	0.25	1	20	12	12	12	1/2"
11	J-BOX PALLAR DR OPENER	R	0.90	1	20	12	12	12	1/2"	C	12	RECEPT., RESTROOM	R	0.90	1	20	12	12	12	1/2"
13	J-BOX PALLAR DR OPENER	R	0.90	1	20	12	12	12	1/2"	A	14	EWC	R	1.00	1	20	12	12	12	1/2"
15	LIGHTING	L	0.90	1	20	12	12	12	1/2"	B	16	RECEPT MEETING ROOM	R	0.54	1	20	12	12	12	1/2"
17	LIGHTING	L	0.90	1	20	12	12	12	1/2"	C	18	RECEPT MTG RM. TV	R	0.54	1	20	12	12	12	1/2"
19	RECEPT	R	0.54	1	20	12	12	12	1/2"	A	20	REFRG.*	R	1.00	1	20	12	12	12	1/2"
21	RECEPT OFFICE	R	0.90	1	20	12	12	12	1/2"	B	22	RECEPT	R	0.54	1	20	12	12	12	1/2"
23	RECEPT	R	0.72	1	20	12	12	12	1/2"	C	24	HP-1	A	1.08	2	20	12	--	12	1/2"
25	EF-3	R	0.70	1	20	12	12	12	1/2"	A	26	---	A	1.08	--	--	12	--	--	--
27	RECEPTACLE	A	0.36	1	20	12	12	12	1/2"	B	28	VAV-3	A	2.50	2	30	10	--	10	3/4"
29	VAV-1	A	0.50	2	20	12	--	12	1/2"	C	30	---	A	2.50	--	--	10	--	--	--
31	---	A	0.50	--	--	12	--	--	--	A	32	RECEPT	R	0.90	1	20	12	12	12	1/2"
33	VAV-2	A	1.25	2	20	12	--	12	1/2"	B	34	RECEPTACLE	R	0.36	1	20	12	12	12	1/2"
35	---	A	1.25	--	--	12	--	--	--	C	36	CU-2	A	2.76	3	30	10	--	10	3/4"
37	CU-1	A	3.69	2	40	8	--	8	1"	A	38	---	A	2.76	--	--	10	--	--	--
39	---	A	3.69	--	--	8	--	--	--	B	40	---	A	2.76	--	--	10	--	--	--
41	RECEPTACLE	A	0.72	1	20	12	12	12	1/2"	C	42									

EQUIPMENT SERVED	CONN. LOAD	LF	DF	DESIGN LOAD (KVA)
LIGHTING	3.0	1.25		3.75
MISC. EQUIPMENT	5.1		1.00	5.10
RECEPTACLES (1ST 10KVA)	10.0		1.00	10.00
REMAINING RECEPTACLES	5.4		0.50	2.70
HVAC EQUIPMENT	37.8		1.00	37.77
KITCHEN	0.0		1.00	0.00
			TOTAL	59.32

REMARKS:

-PROVIDE NEUTRAL & GROUND BUS
-PROVIDE TYPE WRITTEN DIRECTORY
-PROVIDE FEED THRU LUGS
*PROVIDE GFCI BREAKER

42 CIRCUITS — 165 AMPS

PANEL A — SECTION 2

RATING: 400 AMP M.L.O. | SERVICE: 120/208V, 3Ø, 4 WIRE | LUG LOCATION: BOTTOM | MOUNTING: SURFACE | AIC: 22KAIC | TYPE: SQUARE D

CKT NO.	EQUIPMENT SERVED	-LD TYP	KVA	CKT. BKR. POLE	CKT. BKR. TR	BRANCH CIRCUIT Ø	NEUT	GND	COND	Ø	CKT NO.	EQUIPMENT SERVED	-LD TYP	KVA	CKT. BKR. POLE	CKT. BKR. TR	BRANCH CIRCUIT Ø	NEUT	GND	COND
43	EWH-1	M	2.25	2	30	10	--	10	3/4"	A	44	AHU-1	A	0.67	2	20	12	--	12	1/2"
45	---	M	2.25	--	--	10	--	--	--	B	46	---	A	0.67	--	--	12	--	--	--
47	HWRP-1	M	0.10	1	20	12	12	12	1/2"	C	48	AHU-2	A	2.61	3	30	10	--	10	3/4"
49	SITE LIGHTING	L	0.15	2	20	12	12	12	1/2"	A	50	---	A	2.61	--	--	10	--	--	--
51	---	L	0.15	--	--	12	--	--	--	B	52	---	A	2.61	--	--	10	--	--	--
53	RC-1	M	0.50	1	20	12	12	12	1/2"	C	54	SPARE			1	20				
55	SPARE			1	20					A	56	SPARE			1	20				
57	SPARE			1	20					B	58	SPARE			1	20				
59	SPARE			1	20					C	60	SPARE			1	20				
61	SPARE			1	20					A	62	SPARE			1	20				
63	SPARE			1	20					B	64	SPARE			1	20				
65	SPARE			1	20					C	66	SPARE			1	20				
67	SPARE			1	20					A	68	SPARE			1	20				
69	SPACE									B	70	SPACE								
71	SPACE									C	72	SPACE								
73	SPACE									A	74	SPACE								
75	SPACE									B	76	SPACE								
77	SPACE									C	78	SPACE								
79	SPACE									A	80	SPACE								
81	SPACE									B	82	SPACE								
83										C	84	SPACE								

REMARKS

-PROVIDE NEUTRAL & GROUND BUS
-PROVIDE TYPE WRITTEN DIRECTORY

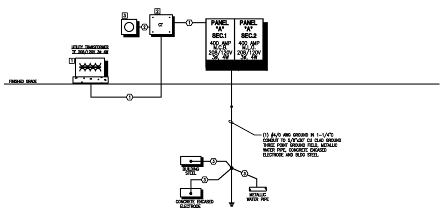
42 CIRCUITS

WIRE AND CONDUIT SCHEDULE

SYMBOL	CONDUCTORS PER/PHASE	CONDUCTORS NEUTRAL	COPPER GROUND	CONDUIT
1	250 KCMIL 2 PARALLEL SET	250 KCMIL 2 PARALLEL SET	----	(2) 4"
2	#10 AWG CU	#10 AWG CU	#10 AWG CU	(2)x1-1/4"C (1) 1-1/4"C SPARE
3	-----	----	#2 AWG	1-1/4"

ELECTRICAL RISER NOTES:

1. PAD MOUNTED TRANSFORMER WITH CONCRETE HOUSEKEEPING PAD CONSTRUCTED PER UTILITY COMPANY REQUIREMENTS. FIELD VERIFY THE EXACT LOCATION PRIOR TO BIDDING. SECONDARY VOLTAGE 208/120V, 3ph, 4W.
2. CT SERVICE 3Ø, 4W, W.P. METER SOCKET MOUNTED ON BUILDING. VERIFY TYPE WITH LOCAL UTILITY REGULATIONS
3. WEATHER PROOF METER CAN MOUNTED TO BUILDING EXTERIOR.



ELECTRICAL RISER DIAGRAM

N.T.S.

CA# 26308 I19140.00

INGENUITY ENGINEERS, INC.

med studio ARCHITECTURE

FLORIDA INSTITUTE OF TECHNOLOGY
MERTEN'S MARINE CENTER
EAST RIVER DRIVE
MELBOURNE, FL 32901

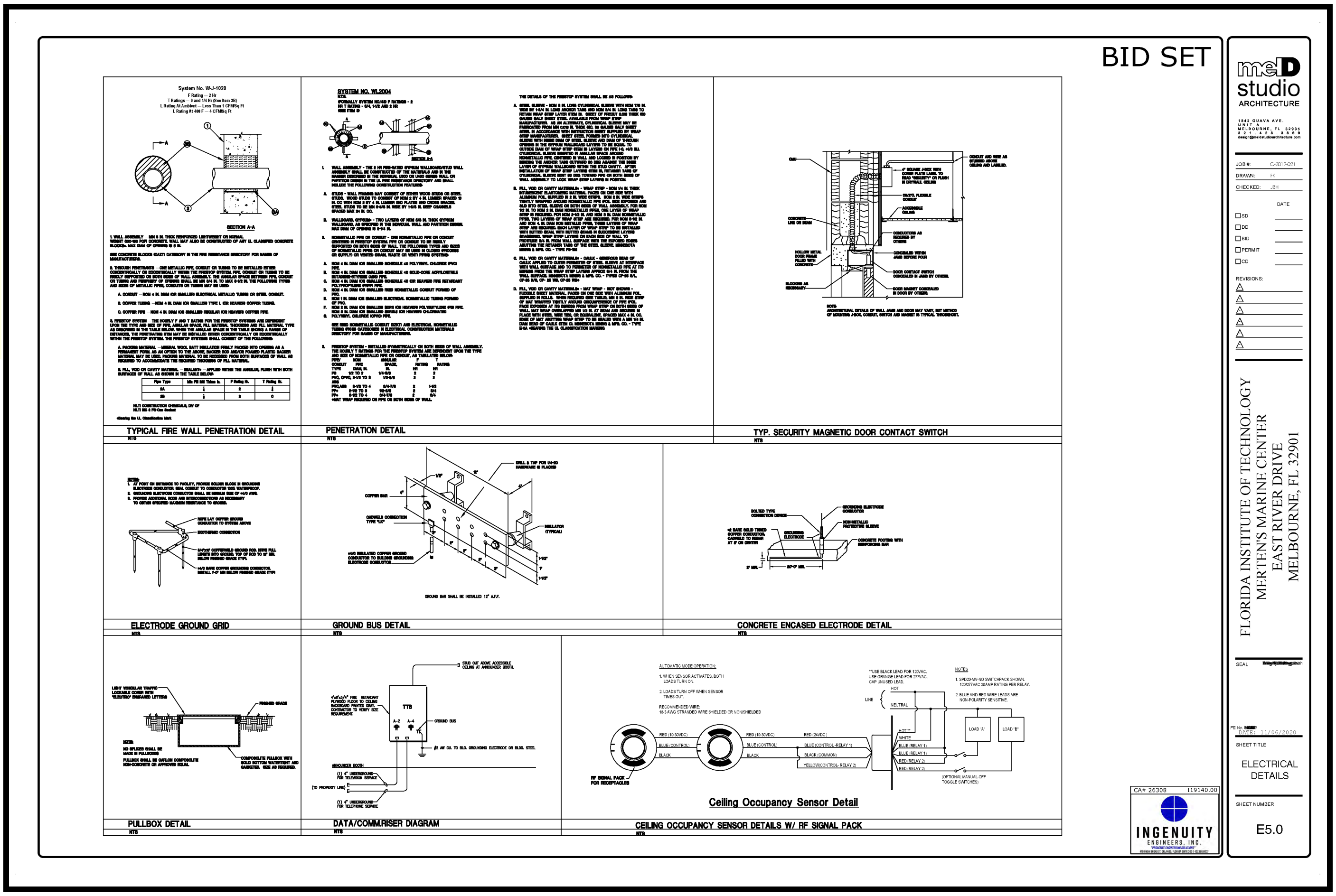
DATE: 11/06/2020

SHEET TITLE: ELECTRICAL PANEL SCHEDULES

SHEET NUMBER: E4.0

Page: 9

Mod_10401_Rationale_Florida_Tech_Mertens_Marine_Center_Bid_Set Example.pdf



BID SET
TYPICAL FIRE WALL PENETRATION DETAIL
PENETRATION DETAIL
TYP. SECURITY MAGNETIC DOOR CONTACT SWITCH
ELECTRODE GROUND GRID
GROUND BUS DETAIL
CONCRETE ENCASED ELECTRODE DETAIL
PULLBOX DETAIL
DATA/COMM.RISER DIAGRAM
Ceiling Occupancy Sensor Detail
CEILING OCCUPANCY SENSOR DETAILS W/ RF SIGNAL PACK
meD studio
ARCHITECTURE
FLORIDA INSTITUTE OF TECHNOLOGY
MERTEN'S MARINE CENTER
EAST RIVER DRIVE
MELBOURNE, FL 32901
INGENUITY
ENGINEERS, INC.
ELECTRICAL DETAILS
E5.0

SECTION 01 91 00

TOTAL BUILDING COMMISSIONING
05/19

PART 1 GENERAL

1.1 SUMMARY

Commission the building systems listed herein. Employ the services of an independent Commissioning Firm. The Commissioning Firm must be a 1st tier subcontractor of the General or Prime Contractor and must be financially and corporately independent of all other subcontractors. The Commissioning Firm must employ a Lead Commissioning Specialist that coordinates all aspects of the commissioning process. Conform to the commissioning procedures outlined in this specification.

1.2 SYSTEMS TO BE COMMISSIONED

Commission the following systems:

Heating, Ventilating, Air Conditioning, and Refrigeration Systems (HVAC)
Building Automation System

Lighting Systems
Power Distribution Systems

Service Water Heating Systems
Plumbing Systems

Energy and Water Utility Metering Systems and Sub-Meters

Building Envelope: include moisture, thermal integrity, and air tightness for the entire buidling envelope including systems such as walls, fenestration.

1.3 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

ASHRAE 202 (2013; Addenda B 2018) Commissioning Process for Buildings and Systems

ASSOCIATED AIR BALANCE COUNCIL (AABC)

ACG Commissioning Guideline (2005) Commissioning Guideline

NATIONAL ENVIRONMENTAL BALANCING BUREAU (NEBB)

NEBB Commissioning Standard (2009) Procedural Standards for Whole

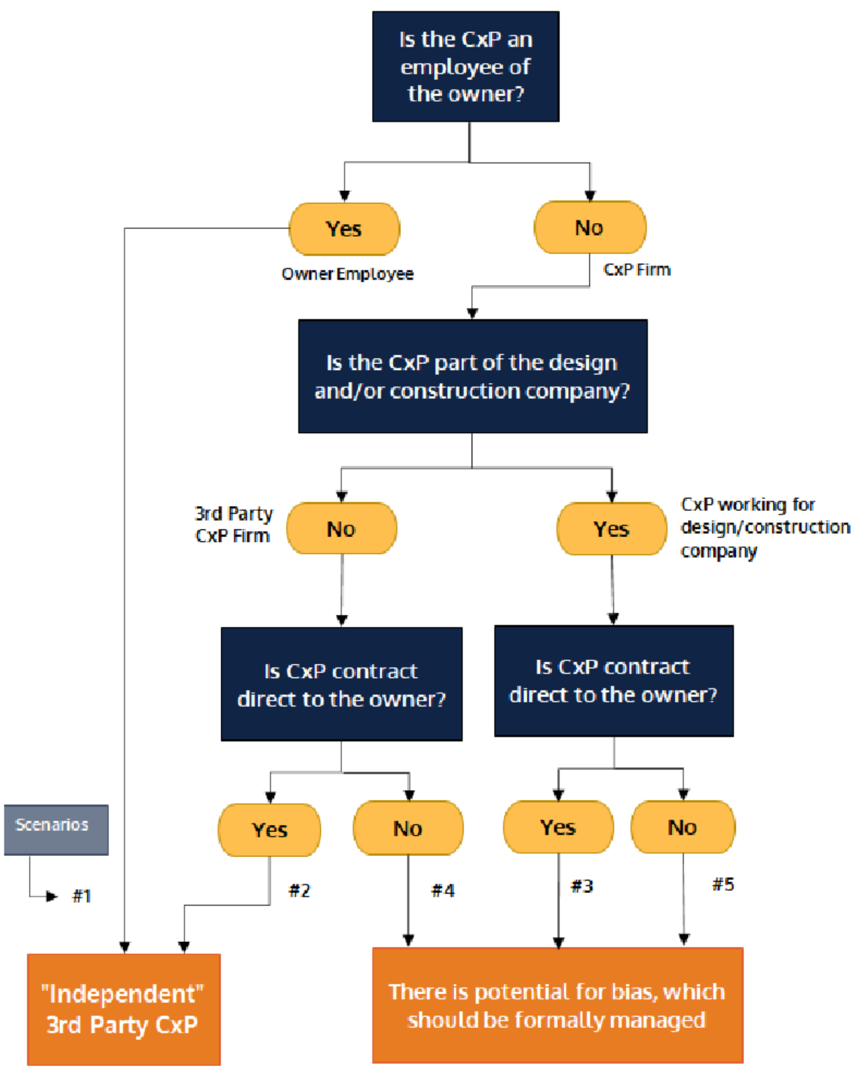
Multiple Systems Third Party Commissioning	
2018 ASHRAE Standard 202 Informative Appendix G, Cx Process Specifications, Section G2	"G2.2) When the Owner's organization cannot perform the CxP duties with qualified personnel, then the CxP should have a separate professional services agreement with the Owner, as this avoids conflicts of interest and provides independence from the other parties (the Owner's project manager, designers of record, construction managers, suppliers and construction contractors). This professional services agreement defines the duties, rights, and responsibilities of the CxP for each phase of the project. This separate relationship allows the CxP to act independently as director of Cx Activities, to focus on achieving the OPR, and to communicate directly with the Owner." "G2.4) If the CxP is an employee, associate, or partner of the same organization as the designer of record or construction management firm, there is a conflict of interest. While not a recommended approach, in these instances, the CxP must have a separate professional service agreement, be organizationally separate from the Design Team or Construction Team, and define and manage the conflict of interest to provide the Owner with the independence required for the Cx to be successful." **Note: this references an appendix to the ASHRAE Standard. As an appendix, it does not contain requirements necessary for conformance to the standard.**
2018 International Green Construction Code (IGCC) Informative Appendix I, Section I101 (I1.c)	***Applies to Mechanical/Electrical/Plumbing, for Buildings > 10,000 SF*** "The *Cx provider* and the functional performance test (*FPT) provider* should be independent of the building system design and construction functions of the systems being commissioned. The *Cx provider* and *FPT provider* should disclose possible conflicts of interest to ensure objectivity." **Note: this references an appendix to the IGCC code. As an appendix, it does not carry the same enforcement authority as the content written within the code sections.**
ASHRAE 90.1-2019	***Applies to building systems, controls, and building envelope:*** "Verification and Testing Providers shall be Owner's employees, commissioning providers, qualified designers or experienced technicians not involved in design or construction of project." **Note: Many of the commissioning requirements in ASHRAE 90.1-2019 come from ASHRAE Standard 189.1-2017.**

FAQ #2: What is the definition of third-party commissioning?

Summary. The purpose of this document is to define third party commissioning and describe the various means by which building commissioning can be contracted to meet the needs of a project, in the best interest of the Owner.

Definition tied to Contractual Relationship. The term "third-party," or "independent third-party," commissioning is typically used to describe a contractual relationship in which the commissioning provider (CxP) is accountable directly to the Owner and independent of any other entity involved in the project, especially with responsibility for the design or construction of the systems being commissioned.

The following flowchart represents multiple scenarios in which the CxP is connected contractually to the Owner on a project.



Third Party Cx Independence

are considered "independent" third-party contracts.

Scenario #1 – Qualified Provider part of the Owner staff.

Scenario #2 – Qualified Provider hired directly by the Owner with no other relationship to the project's design or construction companies.

Scenario #3 – Qualified Provider hired by the Owner directly, who is not a participating member of the project design or construction team but is employed by one of those companies.

Scenario #4 – Qualified Provider with contractual relationship to design or construction team who is a separate company from those teams. **In this scenario, the CxP is third-party, but not independent.**

Scenario #5 – Qualified Provider who is not a participating member of the project design or construction team but is employed by one of those companies and is contractually obligated to the design or construction team.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

42

EN10407

Date Submitted	02/14/2022	**Section**	402.4	**Proponent**	Jennifer Hatfield
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language Yes**

Related Modifications

Summary of Modification

This proposal makes changes to Table C402.4, aligning the fenestration U-factor and SHGC requirements within that table to what is provided in the 2021 IECC.

Rationale

This proposal is being submitted on behalf of the Fenestration & Glazing Industry Alliance (formerly AAMA). This language brings forward language from the 2021 IECC, providing consistency between the Florida and ICC tables for Fenestration Max U-factor and SHGC Requirements. The majority of changes reflect a consensus agreement between industry and energy advocates to update the fenestration criteria based on a recent comprehensive analysis, providing additional energy savings in every zone while remaining cost-effective and practical. This proposal will also provide consistency with the criteria approved in Addendum AW of ASHRAE 90.1-2019. It is noted that the “Fixed” changes for “Zone 4 except marine” and “Zone 5 and marine 4” were not changes from the 2018 to 2021 IECC but did require updating in the Florida language for complete consistency with what is in the 2021 IECC. As the Florida language for these two “fixed” zones was not reflective of what was in the 2018 IECC.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Minimal effects regarding code enforcement.

Impact to building and property owners relative to cost of compliance with code

This will increase cost of construction, see uploaded support file.

Impact to industry relative to the cost of compliance with code

This will increase the cost of construction, see uploaded support file.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Provides for additional energy savings while remaining cost-effective and practical, supporting the welfare of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Strengthens the code by providing additional energy savings and consistency with the IECC table.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

It does not.

Does not degrade the effectiveness of the code

It does not.

Alternate Language

1st Comment Period History

EN10407-A1

Proponent Jennifer Hatfield **Submitted** 4/17/2022 6:31:30 PM **Attachments** Yes

Rationale:

FGIA (formerly AAMA) is submitting this alternative language comment to only address changes in the two climate zones that exist in Florida, for simplicity. The TAC may want to consider striking the climate zones that do not exist in Florida from all the tables. This language brings forward language from the 2021 IECC and ASHRAE 90.1-2019 for consistency but for the SHGC change that applies climate zone 2 values statewide for simplicity.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None

Impact to building and property owners relative to cost of compliance with code

Will increase cost, see original modification's upload support file.

Impact to industry relative to the cost of compliance with code

Will increase cost, see original modification's upload support file.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Provides for additional energy savings while remaining cost-effective and practical.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Strengthens the code by providing additional energy savings and consistency with IECC and ASHRAE 90.1

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

It does not.

Does not degrade the effectiveness of the code

It does not.

TABLE C402.4
BUILDING ENVELOPE FENESTRATION MAXIMUM *U*-FACTOR AND SHGC REQUIREMENTS

CLIMATE ZONE	1		2	
Vertical fenestration				
U-factor				
Fixed fenestration	0.50		~~0.50~~ 0.45	
Operable fenestration	~~0.65~~ 0.62		~~0.65~~ 0.60	
Entrance doors	~~1.10~~ 0.83		~~0.83~~ 0.77	
SHGC				
~~Orientation~~[a]	~~SEW~~ Fixed	~~N~~ Operable	~~SEW~~ Fixed	~~N~~ Operable
PF < 0.2	0.25	~~0.33~~ 0.23	0.25	~~0.33~~ 0.23
0.2 = PF < 0.5	0.30	~~0.37~~ 0.28	0.30	~~0.37~~ 0.28
PF = 0.5	0.40	~~0.40~~ 0.37	0.40	~~0.40~~ 0.37
Skylights				
U-factor	~~0.75~~ 0.70		0.65	
SHGC	~~0.35~~ 0.30		~~0.35~~ 0.30	

NR = No requirement, PF = Projection factor.

~~a. "N" indicates vertical fenestration oriented within 45 degrees of true north. "SEW" indicates orientations other than "N." For buildings in the southern hemisphere, reverse south and north. Buildings located at less than 23.5 degrees latitude shall use SEW for all orientations.~~

TABLE C402.4
BUILDING ENVELOPE FENESTRATION MAXIMUM *U*-FACTOR AND SHGC REQUIREMENTS

CLIMATE ZONE	1		2	
Vertical fenestration				
U-factor				
Fixed fenestration	0.50		~~0.50~~ 0.45	
Operable fenestration	~~0.65~~ 0.62		~~0.65~~ 0.60	
Entrance doors	~~1.10~~ 0.83		~~0.83~~ 0.77	
SHGC				
~~Orientation[a]~~	~~SEW~~ Fixed	~~N~~ Operable	~~SEW~~ Fixed	~~N~~ Operable
PF < 0.2	0.25	~~0.33~~ 0.23	0.25	~~0.33~~ 0.23
0.2 ≤ PF < 0.5	0.30	~~0.37~~ 0.28	0.30	~~0.37~~ 0.28
PF ≥ 0.5	0.40	~~0.40~~ 0.37	0.40	~~0.40~~ 0.37
Skylights				
U-factor	~~0.75~~ 0.70		0.65	
SHGC	~~0.35~~ 0.30		~~0.35~~ 0.30	

NR = No requirement, PF = Projection factor.

~~a. "N" indicates vertical fenestration oriented within 45 degrees of true north. "SEW" indicates orientations other than "N." For buildings in the southern hemisphere, reverse south and north. Buildings located at less than 23.5 degrees latitude shall use SEW for all orientations.~~

TABLE C402.4
BUILDING ENVELOPE FENESTRATION MAXIMUM *U*-FACTOR AND SHGC REQUIREMENTS

See Image Below

NR = No requirement, PF = Projection factor.

~~a. "N" indicates vertical fenestration oriented within 45 degrees of true north. "SEW" indicates orientations other than "N." For buildings in the southern hemisphere, reverse south and north. Buildings located at less than 23.5 degrees latitude shall use SEW for all orientations.~~

CLIMATE ZONE	0 AND 1		2		3		4 EXCEPT MARINE		5 AND MARINE 4		6		7		8	
Vertical fenestration																
***U*-factor**																
Fixed fenestration	0.5		~~0.50~~ 0.45		~~0.46~~ 0.42		~~0.38~~ 0.36		~~0.38~~ 0.36		~~0.36~~ 0.34		0.29		~~0.29~~ 0.26	
Operable fenestration	~~0.65~~ 0.62		~~0.65~~ 0.60		~~0.60~~ 0.54		0.45		0.45		~~0.43~~ 0.42		~~0.37~~ 0.36		~~0.37~~ 0.32	
Entrance doors	~~1.10~~ 0.83		~~0.83~~ 0.77		~~0.77~~ 0.68		~~0.77~~ 0.63		~~0.77~~ 0.63		~~0.77~~ 0.63		~~0.77~~ 0.63		~~0.77~~ 0.63	
SHGC																
~~Orientation[a]~~	~~SEW Fixed~~	~~N Operable~~	~~SEW Fixed~~	~~N Operable~~	~~SEW Fixed~~	~~N Operable~~	~~SEW Fixed~~	~~N Operable~~	~~SEW Fixed~~	~~N Operable~~	~~SEW Fixed~~	~~N Operable~~	~~SEW Fixed~~	~~N Operable~~	~~SEW Fixed~~	~~N Operable~~
PF < 0.2	~~0.25~~ 0.23	~~0.33~~ 0.21	0.25	~~0.33~~ 0.23	0.25	~~0.33~~ 0.23	~~0.40~~ 0.36	~~0.53~~ 0.33	~~0.40~~ 0.38	~~0.53~~ 0.33	~~0.40~~ 0.38	~~0.53~~ 0.34	~~0.45~~ 0.40	~~NR~~ 0.36	~~0.45~~ 0.40	~~NR~~ 0.36
0.2 ≤ PF < 0.5	~~0.30~~ 0.28	~~0.37~~ 0.25	0.3	~~0.37~~ 0.28	0.3	~~0.37~~ 0.28	~~0.48~~ 0.43	~~0.58~~ 0.40	~~0.48~~ 0.46	~~0.58~~ 0.40	~~0.48~~ 0.46	~~0.58~~ 0.41	~~NR~~ 0.48	~~NR~~ 0.43	~~NR~~ 0.48	~~NR~~ 0.43
PF ≥ 0.5	~~0.40~~ 0.37	~~0.40~~ 0.34	0.4	~~0.40~~ 0.37	0.4	~~0.40~~ 0.37	~~0.64~~ 0.58	~~0.64~~ 0.53	~~0.64~~ 0.61	~~0.64~~ 0.53	~~0.64~~ 0.61	~~0.64~~ 0.54	~~NR~~ 0.64	~~NR~~ 0.58	~~NR~~ 0.64	~~NR~~ 0.58
Skylights																
***U*-factor**	~~0.75~~ 0.70		0.65		0.55		0.5		0.5		0.5		~~0.50~~ 0.44		~~0.50~~ 0.41	
SHGC	~~0.35~~ 0.30		~~0.35~~ 0.30		~~0.35~~ 0.30		0.4		0.4		0.4		NR		NR	

TABLE C402.4
BUILDING ENVELOPE FENESTRATION MAXIMUM *U*-FACTOR AND SHGC REQUIREMENTS

CLIMATE ZONE	0 AND 1		2		3		4 EXCEPT MARINE		5 AND MARINE 4		6		7		8	
Vertical fenestration																
***U*-factor**																
Fixed fenestration	0.50		~~0.50~~ 0.45		~~0.46~~ 0.42		~~0.38~~ 0.36		~~0.38~~ 0.36		~~0.36~~ 0.34		0.29		~~0.29~~ 0.26	
Operable fenestration	~~0.65~~ 0.62		~~0.65~~ 0.60		~~0.60~~ 0.54		0.45		0.45		~~0.43~~ 0.42		~~0.37~~ 0.36		~~0.37~~ 0.32	
Entrance doors	~~1.10~~ 0.83		~~0.83~~ 0.77		~~0.77~~ 0.68		~~0.77~~ 0.63		~~0.77~~ 0.63		~~0.77~~ 0.63		~~0.77~~ 0.63		~~0.77~~ 0.63	
SHGC																
~~Orientation[a]~~	~~SEW~~ Fixed	~~N~~ Operable	~~SEW~~ Fixed	~~N~~ Operable	~~SEW~~ Fixed	~~N~~ Operable	~~SEW~~ Fixed	~~N~~ Operable	~~SEW~~ Fixed	~~N~~ Operable	~~SEW~~ Fixed	~~N~~ Operable	~~SEW~~ Fixed	~~N~~ Operable	~~SEW~~ Fixed	~~N~~ Operable
PF < 0.2	~~0.25~~ 0.23	~~0.33~~ 0.21	0.25	~~0.33~~ 0.23	0.25	~~0.33~~ 0.23	~~0.40~~ 0.36	~~0.53~~ 0.33	~~0.40~~ 0.38	~~0.53~~ 0.33	~~0.40~~ 0.38	~~0.53~~ 0.34	~~0.45~~ 0.40	~~NR~~ 0.36	~~0.45~~ 0.40	~~NR~~ 0.36
0.2 ≤ PF < 0.5	~~0.30~~ 0.28	~~0.37~~ 0.25	0.30	~~0.37~~ 0.28	0.30	~~0.37~~ 0.28	~~0.48~~ 0.43	~~0.58~~ 0.40	~~0.48~~ 0.46	~~0.58~~ 0.40	~~0.48~~ 0.46	~~0.58~~ 0.41	~~NR~~ 0.48	~~NR~~ 0.43	~~NR~~ 0.48	~~NR~~ 0.43
PF ≥ 0.5	~~0.40~~ 0.37	~~0.40~~ 0.34	0.40	~~0.40~~ 0.37	0.40	~~0.40~~ 0.37	~~0.64~~ 0.58	~~0.64~~ 0.53	~~0.64~~ 0.61	~~0.64~~ 0.53	~~0.64~~ 0.61	~~0.64~~ 0.54	~~NR~~ 0.64	~~NR~~ 0.58	~~NR~~ 0.64	~~NR~~ 0.58
Skylights																
U-factor	~~0.75~~ 0.70		0.65		0.55		0.50		0.50		0.50		~~0.50~~ 0.44		~~0.50~~ 0.41	
SHGC	~~0.35~~ 0.30		~~0.35~~ 0.30		~~0.35~~ 0.30		0.40		0.40		0.40		NR		NR	

NR = No requirement, PF = Projection factor.

~~1. a. "N" indicates vertical fenestration oriented within 45 degrees of true north. "SEW" indicates orientations other than "N." For buildings in the southern hemisphere, reverse south and north. Buildings located at less than 23.5 degrees latitude shall use SEW for all orientations.~~

CE84-19

IECC®: TABLE C402.4

Proponents: Thomas Culp, representing the Glazing Industry Code Committee and the Aluminum Extruders Council (culp@birchpointconsulting.com); Jeff Inks, Representing the Window and Door Manufacturers Association, representing Window and Door Manufacturers Association (jinks@wdma.com); Jennifer Hatfield, representing American Architectural Manufacturers Association (jen@jhatfieldandassociates.com); Chris Mathis, representing Mathis Consulting Company (chris@mathisconsulting.com)

2018 International Energy Conservation Code

Revise as follows:

TABLE C402.4
BUILDING ENVELOPE FENESTRATION MAXIMUM *U*-FACTOR AND SHGC REQUIREMENTS

CLIMATE ZONE	1		2		3		4 EXCEPT MARINE		5 AND MARINE 4		6		7		8	
Vertical fenestration																
***U*-factor**																
Fixed fenestration	0.50		0.50		0.46		0.38		0.38		0.36		0.29		0.29	
Operable fenestration	0.65		0.65		0.60		0.45		0.45		0.43		0.37		0.37	
Entrance doors	1.10		0.83		0.77		0.77		0.77		0.77		0.77		0.77	
SHGC																
Orientation[a]	SEW	N	SEW	N	SEW	N	SEW	N	SEW	N	SEW	N	SEW	N	SEW	N
PF < 0.2	0.25	0.33	0.25	0.33	0.25	0.33	0.36	0.48	0.38	0.51	0.40	0.53	0.45	NR	0.45	N
0.2 ≤ PF < 0.5	0.30	0.37	0.30	0.37	0.30	0.37	0.43	0.53	0.46	0.56	0.48	0.58	NR	NR	NR	NR
PF ≥ 0.5	0.40	0.40	0.40	0.40	0.40	0.40	0.58	0.58	0.61	0.61	0.64	0.64	NR	NR	NR	NR
Skylights																
U-factor	0.75		0.65		0.55		0.50		0.50		0.50		0.50		0.50	
SHGC	0.35		0.35		0.35		0.40		0.40		0.40		NR		NR	

NR = No Requirement, PF = Projection Factor.

a. "N" indicates vertical fenestration oriented within 45 degrees of true north. "SEW" indicates orientations other than "N." For buildings in the southern hemisphere, reverse south and north. Buildings located at less than 23.5 degrees latitude shall use SEW for all orientations.

Reason: The purpose of this proposal is to update the fenestration criteria based on a recent comprehensive analysis, providing additional energy savings in every zone while remaining cost-effective and practical. This proposal will also provide consistency with the criteria approved for ASHRAE 90.1-2019 in Addendum AW, which passed with broad consensus and support of both industry groups and energy efficiency advocates. The fenestration energy performance indices (U-factor, SHGC), incremental costs, and energy savings associated with a total of 319 fenestration assemblies using different glazing, frame, spacer, and gas fill technologies were calculated to determine what performance levels showed positive life cycle energy savings in each zone using a heating scalar of 25.2 and a cooling scalar of 22.1, consistent with ASHRAE 90.1 methodology. Energy savings for different combinations of U and SHGC were calculated using the medium office and midrise apartment prototype building models developed by Pacific Northwest National Laboratory. Incremental cost data for each product combination was reviewed in consultation with the ASHRAE 90.1 Envelope Subcommittee, industry representatives, and other stakeholders. Practical considerations of potential limitations of different technologies in different applications, distinctions between product categories, product costs, supply and distribution were also used in shaping the final proposed requirements. This analysis resulted in the comprehensive update to ASHRAE 90.1 in Addendum AW, and those same values are adapted into IECC's different table format in this proposal.

Depending on zone, U-factors are reduced by 0-14% for fixed and operable vertical fenestration, 7-25% for entrance doors, and 0-18% for skylights; SHGC requirements for vertical fenestration and skylights are reduced by 0-14%. Overall, this proposal provides the next step in energy efficiency while relying on commercially available and cost-effective technologies, including increased use of new low-e glass coatings, high performance thermally broken or composite frames, argon gas fill, and warm edge spacers. Additionally, consistency between IECC and ASHRAE 90.1 will improve use and compliance of both standards for the design community, fenestration industry, and building code officials.

Cost Impact: The code change proposal will increase the cost of construction
As described above, the ASHRAE 90.1 fenestration workgroup and envelope subcommittee assessed the incremental cost, energy savings, and life cycle cost effectiveness for 319 fenestration assemblies using a wide range of commercially available technologies: 37 different glazing assemblies (double, triple glazing with different low-e products), 4 levels of frame performance, 3 levels of spacer performance, and 2 different gas fills. Incremental cost data for each product combination was reviewed in consultation with the ASHRAE 90.1 Envelope Subcommittee, industry representatives, and other stakeholders. Life cycle energy savings were assessed in the PNNL medium office and midrise apartment prototype building models in each climate zone using a heating scalar of 25.2 and a cooling scalar of 22.1, and the proposed changes showed positive life cycle energy savings in accordance with ASHRAE 90.1 methodology.

Life cycle analysis was the primary method for determination of cost effectiveness. Nonetheless, simple payback periods for the PNNL medium office building typically ranges from 0-16 years in zones 1-7, and approximately 24 years in zone 8 where the jump from double to triple glazing in the model building increases the apparent payback period. In reality, triple glazing is already common in this extremely cold region (e.g. north slope of Alaska).

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10410

Date Submitted	02/14/2022	**Section**	402.4	**Proponent**	Eric Lacey
Chapter	4	**Affects HVHZ**	No	**Attachments**	**Yes**
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

See attached proposal.

Summary of Modification

This proposal adopts the SHGC requirements for commercial fenestration in both the 2021 IECC and ASHRAE 90.1-2019, but applies climate zone 2 values statewide for simplicity. It also eliminates orientation-specific SHGC requirements in favor of "fixed" and "operable" values.

Rationale

See attached supporting materials

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposal will simplify enforcement by replacing orientation-specific SHGCs with single "fixed" and "operable" values, consistent with fixed and operable values contained in ASHRAE Standard 90.1-2019.

Impact to building and property owners relative to cost of compliance with code

These SHGCs were determined to be life cycle cost-effective through an analysis of a broad range of fenestration assembly types and using ASHRAE's scalar method. Payback periods ranged between 0-16 years, depending on occupancy type and product selection.

Impact to industry relative to the cost of compliance with code

These SHGCs were determined to be optimally cost-effective through ASHRAE's process. Further, we are proposing a single set of SHGCs, rather than separate requirements for the two climate zones in Florida. This should reduce the cost of compliance for fenestration manufacturers.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposal will improve the comfort of building occupants and will help reduce energy use and related emissions.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposal strengthens the code by maintaining consistency with the latest commercial model codes.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The SHGCs required in the 2021 IECC and ASHRAE 90.1-2019 are material-neutral and non product-specific.

Does not degrade the effectiveness of the code

This proposal will improve both the effectiveness and the simplicity of the code by applying a consistent set of SHGCs statewide and across all compliance paths.

TABLE C402.4
BUILDING ENVELOPE FENESTRATION MAXIMUM U-FACTOR AND SHGC REQUIREMENTS

CLIMATE ZONE	1		2	
VERTICAL FENESTRATION				
SHGC				
~~Orientation[a]~~	~~SEW~~ Fixed	~~N~~ Operable	~~SEW~~ Fixed	~~N~~ Operable
PF < 0.2	0.25	~~0.33~~ 0.23	0.25	~~0.33~~ 0.23
0.2 = PF < 0.5	0.30	~~0.37~~ 0.28	0.30	~~0.37~~ 0.28
PF = 0.5	0.40	~~0.40~~ 0.37	0.40	~~0.40~~ 0.37

NR = No Requirement, PF = Projection Factor

~~a. "N" indicates vertical fenestration oriented within 45 degrees of true north. "SEW" indicates orientations other than "N." For buildings in the southern hemisphere, reverse south and north. Buildings located at less than 23.5 degrees latitude shall use SEW for all orientations.~~

Revise Table C402.4 as follows:

TABLE C402.4
BUILDING ENVELOPE FENESTRATION MAXIMUM U-FACTOR AND SHGC REQUIREMENTS

CLIMATE ZONE	1		2	
VERTICAL FENESTRATION				
SHGC				
	Fixed	Operable	Fixed	Operable
PF < 0.2	0.25	~~0.33~~ 0.23	0.25	~~0.33~~ 0.23
0.2 ≤ PF < 0.5	0.30	~~0.37~~ 0.28	0.30	~~0.37~~ 0.28
PF ≥ 0.5	0.40	~~0.40~~ 0.37	0.40	~~0.40~~ 0.37

NR = No Requirement, PF = Projection Factor

~~a. "N" indicates vertical fenestration oriented within 45 degrees of true north. "SEW" indicates orientations other than "N." For buildings in the southern hemisphere, reverse south and north. Buildings located at less than 23.5 degrees latitude shall use SEW for all orientations.~~

Reason Statement

This proposal will bring consistency and a cost-effective improvement in energy efficiency by adopting the SHGC requirements for climate zone 2 of the 2021 IECC and ASHRAE 90.1-2019.

- Consistent with both ASHRAE Standard 90.1-2019 and the 2021 IECC, the orientation-specific SHGC requirements are replaced by single "fixed" and "operable" values, simplifying compliance. For the first time in several code cycles, the IECC and ASHRAE Standard 90.1 apply the same commercial fenestration U-factor and SHGC requirements. ASHRAE conducted extensive cost-effectiveness analyses to determine optimal SHGC requirements for the 2019 edition of the Standard, and the 2021 IECC effectively mirrors these same requirements. Because Florida typically adopts ASHRAE Standard 90.1 as a compliance alternative, it is important that the values remain relatively consistent.
- Credit for projection factors is maintained at a level consistent with both ASHRAE 90.1-2019 and the 2021 IECC. Although permanent projections are not required, code users receive additional efficiency credit where projections effectively reduce direct solar exposure. These numbers have been adjusted to be consistent with the latest model codes.
- The only difference between this proposal and the full model code requirements is that the same SHGC requirements are applied across the whole state, rather than a more stringent set of SHGCs applying in climate zone 1. Although we would prefer the slightly more stringent SHGCs for climate zone 1 in both ASHRAE and the IECC, we believe there is value in a statewide requirement (as Florida currently has), and we are proposing a single set of SHGC requirements for the whole state.
- In the 2021 IECC process, the full SHGC improvements were approved 15-0 in the Committee and no public comment was received, meaning all significant stakeholders were satisfied with the outcome. While this proposal does not adopt all elements of that proposal, we believe the

requirements above will be a reasonable improvement to the code that will improve energy savings and reduce costs statewide.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

44

EN10445

Date Submitted	02/15/2022	**Section**	408.2	**Proponent**	Douglas Baggett
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

10251 10245

Summary of Modification

This proposed modification will serve to keep requirements and verbiage consistent with Mod's 10245 and 10251, as well as, to clearly define the term 'evidence'

Rationale

The modification will keep requirements and verbiage consistent with proposed modifications 10251 & 10245 and will also simplify language by using one term to refer to the person that is certified to provide commissioning. It also clearly defines the term evidence.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

There will be no impact - this would just be a verbiage and clarification modification

Impact to building and property owners relative to cost of compliance with code

There will be no impact - this would just be a verbiage and clarification modification

Impact to industry relative to the cost of compliance with code

There will be no impact - this would just be a verbiage and clarification modification

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This modification will improve the health, safety and welfare of the general public by ensuring the building codes are consistent and by ensuring properly trained and certified individuals commission the mechanical systems

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This modification will improve the code to allow for clear and consistent requirements for commissioning systems

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not degrade the effectiveness of the code

No it does not degrade the effectiveness of the code, it enhances it.

C408.2 Mechanical systems and service water-heating systems commissioning and completion requirements. Prior to the final mechanical and plumbing inspections, the ~~licensed design professional, electrical engineer, mechanical engineer or *approved agency*~~ certified third-party commissioning agent shall provide evidence in the form of completed construction documents, commissioning plan, completed functional performance tests and a Final Commissioning Report of mechanical systems *commissioning* and completion in accordance with the provisions of this section.

Construction document notes shall clearly indicate provisions for *commissioning* and completion requirements in accordance with this section and are permitted to refer to specifications for further requirements. Copies of all documentation shall be given to the owner or owner's authorized agent and made available to the *code official* upon request in accordance with Sections C408.2.4 and C408.2.5.

Exceptions: The following systems are exempt:

1. Mechanical systems and service water heater systems in buildings where the total mechanical equipment capacity is less than 480,000 Btu/h (140.7 kW) cooling capacity and 600,000 Btu/h (175.8 kW) combined service water-heating and space-heating capacity. Capacities of individual systems serving dwelling or sleeping units shall not be counted in determining the total mechanical and/or water heating systems' capacity for the whole building.

2. Systems included in Section C403.3 that serve individual *dwelling units* and *sleeping units.*

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10446

Date Submitted	02/15/2022	**Section**	408.2.3	**Proponent**	Douglas Baggett
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

10251 10445 10123

Summary of Modification

This modification proposes to clarify how functional performance testing should be completed and the roles of the contractor(s) and commissioning agent(s).

Rationale

The proposed modification will ensure commissioning agents are on site and physically observing the functional performance tests.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

There will be little to no impact to the local entity.

Impact to building and property owners relative to cost of compliance with code

There will be little to no impact to the owners.

Impact to industry relative to the cost of compliance with code

There may be a small increase to some construction project costs if functional testing is not currently being witnessed by a certified third-party commissioning agent, but there's no way to know at this time if that is the case.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This modification will improve the health, safety and welfare of the general public by ensuring the building codes are consistent and by ensuring properly trained and certified individuals commission the mechanical systems properly.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This modification will improve the code to allow for clear and consistent requirements for commissioning systems

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not degrade the effectiveness of the code

No it does not degrade the effectiveness of the code, it enhances it.

408.2.3 Functional performance testing. Functional performance testing specified in Sections C408.2.3.1 through C408.2.3.3 shall be ~~conducted~~ witnessed and documented by the certified third-party commissioning agent. The commissioning agent must be present for any functional performance testing to proceed.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

46

EN10448

Date Submitted	02/15/2022	**Section**	408.2.4	**Proponent**	Douglas Baggett
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

10251 10245 10123 10446

Summary of Modification

This proposed modification will serve to keep requirements and verbiage consistent regarding commissioning activities and requirements.

Rationale

It is necessary to keep verbiage and requirements consistent throughout the energy codes in order to prevent confusion and misunderstanding.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

There will be little to no impact to the local entity.

Impact to building and property owners relative to cost of compliance with code

There will be little to no impact to the owners.

Impact to industry relative to the cost of compliance with code

There will be little to no impact to the industry

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposed modification will improve the health, safety and welfare of the general public by ensuring the building codes are consistent with no room for misinterpretation or misunderstanding.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This modification will improve the code by allowing for clear and consistent verbiage and requirements for commissioning systems.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities.

Does not degrade the effectiveness of the code

No it does not degrade the effectiveness of the code, it enhances it.

A preliminary report of commissioning test procedures and results shall be completed ~~and certified~~ by the certified third-party commissioning agent ~~licensed design professional, electrical engineer, mechanical engineer or approved agency~~ and provided to the building owner or owner's authorized agent. The report shall be organized with mechanical and service hot water findings in separate sections to allow independent review. The report shall be identified as "Preliminary Commissioning Report" and shall identify:

1. Itemization of deficiencies found during testing required by this section that have not been corrected at the time of report preparation.
2. Deferred tests that cannot be performed at the time of report preparation because of climatic conditions.
3. Climatic conditions required for performance of the deferred tests.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10449

47

Date Submitted	02/15/2022	**Section**	402.1.3	**Proponent**	Laura Baker
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Improves consistency by applying an R-value for joist/framing floors in cz 1 in Table C402.1.3 that matches the corresponding U-factor in Table C402.1.4.

Rationale

The purpose of this code change proposal is to improve consistency by applying an R-value for joist/framing floors in climate zone 1 in Table C402.1.3 that matches the corresponding U-factor in Table C402.1.4. The U-factor for joist/framing floors in Table C402.1.4 is consistent with a wood-framed floor insulated to R-13, despite the "NR" notation and footnote "e," which indicate no insulation in the assembly. Because other U-factors and R-values for joist/framing floors in Table C402.1.3 are based on wood-framed assemblies, we applied the equivalent R-value requirement for a U-factor of 0.066, which is R-13. This will improve energy efficiency as compared to the current Table C402.1.3, but it will bring consistency to the two prescriptive tables and simplify enforcement.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This will not have a fiscal impact on local entities relative to enforcement of the code. This proposal will simplify enforcement by making Table C402.1.3 consistent with Table C402.1.4.

Impact to building and property owners relative to cost of compliance with code

This proposal will either not have a fiscal impact or will provide energy cost savings to building and property owners by improving the R-value for joist/framing to be consistent with the U-factor table.

Impact to industry relative to the cost of compliance with code

This proposal will neither increase nor decrease the cost of construction for industry. We believe the R-value equivalent in Table C402.1.4 is an error in the IECC and should be made consistent with the U-factor Table.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposal will clarify the R-value for joist/framing floors by aligning the R-value with the value in the U-factor table.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposal will improve the code by clarifying the correct R-value for joist/framing floors by aligning the R-value with the value in the U-factor table.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposal does not discriminate against any materials or systems of construction; it merely aligns the R-value for joist/framing floors with the value in the U-factor table.

Does not degrade the effectiveness of the code

This proposal does not degrade the effectiveness of the code.

TABLE C402.1.3

OPAQUE THERMAL ENVELOPE INSULATION COMPONENT MINIMUM REQUIREMENTS, R-VALUE METHOD[a]

CLIMATE ZONE	1		2	
	All other	Group R	All other	Group R
Floors				
Mass[e]	NR	NR	R-6.3ci	R-8.3ci
Joist/framing	~~NR~~R-13	~~NR~~R-13	R-30	R-30

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10456

48

Date Submitted	02/15/2022	**Section**	402.1.4	**Proponent**	Laura Baker
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Corrects U-factor for roof insulation for All Other metal buildings in cz 1.

Rationale

The purpose of this code change proposal is to correct the U-factor for roof insulation for All Other metal buildings in climate zone 1. Even though the R-values in Table C402.1.3 for both Group R and All Other metal buildings in climate zone 1 are R-19+R 11 LS, the U-factor table applies a higher U-factor for All Other metal buildings. This proposal adopts the U-factor from Group R for both building types in climate zone 1, since it is closest to the R-19+R-11 LS U-factor equivalent in Table A2.3.3 in ASHRAE Standard 90.1 Normative Appendix A. This will improve energy efficiency as compared to the current Table C402.1.4, but it will bring consistency to the two prescriptive tables and simplify enforcement.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposal will not increase or decrease the fiscal impact on local entities relative to code enforcement. In fact, this proposal will simplify enforcement by aligning the R-value and U-factor tables with regard to metal roof insulation.

Impact to building and property owners relative to cost of compliance with code

This proposal will not have any impact or will provide energy cost savings to building and property owners. This proposal improves the U-factor value for metal roofs to align the values with the R-value table in C402.1.3.

Impact to industry relative to the cost of compliance with code

This proposal will neither increase nor decrease the cost of construction. The current metal building roof U-factor for All Other buildings is an error and is inconsistent with the R-value equivalent in Table C402.1.3

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposal improves the code by aligning the U-factor with the R-value for roof insulation for all other metal buildings. This will simplify enforcement and improve roof insulation in those buildings that were not being enforced at the higher R-value.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposal will improve the code by simplifying enforcement by aligning the U-factor for roof insulation for all other metal buildings with the value in the R-value table.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposal does not discriminate against any materials or systems of construction; all it does it align the U-factor for roof insulation for all other metal buildings with the equivalent R-value.

Does not degrade the effectiveness of the code

This proposal will not degrade the effectiveness of the code; it will enhance the effectiveness of the code by simplifying enforcement.

TABLE C402.1.4
OPAQUE THERMAL ENVELOPE ASSEMBLY MAXIMUM REQUIREMENTS, U-FACTOR METHOD[a, b]

CLIMATE ZONE	1		2	
	All other	Group R	All other	Group R
Roofs				
Insulation entirely above roof deck	U-0.048	U-0.039	U-0.039	U-0.039
Metal buildings	U-~~0.044~~0.035	U-0.035	U-0.035	U-0.035
Attic and other	U-0.027	U-0.027	U-0.027	U-0.027

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10459

49

Date Submitted	02/15/2022	**Section**	408.3.1	**Proponent**	Douglas Baggett
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

10251 10245 10446

Summary of Modification

This proposed modification is to provide a consistent requirement for all functional testing to be conducted by a certified third-party commissioning agent.

Rationale

This modification would provide a consistent requirement for all functional testing to be conducted by an independent and objective third-party. It would also go towards limiting conflicts of interest, biased testing and unqualified individuals from performing inspections and tests. It would also serve to encourage fair business practice.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

If commissioning is already being conducted by certified commissioning agents/firms - there will be no impact to the local entity.

Impact to building and property owners relative to cost of compliance with code

If commissioning is already being conducted by certified commissioning agents/firms - there will be no impact to the owners.

Impact to industry relative to the cost of compliance with code

If commissioning is already being conducted by certified commissioning agents/firms - there will be no impact to the industry.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, in that, the public can be assured the testing agency has no vested interest in the design, construction or project as a whole, and therefore, is objective, consistent and fair.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This modification will improve the code by allowing for clear and consistent verbiage and requirements for commissioning systems.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities.

Does not degrade the effectiveness of the code

No it does not degrade the effectiveness of the code, it enhances it.

C408.3.1 Functional testing.

Prior to passing final inspection, the ~~registered design professional or approved agency~~ certified third-party commissioning agent shall provide evidence that the lighting control systems have been tested to ensure that control hardware and software are calibrated, adjusted, programmed and in proper working condition in accordance with the construction documents and manufacturer's instructions. Functional testing shall be in accordance with Sections C408.3.1.1 through C408.3.1.3 for the applicable control type.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10467

50

Date Submitted	02/15/2022	**Section**	405.9	**Proponent**	Colleen Kettles
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

Summary of Modification

Drive Electric Florida requests new section C405.9 to require electric vehicle charging equipment in certain new commercial construction and provides a chart for the number of EV capable parking spaces required. Amends section C405.1 to include reference to the new section.

Rationale

At the time of new construction, it is far less costly to add the electrical service than to later retrofit it. Charging infrastructure is needed due to increasing EV market share. Home is the most common location for charging vehicles. Anyone living in a shared parking area has no way to take advantage of charging from home whereas single family homes with private driveways and garage do. And there is often no practical way for someone living in a multifamily structure to add a charger. This leads to environmental injustice to those who live in multifamily units as they have more carbon monoxide and other pollutants released, as well as limiting their freedom of choice when it comes to vehicle selection. Florida is ranked number two in the United States for the number of registered electric vehicles as of the latest ranking in June 2021. Electric vehicles are an important emerging technology for Florida residents for a number of reasons, as recognized by the Legislature of the State of Florida: “conserves and protects the state’s environmental resources, provides significant economic savings to drivers, and serves an important public interest.”14 This modification will result in the reduction of harmful tailpipe emissions that contribute to public health problems. It will also create direct economic benefits: EV drivers save over $1,000/year in reduced operation and maintenance costs15 and property owners avoid costly parking space retrofits.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This modification will increase the number of inspections to be performed. The cost of enforcement will be offset by permit fees.

Impact to building and property owners relative to cost of compliance with code

The proposed modification increases the cost of construction. Costs for new EV Capable parking spaces range from $300 to $850 per space. Costs for new EV Ready spaces range from $800 to $1300. The cost for EVSE retrofit in can be three or more times the cost of installations in new construction.

Impact to industry relative to the cost of compliance with code

Any increase in cost to comply will be offset by market benefits as buildings constructed under this code will appeal to EV drivers. Industry is adjusting by adopting business models that provide third party installation, operation and maintenance, and revenue sharing with the property owner.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This modification provides an additional resource to reduce greenhouse gas emissions from petroleum fueled vehicles, thus contributing to the reduction in the effects of climate change, which has been identified as a hazard to the health and welfare of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This modification strengthens the code by providing guidance on the installation electric vehicle service equipment.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This modification does not discriminate against any materials, products, methods, or systems of construction of demonstrated capabilities.

Does not degrade the effectiveness of the code

This modification does not degrade the effectiveness of the code. To the contrary, this modification provides guidance on the installation of electric vehicle supply equipment.

Alternate Language

1st Comment Period History

EN10467-A1

Proponent Bryan Holland **Submitted** 3/28/2022 5:36:14 PM **Attachments** Yes

Rationale:

This alternative proposed modification makes a few minor revisions to the original proposed modification. This includes editorial revisions to the definitions and the rules to provide technical clarity. Otherwise, NEMA fully supports the concept of EV-ready provisions in the FBC-EC as proposed and substantiated in the original proposed modification. NEMA urges the TAC(s) and Commission approve this proposed modification.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This alternative proposed modification provides clear and enforceable language for the AHJ.

Impact to building and property owners relative to cost of compliance with code

This alternative proposed modification will increase the cost of compliance for buildings/property owners at time of initial construction while reducing the cost of compliance for an existing building that does not have the capacity or infrastructure in-place for the installation of EVSE.

Impact to industry relative to the cost of compliance with code

This alternative proposed modification will increase the cost of compliance for industry.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This alternative proposed modification improves the general welfare of the public as the electrification of transportation becomes a fundamental of modern society.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This alternative proposed modification improves the code.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This alternative proposed modification does not discriminate against materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

This alternative proposed modification improves the code.

1st Comment Period History

EN10467-G1

Proponent John Edwards Submitted 3/7/2022 9:47:53 AM Attachments No

Comment:

Please give positive consideration to this revision. Many car companies are introducing EVs, and within 10 years the manufacturing capability for EVs could overtake RICE engine vehicles. Taking moderate steps in the code to encourage the installation of charging infrastructure, is a reasonable step to keep pace with the expected move to EVs. Especially in light of the war in Ukraine, and the strategic difficulty created by dependence on foreign oil, it is imperative that the United States, and the State of Florida take steps to reduce our dependence on petroleum-based fuels.

1st Comment Period History

Proponent Matthew Chen Submitted 4/4/2022 12:32:27 PM Attachments Yes

Comment:

SemaConnect, a leading provider of networked electric vehicle charging solutions, is pleased to support Drive Electric Florida's (DEFL) proposed addition for EV capability in commercial multi-family dwellings to the 8th edition

(2023) update to Florida Building Code. We are also a member of DEFL. Drive Electric Florida has requested new section C405.9 to require electric vehicle charging equipment in certain new commercial construction and has provided a chart for the number of EV capable parking spaces required. DEFL also would amend section C405.1 to include reference to the new section. SemaConnect concurs with DEFL that making a provision in the Florida Building Code for EV charging equipment is among the most economical ways to prepare for increasing EV adoption. Florida already has the second largest number of EV registrations in the nation (June 2021). Furthermore, preparing new construction for EV charging is much cheaper than retrofitting existing buildings. The rationale for including EV-capability for commercial multifamily dwellings in the Florida Building Code is amplified by research from the Pacific Northwest National Lab: "costs associated with installing EV charging infrastructure can be substantially more expensive for retrofit scenarios compared to new construction." We also note the findings of the 2020 RMI paper, "Reducing EV Charging Infrastructure Costs" by Chris Nelder and Emily Rogers: "At sites where increased charging needs can be anticipated in the future, utilities and site owners may decide to front-load investment and install excess capacity in the make-ready elements when installing the first set of chargers. This helps 'future-proof' the site by minimizing the effort and cost required to upgrade the number of chargers or power rating of existing chargers later on." (Our full comments are submitted in the attached PDF file.)

1st Comment Period History

EN10467-G3

Proponent	Larsen Dory	Submitted	4/11/2022 1:07:18 PM	Attachments	Yes

Comment:

Please see the attached comments on behalf of the Southern Alliance for Clean Energy.

1st Comment Period History

EN10467-G4

Proponent	Bruce Edelston	Submitted	4/13/2022 4:26:44 PM	Attachments	No

Comment:

The Alliance for Transportation Electrification (ATE)- a national non-profit organization composed of utility companies, auto manufacturers, charging companies, and related industries - files these comments in support of Drive Electric Florida's proposed modification (EN10467-G4) to the Florida Building Code. We believe this is a modest proposal in that it only requires new construction of certain commercial buildings (Multi-family dwellings) to be EV capable. We, along with many other stakeholders would prefer that the code require buildings to be EV-ready as opposed to just capable, which would not greatly increase the costs but would save considerable extra dollars down the road, but EV capable may be more acceptable to builders that might otherwise oppose this modification. A study in California found that making buildings EV-capable saved $2,000 to $4,600 per charging location over having to retrofit a building to accommodate the same charger. Multiplied by the number of charging stations that will be needed to meet the needs of Florida - the second largest state in terms of EV market penetration - the savings could be in the millions or tens of millions of dollars over the next decade. And building owners will be able to recoup most or all of the additional costs by providing charging services to residents or leasing the space to a charging company. The modification is critical to allowing apartment and condo dwellers the same opportunities to charge vehicles as owners of single-family homes. And such a requirement will provide significant benefits to the environment in Florida. With the changes coming to the types of vehicles apartment renters and condo dwellers want to own own and drive, it is common sense to modify the Florida Building Code to allow this fairly modest change to move forward and thereby provide opportunities and benefits to all Floridians.

SECTION C405

ELECTRICAL POWER AND LIGHTING SYSTEMS

C405.1 General (Mandatory). This section covers lighting system controls, the maximum lighting power for interior and exterior applications and electrical energy consumption and electric vehicle power transfer provisions. Dwelling units within multifamily buildings shall comply with Section R404.1. All other dwelling units shall comply with Section R404.1, or with Sections C405.2.4 and C405.3. Sleeping units shall comply with Section C405.2.4, and with Section R404.1 or C405.3. Lighting installed in walk-in coolers, walk-in freezers, refrigerated warehouse coolers and refrigerated warehouse freezers shall comply with the lighting requirements of Section C403.2.14. Parking areas for multi-family residential buildings shall comply with the electric vehicle supply equipment of section C405.9.

[New] C405.9. Electric Vehicle Supply Equipment

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE). Equipment for plug-in power transfer including the ungrounded, grounded, and equipment grounding conductors, and the Electric Vehicle connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatus installed specifically for the purpose of transferring energy between the premises wiring and the Electric Vehicle.

EV CAPABLE SPACE. Electrical panel capacity and space to support a minimum 40-ampere, 208-volt or 240-volt branch circuit for each EV parking space, and the installation of necessary wiring methods and materials to supply the EVSE.

C405.9.2. Electric Vehicle (EV) power transfer for new construction. New construction of multi-family residential buildings shall facilitate future installation and use of Electric Vehicle Supply Equipment (EVSE) in accordance with the NFPA 70.

C405.9.2.1. New construction of multi-family buildings. EV Capable Spaces and EVSE Installed spaces shall be provided in accordance with Table C405.9.1. Where the calculation of percent served results in a fractional parking space, it shall be shall rounded up to the next whole number. The electrical distribution equipment circuit directory shall identify the spaces reserved to support EV charging as "EV Capable". The box or enclosure provided for future EVSE shall be marked "FORE EVSE USE." The marking shall comply with NFPA 70, Section 110.25. The EV parking requirements are based on a percentage of the minimum required parking spaces for a required development.

TABLE C405.9.2.1.

EV CAPABLE AND EVSE INSTALLED SPACE REQUIREMENTS

TYPE	**EV Capable**	**EVSE Installed (threshold)**
Multi-family buildings	20%	2% (requirement begins at 50 spaces)

C405.9.2.2 - Accessibility.

(a) A minimum of one (1) EVSE installed space must be located adjacent to an ADA designated space to provide access to the charging station.

(b) The accessible space must be designated as an EV reserved space.

(c) The EVSE accessible spaces should have all relevant parts located within accessible reach, and in a barrier-free access aisle for the user to move freely between the EVSE and the electric vehicle.

C405.9.2.3. Identification. Construction documents shall indicate the raceway or cable assembly termination point and proposed location of future EV spaces and EVSE. Construction documents shall also provide information on the wiring methods, wiring schematics, and electrical load calculations to verify that the service capacity and premises wiring system have sufficient capacity to simultaneously charge all EVs at all required EV spaces at the full rating of the EVSE.

SECTION C405

ELECTRICAL POWER AND LIGHTING SYSTEMS

C405.1 General (Mandatory). This section covers lighting system controls, the maximum lighting power for interior and exterior applications and electrical energy consumption and electric vehicle charging provisions. Dwelling units within multifamily buildings shall comply with Section R404.1. All other dwelling units shall comply with Section R404.1, or with Sections C405.2.4 and C405.3. Sleeping units shall comply with Section C405.2.4, and with Section R404.1 or C405.3. Lighting installed in walk-in coolers, walk-in freezers, refrigerated warehouse coolers and refrigerated warehouse freezers shall comply with the lighting requirements of Section C403.2.14. Parking areas for multi-family residential buildings shall comply with the electric vehicle supply equipment of section C405.9.

[New] C405.9. Electric Vehicle Supply Equipment

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE). The conductors, including the ungrounded, grounded, and equipment grounding conductors, and the Electric Vehicle connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatus installed specifically for the purpose of transferring energy between the premises wiring and the Electric Vehicle.

EV CAPABLE SPACE. Electrical panel capacity and space to support a minimum 40-ampere, 208/240-volt branch circuit for each EV parking space, and the installation of raceways, both underground and surface mounted, to support the EVSE.

C405.9.2. Electric Vehicle (EV) charging for new construction. New construction of multi-family residential buildings shall facilitate future installation and use of Electric Vehicle Supply Equipment (EVSE) in accordance with the NFPA 70.

C405.9.2.1. New construction of multi-family buildings. EV Capable Spaces and EVSE Installed spaces shall be provided in accordance with Table C405.9.1. Where the calculation of percent served results in a fractional parking space, it shall be shall rounded up to the next whole number. The service panel or sub panel circuit directory shall identify the spaces reserved to support EV charging as “EV Capable”. The raceway location shall be permanently and visibly marked as “EV Capable”. The EV parking requirements are based on a percentage of the minimum required parking spaces for a required development.

TABLE C405.9.2.1.

EV CAPABLE AND EVSE INSTALLED SPACE REQUIREMENTS

TYPE		EVSE Installed (threshold)

	EV Capable	
Multi-family buildings	20%	2% (requirement begins at 50 spaces)

C405.9.2.2 - Accessibility.

(a) A minimum of one (1) EVSE installed space must be located adjacent to an ADA designated space to provide access to the charging station.

(b) The accessible space must be designated as an EV reserved space.

(c) The EVSE accessible spaces should have all relevant parts located within accessible reach, and in a barrier-free access aisle for the user to move freely between the EVSE and the electric vehicle.

-

C405.9.2.3. Identification. Construction documents shall indicate the raceway termination point and proposed location of future EV spaces and EV chargers. Construction documents shall also provide information on amperage of future EVSE, raceway methods, wiring schematics and electrical load calculations to verify that the electrical panel service capacity and electrical system, including any on-site distribution transformers, have sufficient capacity to simultaneously charge all EVs at all required EV spaces at the full rated amperage of the EVSE.

Florida Building Code, Energy Conservation

Modification Request by: Drive Electric Florida, Inc.

Code Version: 2023

Code Change Cycle: 2023 Triennial Original Modification 01/04/2022 - 02/15/2022

Sub Code: Energy Conservation Chapter & Topic Chapter 4 - [CE]

Commercial Energy Efficiency Section: 405.9

Summary of Modification

This modification creates new section C405.9 to require electric vehicle charging equipment (EVSE) in select types of new commercial construction. The number of EV capable parking spaces required would be determined by the attached chart that is part of the modification.

SECTION C405

ELECTRICAL POWER AND LIGHTING SYSTEMS

C405.1 General (Mandatory). This section covers lighting system controls, the maximum lighting power for interior and exterior applications and electrical energy consumption and electric vehicle charging provisions. Dwelling units within multifamily buildings shall comply with Section R404.1. All other dwelling units shall comply with Section R404.1, or with Sections C405.2.4 and C405.3. Sleeping units shall comply with Section C405.2.4, and with Section R404.1 or C405.3. Lighting installed in walk-in coolers, walk-in freezers, refrigerated warehouse coolers and refrigerated warehouse freezers shall comply with the lighting requirements of Section C403.2.14. Parking areas for multi-family residential buildings shall comply with the electric vehicle supply equipment of section C405.9.

[New] C405.9. Electric Vehicle Supply Equipment

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE). The conductors, including the ungrounded, grounded, and equipment grounding conductors, and the Electric Vehicle connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatus installed specifically for the purpose of transferring energy between the premises wiring and the Electric Vehicle.

EV CAPABLE SPACE. Electrical panel capacity and space to support a minimum 40-ampere, 208/240-volt branch circuit for each EV parking space, and the installation of raceways, both underground and surface mounted, to support the EVSE.

C405.9.2. Electric Vehicle (EV) charging for new construction. New construction of multi-family residential buildings shall facilitate future installation and use of Electric Vehicle Supply Equipment (EVSE) in accordance with the NFPA 70.

C405.9.2.1. New construction of multi-family buildings. EV Capable Spaces and EVSE Installed spaces shall be provided in accordance with Table C405.9.1. Where the calculation of percent served results in a fractional parking space, it shall be shall rounded up to the next whole number. The service panel or sub panel circuit directory shall identify the spaces reserved to support EV charging as "EV Capable". The raceway location shall be permanently and visibly marked as "EV Capable". The EV parking requirements are based on a percentage of the minimum required parking spaces for a required development.

TABLE C405.9.2.1.

EV CAPABLE AND EVSE INSTALLED SPACE REQUIREMENTS

TYPE	EV Capable	EVSE Installed (threshold)
Multi-family buildings	20%	2% (requirement begins at 50 spaces)

C405.9.2.2 - Accessibility.

(a) A minimum of one (1) EVSE installed space must be located adjacent to an ADA designated space to provide access to the charging station.

(b) The accessible space must be designated as an EV reserved space.

(c) The EVSE accessible spaces should have all relevant parts located within accessible reach, and in a barrier-free access aisle for the user to move freely between the EVSE and the electric vehicle.

C405.9.2.3. Identification. Construction documents shall indicate the raceway termination point and proposed location of future EV spaces and EV chargers. Construction documents shall also provide information on amperage of future EVSE, raceway methods, wiring schematics and electrical load calculations to verify that the electrical panel service capacity and electrical system, including any on-site distribution transformers, have sufficient capacity to simultaneously charge all EVs at all required EV spaces at the full rated amperage of the EVSE.

cleanenergy.org
Southern Alliance for Clean Energy

April 11, 2022

Florida Department of Business and Professional Regulation
State Building Commission
2601 Blair Stone Rd
Tallahassee, FL 32399

Re: Proposed Code Modifications to the 8th Edition (2023) Update to Florida Building Code (Mod. # EN10467)

Dear Members of the Commission:

Southern Alliance for Clean Energy (SACE) respectfully offers the following supportive comments to help inform proposed Modification EN10467 requested by Drive Electric Florida.

For over 35 years SACE has been a regional leader focused on transforming how we produce and consume energy in the Southeast. We advocate for equitable and responsible energy choices to ensure stronger, healthier, and more prosperous communities throughout the Southeast.

We feel the time is now to amend the Florida Building Code to align requirements for new construction in multi-unit dwellings (MUDs) with electric vehicle demand to ensure we are constructing buildings to meet needs of electric vehicle drivers today and into the future.

Over 80% of electric vehicle (EV) charging happens at home.
Low or no access to home charging is a well established barrier to EV adoption. Home charging is affordable and reliable. Those who lack access to home charging are forced to use less reliable and more expensive public charging. This is leaving too many apartment and condo dwellers without access to the ability to own an EV and have access to some of the benefits of driving electric. EV-ready policies lower the cost barrier of charging station installations in MUDs, increasing the likelihood of access to home charging for MUD residents, including those with low to moderate income, and in turn access to EV ownership.

Energy Justice
Increasing access to energy is a tenant of energy equity. In the past, with broadband interconnection we've seen digital redlining practices that have led to a digital divide on who has access to reliable wifi connection. We cannot let these kinds of inequities persist as we transition to an electrified transportation system. We need to ensure equitable charging access to all Floridians and EV-readiy building codes are key to that.

Cost Effective Approach
Constructing new MUD buildings EV-ready is one of the most cost effective approaches to increasing EV charging infrastructure. As a percentage of total new construction costs, EV-ready costs are typically very low. In one study of multi-family and commercial projects EV-ready costs were an estimated 0.13%-0.17% of total construction costs. This worked out to an

estimated cost of about $920. However, post-construction can be almost 4 times higher, averaging $3,550 per parking spot.

EV Projections

Florida has the second highest EV adoption rates in the country behind only California. The Florida Department of Transportation published an Electric Vehicle Infrastructure "Master Plan" and the high projections anticipate 35% of cars on FL roads will be electric by 2040. The transition to EV is well underway. In 2021, electric car sales more than doubled to 6.6 million, representing close to 9% of the global car market and more than tripling their market share from two years earlier. New car sales We need to be designing and constructing our buildings today for the infrastructure to meet demand.

Vehicle To Grid Technology

With vehicle to grid technology or V2G, instead of just pulling power from the grid, an electric vehicle can store energy and act as a portable battery, discharging part of the power back to the grid or a building in times of needed additional power. The intersection of buildings, electric power and transportation is an emerging opportunity and can only be achieved if we are constructing our buildings to be EV-ready.

Given these potential benefits, SACE encourages you to accept the proposed modification to construct new commercial multi-family dwellings as EV capable and standardize the building code across Florida via the 8th edition (2023) Florida Building Code update.

Sincerely,

Dory Larsen
ET Program Manager
Southern Alliance for Clean Energy

SemaConnect

April 4, 2022

Florida Department of Business and Professional Regulation
State Building Commission
2601 Blair Stone Road
Tallahassee, FL 32399

Re: Proposed Code Modifications to the 8th Edition (2023) Update to Florida Building Code (Mod. # EN10467)

Dear Members of the Commission:

SemaConnect, a leading provider of networked electric vehicle charging solutions, is pleased to support Drive Electric Florida's (DEFL) proposed addition for EV capability in commercial multi-family dwellings to the 8th edition (2023) update to Florida Building Code. We are also a member of DEFL.

Currently, SemaConnect is ranked top two in the electric vehicle charging industry (Level 2) with more than 1,700 clients and over 15,000 charging stations nationwide. At our facility in Bowie, Maryland, we complete 100% final product assembly of our charging stations sold to the North American market.

Drive Electric Florida has requested new section C405.9 to require electric vehicle charging equipment in certain new commercial construction and has provided a chart for the number of EV capable parking spaces required. DEFL also would amend section C405.1 to include reference to the new section.

SemaConnect concurs with DEFL that making a provision in the Florida Building Code for EV charging equipment is among the most economical ways to prepare for increasing EV adoption. Florida already has the second largest number of EV registrations in the nation (June 2021). Furthermore, preparing new construction for EV charging is much cheaper than retrofitting existing buildings. According to Professor Andrew Campbell, executive director of the Energy Institute at the University of California, Berkeley: "Bringing older properties into full compliance with current codes and standards raises the costs of projects." He also suggests that instead of conducting one-off surveys when a building owner wants to make an upgrade, utilities "could perform proactive analyses of excess capacity on circuits and communicate the available capacity to homeowners with properties connected to the circuit."

The rationale for including EV-capability for commercial multifamily dwellings in the Florida Building Code is amplified by research from the Pacific Northwest National Lab: "costs associated with installing EV charging infrastructure can be substantially more expensive for retrofit scenarios compared to new construction."[i] We also note the findings of the 2020 RMI paper, "Reducing EV Charging Infrastructure Costs" by Chris Nelder and Emily Rogers: "At sites where increased charging needs can be anticipated in the future, utilities and site owners may decide to front-load investment and install excess capacity in the make-ready elements when installing the first set of chargers. This helps 'future-proof' the site by minimizing the effort and cost required to upgrade the number of chargers or power rating of existing chargers later on." [ii]

Pre-wiring new construction for EV charging is one of the most cost-efficient ways to prepare for increasing EV adoption. However, "a lack of pre-existing EV charging infrastructure, such as electrical panel capacity, raceways, and pre-wiring, can make the installation of a new charging station cost-prohibitive for a potential EV-owner."[iii] Moreover, "the cost estimate to retrofit an existing building with two EV-ready spaces is $3,710, while new construction cost for the same EV-ready spaces is $920. Thus $2,790 (75%) of the retrofit cost would be avoided if EV-ready infrastructure was included during the initial construction of the parking lot. These additional retrofit costs typically include labor expenses for demolition, trenching and boring, balancing the circuits, and new permitting costs."[iv]

In addition, "avoided retrofit costs for installing Level 2 EV charging stations during new construction range from $272 million to $386 million between 2020 and 2025." "The key factors affecting the cost of installing EVSE in an existing home included insufficient electrical panel capacity for a dedicated 40-ampere charging circuit, location of the electric panel relative to the garage, and permit costs, which averaged 8.6% of the installed cost. The capacity limitation was found to be more prevalent in less-affluent areas."[v]

In summary, including EV-ready/pre-wiring in building codes is an important and very efficient way to reduce costs for consumers and property owners as EV adoption increases during this decade. We strongly support Drive Electric Florida's proposed addition for EV capability in commercial multi-family dwellings to the 8th edition (2023) update to the Florida Building Code.

Thank you again for the opportunity to comment.

Sincerely,

Matthew E. Chen
Director, Government Policy & Programs
SemaConnect, Inc.

[i] “Electric Vehicle Charging for Residential and Commercial Energy Codes,” Technical Brief, Pacific Northwest National Lab, July 2021 https://www.energycodes.gov/sites/default/files/2021-07/TechBrief_EV_Charging_July2021.pdf
[ii] https://rmi.org/wp-content/uploads/2020/01/RMI-EV-Charging-Infrastructure-Costs.pdf
[iii] “Electric Vehicle Charging for Residential and Commercial Energy Codes,” Technical Brief, July 2021: https://www.energycodes.gov/sites/default/files/2021-07/TechBrief_EV_Charging_July2021.pdf
[iv] Ibid
[v] Ibid

www.SemaConnect.com
4961 Tesla Drive, Bowie, MD, 20715 • (800) 663-5633

Code Version: 2023

Code Change Cycle: 2023 Triennial Original Modification 01/04/2022 - 02/15/2022

Sub Code: Energy Conservation Chapter & Topic Chapter 4 - [CE]

Commercial Energy Efficiency Section: 405.9

Rationale

At the time of new construction, it is far less costly to add the electrical service than to later retrofit it. Charging infrastructure is needed due to increasing EV market share. Home is the most common location for charging vehicles. Anyone living in a shared parking area has no way to take advantage of charging from home whereas single family homes with private driveways and garage do. And there is often no practical way for someone living in a multifamily structure to add a charger. This leads to environmental injustice to those who live in multifamily units as they have more carbon monoxide and other pollutants released, as well as limiting their freedom of choice when it comes to vehicle selection.

Florida is ranked number two in the United States for the number of registered electric vehicles as of the latest ranking in June 2021. Electric vehicles are an important emerging technology for Florida residents for a number of reasons, as recognized by the Legislature of the State of Florida: “conserves and protects the state’s environmental resources, provides significant economic savings to drivers, and serves an important public interest.”[14] This modification will result in the reduction of harmful tailpipe emissions that contribute to public health problems. It will also create direct economic benefits: EV drivers save over $1,000/year in reduced operation and maintenance costs[15] and property owners avoid costly parking space retrofits.

In addition, the following reasons should be considered.

Technological advances: Projections by the National Renewable Energy Lab (Department of Energy) indicate that up to 30% of light duty vehicle registrations will be electric by 2030.[1]

Automotive manufacturers and ride services are leading this transformation and recent public commitments include:

- General Motors: Committed to a 100% EV fleet by 2035[2]
- Volvo: Committed to 100% EV fleet by 2030[3]
- Range Rover/Jaguar: Committed to 100% EV by 2025[4]
- Honda Committed to 100% EV by 2040[5]
- Uber: Committed to 100% EV by 2030[6]
- Lyft: Committed to 100% EV by 2030[7]

Additionally, Ford has committed $24 billion by 2025 towards developing EV fleets.[8] For consumers, one result is that the upfront cost of EVs is rapidly decreasing and projected to be less than traditional vehicles by 2024.[9] according to Bloomberg Energy Finance.

Removing prohibitive cost barriers: Costs to make parking EV Capable at the time of construction are typically small, but remove significant financial barriers for building owners to retrofit later—typically *saving around 75%* compared to retrofit costs.[10] Several contributing factors include: demolition and repair of surface parking; breaking and repairing walls; longer conduit runs (also referred to as raceways); significantly upgrading electric service panels; and, soft costs including permits, plans, inspections, and management.

Public Health and Environment: The total life cycle emissions (including battery manufacturing) are substantially lower for EVs, particularly during the useful life phase where zero tailpipe emissions lower air pollutants by 63% in greenhouse gas emissions per mile in Florida.[11]

Cost Equity: EVs are more affordable to drive compared to traditional gasoline vehicles. Fueling in Florida only costs $1.10 per e-Gal compared to $2.25 gallon of gas – over a 50% savings.[12] This cost savings is reduced when charging in public, which is one reason why EV owners charge at home 80% of the time.[13]

Sources cited:

1. Department of Energy National Renewable Energy Lab: Electrification Futures Study (2018), https://www.nrel.gov/docs/fy18osti/71500.pdf
2. GM: commits to 100% electric by 2035 (1/28/21), https://www.forbes.com/sites/samabuelsamid/2021/01/28/general-motors-commits-to-being-carbon-neutral-by-2040/?sh=64e8a5ba6355
3. Volvo: commits to 100% electric by 2030 (3/2/21), https://www.media.volvocars.com/global/en-gb/media/pressreleases/277409/volvo-cars-to-be-fully-electric-by-2030
4. Range Rover Jaguar: commits to 100% electric by 2025 (2/15/21), https://www.jaguarlandrover.com/reimagine
5. NPR: Honda commits to 100% electric by 2040 (4/23/21), https://www.npr.org/2021/04/23/990153361/honda-aims-to-go-all-electric-by-2040#:~:text=via%20Getty%20Images-,A%20Honda%20SUV%20E%20prototype%20is%20displayed%20during%20the%2019th,zero%2Demissions%20vehicles%20by%202040.
6. Uber commits to 100% electric by 2030 (9/7/20), https://www.uber.com/us/en/about/sustainability/
7. Lyft commits to 100% electric by 2030 (6/17/20), https://www.lyft.com/blog/posts/leading-the-transition-to-zero-emissions
8. Ford commits $29 billion to EV and AV by 2030 (2/4/21), https://media.ford.com/content/fordmedia/fna/us/en/news/2021/02/04/ford-raises-planned-investment-ev-av-leadership.html
9. Bloomberg New Energy Finance: New Energy Outlook (2020):
10. Southwest Energy Efficiency Project (SWEEPS), https://www.swenergy.org/transportation/electric-vehicles/building-codes#cost

11. Department of Energy Alternative Fuels Data Center, https://afdc.energy.gov/vehicles/electric_emissions.html

12. Department of Energy, "E-Gallon cost", https://www.energy.gov/maps/egallon

13. Department of Energy, Office of Energy Efficiency and Renewable Energy, "Charging at home", https://www.energy.gov/eere/electricvehicles/charging-home

14. Florida Statute 718.113(8), http://www.leg.state.fl.us/statutes/index.cfm?App_mode=Display_Statute&URL=0700-0799/0718/Sections/0718.113.html

15. AAA, "Owning an Electric Vehicle is the Cure for Most Consumer Concerns", (1/22/20), https://newsroom.aaa.com/2020/01/aaa-owning-an-electric-vehicle-is-the-cure-for-most-consumer-concerns/

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10470

51

Date Submitted	02/15/2022	**Section**	402.5	**Proponent**	Laura Baker
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

C202 - Definitions to add definition of testing unit enclosure area

Summary of Modification

This proposal implements air leakage testing requirements for residential buildings greater than 3 stories in height.

Rationale

The purpose of this code proposal is to require that blower door testing be applied to a sample of units or occupiable spaces in a multiple unit residential construction project. This code proposal is a companion to CE97, which was already approved during the initial code review process. Air leakage can be a significant source of energy waste in buildings, contributing to higher heating and cooling costs for building owners and occupants, and increasing risk related to comfort and durability. Air tightness testing can result in more attention to air barrier sealing and significantly reduced building leakage. Currently, the residential energy code requires air tightness testing for residential buildings three stories and less in height to ensure proper tightness and a controlled indoor environment. However, in the commercial energy code there is no testing requirement for residential buildings four stories or more in height (e.g., apartments, dormitories, hotel guest rooms). Industry standards affecting these buildings have historically relied upon visual verification, as well as material and assembly requirements. Providing adequate control over air leakage can also allow many benefits, including reduced HVAC equipment sizing, better building pressurization, and energy savings due to reduced heating and cooling of infiltrated outside air. In moist climates, ensuring lower leakage through testing can also result in better humidity control and reduced risk of durability issues. Air barrier testing saves energy by reducing infiltration of outside air into and out of the building. Most of the time, outside air is hotter or colder than the comfort temperature being maintained in the residence by the heating and cooling systems. Therefore, reducing the infiltration will reduce energy use for heating and cooling.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This code proposal will not have any fiscal impact to the local entity relative to enforcement of the code. Code officials will be familiar with air leakage testing from the residential code.

Impact to building and property owners relative to cost of compliance with code

This proposal will provide energy cost savings to building and property owners by ensuring that multifamily construction units under the commercial code will be tested for air tightness, which will increase occupant comfort.

Impact to industry relative to the cost of compliance with code

This proposal will increase the cost of construction for multi-family commercial construction by requiring air barrier testing for certain building types. For buildings doing whole building testing, this proposal would decrease the cost of construction.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposal will increase the health and safety of building occupants by ensuring that the building air barrier is operating as intended. This will promote occupant comfort and decrease the need for occupants to alter the thermostat, which leads to excess energy use and costs.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposal will strengthen the code by providing a better method of construction by ensuring that the air barrier is operating as intended.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposal does not discriminate against any materials or systems of construction.

Does not degrade the effectiveness of the code

This proposal does not degrade the effectiveness of the code; rather, it improves the code.

Add new definition as follows:

TESTING UNIT ENCLOSURE AREA. The area sum of all the boundary surfaces that define the *dwelling unit, sleeping unit*, or occupiable *conditioned space* including top/ceiling, bottom/floor, and all side walls. This does not include interior partition walls within the *dwelling unit*, *sleeping unit*, or occupiable *conditioned space*. Wall height shall be measured from the finished floor of the *conditioned space* to the finished floor or roof/ceiling air barrier above.

C402.5 Air leakage—thermal envelope (Mandatory). The building thermal envelope of buildings shall comply with Sections C402.5.1 through C402.5.11.18, or the building thermal envelope shall be tested in accordance with Section C402.5.2 or C402.5.31.2.3. Where compliance is based on such testing, the building shall also comply with Sections C402.5.5, C402.5.6 and C402.5.7.

C402.5.1 Air barriers. A continuous air barrier shall be provided throughout the building thermal envelope. The continuous air barriers shall be located on the inside or outside of the building thermal envelope, located within the assemblies composing the building thermal envelope, or any combination thereof. The air barrier shall comply with Sections C402.5.1.1 and C402.5.1.2.

Exception: Air barriers are not required in buildings located in Climate Zone 2B.

C402.5.1.2 Air barrier compliance. A continuous air barrier for the opaque building envelope shall comply with the following:

1. **Buildings or portions of buildings, including group R and group I occupancyies, shall meet the provisions of Section C402.5.2.1.2.1 or C402.5.1.2.2.**

   Exception: Buildings in Climate Zones 2B, 3C, and 5C.

2. **Buildings or portions of buildings of other than group R and group I occupancy shall meet the provisions of Section C402.5.1.2.3.**

   Exceptions:

   1. **Buildings in Climate Zones 2B, 3B, 3C, and 5C.**
   2. **Buildings larger than 5,000 square feet (464.5 m^2) floor area in Climate Zones 0B, 1, 2A, 4B, and 4C.**
   3. **Buildings between 5,000 square feet (464.5 m^2) and 50,000 square feet (4,645 m^2) floor area in Climate Zones 0A, 3A and 5B.**

3. **Buildings or portions of buildings other than group R and group I occupancy that do not complete air barrier testing shall meet the provisions of Section C402.5.1.2.13 or C402.5.1.42.2, in addition to Section C402.5.1.5.**

Add new text as follows:

C402.5.2. Dwelling and sleeping unit enclosure testing. The building thermal envelope shall be tested in accordance with ASTM E 779, ANSI/RESNET/ICC 380, ASTM E1827 or an equivalent method approved by the code official. The measured air leakage shall not exceed 0.30 cfm/ft^2(1.5 L/sm^2) of the testing unit enclosure area at a pressure differential of 0.2 inch water gauge (50 Pa). Where multiple dwelling units or sleeping units or other occupiable conditioned spaces are contained within one building thermal envelope, each unit shall be considered an individual testing unit and the building air leakage shall be the weighted average of all testing unit results, weighted by each testing unit's testing unit enclosure area. Units shall be tested separately with an unguarded blower door test as follows:

1. **Where buildings have fewer than eight testing units, each testing unit shall be tested.**
2. **For buildings with eight or more testing units the greater of seven units or 20 percent of the testing units in the building shall be tested including a top floor unit, a ground floor unit, and a unit with the largest testing unit enclosure area. Where any tested unit exceeds the maximum air leakage rate, an additional 20 percent of units shall be tested, including a mixture of testing unit types and locations.**

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN9965

52

Date Submitted	02/15/2022	**Section**	405.7.1	**Proponent**	Amanda Hickman
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

None

Summary of Modification

Revision to R405.7.1 Installation criteria for homes claiming the radiant barrier option.

Rationale

This modification simply revises the emissivity value of the operative surface of sheet radiant barriers to be consistent with requirements of ASTM C1313, Standard Specification for Sheet Radiant Barriers for Building Construction Applications. In addition, this modification updates the language to the current ASTM Standard C1743-19 Standard Practice for Installation and Use of Radiant Barrier Systems (RBS) in Residential Building Construction, as C1158 has been discontinued.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No cost impact to changing the emissivity value.

Impact to building and property owners relative to cost of compliance with code

No cost impact to changing the emissivity value.

Impact to industry relative to the cost of compliance with code

No cost impact to changing the emissivity value.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This modification will increase welfare of the general public by ensuring the requirements are correct and up to date.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This modification improves the code and systems of construction.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This modification does not discriminate against materials, as it only corrects the emissivity.

Does not degrade the effectiveness of the code

This modification improves the effectiveness of the code by correcting the emissivity.

Revise as follows:

R405.7.1 Installation criteria for homes claiming the radiant barrier option.
The sheet radiant barrier or IRCC options may be claimed where the radiant barrier system is to be installed in one of the configurations depicted in Figure R405.7.1 and the following conditions are met:

1. It shall be fabricated over a ceiling insulated to a minimum of R-19 with conventional insulation and shall not be used as a means to achieve partial or whole compliance with a minimum attic insulation level of R-19. Either a sheet type or spray applied interior radiation control coating (IRCC) may be used

2. If the radiant barrier material has only one surface with high reflectivity or low emissivity, it shall be facing downward toward the ceiling insulation.

3. The attic airspace shall be vented in accordance with Section R806 of the Florida Building Code, Residential.

4. The radiant barrier system shall conform to ASTM C1313, *Standard Specification for Sheet Radiant Barriers for Building Construction Applications*, or ASTM C1321, *Standard Practice for Installation and Use of Interior Radiation Control Coating Systems (IRCCS) in Building Construction* as appropriate for the type of radiant barrier to be installed. The operative surface shall have an emissivity not greater than ~~0.06~~ 0.10 for sheet radiant barriers or 0.25 for interior radiation control coatings as demonstrated by independent laboratory testing according to ASTM C1371.

5. The radiant barrier system (RBS) shall conform with ASTM C1743, Standard Practice for Installation and Use of Radiant Barrier Systems (RBS) in Residential Building Construction~~ASTM C1158, Use and Installation of Radiant Barrier Systems (RBS) in Building Constructions for Sheet Radiant Barriers,~~ or ASTM C1321, Standard Practice for Installation and Use of Interior Radiation Control Coating Systems (IRCCS) in Building Construction for IRCC systems.

6. The radiant barrier shall be installed so as to cover gable ends without closing off any soffit, gable or roof ventilation.

Add new reference standard Chapter 6 [RE]:

ASTM International

ASTM C1743-19, Standard Practice for Installation and Use of Radiant Barrier Systems (RBS) in Residential Building Construction

Delete reference standard Chapter 6 [RE]:

ASTM International

~~ASTM 1158-05, Standard Practice for Use and Installation of Radiant Barrier Systems (RBS) in Building Construction~~

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10072

53

Date Submitted	02/03/2022	**Section**	402.4	**Proponent**	Bryan Holland
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

This proposed modification makes editorial revisions to Table R402.4.1.1 related to electrical and communication boxes and adds a new section on air-sealed boxes as referenced in the Table.

Rationale

The information provided in Table R402.4.1.1 is extremely vague and unclear with regard to electrical, communication, and other equipment boxes, housings, and enclosures installed within the building thermal envelope and compromising the continuity of the air barrier assembly. This proposed modification provides that clarification. Additionally, the Table indicates "air-sealed" boxes are a permitted alternative but provides no details on that product. A new R402.4.6 provides that guidance.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposed modification will assist the local entity relative to enforcement by clarifying requirements that are both verifiable and enforceable.

Impact to building and property owners relative to cost of compliance with code

This proposed modification will not increase the cost of compliance as the proposal is an editorial clarification of the rules already in effect.

Impact to industry relative to the cost of compliance with code

This proposed modification will no impact industry relative to the cost of compliance as the prescriptive requirements clarified in the proposal are the common practices already used in the field and while the use of air-sealed boxes has gained popularity, they are still not mandatory.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposed modification will improve the health and welfare of the general public by improving the usability and enforcement of the current requirements of the code in more clear language.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposed modification improves the code for all stakeholders.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposed modification does not discriminate against any materials, methods, or systems of constructions.

Does not degrade the effectiveness of the code

This proposed modification improves the effectiveness of the code.

1st Comment Period History

EN10072-G1

Proponent	Jeff Sonne for FSEC	Submitted	4/14/2022 1:19:42 PM	Attachments	No

Comment:

FSEC supports this mod. The mod's language makes more sense as far as sequence of trades in the construction process than the original language.

Revise Table R402.4.1.1 as follows:

COMPONENT	AIR BARRIER CRITERIA	INSULATION INSTALLATION CRITERIA
Electrical/~~phone box on exterior walls~~, communication, and other equipment boxes, housings, and enclosures	~~The air barrier shall be installed behind electrical or communication boxes or air-sealed boxes shall be installed.~~ Boxes, housings, and enclosures that penetrate the *air barrier* shall be caulked, taped, gasketed, or otherwise sealed to the *air barrier* element being penetrated. All concealed openings into the box, housing, or enclosure shall be sealed. The continuity of the *air barrier* shall be maintained around boxes, housings, and enclosures that penetrate the *air barrier*. Alternatively, air-sealed boxes shall be installed in accordance with R402.4.6.	Boxes, housings, and enclosures shall be buried in or surrounded by tightly fitted insulation.

Add new Section as follows:

R402.4.6 Air-Sealed Electrical and Communication Boxes. Air-sealed electrical and communication boxes that penetrate the air barrier of the building thermal envelope shall be caulked, taped, gasketed, or otherwise sealed to the air barrier element being penetrated. Air-sealed boxes shall be buried in or surrounded by insulation. Air-sealed boxes shall be marked in accordance with NEMA OS 4. Air-sealed boxes shall be installed in accordance with the manufacturer's instructions.

Add new Standard Promulgator and Standard to Chapter 6 [RE] Reference Standards:

NEMA

National Electrical Manufacturers Association

1300 North 17th Street, Suite 900

Arlington, VA 22209

NEMA OS 4

Requirements for Air-Sealed Boxes for Electrical and Communication Applications

Published by

National Electrical Manufacturers Association
1300 North 17th Street, Suite 900
Rosslyn, Virginia 22209

www.nema.org

NOTICE AND DISCLAIMER

The information in this publication was considered technically sound by the consensus of persons engaged in the development and approval of the document at the time it was developed. Consensus does not necessarily mean that there is unanimous agreement among every person participating in the development of this document.

The National Electrical Manufacturers Association (NEMA) standards and guideline publications, of which the document contained herein is one, are developed through a voluntary consensus standards development process. This process brings together volunteers and/or seeks out the views of persons who have an interest in the topic covered by this publication. While NEMA administers the process and establishes rules to promote fairness in the development of consensus, it does not write the document and it does not independently test, evaluate, or verify the accuracy or completeness of any information or the soundness of any judgments contained in its standards and guideline publications.

NEMA disclaims liability for any personal injury, property, or other damages of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, application, or reliance on this document. NEMA disclaims and makes no guaranty or warranty, expressed or implied, as to the accuracy or completeness of any information published herein, and disclaims and makes no warranty that the information in this document will fulfill any of your particular purposes or needs. NEMA does not undertake to guarantee the performance of any individual manufacturer or seller's products or services by virtue of this standard or guide.

In publishing and making this document available, NEMA is not undertaking to render professional or other services for or on behalf of any person or entity, nor is NEMA undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances. Information and other standards on the topic covered by this publication may be available from other sources, which the user may wish to consult for additional views or information not covered by this publication.

NEMA has no power, nor does it undertake to police or enforce compliance with the contents of this document. NEMA does not certify, test, or inspect products, designs, or installations for safety or health purposes. Any certification or other statement of compliance with any health- or safety-related information in this document shall not be attributable to NEMA and is solely the responsibility of the certifier or maker of the statement.

CONTENTS

FIGURES

ANNEXES

Foreword

Building and energy codes for energy-efficient construction place a high priority on preserving the building thermal envelope. Installation of doors; windows; and mechanical, electrical, and other systems within exterior walls and ceilings and other separations between conditioned and unconditioned spaces results in penetrations in the air barrier. When these penetrations are not effectively sealed, the air barrier is compromised, resulting in air leakage, both in and out, which increases the energy usage necessary to maintain the desired condition of the air inside the structure.

Besides external walls and ceilings in a building, uninsulated interior walls and interior floor-ceiling cavities not designed specifically for air exchange, present pathways for air leakage. Even though air barriers are not commonly installed here, consideration should be given to using effective sealing techniques at wall, ceiling, and floor penetrations in these areas.

Sealing air-barrier penetrations is not always as simple as applying more insulation, caulk, or expanding foam. Products such as electrical outlet boxes, having design features that address effective sealing of the air-barrier penetrations, also reduce potentially undesirable effects that can result from the use of unspecified sealing techniques.

Annex B of this standard provides pertinent references to the applicable building and energy codes and to other helpful references.

In the preparation of this standards publication, input of users and other interested parties has been sought and evaluated. Inquiries, comments, and proposed or recommended revisions should be submitted by contacting:

Senior Technical Director, Operations
National Electrical Manufacturers Association
1300 North 17th Street, Suite 900
Rosslyn, Virginia 22209

This standards publication was developed by the Outlet and Switch Box Section. Section approval does not necessarily imply that all section members voted for its approval or participated in its development. At the time it was approved, the section was composed of the following members:

2D2C, Inc.—http://www.2d2c.com—Lincolnshire, IL
Allied Moulded Products, Inc.— http://www.alliedmoulded.com—Bryan, OH
Arlington Industries, Inc.—http://www.aifittings.com—Scranton, PA
Eaton's B-Line Business—http://www.cooperbline.com—Highland, IL
Crouse-Hinds by Eaton—http://www.crouse-hinds.com—Syracuse, NY
Emerson Automation Solutions—http://www.emersonindustrial.com/en-US/businesses/Pages/appletongroup.aspx—Rosemont, IL
Pentair Engineered Electrical & Fastening Solutions—http://www.erico.com—Solon, OH
Hubbell Incorporated—http://www.hubbell.com—Shelton, CT
Legrand/Pass & Seymour—http://www.passandseymour.com—Syracuse, NY
RACO—http://www.hubbell.com/Electrical/Raco.aspx—South Bend, IN
Sigma Electric Manufacturing Corporation—http://www.sigmaelectric.com—Garner, NC
Southwire Company—http://www.southwire.com/—Carrollton, GA
Thomas & Betts, A Member of the ABB Group—http://www.tnb.com—Memphis, TN
Wiremold/Legrand—http://www.wiremold.com—West Hartford, CT

Section 1
General

1.1 Scope

This standard establishes a performance test and classification scheme for outlet boxes: wall boxes, ceiling boxes, and floor boxes used for electrical and communication applications having design provisions for reducing the flow of air (air leakage) through the box and at its installed interface with the building structure, when installed as intended for normal use as instructed by the manufacturer.

The classification scheme in this standard meets the intent of the International Energy Conservation Code (IECC) and covers boxes installed in walls, ceilings, and floors where an air barrier is required.

This standard does not cover design or performance of electrical outlet boxes that are addressed in ANSI/UL 514A, CSA C22.2 No.18.1, NMX-J-023-ANCE, ANSI/UL 514C, CSA C22.2 No.18.2, ANSI/NEMA OS1, ANSI/NEMA OS2, IEC 60670-1, IEC 60670-21, or IEC 60670-23.

This standard does not cover environmental classifications for boxes or enclosures addressed in ANSI/UL 50E, CSA C22.2 No. 94.2, or NMX-J-235/2-ANCE.

1.2 References

The following normative documents contain provisions that through reference in this text constitute provisions of this standards publication. By reference herein, these publications are adopted, in whole or in part as indicated, in this standards publication. Unless otherwise stated, references are to the latest edition of the standard.

ASTM International (ASTM)
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959

ASTM E283-04 (2012), *Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen*

Association of Standards and Certification (ANCE)
Av. Lázaro Cárdenas
No. 869
Nueva Industrial Vallejo
Ciudad de México
C.P. 07700 México

NMX-J-023-ANCE, *Metallic Outlet Boxes*
NMX-J-235/2-ANCE, *Enclosures for Electrical Equipment, Environmental Considerations*

Canadian Standards Association (CSA)
5060 Spectrum Way
Mississauga, ON L4W 5N6 Canada

CSA C22.2 No.18.1-13, *Metallic outlet boxes*
CSA C22.2 No.18.2-06 (R2016), *Nonmetallic outlet boxes*
CSA C22.2 No. 94.2-15, Enclosures for electrical equipment, environmental considerations

International Electrotechnical Commission (IEC)
3, rue de Varembé, 1st Floor
Case postale 131
CH -1211 Geneva 20 Switzerland

IEC 60670-1:2015, *Boxes and enclosures for electrical accessories for household and similar fixed installations—Part 1: General requirements*

IEC 60670-21:2004+AMD1:2016 CSV, *Boxes and enclosures for electrical accessories for household and similar fixed installations—Part 21: Particular requirements for boxes and enclosures with provision for suspension means*

IEC 60670-23:2006+AMD1:2016 CSV, *Boxes and enclosures for electrical accessories for household and similar fixed installations—Part 23, Particular requirements for floor boxes and enclosures*

International Code Council (ICC)
500 New Jersey Avenue, NW, 6th Floor
Washington, DC 20001

International Energy Conservation Code (IECC)-2015

Underwriters Laboratories (UL)
333 Pfingsten Road
Northbrook, IL 60062

ANSI/UL 50E, *Enclosures for Electrical Equipment, Environmental Considerations*
ANSI/UL 514A, *Metallic Outlet Boxes*
ANSI/UL 514C, *Standard for Nonmetallic Outlet Boxes, Flush-Device Boxes, and Covers*

1.3 Definitions

air barrier: Material(s) assembled and joined together to provide a barrier to air leakage through the building envelope. An air barrier may be a single material or a combination of materials. [IECC 2015]

For the purpose of this standard, a box providing sealing at the air barrier is a component of the air barrier.

air-sealed boxes: Electrical or communication boxes that are classified and comply with the appropriate provisions of this standard.

building thermal envelope: Basement walls, exterior walls, floor, roof, and any other building elements that enclose conditioned space or provide a boundary between conditioned space and exempt or unconditioned space. [IECC 2015]

conditioned space: An area or room within a building being heated or cooled, containing uninsulated ducts, or with a fixed opening directly into an adjacent conditioned space.

Section 2
Construction

The product's construction shall comply with all requirements of the relevant product standards in accordance with applicable electrical codes.

> Note: Consideration should be given to the impact on compliance with provisions of other standards and requirements for outlet boxes when adapted for classification to this standard. Among these considerations are flammability and temperature rating of materials, electrical continuity (bonding) between metallic components, and the impact on fire resistance ratings for boxes in fire-resistive walls and floor-ceiling assemblies.

Section 3
Performance Criteria

3.1 Air Leakage Performance

Boxes that penetrate the air barrier of the building thermal envelope shall limit air leakage between conditioned and unconditioned spaces when installed as intended. When tested in accordance with section 4, boxes shall have an air leakage rate no greater than 2.0 cubic feet per minute (CFM) (0.944 L/s) at 1.57 psf (75 Pa) test pressure differential.

Section 4
Test Method

4.1 Procedure

4.1.1 General

The procedure for determining the rate of air leakage through electrical outlet boxes shall be in accordance with ASTM E283.

4.1.2 Sampling

The aggregate opening of all samples tested shall be a minimum of 75 in^2. The samples tested shall be of the same construction and type.

4.2 Sample Preparation

4.2.1 Assembly of Wiring Methods

Assembly shall be in accordance with the manufacturer's instructions when provided.

4.2.1.1 Boxes for Use with Cable or Tubing and Conduit

Boxes having provision for conduit or tubing and cable shall be separately tested according to 4.2.1.2 and 4.2.1.3, as applicable.

4.2.1.2 Boxes for Use with Cable Only

Boxes for use with cable shall be tested with one cable and a cable fitting, if required. The largest size cable for which the box is intended shall be tested.

4.2.1.3 Boxes for Use with Conduit or Tubing Only

Boxes for use with conduit or tubing shall be tested as an assembly, with one conduit or tube of the largest trade size for which the box is intended attached by a fitting, if required. The conduit or tube shall be of a length that fits within the test chamber and shall be sealed at the end opposite the box entry.

4.2.2 Mounting in Test Chamber

4.2.2.1

Boxes shall be mounted to the front wall of the test chamber in a fashion that replicates how the sealing feature of the box interacts with the drywall or floor in a typical installation (See Figures 1 and 2).

4.2.2.2

A cut-out of the appropriate size for the box shall be provided in the front wall of the test chamber with a minimum ⅛-inch clearance on all sides. A rigid support plate of a width not exceeding ½ inch may be used to secure the box to the test wall if the mounting method defined in the manufacturer's instructions cannot otherwise replicate the typical sealing interface in the test setup.

Figure 1
Inside Chamber Door with Boxes Mounted

4.2.2.3

No cover plates, covers, or devices shall be installed unless indicated in the manufacturer's supplied instructions as essential for achieving air sealing. Openings for the device are permitted to be obturated.

Boxes equipped with bar hangers or other attachment(s) shall be tested with the bar hanger or attachment(s) assembled. Bar hangers or other attachment(s) are not required to be mounted to the test chamber and are permitted to be modified to fit within the test chamber.

Figure 2
Outside Chamber Door with Boxes Mounted

4.3 Air Flow Measurement

See Annex A for example test apparatus with an internal means for measuring air flow, such as in a blower door/duct leakage test system.

Section 5
Marking and Documentation

5.1 Product Marking

The smallest shipping unit is permitted to be marked “NEMA OS 4” when boxes comply with this standard.

Boxes that comply with this standard are permitted to be marked “NEMA OS 4” or “OS 4.” When used, the marking shall be legible and visible on the inside of the box.

5.2 Installation Instructions

Any particular installation techniques or components that are required to achieve compliance with this standard shall be specified by the manufacturer.

Annex A
(Informative)
Description of Typical Blower Door/Duct Leakage–Style Apparatus for Internal Air Leakage Measurements

A.1 General

This annex provides guidance for constructing a typical blower door/duct leakage system apparatus for internal measurement of air leakage in accordance with ASTM E283, around and through an electrical outlet box (see Figure 3 for typical apparatus configuration).

To ensure accuracy, the test facility should be set up in an area that has very low air movement. Direct air movement from fans or HVAC discharge vents should never be directed toward the apparatus during a test.

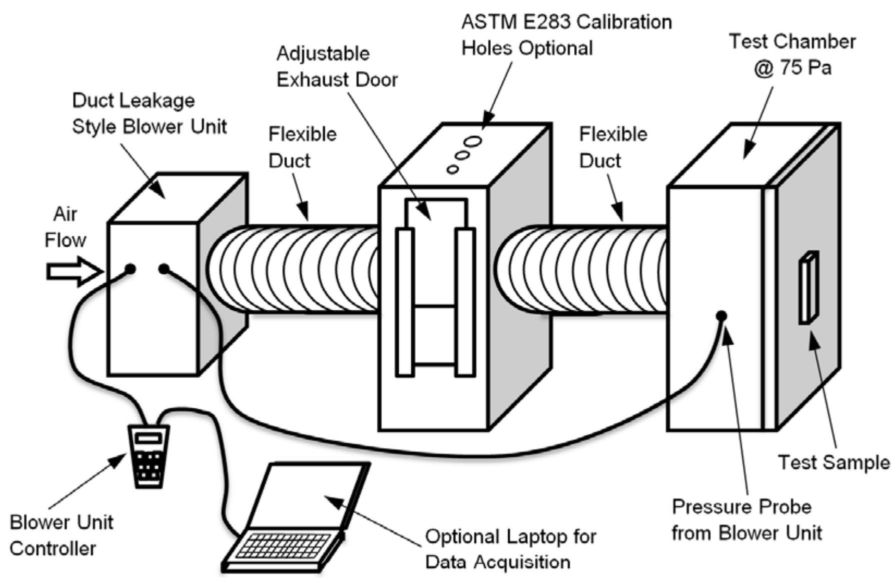


Figure 3
Block Diagram of Blower Door/Duct Leakage–Style Test Apparatus

A.2 Test Chamber

The test chamber can be constructed of any material that will be air-tight when closed and has removable air-tight test panels, each containing cutouts for the particular size and number of outlet boxes to be tested (see Figure 4). Typically, a 2–3 cubic foot enclosure that can hold 75 Pa of internal pressure is adequate. The door of the enclosure is removable so the enclosure can be easily reconfigured with a solid door for calibration/setup or any door configured with a test sample. The pressure probe from the blower unit (the blue tube in Figure 4) is installed in the test chamber. The control unit of the blower is programmed to maintain 75 Pa in the test chamber. Installation of an air diffuser inside the test chamber (Figure 6) is recommended to keep the air from blowing directly on the test sample.

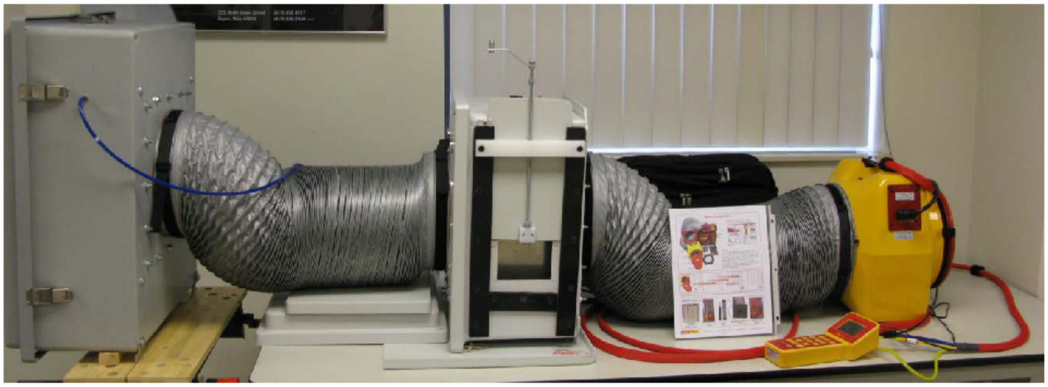


Figure 4
Fabricated Test Chamber with Test Panel Installed

A.3 Air Exhaust/Calibration Chamber

The air exhaust/calibration chamber (Figure 5) has an adjustable door to control the air exhausted from the blower unit. During a typical setup, a test chamber door with no openings is installed on the test chamber. The adjustable door is adjusted to obtain 75 Pa pressure in the test chamber at 100 CFM. This is now the baseline for the test. The test chamber door is exchanged with one that is fitted with a test sample. The blower system input increases as needed to maintain 75 Pa in the test chamber. The unit can optionally be equipped with use double pries, not quotes calibration holes as defined in ASTM E283.

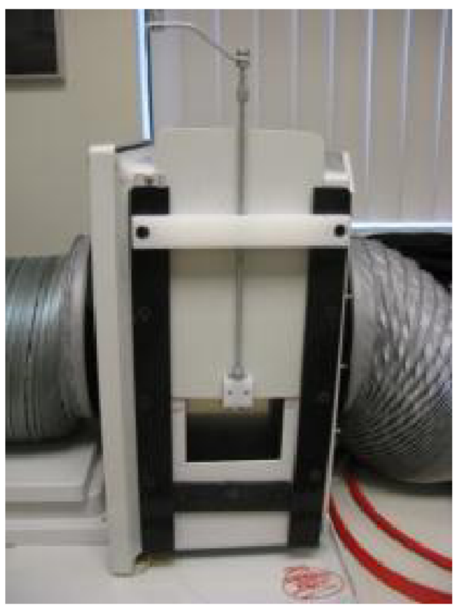


Figure 5
Air Exhaust/Calibration Chamber

A.4 Air Leakage Calculation

The 100 CFM Baseline air pressure (CFM^B) established during calibration is to be subtracted from the pressure reading from the test (CFM^T). The result (CFM^C) is the air leakage through the sample and is used to determine compliance in accordance with clause 3.1.

$$\frac{CFM^T - CFM^B}{Number\ of\ boxes} = CFM^{per\ box}$$

A.5 Air Diffuser in Test Chamber

Installation of some means of diffusing the air coming into the test chamber is recommended so it does not blow directly on the test samples. In the example shown in Figure 6, a steel plate is mounted on standoffs in front of the opening where the duct feeding air into the test chamber is located.

Figure 6
Air Diffuser in Test Chamber

<This page intentionally left blank>

Annex B
(Informative)
Applicable Building and Energy Codes and Other Resources

Primary Resources

International Energy Conservation Code (IECC)
Section C402.4.1.2, "Air Barrier Compliance Options"
Section R402.4, "Air Leakage (Mandatory)"
Section R402.4.4, "Rooms Containing Fuel-Burning Appliances"
Table R402.4.1.1, "Air Barrier and Insulation Installation"
(Definition of air-sealed box)

International Residential Code (IRC)
Chapter 11, Energy Efficiency

International Building Code (IBC)
Chapter 13, Energy Efficiency

Secondary Resources

ANSI/ASHRAE 90.2-2007, *Energy Efficient Design of Low-Rise Residential Buildings*
ANSI/NFRC 400-2014, *Procedure for Determining Fenestration Product Air Leakage*
ASHRAE/IES Standard 90.1-2016, *Energy Standard for Buildings Except Low-Rise Residential Buildings*
ASTM E283-04 (2012), *Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen*
ASTM E779-10, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*
ASTM E2178-13, *Standard Test Method for Air Permeance of Building Materials*
International Green Construction Code 2015 (IGCC)
National Building Code of Canada 2015 (Natural Resources Canada)
NRCan Standard R-2000 (Canada)
National Energy Code of Canada for Houses (NECH)
National Energy Code of Canada for Buildings (NECB) 2015
NEMA LSD 58-2010, *Air Infiltration Ratings for Recessed Luminaires*
NEMA Engineering Bulletin 95 (2007), *Thermal Effects of Type NM-B Cable Encased in Spray-Foam Insulation Used in Residences*

§

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10074

54

Date Submitted	02/03/2022	**Section**	404	**Proponent**	Bryan Holland
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

This proposed modification adds requirements for exterior lighting on residential buildings not current covered by the code.

Rationale

The current code does not have any specific requirements for exterior lighting for residential buildings. This really is not a significant issue one-and two-family dwellings and townhomes, but it is quite significant for other Group R occupancies that are far more likely to have parking lots and other exterior lighting similar to a commercial building. A 4-story multifamily building with exactly the same systems and layout would therefore be subject to exterior lighting requirements while a 3-story variation would not. This creates a loophole in the code for low-rise Group R occupancies. This proposal directs exterior lighting for these occupancies to the commercial code and its LPD requirements. When applied to the low-rise multifamily prototype developed by Pacific Northwest National Laboratories for the code determination studies, this requirement saved up to 0.5% (based on climate zone) whole building energy over the 2015 IECC. Since both 2018 and 2015 editions of the IECC lack exterior lighting requirements, this is a reasonable approximation of savings.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposed modification will require the local entity to confirm the exterior lighting on certain Group R occupancies is in compliance with the new requirement at time of plan review and inspection.

Impact to building and property owners relative to cost of compliance with code

This proposed modification could increase the cost of compliance with the code where excessive or low efficacy lighting is desired, however, it is likely that most exterior lighting installations at Group R occupancies would be able to comply with the new requirement without modification.

Impact to industry relative to the cost of compliance with code

This proposed modification will have no impact on industry as most exterior lighting installations at Group R occupancies will be in compliance without modification.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposed modification will improve the health and welfare of the general public by improving the efficacy of exterior lighting installations on exterior Group R occupancies.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposed modification improves the code by addressing a gap into the code related to exterior lighting on Group R occupancies.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposed modification does not discriminate against any materials, methods, or systems of constructions.

Does not degrade the effectiveness of the code

This proposed modification improves the effectiveness of the code.

1st Comment Period History

EN10074-G1

Proponent	Timothy de Carion	Submitted	3/28/2022 11:15:23 AM	Attachments	No

Comment:

I agree with this modification. Parking lighting and exterior building lighting in three story multifamily buildings must have an energy code provision.

1st Comment Period History

EN10074-G2

Proponent	Jeff Sonne for FSEC	Submitted	4/14/2022 1:58:46 PM	Attachments	No

Comment:

FSEC supports this mod.

R404.1.2 Exterior lighting. Connected exterior lighting for residential buildings shall comply with Section C405.4.

Exceptions:

1. Detached one- and two- family dwellings.

2. Townhouses.

3. Stand-alone solar photovoltaic (PV) powered luminaires.

4. Luminaires with automatic lighting controls.

5. Lamps and luminaires that comply with Section R404.1.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10075

55

Date Submitted	02/03/2022	**Section**	404	**Proponent**	Bryan Holland
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language Yes**

Related Modifications

Summary of Modification

This proposed modification adds interior lighting control requirements for residential buildings.

Rationale

The current code has no requirements for interior lighting controls at residential buildings. However, operational controls for other equipment such as HVAC systems, water heating, and swimming pools have been a fundamental tenant of the energy code for many years and have shown to be extremely cost effective and energy saving. Additionally, the mandatory interior lighting control requirements for commercial buildings and have also proven to improve overall energy efficiency and the effective use of energy. This proposal will significantly improve the energy performance of dwellings at a very low initial cost of construction and meets the mandate outlined in F.S. 553.886 that states; "the Florida Building Code must facilitate and promote the use of cost-effective energy conservation, energy-demand management, and renewable energy technologies in buildings.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposed modification will require the local entity to confirm the design and installation of interior lighting controls at time of plan review and inspection.

Impact to building and property owners relative to cost of compliance with code

This proposed modification will increase the cost of compliance with the code by adding the cost of lighting control devices that comply with the new rule, but will result in overall cost savings for the consumer by reducing energy costs.

Impact to industry relative to the cost of compliance with code

This proposed modification will increase the cost of compliance with the code for industry. Interior lighting control devices do have an initial cost that will need to be applied to the overall premises wiring system.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposed modification will improve the health and welfare of the general public by reducing the energy consumed by lighting in spaces that are not in use or need to be at full on.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposed modification improves the code and meets the mandate outlined in F.S. 553.886 that states; "the Florida Building Code must facilitate and promote the use of cost-effective energy conservation, energy-demand management, and renewable energy technologies in buildings.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposed modification does not discriminate against any materials, methods, or systems of constructions.

Does not degrade the effectiveness of the code

This proposed modification improves the effectiveness of the code.

Alternate Language

1st Comment Period History

EN10075-A1

Proponent Bryan Holland **Submitted** 3/28/2022 10:37:54 AM **Attachments** Yes

Rationale:

This alternative proposed modification adds a definition of "automatic shut-off control" and replaces the two uses of "occupant sensor" with "automatic shut-off" control. No other technical changes or changes to the intent of the original proposed modification.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Same as original proposed modification.

Impact to building and property owners relative to cost of compliance with code

Same as original proposed modification.

Impact to industry relative to the cost of compliance with code

Same as original proposed modification.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Same as original proposed modification.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Same as original proposed modification.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Same as original proposed modification.

Does not degrade the effectiveness of the code

Same as original proposed modification.

Add to Chapter 2 [RE] Definitions:

HABITABLE SPACE. A space in a building for living, sleeping, eating or cooking. Bathrooms, toilet rooms, closets, halls, screen enclosures, sunroom categories as defined at Section R301.2.1.1.1, storage or utility spaces and similar areas are not considered habitable spaces.

AUTOMATIC SHUT-OFF CONTROL. A device capable of automatically turning loads off without manual intervention. Automatic shut-off controls include devices such as, but not limited to, occupancy sensors, vacancy sensors, door switches, programmable time switch (i.e., timeclock), or count-down timers.

Add new Section as Follows:

R404.2 Interior lighting controls. All permanently installed luminaires shall be controlled to comply with R404.2.1 and R404.2.2.

R404.2.1 Habitable spaces. All permanently installed luminaires in habitable spaces shall be controlled with a dimmer or an automatic shut-off control that automatically turns off lights within 20 minutes after all occupants have left the space and shall incorporate a manual control to allow occupants to turn the lights on or off.

R404.2.2 Specific locations. All permanently installed luminaires in bathrooms, hallways, garages, basements, laundry rooms, and utility rooms shall be controlled by an automatic shut-off control that automatically turns off lights within 20 minutes after all occupants have left the space and shall incorporate a manual control to allow occupants to turn the lights on or off.

Add to Chapter 2 [RE] Definitions:

HABITABLE SPACE. A space in a building for living, sleeping, eating or cooking. Bathrooms, toilet rooms, closets, halls, screen enclosures, sunroom categories as defined at Section R301.2.1.1.1, storage or utility spaces and similar areas are not considered habitable spaces.

Add new Section as Follows:

R404.2 Interior lighting controls. All permanently installed luminaires shall be controlled to comply with R404.2.1 and R404.2.2.

R404.2.1 Habitable spaces. All permanently installed luminaires in habitable spaces shall be controlled with a dimmer or an occupant sensor control that automatically turns off lights within 20 minutes after all occupants have left the space and shall incorporate a manual control to allow occupants to turn the lights on or off.

R404.2.2 Specific locations. All permanently installed luminaires in bathrooms, hallways, garages, basements, laundry rooms, and utility rooms shall be controlled by an occupant sensor control that automatically turns off lights within 20 minutes after all occupants have left the space and shall incorporate a manual control to allow occupants to turn the lights on or off.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10076

56

Date Submitted	02/03/2022	**Section**	404	**Proponent**	Bryan Holland
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

This proposed modification adds exterior lighting control requirements for residential buildings.

Rationale

The current code has no requirements for the control of exterior lighting for residential buildings. Exterior lighting controls for commercial buildings has been shown to be extremely cost effective and result in immense energy savings, energy conservation, and the effective use of energy. This proposal corrects this gap in the code and meets the mandate outlined in F.S. 553.886 that states; "the Florida Building Code must facilitate and promote the use of cost-effective energy conservation, energy-demand management, and renewable energy technologies in buildings.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposed modification will require the local entity to confirm the design and installation of exterior lighting controls at residential buildings at time of plan review and inspection.

Impact to building and property owners relative to cost of compliance with code

This proposed modification will increase the cost of compliance with the code at time of installation but will result in energy savings over time.

Impact to industry relative to the cost of compliance with code

This proposed modification will increase the cost of compliance with the code for industry. Exterior lighting control devices have an initial cost of construction.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposed modification will improve the health and welfare of the general public by improving the efficacy of exterior lighting on residential buildings.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposed modification improves the code and meets the mandate outlined in F.S. 553.886 that states; "the Florida Building Code must facilitate and promote the use of cost-effective energy conservation, energy-demand management, and renewable energy technologies in buildings.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposed modification does not discriminate against any materials, methods, or systems of constructions.

Does not degrade the effectiveness of the code

This proposed modification improves the effectiveness of the code.

R404.3 Exterior lighting controls. Where the total permanently installed exterior lighting power is greater than 30 watts, the permanently installed exterior lighting shall comply with the following:

1. Lighting shall be controlled by a manual on and off switch which permits automatic shut-off actions.

Exception: Lighting serving multiple dwelling units.

2. Lighting shall be automatically shut off when daylight is present and satisfies the lighting needs.

3. Controls that override automatic shut-off actions shall not be allowed unless the override automatically returns automatic control to its normal operation within 24 hours.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

57

EN10151

Date Submitted	02/11/2022	**Section**	402.4.1.2	**Proponent**	Timothy de Carion
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Appendix RD -Form for Envelope Leakage Test Report would need to be updated with added code language

Summary of Modification

Testing shall locate leaks in the thermal envelope. When the thermal envelope is insulated and located at the underside of the roof deck, this sealed building cavity becomes part of the building thermal envelope. This added volume must be tested and included in the test with the hatch off.

Rationale

Many certified blower door testers are unaware that the upper building cavity area must be included for testing air leakage. If this unvented attic cavity area has excessive air leakage, humidity will infiltrate into this area and become trapped. This trapped humid air could cause condensation to occur. The air volume of building cavities under the thermal envelope must be included in the air leakage test and attic hatches must remain open for the test.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No additional inspections

Impact to building and property owners relative to cost of compliance with code

No additional testing needed

Impact to industry relative to the cost of compliance with code

No additional cost.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, will prevent leakage in the thermal envelope and reduce humidity and mold problems.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Clarifies existing code.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not discriminate

Does not degrade the effectiveness of the code

Does not weaken code.

R402.4.1.2 Testing. The building or dwelling unit shall be tested and verified as having an air leakage rate not exceeding seven air changes per hour in Climate Zones 1 and 2, and three air changes per hour in Climate Zones 3 through 8. Testing shall be conducted in accordance with ANSI/RESNET/ICC 380 and reported at a pressure of 0.2 inch w.g. (50 pascals). Testing shall be conducted by either individuals as defined in Section 553.993(5) or (7), *Florida Statutes,* or individuals licensed as set forth in Section 489.105(3)(f), (g) or (i) or an *approved* third party. A written report of the results of the test shall be signed by the party conducting the test and provided to the *code official*. Testing shall be performed at any time after creation of all penetrations of the *building thermal envelope*.

Exception: Testing is not required for additions, alterations, renovations or repairs of the building thermal envelope of existing buildings in which the new construction is less than 85 percent of the building thermal envelope.

During testing:

1. Exterior windows and doors, fireplace and stove doors shall be closed, but not sealed, beyond the intended weatherstripping or other infiltration control measures.

2. Dampers including exhaust, intake, makeup air, backdraft and flue dampers shall be closed, but not sealed beyond intended infiltration control measures.

3. Interior doors, if installed at the time of the test, shall be open.

4. Exterior doors for continuous ventilation systems and heat recovery ventilators shall be closed and sealed.

5. Heating and cooling systems, if installed at the time of the test, shall be turned off.

6. Supply and return registers, if installed at the time of the test, shall be fully open.

7. If an attic is both air sealed and insulated at the roof deck, interior access doors and hatches between the conditioned space volume and the attic shall be opened during the test and the volume of the attic shall be added to the conditioned space volume for purposes of reporting an infiltration volume and calculating the air leakage of the home.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10158

58

Date Submitted	02/10/2022	**Section**	405.6.3.1	**Proponent**	Jeff Sonne for FSEC
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Performance compliance instantaneous water heater UEF adjustment factor.

Rationale

The 92% adjustment factor for water heater Energy Factor (EF) is already included the Florida Energy Code; this mod provides the appropriate reduction for the newer Uniform Energy Factor (UEF) rating metric. The 0.94 adjustment for UEF is already used in ANSI/RESNET/ICC 301-2019.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None- updates for UEF rating metric only.

Impact to building and property owners relative to cost of compliance with code

None- updates for UEF rating metric only.

Impact to industry relative to the cost of compliance with code

None- updates for UEF rating metric only.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, updates code by adding newer efficiency metric.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves the code by updating it with newer efficiency metric.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not discriminate; updates the code.

Does not degrade the effectiveness of the code

Improves code effectiveness by updating it with newer efficiency metric.

R405.6.3.1 Water-heating ~~EF~~efficiency adjustment factors.

The Energy Factor (EF) of an instantaneous water heater [those with capacity of two gallons (7.57 L) or less] in the Proposed home shall be reduced to 92 percent of the value in the manufacturer's documentation or AHRI *Directory of Certified Product Performance*. The Uniform Energy Factor (UEF) of an instantaneous water heater in the Proposed home shall be reduced to 94 percent of the value in the manufacturer's documentation or AHRI *Directory of Certified Product Performance*.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10165

59

Date Submitted	02/11/2022	**Section**	405.2	**Proponent**	Jeff Sonne for FSEC
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

10166

Summary of Modification

R-8 insulation requirement for site-wrapped supply ducts for Section R405 compliance.

Rationale

While factory insulated ducts also get compressed, contractor or installer site-wrapped ducts are more susceptible to condensation issues in our climate because they may be wrapped more tightly, overly compressing the insulation. For more information see: https://publications.energyresearch.ucf.edu/wp-content/uploads/2021/01/FSEC-CR-2105-21.pdf

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
Slight impact in applicable cases to verify compliance.

Impact to building and property owners relative to cost of compliance with code
Slight increase in first cost in applicable cases.

Impact to industry relative to the cost of compliance with code
Slight impact in applicable cases.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
Yes; benefits public by reducing likelihood of condensation in applicable cases.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
Yes; strengthens the code by reducing likelihood of condensation in applicable cases.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

No; only addresses condensation concern for applicable cases.

Does not degrade the effectiveness of the code

Increases effectiveness of the code by reducing likelihood of condensation in applicable cases.

1st Comment Period History

EN10165-G1

Proponent	Timothy de Carion	Submitted	3/28/2022 11:18:52 AM	Attachments	No

Comment:

I agree with this code modification. Wrapped duct is know to have condensation issues.

R405.2 Mandatory requirements.

Compliance with this section requires that the mandatory provisions identified in Section R401.2 be met. All supply and return ducts not completely inside the *building thermal envelope* shall be insulated to a minimum of R-6, except site-wrapped supply ducts not completely inside the *building thermal envelope* shall be insulated to a minimum of R-8.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10166

60

Date Submitted	02/11/2022	**Section**	406.2	**Proponent**	Jeff Sonne for FSEC
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

10165

Summary of Modification

R-8 insulation requirement for site-wrapped supply ducts for Section R406 compliance.

Rationale

While factory insulated ducts also get compressed, contractor or installer site-wrapped ducts are more susceptible to condensation issues in our climate because they may be wrapped more tightly, overly compressing the insulation. For more information see: https://publications.energyresearch.ucf.edu/wp-content/uploads/2021/01/FSEC-CR-2105-21.pdf

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Slight impact in applicable cases to verify compliance.

Impact to building and property owners relative to cost of compliance with code

Slight increase in first cost in applicable cases.

Impact to industry relative to the cost of compliance with code

Slight impact in applicable cases.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes; benefits public by reducing likelihood of condensation in applicable cases.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes; strengthens the code by reducing likelihood of condensation in applicable cases.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

No; only addresses condensation concern for applicable cases.

Does not degrade the effectiveness of the code

Increases effectiveness of the code by reducing likelihood of condensation in applicable cases.

R406.2 Mandatory requirements.

Compliance with this section requires that the provisions identified in Sections R401 through R404 labeled as "mandatory" and Section R403.5.3 of the 2015 International Energy Conservation Code be met. For buildings that do not utilize on-site renewable power production for compliance with this section, the building thermal envelope shall be greater than or equal to levels of efficiency and Solar Heat Gain Coefficient in Table 402.1.1 or 402.1.3 of the 2009 International Energy Conservation Code. For buildings that utilize on-site renewable power production for compliance with this section, the building thermal envelope shall be greater than or equal to levels of efficiency and Solar Heat Gain Coefficient in Table R402.1.2 or Table R402.1.4 of the 2015 International Energy Conservation Code.

> **Exception:** Supply and return ducts not completely inside the building thermal envelope shall be insulated to a minimum of R-6.

[New]R406.2.1 Site-wrapped supply ducts.

Site-wrapped supply ducts not completely inside the *building thermal envelope* shall be insulated to a minimum of R-8.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

61

EN10193

Date Submitted	02/11/2022	**Section**	402.4.1.2	**Proponent**	Timothy de Carion
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Appendix RD-FORMS "Envelope Leakage Test Report" would need to be revised to reflect new language.

Summary of Modification

FECC does not mention that blower door that tests results under 3 (ach) requires mechanical ventilation. Code references in the energy code are needed for clarity and ease to find all the code requirements. Efficacy requirements of whole-house mechanical ventilation in R403.6.1 are also referenced.

Rationale

This modification is not a change in intent and practice. It only provides clarity. It is very difficult to find the corresponding code sections that apply to the required mechanical ventilation based on the test results. The code sections that apply should be easy to find from this code section.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No additional inspections required

Impact to building and property owners relative to cost of compliance with code

No impact

Impact to industry relative to the cost of compliance with code

No Impact

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Improves clarity of existing code

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves clarity of existing code

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not discriminate

Does not degrade the effectiveness of the code

No, Makes the current code clear

1st Comment Period History

EN10193-G1

Proponent	pete quintela	Submitted	3/29/2022 1:06:25 PM	Attachments	No

Comment:

Under the current code you have to go to the Florida Residential Building Code to find when mandatory mechanical ventilation is required (below 3 air changes per hour when tested with a door blower at a pressure of 0.2 inch w.c). The top range of air leakage is in the Energy Code. This modification includes what the top and bottom design ranges are for air leakage in the same code section, includes when mandatory ventilation is required. Simplifies enforcement and understanding of the intent of the code. I recommend approval.

1st Comment Period History

EN10193-G2

Proponent	Jeff Sonne for FSEC	Submitted	4/14/2022 1:30:02 PM	Attachments	No

Comment:

FSEC supports this mod.

R402.4.1.2 Testing. The building or dwelling unit shall be tested and verified as having an air leakage rate not exceeding seven air changes per hour in Climate Zones 1 and 2, and three air changes per hour in Climate Zones 3 through 8. Dwelling units with an air leakage rate less than three air changes per hour shall be provided with whole-house mechanical ventilation in accordance with Section R403.6.1 of this code and M1507.3 of the *Florida Building Code, Residential.* Testing shall be conducted in accordance with ANSI/RESNET/ICC 380 and reported at a pressure of 0.2 inch w.g. (50 pascals). Testing shall be conducted by either individual as defined in Section 553.993(5) or (7), *Florida Statutes*, or individuals licensed as set forth in Section 489.105(3)(f), (g) or (i) or an *approved* third party. A written report of the results of the test shall be signed by the party conducting the test and provided to the *code official*. Testing shall be performed at any time after creation of all penetrations of the *building thermal envelope*.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

62

EN10230

Date Submitted	02/11/2022	**Section**	401.2.2	**Proponent**	Jeff Sonne for FSEC
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

Summary of Modification

Additional energy efficiency requirements.

Rationale

This proposal introduces a new section within the code that will require additional efficiency measures (options) for residential buildings which will better allow Florida code to keep up with stringency increases in the 2021 IECC. When taking the prescriptive approach, one of the new Section R407.2 efficiency options must be installed. For the performance approach, the annual total normalized Modified Loads of the proposed design are reduced to 95% of the annual total loads of the standard reference design. The proposal allows a wide range of improvements, providing flexibility for each compliance path. See cost effectiveness analyses and related discussion on pages 28 – 31 of https://publications.energyresearch.ucf.edu/wp-content/uploads/2021/06/FSEC-CR-2112-21.pdf .

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None to slight impact to verify compliance.

Impact to building and property owners relative to cost of compliance with code

The code change proposal will increase the cost of construction. However, for a given project one or more of these efficiency options should be cost effective. See cost analyses and related on pgs. 28 – 31 of https://publications.energyresearch.ucf.edu/wp-content/uploads/2021/06/FSEC-CR-2112-21.pdf.

Impact to industry relative to the cost of compliance with code

The code change proposal will increase the cost of construction. However, for a given project one or more of these efficiency options should be cost effective. See cost analyses and related on pgs. 28 – 31 of https://publications.energyresearch.ucf.edu/wp-content/uploads/2021/06/FSEC-CR-2112-21.pdf.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, benefits public by increasing energy efficiency while maintaining compliance flexibility.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves the code by increasing energy efficiency while maintaining compliance flexibility.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not discriminate; a range of efficiency improvements can be used to comply.

Does not degrade the effectiveness of the code

Improves code effectiveness by increasing energy efficiency while maintaining compliance flexibility.

Alternate Language

1st Comment Period History

EN10230-A1

Proponent	Jeff Sonne for FSEC	**Submitted**	4/16/2022 2:56:25 PM	**Attachments**	Yes

Rationale:

Further research found 8.2 HSPF2 to be a more appropriate efficiency requirement than 10 HSPF2 for this entry. No other changes to mod.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None; just provides more appropriate efficiency requirement than in original mod.

Impact to building and property owners relative to cost of compliance with code

None; just provides more appropriate efficiency requirement than in original mod.

Impact to industry relative to the cost of compliance with code

None; just provides more appropriate efficiency requirement than in original mod.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes; provides more appropriate efficiency requirement than in original mod.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes; provides more appropriate efficiency requirement than in original mod.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

No; just provides more appropriate efficiency requirement than in original mod.

Does not degrade the effectiveness of the code

No; just provides more appropriate efficiency requirement than in original mod.

1st Comment Period History

EN10230-G1

Proponent	Amanda Hickman	Submitted	4/14/2022 11:12:54 AM	Attachments	No

Comment:

LBA does not support the modification, as it is not appropriate for Florida and/or is not cost justified.

[Keep original mod 10230 with following HSPF2 change to Section R407.2.2 (no other changes to original mod)]

R407.2.2 More efficient HVAC equipment performance option. All heating and cooling equipment shall meet or exceed one of the following efficiencies:

1. Greater than or equal to 95 AFUE natural gas furnace and 16 SEER2 air conditioner.

2. Greater than or equal to ~~10~~ <u>8.2</u> HSPF2 / 16 SEER2 air source heat pump.

3. Greater than or equal to 3.5 COP ground source heat pump.

Add new text as follows:

R401.2.2 Additional Energy Efficiency (Mandatory). This section establishes additional requirements applicable to all compliance approaches to achieve additional energy efficiency.

1. For buildings complying under Sections R401 through R404, one of the Additional Efficiency Package Options shall be installed according to Section R407.2.

2. For buildings complying under the simulated performance alternative in Section R405, the *proposed design* of the building under Section R405.3 shall have annual total normalized Modified Loads less than or equal to 95 percent of the annual total loads of the *standard reference design*.

3. For buildings complying under the energy rating index alternative in Section R406, the energy rating index value shall be at least 5 percent less than the energy rating index target specified in Table R406.4.

The option selected for compliance shall be identified in the energy performance level (EPL) display card required by Section R401.3.

SECTION R407
ADDITIONAL EFFICIENCY PACKAGE OPTIONS

R407.1 Scope. This section establishes Additional Efficiency Package Options to achieve additional energy efficiency in accordance with Section R401.2.2.

R407.2 Additional Efficiency Package Options. Additional efficiency package options for compliance with Section R401.2.2 are set forth in Sections R407.2.1 through R407.2.5.

R407.2.1 Enhanced envelope performance option. The total building thermal envelope UA, the sum of *U*-factor times assembly area, shall be less than or equal to 95 percent of the total UA resulting from multiplying the *U*-factors in Table R402.1.4 by the same assembly area as in the proposed building. The UA calculation shall be performed in accordance with Section R402.1.5. The area-weighted average SHGC of all glazed fenestration shall be less than or equal to 95 percent of the maximum glazed fenestration SHGC in Table R402.1.2.

R407.2.2 More efficient HVAC equipment performance option. Allheating and cooling equipment shall meet or exceed one of the following efficiencies:

1. Greater than or equal to 95 AFUE natural gas furnace and 16 SEER2 air conditioner.

2. Greater than or equal to 10 HSPF2 / 16 SEER2 air source heat pump.

3. Greater than or equal to 3.5 COP ground source heat pump.

R407.2.3 Reduced energy use in service water heating option. The hot water system shall meet or exceed one of the following efficiencies:

1. Greater than or equal to 0.82 UEF fossil fuel service water heating system.
2. Greater than or equal to 2.0 UEF electric service water heating system.
3. Greater than or equal to 0.4 Solar Fraction solar water heating system.

R407.2.4 More efficient duct thermal distribution system option. The thermal distribution system shall meet or exceed one of the following efficiencies:

1. 100 percent of ducts and air handlers located entirely within the *building thermal envelope.*
2. 100 percent of ductless thermal distribution system or hydronic thermal distribution system located completely inside the *building thermal envelope.*

R407.2.5 Improved air sealing and efficient ventilation system option. The measured air leakage rate shall be less than or equal to 3.0 ACH50, with an Energy Recovery Ventilator (ERV) installed. Minimum ERV requirements, measured at the lowest tested net supply airflow, shall be greater than or equal to 75 percent Sensible Recovery Efficiency (SRE), greater than or equal to 1.2 CFM/W Fan Energy, and shall not use recirculation as a defrost strategy. In addition, the ERV shall be greater than or equal to 50 percent Latent Recovery/Moisture Transfer (LRMT).

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10252

63

Date Submitted	02/11/2022	**Section**	403.1.3	**Proponent**	David Calabrese
Chapter	4	**Affects HVHZ**	No	**Attachments**	**Yes**
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

The use of electric resistance heaters as backup heating devices can significantly increase winter energy consumption, and air source heat pumps can effectively provide heating without such devices in Florida. This proposed modification minimizes the increase of such winter energy consumption.

Rationale

Reason: The use of electric resistance heaters as backup heating devices can significantly increase winter energy consumption, and air source heat pumps can effectively provide heating without such devices in Florida in the United States. Also, Daikin has observed that it's common for heat pumps to be installed with electric resistance heaters configured to operate in conditions where sufficient heating capacity is available from the heat pump alone. This results in reducing the operation hours of heat pumps and increasing the operation hours of electric resistance heaters. Such setting of heat pump systems will fail to yield expected reduction of GHG emissions and result in higher energy consumption and longer peak demand events. Therefore, Daikin proposes to revise R403.1.3, which defines the use of electric resistance heaters as supplementary heat for heat pumps, to prevent such practice.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposed modification is specifically for residential buildings. Therefore, there will be no impact to local entity relative to enforcement of the code.

Impact to building and property owners relative to cost of compliance with code

The code change proposal will neither increase nor decrease the cost of construction to comply with the code. Requiring the use of the switchover temperature controls will not increase nor decrease such cost either. Yet, it will result in energy savings and lower utilities costs for the end-user.

Impact to industry relative to the cost of compliance with code

This proposed modification is specifically for residential buildings. Therefore, there will be no impact to industry relative to the cost of compliance with code.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This modification will result in energy savings and lower utilities costs for the end-user. The reduced energy use will also reduce emissions of air pollutants and greenhouse gases, which will lead to a reasonable and substantial connection with the health, safety, and welfare of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This modification will optimize the operation of heat pump systems with electric supplementary heat, which leads to improvement of the code.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

No it does not.

Does not degrade the effectiveness of the code

No it does not.

Mandatory requirements for HP switchover temperature

2023 Florida Building Code, Energy Conservation, 8th Edition: R403.1.3

Revise as follows:

R403.1.3 Heat pump supplementary heat (Mandatory).

-

Heat pumps with supplementary electric resistance heaters shall have controls that ~~except during defrost, prevent supplemental heat operation when the capacity of the heat pump compressor can meet the heating load.~~ limit supplemental heat operation to only those times when one of the following applies:

1. The vapor compression cycle cannot provide the necessary heating energy to satisfy the thermostat setting.

2. The heat pump is operating in defrost mode.

3. The vapor compression cycle malfunctions.

4. The thermostat malfunctions.

Mandatory requirements for HP switchover temperature

2023 Florida Building Code, Energy Conservation, 8th Edition: R403.1.3

Revise as follows:

R403.1.3 Heat pump supplementary heat (Mandatory).

Heat pumps with supplementary electric resistance heaters shall have controls that ~~except during defrost, prevent supplemental heat operation when the~~ capacity of the ~~heat pump compressor can meet the heating load.~~ limit supplemental heat operation to only those times when one of the following applies:

1. The vapor compression cycle cannot provide the necessary heating energy to satisfy the thermostat setting.

2. The heat pump is operating in defrost mode.

3. The vapor compression cycle malfunctions.

4. The thermostat malfunctions.

Reason: The use of electric resistance heaters as backup heating devices can significantly increase winter energy consumption, and air source heat pumps can effectively provide heating without such devices in Florida in the United States. Also, Daikin has observed that it's common for heat pumps to be installed with electric resistance heaters configured to operate in conditions where sufficient heating capacity is available from the heat pump alone. This results in reducing the operation hours of heat pumps and increasing the operation hours of electric resistance heaters. Such setting of heat pump systems will fail to yield expected reduction of GHG emissions and result in higher energy consumption and longer peak demand events. Therefore, Daikin proposes to revise R403.1.2, which defines the use of electric resistance heaters as supplementary heat for heat pumps, to prevent such practice.

Cost Impact: The code change proposal will neither increase nor decrease the cost of construction. Requiring the use of the switchover temperature controls will not increase nor decrease the cost of construction - however, it will result in energy savings and lower utilities costs for the end-user.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

64

EN10253

Date Submitted	02/11/2022	**Section**	407	**Proponent**	David Calabrese
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Daikin requests that the 2023 version of Florida IECC incorporates Section R408 of 2021 IECC, with modifications to Section R408.2.2, as Section R407 to continue effectively driving builders and users to optimize the energy performance of their homes.

Rationale

Reason: The 2021 IECC has implemented a new section, R408 Additional Efficiency Package Options, which defines five optional requirements to achieve additional energy efficiency: 1. Enhanced envelope performance option., 2. More efficient HVAC equipment performance option., 3. Reduced energy use in servicing water-heating option., 4. More efficient duct thermal distribution system option., and 5. Improved air sealing and efficient ventilation system option. Daikin requests that the 2023 version of Florida IECC incorporates Section R408 of 2021 IECC as Section R407 to continue effectively driving builders and users to optimize the energy performance of their homes. In addition, variable speed heat pumps provide superior energy performance over commonly used and equivalently rated single and two-stage equipment due to their higher efficiency attained during partial load operation. Also, mini and multi-split systems with variable speed compressors provides homeowners opportunities to further save energy consumption by turning off individual indoor units in unoccupied zones. For the 2023 Florida Building Code, Energy Conservation, 8th Edition, as incorporating Section R408 of 2021 IECC as Section R407, Daikin proposes changes to Section R408.2.2 and reflect the changes to R407.2.2 to accurately capture the energy performance superiority of variable speed air source heat pumps in both centrally ducted and ductless systems. The metrics of HSPF and SEER are being updated to the new metrics of HSPF2 and SEER2 that will be in effect when the 2023 Florida Building Code is adopted by jurisdictions (see 10 CFR 430.32).

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This modification proposal is specifically for residential building and property owners. So there will no impact.

Impact to building and property owners relative to cost of compliance with code

This modification proposal will increase the cost of construction. This proposal may increase the cost of construction including when utilizing variable speed air source heat pumps, but it will result in energy savings and lower utility costs for the end-user.

Impact to industry relative to the cost of compliance with code

This modification proposal is specifically for residential building and property owners. So there will no impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This modification proposal will result in energy savings and lower utility costs for the end-user. The modification will also reduce emissions of air pollutants and greenhouse gases. Them combined will reasonably and substantially improve the health, safety, and welfare of the general public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This modification proposal will drive the market adoption of variable speed heat pumps (VSHP). VSHP has superior energy performance as well as peak power management capability; in other words, they are better HVAC systems.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

No it does not.

Does not degrade the effectiveness of the code

No it does not.

1st Comment Period History

EN10253-G1

Proponent	Amanda Hickman	Submitted	4/14/2022 11:13:23 AM	Attachments	No

Comment:

LBA does not support the modification, as it is not appropriate for Florida and/or is not cost justified.

Section R407

ADDITIONAL EFFICIENCY PACKAGE OPTIONS

R407. 1. Scope.

This section establishes additional efficiency package options to achieve additional energy efficiency in accordance with Section R401.2.

R407.2. Additional efficiency package options.

Additional efficiency package options for compliance with Section R401.2 are set forth in Sections R407.2.1 through R407.2.5.

R407.2.1 Enhanced envelope performance option.

The total *building thermal envelope* UA, the sum of *U-factor* times assembly area, shall be less than or equal to 95 percent of the total UA resulting from multiplying the *U-factors* in Table 402.1.2. by the same assembly area as in the proposed building. The UA calculation shall be performed in accordance with Section R402.1.5. The area-weighted average SHGC of all glazed fenestration shall be less than or equal to 95 percent of the maximum glazed fenestration SHGC in Table 402.1.2.

R407.2.2 More efficient HVAC equipment performance option.

Heating and cooling equipment shall meet one of the following efficiencies:

Centrally Ducted Systems

1. Greater than or equal to 95 AFUE natural gas furnace and 15.2 SEER2 variable speedair conditioner.
2. Greater than or equal to 15.2 SEER2, 8.5 HSPF2 variable speed air source heat pump.
3. Greater than or equal to 3.5 COP ground source heat pump.

-

Ductless Systems

1. Single Zone: 16.9 SEER2, 8.5 HSPF2 variable speed air source heat pump.
2. Multi Zone: 16.9 SEER2, 8.5 HSPF2 variable speed air source heat pump (Non-Ducted Indoor Units).
3. Multi Zone: 15.2 SEER2, 8.5 HSPF2 variable speed air source heat pump (Ducted or Mixed Indoor Units)

R407.2.3. Reduced energy use in service water-heating options.

The hot water system shall meet one of the following efficiencies:

Greater than or equal to 82 EF fossil fuel service water-heating system.
Greater than or equal to 2.0 EF electric service water-heating system.
Greater than or equal to 0.4 solar fraction solar water-heating system.

R407.2.4 More efficient duct thermal distribution system option.

The thermal distribution system shall meet one of the following efficiencies:

1. 100 percent of ducts and air handles located entirely within the *building thermal envelope*.
2. 100 percent of ductless thermal distribution system or hydronic thermal distribution system located completely inside the *building thermal envelope*.
3. 100 percent of duct thermal distribution system located in *conditioned space* as defined by Section R403.4.

-

R407.2.5 Improved air sealing and efficient ventilation system option.

The measured air leakage rate shall be less than or equal to 3.0 ACH50, with either an Energy Recovery Ventilator (ERV) or Heat Recovery Ventilator (HRV) installed. Minimum HRV and ERV requirements, measured at the lowest tested net supply airflow, shall be greater or equal to 75 percent Sensible Recovery Efficiency (SRE), less than or equal to 1.1 cubic feet per minute per watt (0.03m^3/min/watt) and shall not use recirculation as a defrost strategy. In addition, the ERV shall be greater than or equal to 50 percent Latent Recovery/Moisture Transfer (LRMT).

Daikin Proposal for the Florida State Energy Code amendment

Daikin U.S. Corporation ("Daikin") hereby submits the following code change proposal in response to the development process of 2023 Florida Building Code, Energy Conservation, 8th Edition. Daikin U.S. Corporation is a subsidiary of Daikin Industries, Ltd., the world's largest air conditioning equipment manufacturer. The Daikin Group includes Daikin Applied Americas Inc., Daikin North America LLC., and Goodman Manufacturing Company, L.P.

I. Introduction

Buildings account for 40 percent of all US energy consumption and 24 percent of its greenhouse gas (GHG) emissions[1]. Out of those, 22 percent of the consumption and 12 percent of the emissions come from residential buildings[2]. Under the Biden Administration, the United States targets to reduce its GHG emission by 50-52 percent by 2030. To achieve the decarbonization goal, energy efficiency as well as building electrification will need to play a critical role.

Replacement of lower efficiency or carbon intensive HVAC equipment with heat pumps are an effective solution to drive energy efficiency and building electrification and thus building decarbonization. Within heat pumps, variable speed heat pumps have demonstrated superior energy performance over equivalent single and two-stage equipment. For instance, the United States Environmental Protection Agency (U.S. EPA) notes that variable speed equipment and modulating systems specifically provide additional customer comfort advantages by following load, provide further energy efficiency improvements, and provide unique advantages for demand response[3]. The benefits of variable speed equipment are most prevalent when it operates at part-load capacities (i.e., less than 100% capacity). When operating at part-load, it can be significantly more efficient. The efficiency of variable speed equipment increases significantly as its load reduces below 100%. This exceeds the performance of both single and two-stage equipment as load reduces. According to computer simulations, laboratory validated by the Electric Power Research Institute (EPRI), variable speed HVAC equipment reduces its cooling capacity by 25% it results in a 43% reduction in power consumption while for single-speed equipment it would yield only a 25% reduction in power consumption[4]. However, according to National Resource Defense Council (NRDC), "current test procedures do not adequately capture the impact of a variable [speed] unit's control logic, which can have a large

[1] Use of energy in explained - U.S. Energy Information Administration, https:/www.eia.gov/energyexplained/use-of-energy/

[2] Fast Facts on Transportation Greenhouse Gas Emissions | US EPA, https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions

[3] U.S. EPA, ENERGY STAR Residential Air Source Heat Pump and Central Air Conditioning Equipment Version 6.0 Discussion Guide dated August 3, 2018, https://www.energystar.gov/sites/default/files/

[4] HRAI and AHRI, Letter to U.S. EPA Regarding ENERGY STAR Residential Air Source Heat Pump and Central Air Conditioning Equipment Version 6.0 Discussion Guide dated September 21, 2018, https://www.energystar.gov/sites/default/files/AHRI_HRAI_Comments_CAC_ASHP_Discussion%20Guide_09%2021%202018.pdf

impact on efficiency[5]." Lastly, Daikin would like to point out that ductless systems can further improve energy performance of HVAC systems by allowing homeowners to turn off indoor units in unoccupied zones.

In Florida specifically, a large install base, as well as existing use case of electric resistance heaters closely correlates to the state winter peak demand issues. As of 2019, 31% of the total space heating equipment installed in the state's homes were electric resistance heaters (3,010,332 out of the 9,673,682). Heat pumps, typically installed with electric resistance heaters for emergency or supplemental use, account for 55% or 5,339,804 installed, and a large portion of the remainder primarily consists of combustion equipment such as furnaces and boilers (5% of total) including 464,154 gas furnaces. Based on the state's 2019 sales volume of electric resistance heaters (52,846), which represented approximately 10% of the state's residential space heating market and based on the equipment's 2024 sales volume projection (51,553), it will take 204 years for them to be eliminated from the market assuming a linear decline of the sales. Additionally, based on the state's 2019 sales volume of gas furnaces (20,185), which represented approximately 4% of the state's residential space heating market and based on the equipment's 2024 sales volume projection (14,204), it will take 17 years for them to be eliminated from the market assuming a linear decline of the sales[6]. To further boost the proportion of heat pumps, especially variable speed heat pumps including the ones in ductless configuration, effective and aggressive market transformation will be required. Daikin believes that building codes should play a critical role in accelerating the adoption of such technologies in the State of Florida.

Hereby, to execute the forementioned market transformation, Daikin would like to make the following code change proposals for the development process of 2023 Florida Building Code, Energy Conservation, 8th Edition:

II. Code Change Proposal to R403.1.3 Heat Pump Supplementary Heat

The use of electric resistance heaters as backup heating devices can significantly increase winter energy consumption, and air source heat pumps can effectively provide heating without such devices including the cold climate regions in the United States. Also, Daikin has observed that it's common for heat pumps to be installed with electric resistance heaters configured to operate in conditions where sufficient heating capacity is available from the heat pump alone. This results in reducing the operation hours of heat pumps and increasing the operation hours

[5] NRDC, NRDC Comments on ENERGY STAR Program Requirements for Air Source Heat Pump and Central Air Conditioner Equipment Version 6.0, Draft 1 dated May 23, 2019, https://www.energystar.gov/sites/default/files/NRDC%20Comments%20on%20CACASHP%20Draft%201%20V6.0.pdf

[6] Statistics Office

of electric heaters. Such setting of heat pump systems will fail to yield expected reduction of GHG emissions and result in higher energy consumption and longer peak demand events. Therefore, Daikin proposes to revise R403.1.2, which defines the use of electric resistance heaters as supplementary heat for heat pumps, to prevent such practice as following:

R403.1.3 Heat pump supplementary heat (Mandatory).

Heat pumps with supplementary electric resistance heaters shall have controls that~~,~~ ~~except during defrost, prevent supplemental heat operation when the capacity of the heat pump compressor can meet the heating load.~~ limit supplemental heat operation to only those times when one of the following applies:

1. The vapor compression cycle cannot provide the necessary heating energy to satisfy the thermostat setting.

2. The heat pump is operating in defrost mode.

3. The vapor compression cycle malfunctions.

4. The thermostat malfunctions.

III. Code Addition Proposal to Revise and Include the 2021 IECC R408 Additional Efficiency Package Options as R407

Daikin understands that the State of Florida is developing the 2023 building code referring to the 2021 International Energy Conservation Code (IECC). The 2021 IECC has implemented a new section, R408 Additional Efficiency Package Options, which defines five optional requirements to achieve additional energy efficiency: 1. Enhanced envelope performance option., 2. More efficient HVAC equipment performance option., 3. Reduced energy use in servicing water-heating option., 4. More efficient duct thermal distribution system option., and 5. Improved air sealing and efficient ventilation system option. Daikin requests that the 2023 version of the Florida Building Code, Energy Conservation reflects the change and incorporates the section as R407 to more effectively driving builders and users to optimize the energy performance of their homes.

As mentioned in our Introduction, Variable speed heat pumps provide superior energy performance over commonly used and equivalently rated single and two-stage equipment due to their higher efficiency attained during partial load operation. Also, ductless systems with variable speed compressors provide~~s~~ homeowners opportunities to further save energy consumption by turning off individual indoor units in unoccupied zones. Upon incorporating the new section, Daikin also proposes changes to Section R408.2.2 of the 2021 IECC and add the entire Section R408 of the code as Section R407 in the 2023 version of the state energy conservation code.

Section R407
ADDITIONAL EFFICIENCY PACKAGE OPTIONS

R407. 1. Scope.

This section establishes additional efficiency package options to achieve additional energy efficiency in accordance with Section R401.2.

R407.2. Additional efficiency package options.

Additional efficiency package options for compliance with Section R401.2 are set forth in Sections R407.2.1 through R407.2.5.

R407.2.1 Enhanced envelope performance option.

The total *building thermal envelope* UA, the sum of *U-factor* times assembly area, shall be less than or equal to 95 percent of the total UA resulting from multiplying the *U-factors* in Table 402.1.2. by the same assembly area as in the proposed building. The UA calculation shall be performed in accordance with Section R402.1.5. The area-weighted average SHGC of all glazed fenestration shall be less than or equal to 95 percent of the maximum glazed fenestration SHGC in Table 402.1.2.

R407.2.2 More efficient HVAC equipment performance option.

Heating and cooling equipment shall meet one of the following efficiencies:
Centrally Ducted Systems

1. Greater than or equal to 95 AFUE natural gas furnace and 15.2 SEER2 variable speed air conditioner.
2. Greater than or equal to 15.2 SEER2, 8.5 HSPF2 variable speed air source heat pump.
3. Greater than or equal to 3.5 COP ground source heat pump.

Ductless Systems

1. Single Zone: 16.9 SEER2, 8.5 HSPF2 variable speed air source heat pump.
2. Multi Zone: 16.9 SEER2, 8.5 HSPF2 variable speed air source heat pump (Non-Ducted Indoor Units).
3. Multi Zone: 15.2 SEER2, 8.5 HSPF2 variable speed air source heat pump (Ducted or Mixed Indoor Units)

R407.2.3. Reduced energy use in service water-heating options.

The hot water system shall meet one of the following efficiencies:

1. Greater than or equal to 82 EF fossil fuel service water-heating system.

2. Greater than or equal to 2.0 EF electric service water-heating system.
3. Greater than or equal to 0.4 solar fraction solar water-heating system.

R407.2.4 More efficient duct thermal distribution system option.

The thermal distribution system shall meet one of the following efficiencies:

1. 100 percent of ducts and air handles located entirely within the *building thermal envelope*.
2. 100 percent of ductless thermal distribution system or hydronic thermal distribution system located completely inside the *building thermal envelope*.
3. 100 percent of duct thermal distribution system located in *conditioned space* as defined by Section R403.4.

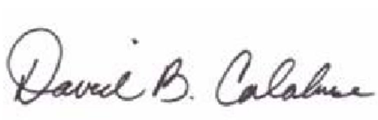
R407.2.5 Improved air sealing and efficient ventilation system option.

The measured air leakage rate shall be less than or equal to 3.0 ACH50, with either an Energy Recovery Ventilator (ERV) or Heat Recovery Ventilator (HRV) installed. Minimum HRV and ERV requirements, measured at the lowest tested net supply airflow, shall be greater or equal to 75 percent Sensible Recovery Efficiency (SRE), less than or equal to 1.1 cubic feet per minute per watt (0.03m^3/min/watt) and shall not use recirculation as a defrost strategy. In addition, the ERV shall be greater than or equal to 50 percent Latent Recovery/Moisture Transfer (LRMT).

IV. Conclusion

Daikin appreciates the opportunity to provide these comments. If you have any questions regarding this submission, please do not hesitate to contact me.

Sincerely,



David Calabrese

Senior Vice President, Government Affairs

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10331

65

Date Submitted	02/13/2022	**Section**	402.2.5	**Proponent**	Greg Johnson
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No

Alternate Language Yes

Related Modifications

Type IV mass timber modifications proposed for the building code.

Summary of Modification

Adds mass timber to the list of mass wall of mass materials and assemblies.

Rationale

See uploaded rationale

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact; just an addition to the list of qualifying materials/assemblies.

Impact to building and property owners relative to cost of compliance with code

No impact; just an addition to the list of qualifying materials/assemblies.

Impact to industry relative to the cost of compliance with code

No impact; just an addition to the list of qualifying materials/assemblies.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Provides for an energy efficient alternative method of compliance.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves the code by providing for an energy efficient alternative method of compliance.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

No material is required or prohibited by this modification.

Does not degrade the effectiveness of the code

Improves the code by providing for an energy efficient alternative method of compliance.

Alternate Language

1st Comment Period History

EN10331-A1

Proponent Jeff Sonne for FSEC **Submitted** 4/16/2022 2:09:57 PM **Attachments** Yes

Rationale:

There are numerous dimensions of logs and timbers so the criteria should be to consider as mass walls only those with a heat capacity of 6 Btu/ft2 F or greater.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None; clarification only.

Impact to building and property owners relative to cost of compliance with code

None; clarification only.

Impact to industry relative to the cost of compliance with code

None; clarification only.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes; clarifies code.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes; clarifies code.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

No; clarification only.

Does not degrade the effectiveness of the code

No; clarification only.

[Modify 10331 as follows]

R402.2.5 Mass walls.

Mass walls for the purposes of this chapter shall be considered above-grade walls of concrete block, concrete, insulated concrete form (ICF), masonry cavity, brick (other than brick veneer), earth (adobe, compressed earth block, rammed earth) and any solid timber/logs, mass timber, or ~~any~~ other walls having a heat capacity greater than or equal to 6 Btu/ft^2 · °F (123 kJ/m^2 · K).

R402.2.5 Mass walls.

Mass walls for the purposes of this chapter shall be considered above-grade walls of concrete block, concrete, insulated concrete form (ICF), masonry cavity, brick (other than brick veneer), earth (adobe, compressed earth block, rammed earth) and solid timber/logs, mass timber, or any other walls having a heat capacity greater than or equal to 6 $Btu/ft^2 \cdot °F$ (123 $kJ/m^2 \cdot K$).

RE402.2.5 Mass timber added to mass walls

The technical requirements for lightweight mass assemblies are in the commercial provisions of the IECC (C402.2.2) and ASHRAE 90.1. Both state that walls can be considered mass if they "have a heat capacity exceeding 5 Btu/ft F where the material weight is not more than 120 pcf." The following calculations demonstrate that typical mass timber walls and floors meet this requirement.

The heat capacity of mass timber is dominated by the wood. The Wood Handbook states that the heat capacity is "practically independent of density or species," and gives equation 4-17, which calculates the heat capacity based upon moisture content and temperature. Using a temperature of 75 °F and a moisture content of 12%, the heat capacity is calculated as 0.393 Btu/lb °F. This calculated value for wood corresponds well with tested values for CLT (KLH rates its CLT at 0.382 Btu/lb °F). The closeness of these values show that the glue has little effect upon the heat capacity.

The temperature of 75 degrees is given in 16 CFR Part 460, which regulates R-values for home insulation (https://www.ftc.gov/policy/federalregister-notices/16-cfr-part-460-labeling-advertising-home-insulation-trade-0).

A moisture content of 12% is the average given in PRG 320: Standard for Performance-Rated Cross-Laminated Timber. Cross-Laminated Timber (CLT) is a type of mass timber.

Unit conversion is needed for comparison with the requirements in the IECC and ASHRAE 90.1, so a density and wall thickness need to be assumed. PRG 320 says that the minimum specific gravity of wood used shall be 0.35. Typical lumber species used in CLT manufacture range in specific gravity from 0.35-0.55. Denser wood will give a higher heat capacity. Per the Wood Handbook, the density of wood with a specific gravity of 0.35 and a moisture content of 12% is 24.0 lb/ft . The density of wood with a specific gravity of 0.55 at 12% moisture content is 38.4 lb/ft .

A 5-ply CLT assembly will be assumed with a thickness given in PRG 320 as 6 7/8". A thinner assembly will likely have gypsum wallboard, which is denser and has a higher heat capacity than wood.

By combining the above assumptions with the calculated heat capacity, typical mass timber CLT walls are shown to have a heat capacity of 5.4-8.6 Btu/ft °F, which meet the requirement of the IECC and ASHRAE 90.1.

For floors, ASHRAE 90.1 has the same minimum heat capacity requirement as walls, so no further calculation is necessary, but the commercial IECC also requires a minimum weight of 25 psf where the material weight is 120 pcf or less. This requirement can be easily met by adding a concrete or gypcrete topping to the mass timber floor panel, which is common practice. Using the minimum CLT density and the same thickness as above, and assuming lightweight concrete topping of 90 pcf, 1.5 inches of concrete will meet the minimum weight requirement. Heavier concrete, denser wood species, or a thicker CLT panel will reduce the thickness of concrete topping needed to meet the weight requirement.

Bibliography: Forest Products Laboratory. Wood handbook - Wood as an engineering material. General Technical Report FPL-GTR-190. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory: 4-12 p.

2010 https://www.fpl.fs.fed.us/documnts/fplgtr/fpl_gtr190.pdf (accessed 02-13-2022)

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

66

EN10358

Date Submitted	02/15/2022	**Section**	402.5	**Proponent**	Laura Baker
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

This proposal updates the mandatory maximum fenestration Solar Heat Gain Coefficients (SHGC) permitted in the performance path consistent with improvements in prescriptive fenestration values.

Rationale

The purpose of this code change proposal is to update the mandatory maximum Solar Heat Gain Coefficients (SHGC) permitted in the performance path consistent with improvements in prescriptive fenestration values made since the maximums were originally included in the code. The fenestration maximums have been in the IECC since the 2006 IECC, and have provided a critical backstop in the event of trade-offs, helping to ensure reasonable energy efficiency and occupant comfort. Over the past 16 years and 5 code update cycles that these backstops have been in place, prescriptive fenestration efficiencies have improved substantially, but the maximum U-factors and SHGCs have never been updated. To maintain the effectiveness of these backstops, we recommend that they be updated. The current SHGC maximum allows builders to essentially double the amount of heat gain (0.25 to 0.50) before hitting the current cap. Improving the SHGC trade-off maximum from 0.50 to 0.40 as we propose above still leaves more trade-off room than was available to builders in 2006 when the cap was originally instituted. We believe that the improved fenestration maximums will be easily met. In fact, based on data collected by the U.S. Department of Energy regarding Residential Energy across 8 states, we expect little or no change in homebuilding practices or any impact on homebuilding costs. In climate zones 1-3, of the 477 homes sampled, over 98% already complied with the proposed SHGC maximum of 0.40. See https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.energycodes.gov%2Fsites%2Fdefault%2Ffiles%2F2019-09%2FPhase_I_Data_for_States_07192019.xlsx&wdOrigin=BROWSELINK Finally, this proposal was approved during the committee action hearings of the 2021 IECC code update process and didn't receive public comment, indicating that it was supported or not opposed by industry advocates.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposal will not fiscally impact any local entity relative to enforcement of code. Local officials are already enforcing the maximum weighted average complies; this merely updates the value.

Impact to building and property owners relative to cost of compliance with code

This proposal will either not affect or will provide energy cost savings for building and property owners from the improved SHGC backstop.

Impact to industry relative to the cost of compliance with code

Thos proposal will have no fiscal impact on industry. Because this is only a change to a trade-off backstop and not a code requirement and because such a high percentage of homebuilders are likely already meeting or exceeding this requirement, we expect no real cost impact in most cases.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposal will improve the health and safety of the general public by making a common sense incremental improvement to the code which will increase occupant comfort.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposal will improve the code by making an incremental improvement to the maximum area-weighted SHGC in the performance path. The prescriptive requirements have improved in the last few cycles, so this will follow those.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposal does not discriminate against materials or systems of construction; it is merely an update of the tradeoff maximum for area-weighted SHGC.

Does not degrade the effectiveness of the code

This proposal will not degrade the effectiveness of the code; it is an improvement to the code.

1st Comment Period History

EN10358-G1

Proponent	Timothy de Carion	Submitted	3/7/2022 1:41:09 PM	Attachments	No

Comment:

I agree with this proposal. Minimum values should be lowered to save energy.

1st Comment Period History

EN10358-G2

Proponent	Amanda Hickman	Submitted	4/14/2022 11:13:47 AM	Attachments	No

Comment:

LBA does not support the modification, as it is not appropriate for Florida and/or is not cost justified.

R405.5.3.4 Maximum fenestration SHGC.

The Proposed Design must have either an area-weighted average maximum fenestration SHGC of ~~0.50~~0.40 or a window area-weighted average overhang depth of 4.0 feet or greater (all conditioned space windows must be included in the calculation). The area-weighted average maximum fenestration *U*-factor permitted using tradeoffs from Section R402.1.5 or R405 shall be 0.48 in Climate Zones 4 and 5 and 0.40 in Climate Zones 6 through 8 for vertical fenestration, and 0.75 in Climate Zones 4 through 8 for skylights. The area-weighted average maximum fenestration SHGC permitted using tradeoffs from Section R405 in Climate Zones 1 through 3 shall be 0.40~~0.50~~.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

67

EN10370

Date Submitted	02/14/2022	**Section**	404	**Proponent**	John Hall
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

Summary of Modification

The proposed modification provides for infrastructure to accomodate future electric vehicle charging equipment in one- and two-family dwellings and townhouses with garages.

Rationale

Florida is ranked number two in the United States for the number of registered electric vehicle as of the latest ranking in June 2021. EVs provide significant economic benefits for consumers through fuel and maintenance cost savings, and have been identified as a key climate strategy to reduce GHG emissions from the U.S. transportation sector. The interest in EVs has grown alongside greater EV model availability and increased vehicle range. Every major auto manufacturer in the world has announced a plan to electrify a significant portion of their vehicle fleets over the next 3-5 years. Ford recently announced an $11 billion investment to reach their goal of 40 EV models by 2022. The goal for GM: 20 EV models by 2023; for VW: 27 EV models by 2022; for Toyota: 10 BEVs by the early 2020's; and similar goals for Volvo, Daimler, Nissan, BMW, and Fiat-Chrysler. However, the lack of access to EV charging stations continues to be a critical barrier to EV adoption. In particular, there are significant logistical barriers for commercial building tenants to upgrade existing electrical infrastructure and install new EV charging stations. A lack of pre-existing EV charging infrastructure, such as electrical panel capacity, raceways, and pre-wiring, can make the installation of a new charging station cost-prohibitive for a potential EV-owner. The installation of an EV charging equipment is made significantly less expensive when the infrastructure is installed during the initial construction phase as opposed to retrofitting existing homes to accommodate the new electrical equipment.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

There will be no cost impact relative to enforcement of the code due to this proposed modification. The inspection activity will be performed during already required inspections that are regularly scheduled.

Impact to building and property owners relative to cost of compliance with code

The cost impact to building and property owners for compliance with the proposed modification will be negligible. The modification seeks only the provision of a raceway and space in the electrical panel to facilitate the installation of EV charging equipment at a future date.

Impact to industry relative to the cost of compliance with code

The cost impact to industry will likewise be negligible due to the limited scope of the proposed modification. No installation of equipment, wiring, or outlet is required by the modification. Only an empty raceway and space in the electrical panel for the future circuit breaker is envisioned.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The proposed modification has a connection with the health, safety, and welfare of the general public through reduction of emissions from the use of fossil fuels and the economic savings of operating an electric vehicle versus the cost of operating fossil fuel powered vehicles.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The proposed modification improves the code by making provision for the implementation of better products and methods of powering transportation. Electrical vehicle use is increasing annually and these systems are crucial to further adoption of the technology.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

The proposed modification does not discriminate against any materials, products, methods, or systems of construction as none are specified. The modification simply provides for the easier implementation of the technology with no destructive effect to the structure.

Does not degrade the effectiveness of the code

The proposed modification does not degrade the effectiveness of the code. The implementation of the code is enhanced through the provision of simplified means of compliance for property owners desiring to operate electric vehicles.

Alternate Language

1st Comment Period History

EN10370-A1

Proponent Bryan Holland **Submitted** 3/28/2022 10:30:55 AM **Attachments** Yes

Rationale:

This alternative proposed modifications makes a few minor revisions to the original proposed modification. This includes a slight revision to the definition of "EVSE," the inclusion of "cable assemblies" in R404.2.3, and editorial revisions to 404.2.4 and 404.25 to provide technical clarity. Otherwise, NEMA fully supports the concept of EV-ready provisions in the FBC-EC as proposed and substantiated in the original proposed modification. NEMA urges the TAC(s) and Commission approve this proposed modification.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This alternative proposed modification provides clear and enforceable language for the AHJ.

Impact to building and property owners relative to cost of compliance with code

This alternative proposed modification will increase the cost compliance for building/property owners at time of initial construction while reducing the cost of compliance for an existing building that does not have the capacity or infrastructure in-place for the installation of EVSE.

Impact to industry relative to the cost of compliance with code

This alternative proposed modification will increase the cost of compliance for industry.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This alternative proposed modification improves the general welfare of the public as the electrification of transportation becomes a fundamental of modern society.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This alternative proposed modification improves the code.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This alternative proposed modification does not discriminate against materials, products, methods, or system of construction.

Does not degrade the effectiveness of the code

This alternative proposed modification improves the effectiveness of the code.

1st Comment Period History

EN10370-G1

Proponent John Hall Submitted 3/31/2022 10:33:59 AM Attachments No

Comment:

I support the alternate language comment submitted by Bryan Holland and endorse it's submission to the TAC(s) for consideration of inclusion in the 2023 FBC.

1st Comment Period History

Proponent Susannah Troner Submitted 4/12/2022 11:10:38 PM Attachments No

Comment:

Writing to express SUPPORT for proposed code modification EN 10370. Residential requirements for basic electrical panel capacity, raceways, and pre-wiring for new one- and two-family dwellings and townhouses with garages will help avoid extreme costs of retrofitting existing homes to install EVSE while having negligible cost impacts. Approximately 80% of EV owners prefer to charge at home as it is more convenient and electricity is cheaper at home compared to using fee-based public chargers that are limited in availability. Our office is responding to more and more inquiries every day from community members regarding EVSE. It is time to require these basic elements to help avoid EVSE scarcity and extreme costs. In addition, the transportation sector generates 55% of our community's carbon pollution and EVs greatly reduce this pollution, resulting in community health and safety benefits which are core objectives of the Florida Building Code.

1st Comment Period History

EN10370-G3

Proponent	kamrath christian	Submitted	4/13/2022 12:33:46 PM	Attachments	No

Comment:

I am writing to express support for proposed code modification EN 10370. We need to be continually adapt how we build to account for growing demand of EV charging in a convenient way. Residential requirements for basic electrical panel capacity, raceways, and pre-wiring for new one- and two-family dwellings and townhouses with garages will help avoid extreme costs of retrofitting existing homes to install EVSE while having negligible cost impacts. Approximately 80% of EV owners prefer to charge at home as it is more convenient and electricity is cheaper at home compared to using fee-based public chargers that are limited in availability. Our office is responding to more and more inquiries every day from community members regarding EVSE. It is time to require these basic elements to help avoid EVSE scarcity and extreme costs. In addition the transportation sector generates 55% of our community's carbon pollution and EVs greatly reduce this pollution, resulting in community health and safety benefits which are core objectives of the Florida Building Code.

1st Comment Period History

EN10370-G4

Proponent	Matthew Chen	Submitted	4/13/2022 4:35:14 PM	Attachments	No

Comment:

SemaConnect, a leading provider of electric vehicle charging solutions based in Bowie, Maryland with many projects in Florida, supports the alternate language comment submitted by Bryan Holland. We respectfully recommend it to the TAC(s) for consideration of inclusion in the 2023 Florida Building Code. Proposed code modification EN 10370 establishes modest but necessary EVSE residential requirements for new construction.

1st Comment Period History

EN10370-G5

Proponent	Nicholas Gunia	Submitted	4/14/2022 10:07:57 AM	Attachments	No

Comment:

As past Chair of the Miami Branch of the South Florida Chapter of the US Green Building Council, I am writing to voice my support for EN10370 for requiring new dwellings to have EVSE. I believe the proposed changes will help future proof our dwellings given the rise of EVs. As such, the proposed changes should be adopted.

1st Comment Period History

EN10370-G6

Proponent	Amanda Hickman	Submitted	4/14/2022 11:14:07 AM	Attachments	No

Comment:

LBA does not support the modification, as it is not appropriate for Florida and/or is not cost justified.

1st Comment Period History

EN10370-G7

Proponent Jeff Sonne for FSEC Submitted 4/14/2022 1:53:47 PM Attachments No

Comment:

FSEC supports Alternate Language Comment A1.

1st Comment Period History

EN10370-G8

Proponent Jared Walker Submitted 4/14/2022 2:23:47 PM Attachments No

Comment:

The Electrification Coalition (EC) is a national, nonpartisan, not-for-profit organization committed to promoting policies and actions that facilitate the deployment of electric vehicles on a mass scale to combat the national security, economic, and public health impacts associated with our nation's dependence on oil. The EC SUPPORTS proposed code modification EN 10370, establishing modest but necessary EVSE residential requirements for new construction. Many EV owners rely heavily on at-home charging for up to 80% of their charging needs. Not having access to such charging creates barriers to ownership for tenants. And while installing EV charging adds modest cost to projects, integrating charging into buildings during construction, rather than retro-fitting, has been found to save up to 80% in project costs.

1st Comment Period History

EN10370-G9

Proponent Estela Tost Submitted 4/14/2022 6:39:31 PM Attachments Yes

Comment:

I am in support of EN10370 for electric vehicle charging infrastructure to require design of one and two family dwellings to include future installation capabilities of electric vehicle supply equipment (EVSE)

1st Comment Period History

EN10370-G10

Proponent Richard Logan Submitted 4/15/2022 9:56:09 AM Attachments No

Comment:

AIA Florida supports this code modification with the alternate language

1st Comment Period History

EN10370-G11

Proponent James Ellis Submitted 4/15/2022 2:27:37 PM Attachments No

Comment:

EV Connect, a leading electric vehicle infrastructure network and services provider with many EVSE projects in Florida, SUPPORTS proposed code modification EN 10370, which establishes modest but necessary EVSE residential requirements for new construction. This proactive code increases construction costs slightly but has a significant positive savings over retrofit for EVSE for the life of the property.

1st Comment Period History

Proponent Sandra St. Hilaire Submitted 4/15/2022 2:43:56 PM Attachments No

Comment:

Writing to express support for proposed code modification EN 10370. Residential requirements for basic electrical panel capacity, raceways, and pre-wiring for new one- and two-family dwellings and townhouses with garages will help avoid extreme costs of retrofitting existing homes to install EVSE while having negligible cost impacts. Approximately 80% of EV owners prefer to charge at home as it is more convenient and electricity is cheaper at home compared to using fee-based public chargers that are limited in availability. Our office is responding to more and more inquiries every day from community members regarding EVSE. It is time to require these basic elements to help avoid EVSE scarcity and extreme costs. In addition the transportation sector generates 55% of our community’s carbon pollution and EVs greatly reduce this pollution, resulting in community health and safety benefits which are core objectives of the Florida Building Code.

1st Comment Period History

EN10370-G13

Proponent	Mike Gibaldi	Submitted	4/15/2022 4:41:26 PM	Attachments	No

Comment:

Our firm, Brickell Energy, with many EVSE projects throughout the State, fully SUPPORTS this proposed code modification, which establishes modest but necessary EVSE residential requirements for new construction. This will make it much easier for people to transition to safer, emission-free electric vehicles because the difficult retrofit costs will be avoided.

1st Comment Period History

EN10370-G14

Proponent	Chris Sanchez	Submitted	4/15/2022 5:11:01 PM	Attachments	No

Comment:

I am in favor of the proposed code modification for EN10370 Residential requirements for basic electrical panel capacity, raceways, and pre-wiring for new one- and two-family dwellings and townhouses with garages will help avoid extreme costs of retrofitting existing homes to install EVSE while having negligible cost impacts. Approximately 80% of EV owners prefer to charge at home as it is more convenient and electricity is cheaper at home compared to using fee-based public chargers that are limited in availability. Our office is responding to more and more inquiries every day from community members regarding EVSE. It is time to require these basic elements to help avoid EVSE scarcity and extreme costs. In addition the transportation sector generates 55% of our community’s carbon pollution and EVs greatly reduce this pollution, resulting in community health and safety benefits which are core objectives of the Florida Building Code.

1st Comment Period History

EN10370-G15

Proponent	Marta Marello	Submitted	4/17/2022 3:56:19 PM	Attachments	No

Comment:

I express support for proposed code modification EN 10370. Retrofitting existing homes to install EVSE is extremely costly while integrating residential requirements for basic electrical panel capacity, raceways, and pre-wiring for new one- and two-family dwellings and townhouses with garages is a much more cost-effective way to accommodate skyrocketing EV use. Approximately 80% of EV owners prefer to charge at home as it is more convenient and electricity is cheaper compared to using fee-based public chargers that are limited in availability. Miami-Dade County's Office of Resilience is spending significantly more time responding to inquiries every day from community members regarding EVSE. It is time to require these basic elements to help transition households into the future without adding to the cost. In addition the transportation sector is the number one contributor to community’s carbon pollution and EVs greatly reduce this pollution, resulting in community health and safety benefits which are core objectives of the Florida Building Code.

R404.2 Electric vehicle (EV) charging for new construction.

New construction shall comply with this Section to facilitate future installation of *electric vehicle supply equipment.*

R404.2.1 Definitions.

ELECTRIC VEHICLE (EV). An automotive-type vehicle for on-road use, such as passenger automobiles, buses, trucks, vans, neighborhood electric vehicles, electric motorcycles, and the like, primarily powered by an electric motor that draws current from a rechargeable storage battery, fuel cell, photovoltaic array, or other source of electric current. Plug-in hybrid electric vehicles (PHEV) are electric vehicles having a second source of motive power. Off-road, self-propelled electric mobile equipment, such as industrial trucks, hoists, lifts, transports, golf carts, airline ground support equipment, tractors, boats, and the like are not considered electric vehicles.

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE). Equipment for plug-in power transfer, including the ungrounded, grounded, and equipment grounding conductors, and the *electric vehicle* connectors, attachment plugs, personnel protection system, and all other fittings, devices, power outlets, or apparatus installed specifically for the purpose of transferring energy between the premises wiring and the electric vehicle.

EV CAPABLE SPACE. Electrical panel capacity and space to support a minimum 40-ampere, 240-volt branch circuit for each EV parking space, and the installation of raceways, both underground and surface mounted, to support the *EVSE*.

R404.2.2 New one- and two-family dwellings and *townhouses* with attached or detached private garages. For each dwelling unit with an attached or detached garage shall be designed with provision for future installation of *electric vehicle supply equipment* in accordance with Section R404.2.3, R404.2.4, and R404.2.5.

R404.2.3 Wiring Method.

A listed raceway of minimum trade size 1 or listed cable assembly with conductors having an ampacity not less than 40 amperes shall be installed to accommodate a branch circuit for *electric vehicle supply equipment*.

The raceway or cable assembly shall originate at properly rated electrical distribution equipment and terminate and outlet box, enclosure, or properly rated receptacle in close proximity to the proposed location of the *electric vehicle supply equipment*.

The raceway or cable assembly shall be continuous from the point of origin to the termination at the proposed location of the *electric vehicle supply equipment*.

The box or enclosure provided for future *electric vehicle supply equipment* shall be labeled “FOR EVSE USE”. The label shall comply with NFPA 70 Section 110.21(B).

R404.2.4 Service Capacity.

The electrical service shall be sized to accommodate a minimum 40-ampere, 240-volt branch (9,600 volt-amperes) circuit for *electric vehicle supply equipment*.

R404.2.5 Electrical distribution equipment capacity.

The electrical distribution equipment from which the *electric vehicle supply equipment* branch circuit originates shall be provided with adequate space for installation of a two-pole overcurrent protective device and have additional capacity not less than 40 amperes or 9,600 volt-amperes. The provided overcurrent device space(s) shall be identified on the circuit directory as "FOR EVSE USE".

SECTION R404

ELECTRICAL POWER AND LIGHTING SYSTEMS

R404.1 Lighting equipment (Mandatory).

Not less than 90 percent of the lamps in permanently installed luminaires shall have an efficacy of at least 45 lumens-per-watt or shall utilize lamps with an efficacy of not less or shall utilize lamps with an efficacy of not less than 65 lumens-per-watt.

R404.1.1 Lighting equipment (Mandatory).

Fuel gas lighting systems shall not have continuously burning pilot lights.

R404.2 Electric vehicle (EV) charging for new construction.

New construction shall comply with this Section to facilitate future installation of *electric vehicle supply equipment.*

R404.2.1 Definitions.

ELECTRIC VEHICLE (EV). An automotive-type vehicle for on-road use, such as passenger automobiles, buses, trucks, vans, neighborhood electric vehicles, electric motorcycles, and the like, primarily powered by an electric motor that draws current from a rechargeable storage battery, fuel cell, photovoltaic array, or other source of electric current. Plug-in hybrid electric vehicles (PHEV) are electric vehicles having a second source of motive power. Off-road, self-propelled electric mobile equipment, such as industrial trucks, hoists, lifts, transports, golf carts, airline ground support equipment, tractors, boats, and the like are not considered electric vehicles.

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE). The conductors, including the ungrounded, grounded, and equipment grounding conductors, and the *Electric Vehicle* connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatus installed specifically for the purpose of transferring energy between the premises wiring and the *Electric Vehicle*.

EV CAPABLE SPACE. Electrical panel capacity and space to support a minimum 40-ampere, 240-volt branch circuit for each EV parking space, and the installation of raceways, both underground and surface mounted, to support the *EVSE*.

R404.2.2 New one- and two-family dwellings and *townhouses* with attached or detached private garages. For each dwelling unit with an attached or detached garage shall be designed with provision for future installation of *electric vehicle supply equipment* in accordance with Section R404.2.3, R404.2.4, and R404.2.5.

R404.2.3 Raceway.

A listed raceway of minimum trade size 1 shall be installed to accommodate a branch circuit for *electric vehicle supply equipment.*

The raceway shall originate at the main electrical panel or a properly rated sub-panel, and terminate in a listed box or enclosure in close proximity to the proposed location of the *electric vehicle supply equipment.*

The raceway shall be continuous from the point of origin to the termination at the proposed location of the *electric vehicle supply equipment.*

The enclosure provided for future *electric vehicle supply equipment* shall be labeled “EV CAPABLE”. The label shall comply with NFPA 70 Section 110.21(B).

R404.2.4 Service Capacity.

The electrical service shall be sized to accommodate a minimum 40-ampere 240-volt branch circuit for *electric vehicle supply equipment.*

R404.2.5 Electrical panel capacity.

The electrical panel from which the electric vehicle supply equipment branch circuit originates shall be rated for, and be provided with open space for installation of a two-pole 40-ampere overcurrent protective device. The provided overcurrent device space(s) shall be identified in the panel circuit directory as “EV CAPABLE”.

Proposed Code Modifications
USER: Estela Tost

Proposed Code Modifications Menu > Modification Search > Modification List > Modification Detail > Submit a Comment > General Comment Detail

OFFICE OF THE SECRETARY

* Required fields

Modification #	EN10370-G9
Name	Estela Tost
Address	8500 SW 117 Avenue Suite 120
City	Miami
State	FL
Zip Code	33183
Email	estelat@baptisthealth.net
Primary Phone	(305) 903-9471
Alternate Phone	(786) 594-6913
Fax	
Code Change Cycle	2023 Triennial First Comment Period 03/03/2022 - 04/17/2022
Code Version	2023
Sub Code	Energy Conservation
Chapter & Topic	Chapter 4 - [RE] - Residential Energy Efficiency
Section	404
	-
Status	Pending DBPR Review

General Comment*

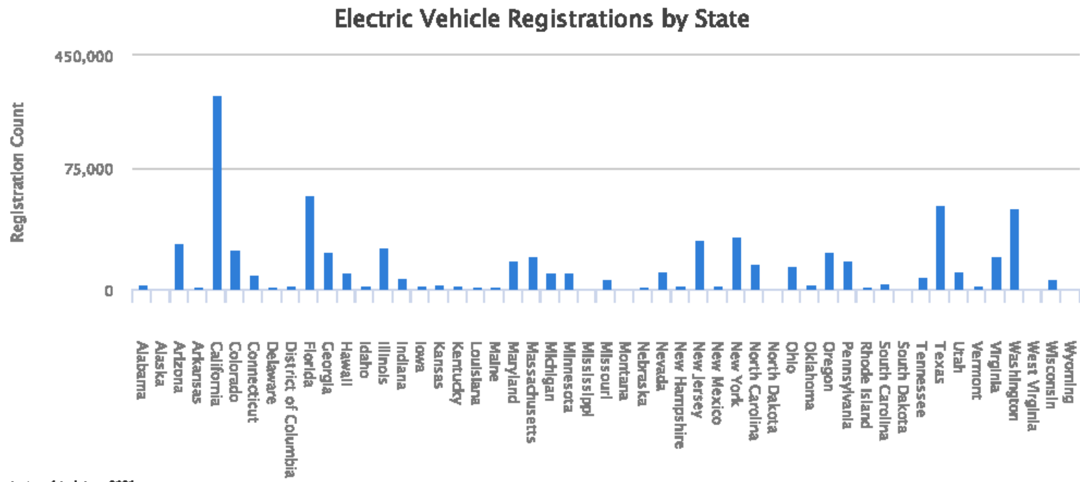
I am in support of EN10370 for electric vehicle charging infrastructure to require design of one and two family dwellings to include future installation capabilities of electric vehicle supply equipment (EVSE)

Upload Comment File

Date Submitted	04/14/2022

Cancel Submit View Original Modification

EN10370Rationale



Last updated: June 2021
Printed on: January 10

Page: 1

Mod_10370_Rationale_Electric Vehicle Registrations By State.pdf

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

68

EN10371

Date Submitted	02/15/2022	**Section**	406.2	**Proponent**	Laura Baker
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Update thermal envelope backstop for homes with on-site renewable energy from the 2015 to the 2018 IECC.

Rationale

The purpose of this proposal is to update the enhanced thermal envelope backstop for homes with on-site renewable energy from the 2015 to the 2018 IECC, maintaining the same approach as set in the 2018 IECC – specifically, using the prescriptive path from the previous code as a backstop in this situation. This backstop is crucial to use of the ERI with on-site renewable energy. We continue to be concerned about the potential magnitude of trade-off credit that may apply if on-site generation is included in the ERI calculation. Analyses have shown that homes can achieve a 20-40 HERS points reduction with average-sized solar PV systems, which would allow enormous trade-offs of the home's permanent envelope efficiency. See, e.g., RESNET, The Impact of Photovoltaic Arrays on the HERS Index (2015); and https://www.energycodes.gov/sites/default/files/documents/ECodes2016_06_Haack.pdf. Without reasonable limits on these solar trade-offs, homes with on-site generation could be built with far less efficiency, including substandard thermal envelopes, creating long-term problems for homeowners and reversing many of the benefits created by the IECC over the past 10 years.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposal will have no fiscal impact on the local entity relative to enforcement of the code. This proposal merely updates the thermal envelope backstop for buildings built under the ERI path with on-site renewables installed from the 2015 to the 2018 IECC.

Impact to building and property owners relative to cost of compliance with code

This proposal may decrease energy costs for building and property owners. Maintaining an improved thermal envelope will increase occupant comfort and decrease energy costs for the life of the building.

Impact to industry relative to the cost of compliance with code

This proposal will either have no fiscal impact or may slightly increase the cost of building properties under the ERI path where on-site renewables are installed, but only slightly because of the small improvements between the 2015 and 2018 IECC.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This will improve the thermal envelope backstop for homes built under the ERI path with on-site renewables, leading to improved occupant comfort and potentially improved air quality.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposal will strengthen the code by updating the thermal envelope backstop to the most recent edition of the IECC prior to the current one.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposal will not discriminate against materials or systems of construction; builders have significant flexibility in homes built under the ERI method, and this proposal would not prohibit those options.

Does not degrade the effectiveness of the code

This proposal will not degrade the effectiveness of the code; it will strengthen the code for homes built under the ERI with on-site renewable generation.

1st Comment Period History

EN10371-G1

Proponent	Amanda Hickman	Submitted	4/14/2022 11:14:25 AM	Attachments	No

Comment:

LBA does not support the modification, as it is not appropriate for Florida and/or is not cost justified.

1st Comment Period History

EN10371-G2

Proponent	Jeff Sonne for FSEC	Submitted	4/14/2022 3:40:30 PM	Attachments	No

Comment:

FSEC opposes this change. The ERI method is already the most stringent in Florida, and the 2018 IECC tables are not much different than the 2015 versions so no code change is needed here.

R406.2 Mandatory requirements.

Compliance with this section requires that the provisions identified in Sections R401 through R404 labeled as "mandatory" and Section R403.5.3 of the 2015 *International Energy Conservation Code* be met. For buildings that do not utilize on-site renewable power production for compliance with this section, the building thermal envelope shall be greater than or equal to levels of efficiency and Solar Heat Gain Coefficient in Table 402.1.1 or 402.1.3 of the 2009 *International Energy Conservation Code*. For buildings that utilize on-site renewable power production for compliance with this section, the building thermal envelope shall be greater than or equal to levels of efficiency and Solar Heat Gain Coefficient in Table R402.1.2 or Table R402.1.4 of the ~~2015~~2018 *International Energy Conservation Code*.

Exception: Supply and return ducts not completely inside the building thermal envelope shall be insulated to a minimum of R-6.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10398

69

Date Submitted	02/14/2022	**Section**	407	**Proponent**	Jeff Sonne for FSEC
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

10230

Summary of Modification

Additional energy efficiency requirements.

Rationale

See attached file.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None to slight impact to verify compliance.

Impact to building and property owners relative to cost of compliance with code

Will increase the cost of construction. However, for a given project one or more of these efficiency options should be cost effective. See cost effectiveness analyses and related on pgs. 28 – 31 of https://publications.energyresearch.ucf.edu/wp-content/uploads/2021/06/FSEC-CR-2112-21.pdf

Impact to industry relative to the cost of compliance with code

Will increase the cost of construction. However, for a given project one or more of these efficiency options should be cost effective. See cost effectiveness analyses and related on pgs. 28 – 31 of https://publications.energyresearch.ucf.edu/wp-content/uploads/2021/06/FSEC-CR-2112-21.pdf

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, benefits public by increasing energy efficiency while maintaining compliance flexibility.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves the code by increasing energy efficiency while maintaining compliance flexibility.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not discriminate; a range of efficiency improvements can be used to comply.

Does not degrade the effectiveness of the code

Improves code effectiveness by increasing energy efficiency while maintaining compliance flexibility.

Alternate Language

1st Comment Period History

EN10398-A5

Proponent Jeff Sonne for FSEC **Submitted** 4/16/2022 12:41:30 PM **Attachments** Yes

Rationale:

See attached.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Similar as original; none to small impact to verify compliance.

Impact to building and property owners relative to cost of compliance with code

Same as original. Will increase the cost of construction. However, for a given project one or more of these efficiency options should be cost effective. See cost effectiveness analyses on pgs. 28 – 31 of https://publications.energyresearch.ucf.edu/wp-content/uploads/2021/06/FSEC-CR-2112-21.pdf

Impact to industry relative to the cost of compliance with code

Same as original. Will increase the cost of construction. However, for a given project one or more of these efficiency options should be cost effective. See cost effectiveness analyses on pgs. 28 – 31 of https://publications.energyresearch.ucf.edu/wp-content/uploads/2021/06/FSEC-CR-2112-21.pdf

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Same as original; benefits public by increasing energy efficiency while maintaining compliance flexibility.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Same as original; improves the code by increasing energy efficiency while maintaining compliance flexibility.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Same as original; does not discriminate- a range of efficiency improvements can be used to comply.

Does not degrade the effectiveness of the code

Same as original; improves code effectiveness by increasing energy efficiency while maintaining compliance flexibility.

1st Comment Period History

EN10398-A4

Proponent Jeff Sonne for FSEC **Submitted** 4/16/2022 9:38:19 AM **Attachments** Yes

Rationale:

Same rational and credit calculation procedure as original mod. This alternative includes additional window credit options and further clarification. Also, AC and HP credits are revised and since we are not yet able to run simulations using the new SEER2 rating, this alternative assumes 15 SEER as being approximately equivalent to new minimum federal standard of 14.3 SEER2 and uses 15 SEER as the new base efficiency for these calculations (equivalency reference: https://seer2.com/region-southeast.html). We simulated current SEER 16 as future SEER2 of 15 as approximation to obtain credit shown.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Same as original; none to slight impact to verify compliance.

Impact to building and property owners relative to cost of compliance with code

Same as original. Will increase the cost of construction. However, for a given project one or more of these efficiency options should be cost effective. See cost effectiveness analyses on pgs. 28 – 31 of https://publications.energyresearch.ucf.edu/wp-content/uploads/2021/06/FSEC-CR-2112-21.pdf

Impact to industry relative to the cost of compliance with code

Same as original. Will increase the cost of construction. However, for a given project one or more of these efficiency options should be cost effective. See cost effectiveness analyses on pgs. 28 – 31 of https://publications.energyresearch.ucf.edu/wp-content/uploads/2021/06/FSEC-CR-2112-21.pdf

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Same as original; benefits public by increasing energy efficiency while maintaining compliance flexibility.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Same as original; improves the code by increasing energy efficiency while maintaining compliance flexibility.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Same as original; does not discriminate- a range of efficiency improvements can be used to comply.

Does not degrade the effectiveness of the code

Same as original; improves code effectiveness by increasing energy efficiency while maintaining compliance flexibility.

1st Comment Period History

EN10398-A2

Proponent Shawn Mullins **Submitted** 3/31/2022 2:00:53 PM **Attachments** Yes

Rationale:

Florida has struggled to adopt an appropriate version of buried ducts due to moisture concerns. This assembly has been shown to adequately address moisture while also allowing for HVAC performance similar to having ducts inside conditioned space. Having this additional option will provide builders and designers with an additional choice to meet energy efficiency goals, while also reducing the negative impact on trades and already strained labor resources.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Consistent with existing proposal

Impact to building and property owners relative to cost of compliance with code

Consistent with existing proposal

Impact to industry relative to the cost of compliance with code

Consistent with existing proposal

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Consistent with existing proposal

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Consistent with existing proposal

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Consistent with existing proposal

Does not degrade the effectiveness of the code

Consistent with existing proposal

1st Comment Period History

Proponent Amanda Hickman Submitted 4/14/2022 11:14:43 AM Attachments No

Comment:

LBA does not support the modification, as it is not appropriate for Florida and/or is not cost justified.

See attached.

Starting from original mod 10398, revise Table R407.2 and footnotes as follows and add two new related sections:

R401.2 Compliance. Projects shall comply with one of the following:

1. Sections R401 through R404 and Section R407.
2. Section R405, Section R407 and the provisions of Sections R401 through R404 labeled "Mandatory."
3. An energy rating index (ERI) approach in Section R406.

Add new text as follows:

SECTION R407
ADDITIONAL ENERGY EFFICIENCY REQUIREMENTS

R407.1 Scope. This section establishes options for additional criteria to be met for one- and two-family dwellings and townhouses, as defined in Section 101.2 of the *Florida Building Code, Residential* to demonstrate compliance with this code.

Exception: These requirements shall not apply to:

1. Townhouses and one- and two-family dwellings complying under the Energy Rating Index (R406)
2. Alterations, renovations and repairs to an existing building
3. Additions with a conditioned floor area of less than 600 square feet.

R407.2 Requirements in order to comply with this code:

1. Buildings utilizing the Section R402.1.3 *R*-value computation prescriptive path to comply with this code shall also comply with sufficient energy efficiency options from Table R407.2 in order to achieve a minimum of 5 energy credits.
2. Buildings utilizing the Section R402.1.4 *U*-factor alternative or Section R402.1.5 Total UA alternative prescriptive path to comply with this code shall also comply with sufficient energy efficiency options from Categories 5 -12 only in Table R407.2 in order to achieve a minimum of 5 energy credits.
3. Buildings utilizing the Section R405 simulated performance alternative path to comply with this code under Section R405.3 shall have *proposed design* annual total normalized Modified Loads less than or equal to 95 percent of the annual total loads of the *standard reference design*.

Table R407.2
ENERGY EFFICIENCY MEASURES

			Climate Zone	
			1	2
CATEGORY[a]	OPT	DESCRIPTION[b]	CREDITS[c,d]	
1	a	Attic Insulation R-38[e]	0.5	-
1	b	Attic Insulation R-49[e]	1.0	1.0
1	c	Attic Insulation R-60[e]	1.5	1.5
2	a	Wall Insulation (16 o.c.) R-15[e]	0.5	0.5
2	b	Wall Insulation (16 o.c.) R-13+3[e]	1.5	2.0
2	c	Wall Insulation (16 o.c.) R-20[e]	2.0	3.0
2	d	Wall Insulation (16 o.c.) R-13+5[e]	2.0	3.0
2	e	Wall Insulation (16 o.c.) R-23 BIB[e]	2.5	4.0
2	f	Wall Insulation (16 o.c.) R-13+10[e]	3.5	5.0
2	g	Wall Insulation (16 o.c.) R-20+5[e]	3.5	5.0
2	h	Wall Insulation (24 o.c.) R-20[e]	2.0	3.5
2	i	Wall Insulation (24 o.c.) R-23 BIB[e]	2.5	4.0
2	j	Wall Insulation (24 o.c.) R-20+5[e]	3.5	5.0
3	a	Mass Wall R-6 c.i.[e,f]	3.0	1.0
3	b	Mass Wall (16 o.c.) R-13[e]	6.0	4.5
3	c	Mass Wall (16 o.c.) R-20[e]	7.5	6.5
3	d	Mass Wall R-12 c.i.[e,f]	6.5	5.5
4	a	Windows U-0.32, SHGC-0.25[g]	~~0.0~~ -	0.5
4	b	Windows U-0.32, SHGC-0.23[g]	1.0	2.0
4	c	Windows U-0.32, SHGC-0.20[g]	2.5	3.0
5	a	Building Tightness- 5 ACH50[h]	2.0	2.5
5	b	Building Tightness- 2 ACH50[h,i]	5.0	6.5
6	a	Ducts in Attic: Reduced Leakage ≤2cfm/100sq.ft.@25Pa[h,k]	3.5	3.5
6	b	Compact Layout: duct surface area ≤15% of conditioned floor area for supply ducts and ≤4% for return ducts	1.0	1.0
6	c	Compact Layout + Reduced Leakage	4.5	5.0
6	d	Ducts 100% Inside Conditioned Space or Ductless	6.5	7.5
6	e	Ducts in Code Minimum Insulated Vented Attic + R-14 Insulation at Roof Deck	5.0	6.0
6	f	Deeply buried and reduced leakage ducts at ≤4cfm/100 sq.ft.@25Pa in sealed attic with diffusion ports; insulation and ducts at ceiling/attic floor[h,k,m]	2.5	3.5
6	g	Deeply buried and reduced leakage ducts at ≤2cfm/100 sq.ft.@25Pa in sealed attic with diffusion ports; insulation and ducts at ceiling/attic floor[h,k,m]	6.5	7.0
7	a	Radiant Barrier- Roof Deck[l]	3.5	4.0
8	a	Furnace or Boiler- 92 AFUE, ECM[j]	0.5	2.0

8	b	Furnace or Boiler- 95 AFUE, ECM[j]	0.5	2.5
8	c	Furnace or Boiler- 96 AFUE, ECM[j]	0.5	2.5
8	d	Furnace or Boiler- 97 AFUE, ECM[j]	0.5	2.5
9	a	Air Conditioner 15 SEER2[j]	~~1.5~~ 3.5	~~1.5~~ 2.5
9	b	Air Conditioner 16 SEER2[j]	~~5.0~~ 6.5	~~4.0~~ 5.0
~~9~~	~~c~~	~~Air Conditioner 18 SEER2[j]~~	~~11.0~~	~~8.5~~
10	a	Heat Pump 15 SEER2 / ~~8.5~~ 7.7 HSPF2[j]	~~2.0~~ 3.5	~~1.5~~ 3.0
10	b	Heat Pump 16 SEER2 / ~~9~~ 8.2 HSPF2[j]	~~5.5~~ 7.0	~~4.5~~ 6.0
~~10~~	~~c~~	~~Heat Pump 18 SEER2 / 10 HSPF2[j]~~	~~11.5~~	~~10~~
11	a	Energy Star Gas WH, 40 gal, high draw, 0.68 UEF/0.69 EF[j]	2.0	2.5
11	b	Energy Star Gas WH, 50 gal, high draw, 0.68 UEF/0.69 EF[j]	3.0	3.0
11	c	Gas instantaneous WH, 0.81 UEF/EF[j]	7.0	7.5
~~11~~	~~d~~	~~Energy Star Gas instantaneous WH, 0.87 UEF/EF[j]~~	~~9.0~~	~~9.0~~
~~11~~	~~e~~	~~High Eff Gas instantaneous WH, 0.9 UEF/EF[j]~~	~~9.5~~	~~10.0~~
11	f	Energy Star elec heat pump WH, 50 gal, 2.0 UEF/1.82 EF[j]	13.5	16.0
~~11~~	~~g~~	~~High Eff elec. heat pump WH, 50 gal, 3.1 UEF/3.2 EF[j]~~	~~17.0~~	~~21.0~~
12	a	>=95% LED Lighting: interior, exterior, and garage	1.0	1.0

a. Category 1 – 4 efficiency options shall not be used for Section R402.1.4 U-factor alternative or Section R402.1.5 Total UA alternative compliance.

b. Only one item in each Category can be counted.

c. Cells containing a dash (-), indicate zero credits because that measure is the baseline requirement or was not shown to improve energy savings.

d. For any measure where the installed efficiency value falls between two thresholds from the table, credit shall only be taken for the threshold that the installed value meets or exceeds.

e. *R*-values are minimums.

f. c.i. = continuous insulation on exterior of mass wall.

g. *U*-factors and SHGC are maximum weighted averages.

h. Building tightness and duct tightness are maximums.

i. Where the air infiltration rate of a *dwelling unit* is less than 3.00 air changes per hour where tested with a blower door at a pressure of 0.2 inch w.c. (50 Pa) in accordance with Section R402.4.1.2, the *dwelling unit* shall be provided with whole-house mechanical ventilation in accordance with *Florida Building Code, Residential*, or *Florida Building Code, Mechanical*.

j. AFUE, SEER2, HSPF2, UEF, and EF are minimums.

k. Measured duct leakage is outside conditioned space.

l. Radiant Barriers shall comply with Section R405.7.1 and shall be installed over the entire roof deck over conditioned space.

m. Deeply buried ducts in sealed attic with diffusion ports and insulation and ducts at ceiling/attic floor shall be in accordance with Section R403.3.7.

[Also add new sections as follows:]

[Chapter 2 Definitions]

VAPOR DIFFUSION PORT. An assembly constructed or installed within a roof assembly at an opening in the roof deck to convey water vapor from an unvented attic to the outside atmosphere.

R403.3 Ducts.

Ducts and air handlers shall be in accordance with Sections R403.3.1 through R403.3.7~~5~~.

R403.3.7 Ducts buried within ceiling insulation (Mandatory).

Where attic supply and return ducts are buried in ceiling insulation, such duct installations shall comply with all of the following:

1. The attic shall be unvented with air-permeable insulation installed on the top of the attic floor or on top of the ceiling and an *approved vapor diffusion port* installed in accordance with Item 5.2 of Section R806.5 of the *Florida Building Code, Residential.*
2. The supply and return ducts shall have an insulation *R*-value not less than R-8.
3. At all points along each duct, the sum of the ceiling insulation *R*-value against and above the top of the duct, and against and below the bottom of the duct, shall be not less than R-19, excluding the *R*-value of the duct insulation.
4. The supply ducts shall be completely buried within ceiling insulation and in compliance with the vapor retarder requirements of Section 604.11 of the *Florida Building Code, Mechanical* or Section M1601.4.6 of the *Florida Building Code, Residential*, as applicable.

    Exception: Sections of the supply duct that are less than 3 feet (914mm) from the supply outlet shall not be required to comply with these requirements.

R403.3.7.1 Effective *R*-value of deeply buried ducts.

Where using the Simulated Performance Alternative compliance option in accordance with Section R401.2 Item #2, sections of ducts that are installed in accordance with Section R403.3.7, located directly on or within 5.5 inches (140 mm) of the ceiling, surrounded with air-permeable attic insulation having an *R*-value of R-30 or greater and located such that the top of the duct is not less than 3.5 inches (89 mm) below the top of the insulation, shall be considered as having an effective duct insulation *R*-value of R-25.

See attached file.

Starting from original mod 10398 text, revise as follows (only changes in this alt. language A4 mod from the original mod are in Table R407.2-- two additional window credit options, mass wall "c.i." clarification footnote, revised AC and HP credits, and re-lettering of footnotes):

R401.2 Compliance. Projects shall comply with one of the following:

1. Sections R401 through R404 and Section R407.
2. Section R405, Section R407 and the provisions of Sections R401 through R404 labeled "Mandatory."
3. An energy rating index (ERI) approach in Section R406.

Add new text as follows:

SECTION R407
ADDITIONAL ENERGY EFFICIENCY REQUIREMENTS

R407.1 Scope. This section establishes options for additional criteria to be met for one- and two-family dwellings and townhouses, as defined in Section 101.2 of the *Florida Building Code, Residential* to demonstrate compliance with this code.

Exception: These requirements shall not apply to:

1. Townhouses and one- and two-family dwellings complying under the Energy Rating Index (R406)
2. Alterations, renovations and repairs to an existing building
3. Additions with a conditioned floor area of less than 600 square feet.

R407.2 Requirements in order to comply with this code:

1. Buildings utilizing the Section R402.1.3 *R*-value computation prescriptive path to comply with this code shall also comply with sufficient energy efficiency options from Table R407.2 in order to achieve a minimum of 5 energy credits.
2. Buildings utilizing the Section R402.1.4 *U*-factor alternative or Section R402.1.5 Total UA alternative prescriptive path to comply with this code shall also comply with sufficient energy efficiency options from Categories 5 -12 only in Table R407.2 in order to achieve a minimum of 5 energy credits.
3. Buildings utilizing the Section R405 simulated performance alternative path to comply with this code under Section R405.3 shall have *proposed design* annual total normalized Modified Loads less than or equal to 95 percent of the annual total loads of the *standard reference design*.

EN10398-A4Text Modification

Mod_10398_A4_Text_Additional Efficiency 10398 Alt Language w Additional Window Options and Revised SEER2 HSPF2 Credits Text.pdf

Table R407.2
ENERGY EFFICIENCY MEASURES

			Climate Zone	
			1	2
CATEGORY[a]	OPT	DESCRIPTION[b]	CREDITS[c,d]	
1	a	Attic Insulation R-38[e]	0.5	-
1	b	Attic Insulation R-49[e]	1.0	1.0
1	c	Attic Insulation R-60[e]	1.5	1.5
2	a	Wall Insulation (16 o.c.) R-15[e]	0.5	0.5
2	b	Wall Insulation (16 o.c.) R-13+3[e]	1.5	2.0
2	c	Wall Insulation (16 o.c.) R-20[e]	2.0	3.0
2	d	Wall Insulation (16 o.c.) R-13+5[e]	2.0	3.0
2	e	Wall Insulation (16 o.c.) R-23 BIB[e]	2.5	4.0
2	f	Wall Insulation (16 o.c.) R-13+10[e]	3.5	5.0
2	g	Wall Insulation (16 o.c.) R-20+5[e]	3.5	5.0
2	h	Wall Insulation (24 o.c.) R-20[e]	2.0	3.5
2	i	Wall Insulation (24 o.c.) R-23 BIB[e]	2.5	4.0
2	j	Wall Insulation (24 o.c.) R-20+5[e]	3.5	5.0
3	a	Mass Wall R-6 c.i.[e,f]	3.0	1.0
3	b	Mass Wall (16 o.c.) R-13[e]	6.0	4.5
3	c	Mass Wall (16 o.c.) R-20[e]	7.5	6.5
3	d	Mass Wall R-12 c.i.[e,f]	6.5	5.5
4	a	Windows U-0.32, SHGC-0.25[g]	~~0.0~~ -	0.5
4	b	Windows U-0.32, SHGC-0.23[g]	1.0	2.0
4	c	Windows U-0.32, SHGC-0.20[g]	2.5	3.0
5	a	Building Tightness- 5 ACH50[h]	2.0	2.5
5	b	Building Tightness- 2 ACH50[h,i]	5.0	6.5
6	a	Ducts in Attic: Reduced Leakage ≤2cfm/100@25[h,k]	3.5	3.5
6	b	Compact Layout: duct surface area ≤15% of conditioned floor area for supply ducts and ≤4% for return ducts	1.0	1.0
6	c	Compact Layout + Reduced Leakage	4.5	5.0
6	d	Ducts 100% Inside Conditioned Space or Ductless	6.5	7.5
6	e	Ducts in Code Minimum Insulated Vented Attic + R-14 Insulation at Roof Deck	5.0	6.0
7	a	Radiant Barrier- Roof Deck[l]	3.5	4.0
8	a	Furnace or Boiler- 92 AFUE, ECM[j]	0.5	2.0
8	b	Furnace or Boiler- 95 AFUE, ECM[j]	0.5	2.5
8	c	Furnace or Boiler- 96 AFUE, ECM[j]	0.5	2.5
8	d	Furnace or Boiler- 97 AFUE, ECM[j]	0.5	2.5
9	a	Air Conditioner 15 SEER2[j]	~~1.5~~ 3.5	~~1.5~~ 2.5
9	b	Air Conditioner 16 SEER2[j]	~~5.0~~ 6.5	~~4.0~~ 5.0
~~9~~	~~c~~	~~Air Conditioner 18 SEER2[j]~~	~~11.0~~	~~8.5~~

10	a	Heat Pump 15 SEER2 / ~~8.5~~ 7.7 HSPF2[j]	~~2.0~~ 3.5	~~1.5~~ 3.0
10	b	Heat Pump 16 SEER2 / ~~9~~ 8.2 HSPF2[j]	~~5.5~~ 7.0	~~4.5~~ 6.0
~~10~~	~~c~~	~~Heat Pump 18 SEER2 / 10 HSPF2[j]~~	~~11.5~~	~~10~~
11	a	Energy Star Gas WH, 40 gal, high draw, 0.68 UEF/0.69 EF[j]	2.0	2.5
11	b	Energy Star Gas WH, 50 gal, high draw, 0.68 UEF/0.69 EF[j]	3.0	3.0
11	c	Gas instantaneous WH, 0.81 UEF/EF[j]	7.0	7.5
11	d	Energy Star Gas instantaneous WH, 0.87 UEF/EF[j]	9.0	9.0
11	e	High Eff Gas instantaneous WH, 0.9 UEF/EF[j]	9.5	10.0
11	f	Energy Star elec heat pump WH, 50 gal, 2.0 UEF/1.82 EF[j]	13.5	16.0
11	g	High Eff elec. heat pump WH, 50 gal, 3.1 UEF/3.2 EF[j]	17.0	21.0
12	a	>=95% LED Lighting: interior, exterior, and garage	1.0	1.0

a. Category 1 – 4 efficiency options shall not be used for Section R402.1.4 U-factor alternative or Section R402.1.5 Total UA alternative compliance.

b. Only one item in each Category can be counted.

c. Cells containing a dash (-), indicate zero credits because that measure is the baseline requirement or was not shown to improve energy savings.

d. For any measure where the installed efficiency value falls between two thresholds from the table, credit shall only be taken for the threshold that the installed value meets or exceeds.

e. *R*-values are minimums.

f. c.i. = continuous insulation on exterior of mass wall.

g. *U*-factors and SHGC are maximum weighted averages.

h. Building tightness and duct tightness are maximums.

i. Where the air infiltration rate of a *dwelling unit* is less than 3.00 air changes per hour where tested with a blower door at a pressure of 0.2 inch w.c. (50 Pa) in accordance with Section R402.4.1.2, the *dwelling unit* shall be provided with whole-house mechanical ventilation in accordance with *Florida Building Code, Residential*, or *Florida Building Code, Mechanical*.

j. AFUE, SEER2, HSPF2, UEF, and EF are minimums.

k. Measured leakage is outside conditioned space.

l. Radiant Barriers shall comply with Section R405.7.1 and shall be installed over the entire roof deck over conditioned space.

Revise Table R407.2 ashighlighted:

_TableR407.2

ENERGYEFFICIENCYMEASURES

			Climate Zone	
			1	2
CATEGORY[k]	OPT	DESCRIPTION[a]	CREDITS[g,h]	
1	a	AtticInsulationR-38b	0.5	-
1	b	AtticInsulationR-49b	1.0	1.0
1	c	AtticInsulationR-60b	1.5	1.5
2	a	WallInsulation(16o.c.)R-15b	0.5	0.5
2	b	WallInsulation(16o.c.)R-13+3b	1.5	2.0
2	c	WallInsulation(16o.c.)R-20b	2.0	3.0
2	d	WallInsulation(16o.c.)R-13+5b	2.0	3.0
2	e	WallInsulation(16o.c.)R-23BIBb	2.5	4.0
2	f	WallInsulation(16o.c.)R-13+10b	3.5	5.0
2	g	WallInsulation(16o.c.)R-20+5	3.5	5.0
2	h	WallInsulation(24o.c.)R-20b	2.0	3.5
2	i	WallInsulation(24o.c.)R-23BIBb	2.5	4.0
2	j	WallInsulation(24o.c.)R-20+5b	3.5	5.0
3	a	MassWallR-6c.i.b	3.0	1.0
3	b	MassWall(16o.c.)R-13b	6.0	4.5
3	c	MassWall(16o.c.)R-20b	7.5	6.5
3	d	MassWallR-12 c.i.b	6.5	5.5
4	a	WindowsU-0.32,SHGC-0.25c	0.0	0.5
5	a	BuildingTightness-5ACH50d	2.0	2.5
5	b	BuildingTightness-2ACH50d,e	5.0	6.5
6	a	DuctsinAttic:ReducedLeakage=2cfm/100@25d,i	3.5	3.5
6	b	Compact Layout: duct surface area =15% of conditionedfloorareaforsupplyductsand=4%for return ducts	1.0	1.0
6	c	CompactLayout+ReducedLeakage	4.5	5.0
6	d	Ducts100%InsideConditionedSpaceorDuctless	6.5	7.5
6	e	DuctsinCodeMinimumInsulatedVentedAttic+R- 14 Insulation at Roof Deck	5.0	6.0
6	F	Deeply buried and tightly sealed ducts in sealed attic with diffusion ports; insulation and ducts at ceiling/attic floor	6.5	7.5
7	a	RadiantBarrier-RoofDeckj	3.5	4.0
8	a	FurnaceorBoiler-92AFUE,ECMf	0.5	2.0
8	b	FurnaceorBoiler-95AFUE,ECMf	0.5	2.5
8	c	FurnaceorBoiler-96AFUE,ECMf	0.5	2.5
8	d	FurnaceorBoiler-97AFUE,ECMf	0.5	2.5

9	a	AirConditioner15SEER2f	1.5	1.5
9	b	AirConditioner16SEER2f	5.0	4.0
9	c	AirConditioner18SEER2f	11.0	8.5
10	a	HeatPump15SEER2/8.5 HSPF2f	2.0	1.5
10	b	HeatPump16SEER2/9 HSPF2f	5.5	4.5
10	c	HeatPump18SEER2/10 HSPF2f	11.5	10
11	a	EnergyStarGasWH,40gal,highdraw, 0.68 UEF/0.69EFf	2.0	2.5
11	b	EnergyStarGasWH,50gal,highdraw, 0.68 UEF/0.69EFf	3.0	3.0
11	c	GasinstantaneousWH,0.81UEF/EFf	7.0	7.5
11	d	EnergyStarGasinstantaneousWH,0.87UEF/EFf	9.0	9.0
11	e	HighEffGasinstantaneousWH,0.9UEF/EFf	9.5	10.0
11	f	EnergyStarelecheatpumpWH,50gal, 2.0 UEF/1.82EFf	13.5	16.0
11	g	HighEffelecheatpumpWH,50gal,3.1UEF/3.2 EFf	17.0	21.0
12	a	>=95%LEDLighting:interior,exterior,andgarage	1.0	1.0

Revise as follows:

R401.2 Compliance. Projects shall comply with one of the following:

1. Sections R401 through R404 and Section R407.
2. Section R405, Section R407 and the provisions of Sections R401 through R404 labeled "Mandatory."
3. An energy rating index (ERI) approach in Section R406.

Add new text as follows:

SECTION R407
ADDITIONAL ENERGY EFFICIENCY REQUIREMENTS

R407.1 Scope. This section establishes options for additional criteria to be met for one- and two-family dwellings and townhouses, as defined in Section 101.2 of the *Florida Building Code, Residential* to demonstrate compliance with this code.

Exception: These requirements shall not apply to:

1. Townhouses and one- and two-family dwellings complying under the Energy Rating Index (R406)
2. Alterations, renovations and repairs to an existing building
3. Additions with a conditioned floor area of less than 600 square feet.

R407.2 Requirements in order to comply with this code:

1. Buildings utilizing the Section R402.1.3 *R*-value computation prescriptive path to comply with this code shall also comply with sufficient energy efficiency options from Table R407.2 in order to achieve a minimum of 5 energy credits.

2. Buildings utilizing the Section R402.1.4 *U*-factor alternative or Section R402.1.5 Total UA alternative prescriptive path to comply with this code shall also comply with sufficient energy efficiency options from Categories 5 -12 only in Table R407.2 in order to achieve a minimum of 5 energy credits.

3. Buildings utilizing the Section R405 simulated performance alternative path to comply with this code under Section R405.3 shall have *proposed design* annual total normalized Modified Loads less than or equal to 95 percent of the annual total loads of the *standard reference design.*

TableR407.2
ENERGY EFFICIENCY MEASURES

			Climate Zone	
			1	2
CATEGORY[k]	OPT	DESCRIPTION[a]	CREDITS[g,h]	
1	a	Attic InsulationR-38[b]	0.5	-
1	b	Attic InsulationR-49[b]	1.0	1.0
1	c	Attic InsulationR-60[b]	1.5	1.5
2	a	Wall Insulation(16o.c.)R-15[b]	0.5	0.5
2	b	Wall Insulation(16o.c.)R-13+3[b]	1.5	2.0
2	c	Wall Insulation(16o.c.)R-20[b]	2.0	3.0
2	d	Wall Insulation(16o.c.)R-13+5[b]	2.0	3.0
2	e	Wall Insulation(16o.c.)R-23BIB[b]	2.5	4.0
2	f	Wall Insulation(16o.c.)R-13+10[b]	3.5	5.0
2	g	Wall Insulation(16o.c.)R-20+5	3.5	5.0
2	h	Wall Insulation(24o.c.)R-20[b]	2.0	3.5
2	i	Wall Insulation (24 o.c.) R-23 BIB[b]	2.5	4.0
2	j	Wall Insulation (24 o.c.) R-20+5[b]	3.5	5.0
3	a	Mass Wall R-6 c.i.[b]	3.0	1.0
3	b	Mass Wall (16 o.c.) R-13[b]	6.0	4.5
3	c	Mass Wall (16 o.c.) R-20[b]	7.5	6.5
3	d	Mass Wall R-12 c.i.[b]	6.5	5.5
4	a	Windows U-0.32, SHGC-0.25[c]	0.0	0.5
5	a	Building Tightness- 5 ACH50[d]	2.0	2.5
5	b	Building Tightness- 2 ACH50[d, e]	5.0	6.5
6	a	Ducts in Attic: Reduced Leakage =2cfm/100@25[d, i]	3.5	3.5
6	b	Compact Layout: duct surface area =15% of conditioned floor area for supply ducts and =4% for return ducts	1.0	1.0
6	c	Compact Layout + Reduced Leakage	4.5	5.0
6	d	Ducts 100% Inside Conditioned Space or Ductless	6.5	7.5
6	e	Ducts in Code Minimum Insulated Vented Attic + R-14 Insulation at Roof Deck	5.0	6.0
7	a	Radiant Barrier- Roof Deck[j]	3.5	4.0
8	a	Furnace or Boiler- 92 AFUE, ECM[f]	0.5	2.0
8	b	Furnace or Boiler- 95 AFUE, ECM[f]	0.5	2.5
8	c	Furnace or Boiler- 96 AFUE, ECM[f]	0.5	2.5
8	d	Furnace or Boiler- 97 AFUE, ECM[f]	0.5	2.5
9	a	Air Conditioner 15 SEER2[f]	1.5	1.5
9	b	Air Conditioner 16 SEER2[f]	5.0	4.0
9	c	Air Conditioner 18 SEER2[f]	11.0	8.5
10	a	Heat Pump 15 SEER2 / 8.5 HSPF2[f]	2.0	1.5
10	b	Heat Pump 16 SEER2 / 9 HSPF2[f]	5.5	4.5
10	c	Heat Pump 18 SEER2 / 10 HSPF2[f]	11.5	10
11	a	Energy Star Gas WH, 40 gal, high draw, 0.68 UEF/0.69 EF[f]	2.0	2.5
11	b	Energy Star Gas WH, 50 gal, high draw, 0.68 UEF/0.69 EF[f]	3.0	3.0
11	c	Gas instantaneous WH, 0.81 UEF/EF[f]	7.0	7.5
11	d	Energy Star Gas instantaneous WH, 0.87 UEF/EF[f]	9.0	9.0
11	e	High Eff Gas instantaneous WH, 0.9 UEF/EF[f]	9.5	10.0

11	f	Energy Star elec heat pump WH, 50 gal, 2.0 UEF/1.82 EF[f]	13.5	16.0
11	g	High Eff elec heat pump WH, 50 gal, 3.1 UEF/3.2 EF[f]	17.0	21.0
12	a	>=95% LED Lighting: interior, exterior, and garage	1.0	1.0

a. Only one item in each Category can be counted.

b. *R*-values are minimums.

c. *U*-factors and SHGC are maximum weighted averages.

d. Building tightness and duct tightness are maximums.

e. Where the air infiltration rate of a *dwelling unit* is less than 3.00 air changes per hour where tested with a blower door at a pressure of 0.2 inch w.c. (50 Pa) in accordance with Section R402.4.1.2, the *dwelling unit* shall be provided with whole-house mechanical ventilation in accordance with *Florida Building Code, Residential*, or *Florida Building Code, Mechanical*.

f. AFUE, SEER2, HSPF2, UEF, and EF are minimums.

g. Cells containing a dash (-), indicate zero credits because that measure is the baseline requirement or was not shown to improve energy savings.

h. For any measure where the installed efficiency value falls between two thresholds from the table, credit shall only be taken for the threshold that the installed value meets or exceeds.

i. Measured leakage is outside conditioned space.

j. Radiant Barriers shall comply with Section R405.7.1 and shall be installed over the entire roof deck over conditioned space.

k. Category 1 – 4 efficiency options shall not be used for Section R402.1.4 *U*-factor alternative or Section R402.1.5 Total UA alternative compliance.

Revise as follows:

R401.2 Compliance. Projects shall comply with one of the following:

1. Sections R401 through R404 and Section R407.
2. Section R405, Section R407 and the provisions of Sections R401 through R404 labeled "Mandatory."
3. An energy rating index (ERI) approach in Section R406.

Add new text as follows:

SECTION R407
ADDITIONAL ENERGY EFFICIENCY REQUIREMENTS

R407.1 Scope. This section establishes options for additional criteria to be met for one- and two-family dwellings and townhouses, as defined in Section 101.2 of the *Florida Building Code, Residential* to demonstrate compliance with this code.

Exception: These requirements shall not apply to:
1. Townhouses and one- and two-family dwellings complying under the Energy Rating Index (R406)
2. Alterations, renovations and repairs to an existing building
3. Additions with a conditioned floor area of less than 600 square feet.

R407.2 Requirements in order to comply with this code:

1. Buildings utilizing the Section R402.1.3 *R*-value computation prescriptive path to comply with this code shall also comply with sufficient energy efficiency options from Table R407.2 in order to achieve a minimum of 5 energy credits.
2. Buildings utilizing the Section R402.1.4 *U*-factor alternative or Section R402.1.5 Total UA alternative prescriptive path to comply with this code shall also comply with sufficient energy efficiency options from Categories 5 -12 only in Table R407.2 in order to achieve a minimum of 5 energy credits.
3. Buildings utilizing the Section R405 simulated performance alternative path to comply with this code under Section R405.3 shall have *proposed design* annual total normalized Modified Loads less than or equal to 95 percent of the annual total loads of the *standard reference design*.

Table R407.2
ENERGY EFFICIENCY MEASURES

			Climate Zone	
			1	2
CATEGORY[k]	OPT	DESCRIPTION[a]	CREDITS[g,h]	
1	a	Attic Insulation R-38[b]	0.5	-
1	b	Attic Insulation R-49[b]	1.0	1.0
1	c	Attic Insulation R-60[b]	1.5	1.5
2	a	Wall Insulation (16 o.c.) R-15[b]	0.5	0.5
2	b	Wall Insulation (16 o.c.) R-13+3[b]	1.5	2.0
2	c	Wall Insulation (16 o.c.) R-20[b]	2.0	3.0
2	d	Wall Insulation (16 o.c.) R-13+5[b]	2.0	3.0
2	e	Wall Insulation (16 o.c.) R-23 BIB[b]	2.5	4.0
2	f	Wall Insulation (16 o.c.) R-13+10[b]	3.5	5.0
2	g	Wall Insulation (16 o.c.) R-20+5	3.5	5.0
2	h	Wall Insulation (24 o.c.) R-20[b]	2.0	3.5
2	i	Wall Insulation (24 o.c.) R-23 BIB[b]	2.5	4.0
2	j	Wall Insulation (24 o.c.) R-20+5[b]	3.5	5.0
3	a	Mass Wall R-6 c.i.[b]	3.0	1.0
3	b	Mass Wall (16 o.c.) R-13[b]	6.0	4.5
3	c	Mass Wall (16 o.c.) R-20[b]	7.5	6.5
3	d	Mass Wall R-12 c.i.[b]	6.5	5.5
4	a	Windows U-0.32, SHGC-0.25[c]	0.0	0.5
5	a	Building Tightness- 5 ACH50[d]	2.0	2.5
5	b	Building Tightness- 2 ACH50[d, e]	5.0	6.5
6	a	Ducts in Attic: Reduced Leakage ≤2cfm/100@25[d, i]	3.5	3.5
6	b	Compact Layout: duct surface area ≤15% of conditioned floor area for supply ducts and ≤4% for return ducts	1.0	1.0
6	c	Compact Layout + Reduced Leakage	4.5	5.0
6	d	Ducts 100% Inside Conditioned Space or Ductless	6.5	7.5
6	e	Ducts in Code Minimum Insulated Vented Attic + R-14 Insulation at Roof Deck	5.0	6.0
7	a	Radiant Barrier- Roof Deck[j]	3.5	4.0
8	a	Furnace or Boiler- 92 AFUE, ECM[f]	0.5	2.0
8	b	Furnace or Boiler- 95 AFUE, ECM[f]	0.5	2.5
8	c	Furnace or Boiler- 96 AFUE, ECM[f]	0.5	2.5
8	d	Furnace or Boiler- 97 AFUE, ECM[f]	0.5	2.5
9	a	Air Conditioner 15 SEER2[f]	1.5	1.5
9	b	Air Conditioner 16 SEER2[f]	5.0	4.0
9	c	Air Conditioner 18 SEER2[f]	11.0	8.5
10	a	Heat Pump 15 SEER2 / 8.5 HSPF2[f]	2.0	1.5
10	b	Heat Pump 16 SEER2 / 9 HSPF2[f]	5.5	4.5
10	c	Heat Pump 18 SEER2 / 10 HSPF2[f]	11.5	10

11	a	Energy Star Gas WH, 40 gal, high draw, 0.68 UEF/0.69 EF[f]	2.0	2.5
11	b	Energy Star Gas WH, 50 gal, high draw, 0.68 UEF/0.69 EF[f]	3.0	3.0
11	c	Gas instantaneous WH, 0.81 UEF/EF[f]	7.0	7.5
11	d	Energy Star Gas instantaneous WH, 0.87 UEF/EF[f]	9.0	9.0
11	e	High Eff Gas instantaneous WH, 0.9 UEF/EF[f]	9.5	10.0
11	f	Energy Star elec heat pump WH, 50 gal, 2.0 UEF/1.82 EF[f]	13.5	16.0
11	g	High Eff elec heat pump WH, 50 gal, 3.1 UEF/3.2 EF[f]	17.0	21.0
12	a	>=95% LED Lighting: interior, exterior, and garage	1.0	1.0

a. Only one item in each Category can be counted.

b. *R*-values are minimums.

c. *U*-factors and SHGC are maximum weighted averages.

d. Building tightness and duct tightness are maximums.

e. Where the air infiltration rate of a *dwelling unit* is less than 3.00 air changes per hour where tested with a blower door at a pressure of 0.2 inch w.c. (50 Pa) in accordance with Section R402.4.1.2, the *dwelling unit* shall be provided with whole-house mechanical ventilation in accordance with *Florida Building Code, Residential*, or *Florida Building Code, Mechanical*.

f. AFUE, SEER2, HSPF2, UEF, and EF are minimums.

g. Cells containing a dash (-), indicate zero credits because that measure is the baseline requirement or was not shown to improve energy savings.

h. For any measure where the installed efficiency value falls between two thresholds from the table, credit shall only be taken for the threshold that the installed value meets or exceeds.

i. Measured leakage is outside conditioned space.

j. Radiant Barriers shall comply with Section R405.7.1 and shall be installed over the entire roof deck over conditioned space.

k. Category 1 – 4 efficiency options shall not be used for Section R402.1.4 *U*-factor alternative or Section R402.1.5 Total UA alternative compliance.

Rationale: Same overall rational and credit calculation procedure as original mod 10398. This alternative mod includes the following:

- Further clarification and re-lettering of footnotes.
- The same additional window credit options as submitted with Alternative Language Comment A4.
- AC and HP credits are revised as in Alterative Language Comment A4. As noted in the A4 mod reason, since we are not yet able to run simulations using the new SEER2 rating, this alternative assumes 15 SEER as being approximately equivalent to new minimum federal standard of 14.3 SEER2 and uses 15 SEER as the new base efficiency for these calculations (equivalency reference: https://seer2.com/region-southeast.html). We simulated current SEER 16 as future SEER2 of 15 as approximation to obtain credit shown.
- Similar buried duct Table R407.2 credit entries as provided in alternative language mod A2 plus two new code sections to provide further buried duct compliance details. The buried duct credits and related new code sections provide a cost effective duct installation and insulation option for the Florida climate. Research is currently underway to verify that insulation buried R-8 ducts in unvented attics with vapor diffusion ports and insulation only on the attic floor (top of ceiling) will perform well in Florida. Verification results will be available before the close of the second comment period in August 2022, and will be provided for public and Energy TAC review via a comment submitted at that time. If any changes to the mod are needed based on these results, they will also be made during the second comment period.
- New Section R403.3.7.1 *Effective R-value of deeply buried ducts* provides appropriate performance compliance duct insulation credit for ducts buried in insulation per new Section R403.3.7. Same credit is already included in the 2021 IECC.
- Table R407.2 credits 9c, 10c, 11d, 11e, and 11g are removed since lower efficiency options of same equipment type already meet the 5 credit requirement.

This proposal introduces a new section within the code that will require additional efficiency measures (options) for residential buildings which will better allow Florida code to keep up with stringency increases in the 2021 IECC. When taking the prescriptive approach, options from the table with assigned credit values must be selected in order to achieve 5 credits. For the performance approach, the annual total normalized Modified Loads of the *proposed design* are reduced to 95% of the annual total loads of the *standard reference design*. The ERI path has not been included in this proposal as it is currently the most stringent path in the code. The proposal allows a wide range of improvements, providing flexibility for each compliance path.

The prescriptive energy efficiency measures listed in Table 407.2 were determined as follows:

- Annual simulations were run in EnergyGauge USA for base code Miami (representing CZ1) and Tampa (representing CZ2) prescriptive projects and the cooling, heating, and water heating use was summed for each (with lighting use added for the LED credit option).

- The base energy use was divided by 100 to determine 1% savings.

- Annual simulations were then run for each of the credit options. For ceiling insulation and radiant barrier credit options both single- and two-story projects were run.

- The differences in energy use between the base and credit option runs were determined and divided by the 1% savings use to determine credits for each option, with the credit values truncated to the nearest 0.5.

The energy performance target of 5% (or 5 credits) represents an incremental level of improvement that can be achieved through one or more compliance options (individual measures or a combination of measures). For a given project one or more of these efficiency options should be cost effective. See cost effectiveness analyses and related discussion on pages 28 – 31 of https://publications.energyresearch.ucf.edu/wp-content/uploads/2021/06/FSEC-CR-2112-21.pdf

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10453

70

Date Submitted	02/15/2022	**Section**	403.3.3	**Proponent**	Eric Lacey
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes | **Alternate Language No**

Related Modifications

Summary of Modification

This proposal improves building efficiency and conditioning system operation by requiring duct testing in all compliance paths.

Rationale

This proposal will help ensure consistent energy efficiency performance across all new homes, whether constructed to the prescriptive, performance, or ERI paths, by requiring duct leakage testing for homes built to the performance path. See attached file for supporting information.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposal should have no negative impacts on local entities enforcing the codes. It will provide additional verification that the building complies with the code.

Impact to building and property owners relative to cost of compliance with code

For buildings that would have been exempt from a duct test requirement, we expect the increase in cost to be between $200-300 per home for a duct tightness test. This cost will be rapidly repaid by improved performance and lower likelihood of builder callback.

Impact to industry relative to the cost of compliance with code

There will be some increased cost of compliance for homes that would have been exempt, but duct testing is well-established in Florida and is already required in the prescriptive and ERI paths.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Duct testing will improve building occupant comfort and will reduce energy use, which will benefit the general public by reducing peak loads and related emissions.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposal applies the same level of verification of duct tightness across all compliance paths, improving the consistency of the code and improving the performance of buildings.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposal does not discriminate against any materials or methods.

Does not degrade the effectiveness of the code

This proposal will substantially improve the effectiveness of the code.

1st Comment Period History

EN10453-G1

Proponent	Timothy de Carion	Submitted	3/28/2022 11:11:05 AM	Attachments	No

Comment:

I agree with this code modification. This is a minimum IECC requirement that is already mandated in other states. Duct leakage is a great waste of energy. I personally have found homes with ducts not attached to boots. Gross errors will be identified.

1st Comment Period History

EN10453-G2

Proponent	Amanda Hickman	Submitted	4/14/2022 11:15:01 AM	Attachments	No

Comment:

LBA does not support the modification, as it is not appropriate for Florida and/or is not cost justified.

R403.3.3 Duct testing (Mandatory).

Ducts shall be pressure tested to determine air leakage by one of the following methods:

Rough-in test: Total leakage shall be measured with a pressure differential of 0.1 inch w.g. (25 Pa) across the system, including the manufacturer's air handler enclosure if installed at the time of the test. All registers shall be taped or otherwise sealed during the test.

Postconstruction test: Total leakage shall be measured with a pressure differential of 0.1 inch w.g. (25 Pa) across the entire system, including the manufacturer's air handler enclosure. Registers shall be taped or otherwise sealed during the test.

Exceptions:

1. A duct air leakage test shall not be required where the ducts and air handlers are located entirely within the building thermal envelope.
2. ~~Duct testing is not mandatory for buildings complying by Section R405 of this code.~~ Duct leakage testing is required for Section R405 compliance~~ where credit is taken for leakage~~, and a duct air leakage Q_n to the outside of less than 0.080 (where Q_n = duct leakage to the outside in cfm per 100 square feet of conditioned floor area tested at 25 Pascals) is indicated in the compliance report for the *proposed design*.

A written report of the results of the test shall be signed by the party conducting the test and provided to the *code official*.

Proposal to Eliminate Performance Path Exception to Duct Leakage Test

This proposal improves building energy efficiency and provides an important consumer safeguard by requiring duct leakage testing in homes built to the performance path. Currently, the Florida Building Code requires a duct leakage test for homes built to both the prescriptive path and the Energy Rating Index, but section R403.3.3 exempts homes built to the performance path from this requirement. This exception is not part of any edition of the IECC, and it does not appear in any other state code. It is also inconsistent with the whole concept of the performance path being based upon the actual performance of the building systems. We recommend deleting the exception so that all new homes – regardless of compliance path – will be required to comply with the duct testing requirements in Section R403.3.

Duct leakage rates can be extremely high when ducts are not tested, and the impacts on occupants can be staggering. Without an objective test as a means of quality assurance, even careful builders may not be aware of missed connections or poor sealing. In a recent DOE field study of residential homes in Kentucky, the duct leakage rate of systems not required to be tested was significantly higher than that of systems required to be tested. Tested duct leakage for homes that would have been exempt from testing averaged 18.5 cfm/sq.ft., with individual homes ranging from 6.26 cfm/sq.ft. to as high as 40.36 cfm/sq.ft. *See* https://www.energycodes.gov/compliance/energy-code-field-studies. However, the other homes in the same study that were required to be tested (because at least some ducts were located outside conditioned space) achieved leakage rates of 9.7 cfm/sq.ft., on average – roughly half the leakage rate of homes that qualified for the exemption. Obviously, this is a small sample size, but the Field Studies found similar results in Pennsylvania, where "exempt" homes (with all ducts inside conditioned space) averaged almost 31 cfm/sq.ft. leakage, while homes required to be tested averaged almost 18 cfm/sq.ft. leakage.

When conditioned air is leaking into the attic or even into unintended locations within the building, the occupants are not comfortable, which can lead to adjustments in the thermostat. A single degree difference in cooling in climate zone 2 can lead to a 5.3% (on average) increase in energy costs for the homeowner. Because the performance path allows substantial trading among the efficiency features of a building, it is critical that the actual performance of these systems be measured. Otherwise, homeowners may be paying significantly more for energy costs than anticipated.

The benefits to homeowners of tested, reduced-leakage ducts are well-documented. Every edition of the IECC since the 2009 edition has required duct leakage testing for new homes and the tightness requirement has improved over time. This proposal does not change the overall requirement for duct testing in Florida, nor does it eliminate the exception for ducts located entirely within conditioned space. It simply requires the same level of tightness and testing in the performance path that already applies to the prescriptive and ERI paths.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

71

EN10503

Date Submitted	02/15/2022	**Section**	405.4.2	**Proponent**	Eric Lacey
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

This proposal adopts the fenestration area assumption used in the IECC since the 2012 edition; it will simplify compliance and enforcement by eliminating a set of assumptions that are currently only used in Florida.

Rationale

See the attached reason statement.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposal will simplify enforcement by making performance path assumptions consistent with the model residential energy code, the IECC.

Impact to building and property owners relative to cost of compliance with code

We do not expect a significant change in the cost of compliance.

Impact to industry relative to the cost of compliance with code

We do not expect any impact on industry.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposal will simplify code compliance and will lead to more uniform enforcement of the energy code.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposal will make the Florida Building Code performance path assumptions for fenestration area consistent with the IECC and with essentially every other state that applies the IECC performance path.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposal does not discriminate against any products, methods, or systems of construction.

Does not degrade the effectiveness of the code

This proposal will improve the effectiveness of the code by simplifying it and making it more consistent with standard assumptions for glazing area in performance path calculations.

1st Comment Period History

EN10503-G1

Proponent	Jennifer Hatfield	Submitted	4/15/2022 11:02:34 AM	Attachments	No

Comment:

FGIA (formerly AAMA) supports this proposed modification. We initially attempted to put the current Florida language that had amended the standard reference design assumptions for fenestration into the 2021 edition of the IECC. However, after further reflection we withdrew that proposal as it encroaches on vertical fenestration and confuses the code user. Further, the current approach in Florida does not work with the performance software. The level of complication is not justified and what this proposal attempts to do, by reverting back and aligning with the IECC language is the right thing to do.

TABLE R405.4.2(1)
SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS

BUILDING COMPONENT	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Vertical fenestration other than opaque doors	Vertical fenestration area[h] = (a) The proposed glazing area, where the proposed glazing area is less than 15 percent of the conditioned floor area. (b) 15 percent of the conditioned floor area, where the proposed glazing area is 15 percent or more of the conditioned floor area. ~~The proposed vertical fenestration area (AVF), where the proposed total fenestration area (AF) is less than 15 percent of the conditioned floor area, (CFA) or~~ ~~The adjusted vertical fenestration area (AVF_{adj}), where (AF) is 15 percent or more of CFA. AVF_{adj} shall be calculated as follows:~~ ~~$AVF_{adj} = AVF * 0.15 * CFA/AF$~~	As proposed
	Orientation: equally distributed to four cardinal compass orientations (N, E, S & W).	As proposed
	U-factor: as specified for Fenestration in Table R402.1.4.	As proposed
	SHGC: as specified for Glazed Fenestration in Table R402.1.2 except that for climate zones with no requirement (NR) SHGC = 0.40 shall be used.	As proposed
	Interior shade fraction: 0.92 – (0.21 x SHGC for the standard reference design).	As proposed
	External shading: none	As proposed
Skylights	None ~~Skylight area[h] =~~ ~~The proposed skylight area (ASKY), where the proposed total fenestration area (AF) is less than 15 percent of the conditioned floor area (CFA), or~~ ~~The adjusted skylight area ($ASKY_{adj}$), where AF is 15 percent or more of CFA. $ASKY_{adj}$ shall be calculated as follows:~~ ~~$ASKY_{adj} = ASKY * 0.15 * CFA/AF$~~	As proposed
	~~Orientation: as proposed~~	~~As proposed~~

	~~U-factor: as specified for Skylights in Table R402.1.4~~	~~As proposed~~
	~~SHGC: as specified by the exception in footnote (b) of Table R402.1.2, except that for climate zones with no requirement (NR) SHGC = 0.40 shall be used~~	~~As proposed~~
	~~Interior shade fraction for the area of proposed skylights equipped and rated with factory-installed interior shades, the interior shade fraction is: 0.92 – (0.21 x SHGC)~~ ~~[SHGC as above for the standard reference design]~~	~~As proposed~~
	~~External shading: none~~	~~As proposed~~

RECA – Fenestration Area in Performance Path

Reason Statement

This proposal will simplify code compliance and reduce confusion by applying the same performance path assumptions for vertical fenestration and skylights used in the 2012, 2015, 2018, and 2021 IECC. Florida is the only state that has amended the standard reference design assumptions for fenestration in this way; this approach has also been rejected in the national model code development process. Using the more standard approach to fenestration area in the performance path will make code compliance more straightforward for code users who regularly use compliance software based on the model codes.

Florida's current performance path requires code users to apply a series of calculations based on vertical fenestration and skylights in order to determine the baseline for fenestration efficiency trade-offs; the IECC approach is much more straightforward to calculate – 15% for buildings with ≥15% vertical glazing or the proposed glazing area percentage for buildings with <15% vertical fenestration area. Skylights can also be incorporated into the proposed design, but will be incorporated into the overall energy use of the building, rather than being set against a skylight-specific area assumption.

Because both Florida's fenestration assumptions and the IECC's fenestration assumptions are based on a "floating" 15%, we do not expect meaningful impacts on costs; however, we believe that this will make code compliance and enforcement far more straightforward and predictable.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10510

72

Date Submitted	02/15/2022	**Section**	405.5.2	**Proponent**	Eric Lacey
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

This proposal improves the efficiency of the code by eliminating an unnecessary and wasteful loophole.

Rationale

Please see attached Reason Statement.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No significant impact on local entities.

Impact to building and property owners relative to cost of compliance with code

Building owners will see long-term energy and cost savings as a result of closing this loophole.

Impact to industry relative to the cost of compliance with code

Code users who currently take advantage of these trade-offs in the performance path will no longer be able to use these trade-offs to reduce the efficiency of other building components and will need to find other means of demonstrating compliance.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposal will improve overall efficiency in buildings and will reduce the negative impacts of high peak energy demands and associated emissions.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposal will improve Florida's building code and make it more consistent with the model residential energy code.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This proposal does not discriminate against materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

This proposal substantially improves the effectiveness of the code by eliminating an unnecessary and large loophole.

1st Comment Period History

EN10510-G1

Proponent	Amanda Hickman	Submitted	4/14/2022 11:15:37 AM	Attachments	No

Comment:

LBA does not support the modification, as it is not appropriate for Florida and/or is not cost justified.

1st Comment Period History

EN10510-G2

Proponent	Jeff Sonne for FSEC	Submitted	4/14/2022 3:20:52 PM	Attachments	No

Comment:

FSEC opposes this mod as historically the Florida Energy Code has had the performance compliance reference design equipment efficiencies "non-floating" which offers builders the option to find the most cost effective means of meeting the code while still meeting all mandatory requirements. While the newer ERI compliance method also allows equipment trade-offs, the mandatory requirements for Florida climate and maximum allowed Index usually mean a project already has to pass code by one of the other methods. Thus the performance method is the only method whereby builders can choose the most cost effective option. This mod would also remove reference to Std. 301 from the service water heating calculation; Std. 301 provides a more accurate means of assessing water heating loads.

Table R405.5.2(1) SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS

BUILDING COMPONENT	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Heating systems [d, e]	For other than electric heating without a heat pump: as proposed. Where the proposed design utilizes electric heating without a heat pump, the standard reference design shall be an air source heat pump meeting the requirements of Section C403 of the IECC-Commercial Provisions ~~Type: heat pump if proposed heating system is electric; otherwise as proposed~~ ~~Efficiency: in accordance with prevailing federal minimum standards~~ Capacity: sized in accordance with section R403.7 ~~Fuel type: same as proposed~~	As proposed ~~As proposed~~ ~~As proposed~~ ~~As proposed~~
Cooling systems [d, f]	As proposed. ~~Fuel type: electric~~ Capacity: sized in accordance with Section R403.7. ~~Efficiency: in accordance with prevailing federal minimum standards.~~	As proposed ~~As proposed~~ ~~As proposed~~
Service water heating [d, e, f, g]	As proposed. Use, in units of gal/day = 30 + (10 x N_{br}) Where: N_{br} = number of bedrooms.	As proposed Use, in units of gal/day = 25.5 + (8.5 x N_{br}) Where: N_{br} = Number of bedrooms.
	~~Fuel type: as proposed~~	~~Fuel type: as proposed~~
	~~Use (gal/day): determined in accordance with ANSI/RESNET/ICC 301~~	~~Use (gal/day): determined in accordance with ANSI/RESNET/ICC 301~~
	~~Efficiency: in accordance with prevailing federal minimum standards~~	~~Efficiency: in accordance with prevailing federal minimum standards~~
	~~Energy consumption: determined in accordance with ANSI/RESNET/ICC 301~~	~~Energy consumption:~~

		~~determined in accordance with ANSI/RESNET/ICC 301~~

RECA – Eliminate Equipment Trade-Offs in Performance Path

Reason Statement

This proposal improves the efficiency of the Florida Building Code by closing an unnecessary and wasteful loophole in the performance path. In the current code, builders receive performance path trade-off credit for cooling, heating, and water heating equipment efficiencies above the mandatory federal minimums, even though the federal minimum efficiencies for these covered products are outdated and inefficient, and these systems would have been installed anyway. The result is that unwarranted trade-off credit is used to weaken the efficiency of other building systems, leading to unnecessarily higher energy use over the long-term.

Equipment trade-offs were correctly eliminated in the 2009 version of the IECC and have been consistently rejected in every IECC code update cycle since then. Nearly every state that adopts the IECC has eliminated these trade-offs as well. Equipment trade-offs reduce building efficiency because commonly installed cooling, heating, and water heating equipment far exceeds the federal minimum efficiencies, but states are unable to set more reasonable efficiency requirements (or assumptions in the standard reference design baseline) because of federal preemption. The result is an unwarranted trade-off credit that allows buildings to be constructed to 11-22% less efficient overall than if the trade-offs were not allowed. See http://energyefficientcodes.com/wpcontent/uploads/2013/08/2013-9-23-FIN-Review-Analysis-of-Equipment-Trade-offs-in-Residential-IECC.FIN_.pdf.

Although proponents of equipment trade-offs argue that they are "energy neutral," the reality is that they are a short-term trade-off that will have long-term negative impacts on homeowners – often who are unaware that such trade-offs are taking place. For example, if a trade-off is permitted for water heater efficiency, an instantaneous natural gas water heater would allow the builder to reduce the efficiency of the rest of the home by an average of 9%. The remaining home will be 9% less efficient for its entire useful lifetime. As the water heater is replaced every 10-15 years, the envelope of that home will continue to underperform by 9%. By contrast, under the current code, no trade-off credit is awarded for the instantaneous water heater, which means the rest of the home will be built to meet the code. As the water heater is swapped out in future years, the current code home will outperform the trade-off home by 9%.

The Florida Building Code (like the IECC) already provides another performance-based alternative that provides trade-off credit for equipment efficiency (the Energy Rating Index), but without such a high risk of free ridership. The simulated performance path lacks several of the built-in protections of the ERI path, and thus cannot guarantee an equivalent level of performance. We strongly recommend eliminating these trade-offs from the performance path and implementing provisions consistent with the model code.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

73

EN10517

Date Submitted	02/15/2022	**Section**	404.1	**Proponent**	Jeff Sonne for FSEC
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

Summary of Modification

Increase high-efficacy lighting requirement.

Rationale

The proposed modification is highly cost effective and will better allow Florida code to keep up with stringency increases in the 2021 IECC.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact.

Impact to building and property owners relative to cost of compliance with code

Very small increase in cost.

Impact to industry relative to the cost of compliance with code

Very small increase in cost.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Benefits general public by providing a highly cost effective efficiency improvement.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Strengthens the code by providing a highly cost effective efficiency improvement.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not discriminate; just provides a highly cost effective efficiency improvement.

Does not degrade the effectiveness of the code

Increases code effectiveness by providing a highly cost effective efficiency improvement.

Alternate Language

1st Comment Period History

EN10517-A1

Proponent	Bryan Holland	**Submitted**	3/28/2022 10:49:08 AM	**Attachments**	Yes

Rationale:

This alternative proposed modification meets the intent of the original proposed modification without reverting back to incorrect terminology or placing requirements within a definition.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
Same as the original proposed modification.

Impact to building and property owners relative to cost of compliance with code
Same as the original proposed modification.

Impact to industry relative to the cost of compliance with code
Same as the original proposed modification.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
Same as the original proposed modification.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
Same as the original proposed modification.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
Same as the original proposed modification.

Does not degrade the effectiveness of the code
Same as the original proposed modification.

1st Comment Period History

EN10517-G1

Proponent	Jeff Sonne for FSEC	Submitted	4/14/2022 12:48:19 PM	Attachments	No

Comment:

FSEC supports Alternate Language Comment A1 instead of its original 10517 mod.

~~Not less than 90 percent of the lamps in~~ All permanently installed luminaires, excluding those in kitchen appliances, shall have an efficacy of at least 45 lumens-per-watt or shall utilize lamps with an efficacy of not less than 65 lumens-per-watt.

R404.1 Lighting equipment (Mandatory).

~~Not less than 90 percent of the lamps in permanently installed luminaires shall have an efficacy of at least 45 lumens-per-watt or shall utilize lamps with an efficacy of not less than 65 lumens-per-watt.~~ All permanently installed lighting fixtures, excluding kitchen appliance lighting fixtures, shall contain only *high-efficacy lighting sources.*

[Also add to Section R202:]

HIGH-EFFICACY LIGHTING SOURCES. Any lamp with an efficacy of not less than 65 lumens per watt, or luminaries with an efficacy of not less than 45 lumens per watt.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

74

EN10148

Date Submitted	02/10/2022	**Section**	501.7.2	**Proponent**	Jeff Sonne for FSEC
Chapter	5	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Electric resistance heating prohibition for Climate Zone 2 central equipment replacements.

Rationale

Electric heat pumps are low cost heating systems 2.5 times more efficient than electric resistance. Per Section R403.7.2 electric resistance is already not allowed as the primary space heating system for new Florida residential buildings in Climate Zone 2 when complying via the Prescriptive method; this mod applies this Climate Zone 2 prohibition to complete central equipment replacements in existing residential buildings.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Slight impact in applicable cases to verify compliance.

Impact to building and property owners relative to cost of compliance with code

Some increase in first cost in applicable cases, however most Climate Zone 2 homes built this century are already using heat pumps or gas furnace heating. Replacements should not have heating efficiency lower than original equipment.

Impact to industry relative to the cost of compliance with code

Some increase in applicable cases, however other heating options are readily available and typically used in Climate Zone 2.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes; benefits public by increasing heating efficiency in applicable cases.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes; strengthens the code by increasing heating efficiency in applicable cases.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

No; just requires more efficient heating in applicable cases.

Does not degrade the effectiveness of the code

Increases effectiveness of the code by increasing heating efficiency in applicable cases.

[New] R501.7.2 Electric space heating.

Electric resistance shall not be the primary space heating system type used for complete central equipment replacements in Climate Zone 2.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

75

EN10463

Date Submitted	02/15/2022	**Section**	502.1	**Proponent**	Douglas Baggett
Chapter	5	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

10251 10245

Summary of Modification

This proposed modification will serve to keep commissioning requirements and verbiage consistent, as well as, to treat new construction as new construction - even if it is an addition.

Rationale

This proposed modification would serve to ensure the building's systems fulfill the functional and performance requirements set forth by the owner while also ensuring it functions in tandem and as efficiently as possible with the existing system. It will also ensure consistent verbiage and requirements.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This modification will require the local entity to add specific verbiage and requirements for projects requiring an addition that involves new mechanical equipment and/or air distribution systems. In addition, the local entity may need to create a separate solicitation for a project.

Impact to building and property owners relative to cost of compliance with code

Commissioning for new construction should range between .5%-2% of construction costs depending on the complexity and size. If commissioning has not already been budgeted as part of an addition the owners will experience an impact of that amount to the project. This is based on the GSA Cost Schedule.

Impact to industry relative to the cost of compliance with code

No impact to the industry other than ensuring the project budget incorporates the anticipated cost of commissioning the new system(s).

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This modification will improve the health, safety and welfare of the general public by ensuring any new addition to a building's mechanical systems meet indoor air quality standards and is certified by a person specifically trained for such equipment.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This modification will improve the code by allowing for clear and consistent verbiage and requirements for commissioning systems.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities.

Does not degrade the effectiveness of the code

No it does not degrade the effectiveness of the code, it enhances it.

Additions to an existing building, building system or portion thereof shall conform to the provisions of this code as those provisions relate to new construction without requiring the unaltered portion of the existing building or building system to comply with this code. Additions shall not create an unsafe or hazardous condition or overload existing building systems. An addition shall be deemed to comply with this code if the addition alone complies or if the existing building and addition comply with this code as a single building. Additions shall comply with 502.2. Additions requiring new mechanical equipment shall comply with sections 408.2, 408.2.1, 408.2.3 (proposed modifications for those sections). Additions complying with ANSI/ASHRAE/IESNA 90.1 need not comply with sections C402, C403, C404 and C405.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10087

76

Date Submitted	02/15/2022	**Section**	6	**Proponent**	Amanda Hickman
Chapter	6	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

No

Summary of Modification

AMCA 220 reference standard update

Rationale

This modification updates the reference standard, which is already referenced in the code, to the most current version.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact. This modification only updates to the current version of the standard.

Impact to building and property owners relative to cost of compliance with code

No impact. This modification only updates to the current version of the standard.

Impact to industry relative to the cost of compliance with code

No impact. This modification only updates to the current version of the standard.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This modification updates to the current version of the standard which will improve the wellfare of the public.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This modification only updates to the current version of the standard, which will provide better methods and systems of construction.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This modification only updates to the current version of the standard and does not discriminate against other materials or products.

Does not degrade the effectiveness of the code

This modification updates to the current version of the standard, which will increase the effectiveness of the code.

Revise reference standard as follows:

AMCA 220-~~19~~21 Laboratory Methods of Testing Air Curtain Units for Aerodynamic Performance Rating

STANDARD

ANSI/AMCA Standard 220-21

Laboratory Methods of Testing Air Curtain Units for Aerodynamic Performance Rating

An American National Standard
Approved by ANSI on May 4, 2021

Air Movement and Control Association International
AMCA Corporate Headquarters
30 W. University Drive, Arlington Heights, IL 60004-1893, USA
communications@amca.org ▪ Ph: +1-847-394-0150 ▪ www.amca.org

ANSI/AMCA Standard 220-21

Laboratory Methods of Testing Air Curtain Units for Aerodynamic Performance Rating

Air Movement and Control Association International
30 West University Drive
Arlington Heights, Illinois
60004

AMCA Publications

Authority AMCA Standard 220-21 was adopted by the membership of the Air Movement and Control Association International Inc. on February 16, 2021. It was approved as an American National Standard on May 4, 2021.

Objections The Air Movement and Control Association (AMCA) International Inc. will consider and take action upon all written complaints regarding its standards, certification programs or interpretations thereof. For information on procedures for submitting and handling complaints, write to:

AMCA International, Inc.
30 West University Drive
Arlington Heights, IL 60004-1893
U.S.A.

European AMCA
Avenue de Tervueren 188a
Postbox 4
1150 Brussels, Belgium

Asia AMCA Sdn Bhd
No. 7, Jalan SiLC 1/6,
Kawasan Perindustrian SiLC Nusajaya,
Mukim Jelutong, 79200 Nusajaya, Johor
Malaysia

Disclaimer AMCA uses its best efforts to produce publications for the benefit of the industry and the public in light of available information and accepted industry practices. However, AMCA does not guarantee, certify or assure the safety or performance of any products, components or systems tested, designed, installed or operated in accordance with AMCA publications or that any tests conducted under its publications will be non-hazardous or free from risk.

Review Committee

Voting Members

David Johnson, Chair	Berner International Corp.
Peter Bethlehem	Biddle BV
Mats Careborg	Frico AB representing Systemair Group
Frank R. Cuaderno	Mars Air Systems, LLC
Brian Jones	Powered Aire, Inc.

Non-Voting Members

Abhishek Jain	Air Flow Pvt. Ltd.
Cheolhyeong Lee	Dae-ryun Ind., Co., Ltd.
Sekar Chinnaiyan	Saipem India

Staff

Joseph Brooks (Staff Liaison)	AMCA International Inc.

This page intentionally left blank

Contents

This page intentionally left blank

Laboratory Methods of Testing Air Curtain Units for Aerodynamic Performance Rating

1. Purpose

The purpose of this standard is to establish uniform methods for laboratory testing of air curtain units (ACUs) to determine aerodynamic performance in terms of *airflow* rate, ACU outlet air velocity uniformity, electrical power consumption and air velocity projection for rating, guarantee or code compliance purposes.

It is not the purpose of this standard to specify the testing procedures to be used for design, production or field testing.

2. Scope

The scope of this standard covers the performance testing of ACUs.

3. Normative References

The following standard contains provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below.

ANSI/AMCA Standard 210-16, Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating

4. Definitions/Units of Measure/Symbols

4.1 Definitions

4.1.1 Absolute pressure
The value of a pressure when the datum pressure is absolute zero. It is always positive.

4.1.2 ACU
See air curtain unit (ACU).

4.1.3 Air curtain (ACU airstream)
A directionally controlled airstream with a minimum width-to-depth aspect ratio of 5:1. When applied across the entire height and width of an opening, an air curtain reduces the infiltration or transfer of air from one side of the opening to the other and inhibits the passage of insects, dust or debris. For the purposes of this standard, “air curtain” and “ACU airstream” are synonymous.

4.1.4 Air curtain average core velocity (V_{ca})
The average of air curtain core velocities measured along the air curtain width at a defined plane. For the purposes of this standard, measurement planes are defined per Section 8.2.3.

4.1.5 Air curtain average outlet air velocity (V_a)
The airflow rate of an air curtain per unit area of discharge, calculated when the airflow rate is divided by the air curtain discharge area.

4.1.6 Air curtain core velocity (V_{cx})

The maximum air velocity of the air curtain as measured across the air curtain depth at a specified distance from the discharge nozzle. For the purposes of this standard, the measurement test lines (x) are defined per Section 8.2.1.

4.1.7 Air curtain discharge angle (θ)

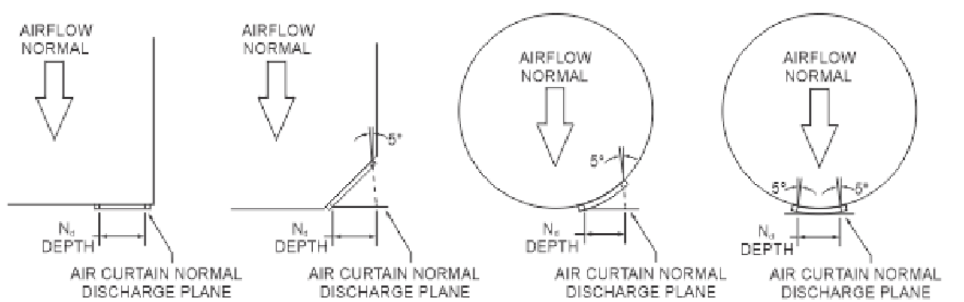
The angle between the ACU normal or plane of the protected opening and the direction in which the airstream leaves the discharge nozzle.

4.1.8 Air curtain discharge area (A_n)

The cross section of the air curtain on the air curtain normal discharge plane. If the ACU discharge nozzle is coplanar with the air curtain normal discharge plane, it shall be equal to the area of the discharge nozzle. If the ACU discharge nozzle is not coplanar with the air curtain normal discharge plane, it shall be equal to the area of the discharge nozzle's projection onto the air curtain normal discharge plane measured from the leading edge of the ACU discharge nozzle to the projection of a 5° line from the trailing edge(s).

4.1.9 Air curtain depth (N_d)

The short dimension of the air curtain measured on the air curtain normal discharge plane. If the ACU discharge nozzle is rectangular and coplanar with the air curtain normal discharge plane, it shall be equal to the ACU discharge nozzle depth. For coplanar, nonrectangular constructions, it shall be equal to the largest value of the short dimension of the ACU discharge nozzle. For nonplanar constructions, it shall be the depth measured on the air curtain normal discharge plane from the leading edge of the ACU discharge nozzle to the projection of a 5° line from the trailing edge. See Annex A for additional examples.

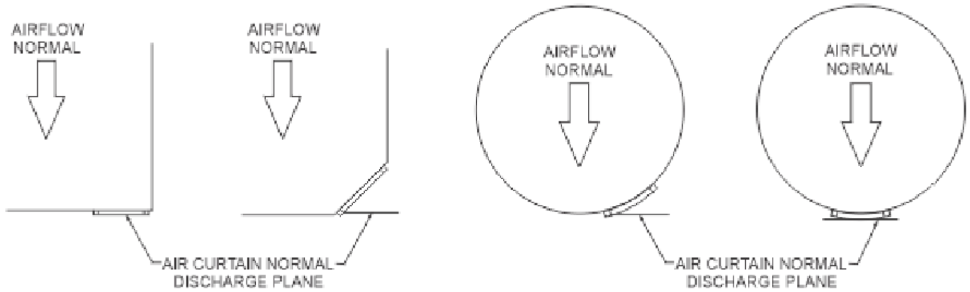


Note – the grills illustrated in the above examples are not indicative of all constructions and are only used to illustrate the measurement location of the leading and trailing edges of the discharge nozzle.

Figure 4.1—Air Curtain Depth

4.1.10 Air curtain normal discharge plane

The plane perpendicular to the airflow normal (0° discharge angle) created by the cross section of the air curtain. It is located at the leading edge of the ACU discharge nozzle.



Note – the grills illustrated in the above examples are not indicative of all constructions and are only used to illustrate the measurement location of the leading and trailing edges of the discharge nozzle.

Figure 4.2—Air Curtain Normal Discharge Plane

4.1.11 Air curtain unit (ACU)
An air-moving device that produces an air curtain (or boundary of air) where its width is at least five times its depth and the discharge is not intended to be connected to unitary ductwork.

4.1.12 ACU airflow rate (Q)
The volume of air that passes through a given area in a unit of time. For the purposes of this standard, the given area is the total of all discharge nozzle areas, measured in accordance with ANSI/AMCA Standard 210.

4.1.13 ACU normal (vector)
A vector declared by the sponsor that identifies the ACU cabinet orientation when it is parallel to the plane of the opening it is protecting.

4.1.14 ACU discharge nozzle
A component or an assembly, which may include adjustable vanes, in the ACU; the assembly or component controls and directs the airstream. For the purposes of this standard, if only one discharge nozzle is present, it is considered the primary discharge nozzle. Discharge nozzles are considered “multiple” when they do not share a common discharge plane. The primary discharge nozzle on a system with multiple discharge nozzles is that which is closest to the plane of the protected opening.

4.1.15 ACU inlet area
The total inside net area of all surfaces where entering airflow first meets the ACU cabinet.

4.1.16 ACU outlet air velocity uniformity (U)
An indicator of the consistency of discharge air velocities across the air curtain width, expressed as a percentage. Refer to Section 8.2.4 for calculation of the value.

4.1.17 ACU power rating (W)
The amount of power, expressed in kW, consumed by the control (if present) and ACU motor(s) at free-air delivery.

4.1.18 ACU target distance
A distance specified by the test sponsor measured from the centerline of the ACU discharge nozzle depth. For the purposes of this standard, the combination of distances defined per Section 7.2.4.4 and the test sponsor determine the target distance(s).

4.1.19 Air curtain velocity projection
The air curtain average core velocity at specified distances from the ACU discharge nozzle’s leading edge. For the purposes of this standard, the measurement test lines are defined per Section 7.2.4.4.

4.1.20 Air curtain width (N_w)
The long dimension of the air curtain measured on the air curtain normal discharge plane. If the ACU discharge nozzle is rectangular and coplanar with the air curtain normal discharge plane, it shall be equal to the ACU discharge nozzle width. For coplanar, nonrectangular constructions, it shall be equal to the largest value of the long dimension of the ACU discharge nozzle. For nonplanar constructions, it shall be the depth measured on the air curtain normal discharge plane from the leading edge of the ACU discharge nozzle to the projection of a 5° line from the trailing edge. See Annex A for additional examples.

4.1.21 Air density (ρ)
The mass per unit volume of air.

4.1.22 Airflow
A flow of air or an air current, specifically one that passes through a dimensionally defined plane.

4.1.23 Barometric pressure (p_b)
The absolute pressure exerted by the atmosphere at a location of measurement.

4.1.24 Determination
The complete set of measurements for a particular test product point of operation. The measurements must be sufficient to determine all performance variables.

4.1.25 Dry-bulb temperature (t_d)
Air temperature measured by a temperature-sensing device without modification to compensate for the effect of humidity.

4.1.26 Free-air delivery
The point of operation where an ACU operates against zero static gauge pressure.

4.1.27 Gauge pressure
The differential pressure between a reference pressure, such as barometric pressure, and the absolute pressure at the point of measurement. It may be positive or negative.

4.1.28 Point of operation
The point on an ACU performance curve corresponding to a particular airflow rate, pressure and power consumption.

4.1.29 Pressure
Force per unit area.

4.1.30 Pressure loss
A specific case of pressure differential. It is the decrease in pressure caused by friction and turbulence.

4.1.31 Stagnation temperature
The temperature that exists by virtue of the air's internal and kinetic energy. If the air is at rest, the stagnation temperature will equal the static temperature.

4.1.32 Standard air
Air having a density of 1.2 kg/m^3 (0.075 lbm/ft^3), a specific heat ratio of 1.4, a viscosity of 1.819 × 10^{-5} Pa·s (1.222 × 10^{-5} lbm/(ft·s)) and an *absolute pressure* of 101.325 kPa (406.78 in. wg). Air at 20°C (68°F), 50% relative humidity and 101.325 kPa (29.92 in. Hg) has these properties, approximately.

4.1.33 Static pressure
The *pressure* that exists by degree of compression only. If expressed as *gauge pressure*, it may be positive or negative.

4.1.34 Static temperature
The temperature that exists by virtue of the internal energy of the air alone. If a portion of the energy is converted to kinetic energy, the *static temperature* is decreased accordingly.

4.1.35 Test
A series of *determinations* for various points of a device's operation.

4.1.36 Total pressure
The air pressure that exists by virtue of the degree of compression and rate of motion of flowing air. Total pressure is equal to the algebraic sum of the velocity pressure and the static pressure at a point. Thus, if the air is at rest, the total pressure will equal the static pressure.

4.1.37 Velocity (dynamic) pressure (P_v)
Pressure that exists by virtue of rate of motion only.

4.1.38 Wet-bulb depression
The difference between the dry- and wet-bulb temperatures at the same location.

4.1.39 Wet-bulb temperature (t_w)
The temperature measured via a temperature sensor covered by a water-moistened wick and exposed to air in motion. Wet-bulb temperature is a close approximation of the temperature of adiabatic saturation.

4.2 Symbols and subscripts

Symbol	Description	SI Unit	I-P Unit
A_n	Air curtain discharge area	m^2	ft^2
n	Number of data points	---	---
N	ACU fan shaft speed	rpm	rpm
N_d	Air curtain depth	mm	in.
N_w	Air curtain width	mm	in.
p_b	Barometric pressure	Pa	in. Hg
P_s	Static pressure	Pa	in. wg
P_t	Total pressure	Pa	in. wg
P_v	Velocity pressure	Pa	in. wg
Q	ACU airflow rate	m^3/s	cfm
ρ	Air density	kg/m^3	lbm/ft^3
s	Standard deviation	---	---
θ	Air discharge angle	degrees	degrees
t_d	Dry-bulb temperature	°C	°F
t_w	Wet-bulb temperature	°C	°F
U	ACU outlet air velocity uniformity	%	%
V_a	Velocity, average outlet	m/s	fpm
V_{cx}	Velocity, air curtain core, at point X	m/s	fpm
V_{ca}	Velocity, average (air curtain core)	m/s	fpm
W	ACU power rating	W	W
Wc	Input power to control	W	W
Wm	Input power to motor	W	W

5. Instruments and Methods of Measurement

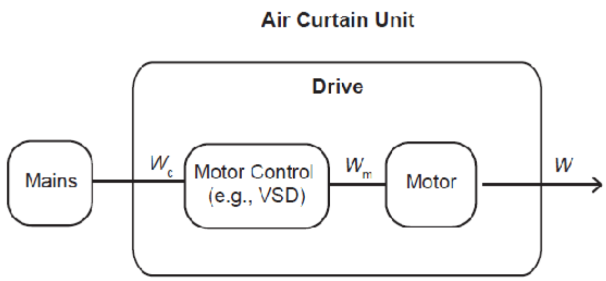
Instruments and methods of measurement shall be in compliance with ANSI/AMCA Standard 210 except where specifically noted.

5.1 Air curtain core velocity measurement

Air curtain core velocity shall be measured with a pitot-static tube and manometer, a hot-wire anemometer or other device that has an accuracy of ±5% of the air velocity being measured. Refer to Section 7.2 for details.

5.2 Power

Power shall be measured with a wattmeter that has a certified accuracy of ±1% of the observed reading. See Figure 5.1.



W shall designate electrical input power; the product of voltage and current; and, in the case of an AC circuit, power factor

Subscripts shall be used in a dynamic sense. For instance,

- W_{mi} indicates a test where motor input power is measured
- W_{cmi} indicates a test where motor control input power is measured

Figure 5.1—Input Power Boundary

6. Equipment and Setups

6.1 Air curtain airflow rate test

The ACU shall be mounted with its inlet(s) sealed to the test chamber in compliance with the requirements of Figure 10.1. The seal shall be adequate to minimize leakage. The primary air discharge nozzle or the nozzle's adjustable vanes shall be set to provide a 15° ± 1° angle as shown in Figure 1B. If the ACU has multiple air discharge nozzles, additional nozzles shall be set to the manufacturer's specifications that meet the requirements dictated by the primary nozzle setting.

6.2 Air velocity projection and ACU outlet air velocity uniformity test

The ACU shall be placed in the testing area in compliance with the requirements of Figure 9.3 so the inlet(s) and outlet discharge nozzle(s) are unrestricted and the air curtain width is perpendicular to the floor. The primary air discharge nozzle or adjustable vanes in the primary air discharge nozzle shall be set to provide a 15° ± 1° air discharge angle as shown in Detail A or B of Figure 1B. Units without an adjustable air discharge nozzle are not required to be angled and shall be mounted so nothing interferes with the airstream for 3000 mm (120 in.). If the ACU has multiple air discharge nozzles, additional nozzles shall be set to the manufacturer's specifications that meet the requirements dictated by the primary nozzle setting.

7. Observations and Conduct of Tests

7.1 Initial conditions
The unit under test shall be energized and operated for not less than 1 min. to allow equilibrium conditions to become established before the first determination.

7.2 Data to be recorded

7.2.1 ACU under test
The following information shall be recorded: manufacturer, trade name, model number, impeller diameter, inlet and outlet areas, number of fans, number of motors and the motor nameplate data.

7.2.2 Test setup
The description of the test setup shall be recorded, including specific dimensions as required per Figures 9.1, 9.2, 9.3, 9.4 and 9.5. Alternately, an annotated photograph of the setup shall be attached to the recorded data.

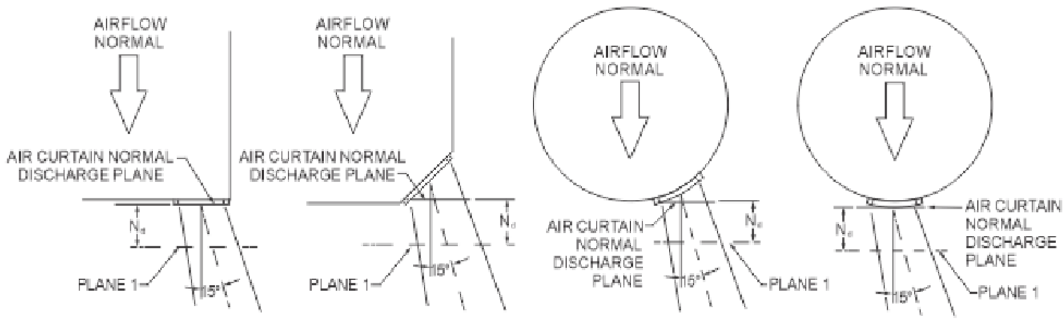
7.2.3 Instruments
The instruments and apparatus used in the test shall be listed. Names, model numbers, serial numbers, scale ranges and calibration information shall be recorded.

7.2.4 Test data

7.2.4.1 Initial and final conditions
Initial and final readings of ambient dry-bulb temperature (t_d), ambient wet-bulb temperature (t_w) and ambient barometric pressure (p_b) shall be recorded for each determination.

7.2.4.2 Airflow rate determination
To establish the airflow rate at free-air delivery, a curve containing a minimum of three determinations is required per ANSI/AMCA Standard 210. See Figures 9.1 and 9.2. The three required determinations include: one determination with the unit working against a pressure of 50 Pa (0.2 in. wg), one against a pressure of 25 Pa (0.1 in. wg) and one against a pressure of 2.5 Pa (0.01 in. wg) or less.

7.2.4.3 ACU outlet air velocity uniformity
The ACU outlet air velocity uniformity *test* shall be based on air curtain core velocity measurements taken on a minimum of five equally spaced test lines on Plane 1. Plane 1 shall be located at a distance equal to one air curtain depth away from the air curtain normal discharge plane. The test line locations at the two ends of the plane shall be one air curtain depth in from each end of the active nozzle as shown in Figure 3. The remaining test line locations shall be equally spaced, and each space shall not exceed 100 mm (4 in.). The maximum air curtain core velocity readings along each test line within the plane shall be recorded. For ACUs with multiple nozzles, a *test* shall be performed for each respective nozzle.



Note – the grills illustrated in the above examples are not indicative of all constructions and are only used to illustrate the measurement location of the leading and trailing edges of the discharge nozzle.

Figure 7.1—Location of Plane 1

7.2.4.4 Air curtain velocity projection test

The air velocity projection test shall be based on air curtain core velocity measurements taken on a minimum of three planes parallel to the air curtain normal discharge plane as shown in Figure 4. The air curtain core velocities shall be recorded on a minimum of five equally spaced test lines across each plane. The test line locations at the two ends of each plane shall be located one air curtain depth in from each end as shown in Figure 4. The remaining test line locations shall be equally spaced and each space shall not exceed 100 mm (4 in.). Record the maximum air curtain air core velocity reading along the test lines within each plane. For ACUs with multiple nozzles, a test shall be performed for each respective nozzle. If all nozzles *are* designed to be run simultaneously, then all shall be operational for each individual test.

The sponsor of the test shall determine the number of test planes by specifying an ACU target distance or a target minimum average air curtain core velocity.

7.2.4.4.1 ACU target distance method

The ACU target distance shall be a minimum of 1000 mm (40 in.) from the air curtain normal discharge plane or whole multiples thereof.

For an ACU target distance greater than or equal to 3000 mm (120 in.), the air curtain core velocities shall be measured at Plane 2 [1000 mm (40 in.)], Plane 3 [2000 mm (80 in.)] and Plane 4 [3000 mm (120 in.)]. Additional readings shall be taken at consecutively numbered planes located at 1000 mm (40 in.) intervals until the *ACU target distance* is reached.

For an ACU target distance of 2000 mm (80 in.), the air curtain core velocity shall be measured at Plane 2 [1000 mm (40 in.)], Plane 2A [1500 mm (60 in.)] and Plane 3 [2000 mm (80 in.)].

For an ACU target distance of 1000 mm (40 in.), the air curtain core velocity shall be measured at Plane 1A [500 mm (20 in.)], Plane 2 [1000 mm (40 in.)] and Plane 2A [1500 mm (60 in.)].

7.2.4.4.2 Minimum air curtain core velocity method

The test shall be terminated upon measurement and calculation of a value less than or equal to the specified minimum average air curtain core velocity.

The first reading shall be taken at Plane 2 [1000 mm (40 in.)]. If the reading is less than the minimum specified average core velocity, readings shall be taken at Plane 1A [500 mm (20 in.)] and Plane 1 located N_d from the air curtain normal discharge plane (see Figure 3) and the test concluded.

If the first reading is greater than the minimum specified average core velocity, the second reading shall be taken at Plane 3 [2000 mm (80 in.)]. If the second reading is less than the minimum specified average core velocity, the third reading shall be taken at Plane 2A [1500 mm (60 in.)] and the test concluded.

If the second reading is greater than the minimum specified average core velocity, the third reading shall be taken at Plane 4 [3000 mm (120 in.)]. If the third reading is less than the minimum specified average core velocity, the test is concluded.

If the third reading is still greater than the minimum specified average core velocity, additional readings shall be taken at 1000 mm (40 in.) intervals until the minimum core velocity is attained.

8. Calculations

Calculations, except as noted below, shall be in compliance with the requirements of ANSI/AMCA Standard 210.

8.1 Air curtain average outlet air velocity (*V_a*)
The average outlet air velocity shall be the unit *airflow* rate divided by the air curtain discharge area or:

$$V_a = Q/A_n \qquad \text{Eq. 8.1}$$

8.2 Outlet air velocity

8.2.1 Air curtain core velocity (*V_{cx}*)
The maximum air velocities of the airstream shall be obtained by traversing each test line, *x*, as shown in Figure 3 and recording each maximum reading using instrumentation per Section 5.1. If velocity pressure is measured via pitot static tube or other velocity pressure measuring device, use Equation 8.2.1 to calculate V_{cx}:

$$V_{cx} = \sqrt{\frac{2P_v}{\rho}} \qquad \text{Eq. 8.2.1 (SI)}$$

$$V_{cx} = 1097.8\sqrt{\frac{P_v}{\rho}} \qquad \text{Eq. 8.2.1 (I-P)}$$

8.2.2 Standard deviation (*s*)

$$s = \sqrt{\frac{\sum(V_{cx})^2 - \left[\frac{(\sum V_{cx})^2}{n}\right]}{n-1}} \qquad \text{Eq. 8.2.2}$$

Where *n* = number of test points

8.2.3 Air curtain average *core velocity* (V_{ca})

$$V_{ca} = \frac{\sum V_{cx}}{n}$$ Eq. 8.2.3

8.2.4 ACU outlet air velocity uniformity (U)
The ACU outlet air velocity uniformity of the ACU shall be expressed as a percentage calculated from the average air curtain core velocity, V_{ca}, and standard deviation, *s*, of Plane 1, Figure 3, using:

$$U = 100 - 100\left(\frac{s}{V_{ca}}\right)\%$$ Eq. 8.2.4

8.3 Air curtain velocity projection
The air curtain velocity projection shall be the average of the air curtain core velocities, V_{cx}, to determine V_{ca} using Equation 8.2.3, for a set of test planes defined in Section 7.2.4.4.

9. Report and Results

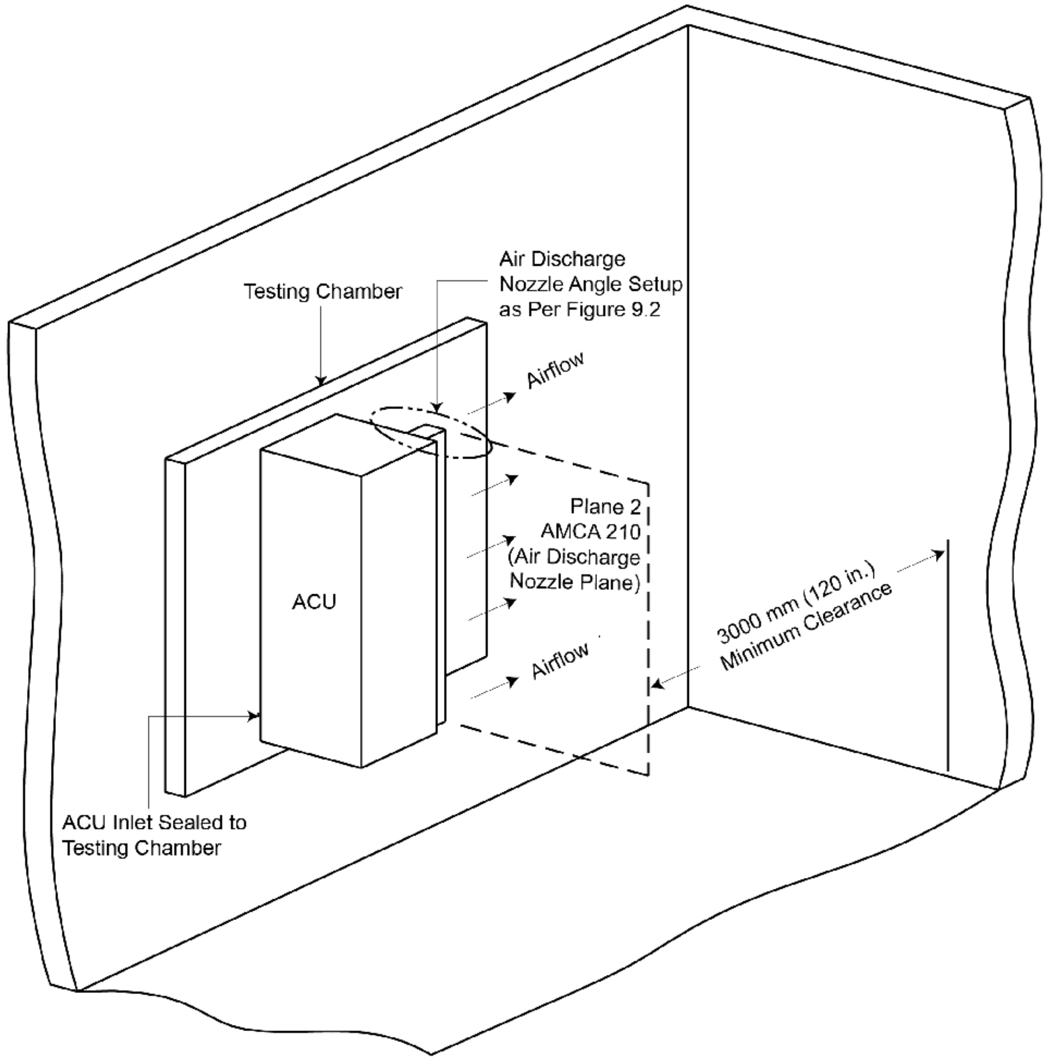
The *test* report shall be presented in consistent units. The following information shall be reported: manufacturer, trade name, model number, impeller diameter, inlet and outlet areas, number of fans, number of motors and the motor nameplate data. The ACU airflow rate shall be presented graphically as shown in Figures 9.6 and 9.7.

In addition, the report shall be in compliance with ANSI/AMCA Standard 210, except as noted in Sections 9.1 and 9.2.

9.1 ACU outlet air velocity uniformity test
The locations and results of the measurements shall be presented in a table with the calculated arithmetic average of the measured results, their standard deviation and uniformity, as shown in Figures 9.8 and 9.9.

9.2 Air velocity projection test
The locations and results of the measurements shall be presented in a table and performance curve meeting the requirements of ANSI/AMCA Standard 210, with the calculated arithmetic average of the measured results, their standard deviation and uniformity for each distance from the air discharge nozzle, as shown in Figures 9.8 through 9.11.

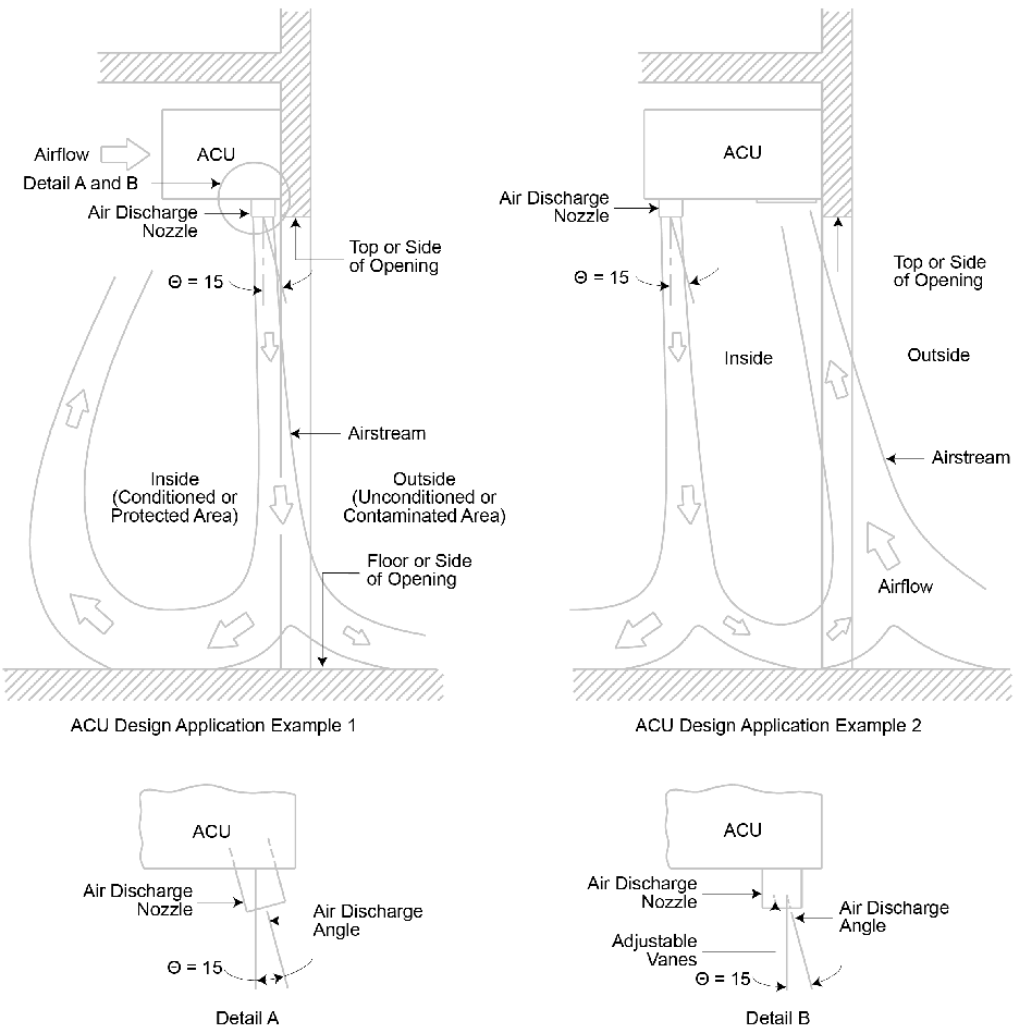
10. Figures



Notes:

1. Unit can be mounted horizontally or vertically.
2. If an ACU has multiple inlets, it shall be mounted so all the inlets are contained within the testing chamber.
3. Air discharge nozzle angle setup shall be per Figure 1B.

Figure 1A — Airflow Rate Test Setup



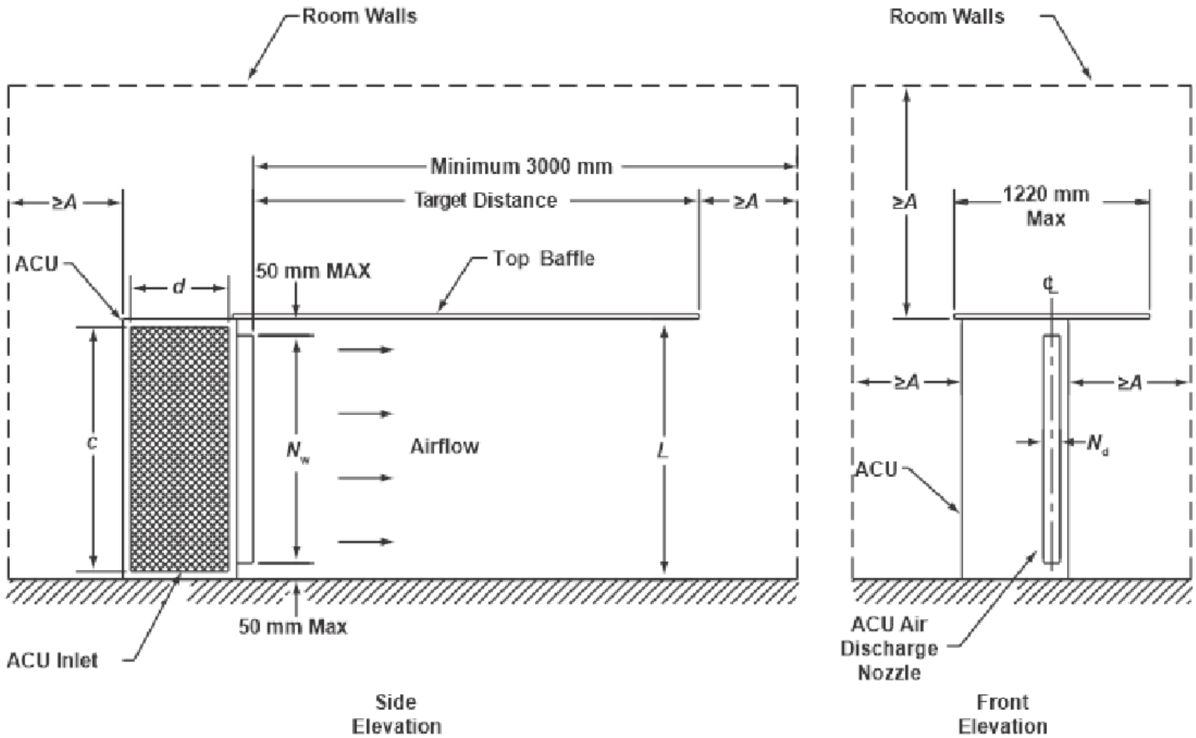
Definitions:
In determining θ, the orientation of the ACU shall be established by the ACU's normal application mounting position. The direction of θ then is defined as a 15° ± 1° angle away from the environment that the ACU is protecting or toward that which normally would be considered the outside.

Units without an adjustable air discharge nozzle are not required to be angled and shall be mounted so nothing interferes with the airstream for 3000 mm (120 in.).

Notes:

1. The examples in Figure 1B are not intended to represent every possible ACU mounting application; they are only to serve as examples of how the direction of Θ shall be determined.
2. For example, the nozzle setup of an ACU designed for outdoor application (not shown) shall be determined by the definition and guidelines illustrated in Figure 1B. Following these criteria yields the direction of Θ to be the same as that shown in Example No. 2 (opposite that shown in Detail A and Detail B).

Figure 1B — Air Discharge Nozzle Angle Setup



Formulae:
A = Two equivalent ACU inlet diameters

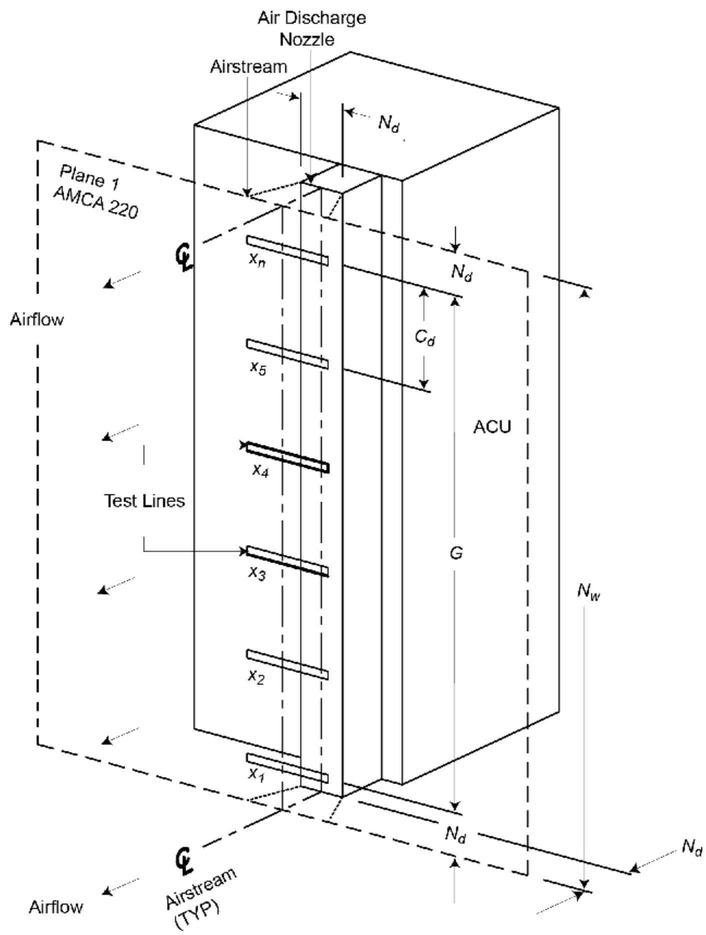
$$A = 4\sqrt{\frac{cd\,*}{\pi}}$$

* For ACUs without a rectangular inlet, substitute the actual value of the inlet area for *cd* in the equation.
* For ACUs with multiple inlets, substitute the sum of all inlet areas for *cd* in the equation.

Notes:

1. See Figures 9.4 and 9.5 for test plane locations.
2. Air discharge nozzle angle setup as noted per Figure 1B.
3. Center baffle(s) over center line of *airflow*.
4. N_d = Air curtain depth
5. N_w = Air curtain width
6. If an ACU has multiple inlets, the nearest surface to each inlet (including the floor) shall be equal to the A value of that inlet. If an ACU must be suspended above the floor, a bottom baffle identical to the top baffle must be used.

Figure 2 — ACU Outlet Air Velocity Uniformity and Air Velocity Projection Test Setup



Formulae:

1. C_d = Test line spacing (See Note 4.)

$$C_d = \frac{G}{n-1} \leq 100\,mm\ (4\,in.)$$

2. V_{ca} = Average air curtain core velocity

$$V_{ca} = \frac{\sum V_{cx}}{n}$$

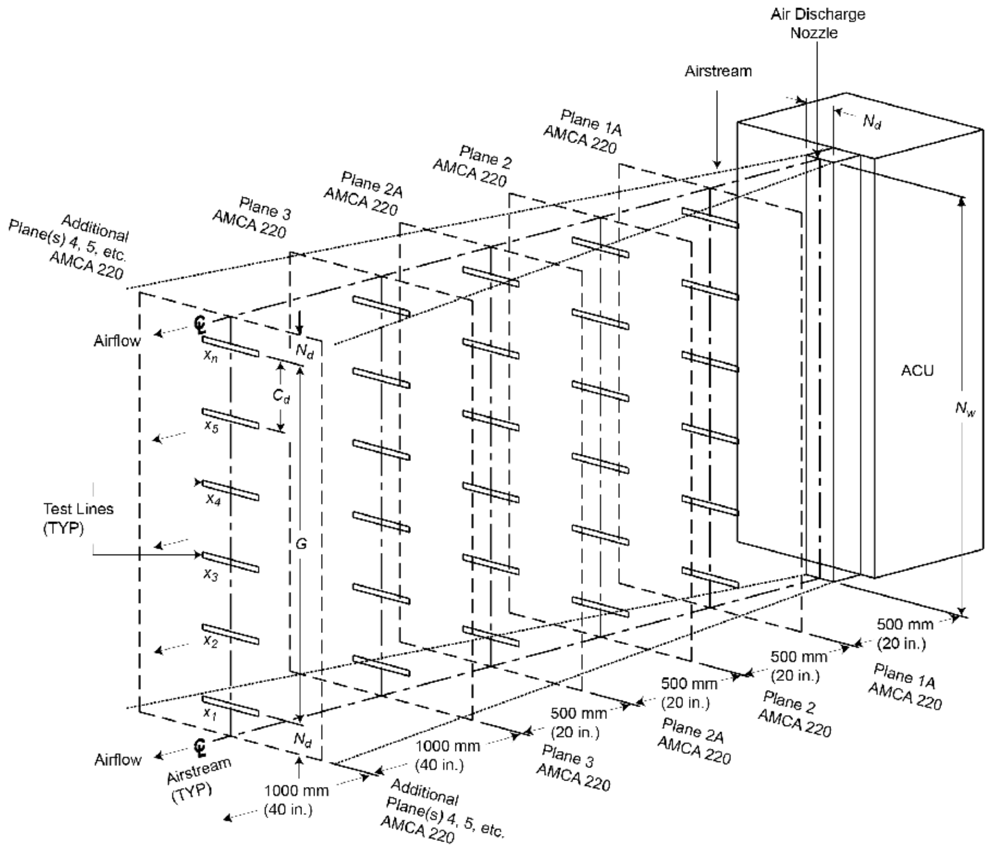
3. s = Standard deviation

$$s = \sqrt{\frac{\sum (V_{cx})^2 - \left[\frac{(\sum V_{cx})^2}{n}\right]}{n-1}}$$

Notes:

1. Air curtain unit setup as per Figure 9.3.
2. Air discharge nozzle angle setup as per Figure 1B.
3. n = Number of test lines (x) (5 minimum)
4. Calculated test line spacing (C_d) shall be less than or equal to 100 mm (4 in.) and rounded to the nearest multiple of 5 mm (1/4 in.).
5. N_d = Air curtain depth
6. N_w = Air curtain width
7. V_{cx} = Core (peak) air velocity along test line x

Figure 3 — ACU Outlet Air Velocity Uniformity Test Lines



Formulae:

1. C_d = Internal test line spacing (See Note 4.)

$$C_d = \frac{G}{n-1} \leq 100\ mm\ (4\ in.)$$

2. V_{ca} = Average air curtain core velocity

$$V_{ca} = \frac{\sum V_{cx}}{n}$$

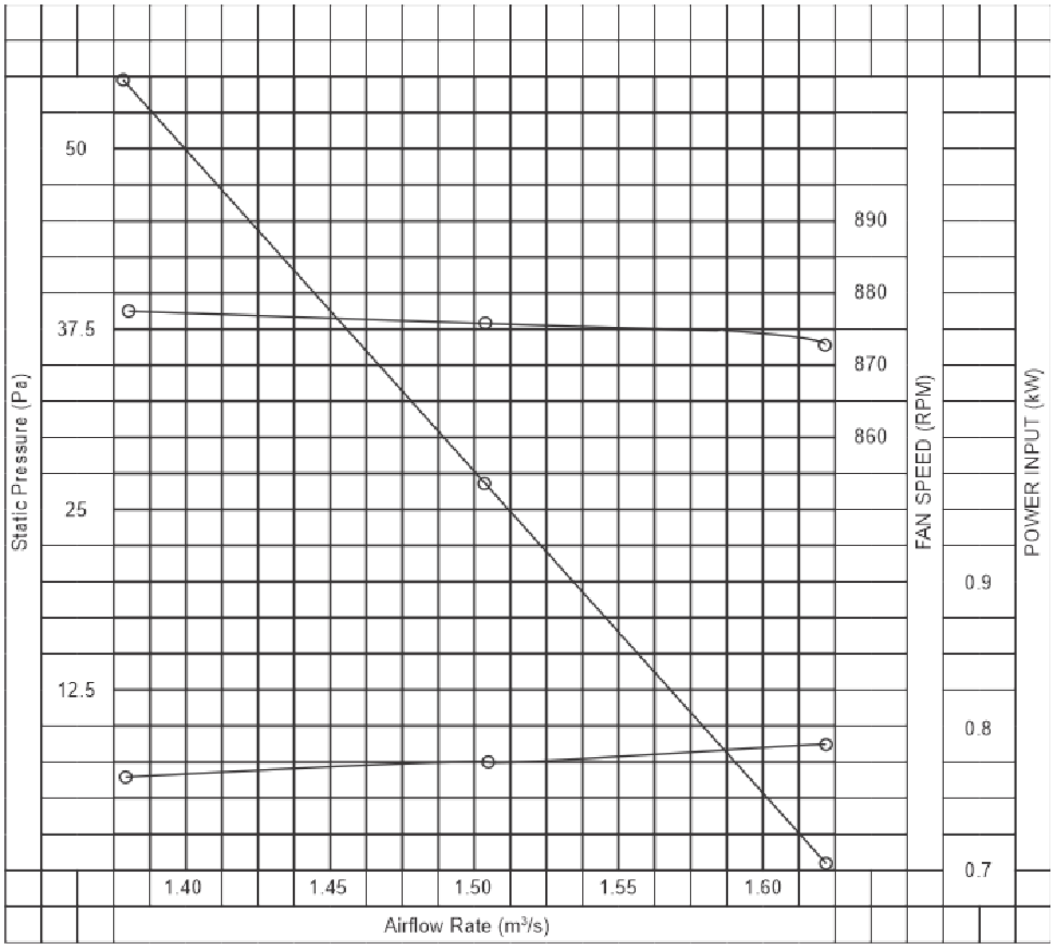
3. s = Standard deviation

$$s = \sqrt{\frac{\sum (V_{cx})^2 - \left[\frac{(\sum V_{cx})^2}{n}\right]}{n-1}}$$

Notes:

1. Air curtain unit setup as per Figure 10.2.
2. Air discharge nozzle angle setup as per Figure 10.1B.
3. n = Number of test lines (x) (5 minimum)
4. Calculated test line spacing (C_d) shall be less than or equal to 100 mm (4 in.) and rounded to the nearest multiple of 5 mm (1/4 in.).
5. Plane locations shall be accurate to ±25 mm (1 in.).
6. Additional planes shall be spaced every 1000 mm (40 in.).
7. N_d = Air curtain depth
8. N_w = Air curtain width
9. V_{cx} = Core (peak) air velocity along test line x

Figure 4 — Air Velocity Projection Test Lines



ACU model: ______________________ ANSI/AMCA 220 figure: __________

N_D: ______________ mm N_W: ______________mm ANSI/AMCA 210 Inlet chamber Figure: __________

Free Delivery Conditions: Air Density: __________kg/m^3

Airflow Rate: ______________________m^3/s Efficiency: __________ %

Average Velocity: __________m/s

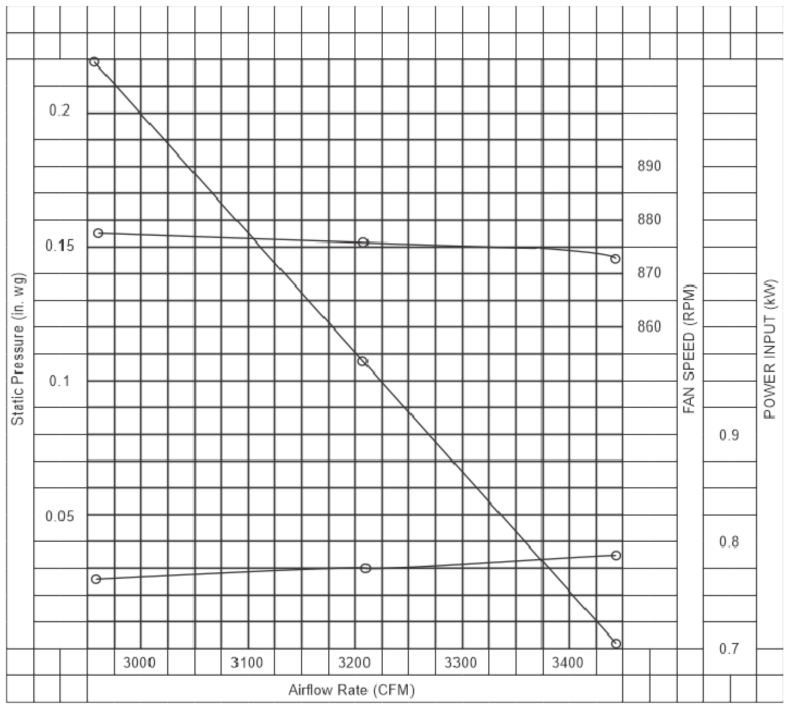
Input Watts: __________

TEST NUMBER: ______________________ CURVE BY: __________

LABORATORY: ______________________ DATE: __________

LOCATIONS: ______________________

Figure 5A — Typical ACU Airflow Rate Performance Curve (SI)



ACU model: ____________________ ANSI/AMCA 220 figure: __________

N_D: __________ in. N_W: __________ in. ANSI/AMCA 210 Inlet chamber Figure: __________

Free Delivery Conditions: Air Density: __________ kg/m³

Airflow Rate: ____________________ cfm Efficiency: __________ %

Average Velocity: __________ fpm

Input Watts: __________

TEST NUMBER: ____________________ CURVE BY: __________

LABORATORY: ____________________ DATE: __________

LOCATIONS: ____________________

Figure 5B — Typical ACU Airflow Rate Performance Curve (I-P)

MANUFACTURER:	XYZ Inc.	TEST NO:	97722-1A
AIR CURTAIN MODEL:	ABC	TETST DATE:	7/22/97
		BY:	SWS/DAJ

N_d	102	mm	N_w	1219	mm
t_{db}	22.2	°C	t_{wo}	17.8	°C

BAROMETRIC PRESSURE:	96.685	kPa	LABORATORY:	AMCA
AIR DENSITY:	1.133	kg/m^3	LOCATION:	Arlington Heights, IL

ANSI/AMCA STANDARD 220 ((Using Pitot-Static Tube)

test line #		PLANE 1		PLANE 2		PLANE 3		PLANE 4	
	DISTANCE	100	mm	1.0	m	2.0	m	3.0	m
	mm from floor	P_v Pa	V_{cx} m/s	P_v Pa	V_{cx} m/s	P_v Pa	V_{cx} m/s	P_v Pa	V_{cx} m/s
1	100.00	178	17.7	28.9	7.14	22.4	6.29	13.7	4.92
2	200.00	159	16.7	24.9	6.63	20.4	6.00	14.9	5.14
3	300.00	274	22.0	37.4	8.13	27.4	6.95	16.2	5.35
4	400.00	224	19.9	41.8	8.59	32.1	7.53	19.4	5.86
5	500.00	155	16.6	44.6	8.87	33.4	7.68	21.2	6.11
6	600.00	126	14.9	58.3	10.14	49.6	9.35	28.6	7.11
7	700.00	155	16.6	45.3	8.94	33.1	7.65	24.4	6.56
8	800.00	209	19.2	42.6	8.67	31.4	7.44	21.4	6.15
9	900.00	349	24.8	36.9	8.07	28.6	7.11	19.9	5.93
10	1000.00	163	17.0	24.4	6.56	21.4	6.15	15.2	5.18
11	1100.00	174	17.5	25.9	6.76	21.9	6.22	14.2	5.01
12									
13									
14									
15									
16									
17									
18									
19									
20									
AVG CORE VEL, V_{ca}		18.45 m/s		8.05 m/s		7.13 m/s		5.76 m/s	
STD.DEVIATION, s		2.86 m/s		1.15 m/s		0.98 m/s		0.70 m/s	
UNIFORMITY, U		85%		86%		86%		88%	

Figure 6A — Sample ACU Outlet Air Velocity Uniformity and Air Curtain Velocity Projection Calculations (SI)

MANUFACTURER:	XYZ Inc.	TEST NO:	97722-1B
AIR CURTAIN MODEL:	ABC	TETST DATE:	7/22/97
		BY:	SWS/DAJ

N_d	4.0	in.	N_w	48	in.
t_{db}	72	°F	t_{wo}	64	°F

BAROMETRIC PRESSURE:	28.55	in. Hg	LABORATORY:	AMCA
AIR DENSITY:	0.0707	lbm/ft^3	LOCATION:	Arlington Heights, IL

ANSI/AMCA STANDARD 220 ((Using Pitot-Static Tube)

test line #	DISTANCE	PLANE 1		PLANE 2		PLANE 3		PLANE 4	
		4.0	in.	40	in.	80	in.	120	in.
	in. from floor	P_v in. wg	V_{ca} fpm	P_v in. wg	V_{cx} fpm	P_v in. wg	V_{cx} fpm	P_v in. wg	V_{ca} fpm
1	4.00	0.714	3483	0.116	1404	0.090	1237	0.055	967
2	8.00	0.637	3290	0.100	1303	0.082	1180	0.060	1010
3	12.00	1.100	4323	0.150	1596	0.110	1367	0.065	1051
4	16.00	0.900	3910	0.168	1689	0.129	1480	0.078	1151
5	20.00	0.624	3256	0.179	1744	0.134	1509	0.085	1202
6	24.00	0.506	2932	0.234	1994	0.199	1839	0.115	1398
7	28.00	0.624	3256	0.182	1758	0.133	1503	0.098	1290
8	32.00	0.840	3778	0.171	1705	0.126	1463	0.086	1209
9	36.00	1.400	4877	0.148	1586	0.115	1398	0.080	1166
10	40.00	0.655	3336	0.098	1290	0.086	1209	0.061	1018
11	44.00	0.700	3449	0.104	1329	0.088	1223	0.057	984
12									
13									
14									
15									
16									
17									
18									
19									
20									
AVG CORE VEL, V_{ca}		3626 fpm		1582 fpm		1401 fpm		1131 fpm	
STD.DEVIATION, s		562 fpm		226 fpm		192 fpm		138 fpm	
UNIFORMITY, U		85%		86%		86%		88%	

Figure 6B — Sample ACU Outlet Air Velocity Uniformity and Air Curtain Velocity Projection Calculations (I-P)

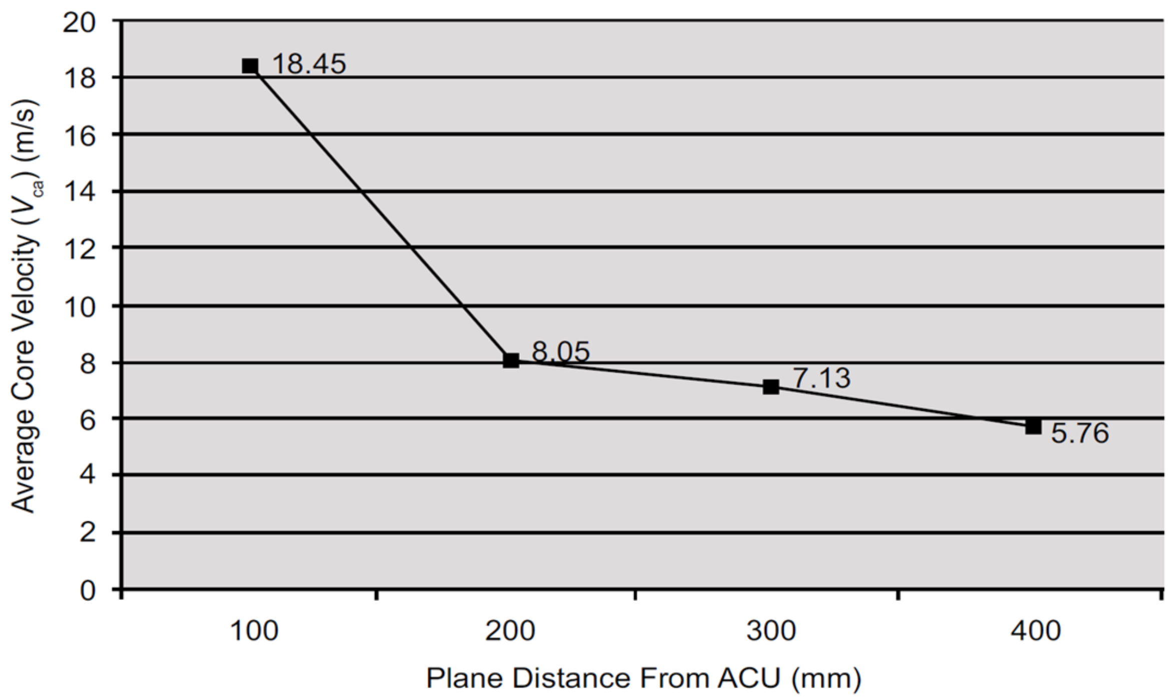


Figure 7A — Sample Air Curtain Velocity Projection Test (SI)

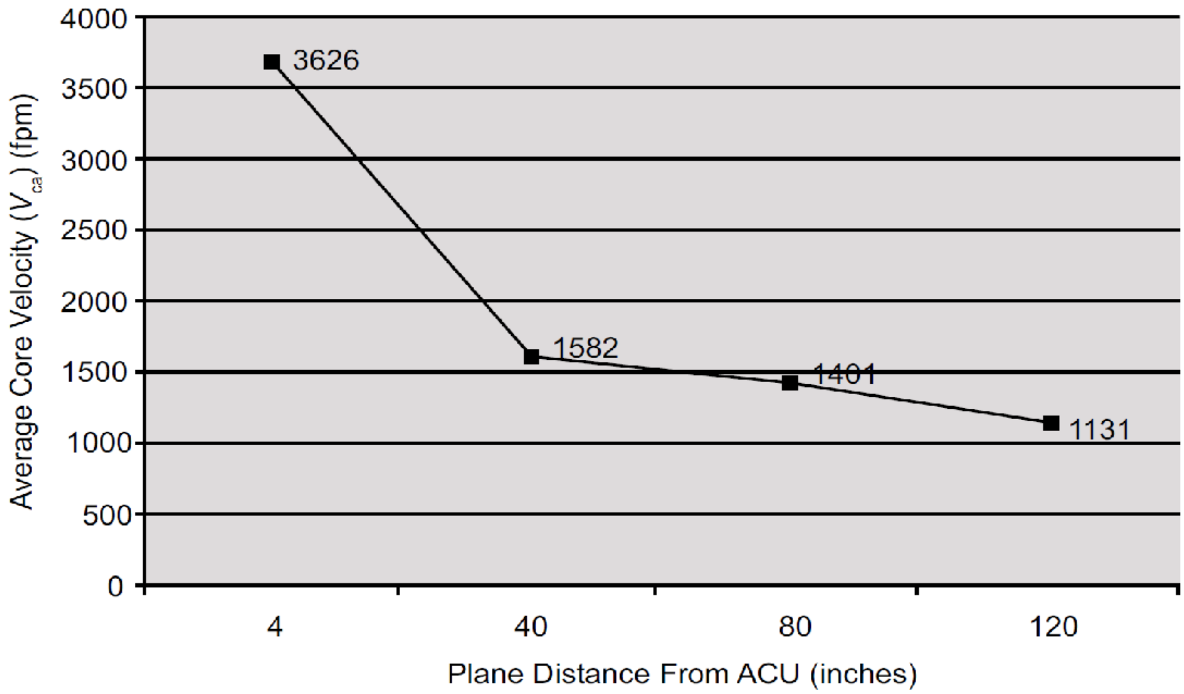


Figure 7B — Sample Air Curtain Velocity Projection Test (I-P)

Annex A
Air Curtain Depth and Width (Informative)

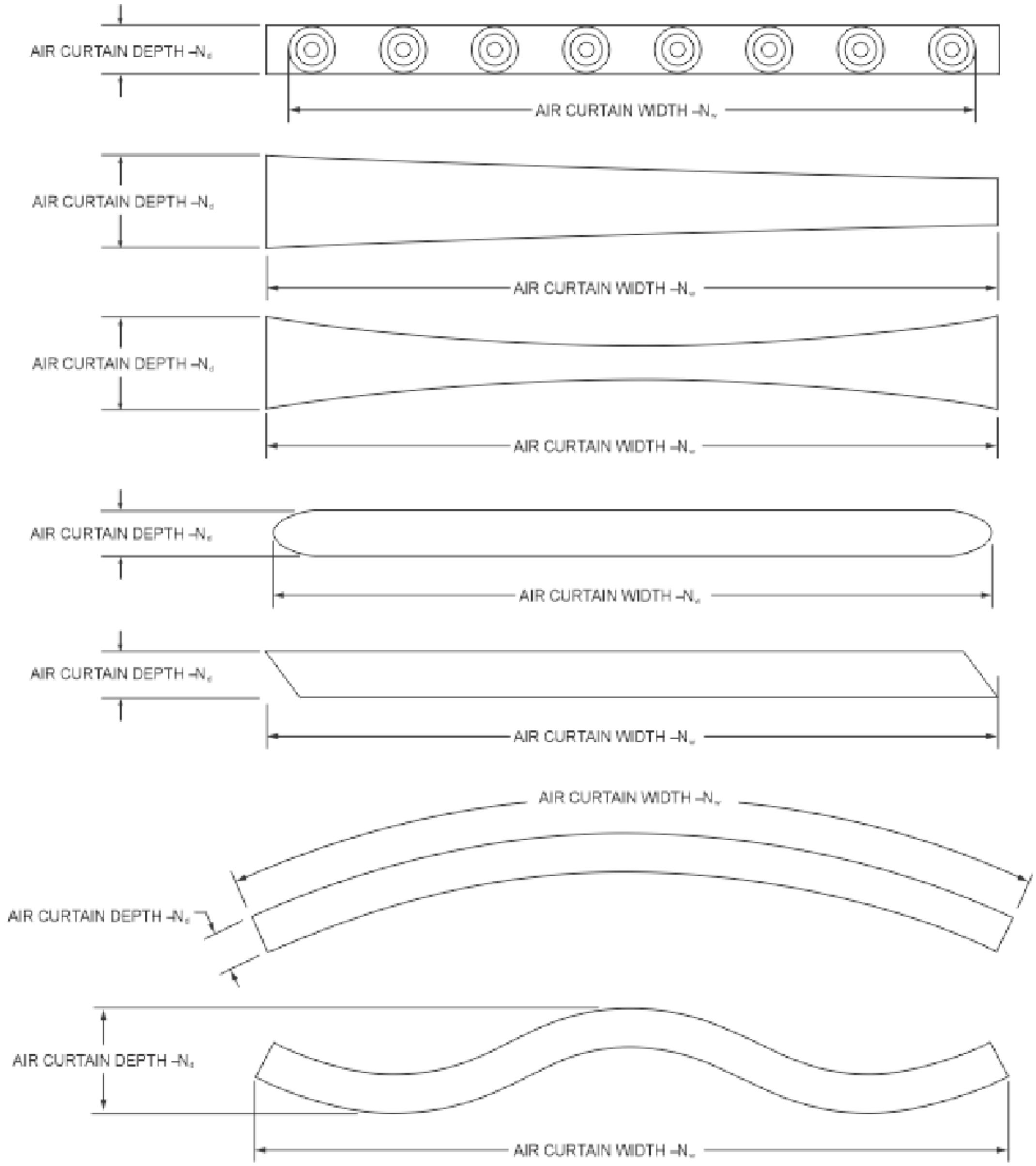


Figure A.1 — Examples of Air Curtain Width and Depth Definitions

Annex B
Air Curtain Discharge Area (Informative)

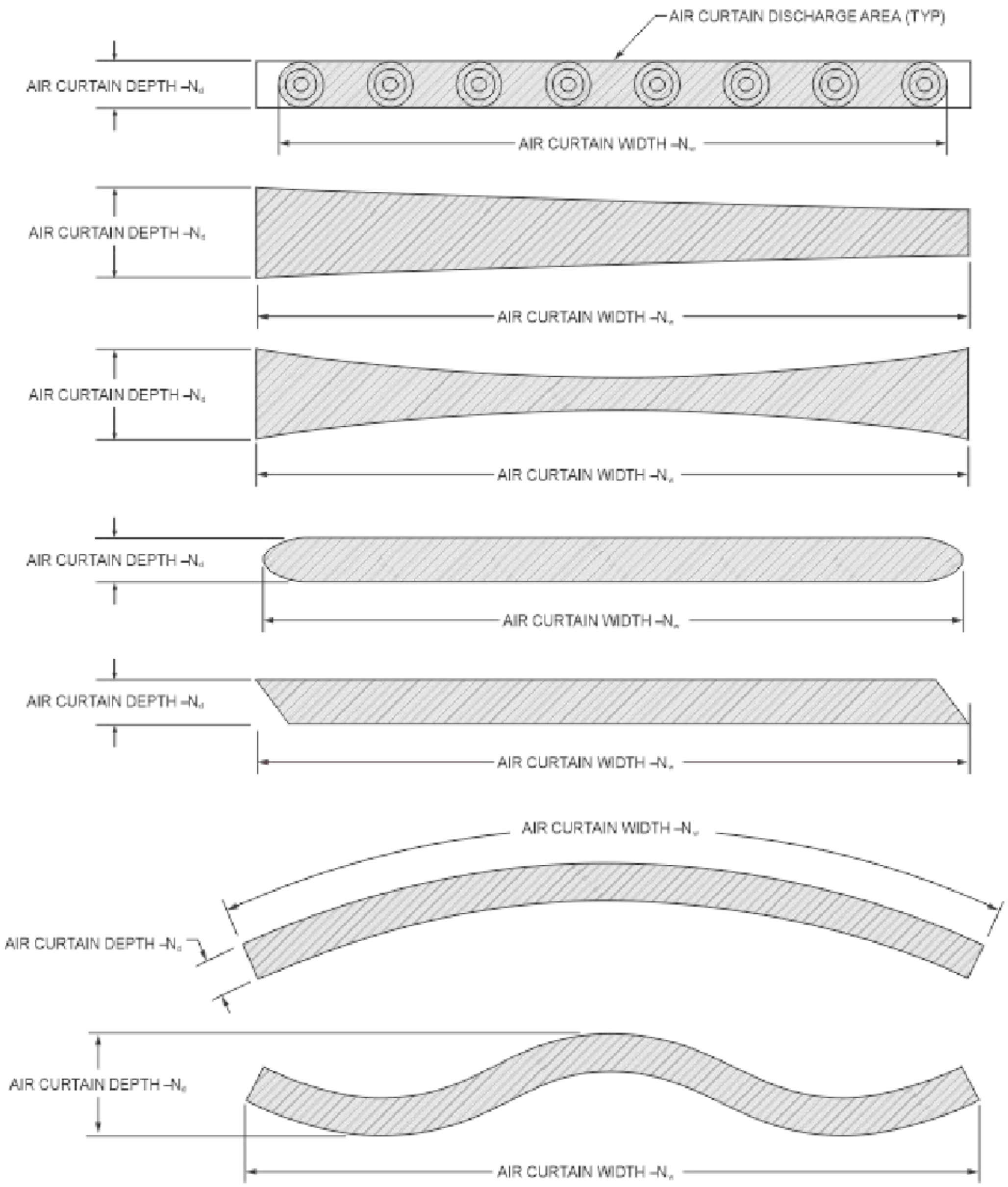


Figure B.1 — Examples of Air Curtain Discharge Areas

Annex C
Uncertainty in Velocity Determination Using Pitot-Static Tube and Manometer (Informative)

Values given in Table C.1 are based on an error equivalent to an indicating column length of 12 Pa (0.05 in. wg) in a vertical manometer having a 1:1 slope ratio.

Table C.1 — Manometer Error

Slope Ratio	Minimum Usable Velocity
1:1	14 m/s (2800 fpm)
2:1	10 m/s (2000 fpm)
5:1	6 m/s (1250 fpm)
10:1	5 m/s (900 fpm)
20:1	3 m/s (630 fpm)

Source: David Johnson, Berner International Corp., 1998

RESOURCES

AMCA Membership Information
http://www.amca.org/member

AMCA International Headquarters and Laboratory
www.amca.org

AMCA White Papers
www.amca.org/whitepapers

Searchable CRP Database of AMCA Certified Products
www.amca.org/certified

VISIT THE AMCA STORE

AMCA provides its Publications and Standards through the AMCA Store. Any document selected will bring up options for a free or at-cost PDF, and, where applicable, at-cost print (hard copy), redline, multi-user license, and PDF + print options. To access member-only pricing and access your 50% discount, first log into amca.org/login or click on amca.org/login from within the AMCA website. For more information on AMCA Publications and Standards, visit www.amca.org/store.

Air Movement and Control Association International

AMCA Corporate Headquarters
30 W. University Drive, Arlington Heights, IL 60004-1893, USA
communications@amca.org ▪ Ph: +1-847-394-0150 ▪ www.amca.org

The Air Movement and Control Association International Inc. is a not-for-profit association of the world's manufacturers of air system equipment, such as fans, louvers, dampers, air curtains, airflow measurement stations, acoustic attenuators, and other air system components for the industrial and commercial markets.

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

EN10524

77

Date Submitted	02/15/2022	**Section**	6	**Proponent**	Jennifer Hatfield
Chapter	6	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Chapter 6 (RE) Reference Standards

Summary of Modification

Updates to the latest ANSI approved industry standard for portable electric spa energy efficiency.

Rationale

This proposal is being submitted on behalf of the Pool & Hot Tub Alliance (formerly APSP). It simply updates to the 2019 edition of the ANSI/APSP/ICC-14 Standard, which provides for the latest edition that manufacturers of Portable Electric Spas are complying with today.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact.

Impact to building and property owners relative to cost of compliance with code

No impact.

Impact to industry relative to the cost of compliance with code

No impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Provides for the latest energy efficiency requirements for portable electric spas, which provides energy savings for consumers.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves the code by providing for the latest edition.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

It does not.

Does not degrade the effectiveness of the code

It does not.

APSP (PHTA Standards)

Pool & Hot Tub Alliance
Association of Pool and Spa Professionals
2111
Eisenhower Avenue, Suite 500
Alexandria, VA 22314

ANSI/APSP/ICC 14-1419
American National Standard for Portable Electric Spa Energy Efficiency
C404.10

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

78

EN10205

Date Submitted	02/14/2022	**Section**	6	**Proponent**	Jeff Sonne for FSEC
Chapter	6	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Update ANSI/RESNET/ICC 380 standard.

Rationale

Update Florida code to latest version of ANSI/RESNET/ICC 380. The 2019 version of the standard incorporates all addenda to the 2016 version and extends testing in support of Energy Ratings to Dwelling and Sleeping Units in multi-unit buildings. ANSI/RESNET/ICC 380-2019 is available for review at: https://codes.iccsafe.org/content/RESNET3802019P1

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None-- just updates standard.

Impact to building and property owners relative to cost of compliance with code

None-- just updates standard.

Impact to industry relative to the cost of compliance with code

None-- just updates standard.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, updates code to latest standard.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves code by updating it to latest standard.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

No, only updates to latest standard.

Does not degrade the effectiveness of the code

Does not degrade code, only updates it to latest standard.

EN10205Text Modification

ANSI/RESNET/ICC 380—20169

Standard for Testing Airtightness of Building, Dwelling Unit, and Sleeping Unit Enclosures,; Airtightness of Heating and Cooling Air Distribution Systems; and Airflow of Mechanical Ventilation Systems

R402.4.1.2, R403.3.2, Table R405.5.2(1) and Appendix RD

Mod_10205_TextOfModification.pdf Page: 1

TAC: Energy

Total Mods for **Energy** in **Pending Review : 79**

Total Mods for report: 79

Sub Code: Energy Conservation

79

EN10525

Date Submitted	02/15/2022	**Section**	6	**Proponent**	Jennifer Hatfield
Chapter	6	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Chapter 6 (CE) Reference Standards

Summary of Modification

Updates to the latest ANSI approved industry standards for both portable electric spa energy efficiency, and pool and inground spas.

Rationale

This proposal is being submitted on behalf of the Pool & Hot Tub Alliance (formerly APSP). It simply updates to the latest editions of both standards. The APSP-14, 2019 edition is what portable electric spas are complying with today. And with the APSP-15, it is imperative this 2021 edition is adopted to ensure alignment with the federal dedicated purpose pool pump rule from the US DOE.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact.

Impact to building and property owners relative to cost of compliance with code

No impact.

Impact to industry relative to the cost of compliance with code

No impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Provides for the latest energy efficiency requirements, which provides energy savings for consumers.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves the code by providing for the latest editions.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

It does not.

Does not degrade the effectiveness of the code

It does not.

APSP (PHTA Standards)

Pool & Hot Tub Alliance
~~Association of Pool and Spa Professionals~~
2111 Eisenhower Avenue, Suite 500
Alexandria, VA 22314

ANSI/APSP/ICC 14—~~14~~19
American National Standard for Portable Electric Spa Energy Efficiency
R403.11

ANSI/~~APSP~~PHTA/ICC 15—~~11~~2021
American National Standard for Residential Swimming Pool and Spa Energy Efficiency with Addenda A approved January 9, 2013
R403.12