ENERGY TAC
WITH COMMENTS

This document created by the Florida Department of Business and Professional Regulation - 850-487-1824

Total Mods for report: 26

TAC: Energy

Total Mods for **Energy** in **Approved as Submitted: 10**

Total Mods for report: 26

Sub Code: Energy Conservation

EN7675

1

Date Submitted	12/12/2018	**Section**	1	**Proponent**	Jeff Sonne for FSEC
Chapter	Appendix RD	**Affects HVHZ**	No	**Attachments**	Yes

TAC Recommendation Approved as Submitted

Commission Action Pending Review

Comments

General Comments **No** **Alternate Language** **Yes**

Related Modifications

7677

Summary of Modification

Add Envelope Leakage Test Report to Appendix RD.

Rationale

The 2017 version of this report form is currently available through FBC approved residential Florida Energy Conservation Code software. Providing it in the Code will help facilitate consistent building air leakage compliance verification.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None or help facilitate code enforcement.

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

Lower to no cost; blower door tester would only need to maintain one form for the entire state.

Impact to industry relative to the cost of compliance with code

Lower to no cost; blower door tester would only need to maintain one form for the entire state.

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

Lower to no cost; blower door tester would only need to maintain one form for the entire state.

Requirements

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

Benefits general public by facilitating building air leakage testing verification consistency.

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

Improves the code by facilitating building air leakage testing verification consistency.

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

Does not discriminate; facilitates building air leakage testing verification consistency.

Does not degrade the effectiveness of the code

Increases code effectiveness by facilitating building air leakage testing verification consistency.

Alternate Language

2nd Comment Period

7675-A2

Proponent Jeff Sonne for FSEC **Submitted** 5/24/2019 **Attachments** Yes

Rationale

This A2 version is the same as the A1 mod (which adds ANSI/RESNET/ICC 380 recording requirements to the test form), except A1 references the 2016 version of ANSI/RESNET/ICC 380 while A2 references the new 2019 version of ANSI/RESNET/ICC 380 (via four small changes on the form itself and by changing the residential Florida Energy Code's Chapter 6 reference entry for Standard 380 from the 2016 to 2019 version). ANSI/RESNET/ICC 380-2019 is attached as a PDF file for review purposes.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Same as original mod.

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

Same as original mod.

Impact to industry relative to the cost of compliance with code

Same as original mod.

Impact to Small Business relative to the cost of compliance with code

Lower to no cost; blower door tester would only need to maintain one form for the entire state.

Requirements

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

Same as original mod.

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

Same as original mod.

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

Same as original mod.

Does not degrade the effectiveness of the code

Same as original mod.

Alternate Language

2nd Comment Period

7675-A1

Proponent Jeff Sonne for FSEC **Submitted** 5/24/2019 **Attachments** Yes

Rationale

Same as original mod. This mod A1 version adds ANSI/RESNET/ICC 380 recording requirements to the form.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Same as original mod.

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

Same as original mod.

Impact to industry relative to the cost of compliance with code

Same as original mod.

Impact to Small Business relative to the cost of compliance with code

Lower to no cost; blower door tester would only need to maintain one form for the entire state.

Requirements

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

Same as original mod.

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

Same as original mod.

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

Same as original mod.

Does not degrade the effectiveness of the code

Same as original mod.

[Two changes in attached file: 1) new test form to take the place of the original mod's Appendix RD test form in its entirety, and 2) update to related Chapter 6 ANSI Standard reference.]

[See test form in attached file, to take the place of the original mod's form in its entirety.]

[Add attached test report in its entirety.]

Envelope Leakage Test Report (Blower Door Test)

2020 Florida Building Code, Energy Conservation, 7th Edition
Residential Prescriptive, Performance or ERI Method Compliance
ANSI/ RESNET/ ICC 380 Reporting Compliant

Permit Jurisdiction:	**Permit #:**		
Builder:	**Community:**		**Lot:**
Address:	**Unit:**	**City:**	**Zip:**

Air Leakage Test Results *Passing results must meet either the Performance, Prescriptive, or ERI Method*

○ **PRESCRIPTIVE METHOD -** The building or dwelling unit shall be tested and verified as having an air leakage rate of *not* exceeding 7 air change per hour at a pressure of 0.2 inch w.g. (50 Pascals) in Climate Zones 1 and 2.

○ **PERFORMANCE or ERI METHOD -** The building or dwelling unit shall be tested and verified as having an air leakage rate of *not* exceeding the selected ACH(50) value, as shown on FORM R405-2020 (Performance) or R406-2020 (ERI), section labeled as Infiltration, sub-section ACH50.

ACH(50) specified on Form R405-2020 Energy Calc (Performance) or R406-2020 (ERI): ☐

$$\frac{}{Adjusted\ CFM(50)^{*}} \times 60 \div \frac{}{Building\ Infiltration\ Volume} = \frac{}{ACH(50)}$$

☐ **PASS (mechanical ventilation not required)**

☐ **PASS (with mechanical ventilation installation verified)**

☐ **FAIL (ACH(50) too high)** ☐ **FAIL (mechanical ventilation required)**

Method for calculating building infiltration volume:

○ Retrieved from architectural plans
○ Code software calculated
○ Field measured and calculated

Testing shall be conducted in accordance with ANSI/RESNET/ICC 380 and reported at a pressure of 0.2 inch w.g. (50 pascals) as required by Section R402.4.1.2 of the Florida Building Code, Energy Conservation.

ANSI/RESNET/ICC 380 Mandatory Recorded Data

Test Type: ☐ Multi-Point ☐ One-Point (*CFM results adjusted by 10% as per 3.5.1 ANSI/RESNET/ICC 380-2016)

Test Method: ☐ Pressurization ☐ Depressurization

Note: Multi-point Test requires supplemental documentation for the recording of at least five pressure differences and the airflow measured over at least a 10 –second period, as stated in ANSI/RESNET/ICC 380 3.4.2.2. Building official may request this documentation.

Indoor Temp: ☐ **Outdoor Temp:** ☐ **Altitude:** ☐ **Baseline Reading:** ☐

Opening Used for Blower Door: ☐

Weather Conditions: ○ Calm ○ Low winds ○ Very Windy

Blower Door:	Model #		Serial #	
Pressure Gauge:	Model #		Serial #	

Crawlspace Vents:	**Attic:**	**Attic Access:**	**Attic Exterior Access:**	
☐ Closed ☐ Open ☐ N/A	☐ Vented ☐ Unvented	☐ Open ☐ Closed ☐ N/A	☐ Open ☐ Closed	
Basement Access:	**Dryer Damper:**	**Fireplace Damper:**	**Range Hood Damper:**	**All other exterior openings:**
☐ Open ☐ Closed ☐ N/A	☐ N/A ☐ Closed	☐ N/A ☐ Closed	☐ N/A ☐ Closed	☐ N/A ☐ Closed

Testing Company

Company Name: ______________________________ Phone: ________________

I hereby verify that the above Air Leakage result are in accordance with the 2020 Edition Florida Building Code Energy Conservation requirements according to the compliance method selected above.

Signature of Tester: ______________________________ Date of Test: ____________

Printed Name of Tester: ______________________________

License/Certification #: ______________________________ Issuing Authority: ________________

(Copy of License / Certificate of the tester may be requested)

[Enter date printed, software product, and software certification status]

Envelope Leakage Test Report (Blower Door Test)

2020 Florida Building Code, Energy Conservation, 7th Edition
Residential Prescriptive, Performance or ERI Method Compliance
ANSI/ RESNET/ ICC 380 Reporting Compliant

Permit Jurisdiction:	**Permit #:**	
Builder:	**Community:**	**Lot:**
Address:	**Unit:** **City:**	**Zip:**

Air Leakage Test Results *Passing results must meet either the Performance, Prescriptive, or ERI Method*

○ **PRESCRIPTIVE METHOD -** The building or dwelling unit shall be tested and verified as having an air leakage rate of *not* exceeding 7 air change per hour at a pressure of 0.2 inch w.g. (50 Pascals) in Climate Zones 1 and 2.

○ **PERFORMANCE or ERI METHOD -** The building or dwelling unit shall be tested and verified as having an air leakage rate of *not* exceeding the selected ACH(50) value, as shown on FORM R405-2020 (Performance) or R406-2020 (ERI), section labeled as Infiltration, sub-section ACH50.

ACH(50) specified on Form R405-2020 Energy Calc (Performance) or R406-2020 (ERI): ☐

$$\frac{\qquad}{Adjusted\ CFM(50)^{*}} \times 60 \div \frac{\qquad}{Building\ Infiltration\ Volume} = \frac{\qquad}{ACH(50)}$$

☐ **PASS (mechanical ventilation not required)**

☐ **PASS (with mechanical ventilation installation verified)**

☐ **FAIL (ACH(50) too high)** ☐ **FAIL (mechanical ventilation required)**

Method for calculating building infiltration volume:

○ Retrieved from architectural plans
○ Code software calculated
○ Field measured and calculated

Testing shall be conducted in accordance with ANSI/RESNET/ICC 380 and reported at a pressure of 0.2 inch w.g. (50 pascals) as required by Section R402.4.1.2 of the Florida Building Code, Energy Conservation.

ANSI/RESNET/ICC 380 Mandatory Recorded Data

Test Type: ☐ Multi-Point ☐ One-Point (*CFM results adjusted by 10% as per 4.5.1 ANSI/RESNET/ICC 380-2019)

Test Method: ☐ Pressurization ☐ Depressurization

Note: Multi-point Test requires supplemental documentation for the recording of at least five pressure differences and the airflow measured over at least a 10 –second period, as stated in ANSI/RESNET/ICC 380 4.4.2.2. Building official may request this documentation.

Indoor Temp: ☐ **Outdoor Temp:** ☐ **Altitude:** ☐ **Baseline Reading:** ☐

Opening Used for Blower Door: ☐

Weather Conditions: ○ Calm ○ Low winds ○ Very Windy	**Blower Door:**	Model # ☐	Serial # ☐	
	Pressure Gauge:	Model # ☐	Serial # ☐	

Crawlspace Access:	**Attic:**	**Attic Access:**	**Attic Exterior Access:**	
☐ Closed ☐ Open ☐ N/A	☐ Vented ☐ Unvented	☐ Open ☐ Closed ☐ N/A	☐ Open ☐ Closed	
Basement Access:	**Dryer Damper:**	**Fireplace Damper:**	**Range Hood Damper:**	**All other exterior openings:**
☐ Open ☐ Closed ☐ N/A	☐ N/A ☐ Closed	☐ N/A ☐ Closed	☐ N/A ☐ Closed	☐ N/A ☐ Closed

Testing Company

Company Name: ______________________ Phone: ______________

I hereby verify that the above Air Leakage result are in accordance with the 2020 Edition Florida Building Code Energy Conservation requirements according to the compliance method selected above.

Signature of Tester: ______________________ Date of Test: ____________

(Copy of License / Certificate of the tester may be requested)

Printed Name of Tester: ______________________

License/Certification #: ______________________ Issuing Authority: ______________

[Enter date printed, software product, and software certification status]

[Also make the following related change to the Florida Energy Conservation Code Chapter 6 [RE] ANSI reference section to update to latest version of ANSI/RESNET/ICC 380:]

Standard reference number	Title	Referenced in code section number
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

[No other changes to Chapter 6.]

Envelope Leakage Test Report (Blower Door Test)

Residential Prescriptive, Performance or ERI Method Compliance
2020 Florida Building Code, Energy Conservation, 7th Edition

Jurisdiction:	Permit #:

Job Information

Builder:	Community:	Lot:
Address:		
City:	State: FL	Zip:

Air Leakage Test Results

Passing results must meet either the Performance, Prescriptive, or ERI Method

○ **PRESCRIPTIVE METHOD-**The building or dwelling unit shall be tested and verified as having an air leakage rate of not exceeding 7 air changes per hour at a pressure of 0.2 inch w.g. (50 Pascals) in Climate Zones 1 and 2.

○ **PERFORMANCE or ERI METHOD-**The building or dwelling unit shall be tested and verified as having an air leakage rate of not exceeding the selected ACH(50) value, as shown on Form R405-2020 (Performance) or R406-2020 (ERI), section labeled as infiltration, sub-section ACH50.

ACH(50) specified on Form R405-2020-Energy Calc (Performance) or R406-2020 (ERI): ____

_________ x 60 ÷ _____________ = _____________

CFM(50) Building Volume ACH(50)

☐ **PASS**

☐ When ACH(50) is less than 3, mechanical ventilation installation must be verified by building department.

Method for calculating building volume:

○ Retrieved from architectural plans

○ Code software calculated

○ Field measured and calculated

R402.4.1.2 Testing. 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 Statues.*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.*

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, back draft 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.

Testing Company

Company Name: ________________________________ Phone: ______________________

I hereby verify that the above Air Leakage results are in accordance with the 2020 7th Edition Florida Building Code Energy Conservation requirements according to the compliance method selected above.

Signature of Tester: ________________________________ Date of Test: ______________________

Printed Name of Tester: ________________________________

License/Certification #: __________________________ Issuing Authority: ______________________

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RESNET®
RESIDENTIAL ENERGY SERVICES NETWORK

ICC INTERNATIONAL CODE COUNCIL®

ANSI/RESNET/ICC 380-2019

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

Approved American National Standard
ANSI

November 21, 2018

Residential Energy Services Network, Inc.
P.O. Box 4561
Oceanside, CA 92052-4561
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International Code Council
500 New Jersey Avenue, NW, 6th Floor
Washington, D.C. 20001
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The 2019 edition of this Standard was first approved for publication on November 1, 2018, by the RESNET Standards Management Board.

SPECIAL NOTE

This ANSI/RESNET/ICC Standard is a voluntary consensus standard developed under the auspices of the Residential Energy Services Network (RESNET) in accordance with RESNET's *Standards Development Policy and Procedures Manual*, Version 2.1, August 25, 2017. RESNET is an American National Standards Institute (ANSI) Accredited Standards Developer. Consensus is defined by ANSI as "substantial agreement reached by directly and materially affected interest categories." This signifies the concurrence of more than a simple majority but not necessarily unanimity. Consensus requires that all views and objections be considered, and that an effort be made toward their resolution. Compliance with this standard is voluntary until and unless a legal jurisdiction makes compliance mandatory.

RESNET obtains consensus through participation of it national members, associated societies, and public review.

This is the second edition of this Standard and supercedes the first edition that was designated and titled ANSI/RESNET 380-2016 Standard for Testing Airtightness of Building Enclosures, Airtightness of Heating and Cooling Air Distribution Systems, and Airflow of Mechanical Ventilation Systems. This second edition incorporates a number of substantive changes, the more significant of which are all addenda to the first edition and criteria specific to attached Dwelling and attached Sleeping Units in buildings of all heights.

This Standard is under continuous maintenance in accordance with Section 10.9 of the *RESNET Standard Development Policy and Procedures Manual.* Continuous maintenance proposals should be submitted to the Manager of Standards via the online form on the RESNET website. The Procedures Manual and online forms for submitting continuous maintenance proposals and requests for interpretation can be accessed from the website at www.resnet.us/blog/resnet-consensus-standards/ under the heading **RESNET CONSENSUS STANDARDS**.

The Manager of Standards should be contacted for:

a. Interpretation of the contents of this Standard
b. Participation in the next review of the Standard
c. Offering constructive criticism for improving the Standard
d. Permission to reprint portions of the Standard

Table of Contents

ANSI/RESNET/ICC 380-2019

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

Forward (Informative)

Standard 380 has been developed to provide a consensus national standard for consistent measurement of several air-flow related building metrics. It builds on existing American National Standards to provide standard procedures essential to the evaluation of the energy performance of Residential Buildings, as well as Dwelling Units and Sleeping Units within Residential or Commercial Buildings.

This Standard provides a consistent, uniform methodology for evaluating the airtightness of building, Dwelling Unit, and Sleeping Unit enclosures and heating and cooling air distribution systems, and the air flows of mechanical ventilation systems. These test procedures can be used as diagnostics, in quality assurance and control, for determining compliance with codes and standards, and to determine inputs to energy simulations and ratings. The Standard recognizes that some test procedures are easier to perform depending on building and HVAC system characteristics and that different codes and standards have specific testing requirements. Therefore, the Standard presents several alternative approaches for each measurement to allow flexibility in application of the standard.

Requirements for recording, documenting and reporting how the tests established by this standard are conducted and the test results shall be those established by the adopting entities.

This Standard is under continuous maintenance pursuant to RESNET's ANSI-accredited *Standards Development Policy and Procedures Manual*. Forms and procedures for submitting change proposals may be found on RESNET's Website at www.resnet.us/blog/resnet-consensus-standards/ under the heading **STANDARDS DEVELOPMENT**. When proposed addenda are available for public review and when approved addenda are published, notices will be published on RESNET's Website.

This Standard contains both normative and informative material. Normative materials make up the body of the Standard and must be complied with to conform to the Standard. Informative materials are clearly marked as such, are not mandatory, and are limited to this forward, footnotes, references and annexes.

1. Purpose

1.1. The provisions of this document are intended to establish national standards for testing the airtightness of enclosures and heating and cooling air distribution systems, and the airflow of mechanical ventilation systems. This Standard is intended for use by parties including home energy raters, energy auditors, or code officials who are evaluating the performance of Residential Buildings, or of Dwelling Units or Sleeping Units within Residential or Commercial Buildings.

2. Scope

2.1. This Standard defines procedures for measuring the airtightness of building, Dwelling Unit, and Sleeping Unit enclosures, the airtightness of heating and cooling air distribution systems, and the airflow of mechanical ventilation systems.

This Standard is applicable to all Dwelling Units and Sleeping Units in Residential and Commercial Buildings. The term Dwelling Unit can be replaced with Sleeping Unit throughout the standard, except where specifically noted.

This Standard provides separate procedures for measuring the airtightness of building enclosures and the airtightness of attached Dwelling Unit and Sleeping Unit enclosures.

The procedure for measuring the airtightness of heating and cooling air distribution systems is applicable to Dwelling Units and Sleeping Units with their own duct system separate from other Dwelling Units and Sleeping Units.

The procedure for measuring the airflow of mechanical ventilation systems is applicable to Dwelling Units and Sleeping Units with their own ventilation system or with a central/shared system.

3. Definitions

Blower Door – A device that combines an Air-Moving Fan as defined in Section 4.1.1, an Airflow Meter as defined in Section 4.1.3, and a covering to integrate the Air-Moving Fan into the building or Dwelling Unit opening.

Commercial Building – All buildings that are not included in the definition of Residential Buildings.

Compartmentalization Boundary - The surface that bounds the Infiltration Volume of the Dwelling Unit.

Conditioned Floor Area (CFA)[1] – The floor area of the Conditioned Space Volume within a building or Dwelling Unit, not including the floor area of attics, crawlspaces, and basements below air sealed and insulated floors. The following specific spaces are addressed to ensure consistent application of this definition:

[1] (Informative Note) Informative Annex A contains a table that summarizes parts of a Dwelling Unit that are included in Conditioned Floor Area.

- The floor area of a wall assembly that is adjacent to Conditioned Space Volume shall be included.
- The floor area of a basement shall be included if the party conducting the evaluation has either:
    - Obtained an ACCA Manual J, S, and either B or D report and verified that both the heating and cooling equipment and distribution system are designed to offset the entire design load of the volume, or,
    - Verified through visual inspection that both the heating and cooling equipment and distribution system serve the volume and, in the judgement of the party conducting evaluations, are capable of maintaining the heating and cooling temperatures specified by the Thermostat section in Table 4.2.2(1) of ANSI/RESNET/ICC 301.
- The floor area of a garage shall be excluded, even when it is conditioned.
- The floor area of a thermally isolated sunroom shall be excluded.
- The floor area of an attic shall be excluded, even when it is Conditioned Space Volume.
- The floor area of a crawlspace shall be excluded, even when it is Conditioned Space Volume.

Conditioned Space Volume[2] **-** The volume within a building or Dwelling Unit serviced by a space heating or cooling system designed to maintain space conditions at 78 °F (26 °C) for cooling and 68 °F (20 °C) for heating. The following specific spaces are addressed to ensure consistent application of this definition:

- If the volume both above and below a floor assembly meets this definition and is part of the subject Dwelling Unit, then the volume of the floor assembly shall also be included. Otherwise the volume of the floor assembly shall be excluded.
    - Exception: The wall height shall extend from the finished floor to the bottom side of the floor decking above the subject Dwelling Unit for non-top floor level Dwelling Units and to the exterior enclosure air barrier for top floor level Dwelling Units.
- If the volume of at least one of the spaces horizontally adjacent to a wall assembly meets this definition, and that volume is part of the subject Dwelling Unit, then the volume of the wall assembly shall also be included. Otherwise, the volume of the wall assembly shall be excluded.
    - Exception: If the volume of one of the spaces horizontally adjacent to a wall assembly is a Dwelling Unit other than the subject Dwelling Unit, then the volume of that wall assembly shall be evenly divided between both adjacent Dwelling Units.

[2] (Informative Note) Informative Annex A has a table that summarizes parts of a Dwelling Unit that are included in Conditioned Space Volume.

- The volume of an attic that is not both air sealed and insulated at the roof deck shall be excluded.
- The volume of a vented crawlspace shall be excluded.
- The volume of a garage shall be excluded, even when it is conditioned.
- The volume of a thermally isolated sunroom shall be excluded.
- The volume of an attic that is both air sealed and insulated at the roof deck, the volume of an unvented crawlspace, and the volume of a basement shall only be included if the volume is contiguous with the subject Dwelling Unit and the party conducting evaluations has either:
  - Obtained an ACCA Manual J, S, and either B or D report and verified that both the heating and cooling equipment and distribution system are designed to offset the entire design load of the volume, or,
  - Verified through visual inspection that both the heating and cooling equipment and distribution system serve the volume and, in the judgement of the party conducting evaluations, are capable of maintaining the heating and cooling temperatures specified by the Thermostat section in Table 4.2.2(1) of ANSI/RESNET/ICC 301.
- The volume of a mechanical closet, regardless of access location, that is contiguous with the subject Dwelling Unit shall be included if:
  - it is serviced by a space heating or cooling system designed to maintain space conditions at 78 °F (26 °C) for cooling and 68 °F (20 °C) for heating, and
  - it only includes equipment serving the subject Dwelling Unit, and
  - the mechanical room is not intentionally air sealed from the subject Dwelling Unit

Dwelling - Any building that contains one or two Dwelling Units used, intended, or designed to be built, used, rented, leased, let or hired out to be occupied, or that are occupied for living purposes.

Dwelling Unit - a single unit providing complete, independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, cooking, and sanitation.

Dwelling Unit Mechanical Ventilation – A mechanical exchange of indoor air with outdoor air throughout a Dwelling Unit, using a Balanced System, Exhaust System, Supply System, or combination thereof that is designed to operate continuously or through a programmed intermittent schedule to satisfy a Dwelling Unit ventilation rate.

Infiltration Volume[3] – The sum of the Conditioned Space Volume and additional adjacent volumes in the Dwelling Unit that meet the following criteria:

[3] (Informative Note) Informative Annex A has a table that summarizes parts of a Dwelling Unit that are included in Infiltration Volume.

- Crawlspaces and floor assemblies above crawlspaces, when the access doors or hatches between the crawlspace and Conditioned Space Volume are open during the enclosure airtightness test (Section 4.2.3),
- Attics, when the access doors or access hatches between the attic and Conditioned Space Volume are open during the enclosure airtightness test (Section 4.2.4),
- Basements and floor assemblies above basements, where the doors between the basement and Conditioned Space Volume are open during the enclosure airtightness test (Section 4.2.5).

Residential Building - Includes detached single-family Dwellings, two-family Dwellings and multiple single-family Dwellings (Townhouses) as well as International Building Code Group R-2, R-3 and R-4 buildings three stories or less in height above grade plane. (i.e. residential other than where occupants are transient, such as hotels and motels)

Sleeping Unit – A room or space in which people sleep, which can also include permanent provisions for living, eating, and either sanitation or kitchen facilities but not both. Such rooms and spaces that are also part of a Dwelling Unit are not Sleeping Units.

Townhouse - A single-family Dwelling Unit constructed in a group of three or more attached units in which each unit extends from foundation to roof and with open space on at least two sides.

Unconditioned Space Volume[4] - The volume within a building or Dwelling Unit that is not Conditioned Space Volume but which contains heat sources or sinks that influence the temperature of the area or room. The following specific spaces are addressed to ensure consistent application of this definition for inclusion in Unconditioned Space Volume:

- If either one or both of the volumes above and below a floor assembly is Unconditioned Space Volume, then the volume of the floor assembly shall be included.
- If the volume of both of the spaces horizontally adjacent to a wall assembly are Unconditioned Space Volume, then the volume of the wall assembly shall be included.
- The volume of an attic that is not both air sealed and insulated at the roof deck shall be included.
- The volume of a vented crawlspace shall be included.
- The volume of an attached garage shall be included, even when it is conditioned.
- The volume of a thermally isolated sunroom shall be included.
- The volume of an attic that is both air sealed and insulated at the roof deck, the volume of an unvented crawlspace, and the volume of a basement shall be included unless it meets the definition of Conditioned Space Volume.

Whole-House Fan – A forced air system consisting of a fan or blower that exhausts at least 5 ACH of indoor air to the outdoors and thereby drawing outdoor air into a home through open windows and doors for the purpose of cooling the home.

[4] (Informative Note) Informative Annex A has a table that summarizes parts of a Dwelling Unit that are included in Unconditioned Space Volume.

4. Procedure for Measuring Airtightness of Building or Dwelling Unit Enclosure

4.1. Equipment

The Equipment listed in this section shall have their calibrations checked at the manufacturer's recommended interval, and at least annually if no time is specified.

4.1.1. Air-Moving Fan. A fan that is capable of moving air into or out of the building or Dwelling Unit to achieve one or more target pressure differences between the building or Dwelling Unit and the exterior.

4.1.2. Manometer. A device that is capable of measuring pressure difference with a maximum error of 1 % of reading, or 0.25 Pa (0.001 in. H2O), whichever is greater.

4.1.3. Airflow Meter. A device to measure volumetric airflow with a maximum error of 5% of the measured flow.

4.1.4. Thermometer. An instrument to measure air temperature with an accuracy of ±1°C (2°F).

4.1.5. Blower Door. A device that combines an Air-Moving Fan as defined in Section 4.1.1, an Airflow Meter as defined in Section 4.1.3, and a covering to integrate the Air-Moving Fan into the building opening.

4.2. Procedure to Prepare the Building or Dwelling Unit for Testing[5]

4.2.1. Fenestration. Exterior doors and windows shall be closed and latched.

4.2.2. Attached garages. All exterior garage doors and windows shall be closed and latched unless the Blower Door is installed between the Conditioned Space Volume and the garage, in which case the garage shall be opened to outside by opening at least one exterior garage door.

4.2.3. Crawlspaces. Crawlspaces shall be configured as follows and the position of the crawlspace access doors and hatches shall be recorded. When the access doors and hatches between Conditioned Space Volume and the crawlspace are closed, due to requirements in 4.2.3.1or 4.2.3.2.1, the crawlspace shall be excluded from Infiltration Volume and Conditioned Space Volume.

4.2.3.1. If a crawlspace is vented to the exterior, interior access doors and hatches between the Conditioned Space Volume and the crawlspace shall be closed. Exterior crawlspace access doors, hatches, and vents shall be left in their as-found position.

4.2.3.2. If a crawlspace is not vented to the exterior, all access doors and hatches between the Conditioned Space Volume and crawlspace shall be opened.

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[5] (Normative Note) It is permissible for air tightness testing of Dwelling Units that contain fire suppression systems to be performed with temporary sprinkler head covers in place.

Exterior crawlspace access doors, hatches, and vents shall be closed to the extent possible.

4.2.3.2.1. Exception: If the floor above the crawlspace is air sealed and insulated, the access doors and hatches between the Conditioned Space Volume and crawlspace shall be closed. Exterior crawlspace access doors, hatches, and vents shall be left in their as-found position.

4.2.4. Attics. Attics shall be configured as follows and the position of the attic access doors and hatches shall be recorded. When the access doors and hatches between the Conditioned Space Volume and the attic are closed, due to requirements in 4.2.4.1 or there are no access doors, the attic shall be excluded from Infiltration Volume and Conditioned Space Volume.

4.2.4.1. If an attic is not *both* air sealed and insulated at the roof deck, access doors and hatches between the Conditioned Space Volume and the attic shall be closed. Exterior attic access doors, hatches and vents shall be left in their as-found position.

4.2.4.2. 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. Exterior attic access doors, vents, and hatches shall be closed to the extent possible.

4.2.5. Basements. Basements shall be configured as follows and the position of the basement doors shall be recorded. When doors between the Conditioned Space Volume and the basement are closed, due to requirements in 4.2.5.1.1, the basement shall be excluded from Infiltration Volume and Conditioned Space Volume.

4.2.5.1. All doors between the Conditioned Space Volume and basement shall be opened. Exterior basement access doors, vents, and hatches shall be closed to the extent possible.

4.2.5.1.1. Exception: When the floor above the basement is air sealed and insulated, doors between the basement and Conditioned Space Volume shall be closed. Exterior basement access doors, hatches and vents shall be left in their as-found position.

4.2.6. Interior doors. All doors between rooms inside the Conditioned Space Volume shall be opened.

4.2.7. Chimney dampers and combustion-air inlets on solid fuel appliances. Chimney dampers and combustion-air inlets on solid fuel appliances shall be closed. Precautions shall be taken to prevent ashes or soot from entering the building or Dwelling Unit during testing.

4.2.8. Combustion appliance flue vents. Combustion appliance flue vents shall be left in their as-found position.

4.2.9. Fans. Any fan or appliance capable of inducing airflow across the building or Dwelling Unit enclosure shall be turned off including, but not limited to, clothes dryers, attic and crawlspace fans, kitchen and bathroom exhaust fans, air handlers, and ventilation fans used in a Dwelling Unit Mechanical Ventilation system[6]. The party conducting the test shall not turn on fans in adjacent attached Dwelling Units. For continuously operating central ventilation systems serving more than one Dwelling Unit in a building with multiple Dwelling Units, the registers shall be sealed in the subject Dwelling Unit. The central ventilation system shall be turned off where possible. If it is not possible to turn off the system, then it can be left operating provided sealing select registers will not compromise the system and the sealed registers remain sealed during the test.

4.2.10. Dampers

4.2.10.1. Non-motorized dampers[7] that connect the Conditioned Space Volume to the exterior or to Unconditioned Space Volumes shall be left in their as-found positions.[8]

4.2.10.2. Motorized dampers that connect the Conditioned Space Volume to the exterior or to Unconditioned Space Volume shall be placed in their closed positions and shall not be further sealed.

4.2.11. Non-dampered openings for ventilation, combustion air and make-up air

4.2.11.1. Non-dampered ventilation openings of intermittently operating local exhaust ventilation systems[9] that connect the Conditioned Space Volume to the exterior or to Unconditioned Space Volume shall be left open.

4.2.11.2. Non-dampered ventilation openings of intermittently operating Dwelling Unit ventilation systems, including HVAC fan-integrated outdoor air inlets, that connect the Conditioned Space Volume to the exterior or to Unconditioned Space Volume shall not be sealed.

4.2.11.3. Non-dampered ventilation openings of continuously operating local exhaust ventilation systems[10] that connect the Conditioned Space Volume to the exterior or to Unconditioned Space Volume shall be sealed at the exterior of the enclosure where conditions allow.

4.2.11.4. Non-dampered ventilation openings of continuously operating Dwelling Unit ventilation systems that connect the Conditioned Space Volume to the exterior or to Unconditioned Space Volume shall be sealed at the exterior of the enclosure where conditions allow.

4.2.11.5. All other non-dampered intentional openings between Conditioned Space Volume and the exterior or Unconditioned Space Volume shall be left open.[11] This includes non-dampered openings to a duct, unless it has a fan that is

[6] (Informative Note) For example, a system intended to meet ASHRAE Standard 62.2.
[7] (Informative Note) For example, pressure-activated operable dampers and fixed dampers.
[8] (Informative Note) For example, a fixed damper in a duct supplying outdoor air for an intermittent ventilation system that utilizes the HVAC fan shall be left in its as-found position.
[9] (Informative Note) For example, bath fan and kitchen range fan.
[10] (Informative Note) For example, bathroom or kitchen exhaust.
[11] (Informative Note) For example, un-dampered combustion air or make-up air openings shall be left in their open position.

independent of the HVAC air-handler fan directly connected to the duct and continuously inducing a pressure difference[12].

4.2.12. Whole-House Fan louvers/shutters. Whole-House Fan louvers and shutters shall be closed. In addition, if there is a seasonal cover present, it shall be installed.

4.2.13. Evaporative coolers. The opening to the exterior of evaporative coolers shall be placed in its off position. In addition, if there is a seasonal cover present, it shall be installed.

4.2.14. Operable window trickle-vents and through-the-wall vents. Operable window trickle-vents and through-the-wall vents shall be closed.

4.2.15. Heating and cooling supply registers and return grilles. Heating and cooling supply registers and return grilles shall be left in their as-found position and left uncovered.

4.2.16. Plumbing drains with p-traps. Plumbing drains with empty p-traps shall be sealed or filled with water.

4.2.17. Vented combustion appliances. Vented combustion appliances shall remain off or in "pilot only" mode for the duration of the test.

4.2.18. Required air bypass. Where building code or manufacturer specifications require air bypass around a component, the leakage point shall not be sealed[13].

4.3. Procedures to Install the Test Apparatus and Prepare for Airtightness Test

4.3.1. Procedure to Install the Test Apparatus and Prepare for Airtightness Test for a Detached Dwelling Unit

4.3.1.1. The Blower Door shall be installed in an exterior doorway or window that has an unrestricted air pathway into the Dwelling Unit and no obstructions to airflow within 5 feet of the fan inlet and 2 feet of the fan outlet. The opening that is chosen shall be noted on the test report. The system shall not be installed in a doorway or window exposed to wind, where conditions allow. It is permissible to use a doorway or window between the Conditioned Space Volume and an Unconditioned Space Volume as long as the Unconditioned Space Volume has an unrestricted air pathway to the outdoors and all operable exterior windows and doors of the Unconditioned Space Volume are opened to the outdoors.

4.3.1.2. Tubing shall be installed to measure the difference in pressure between the enclosure and the outdoors in accordance with manufacturer's instructions. The tubing, especially vertical sections, shall be positioned out of direct sunlight.

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[12] (Informative Note) For example, a non-dampered duct connecting an air handler to outside shall be left open, even if a separate continuous or intermittent bathroom exhaust fan is present in the Dwelling Unit.
[13] (Informative Note) For example, fire and smoke suppression systems.

4.3.1.3. The indoor and outdoor temperatures shall be measured using the Thermometer and recorded. Observations of general weather conditions shall be recorded.

4.3.1.4. The altitude of the building site above sea level shall be recorded with an accuracy of 500 feet (150 m).

4.3.1.5. The model and serial number(s) of all measurement equipment shall be recorded.

4.3.1.6. If the results of the test will be reported as Air Changes Per Hour at 50 Pa (0.2 in. H_2O) (ACH50), the Infiltration Volume of the Dwelling Unit shall be recorded.

4.3.1.7. If the results of the test will be reported as Specific Leakage Area (SLA), the Conditioned Floor Area of the Dwelling Unit shall be recorded.

4.3.1.8. If the results of the test will be reported as Cubic Feet per Minute per square foot of enclosure surface area at 50 Pa (0.2 in. H_2O) (CFM50/ft^2 of enclosure), the Compartmentalization Boundary area of the Dwelling Unit shall be recorded.

4.3.2. Procedure to Install the Test Apparatus and Prepare for Airtightness Test for an Attached Dwelling Unit[14]

4.3.2.1. Pressures shall be induced only via a Blower Door (or Blower Doors) attached to the subject Dwelling Unit. Pressures shall not be induced through the use of Blower Doors attached to spaces adjacent to the subject Dwelling Unit.

4.3.2.2. The Blower Door shall be installed in a doorway leading to an enclosed space[15], when one exists. The Blower Door shall have an unrestricted air pathway into the subject Dwelling Unit and no obstructions to airflow within 5 feet of the fan inlet and 2 feet of the fan outlet. When a doorway leading to an enclosed space is not available, the Blower Door is permitted to be installed in an exterior door or window. The tubing setup procedures listed in Section 4.3.1.2 shall be followed. The opening that is chosen shall be noted on the test report.

4.3.2.2.1. The reference tube for the Dwelling Unit pressure shall terminate in the enclosed space. The end of the reference tube shall be located where it is not impacted by the turbulence created by the fan. Tubing shall be installed to measure the difference in pressure between the subject Dwelling Unit and the enclosed space in accordance with manufacturer's instructions.

[14] (Informative Note) This test is the same as a compartmentalization test.
[15] (Informative Note) For example, a corridor.

4.3.2.2.2. An unrestricted air pathway larger than 20 square feet shall be opened between the enclosed space and outside[16].

4.3.2.2.2.1. Where an unrestricted air pathway larger than 20 square feet cannot be created, the pressure difference between the enclosed space and outside shall be measured. The pressure difference shall change by less than 3 Pa when the Blower Door is turned on to pressurize or depressurize the subject Dwelling Unit by 50 Pa[17].

4.3.2.2.3. When a doorway leading to an enclosed space is not available, the Blower Door is permitted to be installed in an exterior door or window. The tubing setup procedures listed in Section 4.3.1.2 shall be followed.

4.3.2.3. Where access is permitted, open doors between the enclosed space and any Dwelling Units that are horizontally adjacent to the subject Dwelling Unit[18].

4.3.2.3.1. Leave windows and interior doors in adjacent Dwelling Units in the condition they are found.

4.3.2.4. The door where the Blower Door is installed shall be inspected for the presence of a door seal installed to minimize air leakage between the door and door frame. Where such seal is not present or is not properly installed, 140 CFM50 shall be added to the measured airflow. This adjustment, and the presence, installation quality and condition of the door seal shall be documented in the final test report[19].

4.3.2.5. If a door is present between the subject Dwelling Unit and its mechanical closet, it shall be open during the test if the mechanical closet is Conditioned Space Volume and closed during the test if the mechanical closet is Unconditioned Space Volume.

4.3.2.6. Ductwork between units shall be sealed at the register(s) of the subject Dwelling Unit.

4.3.2.7. Where the crawlspace volume is continuous below multiple adjacent Dwelling Units, interior access doors and hatches between the subject Dwelling Unit and the crawlspace shall be closed. Exterior crawlspace access doors, hatches and vents shall be left in their as-found position.

4.3.2.8. Where the attic volume is continuous above multiple adjacent Dwelling Units, interior access doors and hatches between the subject Dwelling Unit and the attic shall be closed. Exterior attic access doors, hatches and vents shall be left in their as-found position.

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[16] (Informative Note) For example, 1) opening windows in a corridor 2) opening a door between a corridor and a common stairwell and also opening a door between the common stairwell and outside 3) opening a door between an adjacent Dwelling Unit and the corridor and also opening windows in the adjacent unit.

[17] (Informative Note) It is permitted to reduce the pressure difference between the enclosed space and outside by opening interior doors to increase the volume of the enclosed space.

[18] (Informative Note) For example, the units on either side of the subject Dwelling Unit in a double loaded corridor style subject Dwelling Unit (2 units total).

[19] (Normative Note) The adjustment may be subsequently removed if the door sweep continuity is inspected and confirmed.

4.3.2.9. Where the basement volume is continuous below multiple adjacent Dwelling Units, interior doors between the subject Dwelling Unit and the basement shall be closed. Exterior basement access doors, hatches and vents shall be left in their as-found position.

4.3.2.10. Where the mechanical room volume is continuous below multiple adjacent Dwelling Units, interior doors between the subject Dwelling Unit and the mechanical room shall be closed. Exterior mechanical room access doors, hatches and vents shall be left in their as-found position.

4.3.2.11. The indoor and outdoor temperatures shall be measured using the Thermometer and recorded. Observations of general weather conditions shall be recorded.

4.3.2.12. The altitude of the building site above sea level shall be recorded with an accuracy of 500 feet (150 m).

4.3.2.13. The model and serial number(s) of all measurement equipment shall be recorded.

4.3.2.14. If the results of the test will be reported as Air Changes Per Hour at 50 Pa (0.2 in. H_2O) (ACH50), the Infiltration Volume of the Dwelling Unit shall be recorded.

4.3.2.15. If the results of the test will be reported as Specific Leakage Area (SLA), the Conditioned Floor Area of the Dwelling Unit shall be recorded.

4.3.2.16. If the results of the test will be reported as Cubic Feet per Minute per square foot of enclosure surface area at 50 Pa (0.2 in. H_2O) (CFM50/ft^2 of enclosure), the Compartmentalization Boundary area of the Dwelling Unit shall be recorded.

4.4. Procedure to Conduct Airtightness Test. The leakage of the enclosure shall be measured using either the One-Point Airtightness Test in Section 4.4.1 or the Multi-Point Airtightness Test in Section 4.4.2.

4.4.1. One-Point Airtightness Test

4.4.1.1. With the Air-Moving Fan turned off and sealed, the pressure difference across the enclosure shall be recorded using the Manometer, with the outside as the reference. The measurement shall represent the average value over at least a 10-second period and shall be defined as the Pre-Test Baseline Dwelling Unit Pressure.

4.4.1.2. The Air-Moving Fan shall be unsealed, turned on, and adjusted to create an induced enclosure pressure difference of 50 ±3 Pa (0.2 in. ±0.012 H_2O), defined as the induced enclosure pressure minus the Pre-Test Baseline Dwelling Unit Pressure. Note that this value is permitted to be positive or negative, which will be dependent upon whether the enclosure is pressurized or depressurized. An indication of whether the Air-Moving Fan pressurized or depressurized the Dwelling Unit shall be recorded.

If a 50 Pa (0.2 in. H_2O) induced enclosure pressure difference is achieved, then the average value of the induced enclosure pressure difference and the airflow at 50 Pa (0.2 in. H_2O), measured over at least a 10-second period, shall be recorded.

If a 50 Pa (0.2 in. H_2O) induced enclosure pressure difference is not achieved, then additional Air-Moving Fans shall be used or the highest induced enclosure pressure difference ($dP_{measured}$) and airflow ($Q_{measured}$) that was achieved with the equipment available, measured over at least a 10-second period, shall be recorded. A minimum of 15 Pa (0.06 in. H_2O) must be induced across the enclosure for the test to be valid.

4.4.1.3. The Air-Moving Fan shall be turned off and the Dwelling Unit returned to its as-found condition.

4.4.1.4. If an induced enclosure pressure difference of 50 Pa (0.2 in. H_2O) was not achieved in Section 4.4.1.2, then the recorded airflow ($Q_{measured}$) shall be converted to a nominal airflow at 50 Pa (0.2 in. H_2O) using Equation 1. Alternately, a Manometer that is equipped to automatically make the conversion to CFM50 or CMS50 is permitted to be used.

$$CFM50\left(\frac{ft^3}{min}\right) = Q_{measured}\left(\frac{ft^3}{min}\right)\left(\frac{50}{dP_{measured}}\right)^{0.65} \quad (1a)$$

$$CMS50\left(\frac{m^3}{s}\right) = Q_{measured}\left(\frac{m^3}{s}\right)\left(\frac{50}{dP_{measured}}\right)^{0.65} \quad (1b)$$

4.4.1.5. Corrected CFM50 (corrected CMS50) shall be calculated by making the adjustments due to density and viscosity using Section 9 of ASTM E779[20]. Equations 1 and 2 in Section 9 shall be used to convert air flows to flows through the building envelope. Equation 4 in Section 9 shall be used to convert to standard conditions by substituting CFM50 (CMS50) for C and Corrected CFM50 (corrected CMS50) for C_0.

4.4.1.6. The Effective Leakage Area (ELA) shall be calculated using Equation 2:

$$ELA(in^2) = \frac{Corrected\ CFM50}{18.2} \quad (2a)$$

$$ELA(m^2) = \frac{Corrected\ CMS50}{13.6} \quad (2b)$$

4.4.2. Multi-Point Airtightness Test

4.4.2.1. With the Air-Moving Fan turned off and sealed, the pressure difference across the enclosure shall be recorded using the Manometer, with the outside as the reference. The measurement shall represent the average value over at least a 10-second period and shall be defined as the Pre-Test Baseline Dwelling Unit Pressure.

[20] (Normative Note) Software provided by manufacturers of test equipment is permitted to be used to perform these calculations if the manufacturer certifies that the calculations are performed in accordance with ASTM E779.

4.4.2.2. The Air-Moving Fan shall be unsealed, turned on, and adjusted to create at least five induced enclosure pressure differences at approximately equally-spaced pressure stations between 10 Pa (0.04 in. H_2O) and either 60 Pa (0.24 in. H_2O) or the highest achievable pressure difference up to 60 Pa. The induced enclosure pressure difference is defined as the measured enclosure pressure at the pressure station, with reference to the exterior, minus the Pre-Test Baseline Dwelling Unit Pressure. If a manometer is used that has automatic baseline adjustments[21] then the Pre-Test Baseline Dwelling Unit Pressure shall not be subtracted from the adjusted value. The induced enclosure pressure difference is positive for pressurization and negative for depressurization. An indication of whether the Air-Moving Fan pressurized or depressurized the Dwelling Unit shall be recorded.

At each pressure station, the average value of the induced enclosure pressure difference, and the airflow, measured over at least a 10-second period, shall be recorded. The highest induced enclosure pressure difference shall be at least 25 Pa (0.1 in. H_2O). If 25 Pa (0.1 in. H_2O) is not achieved, the One-Point Airtightness Test in Section 4.4.1 shall be used.

4.4.2.3. The Air-Moving Fan shall be turned off and the Dwelling Unit returned to its as-found condition.

4.4.2.4. The airflow at each pressure station shall be corrected for altitude and temperature to determine the corrected airflow using the calculations in Section 9 of ASTM E779[22].

4.4.2.5. The corrected airflow (Q) and the induced enclosure pressure difference measured at each pressure station (dP) shall be used in a log-linearized regression of the form $Q = C(dP)^n$ to calculate[23,24] C and n.

4.4.2.6. The Effective Leakage Area (ELA) shall be calculated using Equation 3:

$$ELA(in^2) = C\left(\frac{ft^3}{minPa^n}\right) \times 0.567 \times 4^{(n-0.5)} \quad (3a)$$

$$ELA(m^2) = C\left(\frac{m^3}{sPa^n}\right) \times 0.775 \times 4^{(n-0.5)} \quad (3b)$$

Where C and n are the values determined in Section 4.4.2.5.

4.4.2.7. The flow through the building or Dwelling Unit enclosure at 50 Pa (0.20 in. H_2O) (CFM50 or CMS50) shall be calculated using Equation 4:

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[21] (Informative Note) for example, a "baseline" or "extrapolation" feature that automatically subtracts a previously-measured baseline from the measured value before displaying the measurement.

[22] (Normative Note) Software provided by manufacturers of test equipment is permitted to be used to perform these calculations if the manufacturer certifies that the calculations are performed in accordance with ASTM E779.

[23] (Informative Note) For example, using the procedures in ASTM E779, Section 9 and Annex A.1.

[24] (Normative Note) Software provided by the test equipment manufacturer that automatically calculates C and n shall not be used unless the manufacturer certifies that the calculations are performed in accordance with ASTM E779.

$$CFM50 = C\left(\frac{ft^3}{minPa^n}\right) \times 50^{(n)} \quad (4a)$$

$$CMS50 = C\left(\frac{m^3}{sPa^n}\right) \times 50^{(n)} \quad (4b)$$

Where C and n are the values determined in Section 4.4.2.5.

4.5. Procedure to Apply Results of Enclosure Air Leakage Test

4.5.1. If the results of the building or Dwelling Unit enclosure air leakage test are to be used for conducting an energy rating or assessing compliance with a building or Dwelling Unit enclosure leakage limit[25], then the corrected airflow determined using a one-point test shall be adjusted using Equation 5a or 5b.

Adjusted CFM50 = 1.1 x Corrected CFM50 (5a)

Adjusted CMS50 = 1.1 x Corrected CMS50 (5b)

The ELA determined in Section 4.4.1.6 for a one-point air leakage test shall be adjusted using Equation 6.

Adjusted ELA = 1.1 x ELA (6)

Other applications of building or Dwelling Unit enclosure air leakage testing and the results of multi-point testing do not require the corrections in this section.

4.5.2. If the results of the building or Dwelling Unit enclosure leakage test are to be converted to Air Changes Per Hour at 50 Pa (0.2 in. H_2O) (ACH50), Specific Leakage Area (SLA), Normalized Leakage Area (NLA), or compartmentalization leakage ratio at 50 Pa ($CFM50/ft^2$), then Equations 7 through 10 shall be used. Where adjusted or corrected CFM50, CMS50 or ELA values have been calculated in previous sections they shall be used in Equations 7 through 10.

ACH50 = CFM50 x 60 / Infiltration Volume in cubic feet (7a)

ACH50 = CMS50 x 3600 / Infiltration Volume in cubic meters (7b)

SLA = 0.00694 x ELA in in^2 */ Conditioned Floor Area in square feet* (8a)

SLA = 10.764 x ELA in m^2 */ Conditioned Floor Area in square meters* (8b)

NLA = SLA x $(S)^{0.4}$*, where S is the number of stories above grade* (9)

$CFM50/ft^2$ *= CFM50 / Compartmentalization Boundary area in square feet* (10)

5. Procedure for Measuring Airtightness of Duct Systems

[25] (Informative Note) For example, defined by code or by an energy efficiency program.

In addition to the test procedures in this section, Test Method A from ASTM E1554 is approved for use provided that the building, Dwelling Unit, and duct system preparation procedures in Sections 5.2.1 through 5.2.8 of this Standard are followed. The supply and return air leakage from Test Method A shall be added together and assumed equivalent to CFM25 or CMS25 to outside.

The leakage to outside test shall be performed using a Blower Door in the main entry to the Dwelling Unit to pressurize or depressurize the individual unit with reference to outside. If the main entry door is in an interior hallway then the hallway shall be well connected to outside through open windows or doors, or an exterior window or door[26] shall be used. Only the ducts serving the Dwelling Unit being tested shall be included in the test.

5.1. Equipment Needed
The Equipment listed in this section shall have their calibrations checked at the manufacturer's recommended interval, and at least annually if no time is specified.

5.1.1. Air-Moving Fan. A fan that is capable of moving air into or out of the duct system to achieve a pressure difference of 25 Pa (0.10 in. H_2O).

5.1.2. Manometer. A device that is capable of measuring pressure difference with an accuracy of ± 1% of reading or 0.25 Pa (0.0010 in. H2O), whichever is greater.

5.1.3. Flow Meter. A device to measure volumetric airflow with a maximum error of 5% of the measured flow.

5.1.4. Thermometer. An instrument to measure air temperature with an accuracy of ±1°C (±2°F).

5.1.5. Duct Leakage Tester. A device that combines an Air-Moving Fan as defined in Section 4.1.1 and a Flow Meter as defined in Section 5.1.3.

5.2. Procedure to Prepare the Building or Dwelling Unit and the Duct System for Testing

5.2.1. The presence of all components that are included in the HVAC design for the Dwelling Unit[27] and integrated with the duct system shall be verified. The leakage from these components must be captured when the test is conducted. If these components have not yet been installed[28], then the test shall not be conducted.

Exception: Complete installation of all components is not required if the authority having jurisdiction allows testing with missing components. Any missing components shall be documented in the final test report.

[26] (Informative Note) Such as windows and doors opening to decks or patios.
[27] (Informative Note) For example, heating, cooling, ventilation, dehumidification, humidification, and filtration components.
[28] (Informative Note) For example, an air handler has not yet been installed in new construction.

5.2.2. The HVAC system controls shall be adjusted so that the air handler fan does not turn on during the test.

5.2.3. Any fans that could change the pressure in either the Conditioned Space Volume or any spaces containing ducts or air handlers[29] shall be turned off.

5.2.4. All vented combustion appliances shall be turned off if there is a possibility that the space containing the appliance will be depressurized during the test procedure.

5.2.5. All filters in the duct system and air handler cabinet shall be removed. If the Duct Leakage Tester is installed at a return grille, any filters present at that grille shall also be removed. If present, filter slot cover(s) shall be replaced after removing filters.

5.2.6. Dampers within the duct system shall be treated as follows:

5.2.6.1. Non-motorized dampers[30] in ducts that connect the Conditioned Space Volume or any space-conditioning duct systems to the exterior or to Unconditioned Space Volume shall be left in their as-found positions.[31]

5.2.6.2. Motorized dampers in ducts that connect the Conditioned Space Volume or any space-conditioning duct systems to the exterior or to Unconditioned Space Volume shall be placed in their closed positions and shall not be further sealed.

5.2.6.3. All zone and bypass dampers shall be set to their open position to allow uniform pressures throughout the duct system.

5.2.6.4. All balancing dampers shall be left in their as-found position.

5.2.7. Non-dampered ventilation openings within the duct system shall be treated as follows:

5.2.7.1. Non-dampered ventilation openings or ducts that serve intermittently operating Dwelling Unit ventilation systems, including HVAC fan-integrated outdoor air inlets, that connect the Conditioned Space Volume or any space-conditioning duct systems to the exterior or to Unconditioned Space Volume shall not be sealed.

5.2.7.2. Non-dampered ventilation openings or ducts that serve continuously operating Dwelling Unit ventilation systems that connect the Conditioned Space Volume or any space-conditioning duct systems to the exterior or to Unconditioned Space Volume shall be sealed at the exterior of the enclosure where conditions allow.

5.2.8. Supply registers and return grilles shall be temporarily sealed at both the face and the perimeter. Registers atop carpets are permitted to be removed and the

[29] (Informative Note) For example, bathroom fans, clothes dryers, kitchen vent hood, attic fan.
[30] (Informative Note) For example, pressure-activated operable dampers, fixed dampers.
[31] (Informative Note) For example, a fixed damper in a duct supplying outdoor air for an intermittent ventilation system that utilizes the HVAC fan shall be left in its as-found position.

face of the duct boot temporarily sealed during testing. For Dwelling Units without registers and grilles present[32], the face of the duct boots shall be sealed instead.

5.3. Procedure to Install the Test Apparatus and Prepare for Airtightness Test

There are two acceptable methods for attaching the Duct Leakage Tester to the duct system. Method 1 is permitted to be used for all duct systems. Method 2 is permitted only if:

i) the duct system has three or fewer return grilles, or

ii) the total duct leakage is less than 50 cfm (25 L/s) at 25 Pa, or

iii) local codes require licensing, that parties conducting the test have not obtained, in order to remove the blower access panel or

iv) the air handler blower access is in an attic or crawlspace that has limited or restricted entry or exit[33]

- *Method 1 Installation*. The air handler blower access panel shall be removed and the Duct Leakage Tester attached to the blower compartment access.
- *Method 2 Installation*. The Duct Leakage Tester shall be attached to the largest return grille in the system. For systems with multiple returns of equal largest size, the return closest to the air handler shall be used. The remaining opening in the return grille and all other return grilles shall be temporarily sealed.

5.3.1. If the duct leakage to outside will be measured, then a Blower Door shall be installed in the enclosure per Sections 4.3.1.1 and 4.3.1.2 for a Detached Dwelling Unit or Section 4.3.2.2 for an attached Dwelling Unit.

5.3.2. The static pressure probe(s) for the Duct Leakage Tester shall be installed using one of the following options.

When using Method 2 for a duct system with more than three returns (based on the exception in Section 5.3 iv), then only Section 5.3.2.4 shall be used.

5.3.2.1. A single static pressure probe shall be located at the supply register closest to the air handler; or,

5.3.2.2. A single static pressure probe shall be located in the main supply trunk line, at least 5 feet from the air handler; or,

5.3.2.3. A single static pressure probe shall be located in the supply plenum; or,

5.3.2.4. A single static pressure probe shall be located according to Section 5.3.2.1, 5.3.2.2, or 5.3.2.3, and a second probe shall be located in the return plenum

[32] (Informative Note) For example, new construction.

[33] (Informative Note) For example, ladders, and temporary, movable, spiral, or articulated stairs will usually be considered a limited or restricted means of entry or exit.

or in the closest return grill to the air handler, unless this is where the Duct Leakage Tester is installed, in which case the second closest return grille to the air handler shall be used. The return duct system pressure probe shall not be located in the airstream of the duct tester.

5.3.3. The Manometer and tubing for the Duct Leakage Tester shall be connected to the pressure probe(s) installed in Section 5.3.2, in accordance with the manufacturer's instructions, so that the duct system pressure is capable of being measured with reference to the inside of the building or Dwelling Unit.

If Section 5.3.2.4 has been selected, then both the supply- and return-side duct system pressure probes shall be connected to a "tee" fitting, and the third leg of the "tee" shall then be connected to the Manometer in the position indicated by the manufacturer's instructions to measure the duct system pressure.

5.3.4. The locations where the Duct Leakage Tester and pressure probe(s) have been installed shall be recorded.

5.4. Procedure to Conduct Airtightness Test

The total leakage of the duct system shall be measured using the total duct leakage test in Section 5.4.1 or the leakage of the duct system to the outside shall be measured using the duct leakage to outside test in Section 5.4.2.

5.4.1. Total Duct Leakage Test

5.4.1.1. If ducts run through Unconditioned Space Volume including attics, garages or crawlspaces, then any vents, access panels, doors, or windows between those spaces and the outside shall be opened. At least one door, window or comparable opening between the building or Dwelling Unit and the outside shall be opened to prevent changes in building or Dwelling Unit pressure when the Duct Leakage Tester is running.

5.4.1.2. The Duct Leakage Tester shall be turned on and adjusted to create an induced duct system pressure difference of 25 ± 3 Pa (0.1± 0.012 in. H_2O) with reference to outside. Note that this value is permitted to be positive or negative, which will be dependent upon whether the duct system is pressurized or depressurized.

If a 25 Pa (0.1 in. H_2O) induced duct system pressure difference is achieved, then the average value of the duct system pressure difference and the airflow at 25 Pa (0.1 in. H_2O) (CFM25, CMS25), measured over at least a 10-second period, shall be recorded.

If a 25 Pa (0.1 in. H_2O) induced duct system pressure difference is not achieved, then the highest induced duct system pressure difference ($dP_{measured}$) and airflow ($CFM_{measured}$, $CMS_{measured}$) that was achieved with the equipment available, measured over at least a 10-second period, shall be recorded.

5.4.1.3. An indication of whether the Duct Leakage Tester is pressurizing or depressurizing the duct system shall be recorded.

5.4.1.4. The Duct Leakage Tester shall be turned off and the Dwelling Unit returned to its as-found condition.

5.4.1.5. If an induced duct system pressure difference of 25 Pa (0.1 in. H_2O) was not achieved in Section 5.4.1.2, then the recorded airflow ($CFM_{measured}$, $CMS_{measured}$) shall be converted to a nominal airflow at 25 Pa (0.1 in. H_2O) (CFM25, CMS25) using Equation 10. Alternately, a Manometer that is equipped to automatically make the conversion to CFM25 or CMS25 is permitted to be used.

$$CFM25 = CFM_{measured}\left(\frac{25}{dP}\right)^{0.6} \quad (10a)$$

$$CMS25 = CMS_{measured}\left(\frac{25}{dP}\right)^{0.6} \quad (10b)$$

5.4.2. Duct Leakage to Outside Test

5.4.2.1. If ducts run outside the Infiltration Volume including attics, garages or crawlspaces, then any vents, access panels, doors, or windows between those spaces and the outside shall be opened. All exterior doors and windows between the Infiltration Volume and outside shall be closed, and other openings to the outside with potential to hinder the ability of the Air-Moving Fan to achieve an induced enclosure pressure difference of 25 Pa (0.1 in. H_2O) with reference to outside shall be closed or covered in some manner. Interior doors shall be opened.

5.4.2.2. With the Air-Moving Fan for the enclosure and the Duct Leakage Tester sealed and turned off, one measurement of the pressure difference across the enclosure shall be recorded, with the outside as the reference. The measurement shall represent the average value over at least a 10-second period and shall be defined as the Pre-Test Baseline Dwelling Unit Pressure.

5.4.2.3. The Air-Moving Fan for the enclosure shall be unsealed, turned on, and adjusted to create an induced enclosure pressure difference of 25 ± 3 Pa (0.1 ±0.012 in. H_2O), defined as the induced enclosure pressure minus the Pre-Test Baseline Dwelling Unit Pressure. Note that this value is permitted to be positive or negative, which will be dependent upon whether the enclosure is pressurized or depressurized.

If a 25 Pa (0.10 in. H_2O) induced enclosure pressure difference is not achieved, then the highest possible value up to 25 (0.10 in. H_2O) Pa shall be achieved with the equipment available.

5.4.2.4. The Duct Leakage Tester shall be unsealed, turned on, and adjusted to create an induced duct system pressure difference of 0.0 ± 0.5 Pa (0.0±0.002 in. H_2O), relative to the Dwelling Unit. If an induced duct system pressure difference of 0.0 Pa (0.0 in. H_2O) is not achieved, then the airflow of the Air-Moving Fan for the enclosure shall be reduced until an induced duct system pressure difference of 0.0 Pa (0.0 in. H_2O) is achieved.

5.4.2.5. The induced enclosure pressure difference shall be re-checked and the Air-Moving Fan for the enclosure shall be adjusted to maintain 25 Pa (0.10 in. H_2O) or the highest achievable value up to 25 (0.10 in. H_2O) Pa, per Section 4.4.2.3, or the airflow required to maintain an induced duct system pressure difference of 0.0 Pa (0.0 in. H_2O), per Section 5.4.2.4.

5.4.2.6. The induced duct system pressure difference shall be re-checked and the Duct Leakage Tester shall be adjusted to maintain 0.0 ± 0.5 Pa (0.0±0.002 in. H_2O), per Section 5.4.2.4.

5.4.2.7. Repeat 5.4.2.5 and 5.4.2.6 until the induced enclosure pressure difference is 25 Pa (0.10 in. H_2O) or the highest achievable value up to 25 Pa (0.10 in. H_2O) and the induced duct system pressure difference is 0.0 Pa (0.0 in. H_2O).

- If a 25 Pa (0.10 in. H_2O) induced enclosure pressure difference is achieved, then the average value of the induced enclosure pressure difference, the induced duct system pressure difference, and the airflow at 25 Pa (0.10 in. H_2O) (CFM25, CMS25), measured over at least a 10-second period, shall be recorded.
- If a 25 Pa (0.10 in. H_2O) induced enclosure pressure difference is not achieved, then the average value of the highest induced enclosure pressure difference (dP_{high}), the induced duct system pressure difference, and the airflow (Q_{high}) that was achieved with the equipment available, measured over at least a 10-second period, shall be recorded.

5.4.2.8. An indication of whether the Air-Moving Fan for the enclosure is pressurizing or depressurizing the Dwelling Unit and whether the Duct Leakage Tester is pressurizing or depressurizing the duct system shall be recorded.

5.4.2.9. The Air-Moving Fan for the enclosure and the Duct Leakage Tester shall be turned off and the Dwelling Unit returned to its as-found condition.

5.4.2.10. If an induced enclosure pressure difference of 25 Pa (0.10 in. H_2O) was not achieved or a different value was used to achieve an induced duct system pressure difference of 0.0 Pa (0.0 in. H_2O), then the recorded airflow ($CFM_{measured}$, $CMS_{measured}$) shall be converted to a nominal airflow at 25 Pa (0.10 in. H_2O) (CFM25,CMS25) using Equation 10. Alternately, a Manometer that is equipped to automatically make the conversion to CFM25 or CMS25 is permitted to be used.

5.5. Procedure to Apply Results of Duct System Leakage Test

5.5.1. If the results of the duct system leakage test are to be used for assessing compliance with a limit on total duct system leakage[34], then the total duct leakage determined in Section 5.4.1.2 or 5.4.1.5 shall be used.

[34] (Informative Note) For example, defined by code or by an energy efficiency program.

5.5.2. If the results of the duct system leakage test are to be used for assessing compliance with a limit on duct system leakage to the outside[35], then the duct system leakage to outside determined in Section 5.4.2.7 or 5.4.2.10 shall be used. Alternatively, the total duct leakage determined in Section 5.4.1.2 or 5.4.1.5 is permitted to be used as if it were the leakage to outside[36].

5.5.3. If the results of the duct system leakage test are to be used for conducting an energy audit or predicting savings from retrofits, then the duct system leakage to outside determined in Section 5.4.2.7 or 5.4.2.10 shall be used.

[35] (Informative Note) For example, defined by code, by an energy efficiency program, or for a home energy rating.
[36] (Informative Note) For example, the total leakage value is permitted to be used in software as if it were leakage to the outside.

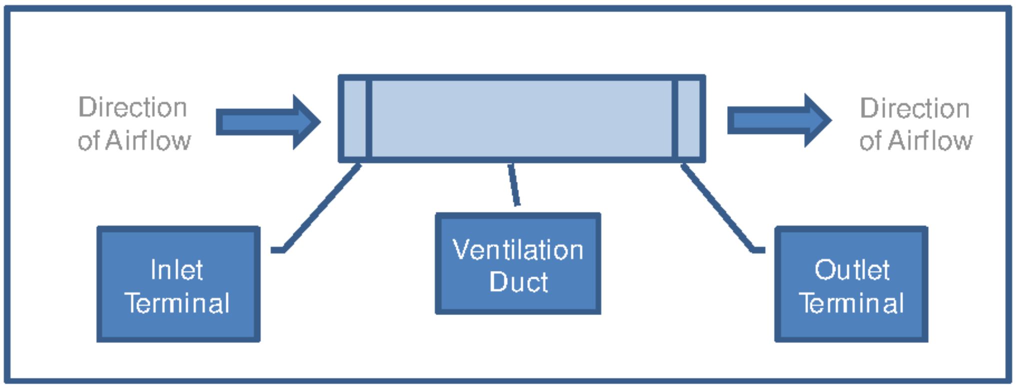
6. Procedure for Measuring Airflow of Mechanical Ventilation Systems

The purpose of this test procedure is to measure the volumetric airflow through a mechanical ventilation system including a Dwelling Unit Mechanical Ventilation system[37] or a local mechanical exhaust system[38, 39].

The airflow is permitted to be measured at the inlet terminal, per Section 6.2; or at the outlet terminal, per Section 6.3; or mid-stream in the ventilation duct, per Section 6.4.

The inlet terminal is defined as the location where the ventilation air enters the mechanical ventilation system and the outlet terminal is defined as the location where the ventilation air exits the mechanical ventilation system. A diagram of these locations for a generic mechanical ventilation system is shown in Figure 1.

Figure 1: Location of Terminals in Generic Mechanical Ventilation System



6.1. Procedure to Prepare the Building or Dwelling Unit and Mechanical Ventilation System for Testing

6.1.1. Interior Doors. All interior doors between rooms inside the Conditioned Space Volume shall be opened.

6.1.2. Ventilation openings. Operable window trickle-vents and through-the-wall vents shall be opened. Dampered and non-dampered ventilation openings shall not be sealed [40].

6.1.3. Supply registers and return grilles. Heating and cooling supply registers and return grilles shall be left in their as-found position and shall not be sealed.

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[37] (Informative Note) For example, an outdoor air duct connected to the return trunk of an HVAC system, an in-line supply fan, an HRV, or an ERV. The mechanical system ventilating the Dwelling Unit may be also ventilating other units.

[38] (Informative Note) For example, bathroom exhaust fan, kitchen exhaust fan.

[39] (Informative Note) Measuring the ventilation air supplied to corridors of buildings with multiple Dwelling Units is beyond the scope of this Standard. However, measuring the flow rate of exhaust or supply systems used for mechanical ventilation in individual Dwelling Units is within the scope of this Standard.

[40] (Informative Note) For example, a fixed damper in a duct supplying outdoor air for an intermittent ventilation system that utilizes the Blower Fan shall be left in its as-found position.

6.1.4. Balancing dampers. All balancing dampers shall be left in their as-found position.

6.1.5. Zone dampers. If a Dwelling Unit Mechanical Ventilation system is to be tested and is interconnected with a Forced-Air System, then all zone and bypass dampers shall be set to their open position. Otherwise, zone and bypass dampers shall be left in their as-found position.

6.1.6. Vented combustion appliances. Vented combustion appliances shall remain off or in "pilot only" mode for the duration of the test.

6.1.7. Forced-Air System Components. If a Dwelling Unit Mechanical Ventilation system is to be tested and uses the Blower Fan of a Forced-Air System as its primary fan, then the presence of all components included in the Forced-Air System design for the Dwelling Unit and integrated with the duct system [41] shall be verified. If these components have not yet been installed [42], then the test shall not be conducted.

6.1.8. Forced-Air System Blower Fan. The system controls shall be adjusted as follows:

6.1.8.1. If a Dwelling Unit Mechanical Ventilation system is to be tested and uses the Blower Fan of a Forced-Air System as its primary fan, then the Forced-Air System controls shall be adjusted to "Fan" mode so that the Blower Fan operates during the test.

6.1.8.2. Otherwise, the Forced-Air System controls shall be adjusted so that the Blower Fan does not operate during the test.

6.1.9. Local Mechanical Exhaust or Dwelling Unit Mechanical Ventilation System Fan. The fan of the Local Mechanical Exhaust system or Dwelling Unit Mechanical Ventilation system under test shall be turned on. For Dwelling Unit Mechanical Ventilation systems that use the Blower Fan of a Forced-Air System as its primary fan, then this shall be accomplished according to Section 6.1.8.

6.1.10. Other Fans. Any other fans that could change the pressure in either the Conditioned Space Volume or any spaces containing the ducts of the Dwelling Unit Mechanical Ventilation system or Local Mechanical Exhaust system [43] under test shall be turned off.

6.2. Procedure to Measure Airflow at Inlet Terminal

This Section defines procedures to measure the airflow of a mechanical ventilation system at an inlet terminal. The airflow is permitted to be measured using a Powered Flow Hood (Section 6.2.1); using an Airflow Resistance Device (Section 6.2.2); or using a Passive Flow Hood (Section 6.2.3).

6.2.1. Powered Flow Hood

6.2.1.1. Equipment Needed

[41] (Informative Note) For example, heating, cooling, ventilation, dehumidification, humidification, and filtration components.
[42] (Informative Note) For example, an air handler has not yet been installed in new construction.
[43] (Informative Note) For example, clothes dryers, attic fan.

The Equipment listed in this section shall have their calibrations checked at the manufacturer's recommended interval, and at least annually if no time is specified.

6.2.1.1.1. Powered Flow Hood. A device consisting of a flow capture element capable of creating an airtight perimeter seal around the inlet terminal; an Airflow Meter capable of measuring the volumetric airflow through the flow capture element with an a maximum error of 5 % or 5 cfm (2.5 L/s or 0.0025 m^3/s), whichever is greater; and a variable-speed Air-Moving Fan that is capable of moving air through the flow capture element and Airflow Meter.

6.2.1.1.2. Manometer. A device that is capable of measuring the static pressure inside the flow capture element relative to the room with a maximum error of 1% of reading or 0.25 Pa (0.0010 in. H2O), whichever is greater.

6.2.1.2. Procedure to Conduct Airflow Test

6.2.1.2.1. The flow capture element of the Powered Flow Hood shall be placed over the inlet terminal, ensuring that an airtight perimeter seal has been created.

6.2.1.2.2. The variable-speed Air-Moving Fan shall be turned on and the airflow adjusted until, using the Manometer, zero pressure difference (+/- 0.1 Pa (0.0004 in H_2O)) is measured between the flow capture element and the room.

6.2.1.2.3. The average volumetric airflow through the Airflow Meter, measured over at least a 10-second period, shall be recorded, and the variable-speed Air-Moving Fan shall be turned off.

6.2.2. Airflow Resistance Device

6.2.2.1. Equipment Needed

The Equipment listed in this section shall have their calibrations checked at the manufacturer's recommended interval, and at least annually if no time is specified.

6.2.2.1.1. Airflow Resistance Device. A device consisting of a flow capture element that has a known opening area and is capable of creating an airtight perimeter seal around the inlet terminal.

6.2.2.1.2. Manometer. A device that can measure pressure difference with a maximum error of 1% of reading or 0.25 Pa (0.0010 in. H2O), whichever is greater.

6.2.2.2. Procedure to Conduct Airflow Test

6.2.2.2.1. The flow capture element of the Airflow Resistance Device shall be placed over the inlet terminal, ensuring that an airtight perimeter seal has been created.

6.2.2.2.2. The opening area of the Airflow Resistance Device shall be adjusted until, using the Manometer, the pressure difference between the flow capture element and the room meets the manufacturer's requirements. If no manufacturer's requirement exists then the pressure shall be between 1 and 8 Pa (0.004 and 0.032 in. water).

6.2.2.2.3. The average pressure difference (dP) between the flow capture element and the room, measured over at least a 10-second period, shall be recorded.

6.2.2.2.4. Using the average pressure difference, the airflow shall be calculated using the manufacturer's flow conversion table or, for devices without a flow conversion table, the following equations:

$$Airflow\ (CFM) = Opening\ Area\ x\ 1.07\ x\ (dP)^{0.5} \quad (11a)$$

$$Airflow\ (L/s) = Opening\ Area\ x\ 0.078\ x\ (dP)^{0.5} \quad (11b)$$

Where: For Eq. 11a, Opening Area is in in^2 and dP is in Pa
For Eq. 11b, Opening Area is in cm^2 and dP is in Pa

6.2.2.3. Limitations of Procedure. An Airflow Resistance Device is only permitted to be used on mechanical ventilation systems that do not have multiple duct branches.

6.2.3. Passive Flow Hood

6.2.3.1. Equipment Needed

The Equipment listed in this section shall have their calibrations checked at the manufacturer's recommended interval, and at least annually if no time is specified.

6.2.3.1.1. Passive Flow Hood. A device consisting of a flow capture element capable of creating an airtight perimeter seal around the inlet terminal; and an Airflow Meter capable of measuring the volumetric airflow through the flow capture element with a maximum error of 5 % or 5 cfm (2.5 L/s or 0.0025 m^3/s), whichever is greater.

6.2.3.1.2. Manometer. A device that is capable of measuring pressure difference with a maximum error of 1% of reading or 0.25 Pa (0.0010 in. H2O), whichever is greater.

6.2.3.2. Procedure to Conduct Airflow Test

6.2.3.2.1. The flow capture element of the Passive Flow Hood shall be placed over the inlet terminal, ensuring that an airtight perimeter seal has been created.

6.2.3.2.2. A tube shall be inserted inside the flow capture element between the Airflow Meter and inlet terminal to allow for measurement of the pressure difference between inside the Passive Flow Hood and the room. Devices that have a built-in pressure tube are acceptable.

6.2.3.2.3. The pressure difference between the flow capture element and the room shall be measured. The procedure shall be terminated and no results recorded if: (1) the pressure difference exceeds test equipment manufacturer's recommendations, or (2) there is no manufacturer recommendation, and the pressure difference is more than 8 Pa.

6.2.3.2.4. The airflow through the Airflow Meter shall be averaged over at least a 10-second period.

6.3. Procedure to Measure Airflow at Outlet Terminal

This Section defines procedures to measure the airflow of a mechanical ventilation system at an outlet terminal. The airflow is permitted to be measured using a Powered Flow Hood (Section 6.3.1) or using a Bag Inflation Device (Section 6.3.2).

6.3.1. Powered Flow Hood. To measure airflow at an outlet terminal using a Powered Flow Hood, Section 6.2.1 shall be followed except with all occurrences of the phrase "inlet terminal" replaced with "outlet terminal".

6.3.2. Bag Inflation Device

6.3.2.1. Equipment Needed

6.3.2.1.1. Bag Inflation Device. A flow capture element capable of creating an airtight perimeter seal around the outlet terminal that is connected to a plastic bag of known volume and holds the bag open[44], and a shutter that controls airflow into the bag.

The plastic bag shall be selected such that three or more measurements of a single outlet terminal produce results that are within 20% of each other.

The volume of the plastic bag shall be selected such that the bag will completely fill with air from the outlet terminal in the range of 3 to 20 seconds.

6.3.2.1.2. Stopwatch. A stopwatch capable of recording elapsed time +/- 0.1 seconds.

6.3.2.2. Procedure to Conduct Airflow Test

6.3.2.2.1. The bag shall be completely emptied of air and the shutter closed to prevent airflow into the bag.

6.3.2.2.2. The Bag Inflation Device shall be placed over the outlet terminal.

6.3.2.2.3. The shutter shall be removed rapidly and the Stopwatch started.

6.3.2.2.4. The Stopwatch shall be stopped when the bag is completely filled with air from the outlet terminal and the elapsed time recorded.

6.3.2.2.5. The airflow shall be calculated using the following equations:

[44] (Informative Note) For example, a lightweight frame made of wood, plastic or metal wire.

$$Airflow\ (CFM) = \frac{8 \times Volume}{Elapsed\ Time} \quad (12a)$$

$$Airflow\ (L/s) = \frac{4 \times Volume}{Elapsed\ Time} \quad (12b)$$

Where: Volume = The volume of the plastic bag, in gallons
Elapsed Time = The time that elapsed until the bag was filled, in seconds.

6.4. Procedure to Measure Airflow Mid-Stream in the Ventilation Duct

This Section defines a procedure to measure the airflow of a mechanical ventilation system mid-stream in the ventilation duct. The airflow is permitted to be measured using an Airflow Measurement Station (Section 6.4.1) or using an Integrated Diagnostic Tool (Section 6.4.3).

6.4.1. Equipment Needed

6.4.1.1. Airflow Measurement Station. An Airflow Measurement Instrument capable of simultaneously measuring and averaging velocity pressure across a duct diameter with a maximum error of 10% or 5 CFM (2.5 L/s), whichever is greater, coupled with a section of permanently installed smooth-walled ductwork designed to facilitate accurate readings. The Airflow Measurement Instrument shall either be temporarily inserted into the Station for the duration of the procedure or be permanently installed as part of the Station.[45] The Airflow Measurement Instrument shall contain a port that allows it to be connected to a Manometer. Any temporary air flow station shall have its calibration checked at the manufacturer's recommended interval, and at least annually if no time is specified.

6.4.1.2. Manometer. A device that is capable of measuring pressure difference with a maximum error of 1% of reading or 0.25 Pa (0.0010 in. H2O), whichever is greater.

6.4.2. Procedure to Conduct Airflow Test

6.4.2.1. The Air Flow Measurement Station shall be installed in an accessible location, per manufacturer's instructions, or it shall be verified that such a device has been installed and is accessible. If the Airflow Measurement Instrument is not permanently installed, it shall be inserted into the measurement port of the Station.

6.4.2.2. The installation shall be visually verified to comply with the Airflow Measurement Instrument's specifications for minimum distance to both upstream and downstream duct fittings and fan outlets.[46]

6.4.2.3. The cross-sectional area of the duct at the Station shall be recorded in ft^2 or m^2.

[45] (Informative Note) For example, as part of a manufacturer-assembled device consisting of the instrument factory-mounted in a housing.
[46] (Informative Note) To minimize turbulence and ensure an accurate reading.

6.4.2.4. The Manometer shall be connected to the Airflow Measurement Instrument, and the average velocity pressure, measured over at least a 10-second period, shall be recorded.

6.4.2.5. If the Airflow Measurement Instrument is not permanently installed, then it shall be removed and the port sealed with a sheet metal plug or metallic tape.

6.4.2.6. Using the average velocity pressure, the average velocity in feet per minute (FPM) or meter per second (m/s) shall be calculated using the Airflow Measurement Instrument manufacturer's velocity conversion table or equation.

6.4.2.7. Equation 13 shall be used to convert the average velocity to airflow.

$$Airflow\ (CFM) = V\ x\ A \qquad (13a)$$

$$Airflow\ (L/s) = 1000\ x\ V\ x\ A \qquad (13b)$$

Where:

For Equation 13a, V = Velocity, in fpm, and A = Cross-Sectional Duct Area, in ft^2.

For Equation 13b, V = Velocity, in m/s, and A = Cross-Sectional Duct Area, in m^2.

6.4.3. Integrated Diagnostic Tool

6.4.3.1. Equipment

6.4.3.1.1. Integrated Diagnostic Tool. A tool that is integrated into the ventilation equipment[47] that permits assessment of airflow. The maximum error of the integrated diagnostic tool shall be 15% of the highest flow setting of the ventilation equipment.

6.4.3.2. Procedure to Conduct Airflow Test. Follow the manufacturer-provided instructions for the Integrated Diagnostic Tool to determine the airflow.

7. Air Handler Flow

7.1. The air handler flow shall be measured in accordance with ASHRAE 152 or ASTM E1554M.

8. Hazards

8.1. Equipment Guards - The air-moving equipment shall be listed by an accredited certification body[48] and include all proper guards or cages to house the fan or blower and to prevent accidental access to any moving parts of the equipment.

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[47] (Informative Note) For example, pressure taps, a device that measures a parameter such as watt draw that can be translated to airflow.

[48] (Informative Note) Listing is indicated by the certification body's certification mark on the equipment such as "UL", "CSA", "CE" or equivalent.

8.2. Personal Protective Equipment - Use of safety equipment appropriate for general fieldwork is required; all local or federal OSHA requirements shall be followed.

8.3. Debris and Fumes - The blower or fan forces a large volume of air into or out of a building or Dwelling Unit while in operation. Caution shall be exercised against sucking debris or exhaust gases from fireplaces and flues into the interior of the building or Dwelling Unit. Care shall be exercised to prevent damage to internal furnishings, plants or pets due to influx of cold, warm or humid air. If the building or Dwelling Unit will not remain unoccupied, except for testing personnel during the test, care shall be exercised regarding the potential for the fans to introduce respiratory hazards to the breathing zone of the occupied space.

8.4. Access and Working Space - The testing procedures for ventilation flow measurements sometimes require the use of ladders and/or access to equipment rooms, unfinished attics, and other volumes containing air distribution ducting in the building or Dwelling Unit that are not intended for occupancy. Caution must be exercised in these spaces to avoid injury and damage to the building or Dwelling Unit.

9. Normative References

ACCA, “Manual B Balancing and Testing Air and Hydronic Systems”, Air Conditioning Contractors of America, Arlington, VA.

ACCA, “Manual D Residential Duct Systems”, [ANSI/ACCA 1 Manual D-2016], Air Conditioning Contractors of America, Arlington, VA.

ACCA, “Manual J Residential Load Calculation,” 8th Edition, [ANSI/ACCA 2 Manual J-2016]. Air Conditioning Contractors of America, Arlington, VA.

ACCA, “Manual S Residential Heating and Cooling Equipment Selection”, 2nd Edition, [ANSI/ACCA 3 Manual S-2014]. Air Conditioning Contractors of America, Arlington, VA.

ANSI/RESNET/ICC 301-2019 “Standard for the Calculation and Labeling of the Energy Performance of Dwelling and Sleeping Units using an Energy Rating Index” and ANSI approved Addenda. Residential Energy Services Network, Oceanside, CA.

ASHRAE Standard 62.2-2016 "Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings", ASHRAE, Atlanta, GA.

ASHRAE 152-2014 “Method of Test for Determining the Design and Seasonal Efficiencies of Residential Thermal Distribution Systems”, ASHRAE, Atlanta, GA.

ASTM E1554-13 “Standard Test Methods for Determining Air Leakage of Air Distribution Systems by Fan Pressurization”, published by ASTM International, www.astm.org

ASTM E779-10 “Standard Test Method for Determining Air Leakage Rate by Fan Pressurization”, published by ASTM International, www.astm.org

International Building Code 2018, International Code Council, Washington, D.C.

10. Informative References

American National Standards Institute, ANSI, (http://www.ansi.com)

International Code Council, ICC, (http://www.iccsafe.org)

Occupational Safety and Health Administration, OSHA, (https://www.osha.gov)

Residential Energy Services Network, Inc., RESNET, (http://www.resnet.us)

Informative Annex A

Space Type	Included In the Following Categories?			
	Conditioned Space Volume	Unconditioned Space Volume	Conditioned Floor Area	Infiltration Volume
Space conditioned to 68/78F (excluding attics, basements, crawlspaces, garages, and sunrooms, which are addressed below)	Yes		Yes	Yes
Attic				
Attic air sealed & insulated at roof deck, and conditioned [1]	Yes			Sometimes
Attic air sealed & insulated at roof deck, but not conditioned		Yes		Sometimes
Attic not air sealed & insulated at roof deck		Yes		
Walls				
Wall assembly, where at least one horizontally-adjacent space is conditioned, and where it is part of the subject Dwelling Unit (it is not adjacent to another Dwelling Unit)	Yes		Yes	Yes
Wall assembly, where both horizontally-adjacent spaces are conditioned, and where one of the spaces is *not* part of the subject Dwelling Unit (it is a wall that separates the subject Dwelling Unit from an adjacent Dwelling Unit)	Yes, but only ½ of the wall is included		Yes, but only ½ of the wall area	Yes, but only ½ of the volume
Wall assembly, with both horizontally-adjacent spaces unconditioned		Yes		
Floors				
Floor assembly, where volume above & below is conditioned, and where it is part of the subject Dwelling Unit (floor cavity above the subject Dwelling Unit's ceiling), or bottom-floor floor cavity below the subject Dwelling Unit). All floor cavities are part of the subject Dwelling Unit when there are no other Dwelling Units above or below the subject Dwelling Unit.	Yes			Yes
Floor assembly, with either volume above or below unconditioned		Yes		Yes
Floor assembly, with both volume above and below unconditioned		Yes		
Crawlspaces				
Unvented crawlspace, conditioned [1]	Yes			Sometimes [3]
Unvented crawlspace, not conditioned		Yes		Sometimes [3]
Vented crawlspace		Yes		

Other				
Basement, conditioned [2]	Yes		Yes	Sometimes [3]
All other basements		Yes		Sometimes [3]
Garage, even if conditioned		Yes		
Thermally isolated sunroom		Yes		
Mechanical closet in Conditioned Space Volume[4]	Yes		Yes	Yes
Mechanical closet not in Conditioned Space Volume[4]		Yes		

1) *To be considered conditioned, the party conducting evaluations must obtain an ACCA Manual J, S, and either B or D report and verify that both the heating and cooling equipment and distribution system are designed to offset the entire design load of the volume.*
2) *To be considered conditioned, the party conducting evaluations must: obtain an ACCA Manual J, S, and either B or D report and verify that both the heating and cooling equipment and distribution system are designed to offset the entire design load of the volume; or verify through visual inspection that both the heating and cooling equipment and distribution system serve the volume and, in the judgement of the party conducting evaluations, are capable of maintaining the heating and cooling temperatures specified by the Thermostat section in Table 4.2.2(1) of ANSI/RESNET/ICC 301.*
3) *Include attic, basement or crawl space in Infiltration Volume if the door(s) or hatch(es) between that space and Conditioned Space Volume are open during enclosure air leakage testing (Section 4.2.3, 4.2.4, and 4.2.5).*
4) *Refer to definition of Conditioned Space Volume*

EN7678

Date Submitted	12/10/2018	**Section**	1	**Proponent**	Jeff Sonne for FSEC
Chapter	Appendix RD	**Affects HVHZ**	No	**Attachments**	Yes

TAC Recommendation Approved as Submitted
Commission Action Pending Review

Comments

General Comments **No** **Alternate Language** **Yes**

Related Modifications

Summary of Modification

Modify Energy Performance Level (EPL) Display Card.

Rationale

The proposed new EPL Display Card provides additional project component and equipment information compared to the current EPL Card, including breaking out windows by SHGC and U-factor (instead of averaging), and allowing additional floor, wall, ceiling and HVAC system types to be shown as needed. This additional detail is especially helpful for efficiency verification of larger projects and has been requested by some building departments.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Should assist code officials by providing more detailed EPL Card.

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

None; only facilitates verification.

Impact to industry relative to the cost of compliance with code

None; only facilitates verification.

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

None; only facilitates verification.

Requirements

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

Benefits general public by facilitating code compliance verification.

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

Improves the code by facilitating code compliance verification.

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

Does not discriminate; facilitates code compliance verification.

Does not degrade the effectiveness of the code

Increases effectiveness of the code by facilitating code compliance verification.

2nd Comment Period

7678-A1

Proponent Jeff Sonne for FSEC **Submitted** 5/22/2019 **Attachments** Yes

Rationale

Same rationale as original mod which was approved during first TAC meeting. This alternative language version revises "Energy Rating" language in the first footnote of the Card as agreed on during the first TAC meeting. It also fixes Windows section Area Weighted Average Overhang Depth and SHGC units errors, removes a typo asterisk from the Heating systems section and adds date/time, software version and page numbering at the bottom of the card.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Same as original mod.

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

Same as original mod.

Impact to industry relative to the cost of compliance with code

Same as original mod.

Impact to Small Business relative to the cost of compliance with code

None; only facilitates verification.

Requirements

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

Same as original mod.

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

Same as original mod.

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

Same as original mod.

Does not degrade the effectiveness of the code

Same as original mod.

EN7678 -A1 Text Modification

[See attached file.]

Page: 1

http://www.floridabuilding.org/Upload/Modifications/Rendered/Mod_7678_A1_TextOfModification_1.png

[Starting from the original mod, make the following changes as indicated below: 1) change the Energy Rating language in the first footnote, 2) fix Windows section Area Weighted Average Overhang Depth and SHGC units errors, 3) remove typo asterisk from Heating system section, 4) add date and time, software version and compliance statement, and page numbering at bottom of card:]

ENERGY PERFORMANCE LEVEL (EPL) DISPLAY CARD

ESTIMATED ENERGY PERFORMANCE INDEX* = [value]

The lower the Energy Performance Index, the more efficient the home.

[Address]

1.	New home or, addition		
2.	Single family or multiple family	-family	
3.	Number of units (if multiple family)	[#]	
4.	Number of Bedrooms	[#]	
5.	Is this a worst case? (yes/no)		
6.	Conditioned floor area (sq. ft.)		
7.	Windows**	Description	Area
	a. U-Factor: SHGC:	U-Factor: SHGC:	ft²
	b. U-Factor: SHGC:	[Type or N/A], U =	ft²
	c. U-Factor: SHCG:	[Type or N/A], U =	ft²
	d. U-Factor: SHGC:	[Type or N/A], U =	ft²
	Area Weighted Average Overhang Depth:		ft<u>.</u>~~²~~
	Area Weighted Average SHGC:		~~ft.~~
8.	Skylights	Description	Area
	a. U-Factor: SHGC:	U-Factor: SHGC:	ft²
9.	Floor type, insulation level	Insulation	Area
	a. [Type]	R =	ft²
	b. [Type or N/A]	R =	ft²
	c. [Type or N/A]	R =	ft²

10. Wall type and insulation	Insulation	Area	
a. [Type]	R =	ft²	
b. [Type or N/A]	R =	ft²	
c. [Type or N/A]	R =	ft²	
d. [Type or N/A]	R =	ft²	
11. Ceiling type and insulation level	Insulation	Area	
a. [Type]	R =	ft²	
b. [Type or N/A]	R =	ft²	
c. [Type or N/A]	R =	ft²	
12. Ducts, location and insulation level			
a. Sup: [loc.], Ret: [loc], AH: [loc]		R	ft²
b. Sup: , Ret: , AH: [or N/A]			
13. Cooling systems	kBtu/hr	Efficiency	
a. [Type]			
b. [Type or N/A]			
c. [Type or N/A]			
14. Heating systems	kBtu/hr	Efficiency	
a. [Type]			
b. [Type or N/A]			
c. [Type or N/A]~~*~~			
15. Water heating system			
a. [Type]	Cap: [#] gallons		
b. Conservation features	UEF:		

Use medium draw pattern UEF provided by manufacturer.

Credits (Performance method)

I certify that this home has complied with the *Florida Building Code, Energy Conservation,* through the above energy saving features which will be installed (or exceeded) in this home before final inspection. Otherwise, a new EPL Display Card will be completed based on installed Code compliant features.

Builder Signature: ______________________________ Date: _____________________

Address of Home: _____________________________________ City/FL Zip: __________________________

*Note: This is not a Building Energy Rating. If your Index is below 70, your home may qualify for energy efficient mortgage (EEM) incentives if you obtain a<u>n</u> ~~Florida~~ Energy~~Gauge~~ Rating. For information about the *Florida Building Code, Energy Conservation*, contact the Florida Building Commission's support staff.

**Label required by Section R303.1.3 of the *Florida Building Code, Energy Conservation*, if not DEFAULT.

<u>[Date and time]</u> <u>[Software version and code compliance statement]</u> <u>[Page # of #]</u>

[Replace existing EPL Display Card in its entirety with the EPL Display Card below (also attached as PDF).]

SEE IMAGES BELOW

ENERGY PERFORMANCE LEVEL (EPL) DISPLAY CARD

ESTIMATED ENERGY PERFORMANCE INDEX* = [value]

The lower the Energy Performance Index, the more efficient the home.

[Address]

1. New home or, addition
2. Single family or multiple family ______-family
3. Number of units (if multiple family) ______[#]
4. Number of Bedrooms ______[#]
5. Is this a worst case? (yes/no)
6. Conditioned floor area (sq. ft.)

7. Windows**	Description	Area
a. U-Factor: SHGC:	U-Factor: SHGC:	ft^2
b. U-Factor: SHGC:	[Type or N/A], U =	ft^2
c. U-Factor: SHCG:	[Type or N/A], U =	ft^2
d. U-Factor: SHGC:	[Type or N/A], U =	ft^2
Area Weighted Average Overhang Depth:		ft^2
Area Weighted Average SHGC:		ft.

8. Skylights	Description	Area
a. U-Factor: SHGC:	U-Factor: SHGC:	ft^2

9. Floor type, insulation level	Insulation	Area
a. [Type]	R =	ft^2
b. [Type or N/A]	R =	ft^2
c. [Type or N/A]	R =	ft^2

10. Wall type and insulation	Insulation	Area
a. [Type]	R =	ft^2
b. [Type or N/A]	R =	ft^2
c. [Type or N/A]	R =	ft^2
d. [Type or N/A]	R =	ft^2

11. Ceiling type and insulation level	Insulation	Area
a. [Type]	R =	ft^2
b. [Type or N/A]	R =	ft^2
c. [Type or N/A]	R =	ft^2

12. Ducts, location and insulation level
   a. Sup: [loc.], Ret: [loc], AH: [loc] — R ______ ft^2
   b. Sup: , Ret: , AH: [or N/A]

13. Cooling systems	kBtu/hr	Efficiency
a. [Type]		
b. [Type or N/A]		
c. [Type or N/A]		

14. Heating systems	kBtu/hr	Efficiency
a. [Type]		
b. [Type or N/A]		
c. [Type or N/A]*		

15. Water heating system
   a. [Type] — Cap: [#] gallons
   b. Conservation features — UEF:

Use medium draw pattern UEF provided by manufacturer.

Credits (Performance method)

I certify that this home has complied with the *Florida Building Code, Energy Conservation*, through the above energy saving features which will be installed (or exceeded) in this home before final inspection. Otherwise, a new EPL Display Card will be completed based on installed Code compliant features.

Builder Signature: ______________________ Date: ______________

Address of Home: ______________________ City/FL Zip: ______________

*Note: This is not a Building Energy Rating. If your Index is below 70, your home may qualify for energy efficient mortgage (EEM) incentives if you obtain a Florida EnergyGauge Rating. For information about the *Florida Building Code, Energy Conservation*, contact the Florida Building Commission's support staff.

**Label required by Section R303.1.3 of the *Florida Building Code, Energy Conservation*, if not DEFAULT.

~~ENERGY PERFORMANCE LEVEL (EPL) DISPLAY CARD~~

~~ESTIMATED ENERGY PERFORMANCE INDEX* = ____~~

~~The lower the Energy Performance Index, the more efficient the home.~~

~~1.~~	~~New home or, addition~~	~~1.__________~~
~~2.~~	~~Single-family or multiple-family~~	~~2.__________~~
~~3.~~	~~No. of units (if multiple-family)~~	~~3.__________~~
~~4.~~	~~Number of bedrooms~~	~~4.__________~~
~~5.~~	~~Is this a worst case? (yes/no)~~	~~5.__________~~
~~6.~~	~~Conditioned floor area (sq. ft.)~~	~~6.__________~~
~~7.~~	~~Windows, type and area~~	
	~~a) U-factor:~~	~~7a.__________~~
	~~b) Solar Heat Gain Coefficient (SHGC)~~	~~7b.__________~~
	~~c) Area~~	~~7c.__________~~
~~8.~~	~~Skylights~~	
	~~a) U-factor~~	~~8a.__________~~
	~~b) Solar Heat Gain Coefficient (SHGC)~~	~~8b.__________~~
~~9.~~	~~Floor type, insulation level:~~	
	~~a) Slab-on-grade (R-value)~~	~~9a.__________~~
	~~b) Wood, raised (R-value)~~	~~9b.__________~~
	~~c) Concrete, raised (R-value)~~	~~9c.__________~~
~~10.~~	~~Wall type and insulation:~~	
	~~A. Exterior:~~	
	~~1. Wood frame (Insulation R-value)~~	~~10A1.__________~~
	~~2. Masonry (Insulation R-value)~~	~~10A2.__________~~
	~~B. Adjacent:~~	
	~~1. Wood frame (Insulation R-value)~~	~~10B1.__________~~
	~~2. Masonry (Insulation R-value)~~	~~10B2.__________~~
~~11.~~	~~Ceiling type and insulation level~~	
	~~a) Under attic~~	~~11a.__________~~
	~~b) Single assembly~~	~~11b.__________~~
	~~c) Knee walls/skylight walls~~	~~11c.__________~~
	~~d) Radiant barrier installed~~	~~11d.__________~~
~~12.~~	~~Ducts, location & insulation level~~	
	~~a) Supply ducts~~	~~R=__________~~
	~~b) Return ducts~~	~~R=__________~~
	~~c) AHU location~~	

~~13.~~	~~Cooling system:~~	~~Capacity:~~_________
	~~a) Split system~~	~~SEER~~_________
	~~b) Single package~~	~~SEER~~_________
	~~c) Ground/water source~~	~~COP~~_________
	~~d) Room unit/PTAC~~	~~EER~~_________
	~~e) Other~~_________	_________
~~14.~~	~~Heating system:~~	
	~~a) Split system heat pump~~	~~HSPF~~_________
	~~b) Single package heat pump~~	~~HSPF~~_________
	~~c) Electric resistance~~	~~COP~~_________
	~~d) Gas furnace, natural gas~~	~~AFUE~~_________
	~~e) Gas furnace, LPG~~	~~AFUE~~_________
	~~f) Other~~_________	_________
~~15.~~	~~Water heating system~~	
	~~a) Electric resistance~~	~~EF~~_________
	~~b) Gas fired, natural gas~~	~~EF~~_________
	~~c) Gas fired, LPG~~	~~EF~~_________
	~~d) Solar system with tank~~	~~EF~~_________
	~~e) Dedicated heat pump with tank~~	~~EF~~_________
	~~f) Heat recovery unit~~	~~HeatRec%~~_________
	~~g) Other~~_________	_________
~~16.~~	~~HVAC credits claimed (Performance Method)~~	_________
	~~a) Ceiling fans~~	_________
	~~b) Cross ventilation~~	_________
	~~c) Whole house fan~~	_________
	~~d) Multizone cooling credit~~	_________
	~~e) Multizone heating credit~~	_________
	~~f) Programmable thermostat~~	_________

~~*Label required by Section R303.1.3 of the Florida Building Code, Energy Conservation, if not DEFAULT.~~

~~I certify that this home has complied with the Florida Building Code, Energy Conservation, through the above energy saving features which will be installed (or exceeded) in this home before final inspection. Otherwise, a new EPL display card will be completed based on installed code compliant features.~~

~~Builder Signature:~~______________________________ ~~Date:~~______________________________

__________ __________

~~Address of New Home:~~ ______________________

~~City/FL Zip:~~ ______________________

EN7940

Date Submitted	12/11/2018	**Section**	303.1.3	**Proponent**	Joseph Hetzel
Chapter	3	**Affects HVHZ**	No	**Attachments**	No

TAC Recommendation Approved as Submitted
Commission Action Pending Review

Comments

General Comments **No** **Alternate Language** **Yes**

Related Modifications

Summary of Modification

Title the default door U-factor table as applying to opaque doors, and distinguish that table from the "glazed fenestration" table retitled to apply to windows, glass doors and skylights.

Rationale

The default U-factor tables should distinguish opaque doors from glazed windows, doors and skylights. The headings in the tables should be revised accordingly. The proposal was submitted as CE30-16 Part 2 (Residential) and was approved as submitted. See Code Modification 7930 for coordinated language.

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

No impact.

Requirements

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

No adverse effect on health, safety, and welfare by distinguishing default opaque door U-factor values from default glazed product U-factor values.

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

Strengthens and improves the code by distinguishing default opaque door U-factor values from default glazed product U-factor values.

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

No discrimination.

Does not degrade the effectiveness of the code

Improves the effectiveness of the code by distinguishing default opaque door U-factor values from default glazed product U-factor values.

2nd Comment Period

7940-A2

Proponent Joseph Hetzel **Submitted** 5/16/2019 **Attachments** Yes

Rationale

This is a typographical change.

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

None

Impact to industry relative to the cost of compliance with code

None

Impact to Small Business relative to the cost of compliance with code

No impact.

Requirements

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

No adverse effect.

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

Improves the code by clarifying the U-factor heading in the Table.

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 degrade its effectiveness.

1st Comment Period History

EN7940-G1

Proponent John Woestman **Submitted** 2/11/2019 **Attachments** No

Comment:

Inserting "Opaque"in the column heading "Opaque U-Factor" in TABLE R303.1.3(2) may lead to confusion. Suggest insert "Opaque Door" to read "Opaque Door U-Factor".

OR

Leave the column heading as is because revising the title of TABLE R303.1.3(2) accomplishes the desired result.

In the Table heading, change "Opaque U-factor" to "U-factor".

TABLE R303.1.3(2)

DEFAULT OPAQUE DOOR *U*-FACTORS

DOOR TYPE	*OPAQUE* *U*-FA
Uninsulated Metal	1.20
Insulated Metal	0.60
Wood	0.50
Insulated, nonmetal edge, max 45% glazing,any glazing double pane	0.35

TABLE R303.1.3(3)

DEFAULT ~~GLAZED FENESTRATION~~WINDOW, GLASS DOOR AND SKYLIGHT SHGC AND VT

[table unchanged]

EN8045

Date Submitted 12/12/2018
Chapter 4
Section 401.2
Affects HVHZ Yes
Proponent Joseph Belcher for FHBA
Attachments No
TAC Recommendation Approved as Submitted
Commission Action Pending Review

Comments

General Comments **Yes** **Alternate Language** **No**

Related Modifications

Summary of Modification

Eliminated mandatory automatic controlled receptacles.

Rationale

ASHRAE 90.1 requires at least 50% of electric receptacles (125 volt, 15-and 20-amp) be on a control that cuts power off after some period of time or when areas are unoccupied. The provisions apply to receptacles in private offices, conference rooms, copy or printer rooms, break rooms, classrooms and individual workstations.

Numerous Florida electrical contractors report that there are significant associated costs to compliance. There is concern that in actual practice there is very little energy saved. The reasons for potentially diminished savings depend upon occupants choosing to use the controlled receptacles and upon the actual power saved when chosen devices are automatically switched off.

Persons working in the spaces tend to not use the controlled outlets. Reasons cited are they do not want to risk the receptacle turning off while they are using computers, telephone chargers, radios and other devices. Many workers intentionally leave personal computers on to allow access from outside the work location. Break rooms typically have microwaves, refrigerators, other appliances with clocks, coffee pots with warmer plates and controlled receptacles based on occupancy can create a myriad of problems. The controlling devices are considerably more expensive than a typical uncontrolled outlet with little chance of return through energy savings.

Electric contractors and others express concerns about the increased use of extension cords and power strips to avoid the controlled receptacles. There is also a serious potential for uncontrolled circuits to be overloaded with outlet multipliers and other devices meant for temporary use. The cumulative effect is believed to be increasing fire hazards. This proposal will eliminate the mandatory use of controlled receptacles. Building owners would still have the option to use such controls on their own volition

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

Should result in reduced construction costs for property owners.

Impact to industry relative to the cost of compliance with code

Will result in reduced construction costs for industry.

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

Will result in reduced construction costs for small business.

Requirements

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

The change impacts public health and safety by eliminating a provision that indirectly may increase potential fire hazards.

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

The change improves the code by eliminating a provision that indirectly may increase potential fire hazards.

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 upgrades the effectiveness of the code.

2nd Comment Period

EN8045-G1

Proponent Bryan Holland **Submitted** 5/21/2019 **Attachments** Yes

Comment:

Please reconsider this proposed modification and vote "quot;no affirmative recommendation". The section of the code being modified is not appropriate. C401.2.1 applies to those buildings elected by the owner or design professional to comply with ASHRAE 90.1 by choice. However, those who elect to comply with one of the other two compliance paths (C401.2.2 or C401.2.3) will still have to comply with C405.6 as this is a mandatory provision. Why would we want to exempt automatic receptacle requirements in ASHRAE 90.1 compliant buildings while still mandating this requirement in FBC, Energy Conservation compliant buildings? Besides, the substantiation provided by the proponent is unfounded and inaccurate. Please see the rationale and substantiation attached for the FACTS and TRUTH about automatic receptacle control.

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) and section 8.4.2 of the standard.
2. The requirements of Sections C402 through C405. In addition, commercial buildings shall comply with Section C406 and tenant spaces shall comply with Section C406.1.1.
3. The requirements of Sections C402.5, C403.2, C404, C405.2, C405.3, C405.5, C405.6 and C407. The building energy cost shall be equal to or less than 85 percent of the standard reference design building.

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

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Environmental Energy Technologies Division
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May 2004

To download this paper and related data go to:
http://enduse.lbl.gov/Projects/OffEqpt.html

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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.

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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).

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[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		

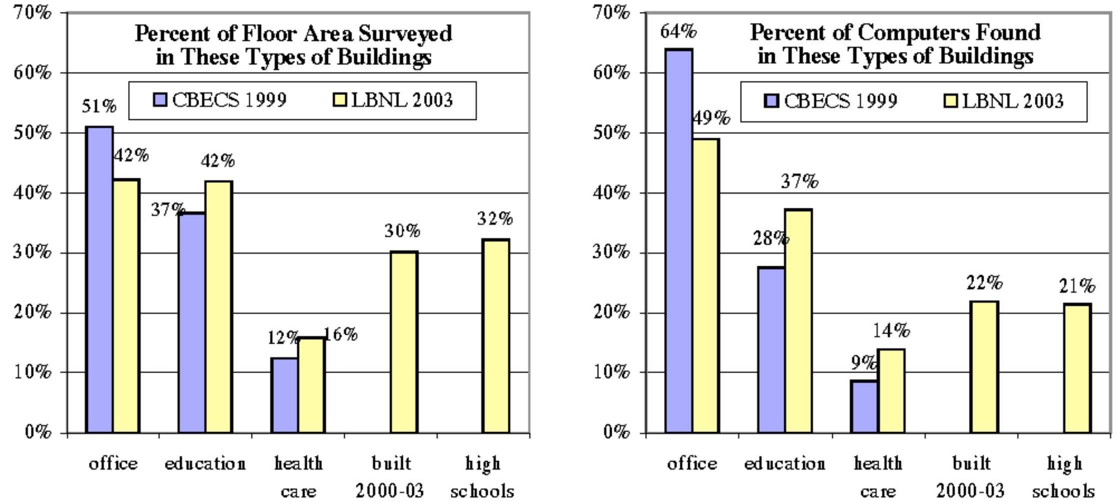
Our characterization of offices differs slightly from that of CBECS. By our definition a small office has <50 employees, a medium office has 50-500 employees, and a large office has >500 employees on site. Also, CBECS appears to classify offices by the number of employees per building, while we classify 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.

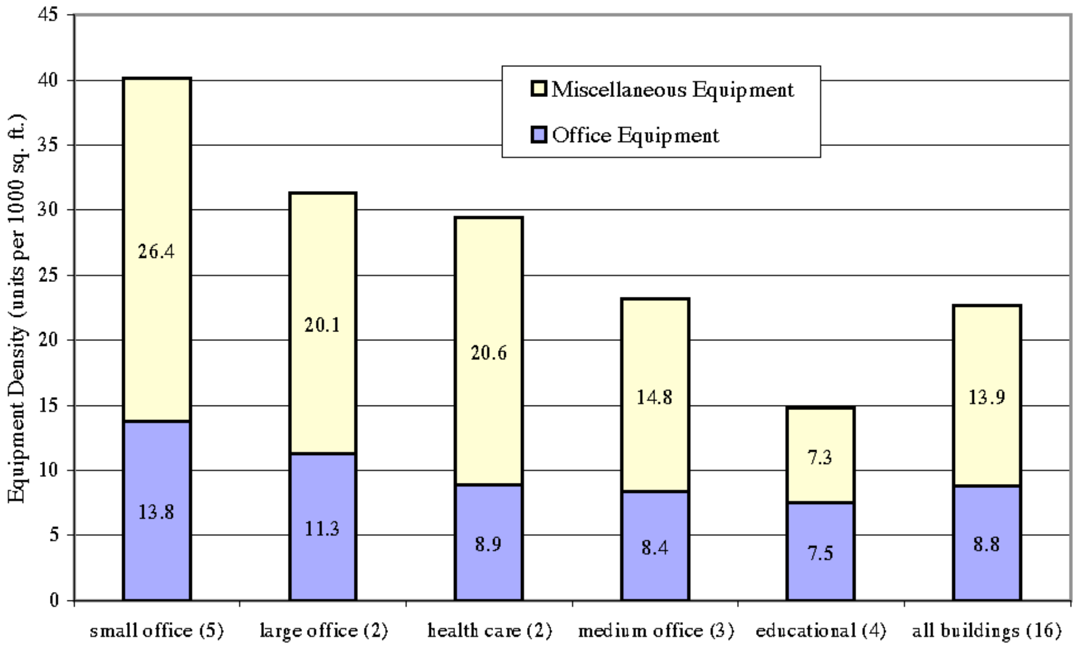
Table 2. Office and Miscellaneous Equipment: Number of Units and Density
sorted by Density of Office Equipment (units/1000 ft^2)

		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.

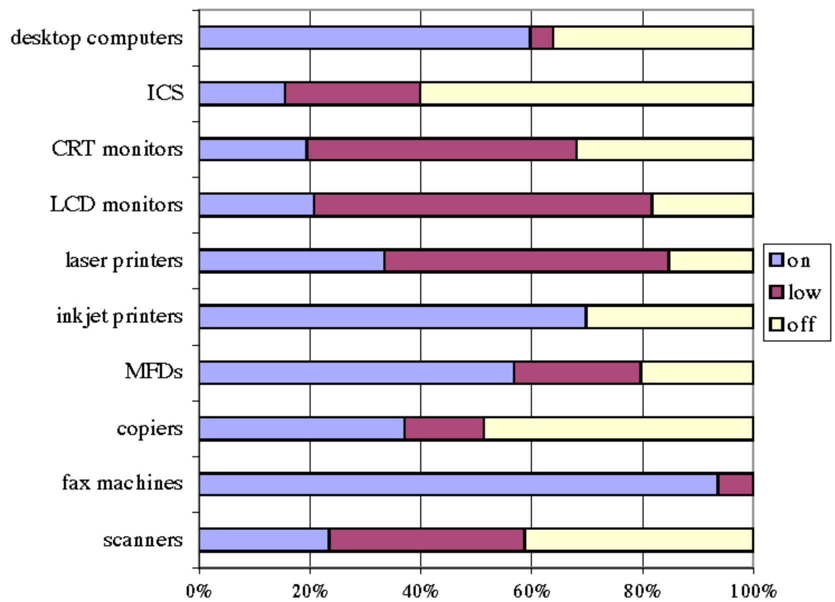
Not surprisingly, turn-off rates were lowest among fax machines and server computers. Turn-off rates were highest for integrated computer systems (60%), copiers (48%), and scanners (41%). PM rates were highest among LCD monitors (75%), CRT monitors (71%), ICSs (61%), scanners (60%), and laser printers (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

Computer	Computer Power state	No.	Monitor Power State: Off	Low	On	Monitor Power Management *: 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.

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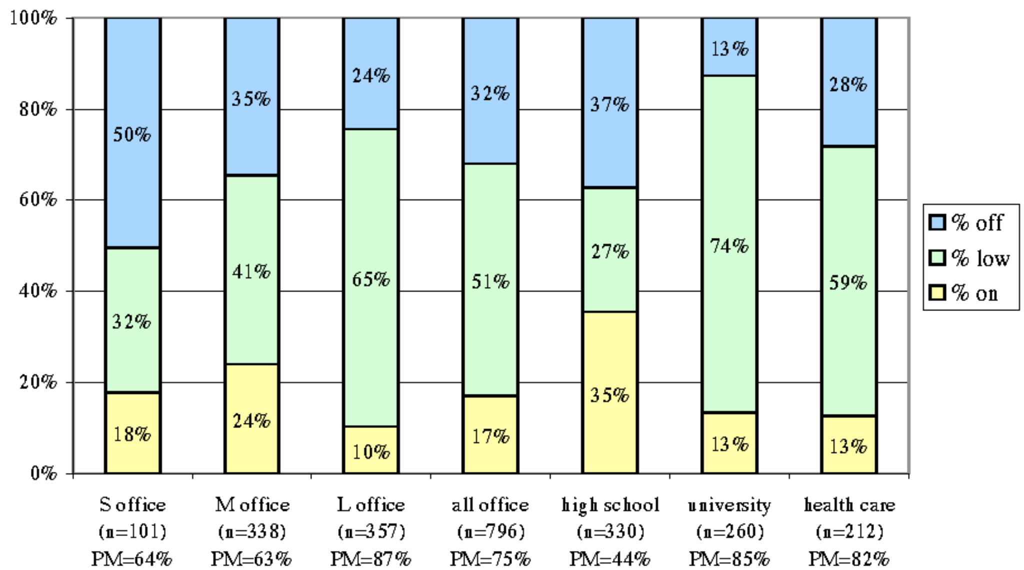
[3] **EZ Save** software was developed by the Department of Energy and adapted by the EPA ENERGY STAR program.

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

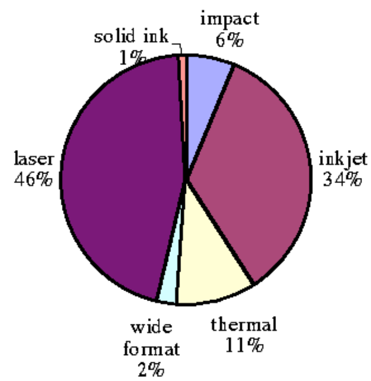


In our sample, monitor PM rates were by far the lowest in high schools (44%) and highest in university buildings (85%) and large offices (87%). Monitor turn-off rates were lowest in university buildings (13%) and highest in small offices (50%). In addition to the low monitor PM rate, a relatively high 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.

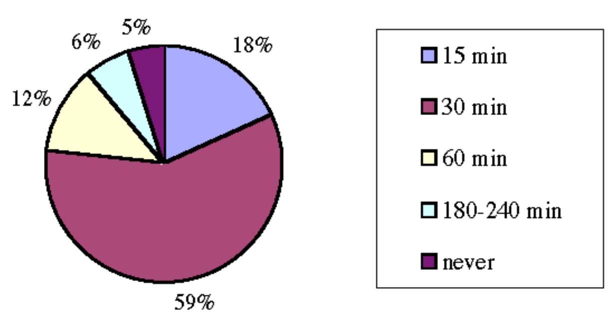
Figure 5. Printer Sample, by Technology



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

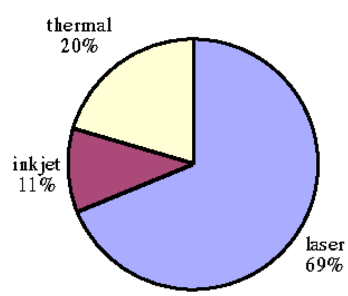
Of the 33 copy machines in Table 3, 48% were off and 29% of those that were not off were in low power. This low PM rate may be due in part to the fact that copiers often have powersave delay settings of two hours or more, and some of the copiers that we found on would eventually have entered low power.

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

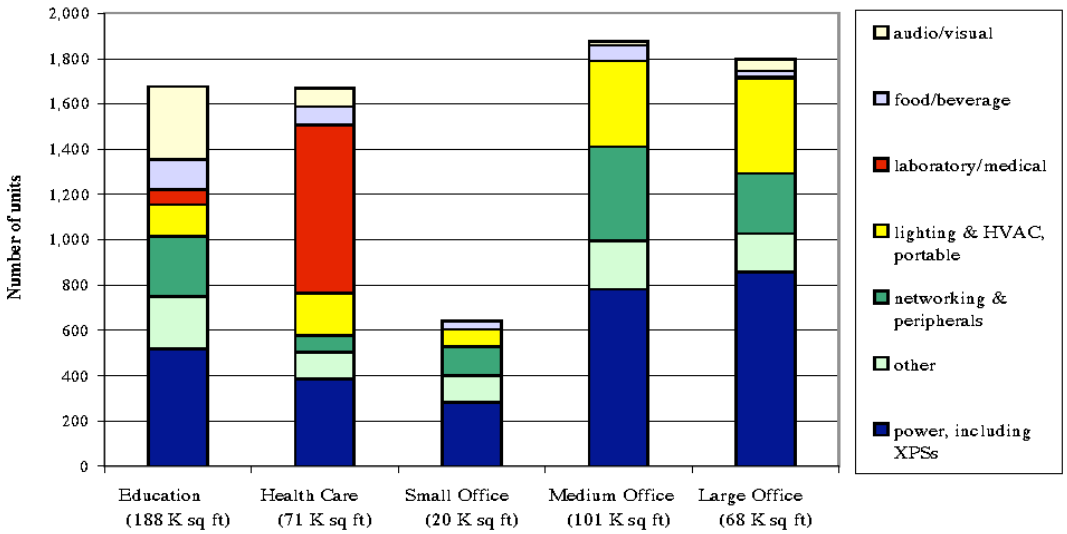
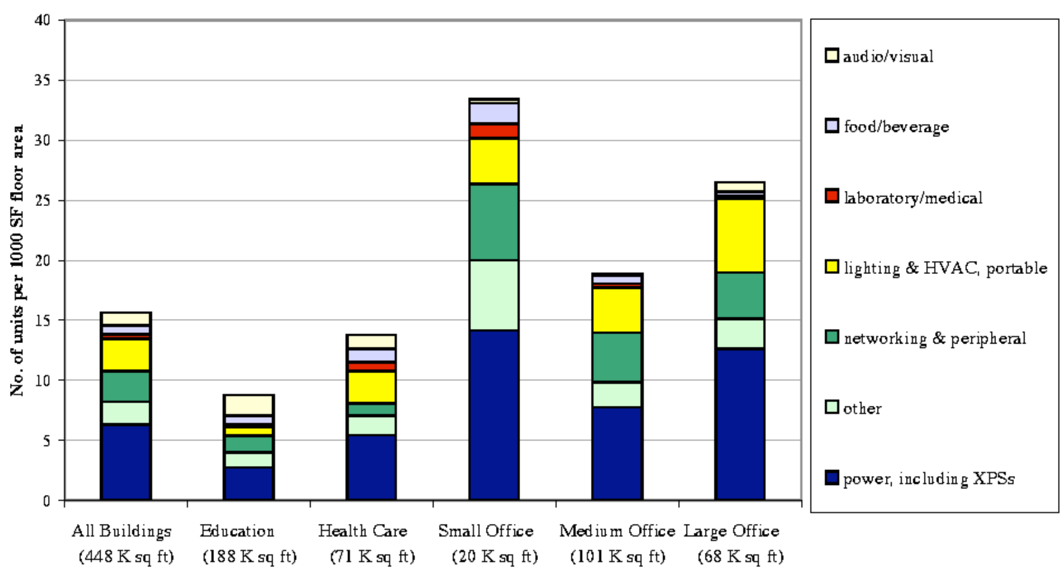


Figure 9. Miscellaneous Equipment Density, per 1000 ft^2 Floor Area



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:

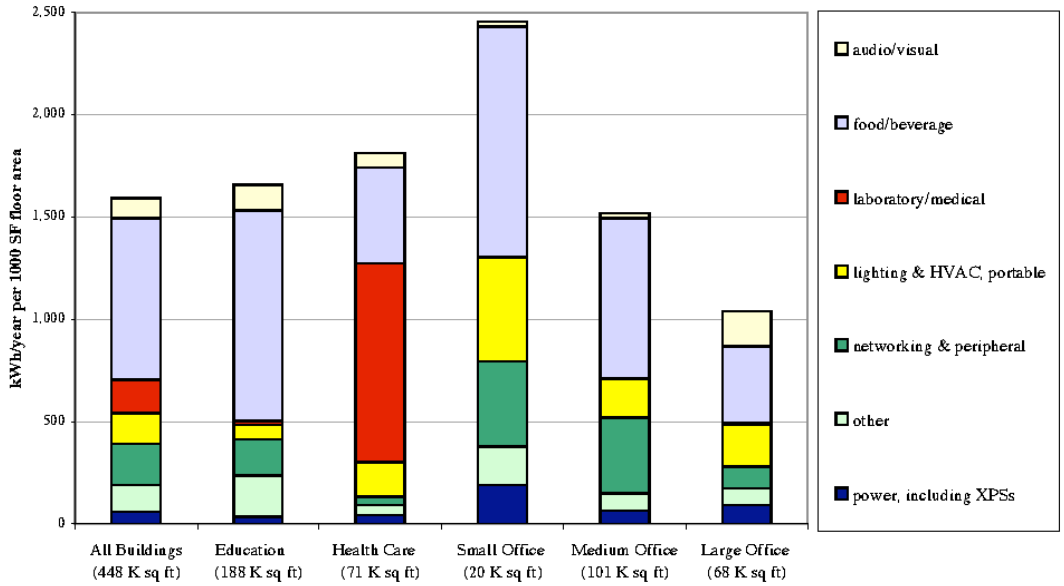
1) refrigerated vending machines
2) commercial refrigerators
3) commercial freezers
4) microwave ovens
5) coffee makers, commercial or specialty
6) hot food cabinets
7) coffee makers, residential models
8) small (undercabinet) refrigerators
9) room temperature vending machines
10) visi-coolers

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

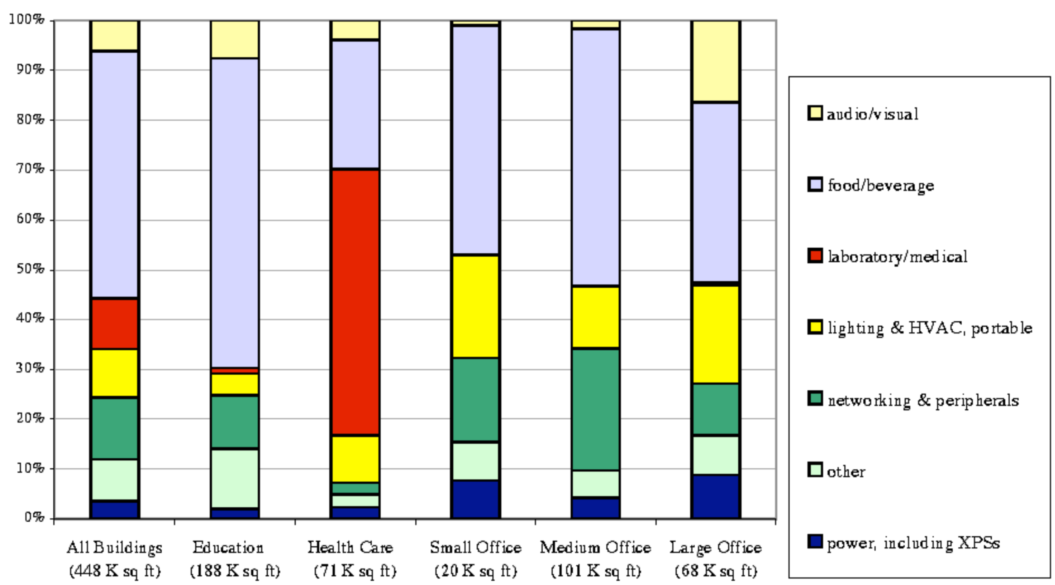


Table 9. Top 50 Miscellaneous Equipment Types, by Unit Energy Consumption

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

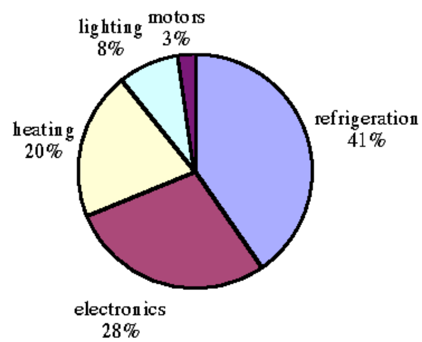
Finally, we characterized the top 50 miscellaneous equipment types in Table 10 according to these broader end-use or technology categories: electronics, heating, lighting, motors, and refrigeration. For equipment that could belong in more than one of these categories, we categorized it based on its primary 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

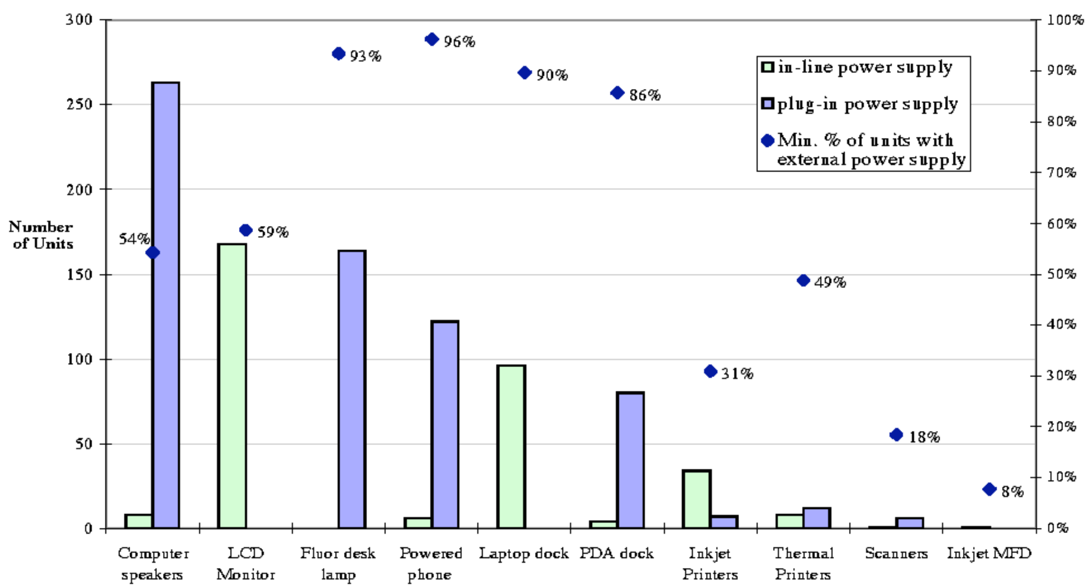


External Power Supplies

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 ft²*, was about 9 for office equipment and 14 for miscellaneous equipment, for a sum of about 23 units per 1000 gross ft². 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.

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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.

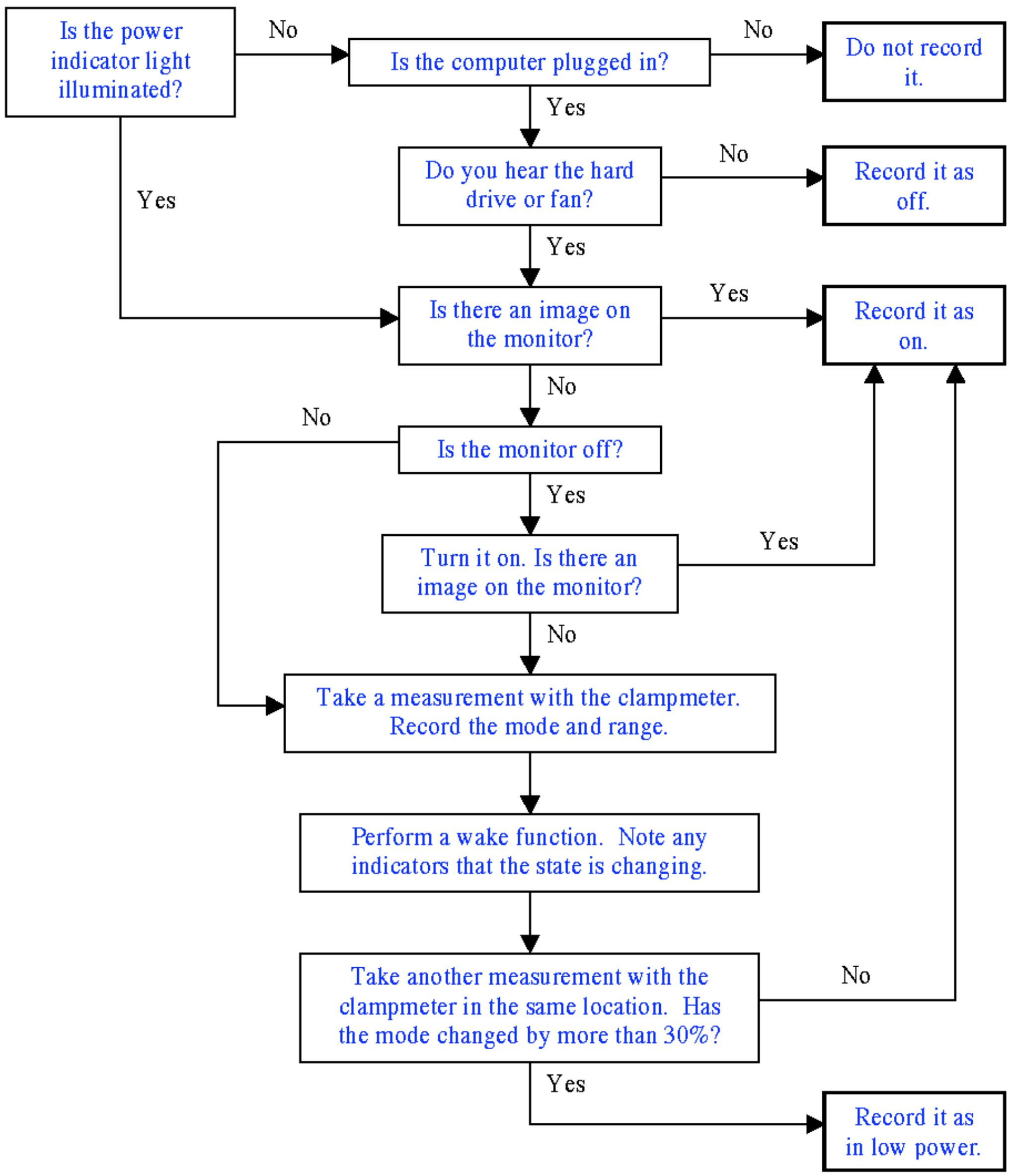
Site M

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

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Reducing Office Plug Loads through Simple and Inexpensive Advanced Power Strips

Preprint

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Reducing Office Plug Loads through Simple and Inexpensive Advanced Power Strips

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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.

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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.

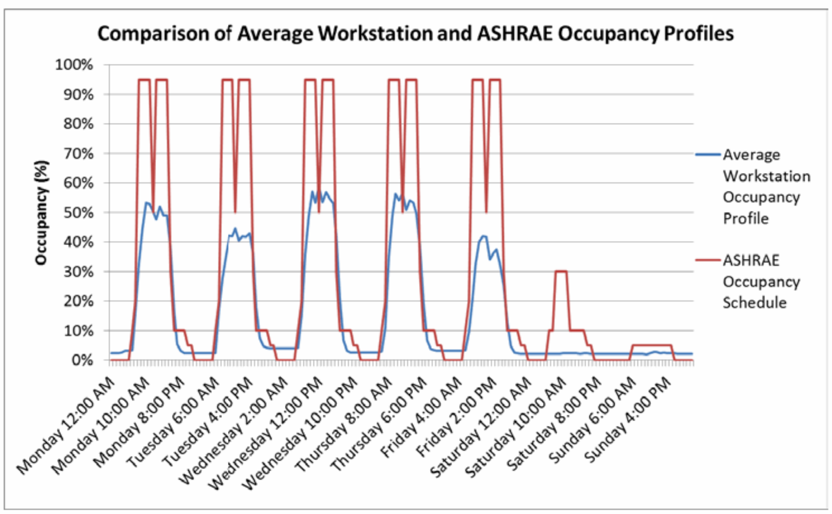

Figure 1 Comparison of the average workstation occupancy rates observed during the demonstration project compared to the ASHRAE occupancy profiles for buildings. (Credit: Ian Metzger, NREL)

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.

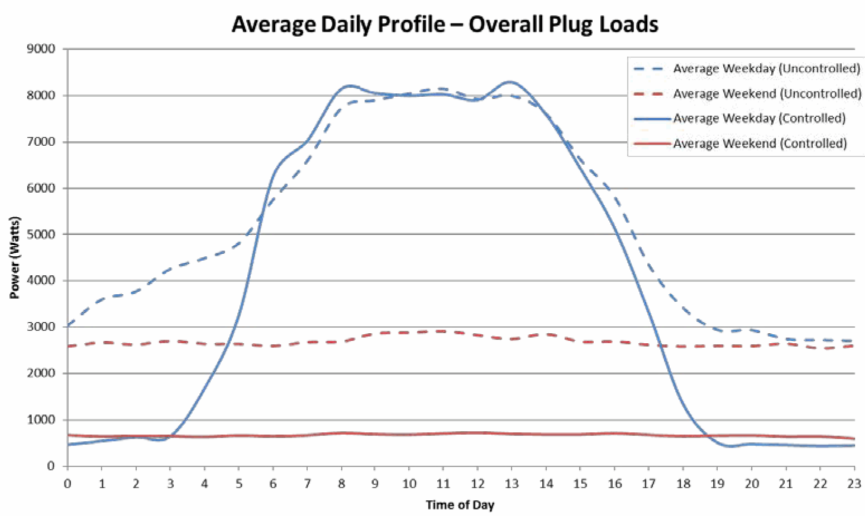

Figure 2 Baseline and APS schedule timer control plug load energy consumption profiles. (Credit: Michael Sheppy, NREL)

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.

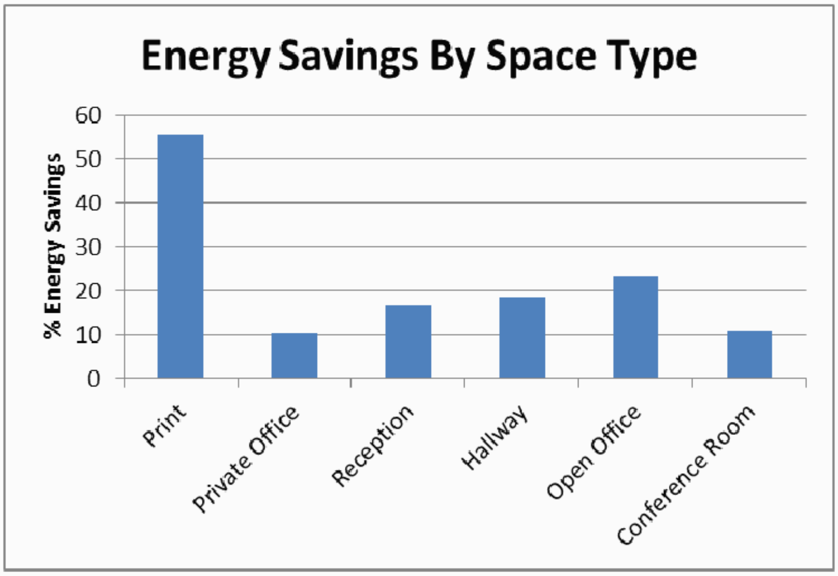

Figure 3 Energy savings by space type. (Credit: Michael Sheppy, NREL)

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.

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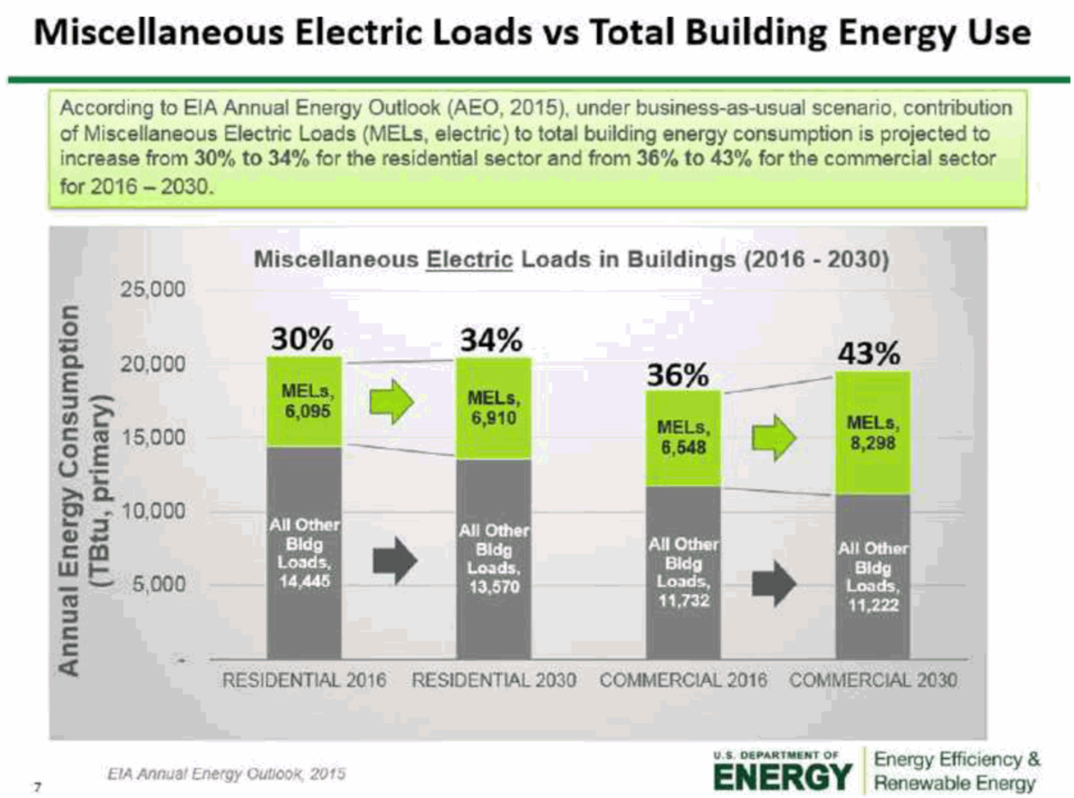
Although commercial buildings continue to decrease their energy use through more efficient lighting, mechanical, and domestic water systems, the Miscellaneous Electrical Loads (MELs) energy segment continues to rise. More and more electrical power consuming devices are being plugged into building electrical systems. Some, such as fans, space heaters, printers, monitors, plug in lamps are left on, when spaces are unoccupied. Other devices may be left plugged in and continue to draw power even when inactive or in standby modes. This wastes energy and is counter to the energy efficiency aim of the IECC.

For more than eight years, other energy efficiency codes have included automatic receptacle control provisions to reduce the wasted energy including CA Title 24, Washington State Energy Code, Florida Energy Code, and ASHRAE 90.1. The Annual Energy Outlook of 2015 from the US EIA, indicate that these load categories will grow from 36% of a commercial buildings energy use, to 43% over the next 15 years.



This provision simply assures receptacle loads that are not needed when building occupants leave high receptacle load use areas, are automatically turned off, saving the energy that would otherwise be wasted. It requires that controlled receptacles clearly be marked as required by NFPA 70, to eliminate user confusion of proper use, and provides good practice exceptions where controlling receptacles would endanger safety and security, or areas of continuous operation.

Expressed safety concerns where extensive use of extension cords and plug strips would be used are unfounded. There are no documented studies validating this problem exists. Although there are no requirements for receptacle density in commercial buildings, a design professional will ensure there is an appropriate distribution of receptacles to effectively accomplish the mission of the building. There's no evidence that the distribution of receptacle outlets and controlling some of them has any adverse impact on the utility of this requirement.

Enforceability of this provision is straight forward for building departments and their inspectors. Construction drawings indicate which receptacles are controlled and which are uncontrolled. Onsite inspection will clearly show complying labelled receptacles and operation is easily varied with the shut-off controls already in place with the lighting system.

There have been a considerable number of studies over the years that share the viability and cost effectiveness of automatic receptacle control. Some noted here.

1. One study demonstrated effectiveness (e.g. Zhang2012) with simply payback on this type of equipment between 1.5 and 9 years for small and large offices. This considers the most comprehensive information on office plug load types, installation densities, usage patterns, and power states based on field surveys and monitoring (Kawamoto 2000, 2001; Moorefield, Frazer & Bendt 2011; Roberson 2002, 2004; Roth 2002, 2004; Sanchez 2007; Webber 2001, 2005).

2. A CASE initiative study for CA Title 24-2013 found that smaller office buildings (10,000 sqft) had an annual electrical savings of 4,900 kwh/year and a demand savings of 1.97 kW based on installed costs and utilization of lighting control system elements already installed. The simple payback was 4.2 years. For larger office buildings (175,000 sqft) the annual electrical savings were 107,000 kwh/year and a demand savings of 23.6 kW for a simple payback of 2.4 years.

3. A GSA Green Proving Ground Program study conducted in 8 buildings with monitored receptacle control found "Results underscored the effectiveness of schedule-based functionality, which reduce plug loads at workstations by 26%, even though advanced computer power management was already in place, and nearly 50% in printer room and kitchens." In the study buildings, receptacle loads averaged 21% of building energy use and monitored more than 295 devices over three different test periods to validate the findings. It found payback through timer scheduled control of kitchens of 0.7 years, printer rooms of 1.1 years and miscellaneous devices in 4.1 years. At workstations, the payback was 7.8 years.

4. A study done on "Office Space Plug Load Profiles and Energy Savings Interventions" at the University of Idaho and presented at the ACEEE summer Study in 2012 found that average savings of 0.60 kWh/SF Yr. with plug strip control interventions. This study provided guidance for utility programs to assist with development of plug load efficiency measures and was based on a more detailed report, "Plug Load Profiles" (Acker, B. et. al. 2012).

5. The DOE Better Buildings program issued a December 2015 "Decision Guides for Plug and Process Loads Controls" to help educate and guide decision processes for effective receptacle-based load control. It highlights that "Plug and Process Loads" account for 33% of the total energy consumed by commercial buildings. It sites seven decision strategies including that of integrated plug load controls with other building systems as one of the largest for energy savings across most building types for whole-building retrofit and new construction categories.

6. A study performed “Advancing the Last Frontier: Reduction of Commercial Plug Loads” presented at the ACEEE summer study of 2016, indicated field study results demonstrating savings of 19% when deploying plug in control strategies in office workstation environments.

National Electrical Manufacturers Association

A NEMA Wiring Devices Section White Paper WD ARCP 1-2016

Automatic Receptacle Control to Meet ASHRAE 90.1-2010 and California Title 24

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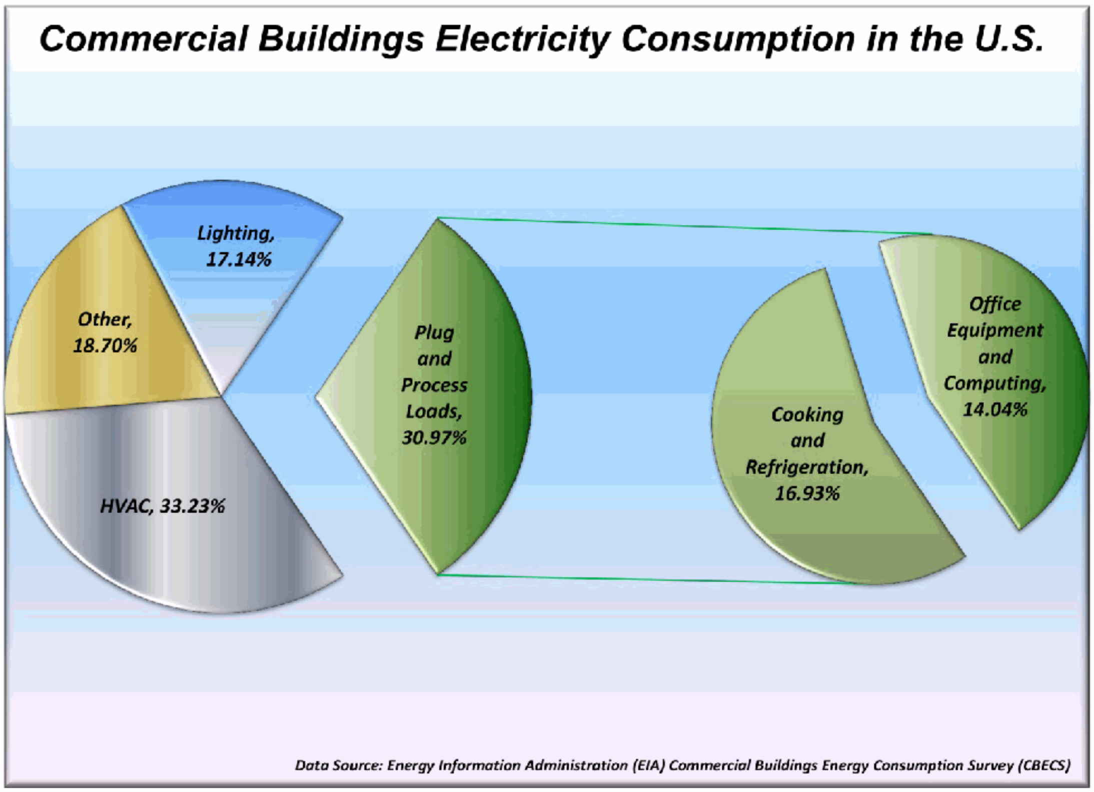
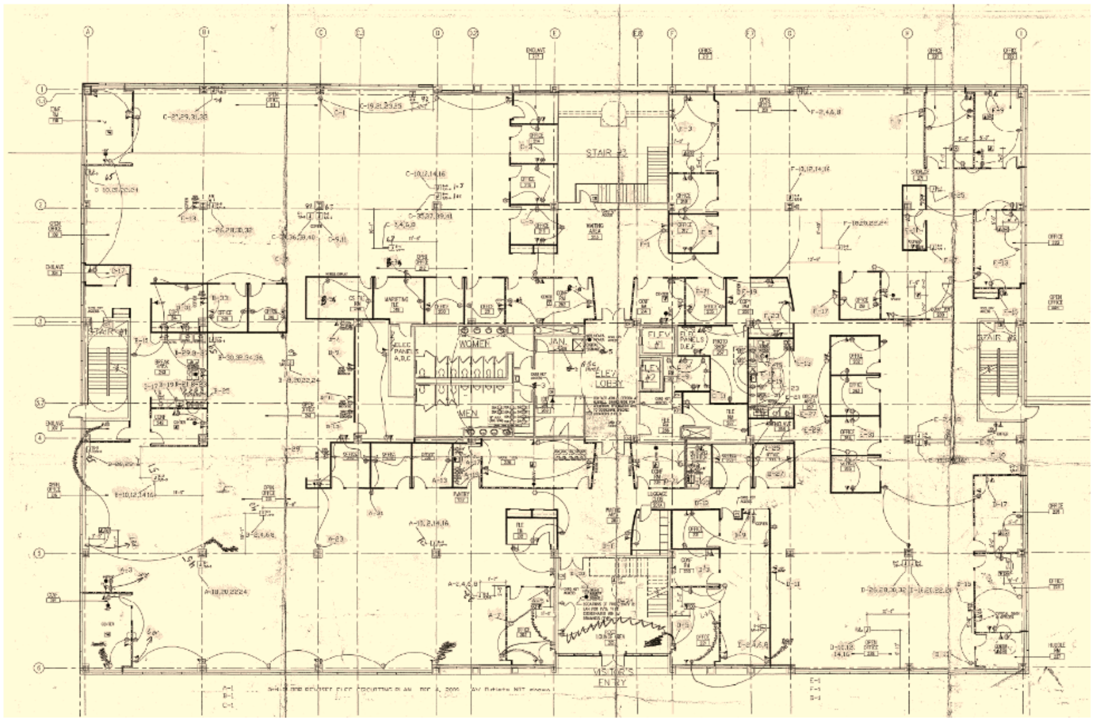
Automatic Receptacle Control to Meet ASHRAE 90.1-2010 and California Title 24

Advances in building construction methodology and product technology have allowed for greater energy efficiency in building design than ever before. In the recent past, HVAC and lighting presented the greatest opportunities to reduce power consumption and conserve energy. Designers and manufacturers have been implementing solutions targeting these systems. Office equipment, appliances, and plug-in lighting loads are the next major area for potential reduction of energy use through management and control. Today, much of what is plugged into a convenience receptacle is uncontrolled. Based on data from the Energy Information Administration Commercial Buildings Energy Consumption Survey of 2012, approximately 30% of the energy used in buildings is by loads that are plugged in.



Both ASHRAE 90.10 and California Electric Code (CEC) Title 24 have identified receptacles as an area requiring energy management and have incorporated explicit requirements for automatic control. They target spaces in a building and require that half (50 percent) of the receptacles are controlled by an automatic shutoff device. Most commonly, these are receptacles in personal offices, conference rooms, and cubicle spaces. (Code excerpts shown at the end of the paper)

Below is a typical commercial office building floorplan.



In this example, 80 percent of the receptacles are required to be controlled; 20 percent are exempt. Further analysis shows that most receptacles are located in the furniture systems or cubicles and conference areas of offices. Receptacles are most often used to control task lighting, followed by computer peripherals and personal devices (e.g., portable electronics, chargers, radios, heaters, fans, etc.). The energy standard requires some receptacles to be controlled. The intent is for the controlled receptacles to provide power when needed by the occupant—that is, when the occupant is present—and minimize wasted energy. Uncontrolled receptacles continuously supply power to equipment, requiring them to be energized at all times. Most computer equipment utilizes a “sleep mode” to optimize energy efficiency. Since the energy consumption on such a mode is very low, it is suitable to keep these devices plugged in to uncontrolled receptacles. Other, more discretionary plug-in items such as fans, heaters, and radios, if used, should be on only when the occupant is in the area, which results in minimum power use.

Circuit Design: Good, Better, Best

ASHRAE 90.1 and CEC Title 24 require automatic shutoff control by a time-of-day device, an occupant sensor, or an automated signal from another control or alarm system. It is up to the designer or building engineer to select the most appropriate technique to comply with the standard. Effectiveness and flexibility varies for each of these techniques, as do the types of buildings.

To better understand plug load, it is critical to examine how a particular building is used. Most commercial buildings serve as work locations, which come alive with people and activity throughout the day. Every building has prime use times (for example, 8 a.m. to 5 p.m.), with a reduction at night and then a slight increase if nighttime cleaning is performed. With a 24/7 work environment, it may be common to have variable hours, with people working earlier or later—not to mention weekends, holidays, and occasional exceptions. Many of today's buildings need to be more responsive to the individual worker and modern work schedule.

A hardwired load controller can be placed in a series with a branch circuit at the breaker panel to control power to the circuits according to preset schedules. Such a controller can be added to the building with minimal changes to the method currently used in circuit design. Either a remotely controllable circuit breaker or remotely controllable relay in a box outside the panel can serve this purpose. Circuits are typically routed conveniently through the building, properly sized to electrical needs and to maximize the number of outlets on a circuit. As a result, however, one circuit may be used for multiple offices and hallways, possibly unrelated to the way they need to be controlled. Office furniture is typically multi-circuited, with at least two circuits per work area, sometimes using isolated ground for computer use. In this instance, using time-based control would facilitate area control but may limit the flexibility of set times.

A sensor-based system, such as is commonly used for keeping lights off in unoccupied areas, can turn-off plug loads when the area is unoccupied. Since one person may be at work late or on a weekend when others are not present, ideally this occupant detection should resolve to a single person, not an entire floor or work group. Typical receptacle circuit design may need to be altered for maximum occupant benefit by limiting it to just a single-person area of use (i.e., only in the office or at the desk where the occupant works). As a result, the power circuit may need to have fewer receptacles, requiring more circuits. For new building construction, more branch circuits can be installed to enable greater control flexibility. For retrofitting existing buildings, wirelessly controlled receptacles can deliver this flexible control.

Open cubicle areas require a different design. As open areas need to be controlled as a group, typically a multiple-circuit control makes sense, similar to a time-based system. It can also be triggered by an overhead sensor, adding flexibility if the worker stays late or comes in on the weekend. Again, individually controlled receptacles, rather than controlled branch circuits, provide maximum flexibility and the best user experience.

Two Approaches for New Construction Applications

Controlled branch circuits may offer the use of two circuits for each duplex receptacle, where one receptacle is on one circuit and the other receptacle is on a second circuit ("split wiring"). In this situation, a wired load controller can control one receptacle, while the other receptacle is only controlled by the circuit breaker (i.e., always left on and not controlled). Using split wiring for every duplex receptacle will give the user the ability to plug into either a controlled or non-controlled outlet in the same location. The occupant will have choice of continuous power or a controlled circuit in the same location.

Choosing to run two circuits and control every other receptacle is another technique. The requirement is that a non-controlled receptacle be within 6 feet of a controlled receptacle.

In either case, concern for user convenience needs to be considered to make sure there are enough outlets to meet the plug-in needs of the occupant. Location is key.

Receptacle Markings

NEC has chosen the symbol ⏻ to indicate an automatically controlled receptacle. As non-controlled receptacles never had an identifier, none is required. Both ASHRAE and the CEC require receptacles to have a permanent marking. The installer may choose to add a permanent marking during construction. There are pre-marked receptacles available from several manufacturers that comply with permanent marking requirements.

The overall intent of the energy code and requirement is to minimize wasted energy and maximize efficiency. The directive is to control plug loads through the management of selected outlets. How this is done is left up to the property owner. It is impossible to say whether minimum compliance or a totally integrated building management system is appropriate without understanding the building and its use. Correct sizing in the design is paramount to proper automatic receptacle control.

Code Excerpts

ASHRAE 90.1-2010 and 2013

8.4.2 Automatic Receptacle Control
The following shall be automatically controlled:

a) At least 50% of all 125 volt, 15 and 20 ampere receptacles in all private offices, conference rooms, rooms used primarily for printing and/or copying functions, break rooms, classrooms, and individual workstations
b) At least 25% of branch circuit feeders installed for modular furniture not shown on the construction documents

This control shall function on

a) a scheduled basis using a time-of-day operated control device that turns receptacles off at specific programmed times—an independent program schedule shall be provided for controlled areas of no more than 5000 ft2 and not more than one floor (the occupant shall be able to manually override the control device for up to two hours);

b) an occupant sensor that shall turn receptacles off within 20 minutes of all occupants leaving a space; or
c) an automated signal from another control or alarm system that shall turn receptacles off within 20 minutes after determining that the area is unoccupied.

All controlled receptacles shall be permanently marked to visually differentiate them from uncontrolled receptacles and are to be uniformly distributed throughout the space.

Plug-in devices shall not be used to comply with section 8.4.2.

Exceptions: Receptacles for the following shall not require an automatic control device:
a) Receptacles specifically designated for equipment requiring continuous operation (24 hours/day, 365 days/year)
b) Spaces where an automatic control would endanger the safety or security of the room or building occupant(s)

California Electric Code (CEC) Title 24 Section 130.5

(d) Circuit Controls for 120-Volt Receptacles.
In all buildings, both controlled and uncontrolled 120 volt receptacles shall be provided in each private office, open office area, reception lobby, conference room, kitchenette in office spaces, and copy room. Additionally, hotel/motel guest rooms shall comply with Item 5. Controlled receptacles shall meet the following requirements, as applicable:

1. Electric circuits serving controlled receptacles shall be equipped with automatic shut-OFF controls following the requirements prescribed in Section 130.1(c)(1 through 5); and
2. At least one controlled receptacle shall be installed within 6 feet from each uncontrolled receptacle or a splitwired duplex receptacle with one controlled and one uncontrolled receptacle shall be installed; and
3. Controlled receptacles shall have a permanent marking to differentiate them from uncontrolled receptacles; and
4. For open office areas, controlled circuits shall be provided and marked to support installation and configuration of office furniture with receptacles that comply with Section 130.5(d) 1, 2, and 3; and
5. For hotel and motel guest rooms at least one-half of the 120-volt receptacles in each guest room shall be controlled receptacles that comply with Section 130.5(d)1, 2, and 3. Electric circuits serving controlled receptacles shall have captive card key controls, occupancy sensing controls, or automatic controls such that, no longer than 30 minutes after the guest room has been vacated, power is switched off.
6. Plug-in strips and other plug-in devices that incorporate an occupant sensor shall not be used to comply with this requirement.

EXCEPTION 1 to Section 130.5(d): In open office areas, controlled circuit receptacles are not required if, at time of final permit, workstations are installed, and each workstation is equipped with an occupant sensing control that is permanently mounted in each workstation, and which controls a hardwired, nonresidential-rated power strip. Plug-in strips and other plug-in devices that incorporate an occupant sensor shall not be used for this exception.

EXCEPTION 2 to Section 130.5(d): Receptacles that are only for the following purposes:

i. Receptacles specifically for refrigerators and water dispensers in kitchenettes.
ii. Receptacles located a minimum of six feet above the floor that are specifically for clocks.
iii. Receptacles for network copiers, fax machines, A/V and data equipment other than personal computers in copy rooms.
iv. Receptacles on circuits rated more than 20 amperes.

National Electrical Code® Article 406

(E) Controlled Receptacle Marking. All nonlocking-type, 125-volt, 15- and 20-ampere receptacles that are controlled by an automatic control device, or that incorporate control features that remove power from the outlet for the purpose of energy management or building automation, shall be marked with the symbol shown in Figure 406.3(E) and located on the controlled receptacle outlet where visible after installation.

Figure 406.3(E) Controlled Receptacle Marking Symbol.

Exception: The marking is not required for receptacles controlled by a wall switch that provide the required room lighting outlets as permitted by 210.70.

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EN8137

Date Submitted	12/14/2018	**Section**	403.2.14	**Proponent**	Amanda Hickman
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Approved as Submitted				
Commission Action	Pending Review				

Comments

General Comments **No** | **Alternate Language** **Yes**

Related Modifications

#8139

Summary of Modification

This modification resolves conflict between Federal preemption rules and code requirements for walk-in coolers and freezers

Rationale

See attached reason statement and bibliography.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This modification will make it easier on code enforcement by clearly indicating that they do not have to address the thermal performance of walk-in systems that are governed by federal requirements. It will also reduce inspection time for code enforcement.

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

This modification will reduce cost to building and property owners as it will clarify that only the DOE requirements apply.

Impact to industry relative to the cost of compliance with code

This modification will reduce costs to industry, as it will clarify that only the DOE requirements apply.

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

This modification will reduce costs to small business, as it will clarify that only the DOE requirements apply.

Requirements

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

Clarifying this section of the code, will improve the welfare of the general public by ensuring that they proper DOE requirements are met.

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

This modification will strengthen the code by clarifying that only the DOE requirements apply.

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

This modification does not discriminate against and materials, products or methods, as it only clarifies that only the DOE requirements apply.

Does not degrade the effectiveness of the code

This modification does not degrade the effectiveness of the code, it improves the effectiveness by clarifying that only the DOE requirements apply.

Alternate Language

2nd Comment Period

8137-A2

Proponent Amanda Hickman **Submitted** 5/23/2019 **Attachments** Yes

Rationale

This comment harmonizes what was recently approved (CE144, CE146 and CE149) during the ICC Committee Action Hearings recently. This modification comment is needed in order to removes the conflict with current federal regulations and updates this section by replacing the outdated prescriptive language to be consistent with current DOE regulations. It also combines the current tables into one, which harmonizes with the federal regulations and recent updates made to ASHRAE90.1.This modification comment will also make enforcement easier for code officials by making explicit that they do not have to address the attributes of walk-in systems preempted by federal requirements.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This modification will make it easier on code enforcement by clearly indicating that they do not have to address the thermal performance of walk-in systems that are governed by federal requirements. It will also reduce inspection time for code enforcement.

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

This modification will reduce cost to building and property owners as it will clarify that only the DOE requirements apply.

Impact to industry relative to the cost of compliance with code

This modification will reduce costs to industry, as it will clarify that only the DOE requirements apply.

Impact to Small Business relative to the cost of compliance with code

This modification will reduce costs to small business, as it will clarify that only the DOE requirements apply.

Requirements

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

Clarifying this section of the code, will improve the welfare of the general public by ensuring that they proper DOE requirements are met.

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

This modification will strengthen the code by clarifying that only the DOE requirements apply.

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

This modification does not discriminate against and materials, products or methods, as it only clarifies that only the DOE requirements apply.

Does not degrade the effectiveness of the code

This modification does not degrade the effectiveness of the code, it improves the effectiveness by clarifying that only the DOE requirements apply.

Alternate Language

1st Comment Period History

8137-A1

Proponent Amanda Hickman **Submitted** 2/18/2019 **Attachments** Yes

Rationale

This comment offers a cleaner and better way of resolving the conflict between the code and current federal requirements for this type of equipment, thereby reducing cost and confusion in the field.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This comment will resolve the conflict between the code and the federal regulations, thereby greatly reducing the confusion that is currently being caused.

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

This comment will resolve the conflict between the code and the federal regulations. It will eliminate the need for unnecessary testing and need to meet unnecessary requirements, thereby, greatly reducing costs.

Impact to industry relative to the cost of compliance with code

This comment will resolve the conflict between the code and the federal regulations. It will eliminate the need for unnecessary testing and need to meet unnecessary requirements, thereby, greatly reducing costs.

Impact to Small Business relative to the cost of compliance with code

This modification will reduce costs to small business, as it will clarify that only the DOE requirements apply.

Requirements

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

Yes. This will ensure that proper requirements are followed.

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

Yes. This will ensure that proper requirements are followed.

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

No. This will only improve the code by ensuring that the proper requirements are followed.

Does not degrade the effectiveness of the code

No. This will only improve the code by ensuring that the proper requirements are followed.

EN8137 -A2 Text Modification

See attached.

Please replace our originally proposed modification with the following proposed modification:

Delete and Substitute as follows:

~~**C403.2.14Refrigeration equipment performance.**~~

~~Refrigeration equipment shall have an energy use in kWh/day not greater than the values of Tables C403.2.14(1) and C403.2.14(2) when tested and rated in accordance with AHRI Standard 1200. The energy use shall be verified through certification under an approved certification program or, where a certification program does not exist, the energy use shall be supported by data furnished by the equipment manufacturer.~~

~~**TABLE C403.2.14(1)**~~

~~**MINIMUM EFFICIENCY REQUIREMENTS: COMMERCIAL REFRIGERATION**~~

~~EQUIPMENT TYPE~~	~~APPLICATION~~	~~ENERGY USE LIMITS (kWh per day)[a]~~	~~TEST PROCEDURE~~
~~Refrigerator with solid doors~~	~~Holding Temperature~~	~~0.10 · V + 2.04~~	~~AHRI 1200~~
~~Refrigerator with transparent doors~~		~~0.12 · V + 3.34~~	
~~Freezers with solid doors~~		~~0.40 · V + 1.38~~	
~~Freezers with transparent doors~~		~~0.75 · V + 4.10~~	
~~Refrigerators/freezers with solid doors~~		~~the greater of 0.12 · V + 3.34 or 0.70~~	
~~Commercial refrigerators~~	~~Pulldown~~	~~0.126 · V + 3.51~~	

A_{nd} is the surface area of the nondisplay door.

TABLE C403.2.16(3)
WALK-IN COOLER AND FREEZER REFRIGERATION SYSTEM EFFICIENCY REQUIREMENTS

CLASS DESCRIPTOR	**CLASS**	**MINIMUM ANNUAL WALK-IN ENERGY FACTOR AWEF (Btu/W-h)**	**Test Procedure**
Dedicated condensing, medium temperature, indoor system	DC.M.I	5.61	AHRI 1250

CLASS DESCRIPTOR	CLASS	MINIMUM ANNUAL WALK-IN ENERGY FACTOR AWEF (Btu/W-h)	Test Procedure
Dedicated condensing, medium temperature, outdoor system	DC.M.O	7.60	
Dedicated condensing, low temperature, indoor system, net capacity (q_{net}) < 6,500 Btu/h	DC.L.I, < 6,500	$9.091 \times 10^{-5} \times qnet + 1.81$	
Dedicated condensing, low temperature, indoor system, net capacity (q_{net}) ≥ 6,500 Btu/h	DC.L.I, ≥ 6,500	2.40	
Dedicated condensing, low temperature, outdoor system, net capacity (q_{net}) < 6,500 Btu/h	DC.L.O, < 6,500	$6.522 \times 10^{-5} \times qnet + 2.73$	
Dedicated condensing, low temperature, outdoor system, net capacity (q_{net}) ≥ 6,500 Btu/h	DC.L.O, ≥ 6,500	3.15	
Unit cooler, medium	UC.M	9.00	
Unit cooler, low temperature, net capacity (q_{net}) < 15,500 Btu/h	UC.L, < 15,500	$1.575 \times 10^{-5} \times qnet + 3.91$	
Unit cooler, low temperature, net capacity (q_{net}) ≥ 15,500 Btu/h	UC.L,, ≥ 15,500	4.15	
-	-	-	
-	-	-	

a. $q_{net}$is net capacity (Btu/hr) as determined in accordance with AHRI Standard 1250

Revise as follows:

C403.2.14Refrigeration equipment performance.

Refrigeration equipment,as defined in 10 CFR part 431,have an energy use in kWh/day not greater than the values of Tables C403.2.14(1)and C403.2.14(2) when tested and rated in accordance with ~~AHRI Standard 1200~~10 CFR part 431.The energy use shall be verified through certification under an approved certification program or, where a certification program does not exist, the energy use shall be supported by data furnished by the equipment manufacturer.

TABLE C403.2.14(1)

MINIMUM EFFICIENCY REQUIREMENTS: COMMERCIAL REFRIGERATION

EQUIPMENT TYPE	APPLICATION	ENERGY USE LIMITS (kWh per day)[a]	TEST PROCEDURE
Refrigerator with solid doors	Holding Temperature	0.10 • V + 2.04	~~AHRI 1200~~ 10 CFR Part 431
Refrigerator with transparent doors		0.12 • V + 3.34	
Freezers with solid doors		0.40 • V + 1.38	
Freezers with transparent doors		0.75 • V + 4.10	
Refrigerators/freezers with solid doors		the greater of ~~0.12 · V + 3.34~~ 0.27AV-0.71 or 0.70	
Commercial refrigerators	Pulldown	0.126 • V + 3.51	

1. a.V = volume of the chiller or frozen compartment as defined in AHAM-HRF-1.

TABLE C403.2.14(2)MINIMUM EFFICIENCY REQUIREMENTS: COMMERCIAL REFRIGERATORS AND FREEZERS

EQUIPMENT TYPE				ENERGY USE LIMITS (kWh/day)[a,b]	TEST PROCEDURE
Equipment Classc	Family Code	Operating Mode	Rating Temperature		
VOP.RC.M	Vertical open	Remote condensing	Medium	0.82 • TDA + 4.07	-

SVO.RC.M	Semivertical open	Remote condensing	Medium	0.83 • TDA + 3.18	-
HZO.RC.M	Horizontal open	Remote condensing	Medium	0.35 • TDA + 2.88	- ~~AHRI 1200~~
VOP.RC.L	Vertical open	Remote condensing	Low	2.27 • TDA + 6.85	10 CFR Part 431
HZO.RC.L	Horizontal open	Remote condensing	Low	0.57 • TDA + 6.88	
VCT.RC.M	Vertical transparent door	Remote condensing	Medium	0.22 TDA + 1.95	
VCT.RC.L	Vertical transparent door	Remote condensing	Low	0.56 • TDA + 2.61	
SOC.RC.M	Service over counter	Remote condensing	Medium	0.51 • TDA + 0.11	
VOP.SC.M	Vertical open	Self-contained	Medium	1.74 • TDA + 4.71	
SVO.SC.M	Semivertical open	Self-contained	Medium	1.73 • TDA + 4.59	
HZO.SC.M	Horizontal open	Self-contained	Medium	0.77 • TDA + 5.55	
HZO.SC.L	Horizontal open	Self-contained	Low	1.92 • TDA + 7.08	
VCT.SC.I	Vertical transparent door	Self-contained	Ice cream	0.67 • TDA + 3.29	
VCS.SC.I	Vertical solid door	Self-contained	Ice cream	0.38 • V + 0.88	
HCT.SC.I	Horizontal transparent door	Self-contained	Ice cream	0.56 • TDA + 0.43	
SVO.RC.L	Semivertical open	Remote condensing	Low	2.27 • TDA + 6.85	
VOP.RC.I	Vertical open	Remote condensing	Ice cream	2.89 • TDA + 8.7	
SVO.RC.I	Semivertical open	Remote condensing	Ice cream	2.89 • TDA + 8.7	
HZO.RC.I	Horizontal open	Remote condensing	Ice cream	0.72 • TDA + 8.74	
VCT.RC.I	Vertical transparent door	Remote condensing	Ice cream	0.66 • TDA + 3.05	
HCT.RC.M	Horizontal transparent door	Remote condensing	Medium	0.16 • TDA + 0.13	
HCT.RC.L	Horizontal transparent door	Remote condensing	Low	0.34 • TDA + 0.26	

HCT.RC.I	Horizontal transparent door	Remote condensing	Ice cream	0.4 • TDA + 0.31	
VCS.RC.M	Vertical solid door	Remote condensing	Medium	0.11 • V + 0.26	
VCS.RC.L	Vertical solid door	Remote condensing	Low	0.23 • V + 0.54	
VCS.RC.I	Vertical solid door	Remote condensing	Ice cream	0.27 • V + 0.63	
HCS.RC.M	Horizontal solid door	Remote condensing	Medium	0.11 • V + 0.26	
HCS.RC.L	Horizontal solid door	Remote condensing	Low	0.23 • V + 0.54	
HCS.RC.I	Horizontal solid door	Remote condensing	Ice cream	0.27 • V + 0.63	
HCS.RC.I	Horizontal solid door	Remote condensing	Ice cream	0.27 • V + 0.63	
SOC.RC.L	Service over counter	Remote condensing	Low	1.08 • TDA + 0.22	
SOC.RC.I	Service over counter	Remote condensing	Ice cream	1.26 • TDA + 0.26	
VOP.SC.L	Vertical open	Self-contained	Low	4.37 • TDA + 11.82	
VOP.SC.I	Vertical open	Self-contained	Ice cream	5.55 • TDA + 15.02	
SVO.SC.L	Semivertical open	Self-contained	Low	4.34 • TDA + 11.51	
SVO.SC.I	Semivertical open	Self-contained	Ice cream	5.52 • TDA + 14.63	
HZO.SC.I	Horizontal open	Self-contained	Ice cream	2.44 • TDA + 9.0	
SOC.SC.I	Service over counter	Self-contained	Ice cream	1.76 • TDA + 0.36	
HCS.SC.I	Horizontal solid door	Self-contained	Ice cream	0.38 • V + 0.88	

a. V = Volume of the case, as measured in accordance with Appendix C of AHRI 1200.

b. TDA = Total display area of the case, as measured in accordance with Appendix D of AHRI 1200.

c.Equipment class designations consist of a combination [(in sequential order separated by periods (AAA).(BB).(C))] of:

(AAA)An equipment family code where:

VOP = vertical open

SVO = semivertical open

HZO = horizontal open

VCT = vertical transparent doors

VCS = vertical solid doors

HCT = horizontal transparent doors

HCS = horizontal solid doors

SOC = service over counter

(BB) An operating mode code:

RC = remote condensing

SC = self-contained

(C) A rating temperature code:

M = medium temperature (38°F)

L = low temperature (0°F)

I = ice-cream temperature (15°F)

For example, "VOP.RC.M" refers to the "vertical-open, remote-condensing, medium-temperature" equipment class.

C403.2.15Walk-in coolers, walk-in freezers, refrigerated warehouse coolers and refrigerated warehouse freezers. *Refrigerated warehouse coolers* and *refrigerated warehouse freezers* shall comply with this section. *Walk-in coolers* and *walk-in freezers* that are not either site assembled or site constructed shall comply with the following:

-

Exception: Walk-in coolers and walk-in freezers regulated under federal law by the Department of Energy in 10 CFR 431, Subpart R - Walk-in Coolers and Walk-in Freezers.

1. Be equipped with automatic door-closers that firmly close walk-in doors that have been closed to within 1 inch (25 mm) of full closure.

Exception: Automatic closers are not required for doors more than 45 inches (1143 mm) in width or more than 7 feet (2134 mm) in height.
2. Doorways shall have strip doors, curtains, spring hinged doors or other method of minimizing infiltration when doors are open.
3. Walk-in coolers and refrigerated warehouse coolers shall contain wall, ceiling, and door insulation of not less than R-25 and walk-in freezers and refrigerated warehouse freezers shall contain wall, ceiling and door insulation of not less than R-32.
Exception: Glazed portions of doors or structural members need not be insulated.
4. Walk-in freezers shall contain floor insulation of not less than R-28.
5. Transparent reach-in doors for walk-in freezers and windows in walk-in freezer doors shall be of triple-pane glass, either filled with inert gas or with heat-reflective treated glass.
6. Windows and transparent reach-in doors for walk-in coolers shall be of double-pane or triple pane, inert gas-filled, heat-reflective treated glass.
7. Evaporator fan motors that are less than 1 hp (0.746 kW) and less than 460 volts shall use electronically commutated motors, brushless direct current motors, or 3-phase motors.
8. Condenser fan motors that are less than 1 hp (0.746 kW) shall use electronically commutated motors, permanent split capacitor-type motors or 3-phase motors.
9. Where antisweat heaters without antisweat heater controls are provided, they shall have a total door rail, glass and frame heater power draw of not more than 7.1 W/ft2 (76 W/m2) of door opening for walk-in freezersand 3.0 W/ft2 (32 W/m2) of door opening for walk-in coolers.
10. Where antisweat heater controls are provided, they shall reduce the energy use of the antisweat heater as a function of the relative humidity in the air outside the door or to the condensation on the inner glass pane.
11. 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.

C403.2.16Walk-in coolers and walk-in freezers.
Site-assembled or site-constructed *walk-in coolers* and *walk-in freezers* shall comply with the following:

Exception: Walk-in coolers and walk-in freezers regulated under federal law by the Department of Energy in 10 CFR 431, Subpart R - Walk-in Coolers and Walk-in Freezers.

-

1. Automatic door closers shall be provided that fully close walk-in doors that have been closed to within 1 inch (25 mm) of full closure.
Exception: Closers are not required for doors more than 45 inches (1143 mm) in width or more than 7 feet (2134 mm) in height.
2. Doorways shall be provided with strip doors, curtains, spring-hinged doors or other method of minimizing infiltration when the doors are open.
3. Walls shall be provided with insulation having a thermal resistance of not less than R-25, ceilings shall be provided with insulation having a thermal resistance of not less than R-25 and doors of *walk-in coolers* and *walk-in freezers* shall be provided with insulation having a thermal resistance of not less than R-32.
Exception: Insulation is not required for glazed portions of doors or at structural members associated with the walls, ceiling or door frame.
4. The floor of *walk-in freezers* shall be provided with insulation having a thermal resistance of not less than R-28.
5. Transparent reach-in doors for and windows in opaque *walk-in freezer* doors shall be provided with triple-pane glass having the interstitial spaces filled with inert gas or provided with heat-reflective treated glass.
6. Transparent reach-in doors for and windows in opaque *walk-in cooler* doors shall be double-pane heat-reflective treated glass having the interstitial space gas filled.
7. Evaporator fan motors that are less than 1 hp (0.746 kW) and less than 460 volts shall be electronically commutated motors or 3-phase motors.

8. Condenser fan motors that are less than 1 hp (0.746 kW) in capacity shall be of the electronically commutated or permanent split capacitor-type or shall be 3-phase motors.
Exception: Fan motors in *walk-in coolers* and *walk-in freezers* combined in a single enclosure greater than 3,000 square feet (279 m^2) in floor area are exempt.
9. Antisweat heaters that are not provided with antisweat heater controls shall have a total door rail, glass and frame heater power draw not greater than 7.1 W/ft^2 (76 W/m^2) of door opening for *walk-in freezers*, and not greater than 3.0 W/ft^2 (32 W/m^2) of door opening for *walk-in coolers*.
10. Antisweat heater controls shall be capable of reducing the energy use of the antisweat heater as a function of the relative humidity in the air outside the door or to the condensation on the inner glass pane.
11. Light sources shall have an efficacy of not less than 40 lumens per Watt, including any ballast losses, or shall be provided with a device that automatically turns off the lights within 15 minutes of when the *walk-in cooler* or *walk-in freezer* was last occupied.

C403.2.17Refrigerated display cases.
Site-assembled or site-constructed refrigerated display cases shall comply with the following:

Exception: Refrigerated display cases regulated under federal law by the Department of Energy in 10 CFR 431, Subpart C - Commercial Refrigerators, Freezers and Refrigerator-Freezers.

1. Lighting and glass doors in refrigerated display cases shall be controlled by one of the following:

1.1 Time switch controls to turn off lights during nonbusiness hours. Timed overrides for display cases shall turn the lights on for up to 1 hour and shall automatically time out to turn the lights off.

1.2 Motion sensor controls on each display case section that reduce lighting power by at least 50 percent within 3 minutes after the area within the sensor range is vacated.

2. Low-temperature display cases shall incorporate temperature-based defrost termination control with a time-limit default. The defrost cycle shall terminate first on an upper temperature limit breach and second upon a time limit breach.

3. Antisweat heater controls shall reduce the energy use of the antisweat heater as a function of the relative humidity in the air outside the door or to the condensation on the inner glass pane.

Replace original modification 8137 with the following comment as proposed as follows:

Revise as follows:

C402.1 General (Prescriptive). Building thermal envelope assemblies for buildings that are intended to comply with the code on a prescriptive basis in accordance with the compliance path described in Item 2 of Section C401.2, shall comply with the following:

1. The opaque portions of the building thermal envelope shall comply with the specific insulation requirements of Section C402.2 and the thermal requirements of either the *R*-value-based method of Section C402.1.3; the *U*-, *C*- and *F*-factor-based method of Section C402.1.4; or the component performance alternative of Section C402.1.5.
2. Roof solar reflectance and thermal emittance shall comply with Section C402.3.
3. Fenestration in building envelope assemblies shall comply with Section C402.4.
4. Air leakage of building envelope assemblies shall comply with Section C402.5.

Alternatively, where buildings have a vertical fenestration area or skylight area exceeding that allowed in Section C402.4, the building and building thermal envelope shall comply with Section C401.2, Item 1 or Section C401.2, Item 3.

Walk-in coolers, walk-in freezers, refrigerated warehouse coolers and refrigerated warehouse freezers shall comply with Section ~~C403.2.15 or C403.2.16~~ C403.2.14.

Delete the following Sections and Tables in their entirety:

C403.2.14 Refrigeration equipment performance

TABLE C403.2.14(1) MINIMUM EFFICIENCY REQUIREMENTS: COMMERCIAL REFRIGERATION

TABLE C403.2.14(2) MINIMUM EFFICIENCY REQUIREMENTS: COMMERCIAL REFRIGERATORS AND FREEZERS
C403.2.15 Walk-in coolers, walk-in freezers, refrigerated warehouse coolers and refrigerated warehouse freezers.
C403.2.16 Walk-in coolers and walk-in freezers.
C403.2.17Refrigerated display cases.

Replace with the following:

C403.2.14 Refrigeration equipment performance. Refrigeration equipment performance shall be determined in accordance with sections C403.2.14.1 and C403.2.14.2 for commercial refrigerators, freezers, refrigerator-freezers, walk-in coolers, walk-in freezers and refrigeration equipment. The energy use shall be verified through certification under an approved certification program or, where a certification program does not exist, the energy use shall be supported by data furnished by the equipment manufacturer.

Exception: Walk-in coolers and walk-in freezers regulated under federal law in accordance with

Subpart R of 10 CFR 431.

C403.2.14.1 Commercial refrigerators, freezers, refrigerator-freezers and refrigeration (Mandatory). Refrigeration equipment, defined in U.S. 10 CFR part 431.62, shall have an energy use in kWh/day not greater than the values of Table C403.2.14.1(1) (when tested and rated in accordance with AHRI Standard 1200.

TABLE

C403.2.14.1(1)

MINIMUM EFFICIENCY REQUIREMENTS: COMMERCIAL REFRIGERATORS AND FREEZERS AND REFRIGERATION

Equipment Category	Condensing Unit Configuration	Equipment Family	Rating Temp (F)	Operating Temp (F)	Equipment Classification[c]	Maximum daily energy consumption kWh/day [d,e]	Test Standard
Remote Condensing Commercial Refrigerators and Commercial Freezers	Remote (RC)	Vertical Open (VOP)	38 (M)	≥32	VOP.RC.M	0.64 x TDA +4.07	AHRI 1200
			0 (L)	<32	VOP.RC.L	2.20 x TDA + 6.85	
		Semivertical Open (SVO)	38 (M)	≥32	SVO.RC.M	0.66 x TDA + 3.18	
			0 (L)	<32	SVO.RC.L	2.20 x TDA + 6.85	
		Horizontal Open (HZO)	38 (M)	≥32	HZO.RC.M	0.35 x TDA + 2.88	
			0 (L)	<32	HZO.RC.L	0.55 x TDA + 6.88	
		Vertical Closed Transparent (VCT)	38 (M)	≥32	VCT.RC.M	0.15 x TDA + 1.95	
			0 (L)	<32	VCT.RC.L	0.49 x TDA + 2.61	
		Horizontal Closed Transparent (HCT)	38 (M)	≥32	HCT.RC.M	0.16 x TDA + 0.13	
			0 (L)	<32	HCT.RC.L	0.34 x TDA + 0.26	
		Vertical Closed Solid (VCS)	38 (M)	≥32	VCS.RC.M	0.10 x V + 0.26	
			0 (L)	<32	VCS.RC.L	0.21 x V + 0.54	
		Horizontal Closed Solid (HCS)	38 (M)	≥32	HCS.RC.M	0.10 x V+ 0.26	
			0 (L)	<32	HCS.RC.L	0.21 x V + 0.54	
		Service Over Counter(SOC)	38 (M)	≥32	SOC.RC.M	0.44 x TDA + 0.11	
			0 (L)	<32	SOC.RC.L	0.93 x TDA + 0.22	
		Vertical Open (VOP)	38 (M)	≥32	VOP.SCSV.M	1.69 x TDA + 4.71	
			0 (L)	<32	VOP.SC.L	4.25 x TDA + 11.82	

EN8137 -A2 Text Modification

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Self-Contained Commercial Refrigerators and Commercial Freezers with and Without Doors	Self-Contained (SC)	Semivertical Open (SVO)	38 (M)	≥32	SVO.SC.M	1.70 x TDA + 4.59	AHRI 1200
			0 (L)	<32	SVO.SC.L	4.26 x TDA +11.51	
		Horizontal Open (HZO)	38 (M)	≥32	HZO.SC.M	0.72 x TDA + 5.55	
			0 (L)	<32	HZO.SC.L	1.90 x TDA + 7.08	
		Vertical Closed Transparent (VCT)	38 (M)	≥32	VCT.SC.M	0.10 x V + 0.86	
			0 (L)	<32	VCT.SC.L	0.29 x V+ 2.95	
		Vertical Closed Solid (VCS)	38 (M)	≥32	VCS.SC.M	0.05 x V + 1.36	
			0 (L)	<32	VCS.SC.L	0.22 x V + 1.38	
		Horizontal Closed Transparent (HCT)	38 (M)	≥32	HCT.SC.M	0.06 x V + 0.37	
			0 (L)	<32	HCT.SC.L	0.08 x V + 1.23	
		Horizontal Closed Solid (HCS)	38 (M)	≥32	HCS.SC.M	0.05 x V + 0.91	
			0 (L)	<32	HCS.SC.L	0.06 x V + 1.12	
		Service Over Counter(SOC)	38 (M)	≥32	SOC.SC.M	0.52 x TDA + 1.00	
			0 (L)	<32	SOC.SC.L	1.10 x TDA + 2.10	
Self-Contained Commercial Refrigerators with Transparent Doors for Pull-Down Temperature Applications	Self-Contained (SC)	Pull-Down (PD)	38 (M)	≥32	PD.SC.M	0.11 x V + 0.81	AHRI 1200
	Remote (RC)	Vertical Open (VOP)	-15 (I)	≤-5[b]	VOP.RC.I	2.79 x TDA + 8.70	AHRI 1200
		Semivertical Open (SVO)	-15 (I)	≤-5[b]	SVO.RC.I	2.79 x TDA + 8.70	
		Horizontal Open (HZO)	-15 (I)	≤-5[b]	HZO.RC.I	0.7 x TDA + 8.74	
		Vertical Closed Transparent (VCT)	-15 (I)	≤-5[b]	VCT.RC.I	0.58 x TDA + 3.05	
		Horizontal Closed Transparent (HCT)	-15 (I)	≤-5[b]	HCT.RC.I	0.4 x TDA + 0.31	
		Vertical Closed Solid (VCS)	-15 (I)	≤-5[b]	VCS.RC.I	0.25 x V + 0.63	
		Horizontal Closed Solid (HCS)	-15 (I)	≤-5[b]	HCS.RC.I	0.25 x V + 0.63	
		Service Over Counter(SOC)	-15 (I)	≤-5[b]	SOC.RC.I	1.09 x TDA + 0.26	

Commercial Ice-Cream Freezers	Self-Contained (SC)	Vertical Open (VOP)	-15 (I)	≤-5 [b]	VOP.SC.I	5.4 x TDA + 15.02	AHRI 1200
		Semivertical Open (SVO)	-15 (I)	≤-5 [b]	SVO.SC.I	5.41 x TDA + 14.63	
		Horizontal Open (HZO)	-15 (I)	≤-5 [b]	HZO.SC.I	2.42 x TDA 9.00	
		Vertical Closed Transparent (VCT)	-15 (I)	≤-5 [b]	VCT.SC.I	0.62 x TDA + 3.29	
		Horizontal Closed Transparent (HCT)	-15 (I)	≤-5 [b]	HCT.SC.I	0.56 x TDA + 0.43	
		Vertical Closed Solid (VCS)	-15 (I)	≤-5 [b]	VCS.SC.I	0.34 × V + 0.88.	
		Horizontal Closed Solid (HCS)	-15 (I)	≤-5 [b]	HCS.SC.I	0.34 × V + 0.88.	
		Service Over Counter (SOC)	-15 (I)	≤-5 [b]	SOC.SC.I	1.53 x TDA + 0.36	

a. The meaning of the letters in this column is indicated in the columns to the left.

b. Ice-cream freezer is defined in 10 CFR 431.62 as a commercial freezer that is designed to operate at or below −5 °F and that the manufacturer designs, markets, or intends for the storing, displaying, or dispensing of ice cream.

c. Equipment class designations consist of a combination (in sequential order separated by periods (AAA).(BB).(C)) of the following:
(AAA)—An equipment family code (VOP = vertical open, SVO = semivertical open, HZO = horizontal open, VCT = vertical closed transparent doors, VCS = vertical closed solid doors, HCT = horizontal closed transparent doors, HCS = horizontal closed solid doors, and SOC = service over counter); (BB)—An operating mode code (RC = remote condensing and SC = self-contained); and (C)—A rating temperature code (M = medium temperature [38°F], L = low temperature [0°F], or I = ice cream temperature [-15°F]). For example, "VOP.RC.M" refers to the "vertical open, remote condensing, medium temperature" equipment class.

d. V is the volume of the case (ft^3) as measured in AHRI Standard 1200, Appendix C.

e. TDA is the total display area of the case (ft^2) as measured in AHRI Standard 1200, Appendix D.

(AAA)	An equipment family code where:		
	VOP	=	vertical open
	SVO	=	semivertical open
	HZO	=	horizontal open
	HCT	=	horizontal transparent doors
	HCS	=	horizontal solid doors
	SOC	=	service over counter
(BB)	An operating mode code:		
	RC	=	remote condensing
	SC	=	self-contained
(C)	A rating temperature code:		
	M	=	medium temperature (38°F)
	L	=	low temperature (0°F)
	I	=	ice-cream temperature (15°F)

C403.2.14.2 Walk-in coolers, walk-in freezers (Mandatory). Walk-in cooler and walk-in freezer refrigeration systems, except for walk-in process cooling refrigeration systems as defined in U.S. 10 CFR 431.302, shall meet the requirements of Tables C403.2.14.2(1), C403.2.14.2(2), and C403.2.14.2(3)

TABLE C403.2.14.2(1) WALK-IN COOLER AND FREEZER DISPLAY DOOR EFFICIENCY REQUIREMENTS[a]

CLASS DESCRIPTOR	CLASS	MAXIMUM ENERGY CONSUMPTION (kWh/day)[a]
Display door, medium temperature	DD, M	$0.04 \times A_{dd} + 0.41$
Display door, low temperature	DD, L	$0.15 \times A_{dd} + 0.29$

a. A_{dd} is the surface area of the display door.

TABLE C403.2.14.2(2) WALK-IN COOLER AND FREEZER NONDISPLAY DOOR EFFICIENCY REQUIREMENTS[a]

CLASS DESCRIPTOR	CLASS	MAXIMUM ENERGY CONSUMPTION (kWh/day)[a]
Passage door, medium temperature	PD, M	$0.05 \times A_{nd} + 1.7$
Passage door, low temperature	PD, L	$0.14 \times A_{nd} + 4.8$
Freight door, medium temperature	FD, M	$0.04 \times A_{nd} + 1.9$
Freight door, low temperature	FD, L	$0.12 \times A_{nd} + 5.6$

a. A_{nd} is the surface area of the nondisplay door.

TABLE C403.2.14.2(3) WALK-IN COOLER AND FREEZER REFRIGERATION SYSTEM EFFICIENCY REQUIREMENTS

CLASS DESCRIPTOR	CLASS	MINIMUM ANNUAL WALK-IN ENERGY FACTOR AWEF (Btu/W-h)[a]	Test Procedure
Dedicated condensing, medium temperature, indoor system	DC.M.I	5.61	
Dedicated condensing, medium temperature, outdoor system	DC.M.I O	7.60	
Dedicated condensing, low temperature, indoor system, net capacity (q_{net}) < 6,500 Btu/h	DC.L.I, < 6,500	$9.091 \times 10^{-5} \times q_{net} + 1.81$	
Dedicated condensing, low temperature, indoor system, net capacity (q_{net})≥6,500 Btu/h	DC.L.I, ≥6,500	2.40	

Dedicated condensing, low temperature, outdoor system, net capacity (q_{net}) < 6,500 Btu/h	DC.L.O, < 6,500	$6.522 \times 10^{-5} \times qnet + 2.73$	AHRI 1250
Dedicated condensing, low temperature, outdoor system, net capacity (q_{net})≥6,500 Btu/h	DC.L.O, ≥6,500	3.15	
Unit cooler, medium	UC.M	9.00	
Unit cooler, low temperature, net capacity (q_{net}) < 15,500 Btu/h	UC.L, < 15,500	$1.575 \times 10^{-5} \times qnet + 3.91$	
Unit cooler, low temperature, net capacity (q_{net})≥15,500 Btu/h	UC.L, ≥15,500	4.15	

a. q_{net} is net capacity (Btu/hr) as determined in accordance with AHRI Standard 1250

Add new standard(s) to Chapter 6 as follows:

DOE

U.S. Department of Energy
c/o Superintendent of Documents 1000
Independence Avenue SW
Washington DC 20585

U.S. 10 Part CFR 431, Subpart R: Commercial Refrigerators, Freezers and Refrigerator-Freezers

DOE

U.S. Department of Energy
c/o Superintendent of Documents 1000
Independence Avenue SW
Washington DC 20585

U.S. 10 Part CFR 431, Subpart R: Walk-in Coolers and Walk-in Freezers

AHRI

Air-Conditioning, Heating, & Refrigeration
Institute
2111 Wilson Blvd, Suite 500
Arlington VA 22201

AHRI 1250-(I-P) 2014: Standard for Performance Rating in Walk-in Coolers and Freezers

Reason statement:

This section of the Florida code is currently in conflict with, and preempted by, federal requirements for many walk-in coolers and walk-in freezers. This is because the 2015 International Energy Conservation Code (IECC) included provisions for commercial refrigeration products in conflict with the Department of Energy's (DOE) federal minimum efficiency standards. Manufacturers have been required to comply with DOE's energy conservation standards since 1990. The adopted IECC language within Florida codes have made it difficult for manufacturers that are selling HVAC equipment in Florida to comply with the local code, especially when it conflicts with the Code of Federal Regulations.

Under 42 U.S.C. 6297(a), it states:

§6297. Effect on other law

(a) Preemption of testing and labeling requirements

(1) Effective on March 17, 1987, this part supersedes any State regulation insofar as such State regulation provides at any time for the disclosure of information with respect to any measure of energy consumption or water use of any covered product if—

(A) such State regulation requires testing or the use of any measure of energy consumption, water use, or energy descriptor in any manner other than that provided under section 6293 of this title; or

(B) such State regulation requires disclosure of information with respect to the energy use, energy efficiency, or water use of any covered product other than information required under section 6294 of this title.

The states are prohibited from regulating additional testing or disclosure of information that is already requested by the DOE. Thus, federal law preempts any state code that conflicts with federal Energy Policy and Conservation Standards.

The proposed changes to this section remove this conflict by removing specific code requirements for these products and by directly referencing the federal requirements. The section governing refrigerated warehouse coolers and refrigerated warehouse freezers has been simplified, removing reference to those federally-governed products.

Bibliography:

1. ENERGY INDEPENDENCE AND SECURITY ACT OF 2007, Section 312, Walk-in Coolers and Walk-in Freezers.

2. Code of Federal Regulations, 10 CFR 431.306

3. 2014-06-03 Energy Conservation Program: Energy Conservation Standards for Walk-In Coolers and Freezers; Final Rule

https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=396fdbc135febfc51995dca67c2cee17&mc=true&n=pt10.3.431&r=PART&ty=HTML#sp10.3.431.c

EN7570

Date Submitted	11/30/2018	**Section**	403.3.3	**Proponent**	Jeff Sonne for FSEC
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Approved as Submitted				
Commission Action	Pending Review				

Comments

General Comments **No** | **Alternate Language** **Yes**

Related Modifications

7575

Summary of Modification

Clarifies that duct testing is required for simulated performance compliance if credit is taken for duct sealing beyond default leakage.

Rationale

There is a need to clarify when duct leakage testing is required for performance compliance.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

While seen by the proponent as a clarification, in some cases this change may require some additional enforcement effort.

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

None, or small in some cases if duct leakage lower than default was used for performance compliance in the past but not tested.

Impact to industry relative to the cost of compliance with code

None, or small in some cases if duct leakage lower than default was used for performance compliance in the past but not tested.

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

None, or small in some cases if duct leakage lower than default was used for performance compliance in the past but not tested.

Requirements

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

Benefits general public by clarifying that verification is required if duct leakage lower than default is used for performance compliance.

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

Improves the code by clarifying that verification is required if duct leakage lower than default is used for performance compliance.

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

Does not discriminate; provides clarification.

Does not degrade the effectiveness of the code

Increases code effectiveness by clarifying that verification is required if duct leakage lower than default is used for performance compliance.

Alternate Language

2nd Comment Period

7570-A1

Proponent Jeff Sonne for FSEC **Submitted** 5/22/2019 **Attachments** Yes

Rationale

Same as original mod; to clarify when duct leakage testing is required for performance compliance. Wording changes 1) address a public comment as agreed to during first TAC meeting and 2) add further clarification language to define Qn.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Same as original mod. A1 adds further clarification language to facilitate code enforcement.

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

Same as original mod.

Impact to industry relative to the cost of compliance with code

Same as original mod.

Impact to Small Business relative to the cost of compliance with code

None, or small in some cases if duct leakage lower than default was used for performance compliance in the past but not tested.

Requirements

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

Same as original mod.

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

Same as original mod.

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

Same as original mod.

Does not degrade the effectiveness of the code

Same as original mod.

[Replace original mod with the following:]

R403.3.3 Duct testing (Mandatory).

Ducts shall be pressure tested to determine air leakage by one of the following methods:

1. 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.
2. 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*.

[No other changes to section.]

R403.3.3 Duct testing (Mandatory).

Ducts shall be pressure tested to determine air leakage by one of the following methods:

1. 1.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.
2. 2.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. 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. 2.Duct testing is not mandatory for buildings complying by Section R405 of this code when a duct air leakage Qn to outside of 0.080 is indicated in the compliance report for the *proposed design*.

[No other changes to section.]

EN7575

Date Submitted	11/30/2018	**Section**	405.2.3	**Proponent**	Jeff Sonne for FSEC
Chapter	4	**Affects HVHZ**	No	**Attachments**	No

TAC Recommendation Approved as Submitted
Commission Action Pending Review

Comments

General Comments **No** **Alternate Language** **Yes**

Related Modifications

7570

Summary of Modification

Clarifies that for simulated performance compliance, the tested duct air leakage rate must not exceed the leakage rate of the proposed design.

Rationale

There is a need to clarify that when credit is taken for duct sealing beyond default leakage for performance compliance, the tested duct air leakage rate must not exceed the leakage rate of the proposed design.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

While seen by the proponent as a clarification, in some cases this change may require some additional enforcement effort.

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

None, or small in some cases if duct leakage lower than default was used for compliance in the past but not tested.

Impact to industry relative to the cost of compliance with code

None, or small in some cases if duct leakage lower than default was used for compliance in the past but not tested.

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

None, or small in some cases if duct leakage lower than default was used for compliance in the past but not tested.

Requirements

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

Benefits general public by clarifying that verification is required if duct leakage lower than default is used for performance compliance.

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

Improves the code by clarifying that verification is required if duct leakage lower than default is used for performance compliance.

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

Does not discriminate; provides clarification.

Does not degrade the effectiveness of the code

Increases code effectiveness by clarifying that verification is required if duct leakage lower than default is used for performance compliance.

2nd Comment Period

7575-A1

Proponent Jeff Sonne for FSEC **Submitted** 5/22/2019 **Attachments** Yes

Rationale

Same as original; additional language provides further clarification.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Same as original; additional language provides further clarification to facilitate code enforcement.

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

Same as original.

Impact to industry relative to the cost of compliance with code

Same as original.

Impact to Small Business relative to the cost of compliance with code

None, or small in some cases if duct leakage lower than default was used for compliance in the past but not tested.

Requirements

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

Same as original.

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

Same as original.

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

Same as original.

Does not degrade the effectiveness of the code

Same as original.

[Add the following to the original mod's text:]

R405.2.3. Duct air leakage testing.

In cases where duct air leakage lower than the default Qn to outside of 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 specified for the *proposed design*, testing in accordance with Section R403.3.2 shall verify a duct air leakage rate not exceeding the leakage rate of the *proposed design*. Otherwise, in accordance with Section R403.3.3, duct testing is not mandatory for buildings complying by Section R405.

R405.2.3. Duct air leakage testing.

In cases where duct air leakage lower than the default Qn to outside of 0.080 is specified for the *proposed design*, testing in accordance with Section R403.3.2 shall verify a duct air leakage rate not exceeding the leakage rate of the *proposed design*. Otherwise, in accordance with Section R403.3.3, duct testing is not mandatory for buildings complying by Section R405.

EN7649

Date Submitted	12/3/2018	**Section**	403.13	**Proponent**	Jeff Sonne for FSEC
Chapter	4	**Affects HVHZ**	No	**Attachments**	No

TAC Recommendation Approved as Submitted
Commission Action Pending Review

Comments

General Comments **Yes** **Alternate Language** **Yes**

Related Modifications

7651

Summary of Modification

Adds dehumidifier code sections.

Rationale

Recent Florida Solar Energy Center (FSEC) research conducted for the Florida Building Commission provides code dehumidifier recommendations which are hereby submitted for the 2020 Florida code cycle.

The full FSEC dehumidifier report is available at: http://publications.energyresearch.ucf.edu/wp-content/uploads/2018/07/FSEC-CR-2038-18.pdf.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None if dehumidifiers are not included in a project; if included this change will require some additional enforcement effort.

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

None if dehumidifiers are not included in project; some impact possible in applicable cases depending on current practice.

Impact to industry relative to the cost of compliance with code

None if dehumidifiers are not included in project; some impact possible in applicable cases depending on current practice.

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

None if dehumidifiers are not included in project; some impact possible in applicable cases depending on current practice.

Requirements

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

Benefits general public by providing research based requirements for efficient new construction dehumidifier installations in the state. Also reinforces proper condensate drainage for dehumidifiers.

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

Improves the code by providing research based requirements for efficient new construction dehumidifier installations in the state, and by reinforcing proper condensate drainage for dehumidifiers.

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

Does not discriminate; provides requirements for new code equipment category.

Does not degrade the effectiveness of the code

Does not degrade code effectiveness; provides requirements for new code equipment category, and reinforces proper condensate drainage for dehumidifiers.

Alternate Language

2nd Comment Period

7649-A3

Proponent Jeff Sonne for FSEC **Submitted** 5/24/2019 **Attachments** Yes

Rationale

This A3 modification is submitted to respond to concerns expressed by Mr. Sims and Mr. Britton. The sizing requirement and the general fan on requirement are removed. The word dehumidistat has been replaced with sensor to avoid any interpretation that the control of the dehumidifier is solely limited to a dehumidistat. Many thermostats include humidity sensors for instance. What we have not removed are the requirements #1, 2 and 3 under ducted dehumidifiers. These requirements were the result of completed FBC funded research (http://publications.energyresearch.ucf.edu/wp-content/uploads/2018/07/FSEC-CR-2038-18.pdf) and additional FBC research that is being finalized now. Opponents argue that #3 might go against one of the manufacturer recommended methods. The manufacturer may not have done the research we have. Recommendation #3: "A ducted dehumidifier shall not be ducted to or from a central ducted cooling system on the return duct side upstream from the central cooling evaporator coil" is a result of the FBC funded research that shows this configuration uses more energy in a cooling dominated climate and results in significantly poorer dehumidification of the home than alternatives. This result is not surprising because in these cases 1) the dehumidifier is sending hot, dry air which diminishes the AC's latent performance, and 2) when the dehumidifier operates while the AC is cycled off, hot dehumidifier air evaporates leftover moisture on the AC coil back into the space.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Same as original mod.

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

Same as original mod.

Impact to industry relative to the cost of compliance with code

Same as original mod.

Impact to Small Business relative to the cost of compliance with code

None if dehumidifiers are not included in project; some impact possible in applicable cases depending on current practice.

Requirements

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

Same as original mod.

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

Same as original mod.

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

Same as original mod.

Does not degrade the effectiveness of the code

Same as original mod.

Alternate Language

2nd Comment Period

7649-A1

Proponent Richard Sims **Submitted** 4/18/2019 **Attachments** Yes

Rationale

As written this mod is impossible to comply with. No such sizing method exists. Makes installing per manufacturers instructions illegal in Florida. Places unreasonable restrictions on control methods and use of technology. Ignores natural laws of thermodynamics and creates issues with restrictions on fan operation. Adding Dehumidifier Section to this code should not restrict normal proven uses.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Eliminates poor language Code officials should not have to interpret "undue indirect influence" Code officials should be able to accept manufacturers instructions as proof of proper installation. Eliminates sizing requirements that are not enforceable or possible.

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

Eliminates prohibition where connecting upstream of a coil is the only possible option and the DH will not operate in cooling mode anyway, property owners are being restricted from using a product that can prevent moisture damage and microbial growth.

Impact to industry relative to the cost of compliance with code

Eliminates language where HVAC professionals will be restricted from following manufacturers instructions for dehumidifier connects to central air systems and control configurations available from thermostat and control manufacturers.

Impact to Small Business relative to the cost of compliance with code

None if dehumidifiers are not included in project; some impact possible in applicable cases depending on current practice.

Requirements

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

Removes restrictions in other proposed modifications that keep certain occupants and owners from protecting property and building components from moisture damage and microbial growth.

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

Adds dehumidifier efficiency ratings to Florida Energy Code without placing restrictions upon established uses and methods that work well in Florida's climate.

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

Removes restrictions proposed in other modifications on use of manufacturers proven methods.

Does not degrade the effectiveness of the code

There is no current dehumidifier section in Florida Building Code. This is our one chance to get the first one right.

2nd Comment Period

EN7649-G1

Proponent Jim Britton **Submitted** 5/10/2019 **Attachments** No

Comment:

The proposed Code Modification (as written) puts Contractors and our Local Code Enforcement officials in an awkward position as many of the proposed standards are a deviation from Manufacturer's Specifications and recognized "Best Practices."

Manual S is NOT designed to size Dehumidification Systems. Manual S is strictly built to size Residential Heating and Air Conditioning Systems. There is no means to perform or enforce this proposed requirement.

Manufacturers of Dehumidifiers, Central Air Conditioning Equipment and HVAC Controls specifications support Dehumidification Systems working in conjunction with the AC System fan - as we are looking to treat the whole space, not the small space where the Dehumidifier is set. There are instances where the central fan has to be engaged to remove heat rejected from the Dehumidifier.

The Controls language is confusing. It seems to state that a separate Dehumidifier Control is required. Today, the controls available in most "Thermostats" are far superior in accuracy and operation than a standalone Dehumidifier control. If we are restricted to a straight Dehumidistat, it greatly reduces the potential performance of the Dehumidification system.

[Starting from the original mod, make the following changes:]

R403.13 Dehumidifiers (Mandatory).

If installed, a dehumidifier shall conform to the following requirements:

~~1. Dehumidifier sizing shall be in accordance with ACCA Manual S.~~

~~2~~1. The minimum rated efficiency of the dehumidifier shall be greater than 1.7 Liters/ kWh if the total dehumidifier capacity for the house is less than 75 pints/day and greater than 2.38 Liters/kWh if the total dehumidifier capacity for the house is greater than or equal to 75 pints/day.

~~3. Operation of the dehumidifier shall not require operation of the cooling system air handler fan.~~

~~4~~2. ~~Control of the dehumidifier shall be by a dehumidistat~~ The dehumidifier shall be controlled by a sensor that is installed in a location where it is exposed to mixed house air ~~and does not receive undue direct influence from mechanical ventilation air or supply air from the cooling or heating system(s)~~.

~~5~~3. Any dehumidifier unit located in unconditioned space that treats air from conditioned space shall be insulated to a minimum of R-2.

~~6~~4. Condensate disposal shall be in accordance with Section M1411.3.1 of the *Florida Building Code, Residential*.

R403.13.1 Ducted Dehumidifiers.

Ducted dehumidifiers shall, in addition to conforming to the requirements of Section R403.13, conform to the following requirements:

1. If a ducted dehumidifier is configured with return and supply ducts both connected into the supply side of the cooling system, a backdraft damper shall be installed in the supply air duct between the dehumidifier inlet and outlet duct.

2. If a ducted dehumidifier is configured with only its supply duct connected into the supply side of the central heating and cooling system, a backdraft damper shall be installed in the dehumidifier supply duct between the dehumidifier and central supply duct.

3. A ducted dehumidifier shall not be ducted to or from a central ducted cooling system on the return duct side upstream from the central cooling evaporator coil.

4. Ductwork associated with a dehumidifier located in unconditioned space shall be insulated to a minimum of R-6.

R403.13 Dehumidifiers (Mandatory).

If installed, a dehumidifier shall conform to the following requirements.

~~Dehumidifier sizing shall be in accordance with ACCA Manual S.~~

The minimum rated efficiency of the dehumidifier shall be greater than 1.7 Liters/kWh if the total dehumidifier capacity for the house is less than 75 pints/day and greater than 2.38 Liters/kWh if the total dehumidifier capacity for the house id greater than or equal to 75 pints/day.

~~Operation of the dehumidifier shall not require operation of the cooling system fan.~~

~~Control of the dehumidifier shall be by dehumidistat that is installed in a location where it is exposed to mixed house air and does not receive undue direct influence from mechanical ventilation air or supply air from the cooling or heating system.~~

Any dehumidifier unit located in unconditioned space that treats air from conditioned space shall be insulated to a minimum of R-2.

Condensate disposal shall be in accordance with Section M1411.3.1 of the *Florida Building Code, Residential.*

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2. If a ducted dehumidifier is configured with only its supply duct connected into the supply side of the central heating and cooling system, a backdraft damper shall be installed in the dehumidifier supply duct between the dehumidifier and central supply duct.

3. ~~A ducted dehumidifier shall not be ducted to or from a central ducted cooling system on the return duct side upstream from the central cooling evaporator coil.~~

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If installed, a dehumidifier shall conform to the following requirements:

1. Dehumidifier sizing shall be in accordance with ACCA Manual S.

2. The minimum rated efficiency of the dehumidifier shall be greater than 1.7 Liters/ kWh if the total dehumidifier capacity for the house is less than 75 pints/day and greater than 2.38 Liters/kWh if the total dehumidifier capacity for the house is greater than or equal to 75 pints/day.

3. Operation of the dehumidifier shall not require operation of the cooling system air handler fan.

4. Control of the dehumidifier shall be by a dehumidistat that is installed in a location where it is exposed to mixed house air and does not receive undue direct influence from mechanical ventilation air or supply air from the cooling or heating system(s).

5. Any dehumidifier unit located in unconditioned space that treats air from conditioned space shall be insulated to a minimum of R-2.

6. Condensate disposal shall be in accordance with Section M1411.3.1 of the *Florida Building Code, Residential.*

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2. If a ducted dehumidifier is configured with only its supply duct connected into the supply side of the central heating and cooling system, a backdraft damper shall be installed in the dehumidifier supply duct between the dehumidifier and central supply duct.

3. A ducted dehumidifier shall not be ducted to or from a central ducted cooling system on the return duct side upstream from the central cooling evaporator coil.

4. Ductwork associated with a dehumidifier located in unconditioned space shall be insulated to a minimum of R-6.

FRACCA RECOMMENDED CHANGES TO MOD EN7649

R403.13 Dehumidifiers (Mandatory).

If installed, a dehumidifier shall conform to the following requirements.

Dehumidifier sizing shall be in accordance with ACCA Manual S. This is a ridiculous (non-existent) DH sizing method that is impossible to comply with. ACCA Manual S does not intend or profess to be for any other purpose than sizing residential central heating and cooling equipment. ACCA Manual S worksheets and software cannot be used to size DH units. DH unit manufacturers do not even publish the data that is required to be used in Manual S methodology. It is impossible for anyone to size a dehumidifier using Manual S as directed by ACCA. There is no variation of Manual S available from ACCA for this.

The minimum rated efficiency of the dehumidifier shall be greater than 1.7 Liters/kWh if the total dehumidifier capacity for the house is less than 75 pints/day and greater than 2.38 Liters/kWh if the total dehumidifier capacity for the house id greater than or equal to 75 pints/day.

Operation of the dehumidifier shall not require operation of the cooling system fan. Many legitimate DH uses require operation of the central air fan. DH unit manufacturers have always allowed this configuration. Thermostat and control manufacturers have always provided control modes that support such operation and their instruction manuals provide details to set this up. Where DH units process air within a mechanical closet, circulation using the central air fan is required; otherwise, the DH unit will overheat the space or simply shutoff because the RH level was dropped simply due to excessive heat added to the space. H2o rejection rate is greatly diminished when DH units recirculate the heat added.

Control of the dehumidifier shall be by dehumidistat that is installed in a location where it is exposed to mixed house air and does not receive undue direct influence from mechanical ventilation air or supply air from the cooling or heating system. Integrated control systems that do not require a dehumidistat allow users to operate the DH unit in conjunction with the central air system using remote or local user interface. Dehumidistats serve no purpose where more advanced integrated controls are utilized. There are many cases where integrated controls are superior. Dehumidistats should allowed but not required. We certainly do not need Code Officials to have to interpret things like “undue direct influence”.

Any dehumidifier unit located in unconditioned space that treats air from conditioned space shall be insulated to a minimum of R-2.

Condensate disposal shall be in accordance with Section M1411.3.1 of the *Florida Building Code, Residential.*

FRACCA RECOMMENDED CHANGES TO MOD EN7649

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Ducted dehumidifiers shall, in addition to the requirements of Section R403.13, conform to the following requirements:

1. If a ducted dehumidifier is configured with return and supply ducts both connected to the supply side of the cooling system, a backdraft damper shall be installed in the supply air duct between the dehumidifier inlet and outlet duct. There is no precedent for installing back-draft-dampers in supply air trunk lines of central air systems. There are many reasons this is a bad idea including the additional pressure drop (and noise) created across a BDD in a supply air trunk line. Back-draft dampers are not available in sizes that would be needed in rectangular trunk lines. This idea came from simplified lab set-ups rather than real world central air systems. Nobody can point to any real-world examples of back-draft-dampers in central supply air trunk lines and no DH manufacturer requires it. Code modifications should be based upon field proven best practices; to date, this method has been restricted to test labs rather than real world use.

2. If a ducted dehumidifier is configured with only its supply duct connected into the supply side of the central heating and cooling system, a backdraft damper shall be installed in the dehumidifier supply duct between the dehumidifier and central supply duct.

3. A ducted dehumidifier shall not be ducted to or from a central ducted cooling system on the return duct side upstream from the central cooling evaporator coil. There are legitimate reasons why all DH manufacturers have always allowed connection in this way. All DH unit manufacturers instructions show this configuration as one of the legitimate uses of their product. There are cases where connection to concealed supply air ducts is impossible and the only possible methods are manufacturer approved connection upstream of the evaporator coil.

4. Ductwork associated with a dehumidifier located in unconditioned space shall be insulated to a minimum of R-6.

FRACCA RECOMMENDED CHANGES TO MOD EN7649

FRACCA RECOMMENDED LANGUAGE

R403.13 Dehumidifiers (Mandatory).

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The minimum rated efficiency of the dehumidifier shall be greater than 1.7 Liters/kWh if the total dehumidifier capacity for the house is less than 75 pints/day and greater than 2.38 Liters/kWh if the total dehumidifier capacity for the house id greater than or equal to 75 pints/day.

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6. If a ducted dehumidifier is configured with only its supply duct connected into the supply side of the central heating and cooling system, a backdraft damper shall be installed in the dehumidifier supply duct between the dehumidifier and central supply duct.

7. ~~A ducted dehumidifier shall not be ducted to or from a central ducted cooling system on the return duct side upstream from the central cooling evaporator coil.~~ DELETE IN ENTIRETY

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Condensate disposal shall be in accordance with Section M1411.3.1 of the *Florida Building Code, Residential.*

FRACCA RECOMMENDED CHANGES TO MOD EN7649

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3. A ducted dehumidifier shall not be ducted to or from a central ducted cooling system on the return duct side upstream from the central cooling evaporator coil. There are legitimate reasons why all DH manufacturers have always allowed connection in this way. All DH unit manufacturers instructions show this configuration as one of the legitimate uses of their product. There are cases where connection to concealed supply air ducts is impossible and the only possible methods are manufacturer approved connection upstream of the evaporator coil.

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FRACCA RECOMMENDED CHANGES TO MOD EN7649

FRACCA RECOMMENDED LANGUAGE

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~~Control of the dehumidifier shall be by dehumidistat that is installed in a location where it is exposed to mixed house air and does not receive undue direct influence from mechanical ventilation air or supply air from the cooling or heating system.~~ DELETE IN ENTIRETY

Any dehumidifier unit located in unconditioned space that treats air from conditioned space shall be insulated to a minimum of R-2.

Condensate disposal shall be in accordance with Section M1411.3.1 of the *Florida Building Code, Residential.*

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7. ~~A ducted dehumidifier shall not be ducted to or from a central ducted cooling system on the return duct side upstream from the central cooling evaporator coil.~~ DELETE IN ENTIRETY

8. Ductwork associated with a dehumidifier located in unconditioned space shall be insulated to a minimum of R-6.

EN8371

Date Submitted	12/15/2018	**Section**	501.7	**Proponent**	Oscar Calleja
Chapter	5	**Affects HVHZ**	No	**Attachments**	No

TAC Recommendation Approved as Submitted
Commission Action Pending Review

Comments

General Comments **No** **Alternate Language** **Yes**

Related Modifications

Summary of Modification

On existing Residential buildings, replacement of AC ductwork is required to comply with the Prescriptive requirements of the Energy Code. This means min R-8 ductwork in attics. This Mod removes that requirement allowing for R-6 ductwork to be installed.

Rationale

In most Residential existing dwellings the space needed for AC ductwork is usually a problem. Attic truss space limits the size of ducts that will fit through.

Current Residential Energy Code Section 501.7 mandates that when a complete duct system is replaced the duct must comply with the Prescriptive requirements. Those include a Minimum R value of R-8 for ducts. R-8 ducts have larger outside dimensions and therefore present a problem when replacing smaller sized ducts. This Mod creates an exception so that R-6 ducts can be used but only when the Energy consumption of the dwelling is not increased. That can be proven by utilizing Energy Gauge or other approved software with a before and after whole house annual Energy consumption.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Allows enforcement by requiring an Energy use report when using duct R-value less than R-8.

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

Solves huge problem when R-8 duct will not fit in current attic space. Avoids having to reduce the internal duct size.

Impact to industry relative to the cost of compliance with code

Solves huge problem when R-8 duct will not fit in current attic space. Avoids having to reduce the internal duct size.

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

Solves huge problem when R-8 duct will not fit in current attic space. Avoids having to reduce the internal duct size.

Requirements

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

Allows new air distribution systems to be installed replacing old dirty and leaking ducts.

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

Allows new air distribution systems to be installed replacing old dirty and leaking ducts.

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

Does not discriminate against materials, products or methods.

Does not degrade the effectiveness of the code

Does not degrade the effectiveness of Code by requiring that Energy use of home not be increased.

Alternate Language

2nd Comment Period

8371-A3

Proponent Oscar Calleja **Submitted** 5/26/2019 **Attachments** Yes

Rationale

Mandatory use of R-8 ducts in existing Residential replacements not only is impractical due to typical attic truss space but also adds an undue economic burden to the homeowner. The Code allows R-6 ducts in new construction and should not penalize existing homes with a higher threshold. Most ductwork replacements are done when replacing AC equipment, which is done with new, higher efficiency equipment anyway.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact to enforcement entity.

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

Will provide building and property owners a lower cost of compliance.

Impact to industry relative to the cost of compliance with code

Will provide industry a lower cost of compliance.

Impact to Small Business relative to the cost of compliance with code

Solves huge problem when R-8 duct will not fit in current attic space. Avoids having to reduce the internal duct size.

Requirements

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

Providing a practical and lower cost compliance alternative will incentivize the public to replace their old, leaky ducts. That will improve heath, safety and welfare of the public.

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

Strengthens and improves the Code by making the installation more practical and less costly, thus improving the probability of homeowner compliance.

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

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

Does not degrade the effectiveness of the code

Does not degrade the effectiveness of the code since it prevents the work to be done outside of the Code (due to current difficulty and cost).

Alternate Language

2nd Comment Period

8371-A2

Proponent Jeff Sonne for FSEC **Submitted** 5/22/2019 **Attachments** Yes

Rationale

Original mod 8371 exception language would allow uninsulated ductwork in unconditioned space even if some level of insulation would fit, which would waste energy and could also lead to condensation issues. Also, the original mod's energy use limit could be made up for by an older AC being replaced by a minimum code unit at the same time of the duct change out, which would negate the benefit of the increased equipment efficiency. This A2 mod still provides a duct R-value exception for cases where space for ductwork is limited, but at the same time insures that an unnecessarily low R-value duct is not used.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Same as original mod.

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

Same as original mod.

Impact to industry relative to the cost of compliance with code

Same as original mod.

Impact to Small Business relative to the cost of compliance with code

Solves huge problem when R-8 duct will not fit in current attic space. Avoids having to reduce the internal duct size.

Requirements

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

Same as original mod.

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

Same as original mod.

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

Same as original mod.

Does not degrade the effectiveness of the code

Same as original mod.

Alternate Language

1st Comment Period History

8371-A1

Proponent Jeff Sonne for FSEC **Submitted** 2/14/2019 **Attachments** Yes

Rationale

Alt language intended to insure that if space limitations do not allow Code stipulated duct R-value to be used, the highest R-value that will fit in available space be used.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Same as original mod.

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

Same as original mod.

Impact to industry relative to the cost of compliance with code

Same as original mod.

Impact to Small Business relative to the cost of compliance with code

Solves huge problem when R-8 duct will not fit in current attic space. Avoids having to reduce the internal duct size.

Requirements

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

Same as original mod.

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

Same as original mod.

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

Same as original mod.

Does not degrade the effectiveness of the code

Same as original mod.

1st Comment Period History

EN8371-G1

Proponent David Mann **Submitted** 2/14/2019 **Attachments** Yes

Comment:

Please see attached opposing comment.

R501.7 Building systems and components.

Thermal efficiency standards are set for the following building systems and components where new products are installed or replaced in existing buildings, and for which a permit must be obtained. New products shall meet the minimum efficiencies allowed by this code for the following systems and components:

Heating, ventilating or air-conditioning systems;
Service water or pool heating systems;
Lighting systems; and
Replacement fenestration.

Exceptions:

1. Where part of a functional unit is repaired or replaced. For example, replacement of an entire HVAC system is not required because a new compressor or other part does not meet code when installed with an older system.
2. If the unit being replaced is itself a functional unit, such as a condenser, it does not constitute a repair. Outdoor and indoor units that are not designed to be operated together must meet the U.S. Department of Energy certification requirements contained in Section R303.1.2. Matched systems are required; this match may be verified by any one of the following means:

   a. AHRI data

   b. Accredited laboratory

   c. Manufacturer's letter

   d. Letter from registered P.E. State of Florida

3. Where existing components are utilized with a replacement system, such as air distribution system ducts or electrical wiring for lights, such components or controls need not meet code if meeting code would require that component's replacement.
4. Replacement equipment that would require extensive revisions to other systems, equipment or elements of a building where such replacement is a like-for-like replacement, such as through-the-wall condensing units and PTACs, chillers and cooling towers in confined spaces.
5. <u>If space does not permit replacement air distribution systems to meet the prescriptive R-value requirement of this code, replacement ducts shall have either the same R-value as the ducts being replaced or a higher R-value. Ducts with R-6 insulation value shall be considered sufficient to satisfy the requirements of R501.7.</u>

[Replace original mod 8371 with the following:]

R501.7 Building systems and components.

Thermal efficiency standards are set for the following building systems and components where new products are installed or replaced in existing buildings, and for which a permit must be obtained. New products shall meet the minimum efficiencies allowed by this code for the following systems and components:

Heating, ventilating or air-conditioning systems;
Service water or pool heating systems;
Lighting systems; and
Replacement fenestration.

Exceptions:

1. Where part of a functional unit is repaired or replaced. For example, replacement of an entire HVAC system is not required because a new compressor or other part does not meet code when installed with an older system.
2. If the unit being replaced is itself a functional unit, such as a condenser, it does not constitute a repair. Outdoor and indoor units that are not designed to be operated together must meet the U.S. Department of Energy certification requirements contained in Section R303.1.2. Matched systems are required; this match may be verified by any one of the following means:

    a. AHRI data

    b. Accredited laboratory

    c. Manufacturer's letter

    d. Letter from registered P.E. State of Florida

3. Where existing components are utilized with a replacement system, such as air distribution system ducts or electrical wiring for lights, such components or controls need not meet code if meeting code would require that component's replacement.
4. Replacement equipment that would require extensive revisions to other systems, equipment or elements of a building where such replacement is a like-for-like replacement, such as through-the-wall condensing units and PTACs, chillers and cooling towers in confined spaces.
5. <u>If space does not permit replacement air distribution systems to meet the prescriptive R-value requirement of this code, replacement ducts shall have either the same R-value as the ducts being replaced or the highest available R-value duct insulation that will continuously fit in the available space, whichever is greater.</u>

5. Replacement air distribution systems shall either ~~need not~~ meet current Code's prescriptive R-value requirement or if space does not permit, then the highest available R-value duct insulation that will fit in the available space, as long as overall building energy use after replacement is not more than the original building's energy use prior to alteration.

R501. 7Building systems and components.

Thermal efficiency standards are set for the following building systems and components where new products are installed or replaced in existing buildings, and for which a permit must be obtained. New products shall meet the minimum efficiencies allowed by this code for the following systems and components:

Heating, ventilating or air-conditioning systems;
Service water or pool heating systems;
Lighting systems; and
Replacement fenestration.

Exceptions:

1. Where part of a functional unit is repaired or replaced. For example, replacement of an entire HVAC system is not required because a new compressor or other part does not meet code when installed with an older system.
2. If the unit being replaced is itself a functional unit, such as a condenser, it does not constitute a repair. Outdoor and indoor units that are not designed to be operated together must meet the U.S. Department of Energy certification requirements contained in Section R303.1.2. Matched systems are required; this match may be verified by any one of the following means:

   a. AHRI data
   b. Accredited laboratory
   c. Manufacturer's letter
   d. Letter from registered P.E. State of Florida

3. Where existing components are utilized with a replacement system, such as air distribution system ducts or electrical wiring for lights, such components or controls need not meet code if meeting code would require that component's replacement.
4. Replacement equipment that would require extensive revisions to other systems, equipment or elements of a building where such replacement is a like-for-like replacement, such as through-the-wall condensing units and PTACs, chillers and cooling towers in confined spaces.
5. **Replacement air distribution systems need not meet current Code's prescriptive R-value as long as overall building energy use after replacement is not more than the original building's prior to alteration.**

American Chemistry Council

February 13, 2019

RE: ACC Comments Opposing Florida Building Code 7th Edition Update Energy Proposal #8371

I am writing on behalf of the American Chemistry Council (ACC) to oppose proposal #8371. This proposal exempts replacement duct systems from code R-value requirements. The exemption would result in less insulation and higher energy costs. Ducts are commonly installed in attics, where temperatures can exceed 130-140 degrees Fahrenheit. While we understand the desire for some flexibility in the code requirements as they pertain to existing buildings, the losses in energy efficiency could be significant if this proposal is adopted. Because the opportunities to improve Florida's existing building stock are so rare, we urge the Commission to be especially careful with any proposals that could weaken code provisions that apply to existing buildings.

We appreciate the need for Florida specific amendments, but only so long as they recognize that the model code is a floor, not a ceiling, and do not weaken the substantive requirements of the code. Strong thermal envelope requirements enhance energy efficiency, drive materials and product innovation, and support continued economic and job growth. Therefore we request that you oppose 8371 in favor of the provisions of the 2018 IECC.

About ACC and Building Energy Codes

ACC members apply the science of chemistry to make innovative products and services that make people's lives better, healthier and safer. The business of chemistry is a $526 billion enterprise and a key element of the nation's economy. Chemistry companies are among the largest investors in research and development, investing $91 billion in 2016. In the state of Florida, chemical manufacturing is a $9B industry employing over 15,000 people and another 26,000 in related jobs.

Florida's energy code impacts ACC's members and their employees. The chemical industry supplies many products and materials to the building and construction value chain, including those that deliver energy efficiency throughout the entire structure. ACC's members are also large users of energy so the responsible use of energy is important to the industry's economic health and competitiveness. Energy efficiency is the lowest cost option for meeting energy demand. Energy efficient buildings create economic opportunities for businesses and industry by promoting new energy efficient technologies and reducing energy waste.

ACC has extensive knowledge regarding building code development. ACC is a partner in recent building science research, including projects with the Department of Energy and Home Innovation Research Labs. ACC representatives serve on the ICC, ASHRAE, ASTM, AAMA, and other code and standard setting bodies.

Please contact me at (404) 242-5016 or Michael_Power@AmericanChemistry.com if we can be of any further assistance.

Regards,

americanchemistry.com® 1995 North Park Place, Suite 240 | Atlanta, GA | (770)-421-2991

Michael Power
Senior Director, Southern Region
American Chemistry Council

EN7655

10

Date Submitted	12/3/2018	**Section**	408.3	**Proponent**	Ann Russo8
Chapter	4	**Affects HVHZ**	No	**Attachments**	No

TAC Recommendation Approved as Submitted
Commission Action Pending Review

Comments

General Comments **Yes** **Alternate Language** **No**

Related Modifications

RB187-16

Summary of Modification

This change adds an option for dehumidification for unvented crawl spaces.

Rationale

Typical conditioning measures involve supplying conditioned air from the occupied (conditioned) space of the building or exhausting air from the crawl space with make up air provided from the occupied (conditioned) space of the building. This code change allows another means of conditioning and controlling moisture, specifically dehumidification. Dehumidification is a proven technology.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Adding optional method only. No impact on code enforcement.

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

This change will not increase the cost of construction as it is only adding an optional method for treatment of unvented crawl spaces.

Impact to industry relative to the cost of compliance with code

This change will not increase the cost of construction as it is only adding an optional method for treatment of unvented crawl spaces.

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

This change will not increase the cost of construction as it is only adding an optional method for treatment of unvented crawl spaces.

Requirements

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

This change is only adding an optional method for treatment of unvented crawl spaces so will not effect the code requirements or enforcement.

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

This change is only adding an optional method for treatment of unvented crawl spaces so will not effect the code requirements or enforcement.

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

This change is only adding an optional method for treatment of unvented crawl spaces so will not effect the code requirements or enforcement. Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities.

Does not degrade the effectiveness of the code

This change is only adding an optional method for treatment of unvented crawl spaces so will not effect the code requirements or enforcement. Does not degrade the effectiveness of the code.

2nd Comment Period

EN7655-G1

Proponent Borrone Jeanette **Submitted** 5/21/2019 **Attachments** No

Comment:

I agree with the proposed revision.

Revise as follows:

- **R408.3 Unvented crawl space. Ventilation openings in under-floor spaces specified in Sections R408.1 and R408.2 shall not be required where the following items are provided:**

1. Exposed earth is covered with a continuous Class I vapor retarder. Joints of the vapor retarder shalloverlapby6inches(152mm)andshallbesealedortaped.Theedgesofthevaporretarder shall extend not less than 6 inches (152 mm) up the stem wall and shall be attached and sealed to the stem wall or insulation.

2. One of the following is provided for the under-floorspace:

   2.1.Continuously operated mechanical exhaust ventilation at a rate equal to 1 cubic foot per minute (0.47 L/s) for each 50 square feet (4.7 m_2) of crawl space floor area, including an air pathwaytothecommonarea(suchasaductortransfergrille),andperimeterwallsinsulated in accordance with the Florida Building Code, Energy Conservation.

   2.2.*Conditioned air* supply sized to deliver at a rate equal to 1 cubic foot per minute (0.47 L/s) for each 50 square feet (4.7 m_2) of under-floor area, including a return air pathway to the common area (such as a duct or transfer grille), and perimeter walls insulated in accordance with the Florida Building Code, Energy Conservation.

   2.3.Plenuminexistingstructurescomplyingwith SectionM1601.5,ifunder-floorspaceisusedas aplenum.

2.4. Dehumidification sized to provide 70 pints (33 liters) of moisture removal per day

for every 1,000 ft2 (93 m2) of crawl space floor area.

TAC: Energy

Total Mods for **Energy** in **No Affirmative Recommendation: 16**

Total Mods for report: 26

Sub Code: Energy Conservation

EN7915

11

Date Submitted	12/11/2018	**Section**	202	**Proponent**	Joseph Hetzel
Chapter	2	**Affects HVHZ**	No	**Attachments**	No

TAC Recommendation No Affirmative Recommendation
Commission Action Pending Review

Comments

General Comments **Yes** **Alternate Language** **No**

Related Modifications

Summary of Modification

Clarification to the definitions of Entrance Door and Fenestration.

Rationale

The definition of Entrance Door needs grammatical improvements as shown in the proposal. The key change is adding the word 'occupant' before the purposes of the door. This is to distinguish entrance doors from doors which are used for trucks or other cargo or material movement.
The edit to the definition of Fenestration is for consistency with Table C402.4 as well as some editorial clarity.
The proposal was submitted to the ICC as CE11-16 Part 1 (Commercial) and was approved as submitted.

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

No impact.

Requirements

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

No adverse effect on health, safety and welfare by clarifying the definitions of Entrance Door and Fenestration.

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

Strengthens and improves the code by clarifying the definitions of Entrance Door and Fenestration.

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

No discrimination since it simply involves clarifying the definitions of Entrance Door and Fenestration.

Does not degrade the effectiveness of the code

Improves the effectiveness of the code by clarifying the definitions of Entrance Door and Fenestration.

2nd Comment Period

EN7915-G1

Proponent Dick Wilhelm **Submitted** 5/19/2019 **Attachments** No

Comment:

AAMA supports the language in this proposal

ENTRANCE DOOR. ~~Fenestration products~~<u>A vertical fenestration product</u> used for<u> occupant</u> ingress, egress and access in nonresidential buildings, including, but not limited to, exterior entrances ~~that utilize~~<u>utilizing</u> latching hardware and automatic closers and ~~contain~~<u>containing</u> over 50-percent ~~glass~~<u>glazing</u> specifically designed to withstand heavy ~~use and possibly abuse~~<u>duty usage</u>.

FENESTRATION. Products classified as either <u>skylights or </u>vertical fenestration~~ or skylights~~.

Skylight<u>s</u>. Glass or other transparent or translucent glazing material installed at a slope of less than 60 degrees (1.05 rad) from horizontal. Glazing materials in skylights, including unit skylights, tubular daylighting devices, solariums, sunrooms, roofs and sloped walls are included in this definition.

Vertical fenestration. Windows ~~(~~<u>that are </u>fixed or ~~moveable~~<u>operable</u>~~)~~, opaque doors, glazed doors, glazed block and combination opaque~~/~~<u> and </u>glazed doors composed of glass or other transparent or translucent glazing materials and installed at a slope of ~~at least~~<u>not less than</u> 60 degrees (1.05 rad) from horizontal.

EN8175

Date Submitted 12/14/2018
Chapter 2
Section 202
Affects HVHZ No
Proponent Armin Hauer
Attachments No
TAC Recommendation No Affirmative Recommendation
Commission Action Pending Review

Comments

General Comments Yes
Alternate Language No

Related Modifications

C403.2.12.2 Motor nameplate horsepower

Summary of Modification

added definition

Rationale

Definition is needed for an update to C403.2.12.2.

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

no impact

Requirements

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

The associated proposal C403.2.12.2 corrects an IP / SI conversion error related to shaft power: 6 bhp equals 4476 W mechanical power.

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

The associated proposal C403.2.12.2 moves the clause about fan system motor nameplate into the exceptions section for better clarity.

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

The associated proposal C403.2.12.2 increases the design options for load-matching variable-speed fan motors, accommodates new motor and drive technologies, and it simplifies the motor selection criteria for fans.

Does not degrade the effectiveness of the code

The associated proposal C403.2.12.2 moves the clause about fan system motor nameplate into the exceptions section for better clarity.

2nd Comment Period

EN8175-G1

Proponent Amanda Hickman **Submitted** 5/23/2019 **Attachments** No

Comment:

This modification as well as EN8184 should be approved, as it recognizes recent updates made to ASHRAE 90.1. This will increase design options for load-matching variable-speed fan motors, accommodates new motor and drive technologies, and it simplifies the motor selection criteria for fans. At the Committee Hearing the ICC unanimously approved ASHRAE's an identical proposal (CE136).

Fan Nameplate Electrical Input Power. The nominal electrical input power rating stamped on a fan assembly nameplate.

EN7205

Date Submitted	11/6/2018	**Section**	405.6.3	**Proponent**	Bryan Holland
Chapter	4	**Affects HVHZ**	No	**Attachments**	No

TAC Recommendation No Affirmative Recommendation
Commission Action Pending Review

Comments

General Comments Yes **Alternate Language** No

Related Modifications

Summary of Modification

This proposed modification revises the voltage drop requirement to include "customer-owned service conductors" in addition to feeder conductors and branch circuit conductors.

Rationale

The current requirement for voltage drop does not include customer-owned service conductors which in long runs can result in significant voltage drop. The term “conductors” has been added to feeder and branch circuit to add clarity. A definition of "voltage drop" is being added to harmonize the Florida Energy Code with the IECC and ASHRAE 90.1 Standard.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposed modification will have no impact to the local entity relative to code enforcement.

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

This proposed modification will ensure customer-owned service conductors are included in the voltage drop calculation to prevent unnecessary losses in the complete premises wiring systems.

Impact to industry relative to the cost of compliance with code

This proposed modification could result in an increased cost of compliance if the designer chooses to increase the customer-owner service conductors in response to excess voltage drop.

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

This proposed modification should not have an impact on small business.

Requirements

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

This proposed modification is directly connected 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 proposed modification improves the code by adding a needed definition and revising the prescriptive language of the section to include all conductors on the premises-wiring side of the electrical installation.

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.

Does not degrade the effectiveness of the code

This proposed modification enhances the effectiveness of the code.

2nd Comment Period

EN7205-G2

Proponent Bryan Holland **Submitted** 5/21/2019 **Attachments** No

Comment:

Please reconsider this proposed modification for approval. The revised language simply adds "customer-owned service conductors" to the voltage drop requirement as previously required in earlier editions of the FBC Energy Conservation Code. Excluding these premises wiring conductors from the calculation can results in excess energy losses on the system before a single load is being supplied. Please be advised the ICC Commercial Energy Code Development Committee unanimously voted 15-0 to approve Proposal CE214-19 during the ICC Group B Committee Action Hearings. This will keep the Florida Energy Code aligned with the IECC-C.

2nd Comment Period

EN7205-G3

Proponent Jennifer Privateer **Submitted** 5/22/2019 **Attachments** No

Comment:

agreed as modified

2nd Comment Period

EN7205-G4

Proponent Jennifer Privateer **Submitted** 5/22/2019 **Attachments** No

Comment:

I agree

2nd Comment Period

EN7205-G5

Proponent Harold Barrineau **Submitted** 5/25/2019 **Attachments** No

Comment:

I agree this is a good modification

2nd Comment Period

EN7205-G6

Proponent Harold Barrineau **Submitted** 5/25/2019 **Attachments** No

Comment:

I agree with this modification

1st Comment Period History

EN7205-G1

Proponent Vincent Della Croce **Submitted** 1/8/2019 **Attachments** No

Comment:

I support the proposed modification as it will ensure the Code includes the most current requirements for electrical installations that provide for the health, safety and general welfare of the public.

C405.6.3 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.

Add to Section C202 Definition:

VOLTAGE DROP. A decrease in voltage caused by losses in the wiring systems that connect the power source to the load.

EN7206

Date Submitted	11/6/2018	**Section**	405.6.1	**Proponent**	Bryan Holland
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	No Affirmative Recommendation				
Commission Action	Pending Review				

Comments

General Comments **Yes** **Alternate Language** **No**

Related Modifications

Summary of Modification

This proposed modification revises the section to clarify that compliance with Section 8 Power of the ASHRAE Standard 90.1 is required by Section 405.6.1

Rationale

The purpose of this proposed modification is to align the code with DS 2016-033 and further clarify that Section 8 Power of the ASHRAE Standard 90.1 is the part being referenced by C405.6 Electric power. The revised language will assist those designing, installing, or enforcing the requirements of the Florida Energy Code.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposed modification will assist the local entity when enforcing the requirement of the Florida Energy Code by clarifying exactly what requirements in the ASHRAE Standard 90.1 are applicable to C405.6.1 compliance.

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

This proposed modification will ensure building and property owners have electric distribution systems installed in compliance with both C405.6 of the FBC-EC and Section 8 of ASHRAE Standard 90.1.

Impact to industry relative to the cost of compliance with code

This proposed modification will not change the cost of compliance with the code.

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

This proposed modification will have no impact to small business.

Requirements

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

This proposed modification is directly connected to the health, safety, and welfare of the general public by ensuring electrical power distribution in buildings meet the requirements of the code.

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

This proposed modification improves the code by clarifying the section and giving a pointer to the specific section of ASHARE Standard 90.1 that is applicable.

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.

Does not degrade the effectiveness of the code

This proposed modification enhances the effectiveness of the code by clarifying the rule.

2nd Comment Period

EN7206-G2

Proponent Bryan Holland **Submitted** 5/21/2019 **Attachments** No

Comment:

Please reconsider this proposed modification for approval. The current language is vague, confusing, and not well understood in the field. The revised language adds a pointer to the specific requirements in the ASHRAE standard that are applicable as clearly indicated in Declaratory Statement DS2016-033. It should be noted the Electrical TAC has recommended this modification for approval unanimously 9-0. The electrical industry is the most impacted by the rule and with this vote has shown the need for the code change.

1st Comment Period History

EN7206-G1

Proponent Vincent Della Croce **Submitted** 1/8/2019 **Attachments** No

Comment:

I support the proposed modification as it will ensure the Code includes the most current requirements for electrical installations that provide for the health, safety and general welfare of the public.

C405.6 Electrical power (Mandatory).

C405.6.1 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~~ the requirements of Section 8 Power in ASHRAE Standard 90.1.

Date Submitted	11/12/2018	**Section**	403.4.2.4	**Proponent**	Bryan Holland
Chapter	4	**Affects HVHZ**	No	**Attachments**	No

TAC Recommendation No Affirmative Recommendation
Commission Action Pending Review

Comments

General Comments **Yes** **Alternate Language** **No**

Related Modifications

Summary of Modification

This proposed modification harmonizes requirements for part-load controls for hydronic system of the FBC-Energy with the 2018 IECC.

Rationale

This proposal reduces the threshold where variable flow and variable speed drives (VSD) are required for pumping systems. Requirements for heating pump VSDs are added. 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. Restates the minimum flow exception as a condition requirement, removing the exception with the result of the same code requirement. An exception for pump flow controls on coils requiring freeze protection is added. The first and third exceptions had the words "is not required" added to them, Exception 2 was deleted after having the intent added to the provisions above, then a new exception for freeze protection was added as exception 2 and exception 4 is new. 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 3 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. More details are found in the cost-effectiveness analysis referenced in the cost impact section.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This 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

This proposed modification will impact building and property owners where the increased cost of compliance is passed-on to them from the builder/contractor.

Impact to industry relative to the cost of compliance with code

The cost for VSD and associated controls is approximately $3,920 for 2 horsepower pumps. Costs for larger pumps are proportional. There is no cost for reducing the threshold where variable flow systems are required.

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

This proposed modification will impact small business owners where the increased cost of compliance is passed-on to them from the builder/contractor.

Requirements

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

This proposed modification is directly connected to the health, safety, and welfare of the general public by reducing the threshold horsepower and flow configuration of pump systems.

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

This proposed modification improves and strengthens the code by increasing the efficacy of pump systems used in hydronic heating/cooling applications.

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.

Does not degrade the effectiveness of the code

This proposed modification enhances the effectiveness of the code.

2nd Comment Period

EN7238-G1

Proponent Bryan Holland **Submitted** 5/21/2019 **Attachments** No

Comment:

Please reconsider this proposed modification for approval. Rejection of this code change is leaving an immense amount of energy savings on the table and out of the code which will allow these systems to operate at a much lower efficiency than currently required in the IECC-C and ASHRAE 90.1 Standard. The 200,000 Btu/h capacity and 8-hp rating reduction was supported by industry based on a PNNL study that showed significant cost savings and rapid ROI. This change will significantly improve the performance of the FBC-EC. Please note there is a slight error in the modification. The design output capacity should be 300,000 Btu/h (87.9 kW).

2nd Comment Period

EN7238-G2

Proponent	Jennifer Privateer	**Submitted**	5/22/2019	**Attachments**	No

Comment:

I agree with this proposed modification

2nd Comment Period

EN7238-G3

Proponent	Harold Barrineau	**Submitted**	5/25/2019	**Attachments**	No

Comment:

I like this clarity and agree with 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 or the maximum reduction allowed by the equipment manufacturer for proper operation of equipment 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 as follows: ~~with a combined motor capacity of 10 hp (7.5 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.~~

3.1 Where pumps operate continuously or operate based on a time schedule, pumps with nominal output motor power of 2 hp or more shall have a variable speed drive.

3.2. Where pumps have automatic direct digital control configured to operate pumps only when zone heating or cooling is required, a variable speed drive shall be provided for pumps with motors having the same or greater nominal output power indicated in Table C403.4.4 based on the climate zone and system served.

4. Where a variable speed drive is required by Item 3 of this Section, pump motor power input shall be not more than 30 percent of design wattage at 50 percent of the design water flow. 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 is not required 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~~ Variable pump flow is not required on dedicated coil circulation pumps where needed for freeze protection.

3. Variable pump flow is not required 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.

4. Variable speed drives are not required on heating water pumps where more than 50 percent of annual heat is generated by an electric boiler.

ADD THE FOLLOWING TABLE:

TABLE C403.4.4
VARIABLE SPEED DRIVE (VSD) REQUIREMENTS FOR DEMAND-CONTROLLED PUMPS

CHILLED WATER AND HEAT REJECTION LOOP PUMPS IN THESE CLIMATE ZONES	HEATING WATER PUMPS IN THESE CLIMATE ZONES	VSD REQUIRED FOR MOTORS WITH RATED OUTPUT OF:
1A, 1B, 2B	—	≥ 2 hp
2A, 3B	—	≥ 3 hp
3A, 3C, 4A, 4B	7, 8	≥ 5 hp
4C, 5A, 5B, 5C, 6A, 6B	3C, 5A, 5C, 6A, 6B	≥ 7.5 hp
—	4A, 4C, 5B	≥ 10 hp
7, 8	4B	≥ 15 hp
—	2A, 2B, 3A, 3B	≥ 25 hp
—	1B	≥ 100 hp
—	1A	≥ 200 hp

EN7327

Date Submitted	11/19/2018	**Section**	405.5.2	**Proponent**	Bryan Holland
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	No Affirmative Recommendation				
Commission Action	Pending Review				

Comments

General Comments **Yes** | **Alternate Language** **No**

Related Modifications

Summary of Modification

This proposed modification adds mandatory requirements for gas-fired lighting appliances.

Rationale

This provision will make the lighting section of commercial code consistent with the lighting section of the residential code section R404.1.1. It will also be consistent with other provisions of the code, such as Section C404.9.1 for commercial pool heaters ("Gas-fired heaters shall not be equipped with continuously burning pilot lights"), Table 403.2.3(4) for warm air furnaces, footnotes f and g, ("Units shall also include an IID" - IID is an intermittent ignition device), federal energy efficiency requirements for residential gas ovens, federal energy efficiency requirements for residential gas hot water boilers, and federal efficiency requirements for residential gas steam boilers.

The energy usage of gas lighting with continuously burning pilot lights is very significant. A gas light using 2,500 Btu/hour will give off about the same amount of light as a 60-Watt (205 Btu) incandescent light bulb (about 800-850 lumens). In other words, a gas light will use over 12 times more energy than an incandescent light bulb. When compared to a 10-Watt LED light bulb, the gas light uses over 72 times more energy.

With a continuously burning pilot light, the 2,500 Btu/hour gas light will use 21.9 Million Btu's (or about 215 therms or 215 ccf) of gas per year. In other words, one light will use more than a typical residential gas water heater.

The savings will be significant. Usage will be reduced by at least 50%, and for a 2,500 Btu/hour gas lamp, that translate to a savings of 109.5 Million Btu's per year (or about 107.5 therms per year). At a commercial rate of $0.90 per therm, the savings are $96.75 per year. This will mean that the simple payback will be less than 1-2 years.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This 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

This proposed modification will not change the cost of compliance to building and property owners unless the associated cost is passed onto them by the builder or appliance supplier.

Impact to industry relative to the cost of compliance with code

This proposed modification will increase the cost of compliance with the code. The cost to install a gas light without continuously burning pilot lights is slightly higher (approximately $50-100), depending on the installation and wiring needs.

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

This proposed modification will not change the cost of compliance or impact small business unless the associated cost is passed onto them by the builder or appliance supplier.

Requirements

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

This proposed modification is directly connected to the health, safety, and welfare of the general public by prohibiting the use of an energy wasteful gas-fired lighting ignition system.

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

This proposed modification improves and strengthens the code by harmonizing requirements in the Commercial Energy Code with those found in the Residential Energy Code.

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.

Does not degrade the effectiveness of the code

This proposed modification enhances the effectiveness of the code.

2nd Comment Period

EN7327-G1

Proponent Jennifer Privateer **Submitted** 5/22/2019 **Attachments** No

Comment:

I agree with mod as proposed

2nd Comment Period

EN7327-G2

Proponent	Harold Barrineau	Submitted	5/25/2019	Attachments	No

Comment:

I like this and agree with this modification

C405.5.2 Lighting equipment (Mandatory) Gas-fired lighting appliances shall not be equipped with continuously burning pilot ignition systems.

EN8154

Date Submitted	12/14/2018	**Section**	406.7.1	**Proponent**	George Wiggins (BOAF)
Chapter	4	**Affects HVHZ**	No	**Attachments**	No

TAC Recommendation No Affirmative Recommendation
Commission Action Pending Review

Comments

General Comments **Yes** **Alternate Language** **No**

Related Modifications

None

Summary of Modification

Clarifies that minimum percentage requirements are related to a building's annual hot water requirements & not first hour rating, & Removes combined heat and power system technologies & Expands the qualifying renewable energy technology to any on site renewable

Rationale

This proposal does three things:

1. it clarifies that the minimum percentage requirements are related to a building's annual hot water requirements and not simply to first hour rating,
2. it removes combined heat and power system from the list of technologies that can be used to satisfy this sections requirements, and
3. it expands the qualifying renewable energy technology from only solar energy to any on site renewable energy.

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

None

Impact to industry relative to the cost of compliance with code

None

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

None

Requirements

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

Clarifies current code language to accomplish the goal of energy conservation as part of "welfare of the general public."

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

Improves the code language with more expansive options.

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

Reduces potential discrimination of products or systems by language allowing more options to comply.

Does not degrade the effectiveness of the code

Improves the potential effectiveness of the Code by expanding the opportunity for builders to use on site renewable energy technologies such as wind or biomass in addition to solar energy.

2nd Comment Period

EN8154-G1

Proponent George Wiggins **Submitted** 5/23/2019 **Attachments** No

Comment:

Improves the potential effectiveness of the Code by expanding the opportunity for owners and builders to use on site renewable energy technologies such as wind or biomass in addition to solar energy. In addition, does not result in additional cost.

2nd Comment Period

EN8154-G2

Proponent Harold Barrineau **Submitted** 5/26/2019 **Attachments** No

Comment:

I agree with this modification.

Revise as follows:

C406.7.1 Load fraction. The building service water-heating system shall have one or more of the following that are sized to provide not less than 60 percent of the building's annual hot water requirements, or sized to provide 100 percent of the building's annual hot water requirements if the building shall otherwise comply with Section C403.4.5.

1. Waste heat recovery from service hot water, heat- recovery chillers, building equipment, or process equipment~~, or a combined heat and powersystem~~.

~~Solar~~*On site renewable energy*water-heatingsystems.

EN8184

Date Submitted	12/14/2018	**Section**	403.2.12.2	**Proponent**	Armin Hauer
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes

TAC Recommendation No Affirmative Recommendation
Commission Action Pending Review

Comments

General Comments **Yes** **Alternate Language** **No**

Related Modifications

C202 Definitions

Summary of Modification

Correct conversion error related to shaft power. Move the clause about fan system motor nameplate for better clarity. Increase the design options for load-matching variable-speed fan motors, accommodates new motor and drive technologies, and it simplifies the motor selection criteria for fans.

Rationale

This proposal increases the design options for load-matching variable-speed fan motors, accommodates new motor and drive technologies, and it simplifies the motor selection criteria for fans.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Positive impact. This proposal increases the design options for load-matching variable-speed fan motors, accommodates new motor and drive technologies, and it simplifies the motor selection criteria for fans.

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

Positive impact. This proposal increases the design options for load-matching variable-speed fan motors, accommodates new motor and drive technologies, and it simplifies the motor selection criteria for fans.

Impact to industry relative to the cost of compliance with code

Positive impact. This proposal increases the design options for load-matching variable-speed fan motors, accommodates new motor and drive technologies, and it simplifies the motor selection criteria for fans.

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

Positive impact.

Requirements

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

This proposal corrects an IP / SI conversion error related to shaft power: 6 bhp equals 4476 W mechanical power.

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

This proposal moves the clause about fan system motor nameplate into the exceptions section for better clarity.

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

This proposal increases the design options for load-matching variable-speed fan motors, accommodates new motor and drive technologies, and it simplifies the motor selection criteria for fans.

Does not degrade the effectiveness of the code

This proposal moves the clause about fan system motor nameplate into the exceptions section for better clarity.

2nd Comment Period

EN8184-G1

Proponent Amanda Hickman **Submitted** 5/23/2019 **Attachments** No

Comment:

This modification along with EN8175 should be approved as it recognizes recent updates made to ASHRAE 90.1. This will increase design options for load-matching variable-speed fan motors, accommodates new motor and drive technologies, and it simplifies the motor selection criteria for fans. At the Committee Hearing the ICC unanimously approved ASHRAE's an identical proposal (CE136).

C403.2.12.2 Fan mMotor selection nameplate horsepower

For each fan, the *fan brake horsepower* shall be indicated on the construction documents and the selected motor shall be no larger than the first available motor size greater than the following:

1. For fans less than 6 bhp (4413 4476 W), 1.5 times the *fan brake horsepower*.

2. For fans 6 bhp (4413 4476 W) and larger, 1.3 times the *fan brake horsepower*.

Exceptions:

1. Fans equipped with electronic speed control devices to vary the fan airflow as a function of load.
2. Fans with *fan nameplate electrical input power* of less than 0.89 kW.
3. Systems complying with Section 403.8.1 *fan system motor nameplate hp* (Option 1).
Exceptions: 4. Fans with motor *nameplate horsepower* less than 1 hp (746 W) are exempt from this section.

From: Armin Hauer
To: "Madani, Mo"
Subject: RE: mod 8184
Date: Friday, December 28, 2018 5:00:00 PM

Dear Mo Madani,

thank you for the alert.
I did "grab" the original language from the ICC website:

2017 Florida Building Code - Energy Conservation, Sixth Edition

(First Printing: Jul 2017)

CHAPTER 4 [CE] COMMERCIAL ENERGY EFFICIENCY

C403.2.12.2 Motor nameplate horsepower.

For each fan, the fan brake horsepower shall be indicated on the construction documents and the selected motor shall be not larger than the first available motor size greater than the following:

1. For fans less than 6 bhp (4413 W), 1.5 times the fan brake horsepower.
2. For fans 6 bhp (4413 W) and larger, 1.3 times the fan brake horsepower.
3. Systems complying with Section C403.2.12.1 *fan system motor nameplate hp* (Option 1).

I therefore cannot understand the concern that the original text does not match. Can you please help me?
Sorry, I also do not know the meaning of the acronym BBC in this context.

Proposed Code Modifications
USER: Armin Hauer

Proposed Code Modifications Menu > Manage Proposed Code Modification > **Modification Request History**

Modification #	8184
Modification Status	Need More Information

Date Requested	12/20/2018
More Information Requested	Original text of the proposed mod does not match that of 2017 BBC, EC. Please note - deadline for fixing the proposed mod is ASAP but no later than 12/28/2018
Requested By	Mo Madani
Date Responded	

Best regards

Armin Hauer
Manager
Regulatory and Government Affairs

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From: Madani, Mo [mailto:Mo.Madani@myfloridalicense.com]
Sent: Thursday, December 27, 2018 19:50
To: Armin Hauer
Subject: mod 8184

Mod 8184 – This modification has a "Need for Information."

Please note – deadline for fixing the mod is ASAP but no later than 12/28/2018

Thanks

EN8259

Date Submitted	12/14/2018	**Section**	402.2.7	**Proponent**	John Woestman
Chapter	4	**Affects HVHZ**	No	**Attachments**	No

TAC Recommendation No Affirmative Recommendation
Commission Action Pending Review

Comments

General Comments Yes **Alternate Language** Yes

Related Modifications

Summary of Modification

From an building thermal envelope perspective, air spaces are sometimes not being applied correctly and this proposal provides the necessary direction.

Rationale

Air spaces are not being applied correctly and this proposal provides the necessary direction.
This proposal is consistent with recent limitations placed on the thermal resistance application of reflective and non-reflective airspaces in ASHRAE 90.1-2013 (Addenda Supplement, Addendum AC). The R-values of airspaces are based on the assumption of "no air leakage" (see 2013 ASHRAE Handbook of Fundamentals, Chapter 25, Table 3, footnote b).
Air leakage into and out of an airspace can significantly degrade its R-value, yet there is currently no standard calculation method or test method to discern this impact.
Until such a time that this effect is quantified (for which there is an ASHRAE research project request under consideration), Addendum AC to ASHRAE 90.1 has provided a rational interim solution based on extensive review of available research data and consensus regarding that data. To also provide an interim solution for the common case of enclosed airspaces located behind cladding or outside of the air barrier layer of the building, an allowance is provided to consider such airspaces as being roughly equivalent to that of an indoor air film (e.g., R-0.7). This is also needed because some cladding R-values used in design are based on the assumption of an ideal air space (no air leakage or airflow) which is unrealistic and inappropriate and results in inflated R-values for airspaces that are necessarily leaky and/or intended to provide ventilation behind claddings.

Cost Impact: The energy code is currently silent on this matter. Consequently, this proposal provides guidance and options which may result in reduced construction costs where airspaces are appropriately used to help comply with the code. On the other hand, where air spaces are used inappropriately to comply with the energy code, this proposal may result in an increase in the cost of construction and code compliance.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Proposal provides appropriate technical guidance for the use of air spaces in the building thermal envelope.

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

This proposal provides guidance and options which may result in reduced construction costs where airspaces are appropriately used to help comply with the code. Where air spaces are not appropriately used to comply with the code, this proposal may result in an increase in the cost of code compliance.

Impact to industry relative to the cost of compliance with code

This proposal provides guidance and options which may result in reduced construction costs where airspaces are appropriately used to help comply with the code. Where air spaces are not appropriately used to comply with the code, this proposal may result in an increase in the cost of code compliance.

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

This proposal provides guidance and options which may result in reduced construction costs where airspaces are appropriately used to help comply with the code. Where air spaces are not appropriately used to comply with the code, this proposal may result in an increase in the cost of code compliance.

Requirements

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

Appropriate use of air spaces can be important for complying with energy code requirements.

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

Improves the code with appropriate requirements for air spaces.

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

Appropriately provides guidance on the use of air spaces for energy code compliance and does not discriminate against materials used appropriately.

Does not degrade the effectiveness of the code

Improves the effectiveness of the code.

Alternate Language

2nd Comment Period

8259-A5

Proponent Yarbrough David **Submitted** 5/24/2019 **Attachments** Yes

Rationale

The use of ASTM Test C1363 with airflow through the test specimen is outside the scope of C1363. This type of test is not permitted. The following is a quotation from ASTM C1363. Paragraph 1.14 “This test method does not permit intentional mass transfer of air or moisture through the specimen during measurements”. Note: “mass transfer” means air moving through the test specimen. Further, the specification of a minimum rate of 70 mm/second is not supported by technical literature. This subject, “the impact of air flow on thermal performance” is the subject of a current ASHRAE research project. ASHRAE 1759-TRP: “Impact of Air Flow on Thermal Performance of Airspaces Behind Cladding” (phase 1). One of the objective of the ASHRAE Research project is to establish the procedure for use of a C1363 type apparatus to perform thermal measurements with air flow.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Correct use of test standard

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

None

Impact to industry relative to the cost of compliance with code

None

Impact to Small Business relative to the cost of compliance with code

This proposal provides guidance and options which may result in reduced construction costs where airspaces are appropriately used to help comply with the code. Where air spaces are not appropriately used to comply with the code, this proposal may result in an increase in the cost of code compliance.

Requirements

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

No impact on health safety or welfare of the general public

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

Identifies appropriate use of test method

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

No discrimination

Does not degrade the effectiveness of the code

No

Alternate Language

2nd Comment Period

8259-A4

Proponent Wesley Hall **Submitted** 5/22/2019 **Attachments** Yes

Rationale

The primary problem with this language is that it mixes two distinctly different systems and attempts to incorporate them into a single subsection, specifically “unventilated” and “ventilated” enclosed air spaces. Section 402.2.7 Airspaces. is very efficient in identifying the attributes of an enclosed air space – “enclosed in an unventilated cavity…and is bounded on all sides by building components”. These systems can be tested very efficiently with current test procedures contained within C1363. Additionally the stipulation that it must be inside the air barrier is unnecessary – enclosed air spaces meeting the criteria above can exist inside or outside the air barrier. The key element to this discussion is “unventilated” – if the system is unventilated it can be tested and a thermal performance value can be assigned. The exception that addresses “ventilated systems” is unsubstantiated code language and premature – there are no ASTM test procedures that provide guidance for laboratories, where does this stated flow rate come from, should not a flow rate be assigned to specific assemblies, what supportive data and what test procedure is utilized in determining these flow rates. With all the gray areas included within the exception – my Public Comment remedy is to eliminate the “Exception” and remove the restrictive language that specifies where an “enclosed in an unventilated cavity…and is bounded on all sides by building components” air space must exist. Once the additional work has been completed on covering all the testing requirements for a ventilated system, it will be appropriate, at that time, to develop code language specific to those assemblies.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Improves accuracy of the code

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

Improves accuracy of the code

Impact to industry relative to the cost of compliance with code

Improves accuracy of the code

Impact to Small Business relative to the cost of compliance with code

This proposal provides guidance and options which may result in reduced construction costs where airspaces are appropriately used to help comply with the code. Where air spaces are not appropriately used to comply with the code, this proposal may result in an increase in the cost of code compliance.

Requirements

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

Improves accuracy of the code

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

Improves accuracy of the 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 degrade

2nd Comment Period

EN8259-G1

Proponent	John Woestman	**Submitted**	5/22/2019	**Attachments**	No

Comment:

We ask the TAC to reconsider this proposal.

Enclosed airspaces can provide some level of resistance to heat flow (R-value). Unfortunately, the code provides very little guidance, if any, as to the physical requirements for enclosed airspaces when these airspaces are used to comply with section C401.2 of the Florida Energy Conservation Code.

Airspaces which are not effectively enclosed perform significantly worse thermally.

The requirements of this proposal provide appropriate guidance for enclosed airspaces, and an exception dealing with exterior wall covering material.

2nd Comment Period

EN8259-G2

Proponent	Bill Lippy	**Submitted**	5/24/2019	**Attachments**	No

Comment:

- Inappropriate to include ventilation in a C1363 apparatus – the test method is specific that ventilation must not be a factor in running the test procedures
- There is no test method to instruct Hot Box operators on how to introduce the air flow
- There is not a test method to determine air flow rates in this type of system

Suggested remedy:

- Delete “Exception”
- Focus only on unventilated assemblies until further work is complete on generating the appropriate test methods for ventilates systems

C402.2.7 Airspaces. Where the thermal properties of airspaces are used to comply with this code in accordance with Section C401.2, such airspaces shall be enclosed in an unventilated cavity constructed to minimize airflow into and out of the enclosed air space. Airflow shall be deemed minimized where the enclosed airspace is located on the interior side of the continuous air barrier and is bounded on all sides by building components.

~~**Exception**: the thermal resistance of airspaces located on the exterior side of the continuous air barrier and adjacent to and behind the exterior wall-covering material shall be determined in accordance with~~

~~ASTM C1363 modified with an airflow entering the bottom and exiting the top of the airspace at an air movement rate of not less than 70 mm/second.~~

C402.2.7 Airspaces. Where the thermal properties of airspaces are used to comply with this code in accordance with Section C401.2, such airspaces shall be enclosed in an unventilated cavity constructed to minimize airflow into and out of the enclosed air space. Airflow shall be deemed minimized where the enclosed airspace ~~is located on the interior side of the continuous air barrier and~~ is bounded on all sides by building components.

~~**Exception**: the thermal resistance of airspaces located on the exterior side of the continuous air barrier and adjacent to and behind the exterior wall-covering material shall be determined in accordance with ASTM C1363 modified with an airflow entering the bottom and exiting the top of the airspace at an air movement rate of not less than 70 mm/second.~~

Add new text as follows:

C402.2.7 Airspaces. Where the thermal properties of airspaces are used to comply with this code in accordance with Section C401.2, such airspaces shall be enclosed in an unventilated cavity constructed to minimize airflow into and out of the enclosed airspace. Airflow shall be deemed minimized where the enclosed airspace is located on the interior side of the continuous air barrier and is bounded on all sides by building components.

Exception: The thermal resistance of airspaces located on the exterior side of the continuous air barrier and adjacent to and behind the exterior wall-covering material shall be determined in accordance with ASTM C1363 modified with an airflow entering the bottom and exiting the top of the airspace at an air movement rate of not less than 70 mm/second.

EN7231

Date Submitted	12/6/2018	**Section**	405.5.2(1)	**Proponent**	Kelli Fleming
Chapter	4	**Affects HVHZ**	No	**Attachments**	No

TAC Recommendation No Affirmative Recommendation
Commission Action Pending Review

Comments

General Comments **No** **Alternate Language** **Yes**

Related Modifications

Summary of Modification

The proposed modifications are editorial in nature and are being submitted to maintain consistency with the changes that are anticipated with IECC 2021 changes.

Rationale

The proposed changes are offered to achieve consistency with changes being proposed for the 2021 IECC and to provide additional clarity to code that was previously vague. They are truly editorial changes that are intended to simplify and clarify the current FBC.

This proposal also includes the following coordinating changes:
a) In footnote (h), text from earlier code editions was restored. The restored text clarified how fenestration area is to be calculated. (It was removed in error as part of RE173-13.)
b) Editorial changes in footnote (h) simply coordinate with current terminology in this section.

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
N0 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
No Impact

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
Does not

Does not degrade the effectiveness of the code
Does not

2nd Comment Period

7231-A4

Proponent Kelli Fleming **Submitted** 5/22/2019 **Attachments** Yes

Rationale

Edits were made to correct a table reference and add clarification as requested in EN7231-G2.

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

No Impact

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

Does not

Does not degrade the effectiveness of the code

Does not

1st Comment Period History

EN7231-G1

Proponent pete quintela **Submitted** 1/14/2019 **Attachments** No

Comment:

This mod makes reference to the 2021 Energy Conservation Code. Proponent has not provide a copy of such code.

1st Comment Period History

EN7231-G2

Proponent Jeff Sonne for FSEC **Submitted** 2/15/2019 **Attachments** No

Comment:

By changing the vertical fenestration U-factor reference specification from Table R402.1.4 to Table R402.1.2, this mod changes the U-factor reference to “NR” in climate zone 1; the reference U-factor should be defined.

This mod should also explicitly define the total fenestration area (AF) as the sum of the vertical fenestration and skylight areas.

Building Component	Standard Reference Design	Proposed Design
Vertical Fenestration other than opaque doors	Vertical Fenestration area [h] = (a) The proposed vertical fenestration area (AVF), where the proposed total fenestration area (AF)is less than 15 percent of the conditioned floor area(CFA) (b) The adjusted vertical fenestration area (AVF$_{adj}$), where the proposed fenestration area AF is 15 percent or more of the conditioned floor area CFA. The adjusted vertical fenestration area AVF$_{adj}$ shall be calculated as follows: $AVF_{adj} = AVF \bullet 0.15° \bullet CFA/AF$ where: AVF_{adj} = adjusted vertical fenestration AVF = proposed vertical fenestration area CFA = conditioned floor area AF = proposed total fenestration area	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 climates 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)	Interior shade fraction: 0.92 - (0.21 x SHGC as proposed)
	External shading: none	As proposed
Skylights	Skylight area [h] = (a) The proposed skylight area (ASKY), where the proposed total fenestration area(AF) is less than 15 percent of the conditioned floor area (CFA), or (b) The adjusted skylight area (ASKY$_{adj}$), where the proposed fenestration area AF is 15 percent or greater more of the conditioned floor area CFA. The adjusted skylight areaASKY$_{adj}$ shall be calculated as follows: $ASKY_{adj} = ASKY \bullet 0.15° \bullet CFA/AF$ where: $ASKY_{adj}$ = adjusted vertical fenestration AVF = proposed vertical fenestration area CFA = conditioned floor area AF = proposed total fenestration area	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 including footnote (b) of that table, except that for climates 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 SHGC ratings that include pre- factory-installed interior shades, the interior shade fraction is: 0.92 - (0.21 · SHGC) [SHGC as above for the standard reference design])	As proposed, with shades assumed closed 50% of the time daylight hours
	External shading: none	As proposed

h. Light-transmitting fenestration area includes the area of sash, curbing or other framing elements that are part of the conditioned space enclosure, including light-transmitting assemblies in walls bounding conditioned basements. For doors where the light-transmitting opening is less than 50 percent of the door area, only the light-transmitting area is included.

Unadjusted AF= AVF+ASKY

For residences with conditioned basements, R-2 and R-4 residences and townhouses, the following formula shall be used to determine fenestration area:

$AF = As \cdot FA \cdot F$

where:

AF = Proposed Ttotal fenestration area.

As = Standard reference design total fenestration area.

FA = (Above-grade thermal boundary gross wall area)/(above-grade boundary wall area + 0.5 × below-grade boundary wall area).

F = (Above-grade thermal boundary wall area)/(above-grade thermal boundary wall area + common wall area) or 0.80, whichever is greater, and where:

Thermal boundary wall is any wall that separates conditioned space from unconditioned space or ambient conditions.

Above-grade thermal boundary wall is any thermal boundary wall component not in contact with soil.

Below-grade boundary wall is any thermal boundary wall in soil contact.

Common wall area is the area of walls shared with an adjoining dwelling unit.

LAF, A_s and *CFA* are in the same units.

(other table entries and footnotes are unchanged)

Building Component	Standard Reference Design	Proposed Design
Vertical Fenestration other than opaque doors	Vertical Fenestration area [h] = (a) The proposed vertical fenestration area (AVF), where the proposed total fenestration area (AF) is less than 15 percent of the conditioned floor area (CFA) (b) The adjusted vertical fenestration area (AVF_{adj}), where the proposed fenestration area AF is 15 percent or more of theconditioned floor area CFA. The adjusted vertical fenestration area AVF_{adj} shall be calculated as follows: $AVF_{adj} = AVF \bullet 0.15 \bullet CFA/AF$ where: AVF_{adj} = adjusted vertical fenestration AVF = proposed vertical fenestration area CFA = conditioned floor area AF = proposed total fenestration area	As proposed
	Orientation: equally distributed to four cardinal compass orientations (N, E, S & W)	As proposed
	U-factor: as specified for Fenestration in Table R402.1.42	As proposed
	SHGC: as specified for Glazed Fenestration in Table R402.1.2 except that for climates 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)	Interior shade fraction: 0.92 - (0.21 x SHGC as proposed)
	External shading: none	As proposed
Skylights	Skylight area [h] = (a) The proposed skylight area (ASKY), where the proposed total fenestration area (AF)is less than 15 percent of the conditioned floor area(CFA), or (b) The adjusted skylight area ($ASKY_{adj}$),where the proposed fenestration area AF is 15 percent or greatermore of the conditioned floor areaCFA. The adjusted skylight area $ASKY_{adj}$ shall be calculated as follows: $ASKY_{adj} = ASKY \bullet 0.15 \bullet CFA/AF$ where: $ASKY_{adj}$ = adjusted vertical fenestration AVF = proposed vertical fenestration area CFA = conditioned floor area AF = proposed total fenestration area	As proposed
	Orientation: as proposed	As proposed
	U-factor: as specified for Skylights in Table R402.1.42	As proposed
	SHGC: as specified by the exception in footnote (b) of Table R402.1.2including footnote (b) of that table, except that for climates 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 SHGC ratings that include pre- factory-installed interior shades, the interior shade fraction is: 0.92 - (0.21 · SHGC) [SHGC as above for the standard reference design])	As proposed, with shades assumed closed 50% of the time daylight hours
	External shading: none	As proposed

h. Light-transmitting fenestration area includes the area of sash, curbing or other framing elements that are part of the conditioned space enclosure, including light-transmitting assemblies in walls bounding conditioned basements. For doors where the light-transmitting opening is less than 50 percent of the door area, only the light-transmitting area is included.

For residences with conditioned basements, R-2 and R-4 residences and townhouses, the following formula shall be used to determine fenestration area:

$AF = A_s \cdot FA \cdot F$

where:

AF = Proposed Ttotal fenestration area.

As = Standard reference design total fenestration area.

FA = (Above-grade thermal boundary gross wall area)/(above-grade boundary wall area + 0.5 × below-grade boundary wall area).

F = (Above-grade thermal boundary wall area)/(above-grade thermal boundary wall area + common wall area) or 0.80, whichever is greater, and where:

Thermal boundary wall is any wall that separates conditioned space from unconditioned space or ambient conditions.

Above-grade thermal boundary wall is any thermal boundary wall component not in contact with soil.

Below-grade boundary wall is any thermal boundary wall in soil contact.

Common wall area is the area of walls shared with an adjoining dwelling unit.

LAF. A_s and *CFA* are in the same units.

(other table entries and footnotes are unchanged)

EN7597

Date Submitted	12/13/2018	**Section**	405.5.2	**Proponent**	Jeff Sonne for FSEC
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes

TAC Recommendation No Affirmative Recommendation
Commission Action Pending Review

Comments

General Comments **No** **Alternate Language** **Yes**

Related Modifications

Summary of Modification

Increases reference water heater efficiency for proposed electric water heaters with ~= 55 gallon rated storage volume.

Rationale

For projects with proposed electric water heating systems up to 55 gallons, this code change increases the standard reference efficiency used for performance calculations to the higher federal minimum required for systems larger than 55 gallons. This change is appropriate at this time as highly efficient, cost-effective heat pump water heaters are now readily available which easily surpass this efficiency level. Florida studies (referenced below) show heat pump water heaters save ^ 65% of water heating energy compared to electric resistance, and potentially provide a 3-6% reduction in space cooling. This change would still not require heat pump water heaters to be used for electric water heating though since R405 compliance allows efficiency trade-offs.

The second rationale is this code change should deter the potential practice of installing multiple smaller electric water heaters to avoid having to install an efficient heat pump water heater in homes with large water heating loads.

A stringency impact comparison is provided in the attached PDF.

References:
- Water heating energy savings: http://publications.energyresearch.ucf.edu/wp-content/uploads/2018/06/FSEC-CR-2018-16.pdf
- Space cooling reduction: http://publications.energyresearch.ucf.edu/wp-content/uploads/2018/06/FSEC-RR-644-16.pdf

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

In applicable cases will increase cost of construction.

Impact to industry relative to the cost of compliance with code

In applicable cases will increase cost of construction.

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

In applicable cases will increase cost of construction.

Requirements

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

Benefits public by establishing highly cost effective baseline for efficiency.

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

Strengthens code by making efficiency requirements more consistent for all electric water heater capacities.

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

Does not discriminate; still allows builders to install whichever type of water heater they like.

Does not degrade the effectiveness of the code

Increases effectiveness of the code by making efficiency requirements more consistent for all electric water heater capacities.

Alternate Language

2nd Comment Period

7597-A4

Proponent Jeff Sonne for FSEC **Submitted** 5/20/2019 **Attachments** Yes

Rationale

This mod is the same as mod A3, except it also updates the Energy Code's ANSI/RESNET/ICC 301 reference from the 2014 version to the 2019 version. It in addition modifies the Section R406.4 reference to ANSI/RESNET/ICC 301 to provide version consistency throughout the Energy Code. ANSI/RESNET/ICC 301-2019 is available for review at http://www.resnet.us/blog/wp-content/uploads/2019/01/ANSIRESNETICC301-2019_vf1.23.19.pdf. The Standard is also attached as a PDF file.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Same as mod A3; just also updates Standard 301 reference.

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

Same as mod A3; just also updates Standard 301 reference.

Impact to industry relative to the cost of compliance with code

Same as mod A3; just also updates Standard 301 reference.

Impact to Small Business relative to the cost of compliance with code

In applicable cases will increase cost of construction.

Requirements

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

Same as mod A3; just also updates Standard 301 reference.

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

Same as mod A3; just also updates Standard 301 reference.

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

Same as mod A3; just also updates Standard 301 reference.

Does not degrade the effectiveness of the code

Same as mod A3; just also updates Standard 301 reference.

Alternate Language

2nd Comment Period

7597-A3

Proponent Jeff Sonne for FSEC **Submitted** 5/20/2019 **Attachments** Yes

Rationale

This mod is similar to mod A2 from the first comment period (which added improved hot water code calculation but did not include the original mod language regarding increased reference service water heating efficiency). To address an objection made during the first TAC meeting, instead of including the hot water calculation details in a code appendix as mod A2 did, this mod instead references ANSI/RESNET/ICC 301 Addendum A-2015 for the same calculation details. As described for the A2 mod, the improved hot water calculation language accounts for 1) climate-specific effects on domestic hot water use, 2) the hot water distribution system type, and 3) the use of additional conservation measures. The vetted research behind this mod is described in a 2017 research report by the Florida Solar Energy Center which was funded and approved by the Florida Building Commission: http://publications.energyresearch.ucf.edu/wp-content/uploads/2018/06/FSEC-CR-2066-17.pdf. In summary, this A3 mod addresses the objection made at the first TAC meeting while still supporting the research the FBC funded.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

[Same as mod A2] In many cases none, but some additional verification will be needed if certain additional water heating conservation measures are used for a given project.

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

[Same as mod A2] None in most cases. Slight increase in cost of compliance if heat pump or tankless gas water heaters are used for a project. May reduce cost of compliance for builders who choose to employ efficient water circulation systems.

Impact to industry relative to the cost of compliance with code

[Same as mod A2] None in most cases. Slight increase in cost of compliance if heat pump or tankless gas water heaters are used for a project. May reduce cost of compliance for builders who choose to employ efficient water circulation systems.

Impact to Small Business relative to the cost of compliance with code

In applicable cases will increase cost of construction.

Requirements

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

[Same as mod A2] Benefits public by providing a more comprehensive means of accounting for domestic hot water use in the code.

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

[Same as mod A2] Improves the code by providing a more comprehensive means of accounting for domestic hot water use in the code.

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

[Same as mod A2] Reduces discrimination by providing a more comprehensive means of accounting for domestic hot water use in the code.

Does not degrade the effectiveness of the code

[Same as mod A2] Increases code effectiveness by providing a more comprehensive means of accounting for domestic hot water use in the code.

Alternate Language

1st Comment Period History

7597-A2

Proponent Jeff Sonne for FSEC **Submitted** 2/15/2019 **Attachments** Yes

Rationale

This Alt 2 mod adds the same improved hot water code calculation described in the Alt 1 mod, and removes the original mod language regarding reference service water heating efficiency. As described for the Alt 1 mod, the improved hot water calculation language accounts for 1) climate-specific effects on domestic hot water use, 2) the hot water distribution system type, and 3) the use of additional conservation measures. The vetted research behind this mod is described in a 2017 research report by the Florida Solar Energy Center which was funded and approved by the Florida Building Commission: http://publications.energyresearch.ucf.edu/wp-content/uploads/2018/06/FSEC-CR-2066-17.pdf.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

In many cases none, but some additional verification will be needed if certain additional water heating conservation measures are used for a given project.

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

None in most cases. Slight increase in cost of compliance if heat pump or tankless gas water heaters are used for a project. May reduce cost of compliance for builders who choose to employ efficient water circulation systems.

Impact to industry relative to the cost of compliance with code

None in most cases. Slight increase in cost of compliance if heat pump or tankless gas water heaters are used for a project. May reduce cost of compliance for builders who choose to employ efficient water circulation systems.

Impact to Small Business relative to the cost of compliance with code

In applicable cases will increase cost of construction.

Requirements

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

Benefits public by providing a more comprehensive means of accounting for domestic hot water use 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 more comprehensive means of accounting for domestic hot water use in the code.

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

Reduces discrimination by providing a more comprehensive means of accounting for domestic hot water use in the code.

Does not degrade the effectiveness of the code

Increases code effectiveness by providing a more comprehensive means of accounting for domestic hot water use in the code.

Alternate Language

1st Comment Period History

7597-A1

Proponent Jeff Sonne for FSEC **Submitted** 2/15/2019 **Attachments** Yes

Rationale

This Alt 1 mod adds improved hot water code calculation to the original mod. The improved hot water calculation language accounts for 1) climate-specific effects on domestic hot water use, 2) the hot water distribution system type, and 3) the use of additional conservation measures. The vetted research behind this Alt 1 mod is described in a 2017 research report by the Florida Solar Energy Center which was funded and approved by the Florida Building Commission: http://publications.energyresearch.ucf.edu/wp-content/uploads/2018/06/FSEC-CR-2066-17.pdf.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

In many cases none, but some additional verification will be needed if certain additional water heating conservation measures are used for a given project.

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

None in most cases. Slight increase in cost of compliance if heat pump or tankless gas water heaters are used for a project. However, it allows builders who employ efficient water distribution systems to take credit which may reduce cost.

Impact to industry relative to the cost of compliance with code

None in most cases. Slight increase in cost of compliance if heat pump or tankless gas water heaters are used for a project. However, it allows builders who employ efficient water distribution systems to take credit which may reduce cost.

Impact to Small Business relative to the cost of compliance with code

In applicable cases will increase cost of construction.

Requirements

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

Benefits public by providing a more comprehensive means of accounting for domestic hot water use 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 more comprehensive means of accounting for domestic hot water use in the code.

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

Reduces discrimination by providing a more comprehensive means of accounting for domestic hot water use in the code.

Does not degrade the effectiveness of the code

Increases code effectiveness by providing a more comprehensive means of accounting for domestic hot water use in the code.

[Starting from 2017 Florida Energy Code Table R405.5.2(1) Service water heating section, make the following changes to stipulate ANSI/RESNET/ICC Standard 301 for the reference and proposed designs' hot water use and energy consumption specifications:]

	STANDARD REFERENCE DESIGN	**PROPOSED DESIGN**
Service water heating [d, e, f, g]	Fuel type: as proposed Use (gal/day): ~~same as proposed design~~ determined in accordance with ANSI/RESNET/ICC 301 Efficiency: in accordance with prevailing federal minimum standards	Fuel type: As proposed Use (gal/day): ~~= 30 + (10 × *Nbr*)~~ determined in accordance with ANSI/RESNET/ICC 301 Efficiency: As proposed
	Energy consumption: determined in accordance with ANSI/RESNET/ICC 301	Energy consumption: determined in accordance with ANSI/RESNET/ICC 301

[No other changes to Table R405.5.2(1).]

[Also make the following related change to Florida Energy Code Chapter 6 [RE] ANSI reference section to update to latest version of ANSI/RESNET/ICC 301 (ANSI/RESNET/ICC-2019 includes Addendum A-2015, so the reference to Addendum A-2015 is no longer needed):]

Standard reference number	Title	Referenced in code section number
ANSI/RESNET/ICC 301—2014~~4~~9	Standard for the Calculation and Labeling of the Energy Performance of ~~Low-Rise Residential Buildings~~ Dwelling and Sleeping Units ~~U~~using an Energy Rating Index	Table R405.5.2(1), R406.4
~~ANSI/RESNET/ICC 301—2014, Addendum A-2015~~	~~Amendment on Domestic Hot Water Systems~~	~~R406.4~~

[No other changes to Chapter 6.]

[Also make the following related change to Florida Energy Code Section R406.4 (to also update this section to ANSI/RESNET/ICC-2019):]

R406.4 ERI-based compliance.

The ERI for the rated design shall be determined in accordance with ANSI/RESNET/ICC 301, ~~including Addendum A-2015,~~ and be shown to have an ERI less than or equal to the appropriate value listed in Table R406.4.

[No other changes to this section.]

[Starting from 2017 Florida Energy Code Table R405.5.2(1) Service water heating section, make the following changes to stipulate ANSI/RESNET/ICC Standard 301 Addendum A-2015 for the reference and proposed designs' hot water use and energy consumption specifications:]

	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Service water heating [d, e, f, g]	Fuel type: as proposed	Fuel type: As proposed
	Use (gal/day): ~~same as proposed design~~ determined in accordance with ANSI/RESNET/ICC 301 Addendum A-2015	Use (gal/day): ~~= 30 + (10 × *Nbr*)~~ determined in accordance with ANSI/RESNET/ICC 301 Addendum A-2015
	Efficiency: in accordance with prevailing federal minimum standards	Efficiency: As proposed
	Energy consumption: determined in accordance with ANSI/RESNET/ICC 301 Addendum A-2015	Energy consumption: determined in accordance with ANSI/RESNET/ICC 301 Addendum A-2015

[No other changes to Table R405.5.2(1).]

[See attached file which adds the improved hot water code calculation language same as the Alt 1 mod does, but removes the original mod's service water heating reference changes.]

[See attached file which adds improved hot water code calculation language to original mod.]

[Add footnote "i" to Table R405.5.2(1) Service water heating standard reference design efficiency specification]:

	STANDARD REFERENCE DESIGN	**PROPOSED DESIGN**
Service water heating [d, e, f, g]	Fuel type: as proposed Use: same as proposed design Efficiency: in accordance with prevailing federal minimum standards[i]	As proposed gal/day = 30 + (10 × Nbr) As proposed

i. For a proposed design with an instantaneous electric resistance water heater or electric storage-type water heater with a rated storage volume between 0 and 55 gallons, the standard reference design efficiency shall be the prevailing federal minimum standard efficiency of a 56 gallon electric storage-type water heater.

[No other changes to table.]

[Starting from original 7597 Table R405.5.2(1) Service water heating mod, make the following additional changes to add improved hot water code calculation language:]

	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Service water heating [d, e, f, g]	Fuel type: as proposed Use(gal/day): ~~same as proposed design~~ determined in accordance with Appendix RD Efficiency: in accordance with prevailing federal minimum standards[i]	As proposed Use (gal/day): ~~= 30 + (10 × Nbr)~~ determined in accordance with Appendix RD Efficiency: As proposed
	Energy Consumption: determined in accordance with Appendix RD	Energy Consumption: determined in accordance with Appendix RD

i. For a proposed design with an instantaneous electric resistance water heater or electric storage-type water heater with a rated storage volume between 0 and 55 gallons, the standard reference design efficiency shall be the prevailing federal minimum standard efficiency of a 56 gallon electric storage-type water heater.

[All other parts of Table R405.5.2(1) remain unchanged.]

[Add new residential energy conservation volume appendix as follows and renumber current Appendix RD to Appendix RE:]

APPENDIX RD

CALCULATION OF HOT WATER ENERGY CONSUMPTION

#-1 Domestic Hot Water (DHW) System Modeling. Domestic hot water energy consumption shall be modeled and simulated monthly or more frequently using monthly or more frequent simulation time steps in accordance with Sections #-1.1 through #-2.2. Annual domestic hot water energy consumption shall be set equal to the sum of the simulated monthly values.

#-1.1 Standard Reference Design Hot Water Use. Domestic hot water system use in gallons per day for the Standard Reference Design shall be determined in accordance with Equation #-1

$$HWgpd = (refDWgpd+refCWgpd+F_{mix}*(refFgpd + refWgpd))*Ndu \quad \text{Eq. \#-1}$$

where:

HWgpd = gallons per day of hot water use

refDWgpd = reference dishwasher gallons per day = ((88.4+34.9*Nbr)*8.16)/365
refCWgpd = reference clothes washer gallons per day =

(4.52*(164+46.5*Nbr))*((3*2.08+1.59)/(2.874*2.08+1.59))/365

$F_{mix} = 1 - ((T_{set} - T_{use}) / (T_{set} - T_{mains}))$
where

T_{set} = Water heater set point temperature = 125 F

T_{use} = Temperature of mixed water at fixtures = 105 F

$T_{mains} = (T_{amb,avg} + offset) + ratio * (\Delta T_{amb,max} / 2) * \sin(0.986 * (day\# - 15 - lag) - 90)$
where

T_{mains} = temperature of potable water supply entering residence (°F)
$T_{amb,avg}$ = annual average ambient air temperature (°F)

$\Delta T_{amb,max}$ = maximum difference between monthly average ambient air temperatures (e.g., $T_{amb,avg,july} - T_{amb,avg,january}$) (°F)

0.986 = degrees/day (360/365)

day# = Julian day of the year (1-365)

offset = 6°F

ratio = $0.4 + 0.01 (T_{amb,avg} - 44)$

lag = $35 - 1.0 (T_{amb,avg} - 44)$

refFgpd = 14.6 + 10.0*Nbr = reference climate-normalized daily fixture water use (in gallons per day)

refWgpd = $9.8 * Nbr^{0.43}$ = reference climate-normalized daily hot water waste due to distribution system losses (in gallons per day)

where

Nbr = number of bedrooms in each dwelling unit
Ndu = number of like dwelling units

#-2 Proposed Design Hot Water Use. Domestic hot water system use in gallons per day for the Proposed Design shall be determined in accordance with Equation #-2

$$HWgpd = (DWgpd + CWgpd + F_{eff} * adjF_{mix} * (refFgpd + oWgpd + sWgpd * WD_{eff})) * Ndu \quad \text{Eq. \#-2}$$

where:

HWgpd = gallons per day of hot water use in Rated home

DWgpd = dishwasher gallons per day = ((88.4+34.9*Nbr)*8.16)/365
CWgpd = clothes washer gallons per day =

(4.52*(164+46.5*Nbr))*((3*2.08+1.59)/(2.874*2.08+1.59))/365

F_{eff} = fixture effectiveness in accordance with Table #(1)

Table #(1) Hot water fixture effectiveness

Plumbing Fixture Description	F_{eff}
Standard-flow: showers <2.5 gpm and faucets <2.2 gpm	1.00
Low-flow: all showers and faucets ≤2.0 gpm	0.95

$adjF_{mix} = 1 - ((T_{set} - T_{use}) / (T_{set} - WH_{in}T))$
where

T_{set} = 125 °F = water heater set point temperature

T_{use} = 105 °F = temperature of mixed water at fixtures
$WH_{in}T$ = water heater inlet temperature

where

$WH_{in}T = T_{mains} + WH_{in}T_{adj}$ for DWHR systems and where $WH_{in}T_{adj}$ is calculated in accordance with equation #-5

$WH_{in}T = T_{mains}$ for all other hot water systems

T_{mains} = temperature of potable water supply entering the residence calculated in accordance with Section #-1

refFgpd = reference climate-normalized daily fixture water use calculated in accordance with Section #-1.1

oWgpd = refWgpd * oFrac * (1-oCD$_{eff}$) **Eq. #-3**

where

oWgpd = daily standard operating condition waste hot water quantity

oFrac = 0.25 = fraction of hot water waste from standard operating conditions
oCD_{eff} = Approved Hot Water Operating Condition Control Device effectiveness

(default = 0.0)

sWgpd = (refWgpd – refWgpd * oFrac) * pRatio * sysFactor **Eq. #-4**

where

sWgpd = daily structural waste hot water quantity

refWgpd = reference climate-normalized distribution system waste water use calculated in accordance with Section #-1.1

oFrac = 0.25 = fraction of hot water waste from standard operating conditions
pRatio = hot water piping ratio

where

for Standard systems:

pRatio = PipeL / refPipeL
where

PipeL = measured length of hot water piping from the hot water heater to the farthest hot water fixture, measured longitudinally from plans, assuming the hot water piping does not run diagonally, plus 10 feet of piping for each floor level, plus 5 feet of piping for unconditioned basements (if any)

refPipeL = $2*(CFA/Nfl)^{0.5} + 10*Nfl + 5*Bsmt$ = hot water piping length for Reference Home

where

CFA = conditioned floor area

Nfl = number of conditioned floor levels in the residence, including conditioned basements

Bsmt = presence =1.0 or absence = 0.0 of an unconditioned basement in the residence

for recirculation systems:

pRatio = BranchL /10
where

BranchL = measured length of the branch hot water piping from the recirculation loop to the farthest hot water fixture from the recirculation loop, measured longitudinally from plans, assuming the branch hot water piping does not run diagonally

sysFactor = hot water distribution system factor from Table #(2)

Table #(2) Hot Water Distribution System Insulation Factors

Distribution System Description	sysFactor	
	No pipe insulation	≥R-3 pipe insulation
Standard systems	1.00	0.90
Recirculation systems	1.11	1.00

WD_{eff} = distribution system water use effectiveness from Table#(3)

Table #(3) Distribution system water use effectiveness

Distribution System Description	WD_{eff}
Standard systems	1.00
Recirculation systems	0.10

Ndu = number of dwelling units

#-2.1 Drain Water Heat Recovery (DWHR) Units

If DWHR unit(s) is (are) installed in the Rated Home, the water heater potable water supply temperature adjustment ($WH_{in}T_{adj}$) shall be calculated in accordance with Equation #-5.

$$WH_{in}T_{adj} = Ifrac*(DWHR_{in}T - T_{mains})*DWHR_{eff}*PLC*LocF*FixF \qquad \text{Eq. \#-5}$$

where

$WH_{in}T_{adj}$ = adjustment to water heater potable supply inlet temperature (°F)

$Ifrac = 0.56 + 0.015*Nbr – 0.0004*Nbr^2$ = fraction of hot water use impacted by DWHR
$DWHR_{in}T$ = 97 °F

T_{mains} = calculated in accordance with Section #-1.1

$DWHR_{eff}$ = Drain Water Heat Recovery Unit efficiency as rated and labeled in accordance with CSA 55.1

where

$DWHR_{eff} = DWHR_{eff}*1.082$ if low-flow fixtures are installed in accordance with Table #(1)

PLC = 1 - 0.0002*pLength = piping loss coefficient
where

for standard systems:

pLength = pipeL as measured accordance with Section #-2

for recirculation systems:

pLength = branchL as measured in accordance with Section #-2

LocF = a performance factor based on the installation location of the DWHR determined from Table #(4)

Table#(4) Location factors for DWHR placement

DRHR Placement	LocF
Supplies pre-heated water to both the fixture cold water piping and the hot water heater potable supply piping	1.000
Supplies pre-heated water to only the hot water heater potable supply piping	0.777
Supplies pre-heated water to only the fixture cold water piping	0.777

FixF = Fixture Factor

where

FixF = 1.0 if all of the showers in the home are connected to DWHR units

FixF = 0.5 if there are 2 or more showers in the home and only 1 shower is connected to a DWHR unit.

#-2.2 Hot Water System Annual Energy Consumption

Service hot water energy consumption shall be calculated using Approved Software Tools and the provisions of Section #-1, Section #-2 and Section #-2.1 shall be followed to determine appropriate inputs to the calculations.

If the Proposed Design includes a hot water recirculation system, the annual electric consumption of the recirculation pump shall be added to the total hot water energy consumption. The recirculation pump kWh/y shall be calculated using Equation #-6

pumpkWh/y = pumpW * Efact **Eq. #-6**

where:

pumpW = pump power in watts (default pumpW = 50 watts)

Efact = factor selected from Table #(5)

Table #(5) Annual electricity consumption factor for hot water recirculation system pumps

Recirculation System Description	Efact
Recirculation without control or with timer control	8.76

Recirculation with temperature control	1.46
Recirculation with demand control (presence sensor)	0.15
Recirculation with demand control (manual)	0.10

Results from standard hot water energy consumption calculations considering only tested Energy Factor data ($stdEC_{HW}$) shall be adjusted to account for the energy delivery effectiveness of the hot water distribution system in accordance with equation #-7.

$$EC_{HW} = stdEC_{HW} * (E_{waste} + 128) / 160 \quad \text{Eq. \#-7}$$

where E_{waste} is calculated in accordance with equation #-8.

$$E_{waste} = oEW_{fact} * (1 - oCD_{eff}) + sEW_{fact} * pEratio \quad \text{Eq. \#-8}$$

where

$oEW_{fact} = EW_{fact} * oFrac$ = standard operating condition portion of hot water energy waste where

EW_{fact} = energy waste factor in accordance with Table #(6) oCD_{eff} is in accordance with Section #-2

$sEW_{fact} = EW_{fact} - oEW_{fact}$ = structural portion of hot water energy waste pEratio = piping length energy ratio

where

for standard system: pEratio = PipeL / refpipeL for recirculation systems: pEratio = LoopL / refLoopL and where

LoopL = hot water recirculation loop piping length including both supply and return sides of the loop, measured longitudinally from plans, assuming the hot water piping does not run diagonally, plus 20 feet of piping for each floor level greater than one plus 10 feet of piping for unconditioned basements.

refLoopL = 2.0*refPipeL - 20

Table #(6) Hot water distribution system relative annual energy waste factors

Distribution System Description	EW_{fact}	
	No pipe insulation	>R-3 pipe insulation
Standard systems	32.0	28.8
Recirculation without control or with timer control	500	250
Recirculation with temperature control	375	187.5
Recirculation with demand control (presence sensor)	64.8	43.2
Recirculation with demand control (manual)	43.2	28.8

[Starting from original 7597 Table R405.5.2(1) Service water heating mod, make the following changes, in effect removing the original mod's standard reference design efficiency change and adding improved hot water code calculation language:]

	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Service water heating d, e, f, g	Fuel type: as proposed Use (gal/day): same as proposed design determined in accordance with Appendix RD Efficiency: in accordance with prevailing federal minimum standards[i]	Fuel type: As proposed Use (gal/day): = 30 + (10 × Nbr) determined in accordance with Appendix RD Efficiency: As proposed
	Energy Consumption: determined in accordance with Appendix RD	Energy Consumption: determined in accordance with Appendix RD

i. For a proposed design with an instantaneous electric resistance water heater or electric storage-type water heater with a rated storage volume between 0 and 55 gallons, the standard reference design efficiency shall be the prevailing federal minimum standard efficiency of a 56 gallon electric storage-type water heater.

[All other parts of Table R405.5.2(1) remain unchanged.]

[Add new residential energy conservation volume appendix as follows and renumber current Appendix RD to Appendix RE:]

APPENDIX RD

CALCULATION OF HOT WATER ENERGY CONSUMPTION

#-1 Domestic Hot Water (DHW) System Modeling. Domestic hot water energy consumption shall be modeled and simulated monthly or more frequently using monthly or more frequent simulation time steps in accordance with Sections #-1.1 through #-2.2. Annual domestic hot water energy consumption shall be set equal to the sum of the simulated monthly values.

#-1.1 Standard Reference Design Hot Water Use. Domestic hot water system use in gallons per day for the Standard Reference Design shall be determined in accordance with Equation #-1

$$HWgpd = (refDWgpd+refCWgpd+F_{mix}*(refFgpd + refWgpd))*Ndu \qquad \text{Eq. \#-1}$$

where:

HWgpd = gallons per day of hot water use

refDWgpd = reference dishwasher gallons per day = ((88.4+34.9*Nbr)*8.16)/365

refCWgpd = reference clothes washer gallons per day =

(4.52*(164+46.5*Nbr))*((3*2.08+1.59)/(2.874*2.08+1.59))/365

$F_{mix} = 1 - ((T_{set} - T_{use}) / (T_{set} - T_{mains}))$
where

T_{set} = Water heater set point temperature = 125 F

T_{use} = Temperature of mixed water at fixtures = 105 F

$T_{mains} = (T_{amb,avg} + \mathit{offset}) + \mathit{ratio} * (\Delta T_{amb,max} / 2) * \sin(0.986 * (day\# - 15 - \mathit{lag}) - 90)$
where

T_{mains} = temperature of potable water supply entering residence (°F)
$T_{amb,avg}$ = annual average ambient air temperature (°F)

$\Delta T_{amb,max}$ = maximum difference between monthly average ambient air temperatures (e.g., $T_{amb,avg,july} - T_{amb,avg,january}$) (°F)

0.986 = degrees/day (360/365)

day# = Julian day of the year (1-365)

offset = 6°F

ratio = $0.4 + 0.01 (T_{amb,avg} - 44)$

lag = $35 - 1.0 (T_{amb,avg} - 44)$

refFgpd = 14.6 + 10.0*Nbr = reference climate-normalized daily fixture water use (in gallons per day)

refWgpd = $9.8 * Nbr^{0.43}$ = reference climate-normalized daily hot water waste due to distribution system losses (in gallons per day)

where

Nbr = number of bedrooms in each dwelling unit
Ndu = number of like dwelling units

#-2 Proposed Design Hot Water Use. Domestic hot water system use in gallons per day for the Proposed Design shall be determined in accordance with Equation #-2

$$HWgpd = (DWgpd + CWgpd + F_{eff} * adjF_{mix} * (refFgpd + oWgpd + sWgpd * WD_{eff})) * Ndu \quad \textbf{Eq. \#-2}$$

where:

HWgpd = gallons per day of hot water use in Rated home

DWgpd = dishwasher gallons per day = ((88.4+34.9*Nbr)*8.16)/365
CWgpd = clothes washer gallons per day =

(4.52*(164+46.5*Nbr))*((3*2.08+1.59)/(2.874*2.08+1.59))/365

F_{eff} = fixture effectiveness in accordance with Table #(1)

Table #(1) Hot water fixture effectiveness

Plumbing Fixture Description	F_{eff}
Standard-flow: showers ≤2.5 gpm and faucets ≤2.2 gpm	1.00
Low-flow: all showers and faucets ≤2.0 gpm	0.95

$adjF_{mix} = 1 - ((T_{set} - T_{use}) / (T_{set} - WH_{in}T))$
where

T_{set} = 125 °F = water heater set point temperature

T_{use} = 105 °F = temperature of mixed water at fixtures
$WH_{in}T$ = water heater inlet temperature

where

$WH_{in}T = T_{mains} + WH_{in}T_{adj}$ for DWHR systems and where $WH_{in}T_{adj}$ is calculated in accordance with equation #-5

$WH_{in}T = T_{mains}$ for all other hot water systems

T_{mains} = temperature of potable water supply entering the residence calculated in accordance with Section #-1

refFgpd = reference climate-normalized daily fixture water use calculated in accordance with Section #-1.1

oWgpd = refWgpd * oFrac * (1-oCD$_{eff}$) **Eq. #-3**

where

oWgpd = daily standard operating condition waste hot water quantity

oFrac = 0.25 = fraction of hot water waste from standard operating conditions
oCD_{eff}= Approved Hot Water Operating Condition Control Device effectiveness

(default = 0.0)

sWgpd = (refWgpd – refWgpd * oFrac) * pRatio * sysFactor **Eq. #-4**

where

sWgpd = daily structural waste hot water quantity

refWgpd = reference climate-normalized distribution system waste water use calculated in accordance with Section #-1.1

oFrac = 0.25 = fraction of hot water waste from standard operating conditions
pRatio = hot water piping ratio

where

for Standard systems:

pRatio = PipeL / refPipeL
where

PipeL = measured length of hot water piping from the hot water heater to the farthest hot water fixture, measured longitudinally from plans, assuming the hot water piping does not run diagonally, plus 10 feet of piping for each floor level, plus 5 feet of piping for unconditioned basements (if any)

refPipeL = $2*(CFA/Nfl)^{0.5} + 10*Nfl + 5*Bsmt$ = hot water piping length for Reference Home

where

CFA = conditioned floor area

Nfl = number of conditioned floor levels in the residence, including conditioned basements

Bsmt = presence =1.0 or absence = 0.0 of an unconditioned basement in the residence

for recirculation systems:

pRatio = BranchL /10
where

BranchL = measured length of the branch hot water piping from the recirculation loop to the farthest hot water fixture from the recirculation loop, measured longitudinally from plans, assuming the branch hot water piping does not run diagonally

sysFactor = hot water distribution system factor from Table #(2)

Table #(2) Hot Water Distribution System Insulation Factors

Distribution System Description	sysFactor	
	No pipe insulation	≥R-3 pipe insulation
Standard systems	1.00	0.90
Recirculation systems	1.11	1.00

WD_{eff} = distribution system water use effectiveness from Table#(3)

Table #(3) Distribution system water use effectiveness

Distribution System Description	WD_{eff}
Standard systems	1.00
Recirculation systems	0.10

Ndu = number of dwelling units

#-2.1 Drain Water Heat Recovery (DWHR) Units

If DWHR unit(s) is (are) installed in the Rated Home, the water heater potable water supply temperature adjustment ($WH_{in}T_{adj}$) shall be calculated in accordance with Equation #-5.

$$WH_{in}T_{adj} = Ifrac*(DWHR_{in}T - T_{mains})*DWHR_{eff}*PLC*LocF*FixF \qquad \text{Eq. \#-5}$$

where

$WH_{in}T_{adj}$ = adjustment to water heater potable supply inlet temperature (°F)

$Ifrac = 0.56 + 0.015*Nbr - 0.0004*Nbr^2$ = fraction of hot water use impacted by DWHR
$DWHR_{in}T$ = 97 °F

T_{mains} = calculated in accordance with Section #-1.1

$DWHR_{eff}$ = Drain Water Heat Recovery Unit efficiency as rated and labeled in accordance with CSA 55.1

where

$DWHR_{eff} = DWHR_{eff}*1.082$ if low-flow fixtures are installed in accordance with Table #(1)

PLC = 1 - 0.0002*pLength = piping loss coefficient
where

for standard systems:

pLength = pipeL as measured accordance with Section #-2

for recirculation systems:

pLength = branchL as measured in accordance with Section #-2

LocF = a performance factor based on the installation location of the DWHR determined from Table #(4)

Table#(4) Location factors for DWHR placement

DRHR Placement	LocF
Supplies pre-heated water to both the fixture cold water piping and the hot water heater potable supply piping	1.000
Supplies pre-heated water to only the hot water heater potable supply piping	0.777
Supplies pre-heated water to only the fixture cold water piping	0.777

FixF = Fixture Factor

where

FixF = 1.0 if all of the showers in the home are connected to DWHR units

FixF = 0.5 if there are 2 or more showers in the home and only 1 shower is connected to a DWHR unit.

#-2.2 Hot Water System Annual Energy Consumption

Service hot water energy consumption shall be calculated using Approved Software Tools and the provisions of Section #-1, Section #-2 and Section #-2.1 shall be followed to determine appropriate inputs to the calculations.

If the Proposed Design includes a hot water recirculation system, the annual electric consumption of the recirculation pump shall be added to the total hot water energy consumption. The recirculation pump kWh/y shall be calculated using Equation #-6

pumpkWh/y = pumpW * Efact **Eq. #-6**

where:

pumpW = pump power in watts (default pumpW = 50 watts)

Efact = factor selected from Table #(5)

Table #(5) Annual electricity consumption factor
for hot water recirculation system pumps

Recirculation System Description	Efact
Recirculation without control or with timer control	8.76

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Results from standard hot water energy consumption calculations considering only tested Energy Factor data ($stdEC_{HW}$) shall be adjusted to account for the energy delivery effectiveness of the hot water distribution system in accordance with equation #-7.

$$EC_{HW} = stdEC_{HW} * (E_{waste} + 128) / 160 \qquad \text{Eq. \#-7}$$

where E_{waste} is calculated in accordance with equation #-8.

$$E_{waste} = oEW_{fact} * (1 - oCD_{eff}) + sEW_{fact} * pEratio \qquad \text{Eq. \#-8}$$

where

$oEW_{fact} = EW_{fact} * oFrac$ = standard operating condition portion of hot water energy waste where

EW_{fact} = energy waste factor in accordance with Table #(6) oCD_{eff} is in accordance with Section #-2

$sEW_{fact} = EW_{fact} - oEW_{fact}$ = structural portion of hot water energy waste pEratio = piping length energy ratio

where

for standard system: pEratio = PipeL / refpipeL for recirculation systems: pEratio = LoopL / refLoopL and where

LoopL = hot water recirculation loop piping length including both supply and return sides of the loop, measured longitudinally from plans, assuming the hot water piping does not run diagonally, plus 20 feet of piping for each floor level greater than one plus 10 feet of piping for unconditioned basements.

refLoopL = 2.0*refPipeL - 20

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relative annual energy waste factors

Distribution System Description	EW_{fact}	
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Recirculation with demand control (manual)	43.2	28.8

ANSI/RESNET/ICC 301-2019

Standard for the Calculation and Labeling of the Energy Performance of Dwelling and Sleeping Units using an Energy Rating Index

December 18, 2018

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The 2019 edition of this Standard was first approved for publication on December, 11, 2018, by the RESNET Standards Management Board.

SPECIAL NOTE

This ANSI/RESNET/ICC Standard is a voluntary consensus standard developed under the auspices of the Residential Energy Services Network (RESNET) in accordance with RESNET's *Standards Development Policy and Procedures Manual*, Version 2.1, August 25, 2017. RESNET is an American National Standards Institute (ANSI) Accredited Standards Developer. Consensus is defined by ANSI as "substantial agreement reached by directly and materially affected interest categories." This signifies the concurrence of more than a simple majority but not necessarily unanimity. Consensus requires that all views and objections be considered, and that an effort be made toward their resolution. Compliance with this standard is voluntary until and unless a legal jurisdiction makes compliance mandatory.

RESNET obtains consensus through participation of it national members, associated societies, and public review.

The initial publication of the first edition of this Standard was designated and titled ANSI/RESNET 301-2014 Standard for the Calculation and Labeling of the Energy Performance of Low-Rise Residential Buildings using the HERS Index. The designation and title were changed to ANSI/RESNET/ICC 301-2014 Standard for the Calculation and Labeling of the Energy Performance of Low-Rise Residential Buildings using an Energy Rating Index as noted in the amendment proceeding for ANSI/RESNET/ICC 301-2014 Addendum B-2015. The second publication of the Standard first edition incorporated the designation and title changes and other non-substantive editorial changes to the first publication. This second edition of the Standard, ANSI/RESNET/ICC 301-2019 Standard for the Calculation and Labeling of the Energy Performance of Low-Rise Residential Buildings using an Energy Rating Index, incorporates a number of substantive changes, the more significant of which are all addenda to the first edition and criteria specific to Attached Dwelling and attached Sleeping Units in buildings of all heights.

This Standard is under continuous maintenance in accordance with Section 10.9 of the *RESNET Standard Development Policy and Procedures Manual.* Continuous maintenance proposals should be submitted to the Manager of Standards via the online form on the RESNET website. The Manual and online form can be accessed from the website at www.resnet.us/blog/resnet-consensus-standards/ under the heading **STANDARDS DEVELOPMENT**.

The Manager of Standards should be contacted for:

a. Interpretation of the contents of this Standard
b. Participation in the next review of the Standard
c. Offering constructive criticism for improving the Standard
d. Permission to reprint portions of the Standard

Contents

ANSI/RESNET/ICC 301-2019

Standard for the Calculation and Labeling of the Energy Performance of Dwelling and Sleeping Units using an Energy Rating Index

Forward (Informative)

This Standard provides a consistent, uniform methodology for evaluating and labeling the energy performance of Dwelling Units and Sleeping Units, including all detached and attached housing types. The terms Dwelling Unit and Sleeping Unit are interchangeable with the term home, except where specifically noted. The methodology compares the energy performance of an actual home with the energy performance of a reference home of the same geometry, resulting in a relative Energy Rating called the Energy Rating Index (ERI). Where the energy performance of the actual home and the reference home are equal, the Energy Rating Index is 100 and where the actual home requires no net Purchased Energy annually, the Energy Rating Index is 0 (zero).

The Energy Rating Reference Home used for this comparative analysis has the energy attributes of the 2006 International Energy Conservation Code (IECC) *Standard Reference Design*. Thus, the Energy Rating Index is relative to the minimum building energy efficiency requirements of the 2006 IECC. As a result, the Energy Rating Reference Home performance will not comport with state or local building codes that differ in stringency from the 2006 IECC. Where local building energy codes are less stringent than the 2006 IECC, the Energy Rating Index for the local standard will be greater than 100 and where local building energy codes are more stringent than the 2006 IECC, the Energy Rating Index for the local standard will be less than 100. Because the Energy Rating Index accounts for all lighting, appliances and Miscellaneous Energy Loads, there is never a 1-to-1 correspondence between code compliance (even under the 2006 IECC) and an Energy Rating Index of 100.

This standard does not provide a methodology for the calculation of an 'Energy Rating Index' for a whole building that contains more than one Dwelling Unit or Sleeping Unit. Section 5.1.4.5 provides a method to calculate a 'composite Energy Rating Index' substitute that is allowed to represent the residential portions of a single building that contains more than one Dwelling or Sleeping Unit or a group of multiple Detached Dwelling Units.

This Standard contains both normative and informative material. The body of the Standard is normative and must be complied with to conform to the Standard. Informative materials are not mandatory and are limited to this forward, footnotes, references, and annexes, all of which are clearly marked as informative.

The designation and title of the first edition of this Standard were revised effective November 17, 2015. The original designation, "ANSI/RESNET 301-2014," was revised to "ANSI/RESNET/ICC 301-2014." The title, "Standard for the Calculation and Labeling of Low-Rise Residential Buildings using the HERS Index," was revised to "Standard for the

Calculation and Labeling of Low-Rise Residential Buildings using the Energy Rating Index." All references to "HERS" within the Standard were revised to "Energy Rating." The change in designation adds recognition of the International Code Council (ICC) as a sponsor of the Standard. Non-substantive editorial changes to ANSI/RESNET 301-2014 noted in the amendment proceeding for ANSI/RESNET/ICC 301-2014 Addendum B-2015 and in the "Special Note" above were published in that edition.

This is the second edition of the Standard and is the first update in its five year revision cycle. The designation is updated to indicate year 2019 and the title and scope are modified to reflect its expansion to cover dwelling and Sleeping Units in buildings of any height. The terminology of the title and scope have been revised for consistency with the International Code Council model building codes.

1. **Purpose.** The provisions of this document establish Energy Rating and labeling Standards, consistent with the provisions of the Energy Policy Act of 1992, which provides for uniformity and consistency in the Rating and labeling of Dwelling Units and Sleeping Units in detached and attached housing types.

2. **Scope.** This standard is applicable to Dwelling Units and Sleeping Units in Residential or Commercial Buildings, excepting hotels and motels.[1] Energy Ratings determined in accordance with this standard are for individual Dwelling Units or Sleeping Units only. This standard does not provide procedures for determining Energy Ratings for whole buildings containing more than one unit.

3. **Definitions.** The following terms[2] and acronyms have specific meanings as used in this Standard. In the event that definitions given here differ from definitions given elsewhere, the definitions given here shall govern.

3.1. General. Unless stated otherwise, the terms and words in Section 3.2 shall have the meanings indicated therein. Words used in the present tense include the future, words in the masculine gender include the feminine and neuter, and singular and plural are interchangeable. Terms not defined in Section 3.2 shall have ordinary accepted meanings the context implies.

3.2. Definitions.

Air Source Heat Pump (ASHP) – Vapor compression heating and cooling equipment that uses the outdoor air as the heat source or sink for heat (see also Heat Pump).

Annual Fuel Utilization Efficiency (AFUE) **–** A measure of the efficiency of gas or oil fired furnaces and boilers calculated as the furnace heating energy output divided by fuel energy input. AFUE does not include electrical energy for fans, or electronic ignition systems (see also Electric Auxiliary Energy).

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[1] (Normative Note) The terms Dwelling Unit and Sleeping Unit are interchangeable with the term home throughout this Standard, except where specifically noted.

[2] (Informative Note) When used in this Standard, the first letter of each word is capitalized, to indicate that the term is defined in Section 3.2.

Approved – Shall mean approved by an entity adopting and requiring the use of this Standard as a result of investigation and tests conducted by the entity or by reason of accepted principles or tests by nationally recognized organizations.

Approved Hot Water Operational Control Device – A means of controlling the waste hot water in residences that is Approved for use based on empirical test data and where the control effectiveness of the device is clearly labeled in terms of its overall reduction of operational waste hot water.

Approved Rating Provider – An Approved entity responsible for the approval of Approved Testers and Approved Inspectors and the certification of raters working under its auspices and who is responsible for the Quality Assurance of such Certified Raters and for the Quality Assurance of Energy Ratings produced by such Certified Raters.

Approved Software Rating Tool [3] – A computerized procedure that is Approved for the purpose of conducting Energy Ratings and calculating the annual energy consumption, annual energy costs and an Energy Rating Index for a home.

Approved Inspector – An individual who, by virtue of training and examination, has demonstrated competence in the performance of on-site inspections in accordance with requirements of Appendix A and Appendix B and who has been Approved by an Approved Rating Provider to conduct such tests.

Approved Tester – An individual who, by virtue of training and examination, has demonstrated competence in the performance of on-site testing in accordance with requirements of Standard ANSI/RESNET/ICC 380 and who has been Approved by an Approved Rating Provider to conduct such tests.

Attached Dwelling Unit – A Dwelling Unit sharing demising walls, floors, ceilings, or common corridors with another Dwelling Unit or Occupiable Space.

Average Dwelling Unit Energy Rating Index – A single, composite Energy Rating Index substitute that can be used to represent the residential portions of a single building. This substitute is established by averaging the Energy Rating Index of each Dwelling Unit in the building and is calculated in accordance with Section 5.1.4.5.

Auxiliary Electric Consumption – The annual auxiliary electrical energy consumption for a fossil fuel fired furnace, boiler or Ground Source Heat Pump in Kilowatt-Hours per year.

Balanced Ventilation System (Balanced System) – A Ventilation system where the total supply airflow and total exhaust airflow are simultaneously within 10% of their average.

Baseline Existing Home Model – The original energy features and standard operating conditions of an existing home that is (or will be) subjected to improvements through a home energy efficiency retrofit.

[3] (Informative Note) A list of software rating tools meeting the requirements of RESNET Publication No. 002-2017 and Approved by RESNET is online at http://www.resnet.us/professional/programs/energy_rating_software.

Bedroom – For one- and two-family Dwellings and Townhouses, a room[4] or space 70 square feet of floor area or greater, with egress window or skylight, and doorway to the main body of the Dwelling Unit, that can be used for sleeping. For all other Dwelling Units, a room[5] or space that can be used for sleeping. For all Dwelling or Sleeping Units, the number of Bedrooms shall not be less than one.

Biomass Fuel – Plant or animal waste materials that have been processed to be capable of providing useful heat through combustion.

British Thermal Unit (Btu) – An energy unit equal to the amount of heat needed to raise one pound of water one degree Fahrenheit at a constant pressure of one atmosphere; equal to approximately 1055 joules.

Certified Rater – An individual who has become qualified to conduct Energy Ratings through certification by an Approved Rating Provider.

Chiller – Vapor compression cooling equipment that uses the outdoor air or water circulated through a Cooling Tower as a heat sink for cooling.

Coefficient of Performance (COP) – The ratio of the rate of heat delivered to the rate of energy input, in consistent units, for a complete Heat Pump system under designated operating conditions.

Commercial Building – All buildings that are not included in the definition of Residential Buildings.

Compartmentalization Boundary – The surface area that bounds the Infiltration Volume of the Dwelling Unit.

Conditioned Floor Area (CFA)[5] – The floor area of the Conditioned Space Volume within a building or Dwelling Unit, not including the floor area of attics, crawlspaces, and basements below air sealed and insulated floors. The following specific spaces are addressed to ensure consistent application of this definition:

- The floor area of a wall assembly that is adjacent to Conditioned Space Volume shall be included.
- The floor area of a basement shall be included if the party conducting the evaluation has either:
  - Obtained an ACCA Manual J, S, and either B or D report and verified that both the heating and cooling equipment and distribution system are designed to offset the entire design load of the volume, or,
  - Verified through visual inspection that both the heating and cooling equipment and distribution system serve the volume and, in the judgement of the party conducting evaluations, are capable of maintaining the heating

[4] (Informative Note) A "den," "library," "home office" or other similar rooms with a closet, egress window, doorway to the main body of the Dwelling Unit, and 70 square feet of floor area or greater are considered a Bedroom, but living rooms, foyers, and other rooms not intended for sleeping, are not. The number of rooms identified as Bedrooms is used to determine the number of occupants.

[5] (Informative Note) Informative Annex A of Standard ANSI/RESNET/ICC 380 contains a table that summarizes parts of a Dwelling Unit that are included in Conditioned Floor Area.

and cooling temperatures specified by the Thermostat section in Table 4.2.2(1).

- The floor area of a garage shall be excluded, even when it is conditioned.
- The floor area of a thermally isolated sunroom shall be excluded.
- The floor area of an attic shall be excluded, even when it is Conditioned Space Volume.
- The floor area of a crawlspace shall be excluded, even when it is Conditioned Space Volume.

***Conditioned Space Volume*[6] -** The volume within a Dwelling Unit serviced by a space heating or cooling system designed to maintain space conditions at 78 °F (26 °C) for cooling and 68 °F (20 °C) for heating. The following specific spaces are addressed to ensure consistent application of this definition:

- If the volume both above and below a floor assembly meets this definition and is part of the Rated Dwelling Unit, then the volume of the floor assembly shall also be included. Otherwise the volume of the floor assembly shall be excluded.
  - Exception: The wall height shall extend from the finished floor to the bottom side of the floor decking above the Rated Dwelling Unit for non-top floor level Dwelling Units and to the exterior enclosure air barrier for top floor level Dwelling Units.
- If the volume of at least one of the spaces horizontally adjacent to a wall assembly meets this definition, and that volume is part of the Rated Dwelling Unit, then the volume of the wall assembly shall also be included. Otherwise, the volume of the wall assembly shall be excluded.
  - Exception: If the volume of one of the spaces horizontally adjacent to a wall assembly is a Dwelling Unit other than the Rated Dwelling Unit, then the volume of that wall assembly shall be evenly divided between both adjacent Dwelling Units.
- The volume of an attic that is not both air sealed and insulated at the roof deck shall be excluded.
- The volume of a vented crawlspace shall be excluded.
- The volume of a garage shall be excluded, even when it is conditioned.
- The volume of a thermally isolated sunroom shall be excluded.
- The volume of an attic that is both air sealed and insulated at the roof deck, the volume of an unvented crawlspace, and the volume of a basement shall only be included if the volume is contiguous with the Rated Dwelling Unit and the party conducting evaluations has either:
  - Obtained an ACCA Manual J, S, and either B or D report and verified that both the heating and cooling equipment and distribution system are designed to offset the entire design load of the volume, or,
  - Verified through visual inspection that both the heating and cooling equipment and distribution system serve the volume and, in the judgement of the party conducting evaluations, are capable of maintaining the heating

[6] (Informative Note) Informative Annex A of Standard ANSI/RESNET/ICC 380 contains a table that summarizes parts of a Dwelling Unit that are included in Conditioned Space Volume.

and cooling temperatures specified by the Thermostat section in Table 4.2.2(1).

- The volume of a mechanical closet, regardless of access location, that is contiguous with the Rated Dwelling Unit shall be included if:
  - it is serviced by a space heating or cooling system designed to maintain space conditions at 78 °F (26 °C) for cooling and 68 °F (20 °C) for heating, and
  - it only includes equipment serving the Rated Dwelling Unit, and
  - the mechanical room is not intentionally air sealed from the Rated Dwelling Unit.

Confirmed Rating **–** A Rating accomplished using data gathered from verification of all rated features of the home in accordance with this Standard.

Cooling Tower **–** A heat rejection device that rejects heat to the atmosphere.

Design Approval Primary Inspection Agency (DAPIA) – A third-party agency designated by the U.S. Department of Housing and Urban Development (HUD) to be responsible for evaluating manufactured home designs submitted to it by the manufacturer and for assuring that they conform to the HUD standards for manufactured homes.

Detached Dwelling Unit – A Dwelling Unit that does not meet the definition of Attached Dwelling Unit.

Distribution System Efficiency (DSE)[7] – A system efficiency factor that adjusts for the energy losses associated with the delivery of energy from the equipment to the source of the load.[8]

Drain Water Heat Recovery (DWHR) Unit – A heat exchanger unit that uses outgoing warm drain water to pre-heat incoming cold freshwater and is rated for efficiency and pressure loss according to CSA B55.1, and complies with CSA B55.2.

Dwelling – Any building that contains one or two Dwelling Units used, intended, or designed to be built, used, rented, leased, let or hired out to be occupied, or that are occupied for living purposes.

Dwelling Unit **–** A single unit providing complete independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, cooking, and sanitation.

Dwelling-Unit Mechanical Ventilation System – A Ventilation system consisting of powered Ventilation equipment such as motor-driven fans and blowers and related mechanical components such as ducts, inlets, dampers, filters and associated control devices that provides dwelling-unit Ventilation at a known or measured airflow rate.

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[7] (Informative Note) DSE is not included in manufacturer's equipment performance ratings for heating and cooling equipment.

[8] (Informative Note) Such as energy losses associated with heat transfer across duct or piping walls and air leakage to or from forced air distribution systems.

Electric Auxiliary Energy (Eae) – The average annual Auxiliary Electric Consumption for a gas furnace or boiler in Kilowatt-Hours per year as published in the AHRI Consumer's Directory of Certified Efficiency Ratings.

Emittance – A measure of the ability of a surface to emit radiation, expressed as the ratio of the energy radiated within a specific spectral band by a surface to that radiated within that same specific spectral band by a blackbody at the same temperature.

Energy Efficiency Ratio (EER) – The ratio of net equipment cooling capacity in Btu/h to total rate of electric input in Watts under designated operating conditions.

Energy Factor (EF) – A standardized measure of energy efficiency as determined under Department of Energy Regulations, 10 CFR 430.

Energy Policy Act of 1992 (EPAct 92) – An act of the U.S. Congress, passed in 1992, which required the development by the U.S. Department of Energy (DOE) of voluntary guidelines for home energy rating systems.

Energy Rating **–** An unbiased indication of a Dwelling Unit's relative energy performance based on consistent inspection procedures, operating assumptions, climate data and calculation methods in accordance with this Standard.

Energy Rating Disclosure – A set of assertions attested to by the Certified Rater listing all potential financial interests of the Certified Rater with respect to the property being Rated. Where any potential financial interest in the results of the Rating exists on the part of the Certified Rater, it must be disclosed and attested to in writing by the Certified Rater.

Energy Rating Index (ERI) – A numerical integer value that represents the relative energy use of a Rated Home as compared with the energy use of the Energy Rating Reference Home and where an Index value of 100 represents the energy use of the Energy Rating Reference Home and an Index value of 0 (zero) represents a home that uses zero net Purchased Energy annually.

Energy Rating Reference Home – A hypothetical home configured in accordance with the specifications set forth in Section 4.2 of this Standard as the basis of comparison for the purpose of calculating the relative energy efficiency and Energy Rating Index of a Rated Home.

Energy Rating System – The procedures, rules and guidelines by which Energy Ratings are conducted by an Approved Rating Provider, as specified in these Standards.

ENERGY STAR – A joint program of the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE) that encourages energy use reduction by providing ENERGY STAR labels to products and homes meeting the improved energy efficiency requirements of the program.

Exhaust Ventilation System (Exhaust System) **–** One or more fans that remove air from the Dwelling Unit, causing outdoor air to enter by Ventilation inlets or normal leakage paths through the Dwelling Unit envelope.

Existing Home Retrofit – The set of energy efficiency improvements made to an existing home to improve its energy performance.

Failure – When one or more of the Threshold Specifications are not met during inspections or testing.

Fenestration – A glazed opening and its associated sash and framing that is installed into a building.

Framing Fraction (FF) – The fractional area of walls, ceilings, floors, roofs and other enclosure elements comprising the structural framing elements with respect to the total Gross Area of the component.

Glazing – Sunlight-transmitting Fenestration, including the area of sash, curbing or other framing elements, that enclose Conditioned Space Volume. For doors where the sunlight-transmitting opening is less than 50% of the door area, the Glazing area of the sunlight transmitting opening area shall be used. For all other doors, the Glazing area is the rough frame opening area for the door, including the door and the frame.

Gross Area – The area of a building enclosure component that includes the areas of the Fenestration areas that are not normally included in the net area of the enclosure component. Normally the simple area calculated as the overall length times the overall width of the enclosure component.[9]

Ground Source Heat Pump (GSHP) – Vapor compression heating and cooling equipment that uses the ground (or ground water) as the heat source or sink for heat (see also Heat Pump).

Heat Pump – A vapor-compression refrigeration device that includes a reversing valve and optimized heat exchangers so that the direction of heat flow is reversed in order to transfer heat from one location to another using the physical properties of an evaporating and condensing fluid known as a refrigerant.[10]

Heating Seasonal Performance Factor (HSPF) – A standardized measure of Heat Pump efficiency, based on the total heating output of a Heat Pump, in Btu, divided by the total electric energy input, in Watt-hours, under test conditions specified by the Air Conditioning and Refrigeration Institute Standard 210/240.

Improved Home Model – The energy features and standard operating conditions of a home after an Existing Home Retrofit has been accomplished to improve the energy performance of the home.

Index Adjustment Design (IAD) – A home design comprising 2-stories and 3 Bedrooms with Conditioned Floor Area of 2,400 ft^2 used to determine the percentage improvement over the Energy Rating Reference Home for the purposes of determining the Index Adjustment Factor that is applied to the Rated Home.

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[9] (Informative Note) Such as a wall.

[10] (Informative Note) Most commonly, Heat Pumps draw heat from the air or from the ground moving the heat from a low temperature heat source to a higher temperature heat sink.

Index Adjustment Factor (IAF) – A value calculated using the percentage improvement of the Index Adjustment Design to determine the impact of home size, number of Bedrooms and number of stories on the Energy Rating Index of the Rated Home.

Infiltration – The exchange of outdoor and indoor air through small cracks and penetrations in home enclosures driven by pressure differences between the indoor and outdoor environment.

Infiltration Volume[11] – The sum of the Conditioned Space Volume and additional adjacent volumes in the Dwelling Unit that meet the following criteria:
- Crawlspaces and floor assemblies above crawlspaces, when the access doors or hatches between the crawlspace and Conditioned Space Volume are open during the enclosure airtightness test,
- Attics, when the access doors or access hatches between the attic and Conditioned Space Volume are open during the enclosure airtightness test,
- Basements and floor assemblies above basements, where the doors between the basement and Conditioned Space Volume are open during the enclosure airtightness test.

In-Plant Inspection Agency (IPIA) – A third-party agency designated by the U.S. Department of Housing and Urban Development (HUD) to ensure the construction quality of manufactured housing.

Insulated Sheathing – An insulating board with a core material having a minimum R-Value of R-2.

Internal Gains – The heat gains within a home attributable to lights, people, hot water tanks, equipment, appliances, and Miscellaneous Energy Loads internal to the Conditioned Space Volume.

International Energy Conservation Code (IECC) – The model building energy efficiency code as promulgated by the International Code Council.

kBtu **–** One thousand British Thermal Units (Btu).

Kilowatt-Hour (kWh) – One thousand Watt-Hours (see also Watt-Hour); approximately equal to 3412 Btu.

Latent Energy – Energy associated with the amount of moisture vapor in the air. The term refers to moisture vapor that is added to an indoor space by Internal Gains, a humidifier or by outdoor air introduced to the indoor space or to moisture vapor that is removed from an indoor space by air conditioning, Ventilation or dehumidification (see also Sensible Energy).

Manual J – The procedures published by the Air Conditioning Contractors of America (ACCA) used to estimate the heating and air conditioning loads of homes.

MBtu – One million British Thermal Units (Btu).

[11](Informative Note) Informative Annex A of Standard ANSI/RESNET/ICC 380 contains a table that summarizes parts of a Dwelling Unit that are included in Infiltration Volume.

Minimum Rated Features – The characteristics of the building elements which are the basis for the calculation of end use loads and energy consumption for the purpose of an Energy Rating, and which are evaluated by Certified Raters or Approved Inspectors, in accordance with the on-site inspection procedures described in Appendix B, in order to collect the data necessary to create an Energy Rating using an Approved Software Rating Tool.

Miscellaneous Energy Loads (MELs) – Energy uses that are not attributable to space heating, space cooling, hot water heating or well-defined energy uses of specific appliances that have a large saturation in homes.

Multifamily Buffer Boundary – An unconditioned building space located directly adjacent to the Compartmentalization Boundary of the Dwelling Unit.[12]

National Appliance Energy Conservation Act (NAECA) – Legislation by the United States Congress that regulates energy consumption of specific household appliances in the United States, first passed as the Energy policy and Conservation Act in 1975 (Public Law 94-163) and amended in 1987 and 1988 (Public Laws 100-12 and 100-357), 1992 (Public Law 102-486) and 2005 (Public Law 109-58) and 2007 (Public Law 110-140).

Natural Ventilation – The purposeful introduction of outdoor air into the home through open skylights, windows and doors with the specific purpose of improving indoor comfort without the use of HVAC equipment.

Non-Freezing Space – For modeling purposes, the temperature of this space shall float with outside temperature but shall be no lower than 40°F. Applicable only in buildings containing multiple Dwelling Units.

Occupiable Space – A room or enclosed space designed for human occupancy in which individuals congregate for amusement, educational or similar purposes or in which occupants are engaged at labor, and which is equipped with means of egress and light and Ventilation facilities meeting the requirements of this standard.

On-Site Power Production (OPP) – Electric power produced on the site of a Rated Home. OPP shall be the net electrical power production, such that it equals the gross electrical power production minus any purchased fossil fuel energy used to produce the on-site power, converted to equivalent electric energy use at a 40% conversion efficiency in accordance with Equation 4.1-3 of this Standard.

Pascal (Pa) – The metric unit of pressure equaling 1 Newton per square meter.

Performance Threshold – The specific pass/fail criterion for the inspection or testing of each Minimum Rated Feature, which is based on a predetermined prescriptive or worst-case specification.

Projected Rating **–** A Rating[13] accomplished using Minimum Rated Feature data derived from plans and specifications.

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[12] (Informative Note) Such as stairwells, elevator shafts, and refuse closets.
[13] (Informative Note) Projected Ratings are commonly generated prior to the construction of a new building or prior to the implementation of energy-efficiency improvements to an existing building.

Purchased Energy – The portion of the total energy requirement of a home purchased from a utility or other energy supplier.

Quality Assurance – The systematic processes intended to ensure reliable compliance with applicable standards.

Qualifying Light Fixture Locations – For the purposes of Rating, those light fixtures located within the contiguous area that is for the sole use of the Rated Home occupants, limited to kitchens, dining rooms, living rooms, family rooms/dens, bathrooms, hallways, stairways, entrances, Bedrooms, garage[14], utility rooms[15], home offices, and all outdoor fixtures mounted on the exterior of the Rated Home or on a pole. This excludes plug-in lamps, closets[16], unconditioned basements, lighting for common spaces, parking lot lighting, and landscape lighting.

Qualifying Tier I Light Fixture – A light fixture located in a Qualifying Light Fixture Location that contains fluorescent lamps.

Qualifying Tier II Light Fixture – A light fixture located in a Qualifying Light Fixture Location that contains LED lamps; an integrated LED fixture; an outdoor light fixture that is controlled by a photocell; or an indoor fixture controlled by a motion sensor.

Rated Home – The specific real property that is evaluated using the Energy Rating procedures specified by this Standard.

Rating – See Energy Rating.

Reference Home – See Energy Rating Reference Home.

Renewable Energy System – Means of producing thermal energy or producing electric power that rely on naturally-occurring, on-site resources that are not depleted as a result of their use. Renewable Energy Systems shall include, but are not limited to, solar energy systems, wind energy systems and biomass energy systems.

Residential Building – Includes detached one-family Dwellings and two-family Dwellings and multiple single-family Dwellings (Townhouses) and Group R-2, R-3 and R-4 buildings three stories or less in height above grade plane.[17]

Residual Miscellaneous Energy Loads (Residual MELs) – The miscellaneous energy uses within a Rated Home that are included in the energy use but are not explicitly accounted for as distinct end uses by the Minimum Rated Features of the home.

Revenue-Based Price – The electric, natural gas or other fuel rate that is calculated as the total units sold divided by the total revenues received.

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[14] (Normative Note) Garages shall include an attached garage or carport if the space is not shared with other Dwelling Units.
[15] (Normative Note) Utility rooms shall include rooms used for laundry and rooms used as workshops.
[16] (Normative Note) Closets shall include pantries, linen closets, clothes closets, closets with mechanical equipment, and storage closets inside or outside of the Dwelling Unit.
[17] (Normative Note) The definition of *Residential Building* corresponds to the IECC definition of *Residential Building*. The Occupancy Groups R-2, R-3 and R-4 are as established by the IBC.

R-Value **–** The inverse of the time rate of heat flow through a body from one of its bounding surfaces to the other surface for a unit temperature difference between the two surfaces, under steady state conditions, per unit area (h·ft^2·°F/Btu) [m^2·K/W].

Sampled Feature – A building element, component, or group thereof that is evaluated for compliance with Threshold Specifications by using Sampling.

Sampled Project – A building with multiple units or a group of buildings with multiple units to which Sampling is applied.

Sampled Rating **–** A Rating type that encompasses a set of Dwelling Units and is accomplished using data gathered from verification of fewer than 100% of the instances of each minimum rated feature within that set in accordance with this Standard.

Sampling – A process whereby fewer than 100% of the Dwelling Units are inspected, tested, or modeled to demonstrate compliance with a set of Threshold Specifications.

Seasonal Energy Efficiency Ratio (SEER) – A standardized measure of air conditioner efficiency based on the total cooling output of an air conditioner in Btu/h, divided by the total electric energy input, in Watt-hours, under test conditions specified by the Air Conditioning and Refrigeration Institute Standard 210/240.

Sensible Energy **–** Energy associated with the amount of heat contained in the air, as contrasted with Latent Energy, which is energy associated with the amount of moisture vapor contained in the air.[18]

Shall – As used in this Standard, the word 'shall' means that the action specified is mandatory and must be accomplished by the responsible party.

Sleeping Unit **–** A room or space in which people sleep, which can also include permanent provisions for living, eating, and either sanitation or kitchen facilities but not both. Such rooms and spaces that are also part of a Dwelling Unit are not Sleeping Units.

Solar Absorptance **–** The fraction of normal incident solar radiation striking a surface that is not reflected or transmitted.

Specific Leakage Area (SLA) **–** The unitless ratio of the Effective Leakage Area (ELA) of a home enclosure as defined by ASHRAE Standard 62.2 divided by the home's Conditioned Floor Area, given in the same units of measure.

Supply Ventilation System (Supply System) **–** One or more fans that supply outdoor air to the Dwelling Unit. Supply Ventilation Systems shall be designed and constructed to provide Ventilation air directly from the outdoors to the Dwelling Unit.

Threshold Specifications – A set of qualification criteria that are established based on a Worst-Case Analysis of an explicit design specification.[19]

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[18] (Informative Note) The total energy contained in the air (also called enthalpy) is equal to the sum of the latent and the sensible energies contained in the air.

[19] (Informative Note) Such as the ENERGY STAR® Reference Design adopted by the U.S. Environmental Protection Agency.

Threshold Rating - A Rating accomplished using Threshold Specifications to determine the Energy Rating Index where verification of all Minimum Rated Features is accomplished through field inspections and testing conducted on every home.

Therm **–** An energy unit equal to 100,000 British Thermal Units (Btu); usually used to measure the consumption of natural gas.

T_{mains} – The temperature of the potable water supply entering the residence.

Townhouse - A single-family Dwelling Unit constructed in a group of three or more attached units in which each unit extends from the foundation to roof and with open space on at least two sides.

Typical Existing Home – A representation of existing U.S. housing stock that assumes standard operating conditions and which is assigned an Energy Rating Index of 130 based on U.S. Department of Energy estimates.

U-Factor **–** The coefficient of heat transmission (air to air) through a building component or assembly, equal to the time rate of heat flow per unit area and unit temperature difference between the warm side and cold side air films (Btu/h·ft^2·°F) [W/m^2·K].

Unconditioned Space Volume[20] **–** The volume within a building or Dwelling Unit that is not Conditioned Space Volume but which contains heat sources or sinks that influence the temperature of the area or room. The following specific spaces are addressed to ensure consistent application of this definition:

- If either one or both of the volumes above and below a floor assembly is Unconditioned Space Volume, then the volume of the floor assembly shall be included.
- If the volume of both of the spaces horizontally adjacent to a wall assembly are Unconditioned Space Volume, then the volume of the wall assembly shall be included.
- The volume of an attic that is not both air sealed and insulated at the roof deck shall be included.
- The volume of a vented crawlspace shall be included.
- The volume of a garage shall be included, even when it is conditioned.
- The volume of a thermally isolated sunroom shall be included.
- The volume of an attic that is both air sealed and insulated at the roof deck, the volume of an unvented crawlspace, and the volume of a basement shall be included unless it meets the definition of Conditioned Space Volume.

Uniform Energy Factor (UEF) – DOE's standard for communicating the energy efficiency of water heaters.

Unrated Conditioned Space – A building location used only in Ratings of attached units, beyond the boundaries of the rated Dwelling Unit and serviced by a space heating or cooling system designed to maintain space conditions at 78 °F (26 °C) ± 5°F for cooling and 68 °F (20 °C) ± 5°F for heating. The energy for conditioning Unrated Conditioned

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[20] (Informative Note) Informative Annex A of Standard ANSI/RESNET/ICC 380 contains a table that summarizes parts of a Dwelling Unit that are included in Unconditioned Space Volume.

Space is not counted in the Rated Home or Energy Rating Reference Home. This is distinct from Unrated Heated Space, and from Conditioned Space Volume.

Unrated Heated Space – A building location used only in Ratings of attached units for shared service equipment such as shared laundry, heating, cooling, hot water, or Ventilation. Unrated Heated Space is outside of the Conditioned Space Volume and only interacts with the Rated Home via the shared services located within. The energy for heating the Unrated Heated Space is not counted in the Rated Home or Energy Rating Reference Home.

Variable Refrigerant Flow Multi-Split Air Conditioning and Heat Pump Equipment (VRF) – Commercial-grade air conditioning or Heat Pumps with variable refrigerant flow that use the outdoor air as the heat source or sink (see also Heat Pump).[21]

Ventilation – The process of providing outdoor air directly to a Dwelling Unit by natural or mechanical means. Such air may or may not be conditioned.

Water Loop Heat Pump (WLHP) – Vapor compression heating and cooling equipment that uses water as its heat source and heat sink (see also Heat Pump).

Watt – Energy flow rate equal to one joule per second; approximately equal to 3.412 Btu per hour.

Watt-Hour – A unit of energy equal to an energy flow rate of one Watt for a duration of one hour or 3,600 joules; approximately equal to 3.412 Btu.

Whole-House Fan – A forced air system consisting of a fan or blower that exhausts at least 5 ACH of indoor air to the outdoors thereby drawing outdoor air into a home through open windows and doors for the purpose of cooling the home.

Window Film – Fenestration attachment products which consist of a flexible adhesive-backed polymer film which is applied to the interior or exterior surface of an existing Glazing system.

Worst-Case Analysis – An analysis for which the Minimum Rated Features of the Dwelling Unit are configured to provide the largest Energy Rating Index when four ordinal home orientations and the least energy efficient Minimum Rated Features for the specified design are considered by the Analysis.

3.3. Acronyms.

ACH – Air Changes per Hour

ACH50 – Air Changes per Hour at 50 Pascals

AFUE – Annual Fuel Utilization Efficiency

AHRI - Air-Conditioning, Heating, and Refrigeration Institute

ASHP – Air Source Heat Pump

[21] (Informative Note) The large outdoor units typically serve multiple Dwelling Units; indoor units can be ducted units, non-ducted units, or a mix of both.

***ASHRAE* –** American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.

***ASTM* –** ASTM International, originally known as the American Society for Testing and Materials (ASTM)

Btu – British Thermal Unit

CEC – California Energy Commission

CFA – Conditioned Floor Area

CFIS – Central Fan Integrated Supply

cfm – Cubic Feet per Minute

COP – Coefficient of Performance

***CRRC* –** Cool Roof Rating Council

***DAPIA* –** Design Approval Primary Inspection Agency

DOE – U.S. Department of Energy

DSE – Distribution System Efficiency

DWHR – Drain Water Heat Recovery

Eae – Electric Auxiliary Energy

***EER* –** Energy Efficiency Ratio

***EF* –** Energy Factor

ELA – Effective Leakage Area

***EPA* –** U.S. Environmental Protection Agency

***EPAct 92* –** Energy Policy Act of 1992

***ERI* –** Energy Rating Index

FF – Framing Fraction

gpm – Gallons per Minute

***GSHP* –** Ground Source Heat Pump

***HSPF* –** Heating Seasonal Performance Factor

***HUD* –** U.S. Department of Housing and Urban Development

***HVAC* –** Heating, Ventilating and Air Conditioning

IAD – Index Adjustment Design

IAF – Index Adjustment Factor

IBC –International Building Code

ICC – International Code Council

IDR – Innovative Design Request

IECC – International Energy Conservation Code

IMEF – Integrated Modified Energy Factor

IPIA – In-Plant Inspection Agency

IRC – International Residential Code for One- and Two-Family Dwellings

kWh – Kilowatt-Hour

MELs – Miscellaneous Energy Loads

MEPR – Manufacturer's Equipment Performance Rating

NAECA – National Appliance Energy Conservation Act

OPP - On-Site Power Production

Pa – Pascal

RESNET – Residential Energy Services Network, Inc.

SEER – Seasonal Energy Efficiency Ratio

SHW – Service Hot Water

SL – Standby Loss

SLA – Specific Leakage Area

SRCC – Solar Rating & Certification Corporation

TE – Thermal Efficiency

TPO – Thermoplastic polyolefin

UEF – Uniform Energy Factor

VRF – Variable refrigerant flow

WLHP – Water Loop Heat Pump

4. Energy Rating Calculation Procedures.

4.1. Determining the Energy Rating Index. The Energy Rating Index for a Rated Home shall be determined in accordance with Sections 4.1.1 and 4.1.2. This standard shall not be used to calculate the Energy Rating Index for a whole building that contains more than one Dwelling Unit or Sleeping Unit.

4.1.1. Calculating End Use Loads. The normalized Modified End Use Loads (nMEUL) for space heating and cooling and service hot water use shall each be determined in accordance with Equation 4.1-1:

nMEUL = REUL * (nEC_x / EC_r) **(Eq. 4.1-1)**

where:

nMEUL = normalized Modified End Use Loads (for heating, cooling, or hot water) as computed using an Approved Software Rating Tool.

REUL = Reference Home End Use Loads (for heating, cooling or hot water) as computed using an Approved Software Rating Tool.

nEC_x = normalized Energy Consumption for the Rated Home's end uses (for heating, including Auxiliary Electric Consumption, cooling or hot water) as computed using an Approved Software Rating Tool.

EC_r = estimated Energy Consumption for the Reference Home's end uses (for heating, including Auxiliary Electric Consumption, cooling or hot water) as computed using an Approved Software Rating Tool.

and where:

nEC_x = (a* EEC_x – b)*(EC_x * EC_r * DSE_r) / (EEC_x * REUL) **(Eq. 4.1-1a)**

where:

EC_x = estimated Energy Consumption for the Rated Home's end uses (for heating, including Auxiliary Electric Consumption, cooling or hot water) as computed using an Approved Software Rating Tool.

EEC_x = Equipment Efficiency Coefficient for the Rated Home's equipment, such that EEC_x equals the energy consumption per unit load in like units as the load, and as derived from the Manufacturer's Equipment Performance Rating (MEPR) such that EEC_x equals 1.0 / MEPR for AFUE, COP or EF ratings, or such that EEC_x equals 3.413 / MEPR for HSPF, EER or SEER ratings.

DSE_r = REUL/EC_r * EEC_r

For simplified system performance methods, DSE_r equals 0.80 for heating and cooling systems and 1.00 for hot water systems [see Table 4.2.2(1)]. However, for detailed modeling of heating and cooling systems, DSE_r less than 0.80 occurs as a result of part load performance degradation, coil air flow degradation, improper system charge and auxiliary resistance heating for Heat Pumps. Except as otherwise provided by these Standards, where detailed systems modeling is employed, it must be applied equally to both the Reference and the Rated Homes.

EEC_r = Equipment Efficiency Coefficient for the Reference Home's equipment, such that EEC_r equals the energy consumption per unit load in like units as the load, and as derived from the Manufacturer's Equipment Performance Rating (MEPR) such that EEC_r equals 1.0 / MEPR for AFUE, COP or EF ratings, or such that EEC_r equals 3.413 / MEPR for HSPF, EER or SEER ratings and where the coefficients 'a' and 'b' are as defined by Table 4.1.1(1) below:

Table 4.1.1(1) Coefficients 'a' and 'b'

Fuel Type and End Use	a	b
Electric space heating	2.2561	0
Fossil fuel* space heating	1.0943	0.4030
Biomass space heating	0.8850	0.4047
Electric air conditioning	3.8090	0
Electric water heating	0.9200	0
Fossil fuel* water heating	1.1877	1.0130

*Such as natural gas, liquid propane gas, fuel oil

4.1.2. Calculating the Energy Rating Index. The Energy Rating Index shall be determined in accordance with Equation 4.1-2:

$$\textbf{Energy Rating Index} = PEfrac * (TnML / (TRL * IAF_{RH})) * 100 \qquad \textbf{(Eq. 4.1-2)}$$

where:

TnML = $nMEUL_{HEAT} + nMEUL_{COOL} + nMEUL_{HW} + EUL_{LA}$ (MBtu/y).
TRL = $REUL_{HEAT} + REUL_{COOL} + REUL_{HW} + REUL_{LA}$ (MBtu/y).
IAF_{RH} = Index Adjustment Factor of Rated Home, per Eq. 4.3-2

and where:

EUL_{LA} = The Rated Home end use loads for lighting, appliances and MELs as defined by Section 4.2.2.5.2, converted to MBtu/y, where MBtu/y = (kWh/y)/293 or (Therms/y)/10, as appropriate.
$REUL_{LA}$ = The Reference Home end use loads for lighting, appliances and MELs as defined by Section 4.2.2.5.1, converted to MBtu/y, where MBtu/y = (kWh/y)/293 or (Therms/y)/10, as appropriate.

and where:

PEfrac = (TEU - OPP) / TEU
TEU = Total energy use of the Rated Home including all rated and non-rated energy features where all fossil fuel site energy uses (Btu_{fossil}) are converted to equivalent electric energy use (kWh_{eq}) in accordance with Equation 4.1-3.
OPP = On-Site Power Production as defined by Section 4.2.2.6 of this Standard.

$$kWh_{eq} = (Btu_{fossil} * 0.40) / 3412 \qquad \textbf{(Eq. 4.1-3)}$$

4.2. Energy Rating Reference Home and Rated Home Configuration.

4.2.1. General Requirements. Except as specified by this Section, the Energy Rating Reference Home and the Rated Home shall be configured and analyzed using identical methods and techniques.

4.2.2. Residence Specifications. The Energy Rating Reference Home and Rated Home shall be configured and analyzed as specified by Table 4.2.2(1).

Table 4.2.2(1) Specifications for the Energy Rating Reference and Rated Homes

Building Component	Energy Rating Reference Home	Rated Home
Above-grade walls	Type: wood frame Gross Area: same as Rated Home U-Factor: from Table 4.2.2(2) Solar Absorptance = 0.75 Emittance = 0.90	Same as Rated Home Same as Rated Home Same as Rated Home Same as Rated Home Same as Rated Home
Conditioned basement walls	Type: same as Rated Home Gross Area: same as Rated Home U-Factor: from Table 4.2.2(2) with the insulation layer on the interior side of walls	Same as Rated Home Same as Rated Home Same as Rated Home
Floors over Unconditioned Space Volume, Non-Freezing Space or outdoor environment	Type: wood frame Gross Area: same as Rated Home U-Factor: from Table 4.2.2(2)	Same as Rated Home Same as Rated Home Same as Rated Home
Ceilings	Type: wood frame Gross Area: same as Rated Home U-Factor: from Table 4.2.2(2)	Same as Rated Home Same as Rated Home Same as Rated Home
Roofs	Type: composition shingle on wood sheathing Gross Area: same as Rated Home Solar Absorptance = 0.75 Emittance = 0.90	Same as Rated Home Same as Rated Home Values from Table 4.2.2(4) shall be used to determine Solar Absorptance except where test data are provided for roof surface in accordance with ANSI/CRRC S100. Emittance values provided by the roofing manufacturer in accordance with ANSI/CRRC S100 shall be used when available. In cases where the appropriate data are not known, same as the Reference Home.
Attics	Type: vented with aperture = 1 ft^2 per 300 ft^2 ceiling area	Same as Rated Home
Foundations	Type: same as Rated Home Gross Area: same as Rated Home U-Factor / R-Value: from Table 4.2.2(2)	Same as Rated Home Same as Rated Home Same as Rated Home

Table 4.2.2(1) Specifications for the Energy Rating Reference and Rated Homes

Building Component	Energy Rating Reference Home	Rated Home
Crawlspaces	Type: vented with net free vent aperture = 1ft^2 per 150 ft^2 of crawlspace floor area. Crawlspace walls shall be uninsulated, while the floor above the crawlspace shall be insulated according to Table 4.2.2(2) as a "Floor over Unconditioned Space Volume" [(a)]. U-Factor: from Table 4.2.2(2) for floors over Unconditioned Space Volume or outdoor environment.	Same as the Rated Home, but not less net free Ventilation area than the Reference Home unless an Approved ground cover in accordance with IRC 408.3.1 is used, in which case, the same net free Ventilation area as the Rated Home down to a minimum net free vent area of 1ft^2 per 1,500 ft^2 of crawlspace floor area. Same as Rated Home
Doors	Area: 40 ft^2 for one- and two-family Dwellings and Townhouses; 20 ft^2 for all others Orientation: For exterior doors: North For all other doors, in adiabatic wall U-Factor: same as Fenestration from Table 4.2.2(2)	Same as Rated Home Same as Rated Home Same as Rated Home
Glazing [(b)]	Total area [(c)] =18% of CFA Orientation: equally distributed to four (4) cardinal compass orientations (N,E,S,&W) U-Factor: from Table 4.2.2(2) SHGC: from Table 4.2.2(2) Interior shade coefficient: Summer = 0.70 Winter = 0.85 External shading: none	Same as Rated Home Same as Rated Home Same as Rated Home Same as Rated Home Same as Energy Rating Reference Home [(d)] Same as Rated Home [(e)]
Skylights	None	Same as Rated Home
Thermally isolated sunrooms	None	Same as Rated Home
Air exchange rate	Specific Leakage Area (SLA) [(f)] = 0.00036 assuming no energy recovery, supplemented as necessary to achieve the	In accordance with Standard ANSI/RESNET/ICC 380, obtain airtightness test results for:

Table 4.2.2(1) Specifications for the Energy Rating Reference and Rated Homes

Building Component	Energy Rating Reference Home	Rated Home
	required Dwelling-Unit total air exchange rate (Qtot).(g), (h)	• Building enclosure (for Detached Dwelling Units) • Compartmentalization Boundary (for Attached Dwelling Units). For Attached Dwelling Units with airtightness test results ≤ 0.30 cfm50 per ft^2 of Compartmentalization Boundary, the test results shall be multiplied by reduction factor A_{ext} (j) to determine the Infiltration rate. For Attached Dwelling Units with airtightness test results > 0.30 cfm50 per ft^2 of Compartmentalization Boundary, the test results shall be modeled as the Infiltration rate. For residences without Dwelling-Unit Mechanical Ventilation Systems, or without measured airflow, or where A_{ext} (j) < 0.5 and the Mechanical Ventilation System is solely an Exhaust System, the Infiltration rate (j) shall be as determined above, but not less than 0.30 ACH. For residences with Dwelling-Unit Mechanical Ventilation Systems, the total air exchange rate shall be the Infiltration rate (j) as determined above, in combination (h) with the time-averaged Dwelling-Unit Mechanical Ventilation System rate,(g), (k) which shall be the value measured in accordance

Table 4.2.2(1) Specifications for the Energy Rating Reference and Rated Homes

Building Component	Energy Rating Reference Home	Rated Home
		with Standard ANSI/RESNET/ICC 380. The Dwelling-Unit Mechanical Ventilation System rate shall be increased as needed to ensure that the total air exchange rate is no less than Qtot = 0.03 x CFA + 7.5 x (Nbr+1) cfm
Dwelling-Unit Mechanical Ventilation System fan energy	None, except where a mechanical Ventilation system is specified by the Rated Home, in which case: Where Rated Home has supply-only or exhaust-only Dwelling-Unit Mechanical Ventilation System: 0.35*fanCFM*8.76 kWh/y Where Rated Home has balanced Dwelling-Unit Mechanical Ventilation System without energy recovery or a combination of Supply and Exhaust Systems: 0.70* fanCFM*8.76 kWh/y Where Rated Home has balanced Dwelling-Unit Mechanical Ventilation System with energy recovery: 1.00*fanCFM*8.76 kWh/y And where fanCFM is the minimum continuous Dwelling Unit Mechanical Ventilation System fan flow rate[(g)] for the Rated Home[(l)].	Same as Rated Home [(m), (n)]
Internal Gain	As specified by Table 4.2.2(3)	Same as Energy Rating Reference Home, except as provided by Section 4.2.2.5.2
Internal mass	An internal mass for furniture and contents of 8 pounds per square foot of floor area	Same as Energy Rating Reference Home, plus any additional mass specifically designed as a Thermal

Table 4.2.2(1) Specifications for the Energy Rating Reference and Rated Homes

Building Component	Energy Rating Reference Home	Rated Home
		Storage Element [o] but not integral to the building envelope or structure
Structural mass	For masonry floor slabs, 80% of floor area covered by R-2 carpet and pad, and 20% of floor directly exposed to room air	Same as Rated Home
	For masonry basement walls, same as Rated Home, but with insulation required by Table 4.2.2(2) located on the interior side of the walls	Same as Rated Home
	For other walls, for ceilings, floors, and interior walls, wood frame construction	Same as Rated Home
Heating systems [p], [q]	Fuel type: same as Rated Home	Same as Rated Home [q]
	Efficiencies:	
	Electric: Air Source Heat Pump in accordance with Table 4.2.2(1a)	Same as Rated Home
	Non-electric furnaces: natural gas furnace in accordance with Table 4.2.2(1a)	Same as Rated Home
	Non-electric boilers: natural gas boiler in accordance with Table 4.2.2(1a)	Same as Rated Home
	Capacity: sized in accordance with Section 4.4.3.1.	Same as Rated Home [r]
Cooling systems [p], [s]	Fuel type: Electric	Same as Rated Home [s]
	Efficiency: in accordance with Table 4.2.2(1a)	Same as Rated Home
	Capacity: sized in accordance with Section 4.4.3.1.	Same as Rated Home [r]
Service water heating systems [p], [t], [u],[v]	Fuel type: same as Rated Home	Same as Rated Home [t]
	Efficiency:	
	Electric: EF = 0.97 - (0.00132 * store gal)	Same as Rated Home
	Fossil fuel: EF = 0.67 - (0.0019 * store gal)	Same as Rated Home
	Use (gal/day): Determined in accordance with Section 4.2.2.5.1.4	Determined in accordance with Section 4.2.2.5.2.11
	Tank temperature: 125 °F	Same as Energy Rating Reference Home

Table 4.2.2(1) Specifications for the Energy Rating Reference and Rated Homes

Building Component	Energy Rating Reference Home	Rated Home
Thermal distribution systems	Thermal Distribution System Efficiency (DSE) of 0.80 shall be applied to both the heating and cooling system efficiencies.	Forced air distribution systems duct leakage to outside tests[(w)] shall be conducted and documented by an Approved Tester in accordance with requirements of Standard ANSI/RESNET/ICC 380 with the air handler installed, and the energy impacts calculated with the ducts located and insulated as in the Rated Home. For ductless distribution systems: DSE=1.00 For hydronic distribution systems: DSE=1.00
Thermostat	Type: manual Temperature setpoints: cooling temperature setpoint = 78 °F; heating temperature set point = 68°F	Type: Same as Rated Home Temperature setpoints: same as the Energy Rating Reference Home, except as required by Section 4.4.1

Table 4.2.2(1) Notes:

(a) This applies to the Reference Home crawlspace, regardless of the crawlspace type or insulation location in the Rated Home crawlspace.

(b) Glazing shall be defined as sunlight-transmitting Fenestration, including the area of sash, curbing or other framing elements, that enclose Conditioned Space Volume. Glazing includes the area of sunlight-transmitting Fenestration assemblies in walls bounding conditioned basements. For doors where the sunlight-transmitting opening is less than 50% of the door area, the Glazing area of the sunlight transmitting opening area shall be used. For all other doors, the Glazing area is the rough frame opening area for the door, including the door and the frame.

(c) The following formula shall be used to determine total window area:

$$AG = 0.18 \times CFA \times FA \times F$$

where:
AG = Total Glazing area
CFA = Total Conditioned Floor Area

FA = (gross above-grade thermal boundary wall area) / (gross above-grade thermal boundary wall area + 0.5*gross below-grade thermal boundary wall area)
F = 1- 0.44* (gross common wall area) / (gross above-grade thermal boundary wall area + gross common wall area)

and where:
Thermal boundary wall is any wall that separates Conditioned Space Volume from Unconditioned Space Volume, outdoor environment or the surrounding soil.
Above-grade thermal boundary wall is any portion of a thermal boundary wall not in contact with soil.
Below-grade thermal boundary wall is any portion of a thermal boundary wall in soil contact.
Common wall is the total wall area of walls adjacent to Unrated Conditioned Space, not including foundation walls.
AG + exterior door area shall not exceed the exterior wall area, and the Energy Rating Reference Home door area shall be reduced as necessary to ensure this.

(d) For Fenestrations facing within 15 degrees of true south that are directly coupled to thermal storage mass, the winter interior shade coefficient shall be permitted to increase to 0.95 in the Rated Home.

(e) The term External Shading refers only to permanent, fixed shading devices attached to the building such as fins and overhangs. Window screens, movable awnings, roller shades, safety bars, balcony railings, and shade from adjacent buildings, trees and shrubs shall not be included in the analysis of the Rated Home energy usage.

(f) SLA = ELA / CFA where ELA = 0.054863*cfm50 and where CFA is in square inches.

(g) The required Dwelling-Unit Mechanical Ventilation System airflow rate (Qfan) shall be determined in accordance with the following equation.[22] Where this requires the Rated Home mechanical Ventilation rate to be adjusted in the simulation, and where the Ventilation air is pre-conditioned as part of a shared Ventilation system shared by multiple Dwelling Units, the software shall make corresponding adjustments to the shared preconditioning equipment energy consumption assigned to the Rated Home.

$$Q_{fan} = Q_{tot} - \Phi (Q_{inf} \times A_{ext})$$

where
Q_{fan} = required mechanical Ventilation rate, cfm
Q_{tot} = total required Ventilation rate, cfm
Q_{inf} = Infiltration, cfm calculated using Shelter Class 4
A_{ext} = 1 for Detached Dwelling Units, or the ratio of exterior enclosure surface area that is not attached to garages or other Dwelling Units to Compartmentalization Boundary for Attached Dwelling Units

[22] (Informative Note) Equation taken from Addendum s to ASHRAE Standard 62.2-2016.

Φ=1 for Balanced Ventilation Systems and Q_{inf} / Q_{tot} otherwise

and where
Qtot = 0.03*CFA + 7.5*(Nbr+1), AND
Qinf = 0.0521*cfm50*wsf*(H/Hr)^0.4
OR
Qinf = (NL · wsf · CFA) / 7.3

where
NL = normalized leakage = 1000 · (ELA / CFA) · [H / Hr]^0.4 (where both *ELA* and *CFA* are in square inches)
wsf = weather and shielding factor from Appendix B, ASHRAE Standard 62.2
ELA = cfm50*0.054863 (in^2)
H = vertical distance between lowest and highest above-grade points within the pressure boundary (ft.)
Hr = reference height = 8.202 ft.

(h) Either hourly calculations using the following equation[23] or calculations yielding equivalent results shall be used to determine the combined air exchange rate resulting from Infiltration in combination with Dwelling-Unit Mechanical Ventilation Systems.

$$Q_i = Q_{fan,i} + \Phi\, Q_{inf,i}$$

where
Φ=1 for Balanced Ventilation Systems and otherwise
$\Phi = Q_{inf,i} / (Q_{inf,i} + Q_{fan,i})$
Q_i = combined air exchange rate for the time step 'i', cfm
$Q_{inf,i}$ = Infiltration airflow rate for the time step 'i', cfm calculated using Shelter Class 4
$Q_{fan,i}$ = mechanical Ventilation airflow rate for the time step 'i', cfm

(i) Reduction factor A_{ext} (used only for Attached Dwelling Units) shall be the ratio of exterior envelope surface area[24] to Compartmentalization Boundary.

(j) Envelope (for Detached Dwelling Units) or Compartmentalization Boundary (for Attached Dwelling Units) leakage shall be tested and documented in accordance with requirements of Standard ANSI/RESNET/ICC 380 by an Approved Tester.

(k) Where a shared mechanical Ventilation system serving more than one Dwelling Unit provides any Dwelling-Unit Mechanical Ventilation, the following shall be used to determine the Ventilation airflows in the Rated Home.
1. Where shared Ventilation supply systems provide a mix of recirculated and outdoor air, the supply Ventilation airflow shall be adjusted to reflect the percentage of air that is from outside.

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[23] (Informative Note) Equation taken from ASHRAE Standard 62.2-2016, Normative Appendix C, equations (C7) and (C8).
[24] (Informative Note) Does not include the area where attached to garages or other Dwelling Units.

2. Where the Dwelling-Unit Mechanical Ventilation System is a Supply System or an Exhaust System, and not a Balanced System nor a combination of systems, the Ventilation rate shall be the value measured in the Rated Home or adjusted in accordance with the previous step.
3. Where the Dwelling-Unit Mechanical Ventilation System is a Balanced System or a combination of systems, the system airflows shall be analyzed separately, in accordance with the previous steps. For software that does not explicitly model multiple, separate Supply and Exhaust Systems, the Dwelling-Unit Mechanical Ventilation System shall be modeled as a Balanced System, where the Ventilation rate of the Rated Home is the sum of either the exhaust airflows measured in the Dwelling Unit or the sum of the supply airflows measured in the unit, whichever is greater.

(l) Where Rating software allows for modeling of multiple or hybrid Ventilation system types, the Reference Home mechanical Ventilation fan energy shall be calculated proportionally using the Ventilation system types employed in the Rated Home. The fan CFM contribution of each system type shall be proportional to the product of the airflow and the runtime of each Ventilation system type.

(m) Dwelling-Unit Mechanical Ventilation System fan watts shall be the value observed in the Rated Home for the highest airflow setting. Where not available, fan watts shall be based on Table 4.2.2(1b) for the given system. For systems other than Central Fan Integrated Supply (CFIS), where the airflow cannot be measured, the cfm used to determine fan watts shall be assumed to be equal to Qfan, as determined in accordance with endnote (g) of Table 4.2.2 (1). For CFIS systems, the cfm used to determine fan watts shall be the larger of 400 cfm per 12 kBtu/h cooling capacity or 240 cfm per 12 kBtu/h heating capacity.

Table 4.2.2(1b). Default Ventilation System Fan Power for Rated Home

Equipment Type	**Watts/ cfm**
Exhaust Ventilation fans	0.35
Supply Ventilation fans	0.35
Balanced Ventilation fans	0.70
HRV/ERV fans	1.00
CFIS fans	0.50
Range hoods	0.70

(n) Where the Ventilation system is designed to serve the Ventilation needs of more than one Dwelling Unit, the Rated Home kWh/y fan energy shall be calculated as a proportion of the entire system fan energy, using the system airflow, Ventilation type, fan run time and the rated fan power[25] of the shared system. The Rated Home Ventilation fan energy shall be calculated as the fan power of the entire system[26] multiplied by the ratio of

[25] (Normative Note) Fan motors rated in horsepower shall be converted to Watts by multiplying by 746 and dividing by fan motor efficiency. Where fan motor efficiency is unknown, use 0.65 for single-phase and 0.75 for 3-phase motors.
[26] (Normative Note) For Balanced Systems or combinations of Supply and Exhaust Systems, the system fan power must include all associated fans.

Dwelling Unit airflow to the system airflow. Where the system fan power cannot be determined, 1 Watt/cfm shall be used. Where the Dwelling Unit airflow cannot be measured, the Rated Home shall use Qfan, as determined in accordance with endnote (g) of Table 4.2.2 (1) when calculating fan energy.

(o) Thermal storage element shall mean a component not normally part of the floors, walls, or ceilings that is part of a passive solar system, and that provides thermal storage.[27] A thermal storage element must be in the same room as Fenestration that faces within 15 degrees of true south, or must be connected to such a room with pipes or ducts that allow the element to be actively charged.

(p) For a Rated Home with multiple heating, cooling, or water heating systems using different fuel types, the applicable system capacities and fuel types shall be weighted in accordance with the loads distribution (as calculated by accepted engineering practice for that equipment and fuel type) of the subject multiple systems. For the Energy Rating Reference Home, the minimum efficiencies given in Table 4.2.2(1a) below will be assumed for:

1) A type of device not covered by NAECA in the Rated Home;

2) A Rated Home heated by electricity using a device other than an air-source Heat Pump; or

3) A Rated Home that does not contain one or more of the required HVAC equipment systems.

Table 4.2.2(1a). Energy Rating Reference Home Heating and Cooling Equipment Efficiencies

Rated Home Fuel	Function	Reference Home Device
Electric	Heating	7.7 HSPF Air Source Heat Pump
Non-electric warm air furnace or space heater	Heating	78% AFUE gas furnace
Non-electric boiler	Heating	80% AFUE gas boiler
Any type	Cooling	13 SEER electric air conditioner
Biomass System [(a)]	Heating	63% Efficiency

Notes:
(a) Biomass Fuel systems shall be included in Ratings only when a permanent heating system sized to meet the load of the Dwelling Unit does not exist. Where installed to supplement a permanent heating system that cannot meet the load of the Dwelling Unit, the biomass system shall be assigned only that part of the load that cannot be met by the permanent heating system.

(q) For a Rated Home without a heating system, a gas heating system with the efficiency provided in Table 4.2.2(1a) shall be assumed for both the Energy Rating Reference Home and Rated Home. For a Rated Home that has no access to natural gas or fossil fuel

[27] (Informative Note) Such as enclosed water columns, rock beds, or phase change containers.

delivery, an Air Source Heat Pump with the efficiency provided in Table 4.2.2(1a) shall be assumed for both the Energy Rating Reference Home and Rated Home.

(r) When the Rated Home is in a building with multiple Dwelling Units, and where Dwelling-Unit Mechanical Ventilation System supply air is pre-conditioned by a shared system[28] before delivery[29] to the Dwelling Unit, that shared pre-conditioning system shall be represented in the Rated Home simulation as a separate HVAC system, in addition to the primary space conditioning system serving the Dwelling Unit. The supply airflow delivered to the Rated Home is the only conditioning load that shall be assigned to that shared equipment, and shall be determined as described in Table 4.2.2(1), endnote (k). Accordingly, the capacity of the simulated pre-conditioning equipment shall be the actual capacity pro-rated by the ratio of Rated Home supply airflow divided by total airflow through the actual shared pre-conditioning equipment.

(s) For a Rated Home without a cooling system, an electric air conditioner with the efficiency provided in Table 4.2.2(1a) shall be assumed for both the Energy Rating Reference Home and the Rated Home.

(t) For a Rated Home with a non-storage-type water heater or where a shared water heater provides service hot water to the Rated Home, a 40-gallon storage-type water heater of the same fuel as the proposed water heater shall be assumed for the Energy Rating Reference Home. For tankless water heaters with an Energy Factor, EF shall be multiplied by 0.92 for Rated Home calculations. For tankless water heaters with a Uniform Energy Factor, UEF shall be multiplied by 0.94 for Rated Home calculations. For a Rated Home without a proposed water heater, a 40-gallon storage-type water heater of the same fuel as the predominant fuel type used for the heating system(s) shall be assumed for both the Rated and Energy Rating Reference Homes. In both cases the Energy Factor of the water heater shall be as prescribed for the Energy Rating Reference Home water heater by Table 4.2.2(1).

(u) The Uniform Energy Factor (UEF) or Energy Factor (EF) shall be obtained for residential hot water equipment, or the Thermal Efficiency (TE) and Standby loss (SL) shall be obtained for commercial hot water equipment, from manufacturer's literature or from AHRI directory for equipment being used, where available. For commercial water heaters, where EF or UEF is not available, an Approved commercial hot water system calculator shall be used to determine the EF or UEF.

Where a manufacturer provided or AHRI published EF or UEF is not available for the residential hot water equipment, the guidance provided in i shall be used to determine the effective EF of the water heater. Where a manufacturer provided or AHRI published TE or SL is not available for commercial hot water equipment, the guidance provided in ii shall be used to determine the effective TE and SL of the water heater.

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[28] (Informative Note) For example, a rooftop make-up air unit (MAU), dedicated outdoor air system (DOAS), or shared Energy Recovery Ventilator (ERV), with heating and/or cooling capability.

[29] (Normative Note) "Delivery" includes supply air ducted into the Dwelling Unit, or ducted into the Dwelling Unit's air distribution system, or indirectly through the door undercut or other intentional opening. Where the supply airflow cannot be measured, it shall be equal to the measured exhaust airflow or fanCFM, whichever is greater.

i. For residential oil, gas and electric water heaters or Heat Pumps, default EF values provided in Table 4.5.2(3) for age-based efficiency or Table 4.5.2(4) for non-age-based efficiency shall be used.
ii. For commercial water heaters, values provided in Table C404.2 Minimum Performance of Water-Heating Equipment in the IECC shall be used.

(v) The heat sources and sinks associated with the Service Hot Water System shall be included in the energy balance for the space in which the Service Hot Water System is located.

(w) When both of the following conditions are met and documented, duct leakage testing is not required.

1. At a pre-drywall stage of construction, 100% of the ductwork and air handler shall be visible and visually verified to be contained inside the Conditioned Space Volume. At a final stage of construction, ductwork that is visible and the air handler shall again be verified to be contained in the Conditioned Space Volume.
2. At a pre-drywall stage of construction, the ductwork shall be visually verified to be 100% fully ducted, with no building cavities used as supply or return ducts.

To calculate the energy impacts on the Rated Home, a DSE of 0.88 shall be applied to both the heating and cooling system efficiencies.

Alternatively, for Dwellings and Townhouses only, when all of the following conditions are met and documented, total duct leakage testing is permitted to be conducted in lieu of duct leakage to outside testing and half of the measured total leakage shall be assigned duct leakage to outside. At a final stage of construction, if visible ductwork or the air handler is observed outside the Infiltration Volume or ductwork is no longer 100% fully ducted, duct leakage to outside testing is required:

1. At a pre-drywall stage of construction, 100% of the ductwork and air handler shall be visible and visually verified to be contained inside the Infiltration Volume. At a final stage of construction, ductwork that is visible and the air handler shall again be verified to be contained in the Infiltration Volume.

2. At a pre-drywall stage of construction, the ductwork shall be visually verified to be 100% fully ducted, with no building cavities used as supply or return ducts.

3. At either a pre-drywall stage of construction or a final stage of construction, airtightness of the duct system shall be tested in accordance with requirements of Standard ANSI/RESNET/ICC 380 Total Duct Leakage Test (Section 4.4.1).

The total leakage shall be less than or equal to the greater of: 4 cfm per 100 ft^2 of Conditioned Floor Area served by the duct system being tested, or 40 cfm. For duct systems with 3 or more returns, the total leakage shall be less than or equal to the greater of: 6 cfm per 100 ft^2 of Conditioned Floor Area served by the duct system being tested, or 60 cfm.

4. Airtightness of the Rated Home shall be tested in accordance with requirements of Standard ANSI/RESNET/ICC 380 and shall be less than or equal to 3 ACH50.

Alternatively, for Attached Dwelling Units, excluding Dwellings and Townhouses, total duct leakage testing, at either pre-drywall or final stage of construction, is permitted to be conducted in lieu of duct leakage to outside testing. Software shall calculate the energy impact using the total duct leakage results and prorating based on the percent of duct surface area that is not in Rated Home Conditioned Space Volume, plus a contribution from the associated air handler if located outside the Rated Home Conditioned Space Volume. The air handler contribution shall be a minimum of 2.5% of the supply airflow, where supply airflow is calculated as 400 cfm per 12,000 Btu/h of output capacity of the heating or cooling equipment. The sum of the duct leakage associated with duct surface area outside the Conditioned Space Volume and the air handler leakage shall not exceed the measured duct leakage from the entire duct system.

Table 4.2.2(2). Component Heat Transfer Characteristics for Energy Rating Reference Home [(a)]

Climate Zone [(b)]	Fenestration and Opaque Door U-Factor	Glazed Fene-stration Assembly SHGC	Ceiling U-Factor	Frame Wall U-Factor	Floor Over Uncond-itioned Space U-Factor	Basement Wall U-Factor [(c)]	Slab-on-Grade R-Value & Depth [(d,e)]
1	1.20	0.40	0.035	0.082	0.064	0.360	0
2	0.75	0.40	0.035	0.082	0.064	0.360	0
3	0.65	0.40	0.035	0.082	0.047	0.360	0
4 except Marine	0.40	0.40	0.030	0.082	0.047	0.059	10, 2 ft.
5 and Marine 4	0.35	0.40	0.030	0.060	0.033	0.059	10, 2 ft.
6	0.35	0.40	0.026	0.060	0.033	0.059	10, 4 ft.
7 and 8	0.35	0.40	0.026	0.057	0.033	0.059	10, 4 ft.

Table 4.2.2(2). Component Heat Transfer Characteristics for Energy Rating Reference Home [(a)]

Climate Zone [(b)]	Fenestration and Opaque Door U-Factor	Glazed Fene-stration Assembly SHGC	Ceiling U-Factor	Frame Wall U-Factor	Floor Over Uncond-itioned Space U-Factor	Basement Wall U-Factor [(c)]	Slab-on-Grade R-Value & Depth [(d,e)]

Notes:
(a) Non-fenestration U-Factors shall be obtained from measurement, calculation, or an Approved source.
(b) Climates zones shall be as specified by the 2006 IECC.
(c) For basements that are within the Conditioned Space Volume.
(d) R-5 shall be added to the required R-Value for slabs with embedded heating.
(e) Insulation shall extend downward from the top of the slab vertically to the depth indicated.

Table 4.2.2(3). Internal Gains for Energy Rating Reference Homes [(a)]

End Use Component	Sensible Gains (Btu/day)			Latent Gains (Btu/day)		
	a	b	c	a	b	c
Residual MELs		7.27			0.38	
Interior lighting	4,253	7.48				
Refrigerator [(d)]	5,955		168			
TVs	3,861		645			
Range/Oven (elec) [(b) (d)]	2,228		262	248		29
Range/Oven (gas) [(b) (d)]	4,086		488	1,037		124
Clothes Dryer (elec) [(b) (d)]	661		188	73		21
Clothes Dryer (gas) [(b) (d)]	738		209	91		26
Dishwasher [(d)]	219		87	219		87
Clothes Washer [(d)]	95		26	11		3
Gen water use	-1227		-409	1,245		415
Occupants [(c)]			3716			2,884

Notes:
(a) Table values are coefficients for the following general equation:
Gains = a + b*CFA + c*Nbr
where CFA = Conditioned Floor Area and Nbr = Number of Bedrooms.
(b) For Rated Homes with electric appliance use (elec) values and for Rated homes with natural gas-fired appliance use (gas) values
(c) Software tools shall use either the occupant gains provided above or similar temperature dependent values generated by the software where the number of occupants equals the number of Bedrooms and occupants are present in the home 16.5 hours per day.
(d) When any of these appliances associated with a Rated Home is located in Unrated Heated Space, Unrated Conditioned Space, or otherwise outside of and away from the Dwelling Unit, the Internal Gains associated with that appliance shall be excluded from both the Reference and Rated Homes.

Table 4.2.2(4). Default Solar Absorptance for Various Roofing Surfaces

Roof Materials	Absorptance
White Composition Shingles	0.80
White Tile (including concrete)	0.60
White Metal or White TPO	0.50
All others	0.92

4.2.2.1. All enclosure element Framing Fractions shall be in accordance with Table 4.2.2(5).

Table 4.2.2(5) Default Framing Fractions for Enclosure Elements

Enclosure Element	Frame Spacing (in o.c.)	Default Frame Fraction (% area)
Walls (standard):		
@16" o.c.	16	23%
@24" o.c.	24	20%
Walls (advanced):		
@16" o.c.	16	19%
@24" o.c.	24	16%
Structural Insulated Panels	48	10%
Floors (standard):		
@16" o.c.	16	13%
@24" o.c.	24	10%
Floors (advanced):		
@16" o.c.	16	11%
@24" o.c.	24	8%
Ceilings (standard trusses):		
@16" o.c.	16	14%
@24" o.c.	24	11%
Ceilings (advanced trusses – "raised heel"):		
@16" o.c.	16	10%
@24" o.c.	24	7%
Ceilings (conventional framing):		
@16" o.c.	16	13%
@24" o.c.	24	9%

4.2.2.2. Insulation Inspections: All enclosure elements for the Rated Home shall have their insulation assessed in accordance with this Standard. Insulation shall be rated as Grade I, II, III, or uninsulated in accordance with the on-site inspection procedures equivalent to Normative Appendix A.

4.2.2.2.1. The insulation of the Energy Rating Reference Home enclosure elements shall be modeled as Grade I. The insulation of the Rated Home shall either be inspected according to procedures equivalent to Normative Appendix A or, if confirmed to be present but not fully inspected, shall be modeled as Grade III and shall be recorded as "not inspected" in the rating.

Exceptions:

(a) Modular and manufactured housing using IPIA inspections shall be considered as an acceptable alternative for the Energy Rating inspection where the manufacturer of the home includes the on-site inspection procedures for insulation details and requirements in Appendix A in their DAPIA packages, which are used by IPIAs for their factory inspections.

(b) The R-Values for non-structural materials or for Structural Insulated Panels (SIPs), Insulated Concrete Forms (ICFs), and other pre-manufactured assemblies when accompanied by supporting test data consistent with ASTM C177, ASTM C518, ASTM C1114, ASTM C1363 or ASTM C976.

Thermographic inspection is permitted to be used to determine that an assembly is insulated and achieves a Grade II rating if the person doing the inspection is an ASNT NDT Level III or a licensed engineer, or if the person doing the inspection is working under the direction of an ASNT NDT Level III or a licensed engineer. Thermographic inspection shall not be used to determine an assembly achieves a Grade I rating.

4.2.2.2.2. Insulation Assessment: Insulated surfaces categorized as "Grade I" shall be modeled such that the insulation R-Value is considered at its measured (for loose fill) or labeled value, including other adjustments,[30] for the insulated surface area (not including framing or other structural materials which shall be accounted for separately). Insulated surfaces categorized as "Grade II" shall be modeled such that there is no insulation R-Value for 2% of the insulated surface area and its measured or labeled value, including other adjustments,[31] for the remainder of the insulated surface area (not including framing or other structural materials). Insulated surfaces categorized as "Grade III" shall be modeled such that there is no insulation R-Value for 5% of the insulated surface area and its measured or labeled value, including other adjustments,[32] for the remainder of the insulated surface area (not including framing or other structural materials). Other building materials, including framing, sheathing, and air films, shall be assigned aged or settled values according to ASHRAE Handbook of Fundamentals. In addition, the following accepted conventions shall be used in modeling Rated Home insulation enclosures:

(a) Insulation that does not cover framing members shall not be modeled as if it covers the framing. Insulated surfaces that have continuous insulation, including rigid foam, fibrous batt, loose fill, sprayed insulation or insulated siding, covering

30 (Informative Note) Such as compression and cavity fill versus continuous.
31 (Informative Note) Such as compression and cavity fill versus continuous.
32 (Informative Note) Such as compression and cavity fill versus continuous.

the framing members shall be assessed and modeled according to Section **Error! Reference source not found.** and combined with the cavity insulation, framing and other materials to determine the overall assembly R-Value.

(b) The base R-Value of fibrous insulation that is compressed to less than its full rated thickness in a completely enclosed cavity shall be assessed according to the manufacturer's documentation. In the absence of such documentation, use R-Value correction factor (CF) for Compressed Batt or Blanket from Manual J, 8th edition Table A5-1, Section 7-d.

(c) Areas of an assembly having different insulation types or R-Values (including uninsulated areas in excess of 5% of any otherwise insulated building component) shall be modeled separately, with the applicable R-Values and assembly areas associated with each different insulation situation.

(d) The overall thermal properties of steel-framed walls, ceilings and floors shall be calculated in accordance with the modified zone method specified by Chapter 27, ASHRAE Handbook of Fundamentals or tested in accordance with ASTM Standard C1363. Modification of test results to add or subtract R-Values to the tested assembly that reflect differences between the tested assembly and proposed assemblies is authorized when such differences are continuous and occur outside of the cavity.

4.2.2.3. Renewable Energy Systems shall not be included in the Reference Home.

4.2.2.4. For non-electric warm furnaces and non-electric boilers, the values in Table 4.2.2.4(1) shall be used for Electric Auxiliary Energy (EAE) in the Reference Home.

Table 4.2.2.4(1) Electric Auxiliary Energy for Fossil Fuel Heating Systems

System Type	Eae
Oil boiler	330
Gas boiler	170
Oil furnace	439 + 5.5*Capacity (kBtu/h)
Gas furnace	149 + 10.3*Capacity (kBtu/h)

4.2.2.5. Lighting, Appliances, Miscellaneous Energy Loads (MELs), Ventilation and Service Hot Water Systems.

4.2.2.5.1. Energy Rating Reference Home. Lighting, Appliance and Miscellaneous Energy Loads in the Energy Rating Reference Home shall be determined in accordance with the values provided in Table 4.2.2.5(1) and Table 4.2.2.5(2), as appropriate, and Equation 4.2-1:

$$\text{kWh (or therms) per year} = a + b*CFA + c*Nbr \qquad \text{(Eq. 4.2-1)}$$

where:
'a', 'b', and 'c' are values provided in Table 4.2.2.5(1) and Table 4.2.2.5(2)

CFA = Conditioned Floor Area
Nbr = number of Bedrooms

4.2.2.5.1.1. Electric Reference Homes. Where the Rated Home has electric appliances, the Energy Rating Reference Home lighting, appliance and Miscellaneous Energy Loads shall be determined in accordance with the values given in Table 4.2.2.5(1).

Table 4.2.2.5(1) Lighting, Appliance and Miscellaneous Energy Loads in electric Energy Rating Reference Homes

End Use Component	Units	Equation Coefficients		
		a	b	c
Residual MELs	kWh/y		0.91	
Interior lighting	kWh/y	455	0.80	
Exterior lighting	kWh/y	100	0.05	
Refrigerator	kWh/y	637		18
Televisions	kWh/y	413		69
Range/Oven	kWh/y	331		39
Clothes Dryer	kWh/y	529		150
Dishwasher	kWh/y	78		31
Clothes Washer	kWh/y	38		10

4.2.2.5.1.2. Reference Homes with Natural Gas Appliances. Where the Rated Home has gas appliances, those appliances in the Energy Rating Reference Home shall be determined in accordance with the natural gas and electric appliance loads provided below in Table 4.2.2.5(2), as applicable for each appliance.

Table 4.2.2.5(2) Natural Gas Appliance Loads for Energy Rating Reference Homes with Gas Appliances

End Use Component[a]	Units	Equation Coefficients		
		a	b	c
Range/Oven	Therms/y	22.6		2.7
Range/Oven	kWh/y	22.6		2.7
Clothes Dryer	Therms/y	18.8		5.3
Clothes Dryer	kWh/y	41		11.7

Notes:
(a) Both the natural gas and the electric components shall be included in determining the Energy Rating Reference Home annual energy use for the above appliances.

4.2.2.5.1.3. Garage Lighting. Where the Rated Home includes an enclosed garage, for the sole use of the occupants of the Rated Home, 100 kWh/y shall be added to the energy use of the Reference Home to account for garage lighting.

Lighting for shared parking garages or parking lots shall not be included in the Reference Home.

4.2.2.5.1.4. Service Hot Water Use. Service hot water system use in gallons per day for the Energy Rating Reference Home shall be determined in accordance with Equation 4.2-2:

$$\mathbf{HWgpd = (refDWgpd+refCWgpd + F_{mix}*(refFgpd + refWgpd))} \quad \textbf{(Eq. 4.2-2)}$$

where:

HWgpd = gallons per day of hot water use

refDWgpd = reference dishwasher gallons per day = ((88.4+34.9*Nbr)*8.16)/365

refCWgpd = reference clothes washer gallons per day = (4.52*(164+46.5*Nbr)) *((3*2.08+1.59)/(2.874*2.08+1.59))/365

$F_{mix} = 1 - ((T_{set} - T_{use}) / (T_{set} - T_{mains}))$

where

T_{set} = Water heater set point temperature = 125 F

T_{use} = Temperature of mixed water at fixtures = 105 F

$T_{mains} = (T_{amb,avg} + offset) + ratio * (\Delta T_{amb,max} / 2) * \sin(0.986 * (day\# - 15 - lag) - 90)$

where

T_{mains} = temperature of potable water supply entering residence (°F)

$T_{amb,avg}$ = annual average ambient air temperature (°F)

$\Delta T_{amb,max}$ = maximum difference between monthly average ambient temperatures[33] (°F)

0.986 = degrees/day (360/365)

day# = Julian day of the year (1-365)

offset = 6°F

ratio = $0.4 + 0.01 (T_{amb,avg} - 44)$

lag = $35 - 1.0 (T_{amb,avg} - 44)$

refFgpd = 14.6 + 10.0*Nbr = reference climate-normalized daily fixture water use in Energy Rating Reference Home (in gallons per day)

refWgpd = $9.8*Nbr^{0.43}$ = reference climate-normalized daily hot water waste due to distribution system losses in Energy Rating Reference Home (in gallons per day)

where

Nbr = number of Bedrooms in the Rated Home, not to be less than 1.

[33] (Informative Reference) For example $T_{amb,avg,july} - T_{amb,avg,january}$

4.2.2.5.1.5. Ceiling Fans. Where ceiling fans are included in the Rated Home they shall also be included in the Reference Home in accordance with the provisions of Section 0.

4.2.2.5.2. Energy Rating Rated Homes. The lighting, appliance, hot water heating, and Miscellaneous Energy Loads in the Energy Rating Rated Home shall be determined in accordance with Sections 4.2.2.5.2.1 through 0. For a Rated Home without a refrigerator, dishwasher, range/oven, clothes washer or clothes dryer, the values from Table 4.2.2.5(1) shall be assumed for both the Energy Rating Reference Home and Rated Home.

4.2.2.5.2.1. Residual MELs. Residual miscellaneous annual electric energy use in the Rated Home shall be the same as in the Energy Rating Reference Home and shall be calculated as 0.91*CFA.

4.2.2.5.2.2. Interior Lighting. Interior lighting annual energy use in the Rated Home shall be determined in accordance with Equation 4.2-3:

$$\mathbf{kWh/y = 0.9/0.925*(455 + 0.8*CFA) *[(1 - FFII_{IL} - FFI_{IL}) + FFI_{IL}*15/60 + FFII_{IL}*15/90] + 0.1*(455 + 0.8*CFA)} \quad \textbf{(Eq. 4.2-3)}$$

where:

CFA = Conditioned Floor Area

FFI_{IL} = The ratio of the interior Tier I Qualifying Light Fixtures to all interior light fixtures in Qualifying Light Fixture Locations.

$FFII_{IL}$ = The ratio of the interior Tier II Qualifying Light Fixtures to all interior light fixtures in Qualifying Light Fixture Locations.

For the purpose of adjusting the annual interior lighting energy consumption for calculating the Rating, EUL_{LA} shall be adjusted by ΔEUL_{IL}, which shall be calculated as the annual interior lighting energy use derived by the procedures in this section minus the annual interior lighting energy use derived for the Energy Rating Reference Home in Section 4.2.2.5.1, converted to MBtu/y, where MBtu/y = (kWh/y)/293.

For interior lighting, Internal Gains in the Rated Home shall be modified by 100% of the interior lighting ΔEUL_{IL} converted to Btu/day as follows: $\Delta EUL_{IL} * 10^6 / 365$.

4.2.2.5.2.3. Exterior Lighting. Exterior lighting annual energy use in the Rated Home shall be determined in accordance with Equation 4.2-4:

$$\mathbf{kWh/y = (100 + 0.05*CFA)*[(1 - FFI_{EL} - FFII_{EL}) + 15/60*FFI_{EL} + 15/90*FFII_{EL}]} \quad \textbf{(Eq. 4.2-4)}$$

where

CFA = Conditioned Floor Area

FFI_{EL} = Fraction of exterior fixtures that are Tier I Qualifying Light Fixtures
$FFII_{EL}$ = Fraction of exterior fixtures that are Tier II Qualifying Light Fixtures

For the purpose of adjusting the annual exterior lighting energy consumption for calculating the Rating, EUL_{LA} shall be adjusted by ΔEUL_{EL}, which shall be calculated as the annual exterior lighting energy use derived by the procedures in this section minus the annual exterior lighting energy use derived for the Energy Rating Reference Home in Section 4.2.2.5.1, converted to MBtu/y, where MBtu/y = (kWh/y)/293.

Internal Gains in the Rated Home shall not be modified as a result of reductions in exterior lighting energy use.

4.2.2.5.2.4. Garage Lighting. For Rated Homes with garages, for the sole use of the occupants of the Rated Home, garage annual lighting energy use in the Rated Home shall be determined in accordance with Equation 4.2-5:

$$\mathbf{kWh = 100*[(1 - FFI_{GL} - FFII_{GL}) + 15/60*FFI_{GL} + 15/90*FFII_{GL}]} \quad \textbf{(Eq. 4.2-5)}$$

where:
FFI_{GL} = Fraction of garage fixtures that are Tier I Qualifying Light Fixtures
$FFII_{GL}$ = Fraction of garage fixtures that are Tier II Qualifying Light Fixtures

Lighting for shared parking garages or parking lots shall not be included in the Rated Home.

For the purpose of adjusting the annual garage lighting energy consumption for calculating the Rating, EUL_{LA} shall be adjusted by ΔEUL_{GL}, which shall be calculated as the annual garage lighting energy use derived by the procedures in this section minus the annual garage lighting energy use derived for the Energy Rating Reference Home in Section 4.2.2.5.1, converted to MBtu/y, where MBtu/y = (kWh/y)/293.

Internal Gains in the Rated Home shall not be modified as a result of reductions in garage lighting energy use.

4.2.2.5.2.5. Refrigerators. Refrigerator annual energy use for the Rated Home shall be determined from either refrigerator Energy Guide labels or from age-based defaults in accordance with Table 4.2.2.5.2.5(1).

Table 4.2.2.5.2.5(1) Age-based Refrigerator Defaults

Refrigerator/Freezer Type	Annual kWh Equation
Single-door refrigerator only	(13.5*AV + 299)*VR
Single-door refrigerator/freezer	(13.5*AV + 299)*VR
Refrigerator with top freezer	(16.0*AV + 355)*VR
with TDI	(17.6*AV + 391)*VR
Refrigerator with side-by-side freezer	(11.8*AV + 501)*VR

Refrigerator/Freezer Type	Annual kWh Equation
with TDI	(16.3*AV + 527)*VR
Refrigerator with bottom freezer	(16.6*AV + 367)*VR
Upright freezer only manual defrost	(10.3*AV + 264)*VR
Upright freezer only auto defrost	(14.0*AV + 391)*VR
Chest freezer only	(11.0*AV + 160)*VR
where: AV = Adjusted Volume = (refrigerator compartment volume) + 1.63*(freezer compartment volume) TDI = Through the door ice VR = Vintage Ratio from Table 4.2.2.5.2.5(2)	

Table 4.2.2.5.2.5(2) Age-based Vintage Ratios

Refrigerator Vintage	Vintage Ratio
1980 or before	2.50
1981-1984	1.82
1985-1988	1.64
1989-1990	1.39
1991-1993	1.30
1994-2000	1.00
2001-Present	0.77

Default values for adjusted volume (AV) shall be determined in accordance with Table 4.2.2.5.2.5(3)

Table 4.2.2.5.2.5(3) Default Adjusted Volume Equations

Model Type	Default Equation
Single-door refrigerator only	AV = 1.00 * nominal volume
Single-door refrigerator/freezer	AV = 1.01 * nominal volume
Bottom Freezer	AV = 1.19 * nominal volume
Top Freezer	AV = 1.16 * nominal volume
Side by Side	AV = 1.24 * nominal volume
Freezer only	AV = 1.73 * nominal volume

For the purpose of adjusting the annual refrigerator energy consumption for calculating the Rating, EUL_{LA} shall be adjusted by ΔEUL_{FRIG}, which shall be calculated as the annual refrigerator energy use derived by the procedures in this section minus the annual refrigerator energy use derived for the Energy Rating Reference Home in Section 4.2.2.5.1, converted to MBtu/y, where MBtu/y = (kWh/y)/293.

For refrigerator energy use, Internal Gains in the Rated Home shall be modified by 100% of the refrigerator ΔEUL_{FRIG} converted to Btu/day as follows: $\Delta EUL_{FRIG} * 10^6 / 365$. Internal Gains shall not be modified for refrigerators located in

Unconditioned Space Volume, Unrated Heated Space, Unrated Conditioned Space, or outdoor environment.[34]

4.2.2.5.2.6. Televisions. Television annual energy use in the Rated Home shall be the same as television energy use in the Energy Rating Reference Home and shall be calculated as TVkWh/y = 413 + 69*Nbr, where Nbr is the number of Bedrooms in the Rated Home.

4.2.2.5.2.7. Range/Oven. Range/Oven (cooking) annual energy use for the Rated Home shall be determined in accordance with Equations 4.2-6a through 4.2-6c, as appropriate.

1) For electric cooking:
   kWh/y = BEF * OEF * (331 + 39*Nbr) **(Eq. 4.2-6a)**

2) For natural gas cooking:
   Therms/y = OEF*(22.6 + 2.7*Nbr) **(Eq. 4.2-6b)**
   plus:
   kWh/y = 22.6 + 2.7*Nbr **(Eq. 4.2-6c)**

where:
BEF = Burner Energy Factor = 0.91 for induction ranges and 1.0 otherwise
OEF = Oven Energy Factor = 0.95 for convection types and 1.0 otherwise
Nbr = Number of Bedrooms

For the purpose of adjusting the annual range/oven energy consumption for calculating the Rating, EUL_{LA} shall be adjusted by ΔEUL_{RO}, which shall be calculated as the annual range/oven energy use derived by the procedures in this section minus the annual range/oven energy use derived for the Energy Rating Reference Home in Section 4.2.2.5.1, converted to MBtu/y, where MBtu/y = (kWh/y) / 293 or (Therms/y) / 10, whichever is applicable.

For range/oven energy use, Internal Gains in the Rated Home shall be modified by 80% of the range/oven ΔEUL_{RO} converted to Btu/day as follows: $\Delta EUL_{RO} * 10^6 / 365$. Of this total amount, Internal Gains shall be apportioned as follows, depending on fuel type:

a) For electric range/ovens, 90% sensible Internal Gains and 10% latent Internal Gains
b) For gas range/ovens, 80% sensible Internal Gains and 20% latent Internal Gains.

Internal Gains shall not be modified for range/oven equipment located outside the Rated Home.

[34] (Informative Note) For example, an unconditioned garage.

4.2.2.5.2.8. Clothes Dryers. Clothes Dryer annual energy use for the Rated Home shall be determined in accordance with Equation 4.2-7 and shall be based on the clothes dryer located within the Rated Home. If no clothes dryer is located within the Rated Home, a clothes dryer in the nearest shared laundry room on the project site shall be used, if available for daily use by the occupants of the Rated Home. If the shared laundry room has multiple clothes dryers, the clothes dryer with the lowest EF or CEF shall be used.

kWh/y = 12.5*(164+46.5*Nbr)*FU/EFdry*(CAPw/MEF - LER/392)/(0.2184*(CAPw*4.08+0.24)) **(Eq 4.2-7)**

where:

Nbr = Number of Bedrooms in home

FU = Field Utilization factor = 1.18 for timer controls **or** 1.04 for moisture sensing

EFdry = Efficiency Factor of clothes dryer **or** the default value of 3.01 **or** calculated as 1.15*CEF.

CEF = Combined Energy Factor is the clothes dryer efficiency[35] (lbs dry clothes/kWh) based on current U.S. DOE clothes dryer testing procedures.

CAPw = Capacity of clothes washer (ft^3) from the manufacturer's data **or** the CEC Appliance Efficiency Database **or** the EPA ENERGY STAR website[36] **or** the default value of 2.874 ft^3.

MEF = Modified Energy Factor of clothes washer from the Energy Guide label **or** the default value of 0.817 **or** calculated as 0.503+0.95*IMEF.

IMEF = Integrated Modified Energy Factor, which has replaced MEF as the U.S. DOE Energy Factor test metric for clothes washers.

LER = Labeled Energy Rating of clothes washer (kWh/y) from the Energy Guide label **or** the default value of 704.

For natural gas clothes dryers, annual energy use shall be determined in accordance with Equations 4.2-8a and 4.2-8b.

Therms/y = (result of Eq. 4.2-7)*3412*(1-0.07) *(3.01/EFdry-g)/100000 **(Eq. 4.2-8a)**

kWh/y = (result of Eq. 4.2-7)*0.07*(3.01/EFdry-g) **(Eq. 4.2-8b)**

where:

EFdry-g = Efficiency Factor for gas clothes dryers **or** the default value of 2.67 **or** calculated as 1.15*CEF.

CEF = Combined Energy Factor is the clothes dryer efficiency based on current U.S. DOE clothes dryer testing procedures.

For the purpose of adjusting the annual clothes dryer energy consumption for calculating the Rating, EUL_{LA} shall be adjusted by ΔEUL_{CD}, which shall be

35 (Informative Reference) See the CEC Appliance Efficiency Database http://www.energy.ca.gov/appliances/, or the ENERGY STAR Appliance database https://www.energystar.gov/products/appliances/clothes_dryers.

36 (Informative Reference) http://www.energystar.gov/index.cfm?c=clotheswash.pr_clothes_washers

calculated as the annual clothes dryer energy use derived by the procedures in this section minus the annual clothes dryer energy use derived for the Energy Rating Reference Home in Section 4.2.2.5.1, converted to MBtu/y, where MBtu/y = (kWh/y) / 293 or (Therms/y) / 10, whichever is applicable.

When a Dwelling Unit has no in-unit clothes dryer, and no shared clothes dryers are available in the building or on the project site for daily use by the Rated Home occupants or they exist, but the ratio of Dwelling Units to shared clothes dryers is greater than 14, the clothes dryer values from Table 4.2.2.5(1) shall be assumed for both the Energy Rating Reference Home and Rated Home.

For clothes dryer energy use, total Internal Gains in the Rated Home shall be modified by 15% of the clothes dryer ΔEUL_{CD} converted to Btu/day as follows: $\Delta EUL_{CD} * 10^6 / 365$. Of this total amount, 90% shall be apportioned to sensible Internal Gains and 10% to latent Internal Gains. Internal Gains shall not be modified for clothes dryers located in Unconditioned Space Volume, Unrated Heated Space, Unrated Conditioned Space, or outdoor environment.[37]

4.2.2.5.2.9. Dishwashers. Dishwasher annual energy use for the Rated Home shall be determined in accordance with Equation 4.2-9a and shall be based on the dishwasher located within the Rated Home, with the lowest Energy Factor (highest kWh/y). If no dishwasher is located within the Rated Home, a dishwasher in the nearest shared kitchen in the building shall be used, only if available for daily use by the occupants of the Rated Home.

$$\mathbf{kWh/y = [(86.3 + 47.73/EF)/215]*dWcpy} \qquad \textbf{(Eq. 4.2-9a)}$$

where:
EF = Labeled dishwasher Energy Factor
or
EF = 215/(labeled kWh/y)
dWcpy = (88.4 + 34.9*Nbr)*12/dWcap

where:
dWcap = Dishwasher place setting capacity; Default = 12 settings for standard sized dishwashers and 8 place settings for compact dishwashers

And the change (Δ) in daily hot water use (GPD – gallons per day) for dishwashers shall be calculated in accordance with Equation 4.2-9b.

$$\mathbf{\Delta GPD_{DW} = [(88.4+34.9*Nbr)*8.16 - (88.4+34.9*Nbr)*12/dWcap*(4.6415*(1/EF) - 1.9295)]/365} \qquad \textbf{(Eq. 4.2-9b)}$$

[37] (Informative Note) For example, an unconditioned garage.

For the purpose of adjusting the annual dishwasher energy consumption for calculating the Rating, EUL_{LA} shall be adjusted by ΔEUL_{DW}, which shall be calculated as the annual dishwasher energy use derived by the procedures in this section minus the annual dishwasher energy use derived for the Energy Rating Reference Home in Section 4.2.2.5.1, converted to MBtu/y, where MBtu/y = (kWh/y) / 293 or (Therms/y) / 10, whichever is applicable.

For the purpose of adjusting the daily hot water use for calculating the Rating, the daily hot water use change shall be 'ΔGPD_{DW}' as calculated above.

When a Dwelling Unit has no in-unit dishwasher, and no shared dishwashers are available in the building for daily use of the Rated Home occupants, the energy and hot water use of the Rated Home dishwasher shall be the same as the Energy Rating Reference Home, in accordance with Section 4.2.2.5.1.

For dishwasher energy use, total Internal Gains in the Rated Home shall be modified by 60% of the dishwasher ΔEUL_{DW} converted to Btu/day as follows: $\Delta EUL_{DW} * 10^6 / 365$. Of this total amount, 50% shall be apportioned to sensible Internal Gains and 50% to latent Internal Gains.

Internal Gains shall not be modified for dishwashers located outside the Rated Home.

4.2.2.5.2.10. Clothes Washers. Clothes Washer annual energy use and daily hot water use for the Rated Home shall be determined as follows, and shall be based on the clothes washer located within the Rated Home. If no clothes washer is located within the Rated Home, a clothes washer in the nearest shared laundry room on the project site shall be used, if available for daily use by the occupants of the Rated Home. If the shared laundry room has multiple clothes washers, the clothes washer with the highest LER shall be used.

Annual energy use shall be calculated in accordance with Equation 4.2-10a.

$$\text{kWh/y} = [(LER/392)-[(LER*(\$/kWh)-AGC)/(21.9825*(\$/kWh) - (\$/therm)]/392)*21.9825)]*ACY \quad \textbf{(Eq. 4.2-10a)}$$

where:

LER = Label Energy Rating (kWh/y) from the Energy Guide label
$/kWh = Electric Rate from Energy Guide Label
AGC = Annual Gas Cost from Energy Guide Label
$/therm = Gas Rate from Energy Guide Label
ACY = Adjusted Cycles per Year

and where:

$$ACY = NCY * [(3.0*2.08+1.59)/(CAP_w*2.08+1.59)]$$

where:

$$NCY = (3.0/2.874) * (164 + Nbr*46.5)$$

CAPw = washer capacity in cubic feet from the manufacturer's data **or** the CEC Appliance Efficiency Database[38] **or** the EPA ENERGY STAR website[39] **or** the default value of 2.874 ft^3

Daily hot water use shall be calculated in accordance with Equation 4.2-10b.

CWgpd = 60 * therms/cyc * ACY / 365 (Eq. 4.2-10b)

where:

therms/cyc = (LER * $/kWh - AGC) / (21.9825 * $/kWh - $/therm) / 392

For the purpose of adjusting the annual clothes washer energy consumption for calculating the Rating, EUL_{LA} shall be adjusted by ΔEUL_{CW}, which shall be calculated as the annual clothes washer energy use derived by the procedures in this section minus the annual clothes washer energy use derived for the Energy Rating Reference Home in Section 4.2.2.5.1, converted to MBtu/y, where MBtu/y = (kWh/y) / 293 **or** (Therms/y) / 10, whichever is applicable.

For the purpose of adjusting the daily hot water use for calculating the Rating, the daily hot water use change shall be calculated as the daily hot water use derived by the procedures in this Section minus the gallons per day derived for the Energy Rating Reference Home clothes washer in Section 4.2.2.5.1.4.

When a Dwelling Unit has no in-unit clothes washer, and no shared clothes washers are available in the building or on the project site for daily use by the Rated Home occupants or they exist, but the ratio of Dwelling Units to shared clothes washers is greater than 14, the energy and hot water use of the Rated Home clothes washer shall be the same as the Energy Rating Reference Home, in accordance with Section 4.2.2.5.1.

For clothes washer energy use, total Internal Gains in the Rated Home shall be modified by 30% of the clothes washer ΔEUL_{CW} converted to Btu/day as follows: $\Delta EUL_{CW} * 10^6 / 365$. Of this total amount, 90% shall be apportioned to sensible Internal Gains and 10% to latent Internal Gains. Internal Gains shall not be modified for clothes washers located in Unconditioned Space Volume, Unrated Heated Space, Unrated Conditioned Space, or outdoor environment.[40]

4.2.2.5.2.11. Service Hot Water Use. Service hot water system use in gallons per day for the Rated Home shall be determined in accordance with Equation 4.2-11

$$HWgpd = (DWgpd + CWgpd + F_{eff} * adjF_{mix} * (refFgpd + oWgpd + sWgpd * WD_{eff})) \quad \text{(Eq. 4.2-11)}$$

where:

[38] (Informative Reference) http://www.energy.ca.gov/appliances
[39] (Informative Reference) http://www.energystar.gov/index.cfm?c=clotheswash.pr_clothes_washers
[40] (Informative Note) For example, an unconditioned garage.

HWgpd = gallons per day of hot water use in Rated Home
DWgpd = dishwasher gallons per day
= ((88.4+34.9*Nbr)*12/dWcap*(4.6415*(1/EF)-1.9295))/365
CWgpd = clothes washer gallons per day = 60*((LER*($/kWh)-AGC)/(21.9825*($/kWh) -($/therm))/392)*ACY/365

Where more than one water heater exists in a Rated Home or building, the DWgpd load and CWgpd load must be attributed to the water heater providing that appliance with hot water.

F_{eff} = fixture effectiveness in accordance with Table 4.2.2.5.2.11(1)

Table 4.2.2.5.2.11(1) Hot water fixture effectiveness

Plumbing Fixture Description	F_{eff}
Standard-flow: showers ≤2.5 gpm and faucets ≤2.2 gpm	1.00
Low-flow: all showers and faucets ≤2.0 gpm	0.95

$adjF_{mix} = 1 – ((T_{set} – T_{use}) / (T_{set} – WH_{in}T))$
where
T_{set} = 125 °F = water heater set point temperature
T_{use} = 105 °F = temperature of mixed water at fixtures
$WH_{in}T$ = water heater inlet temperature
where
$WH_{in}T = T_{mains} + WH_{in}T_{adj}$ for DWHR systems and where $WH_{in}T_{adj}$ is calculated in accordance with Equation 4.2-14
$WH_{in}T = T_{mains}$ for all other hot water systems
T_{mains} = temperature of potable water supply entering the residence calculated in accordance with Section 4.2.2.5.1.4
refFgpd = reference climate-normalized daily fixture water use calculated in accordance with Section 4.2.2.5.1.4

oWgpd = refWgpd * oFrac * (1-oCD$_{eff}$) (Eq. 4.2-12)

where
oWgpd = daily standard operating condition waste hot water quantity
oFrac = 0.25
= fraction of hot water waste from standard operating conditions
oCD$_{eff}$ = Approved Hot Water Operational Control Device effectiveness (default = 0.0)

sWgpd = (refWgpd – refWgpd * oFrac) * pRatio * sysFactor (Eq. 4.2-13)

where
sWgpd = daily structural waste hot water quantity
refWgpd = reference climate-normalized distribution system waste water use calculated in accordance with Section 4.2.2.5.1.4
oFrac = 0.25
= fraction of hot water waste from standard operating conditions

pRatio = hot water piping ratio
where
for standard systems:
pRatio = PipeL / refPipeL
where
PipeL = measured length of hot water piping from the hot water heater (or from a shared recirculation loop serving multiple[41] Dwelling Units) to the farthest hot water fixture, measured longitudinally from plans, assuming the hot water piping does not run diagonally, plus 10 feet of piping for each floor level, plus 5 feet of piping for unconditioned basements (if any)
refPipeL = $2*(CFA/Nfl)^{0.5} + 10*Nfl + 5*Bsmt$
= hot water piping length for Reference Home
where
CFA = Conditioned Floor Area
Nfl = number of conditioned floor levels in the Dwelling Unit, including conditioned basements
Bsmt = presence = 1.0 **or**
= absence = 0.0 of an unconditioned basement in the Dwelling Unit
for recirculation systems (entirely within the Rated Home):[42]
pRatio = BranchL /10
where
BranchL = measured length of the branch hot water piping from the recirculation loop to the farthest hot water fixture from the recirculation loop, measured longitudinally from plans, assuming the branch hot water piping does not run diagonally
sysFactor = hot water distribution system factor from Table 4.2.2.5.2.11(2)

Table 4.2.2.5.2.11(2) Hot Water Distribution System Insulation Factors

Distribution System Description	sysFactor	
	No pipe insulation	≥R-3 pipe insulation
Standard systems	1.00	0.90
Recirculation systems	1.11	1.00

WD_{eff} = distribution system water use effectiveness from Table 4.2.2.5.2.11(3) [43]

Table 4.2.2.5.2.11(3) Distribution system water use effectiveness

[41] (Informative Note) Pump energy associated with the shared central recirculation loops are modeled separately from this section, in section 4.2.2.5.2.11.2.
[42] (Normative Note) Attached Dwelling Units shall be modeled with a Standard (non-recirculating) system except for recirculating systems that are entirely within the Rated Home. For instance, an individual Townhouse.

Distribution System Description	WD_{eff}
Standard systems	1.00
Recirculation systems	0.10

4.2.2.5.2.11.1. Drain Water Heat Recovery (DWHR) Units

If DWHR unit(s) is (are) installed and serve the Rated Home, the water heater potable water supply temperature adjustment ($WH_{in}T_{adj}$) shall be calculated in accordance with Equation 4.2-14.

$$WH_{in}T_{adj} = Ifrac*(DWHR_{in}T - T_{mains})*DWHR_{eff}*PLC*LocF*FixF \quad \text{(Eq. 4.2-14)}$$

where

$WH_{in}T_{adj}$ = adjustment to water heater potable supply inlet temperature (°F)

$Ifrac = 0.56 + 0.015*Nbr - 0.0004*Nbr^2$ = fraction of hot water use impacted by DWHR

$DWHR_{in}T$ = 97 °F

T_{mains} = calculated in accordance with Section 4.2.2.5.1.4

$DWHR_{eff}$ = Drain Water Heat Recovery Unit efficiency as rated and labeled in accordance with CSA 55.1

where

$DWHR_{eff} = DWHR_{eff} *1.082$ if low-flow fixtures are installed in accordance with Table 4.2.2.5.2.11(1)

PLC = 1 - 0.0002*pLength = piping loss coefficient

where

for standard systems:

pLength = pipeL as measured accordance with Section 4.2.2.5.2.11

for recirculation systems (entirely within the Rated Home):[43]

pLength = branchL as measured in accordance with Section 4.2.2.5.2.11

LocF = a performance factor based on the installation location of the DWHR determined from Table 4.2.2.5.2.11(4)

Table 4.2.2.5.2.11(4) Location factors for DWHR placement

DWHR Placement	LocF
Supplies pre-heated water to both the fixture cold water piping and the hot water heater potable supply piping	1.000
Supplies pre-heated water to only the hot water heater potable supply piping	0.777
Supplies pre-heated water to only the fixture cold water piping	0.777

FixF = Fixture Factor

[43] (Normative Note) Attached Dwelling Units shall be modeled with a Standard (non-recirculating) system except for recirculating systems that are entirely within the Rated Home. For instance, an individual Townhouse.

where
FixF = 1.0 if all of the showers in the home are connected to DWHR units
FixF = 0.5 if there are 2 or more showers in the home and only 1 shower is connected to a DWHR unit.

4.2.2.5.2.11.2. Hot Water System Annual Energy Consumption

Service hot water energy consumption shall be calculated using Approved Software Tools and the provisions of Section 4.2.2.5.1.4, Section 4.2.2.5.2.11 and Section 4.2.2.5.2.11.1 shall be followed to determine appropriate inputs to the calculations.

If the Rated Home includes a hot water recirculation system either within the Dwelling Unit or in the form of a shared recirculation system serving multiple Dwelling Units, then the annual electric consumption of the recirculation pump shall be added to the total hot water energy consumption. The recirculation pump kWh/y shall be calculated using Equation 4.2-15a for recirculation systems located completely within the Dwelling Unit. The shared recirculation pump kWh/y shall be calculated using Equation 4.2-15b for shared recirculation systems serving multiple Dwelling Units.

pumpkWh/y = pumpW * Efact **(Eq. 4.2-15a)**
where:
pumpW = pump power in Watts (default pumpW = 50 Watts)
Efact = factor selected from Table 4.2.2.5.2.11(5)

Table 4.2.2.5.2.11(5) Annual electricity consumption factor for hot water recirculation system pumps

Recirculation System Description	Efact
Recirculation without control or with timer control	8.76
Recirculation with temperature control	1.46
Recirculation with demand control (presence sensor)	0.15
Recirculation with demand control (manual)	0.10

SharedHWpumpkWh/y = $SHWP_{kW}$*OpHrs/Ndweq **(Eq. 4.2-15b)**
where:

$SHWP_{kW}$= Shared HW pump power in kW. Convert HP to kW with the formula:

kW = HP x 0.746 / motor efficiency. If pump motor efficiency is unknown, use 0.85. If HP is unknown, use 0.25.

OpHrs = annual pump operating hours
= 730 [for demand control]
= 8760 [without control or with timer control]
N_{dweq}= number of Dwelling Units served by the shared HW pump

Results from standard hot water energy consumption data ($stdEC_{HW}$)[44] shall be adjusted to account for the energy delivery effectiveness of the hot water distribution system in accordance with Equation 4.2-16.

$EC_{HW} = stdEC_{HW} * (E_{waste} + 128) / 160$ (Eq. 4.2-16)

where E_{waste} is calculated in accordance with Equation 4.2-17.

$E_{waste} = oEW_{fact} * (1\text{-}oCD_{eff}) + sEW_{fact} * pEratio$ (Eq. 4.2-17)

where:

$oEW_{fact} = EW_{fact} * oFrac$

= standard operating condition portion of hot water energy waste

where

EW_{fact} = energy waste factor in accordance with Table 4.2.2.5.2.11(6)

oCD_{eff} is in accordance with Section 4.2.2.5.2.11 $sEW_{fact} = EW_{fact} - oEW_{fact}$ = structural portion of hot water energy waste

pEratio = piping length energy ratio

where

for standard system: pEratio = PipeL / refpipeL

for recirculation systems (entirely within the Rated Home): [45]

pEratio = LoopL / refLoopL

and where

LoopL = hot water recirculation loop piping length including both supply and return sides of the loop, measured longitudinally from plans, assuming the hot water piping does not run diagonally, plus 20 feet of piping for each floor level greater than one plus 10 feet of piping for unconditioned basements.

refLoopL = 2.0*refPipeL - 20

Table 4.2.2.5.2.11(6) Hot water distribution system relative annual energy waste factors

Distribution System Description	EW_{fact}	
	No pipe insulation	≥R-3 pipe insulation
Standard systems	32.0	28.8
Recirculation without control or with timer control	500	250
Recirculation with temperature control	375	187.5
Recirculation with demand control (presence sensor)	64.8	43.2
Recirculation with demand control (manual)	43.2	28.8

44 (Normative Note) The value for the water heater inlet temperature, $WH_{in}T$, used to determine $adjF_{mix}$ shall be the value for the water heater inlet temperature used to calculate $stdEC_{HW}$.

45 (Normative Note) Attached Dwelling Units shall be modeled with a Standard (non-recirculating) system except for recirculating systems that are entirely within the Rated Home. For instance, an individual Townhouse.

4.2.2.5.2.12. Ceiling Fans. Where the number of ceiling fans included in the Rated Home is equal to or greater than the number of Bedrooms plus one, they shall also be included in the Reference Home. The number of Bedrooms plus one (Nbr+1) ceiling fans shall be assumed in both the Reference Home and the Rated Home. A daily ceiling fan operating schedule equal to 10.5 full-load hours shall be assumed in both the Reference Home and the Rated Home during months with an average outdoor temperature greater than 63 °F. The cooling thermostat (but not the heating thermostat) shall be set up by 0.5 °F in both the Reference and Rated Home during these months.

The Reference Home shall use number of Bedrooms plus one (Nbr+1) standard ceiling fans of 42.6 Watts each. The Rated Home shall use the Labeled Ceiling Fan Standardized Watts (LCFSW), also multiplied by number of Bedrooms plus one (Nbr+1) fans to obtain total ceiling fan wattage for the Rated Home. The Rated Home LCFSW shall be calculated in accordance with Equation 4.2-18.

LCFSW = (3000cfm) / (cfm/Watt as labeled at medium speed) (Eq. 4.2-18)

Where installed ceiling fans in the Rated Home have different values of LCFSW, the average LCFSW shall be used for calculating ceiling fan energy use in the Rated Home.

During periods of fan operation, the fan wattage, at 100% Internal Gain fraction, shall be added to Internal Gains for both the Reference and Rated Homes. In addition, annual ceiling fan energy use, in MBtu/y [(kWh/y)/293], for both the Rated and Reference Homes shall be added to the lighting and appliance end use loads (EUL_{LA} and $REUL_{LA}$, as appropriate) as specified by Equation 4.1-2 in Section 4.1.2.

4.2.2.5.2.13 Dwelling-Unit Mechanical Ventilation System Fans. If Dwelling-Unit Mechanical Ventilation System fans are present in the Rated Home, EUL_{LA} shall be adjusted by adding total annual kWh energy consumption of the Ventilation system in the Rated Home, converted to MBtu/y, where MBtu/y = (kWh/y) / 293.

4.2.2.6. On-Site Power Production. The Energy Rating Reference Home shall not include On-Site Power Production. Where the project site includes On-Site Power Production (OPP), the total OPP shall be computed as the electric energy produced on the project site minus the equivalent electric energy use (kWheq) calculated in accordance with Equation 4.1-3 of any purchased fossil fuels used to produce the total OPP. The total OPP shall be pro-rated to individual Dwelling Units based on the number of Bedrooms where the per-Bedroom OPP is used to determine the Dwelling Unit OPP that is used in the determination of PEfrac.

4.3. Index Adjustment Factor (IAF). The IAF for each Rated Home shall be determined in accordance with Sections 4.3.1 through 4.3.4.

4.3.1. Index Adjustment Design (IAD). An IAD shall be configured in accordance with Table 4.3.1(1). Renewable Energy Systems that offset the energy consumption requirements of the Rated Home shall not be included in the IAD.

Table 4.3.1(1) Configuration of Index Adjustment Design

Building Component	Index Adjustment Design (IAD)
General Characteristics	Number of Stories (NS): Two (2) Number of Bedrooms (Nbr): Three (3) Conditioned Floor Area (CFA): 2400 ft^2 Number of conditioned zones: One (1) No attached garage Wall height: 17 feet (including band joist) Wall width: 34.64 feet facing N, S, E and W All heating, cooling, and hot water equipment shall be located in Conditioned Space Volume.
Foundation	Type: Vented crawlspace Venting: net free vent aperture = 1ft^2 per 150 ft^2 of crawlspace floor area. Gross floor area: 1200 ft^2 Floor U-Factor: Same as Energy Rating Reference Home Foundation wall: 2 feet tall, 2 feet above-grade Wall width: 34.64 feet facing N, S, E and W Wall U-Factor: Same as Energy Rating Reference Home
Above-grade walls	Type: Same as Rated Home. If more than one type, maintain same proportional coverage for each type, excluding any garage wall, Multifamily Buffer Boundary wall, adiabatic wall, and sealed attic gable-end wall areas. U-Factor: Same as Rated Home Solar Absorptance: Same as Rated Home Emittance: Same as Rated Home
Ceilings	Type: Same as Rated Home. If more than one type, maintain same proportional coverage for each type. Gross projected footprint area: 1200 ft^2 U-Factor: Same as Rated Home
Roofs	Type: Same assembly details as Rated Home. The geometry shall be a hip roof with no gable-end walls. If more than one type, maintain same proportional coverage for each type. Gross Area: 1300 ft^2 Solar Absorptance: Same as Rated Home Values from Table 4.2.2(4) shall be used to determine Solar Absorptance except where test data are provided for roof surface in accordance with ANSI/CRRC S100. Emittance: Same as Rated Home Emittance values provided by the roofing manufacturer in accordance with ANSI/CRRC S100 shall be used when available. In cases where the appropriate data are not known, same as the Energy Rating Reference Home.

Building Component	**Index Adjustment Design (IAD)**
Attics	Type: Same as Rated Home. If more than one type, maintain same proportional coverage for each type.
Doors	Area: Same as Rated Home Orientation: Same as Rated Home U-Factor: Same as Rated Home
Glazing	Total area =Same as Energy Rating Reference Home Orientation: equally distributed to four (4) cardinal compass orientations (N,E,S,&W) U-Factor: Area-weighted average U-Factor of Rated Home SHGC: Area-weighted average SHGC of Rated Home Interior shade coefficient: Summer: Same as Energy Rating Reference Home Winter: Same as Energy Rating Reference Home External shading: None
Skylights	Same as Rated Home
Thermally isolated sunrooms	Same as Rated Home
Air exchange rate	Combined [(a)] Infiltration flow rate plus mechanical Ventilation flow rate of 0.03 * CFA + 7.5 * (Nbr+1) cfm Infiltration flow rate shall be determined using the following envelope leakage rates: 5 ACH_{50} in IECC[46] Climate Zones 1-2 3 ACH_{50} in IECC[46] Climate Zones 3-8
Dwelling-Unit Mechanical Ventilation System fan energy	Balanced Ventilation System without energy recovery and with fan power = 0.70 * fanCFM * 8.76 kWh/y
Internal Gains	As specified by Table 4.2.2(3) except that lighting shall be 75% high efficiency
Internal mass	An internal mass for furniture and contents of 8 pounds per square foot of floor area
Structural mass	Same as Energy Rating Reference Home
Heating systems	Fuel type: Same as Rated Home Efficiencies: Electric: Air Source Heat Pump in accordance with Table 4.2.2(1a) Non-electric furnaces: natural gas furnace in accordance with Table 4.2.2(1a) Non-electric boilers: natural gas boiler in accordance with Table 4.2.2(1a) Capacity: sized in accordance with Section 4.4.3.1
Cooling systems	Fuel type: Electric Efficiency: in accordance with Table 4.2.2(1a) Capacity: sized in accordance with Section 4.4.3.1

[46] (Normative Note) Climates zones shall be as specified by the 2006 IECC.

Building Component	Index Adjustment Design (IAD)
Service water heating systems	Fuel type: same as Rated Home Efficiency: Electric: EF = 0.97 - (0.00132 * store gal) Fossil fuel: EF = 0.67 - (0.0019 * store gal) Use: Same as Energy Rating Reference Home Tank temperature: 125 F
Thermal distribution systems	Thermal Distribution System Efficiency (DSE) of 1.00 shall be applied to both the heating and cooling system efficiencies and air distribution systems shall be located within Conditioned Space Volume
Thermostat	Type: manual Temperature set points: cooling temperature set point = 78 F; heating temperature set point = 68 F
Lighting, Appliances and Miscellaneous Energy Loads (MELs)	Same as the Energy Rating Reference Home, except that lighting shall be 75% Tier I

Table 4.3.1(1) Notes:

(a) Either hourly calculations using the following equation or calculations yielding equivalent results shall be used to determine the combined air exchange rate resulting from Infiltration in combination with the Dwelling-Unit Mechanical Ventilation Systems.

$$Qi = Qfan,i + \Phi\ Qinf,i$$

where

Φ=1 for Balanced Ventilation Systems and otherwise

$$\Phi = Qinf,i /(Qinf,i + Qfan,i)$$

Qi = combined air exchange rate for the time step 'i', cfm

Qinf,i = Infiltration airflow rate for the time step 'i', cfm calculated using Shelter Class 4

Qfan,i = mechanical Ventilation airflow rate for the time step 'i', cfm

4.3.2. An Approved[47] Software Rating Tool shall be used to determine the Energy Rating Index for the IAD (ERI_{IAD}).

4.3.3. The saving represented by the IAD shall be calculated using Equation 4.3-1.

$$\mathbf{IAD_{SAVE} = (100 - ERI_{IAD}) / 100} \qquad \textbf{(Eq. 4.3-1)}$$

4.3.4. The IAF for the Rated Home (IAF_{PD}) shall be calculated in accordance with Equation 4.3-2.

$$\mathbf{IAF_{RH} = IAF_{CFA} * IAF_{Nbr} * IAF_{NS}} \qquad \textbf{(Eq. 4.3-2)}$$

[47] (Informative Note) The Residential Energy Services Network (RESNET) accredits energy rating software tools in accordance with RESNET Publication 002.

where:

IAF_{RH} = combined Index Adjustment Factor for Rated Home
IAF_{CFA} = (2400/CFA) ^ [0.304 * (IAD_{SAVE})]
IAF_{Nbr} = 1+ [0.069 * (IAD_{SAVE}) * (Nbr-3)]
IAF_{NS} = (2/NS) ^ [0.12 * (IAD_{SAVE})]

where:

CFA = Conditioned Floor Area
Nbr = Number of Bedrooms
NS = Number of stories

4.4. Operating Condition Assumptions. The annual Purchased Energy consumption for heating, cooling and hot water for both the Rated Home and the Reference Home shall be estimated in accordance with Sections 4.4.1 through 4.4.9.

4.4.1. Programmable Thermostats. Where programmable offsets are available in the Rated Home, 2 °F temperature control point offsets with an 11 p.m. to 5:59 a.m. schedule for heating and a 9 a.m. to 2:59 p.m. schedule for cooling, and with no offsets assumed for the Reference Home;

4.4.2. Local Climate. The climatologically most representative TMY3 or equivalent climate data.

4.4.3. HVAC Sizing. Manufacturer's Equipment Performance Ratings[48] shall be corrected for local climate conditions and mis-sizing of equipment. To determine equipment mis-sizing, the heating and cooling capacity shall be selected in accordance with ACCA Manual S based on building heating and cooling loads calculated in accordance with Manual J, Eighth Edition, ASHRAE Handbook of Fundamentals, or an equivalent computation procedure, using the following assumptions:

4.4.3.1. Energy Rating Reference Home:

4.4.3.1.1. Indoor temperatures shall be 75 °F for cooling and 70 °F for heating.

4.4.3.1.2. Outdoor temperatures shall be the 99.0% and 1.0% design temperatures as published in the ASHRAE Handbook of Fundamentals for the city where the home is located or the most representative city for which design temperature data are available.

4.4.3.1.3. The adjusted total air exchange rate (Qtot, adj) in cubic feet per minute (cfm) shall be the product of 1.4 and the value determined by Equation 4.4-1.

$$Qtot = 0.03 * CFA + 7.5*(Nbr+1) \qquad \textbf{(Eq. 4.4-1)}$$

4.4.3.1.4. All windows shall have blinds/draperies that are positioned in a manner that gives an Internal Shade Coefficient (ISC) of 0.70 in the summer and an ISC of 0.85 in the winter. These values are represented in ACCA Manual J Eighth Edition

48 (Informative Note) For example, HSPF, SEER and AFUE.

as "dark closed blinds" in the summer and "dark, fully drawn roller shades" in the winter.

4.4.3.1.5. Internal Gains shall be 1,600 Btu/h sensible for appliances plus 230 Btu/h sensible and 200 Btu/h latent per occupant, with the number of occupants equal to the number of Bedrooms plus one.

4.4.3.1.6. Heat Pump equipment capacity shall be sized to equal the larger of the building heating and cooling loads calculated in accordance with these procedures.

4.4.3.1.7. Systems shall not be larger than the size calculated using this procedure plus 100 Btu/hr.

4.4.3.2. Rated Home:

4.4.3.2.1. Indoor temperatures shall be 75 ºF for cooling and 70 ºF for heating.

4.4.3.2.2. Outdoor temperatures shall be the 99.0% and 1.0% design temperatures as published in the ASHRAE Handbook of Fundamentals for the city where the home is located or the most representative city for which design temperature data are available.

4.4.3.2.3. The total air exchange rate (Qtot) in cubic feet per minute (cfm) shall be the product of 1.4 and the larger of the value determined by Equation 4.4-1 and the infiltration rate in cfm as determined by testing in accordance with Standard ANSI/RESNET/ICC 380 (and after adjustment by A_{ext} where directed by Table 4.2.2(1) for Attached Dwelling Units).

4.4.3.2.4. Where a Dwelling-Unit Mechanical Ventilation System(s) is provided, the combined total air exchange rate (Infiltration rate and mechanical Ventilation fan rate) shall not be less than the total Ventilation rate determined by the product of the value determined by Equation 4.4-1 and 1.4. Flow rates for bathroom, kitchen and other local exhaust that does not serve as a component of a Dwelling-Unit Mechanical Ventilation System shall not be considered for sizing purposes.

4.4.3.2.5. Windows shall include observed blinds/draperies. For new homes, all windows shall assume blinds/draperies that are positioned in a manner that gives an Internal Shade Coefficient (ISC) of 0.70 in the summer and an ISC of 0.85 in the winter. These values are represented in ACCA Manual J Eighth Edition as "dark closed blinds" in the summer and "dark fully drawn roller shades" in the winter.

4.4.3.2.6. Internal heat gains shall be 1,600 Btu/h sensible plus 230 Btu/h sensible and 200 Btu/h latent per occupant, with the number of occupants equal to the number of Bedrooms plus one.

4.4.3.2.7. Heat Pump equipment capacity shall be sized to equal the larger of the building heating and cooling loads calculated in accordance with these procedures.

4.4.3.2.8. To the degree that the installed equipment capacity for the Rated Home exceeds equipment properly sized in accordance with the above procedures, the impact of the over-sizing on part-load performance shall be accounted accordingly.

4.4.3.2.9. When Dwelling-Unit Mechanical Ventilation System supply air is conditioned before delivery to the Rated Home by a system serving more than one Dwelling Unit, the Ventilation supply air shall be apportioned to the shared mechanical ventilation system that actively conditions it, as described in Table 4.2.2(1), endnote (r). The Ventilation conditioning load is the only space conditioning load that shall be assigned to that shared equipment.

4.4.4. Air Source Heat Pumps and Air Conditioners.

4.4.4.1. For Heat Pumps and air conditioners where a detailed, hourly HVAC simulation is used to separately model the compressor and evaporator energy (including part-load performance), the back-up heating energy, the distribution fan or blower energy and crank case heating energy, the Manufacturer's Equipment Performance Rating (HSPF and SEER[49]) shall be modified as follows to represent the performance of the compressor and evaporator components alone: HSPF, corr = HSPF, mfg / 0.582 and SEER, corr = SEER, mfg / 0.941. The energy uses of all components, including compressor and distribution fan/blower; and crank case heater, shall then be added together to obtain the total energy uses for heating and cooling.

4.4.4.2. For a Chiller, model the Rated Home cooling system efficiency (SEER) using the rated efficiency of the Chiller with allowance for circulation pumps and fans according to the following formula:

$$SEER_{eq} = \frac{(Cap - (aux \times 3.41)) - (aux_{dweq} \times 3.41 \times N_{dweq})}{(Input + aux) + (aux_{dweq} \times N_{dweq})} \quad \textbf{(Eq. 4.4-2)}$$

Where:

Cap = Chiller system output in Btu/hour

aux = Total of the pumping and fan power serving the system in Watts. Convert HP to Watts with the formula:

Watts = HP x 746 / motor efficiency. If motor efficiency is unknown, use 0.85

aux_{dweq} = Total of the in-unit cooling equipment power[50] serving the Dwelling Unit in Watts

Input = Chiller system power in Watts

N_{dweq} = Number of Dwelling Units served by the shared system.

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[49] (Informative Note) For Commercial Variable Refrigerant Flow (VRF) Multi-Split Air Conditioning and Heat Pump Equipment, use IEER in place of SEER.

[50] (Informative Note) For example, this includes all power to run a Water Loop Heat Pump within the Dwelling Unit, not just the air handler energy.

4.4.4.3. For a Cooling Tower with WLHP's, model the Rated Home cooling system efficiency (SEER) using the rated efficiency of the WLHP (EER) with allowance for the Rated Home's portion of the in-building circulation pumps and cooling fans and circulation pumps according to the following formula:

$$\boldsymbol{SEER_{eq}} = \frac{\boldsymbol{WLHP_{cap}} - \left(\frac{\boldsymbol{aux \times 3.41}}{\boldsymbol{N_{dweq}}}\right)}{\boldsymbol{Input} + \left(\frac{\boldsymbol{aux}}{\boldsymbol{N_{dweq}}}\right)} \quad \textbf{(Eq. 4.4-3)}$$

Where:

$WLHP_{cap}$ =WLHP cooling capacity in Btu/hour

aux = Total of the pumping and fan power serving the system in Watts. Convert HP to Watts with the formula:

Watts = HP x 746 / motor efficiency. If motor efficiency is unknown, use 0.85

Input = WLHP system power in Watts using the formula:

$$Input = \frac{WLHP_{cap}}{EER}$$

Where: *EER*=Energy Efficiency Ratio of the WLHP

N_{dweq} = Number of Dwelling Units served by the shared system.

4.4.5. Ground Source Heat Pumps. For residential ground-loop and ground-water water-to-air Heat Pumps that are shipped with an integral blower fan and without a fluid circulation pump, the Auxiliary Electric Consumption for the Rated Home shall be determined as follows:

GSHP Auxiliary Electric Consumption (kWh/y) = $GSHP_{pump}$ - $GSHP_{intp}$ + $GSHP_{fan}$

where:

$GSHP_{pump}$ in Watts is the observed pump nameplate data (Volt*Amps) that shall be added for all periods of Heat Pump operation. Amps are taken from the nameplate as either Run Load Amps (RLA) or Full Load Amps (FLA). Alternatively, pumping energy that is measured on-site with a Watt-hour meter, or using measured V*A are allowed to be substituted. Such measured pumping energy is allowed to be further adjusted for on-site measured duty cycle during Heat Pump operation, when pumping is intermittent during continuous Heat Pump operation.

$GSHP_{intp}$ in Watts is the estimated pump power required to overcome the internal resistance of the ground-water heat exchanger under AHRI test conditions. $GSHP_{intp}$ = W/ton * rated cooling Btu/h/12,000. W/ton shall be 30 for ground loop (closed loop) systems and 15 for ground water (open loop) Heat Pump systems.

$GSHP_{fan}$: If ducts are attached to the system to deliver heating or cooling, the external fan energy in Watts, $GSHP_{fan}$ = (airflow in cfm * 0.2 Watts per cfm), shall be added for all periods of Heat Pump operation. The airflow in cfm shall be (400 * rated cooling Btu/h / 12,000), where 400 is the airflow in cfm per ton (12 kBtu/h) of capacity. Note that for the purposes of calculating adjusted equipment efficiency, $GSHP_{fan}$ shall also be added to the rated heating capacity, and subtracted from the rated cooling capacity of the equipment. For that adjustment, $GSHP_{fan}$ shall be converted to Btu/h by Btu/h = $GSHP_{fan}$ * 3.412.

For the purpose of Projected Ratings only, where $GSHP_{pump}$ cannot be determined, the following adjustments shall be made to the rated efficiency of the GSHP:

Adjusted EER (closed loop) = 0.0000315*EER^3 - 0.0111*EER^2 + 0.959*EER
Adjusted COP (closed loop) = 0.000416*COP^3 - 0.041*COP^2 + 1.0086*COP
Adjusted EER (open loop) = 0.00005*EER^3 - 0.0145*EER^2 +0.93*EER
Adjusted COP (open loop) = 0.00067*COP^3 - 0.0531*COP^2 + 0.976*COP

4.4.5.1. Ground Source Heat Pumps on a shared Hydronic Circulation Loop

For multiple ground-loop and ground-water water-to-air Heat Pumps that are shipped with an integral blower fan, and which share common circulation pump(s), the Auxiliary Electric Consumption for the Rated Home shall be determined as follows:

$$\boldsymbol{Eae = \frac{SP_{kW}}{N_{dweq}} \times 8760 + HPfan_{kW} \times (HLH + CLH)} \quad \textbf{(Eq. 4.4-4)}$$

Where:

SP_{kW}	= Shared Pump power in kW. Convert HP to kW with the formula: kW = HP x 0.746 / motor efficiency. If pump motor efficiency is unknown, use 0.85.
N_{dweq}	= Number of Dwelling Units served by the shared system
HLH	= Annual Heating Load Hours
CLH	= Annual Cooling Load Hours
$HPfan_{kW}$	= Heat Pump distribution fan power in kW

4.4.6. Fossil Fuel Fired Furnaces and Boilers Serving One Unit. For a fossil fuel fired furnace or boiler, the Auxiliary Electric Consumption for the Rated Home shall be determined as follows:

Auxiliary Electric Consumption (kWh/y) = Eae * (HLH) / 2080

where:

HLH = annual heating load hours attributed to the furnace/boiler.
Note: If fan power is needed (kW), it is determined by Eae / 2080.

4.4.7. Fossil Fuel Fired Boilers Serving more than One Unit.

4.4.7.1. Where heat is distributed by baseboard, radiant heat, convectors, or fan coils, the Auxiliary Electric Consumption for the Rated Home shall be determined as follows:

$$Eae = \left(\left(\frac{SP_{kW}}{N_{dweq}}\right) + aux_{in}\right) \times HLH \qquad \textbf{(Eq. 4.4-5)}$$

Where:

SP_{kW}	= Shared pump power in kW. Convert HP to kW with the formula:
	kW = HP x 0.746 / motor efficiency. If pump motor efficiency is unknown, use 0.85.
HLH	= annual heating load hours
N_{dweq}	= number of Dwelling Units served by the shared system
aux_{in}	= In-unit fan coil kW

The Reference Home shall have a boiler that is sized to the Reference Home heating load, in accordance with Section 4.4.3.1. The Rated Home shall have a boiler that is sized to the Rated Home heating load, in accordance with Section 4.4.3.2.

4.4.7.2. Where heat is distributed by Water Loop Heat Pumps within the Dwelling Unit, the Auxiliary Electric Consumption for the Rated Home shall be determined in accordance with Equation 4.4-5, with the value of aux_{in} set to 0.

4.4.7.2.1. The Rated Home shall be configured such that the heating load is assigned to two separate heating systems: 1) a Heat Pump with a capacity that is equal to the Rated Home design load (as calculated in accordance with Section 4.4.3.2) divided by the rated COP of the Water Loop Heat Pump and 2) a boiler with the balance of the capacity of (1-1/COP).

4.4.7.2.2. The Reference Home shall have heating equipment that is sized to the Reference Home heating load (in accordance with Section 4.4.3.1), both a Heat Pump and a boiler, sized to the same proportions of the heating load as the heat pump and boiler in Section 4.4.7.2.1.

4.4.8. Natural Ventilation. Natural Ventilation shall be assumed in both the Reference and Rated Homes during hours when Natural Ventilation will reduce annual cooling energy use. For Attached Dwelling Units, where no operable Glazing is present in the Rated Home, Natural Ventilation shall not be included in either the Reference Home or the Rated Home.

4.4.9. Whole-House Fans. When a Whole-House fan is present in the Rated Home no Whole-House fan shall be assumed in the Reference Home. The fan energy associated with the Whole-House fan shall be included in the normalized Energy Consumption for the Rated Home's cooling end-use (nEC_x).[51]

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[51] (Normative Note) The Whole-House fan shall operate during hours of favorable outdoor conditions.

4.5. Minimum Rated Features. The estimated annual Purchased Energy consumption for heating, cooling, water heating and lighting and appliances set forth in Section 4.2 shall be determined using the energy loss and gain associated with the Minimum Rated Features as set forth in Table 4.5.2(1).

4.5.1. Data Sources. If data for the Minimum Rated Features set forth in Section 4.5.2 cannot be obtained by observation or without destructive disassembly of the home, default values shall be used based on current and historical local building practice and building codes and for modular or manufactured housing available data from the manufacturer.

4.5.2. Standard Features. The Minimum Rated Features associated with the home shall be determined and documented by a Certified Rater or Approved Inspector in accordance with Sections 4.5.2.1 through 4.5.2.3 and the on-site inspection procedures in Appendix A and Appendix B.

4.5.2.1. The envelope thermal characteristics of building elements 1 through 8 set forth in Table 4.5.2(1) shall be determined by site observation. Where thermal characteristics cannot be determined during site observation, the manufacturer's data sheet shall be used.

4.5.2.2. The air leakage and duct leakage values set forth as building elements 9 and 10 in Table 4.5.2(1) shall be determined by using current on-site diagnostic tests conducted in accordance with the requirements set forth in Table 4.2.2(1).

4.5.2.3. The energy efficiency of the mechanical equipment set forth as building elements 11, 12 and 14 in Table 4.5.2(1) shall be determined by data collected on site using the following sources listed in preferential order of use:

(a) Current on-site diagnostic test data as corrected using the following equation:

Eff,rated = Eff,listed * Es,measured / Es,listed

where:

Eff,rated = annual efficiency to use as input to the Rating
Eff,listed = listed annual efficiency by manufacturer or directory
Es,measured = measured steady state efficiency of system
Es,listed = manufacturer's listed steady state efficiency, under the same operating conditions found during measurement; or,

(b) Nameplate data; or,
(c) Manufacturer's data sheet; or,
(d) Equipment directories; or,
(e) When information on the energy efficiency of mechanical equipment cannot be determined, the values set forth in Tables 4.5.2(2); 4.5.2(3); 4.5.2(4) and 4.5.2(5).

Table 4.5.2(1) Minimum Rated Features

Building Element	Minimum Rated Feature
General Project Info	Total number of buildings, Dwelling Units, and total number of Bedrooms in the project.

Table 4.5.2(1) Minimum Rated Features

Building Element	Minimum Rated Feature
1. Floor/Foundation Assembly	Construction type (slab-on-grade, crawlspace, basement), boundary condition (adiabatic, above unconditioned space, above Non-Freezing Space), dimensions, insulation type, value, and location (edge, under slab, cavity, sheathing), framing material and on-center spacing, insulation installation (Grade I, II, or III), vented or unvented (crawlspace), capacitance (if slab or basement receives appreciable solar gain).
2.Walls Assembly	Construction type, boundary condition (adiabatic, ambient, Multifamily Buffer Boundary), insulation value (cavity, sheathing), framing material and on-center spacing, insulation installation (Grade I, II, or III), capacitance, exterior color (light, medium, or dark).
3.Roof/Ceiling Assembly	Construction type, insulation value (cavity, sheathing), framing material and on-center spacing, insulation installation (Grade I, II, or III), framing covered by insulation or exposed, roof color (light, medium, or dark).
4.Rim/Band Joists or Floor Perimeters	Insulation value (cavity, sheathing).
5.Doors	Construction type, insulation value.
6.Windows	Construction type, orientation, U-value (of complete assembly), solar heat gain coefficient (of complete assembly), operable/inoperable, shading due to permanent, fixed shading devices attached to the building such as fins and overhangs. Window screens, security bars, balcony railings, movable awnings, roller shades, and shade from adjacent buildings, trees and shrubs shall not be included.
7.Skylights	Construction type, orientation, tilt, U-value (of complete assembly), solar heat gain coefficient (of complete assembly), shading.
8.Passive Solar System (Direct Gain System)	Solar type, collector type and area, orientation, tilt, efficiency, storage tank size, and pipe insulation value.
9. Air Leakage	Air leakage measurement and type (default estimate, blower door test), Infiltration Volume, Conditioned Space Volume.
10. Distribution System	System type, location, insulation value (duct and pipe), air leakage measurement and type (default estimate, duct pressurization).
11. Heating Equipment	Equipment type, location, capacity, efficiency (AFUE, HSPF, COP), Electric Auxiliary Energy (Eae), power rating of ground fluid circulating pump(s) for ground-loop and ground-water Heat Pumps, power rating of pumping system for shared boiler distribution.

Table 4.5.2(1) Minimum Rated Features

Building Element	Minimum Rated Feature
12. Cooling Equipment	Equipment type, location, capacity, efficiency (SEER, COP, kW/ton), power ratings for the following: Cooling Tower (sprayer pump(s) and fan motor), outdoor system circulation loop pump, indoor system circulation loop pump and Cooling Tower fan/blower and circulation pump.
13. Control Systems	Thermostat type.
14. Service Hot Water Equipment	For Residential Equipment - Equipment type, location, Energy Factor or Uniform Energy Factor, extra tank insulation R-value, flow rates of showers and faucets. For Commercial Equipment - Equipment type, location, Uniform Energy Factor or Thermal Efficiency and Standby Loss, extra tank insulation value, flow rates of showers and faucets. Distribution Related: Distribution System Type (standard, recirculation), Recirculation System controls [none, timer, temperature, demand (manual) or demand (sensor)], pipe insulation R-value, pipe length for standard distribution, branch length for recirculation, supply + return loop length, pump power (Watts, HP).
15. Solar Domestic Hot Water Equipment	System type, collector type and area, orientation, tilt, efficiency, storage tank size, pipe insulation value.
16. Light Fixtures	Number of Qualifying Tier I, Tier II, and non-Qualifying Light Fixtures in Qualifying Light Fixture Locations within the contiguous area that is for the sole use of the Rated Home occupants, including kitchens, dining rooms, living rooms, family rooms/dens, bathrooms, hallways, stairways, entrances, Bedrooms, garage, utility rooms, home offices, and all outdoor fixtures mounted on a building or pole. This excludes plug-in lamps, closets, unconditioned basements, lighting for common spaces, parking lot lighting, and landscape lighting.
17. Refrigerator(s)	Total annual energy consumption (kWh) for all refrigerators located within the Rated Home and any refrigerators outside the Rated Home for daily use by the Rated Home occupants as determined from either the refrigerator Energy Guide label or from age-based defaults as defined in Section 4.2.2.5.2.5.
18. Dishwasher(s)	Labeled Energy Factor (cycles/kWh) or labeled energy consumption (kWh/y) for all dishwashers located within the Rated Home and any dishwashers outside the Rated Home intended for daily use by the Rated Home occupants as defined in Section 4.2.2.5.2.9.
19. Range/Oven	Burner Energy Factor (BEF) and Oven Energy Factor (OEF) as defined in Section 4.2.2.5.2.7.

Table 4.5.2(1) Minimum Rated Features

Building Element	Minimum Rated Feature
20. Clothes Washer	Location, source of hot water, type (residential or commercial); Labeled Energy Rating (kWh/y), electric rate ($/kWh), annual gas cost (AGC), and gas rate ($/therm) from Energy Guide label; and washer capacity (cubic feet) from manufacturer's data or the CEC Appliance Efficiency Database or the EPA ENERGY STAR website, for all clothes washers located within the Rated Home or any clothes washers in the building intended for use by the Rated Home occupants, as defined in Section 4.2.2.5.2.10.
21. Clothes Dryer	Location, clothes washer Modified Energy Factor(MEF) or Integrated Modified Energy Factor (IMEF) and clothes washer Labeled Energy Rating (kWh/y) from Energy Guide label; clothes washer capacity from manufacturer's data or CEC Appliance Efficiency Database or EPA ENERGY STAR website; and clothes dryer Efficiency Factor (EF) or Combined Efficiency Factor (CEF) from CEC Appliance Efficiency Database or EPA ENERGY STAR website, for all clothes dryers located in the Rated Home or any clothes dryers in the building intended for use by the Rated Home occupants, as defined in Section 4.2.2.5.2.8.
22. Ceiling Fans	Total number of ceiling fans in the Dwelling Unit, Labeled cfm, Watts, and cfm/Watt at medium fan speed from each ceiling fan label.
23. Dwelling-Unit Mechanical Ventilation System(s)	Ventilation strategy (Supply, Exhaust, or Balanced), equipment type (individual or shared), daily run hours, measured exhaust airflow, measured supply airflow, system rated airflow, and fan wattage[52]. Where shared systems occur, include percentage of outdoor air in supply air, rated exhaust airflow and rated supply airflow of the shared systems. Fan motor efficiency and horsepower are acceptable substitutes for fan wattage.
24. Systems pre-conditioning Ventilation Air	System type (heating, cooling, both), efficiency, fan power, system rated airflow.
25. On-site Power Production	System type, total annual kWh generation, and total site fuel used in the On-Site Power Production as derived from manufacturer's performance ratings.

Table 4.5.2(2) Default Solid Fuel Combustion Seasonal Efficiencies for Space Heating

Type	Location	Seasonal Efficiency	Notes
EPA-Listed Stove, Furnace or Boiler	Conditioned Space Volume or Unrated Conditioned Space	Contained in the EPA publication "Certified	

[52] (Informative Note) A source for fan wattage is the Certified Home Ventilating Products Directory available from the Heating and Ventilation Institute (HVI).

Table 4.5.2(2) Default Solid Fuel Combustion Seasonal Efficiencies for Space Heating

Type	Location	Seasonal Efficiency	Notes
		Wood Heaters" and posted at http://www.epa.gov/compliance/resources/publications/monitoring/caa/woodstoves/certifiedwood.pdf	
EPA-Listed Stove, Furnace or Boiler	Unconditioned Space Volume	0.85 of EPA listing	
EPA Stove – Not Listed	Conditioned Space Volume or Unrated Conditioned Space	60%	For stoves with documented EPA compliance, but not found on EPA's website list of certified stoves
EPA Stove – Not Listed	Unconditioned Space Volume	50%	For stoves with documented EPA compliance, but not found on EPA's website list of certified stoves
EPA-Listed Stove Insert	Enclosed[53]	Subtract 10% from listed seasonal efficiency	
Non-EPA Stove	Conditioned Space Volume or Unrated Conditioned Space	50%	Not tested or listed by EPA
Non-EPA Stove	Unconditioned Space Volume	40%	Not tested or listed by EPA
Biomass Fuel Furnace or Boiler with Distribution System	Conditioned Space Volume or Unrated Conditioned Space	50%	Not tested or listed by EPA Distribution System Efficiency shall also be considered
Biomass Fuel Furnace or Boiler with Distribution System	Unconditioned Space Volume	40%	Not tested or listed by EPA Distribution System Efficiency shall also be considered

[53] (Informative Note) Such as in a fireplace.

Table 4.5.2(2) Default Solid Fuel Combustion Seasonal Efficiencies for Space Heating

Type	Location	Seasonal Efficiency	Notes
Biomass Fuel Furnace or Boiler with Distribution System	Outside	30%	Not tested or listed by EPA Distribution System Efficiency shall also be considered
Solid Fuel Furnace or Boiler – Independently Tested	Central with ducted or hydronic distribution	0.85 of tested listing	Only permitted with documentation of independent testing lab documentation Distribution System Efficiency shall also be considered

Table 4.5.2(3) Default Values for Mechanical System Efficiency (Age-based) [(a)]

Mechanical Systems	Units	Pre-1960	1960-1969	1970-1974	1975-1983	1984-1987	1988-1991	1992--2005	2006-present
Heating:									
Gas Furnace	AFUE	0.72	0.72	0.72	0.72	0.72	0.76	0.78	0.78
Gas Boiler	AFUE	0.60	0.60	0.65	0.65	0.70	0.77	0.80	0.80
Oil Furnace or Boiler	AFUE	0.60	0.65	0.72	0.75	0.80	0.80	0.80	0.80
Air-Source Heat Pump	HSPF	6.5	6.5	6.5	6.5	6.5	6.80	6.80	7.7
Ground-Water Geothermal Heat Pump	COP	2.70	2.70	2.70	3.00	3.10	3.20	3.50	3.6
Ground-Coupled Geothermal Heat Pump	COP	2.30	2.30	2.30	2.50	2.60	2.70	3.00	3.1
Water Loop Heat Pump	COP	3.25	3.25	3.25	3.57	3.70	3.83	4.23	4.36
Cooling:									
Air-Source Heat Pump	SEER	9.0	9.0	9.0	9.0	9.0	9.40	10.0	13.0
Ground-Water Geothermal Heat Pump	EER	10.00	10.00	10.00	13.00	13.00	14.00	16.0	16.2
Ground-Coupled Geothermal Heat Pump	EER	8.00	8.00	8.00	11.00	11.00	12.00	14.0	13.4

Table 4.5.2(3) Default Values for Mechanical System Efficiency (Age-based) [(a)]

Mechanical Systems	Units	Pre-1960	1960-1969	1970-1974	1975-1983	1984-1987	1988-1991	1992--2005	2006-present
Water Loop Heat Pump	EER	7.73	7.73	7.73	10.30	10.30	11.16	12.88	12.70
Central Air Conditioner	SEER	9.0	9.0	9.0	9.0	9.0	9.40	10.0	13.0
Room Air Conditioner	EER	8.0	8.0	8.0	8.0	8.0	8.10	8.5	8.5
Water Heating[54]:									
Storage Gas	EF	0.50	0.50	0.50	0.50	0.55	0.56	0.56	0.59
Storage Oil	EF	0.47	0.47	0.47	0.48	0.49	0.54	0.56	0.51
Storage Electric	EF	0.86	0.86	0.86	0.86	0.86	0.87	0.88	0.92
(a) Exception: Where the labeled equipment efficiency exists for the specific piece of existing equipment, the labeled efficiency shall be used in lieu of these minimum input constraints.									

TABLE 4.5.2(4) Default Values for Mechanical System Efficiency (not Age-based) [(a)]

Mechanical Systems	Units	Rating
Heating:		
Gas Wall Heater (Gravity)	AFUE	0.72
Gas Floor Furnace	AFUE	0.72
Gas Water Heater (Space Heating)	AFUE	0.75
Electric Furnace	HSPF	3.413
Electric Radiant	HSPF	3.413
Heat Pump Water Heater (Space)	HSPF	5.11
Electric Water Heater (Space)	HSPF	2.73
Cooling:		
Electric Evaporative Cooling	EER	30
Gas Absorption Cooler	COP	0.40
Shared Chiller	kW/ton	0.7
Water Heating:		
Heat Pump	COP	2.00
Instantaneous Electric	EF	0.87
Instantaneous Gas	EF	0.75

[54] (Informative Note) For service hot water provided by a boiler, use the efficiencies for Heating Boiler.

TABLE 4.5.2(4) Default Values for Mechanical System Efficiency (not Age-based) [(a)]

Mechanical Systems	Units	Rating
Solar (Use SRCC Adjustment Procedures)	EF	2.00
(a) Exception: Where the labeled equipment efficiency exists for the specific piece of existing equipment, the labeled efficiency shall be used in lieu of these minimum input constraints.		

Table 4.5.2(5) Default Eae Values

System Type	Eae
Oil boiler	330
Gas boiler (serves one unit)	170
Gas boiler (shared, in-unit baseboard)	220
Gas boiler (shared, in-unit WLHP)	265
Gas boiler (shared, in-unit fan coil)	438
Oil furnace	439 + 5.5 * Capacity (kBtu/h)
Gas furnace	149 + 10.3 * Capacity (kBtu/h)

4.6. Existing Home Retrofit Savings. Energy savings for Existing Home Retrofits shall be determined by comparing a Baseline Existing Home Model with an Improved Home Model in accordance with the provisions of this section.

4.6.1. Baseline Existing Home. The Baseline Existing Home Model for the purposes of determining the energy savings of an Existing Home Retrofit shall be the original configuration of the existing home, including the full complement of lighting, appliances and residual miscellaneous energy use as specified by Tables 4.2.2.5(1) and 4.2.2.5(2). The energy use of these end uses in the Baseline Existing Home Model shall be based on the original home configuration following the provision of Section 4.2.2.5.2.

4.6.1.1. Where multiple appliances of the same type exist in the original configuration of the existing home, the same number of those appliance types shall be included in the Baseline Existing Home Model.

4.6.1.2. Where a standard appliance as defined by Tables 4.2.2.5(1) and 4.2.2.5(2) does not exist in the original configuration of the existing home, the standard default energy use and Internal Gains as specified by Table 4.2.2(3) for that appliance shall be included in the Baseline Existing Home Model.

4.6.2. Improved Home. The Improved Home Model for the purpose of determining the energy savings of an Existing Home Retrofit shall be the existing home's configuration including all energy improvements to the original home and including the full complement of lighting, appliances and residual miscellaneous energy use contained in the home after all energy improvements have been implemented.

4.6.2.1. Where an existing appliance[55] is replaced with a new appliance as part of the improvement, but the existing appliance is not removed from the property, both the new and existing appliance shall be included in the Improved Home Model.

4.6.2.2. Where a standard appliance as defined by Tables 4.2.2.5(1) and 4.2.2.5(2) does not exist in the improved configuration of the existing home, the standard default energy use and Internal Gains as specified by Table 4.2.2(3) for that appliance shall be included in the Improved Home Model.

4.6.2.3. Improvements in lighting and appliance energy use in the Improved Home Model shall be calculated in accordance with Section 4.2.2.5.2.

4.6.3. Standard Operating Conditions.

4.6.3.1. Both the Baseline Existing Home Model and Improved Home Model shall be configured and modeled in accordance with the Rated Home specifications of Table 4.2.2(1). The configuration of the Baseline Existing Home Model shall not violate the specified input constraints in Table 4.6.3(1).

Table 4.6.3(1) Baseline Existing Home Input Constraints

Equipment Constraints [(a)]	**Minimum Value**
Forced-air furnace, AFUE	72%
Hot water / steam boiler, AFUE	60%
Heat Pump, HSPF	6.5
Heat Pump, SEER	9.0
Central air conditioner, SEER	9.0
Room air conditioner, EER	8.0
Gas-fired storage water heater, EF	0.50
Oil-fired storage water heater, EF	0.45
Electric storage water heater, EF	0.86
Enclosure Constraints (including air film conductances)	**Maximum U-Factor**
Wood-frame wall	0.222
Masonry wall	0.250
Wood-frame ceiling with attic (interior to attic space)	0.286
Unfinished roof	0.400
Wood-frame floor	0.222
Single-pane window, wood frame	0.714
Single-pane window, metal frame	0.833
(a) Exception: Where the labeled equipment efficiency exists for the specific piece of existing equipment, the labeled efficiency shall be used in lieu of these minimum input constraints.	

4.6.3.2. Air Distribution Systems.

55 (Informative Note) For example, refrigerator.

4.6.3.2.1. In cases where the air distribution system leakage is not measured in the original Baseline Existing Home Model, the ducts shall be modeled in the spaces in which they are located and the air distribution system leakage to outdoors at 25 Pascal pressure difference shall be modeled in both the Baseline Existing Home Model and the Improved Home Model as 0.10 times the CFA of the home split equally between the supply and return side of the air distribution system with the leakage distributed evenly across the duct system.

Exception: If the air handler unit and a minimum of 75% of its duct system are entirely within the Conditioned Space Volume, the air distribution system leakage to outdoors at 25 Pascal pressure difference shall be modeled in both the Baseline Existing Home Model and the Improved Home Model as 0.05 times the CFA of the home, split equally between the supply and return side of the air distribution system with the leakage distributed evenly across the duct system.

4.6.3.2.2. In cases where the air distribution system leakage is measured:

4.6.3.2.2.1. For the Baseline Existing Home Model, the ducts shall be modeled in the spaces in which they are located and the air distribution system leakage to outdoors at 25 Pascal pressure difference shall be modeled as the lesser of the measured air distribution system leakage to outdoors at 25 Pascal pressure difference in the original Baseline Existing Home Model or 0.24 times the CFA of the home, either split evenly between the supply and return side of the air distribution system or as measured separately with the leakage distributed evenly across the duct system.

4.6.3.2.2.2. For the Improved Home Model, the ducts shall be modeled in the spaces in which they are located and the air distribution system leakage to outdoors at 25 Pascal pressure difference shall be set equal to the measured air distribution system leakage to outdoors at 25 Pascal pressure difference in the Improved Home Model, either split evenly between the supply or return side of the air distribution system or as measured separately with the leakage distributed evenly across the duct system.

4.6.3.3. Both the Baseline Existing Home Model and the Improved Home Model shall be subjected to the operating conditions specified by Section 4.4.

4.6.4. Energy Savings Calculation.

4.6.4.1. Energy units used in the calculation of energy savings shall be the total Dwelling Unit energy use of all fuels (kWh_{tot}) calculated in accordance with Equation 4.6-1.

$$kWh_{tot} = kWh_{elec} + kWh_{eq} \quad \textbf{(Eq. 4.6-1)}$$

where

kWh_{tot} = total Dwelling Unit energy use of all fuels used by the home

kWh_{elec} = Dwelling Unit electric energy used by the home

kWh_{eq} = Dwelling Unit fossil fuel energy used by the home converted to equivalent electric energy use in accordance with Equation 4.1-3

4.6.4.2. Dwelling Unit energy savings (kWh_{tot}) shall be calculated as the difference between the total Dwelling Unit energy use (kWh_{tot}) of the Baseline Existing Home Model and the total Dwelling Unit energy use (kWh_{tot}) of the Improved Home Model.

4.6.4.3. The energy savings percentage of the retrofit shall be calculated as the Dwelling Unit total energy savings (kWh_{tot}) as determined by Section 4.6.4.2 divided by the Dwelling Unit total energy use (kWh_{tot}) of the Baseline Existing Home Model.

4.7. Economic Cost Effectiveness. If Ratings are conducted to evaluate energy saving improvements to the home for the purpose of an energy improvement loan or energy efficient mortgage, indicators of economic cost effectiveness shall use present value costs and benefits, which shall be calculated in accordance with Equations 4.7-1 and 4.7-2.

$$LCC_E = P1*(1^{st}\text{ Year Energy Costs}) \quad \text{(Eq. 4.7-1)}$$

$$LCC_I = P2*(1^{st}\text{ Cost of Improvements}) \quad \text{(Eq. 4.7-2)}$$

where:
LCC_E = Present Value Life Cycle Cost of Energy
LCC_I = Present Value Life Cycle Cost of Improvements
P1 = Ratio of Life Cycle energy costs to the 1^{st} year energy costs
P2 = Ratio of Life Cycle Improvement costs to the first cost of improvements

Present value life cycle energy cost savings shall be calculated as follows:

$$LCC_S = LCC_{E,b} - LCC_{E,i} \quad \text{(Eq. 4.7-3)}$$

where:
LCC_S = Present Value Life Cycle Energy Cost Savings
$LCC_{E,b}$ = Present Value LCC of energy for **baseline** home configuration
$LCC_{E,i}$ = Present Value LCC of energy for **improved** home configuration

Standard economic cost effectiveness indicators shall be calculated as follows:

$$SIR = (LCC_S) / (LCC_I) \quad \text{(Eq. 4.7-4)}$$

$$NPV = LCC_S - LCC_I \quad \text{(Eq. 4.7-5)}$$

where:
SIR = Present Value Savings to Investment Ratio
NPV = Net Present Value of Improvements

4.7.1. Calculation of Ratio Parameters. The ratios represented by parameters P1 and P2 shall be calculated in accordance with Equations 4.7-6a through 4.7-8d.[56]:

$$P1 = 1/(DR-ER)*(1-((1+ER)/(1+DR))\text{^}nAP) \quad \text{(Eq. 4.7-6a)}$$

[56] (Informative Reference) Duffie, J.A. and W.A. Beckman, 1980. *Solar Engineering of Thermal Processes*, pp. 381-406, John Wylie & Sons, Inc., New York, NY.

or if DR = ER then

P1 = nAP / (1+DR) **(Eq. 4.7-6b)**

where:

P1 = Ratio of Present Value Life Cycle Energy Costs to the 1st year Energy Costs
DR = Discount Rate as prescribed in Section 4.7.2
ER = Energy Inflation Rate as prescribed in Section 4.7.2
nAP = number of years in Analysis Period as prescribed in Section 4.7.2

$P2 = DnPmt + P2_A + P2_B + P2_C - P2_D$ **(Eq. 4.7-7)**

where:

P2 = Ratio of Life Cycle Improvement Costs to the first cost of improvements
DnPmt = Mortgage down payment rate as prescribed in Section 4.7.2
$P2_A$ = Mortgage cost parameter
$P2_B$ = Operation & Maintenance cost parameter
$P2_C$ = Replacement cost parameter
$P2_D$ = Salvage value cost parameter

$P2_A$ = (1-DnPmt)*(PWFd/PWFi) **(Eq. 4.7-8a)**

where:

PWFd = Present Worth Factor for the discount rate = 1/DR*[1-(1/(1+DR)^nAP)]
PWFi = Present Worth Factor for the mortgage rate = 1/MR*[1-(1/(1+MR)^nMP)]
DR = Discount Rate as prescribed in Section 4.7.2
MR = Mortgage Interest Rate as prescribed in Section 4.7.2
nAP = number of years of the Analysis Period as prescribed in Section 4.7.2
nMP = number of years of the Mortgage Period

$P2_B$ = MFrac*PWinf **(Eq. 4.7-8b)**

where:

MFrac = annual O&M costs as a fraction of first cost of improvements[57]
PWinf = ratio of present worth discount rate to present worth general inflation rate
= 1/(DR-GR)*{1-[((1+GR)/(1+DR))^nAP]}
or if DR = GR then
= nAP/(1+DR)
GR = General Inflation Rate as prescribed in Section 4.7.2

$P2_C$ = Sum {1/[(1+(DR-GR))^(Life*i)]} for i=1, n **(Eq. 4.7-8c)**

[57] (Informative Note) The maintenance fraction includes all incremental costs over and above the operating and maintenance cost of the "standard" measure. Where components of a system have various lifetimes, the longest lifetime is allowed to be used and the components with shorter lifetimes are allowed to be included as a maintenance cost at the present value of their future maintenance cost. The maintenance fraction is also allowed to be used to represent the degradation in performance of a given system. For example, photovoltaic (PV) systems have a performance degradation of about 0.5% per year and this value can be added to the maintenance fraction for PV systems to accurately represent this phenomenon in this cost calculation procedure.

where:
i = the i^{th} replacement of the improvement
Life = the expected service life of the improvement

$P2_D$ = RLFrac / ((1+DR)^nAP) **(Eq. 4.7-8d)**

where:
RLFrac = Remaining Life Fraction following the end of the analysis period

4.7.2. Standard Economic Inputs. The economic parameter values used in the cost effectiveness calculations specified in Section 4.7.1 shall be determined in accordance with Sections 4.7.2.1 through 4.7.2.10.[58]

4.7.2.1. General Inflation Rate (GR) shall be the greater of the 5-year and the 10-year Annual Compound Rate (ACR) of change in the Consumer Price Index for Urban Dwellers (CPI-U) as reported by the U.S. Bureau of Labor Statistics,[59] where ACR shall be calculated in accordance with Equation 4.7-9:

ACR = [(endVal)/(startVal)]^[1.0/((endYr)-(startYr))]-1.0 **(Eq. 4.7-9)**

where:
ACR = Annual Compound Rate of change
endVal = Value of parameter at end of period
startVal = Value of parameter at start of period
endYr = Year number at end of period
startYr = Year number at start of period

4.7.2.2. Discount Rate (DR) shall be equal to the General Inflation Rate plus 2%.

4.7.2.3. Mortgage Interest Rate (MR) shall be defaulted to the greater of the 5-year and the 10-year average of simple interest rate for fixed rate, 30-year mortgages computed from the Primary Mortgage Market Survey (PMMS) as reported by Freddie Mac unless the Mortgage Interest Rate is specified by a program or mortgage lender, in which case the specified Mortgage Interest Rate shall be used. The Mortgage Interest Rate used in the cost effectiveness calculation shall be disclosed in reporting results.

4.7.2.4. Down Payment Rate (DnPmt) shall be defaulted to 10% of 1^{st} cost of improvements unless the down payment rate is specified by a program or mortgage lender, in which case the specified down payment rate shall be used. The down payment rate used in the cost effectiveness calculation shall be disclosed in reporting results.

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[58] (Informative Note) RESNET shall annually publish Standard Economic Input values for the General Inflation Rate (GI), Discount Rate (DR), Mortgage Interest Rate (MR), Down Payment Rate (DnPmt) and Energy Inflation Rate (ER) determined in accordance with this section that can be used by Approved economic calculation tools.
[59] (Informative Reference) http://www.bls.gov/CPI/#tables

4.7.2.5. Energy Inflation Rate (ER) shall be the greater of the 5-year and the 10-year Annual Compound Rate (ACR) of change in the Bureau of Labor Statistics, Table 3A, Housing, Fuels and Utilities, Household Energy Index[60] as calculated using Equation 4.7-9.

4.7.2.6. Mortgage Period (nMP) shall be defaulted to 30 years unless a mortgage finance period is specified by a program or mortgage lender, in which case the specified mortgage period shall be used. The mortgage period used in the cost effectiveness calculation shall be disclosed in reporting results.

4.7.2.7. Analysis Period (nAP) shall be 30 years.

4.7.2.8. Remaining Life Fraction (RLFrac) shall be calculated in accordance with Equation 4.7-10.

RLFrac = (nAP/Life) – [Integer (nAP/Life)] **(Eq. 4.7-10)**

or if Life > nAP then

RLFrac = (Life-nAP) / nAP

where:

Life = useful service life of the improvement(s)

4.7.2.9. Improvement Costs. The improvement cost for Energy Conservation Measures (ECMs) shall be included on the Economic Cost Effectiveness Report.

4.7.2.9.1. For New Homes the improvement costs shall be the full installed cost of the improvement(s) less the full installed cost associated with the minimum provisions of the energy code or standard in effect where the building is located less any financial incentives that accrue to the home purchaser.

4.7.2.9.2. For Existing Homes the improvement costs shall be the full installed cost of the improvement(s) less any financial incentives that accrue to the home purchaser.

4.7.2.10. Measure Lifetimes. The ECM service life shall be included on the Economic Cost Effectiveness Report. Annex X of this Standard provides informative guidelines for service lifetimes of a number of general categories of ECMs.

5. Certification and Labeling. This section establishes minimum uniform standards for certifying and labeling home energy performance using the Energy Rating Index. These include minimum requirements of the Energy Rating process, standard methods for estimating energy use, energy cost and pollution emission savings, minimum reporting requirements, and specification of the types of Ratings that are performed in accordance with this Standard.

5.1. Rating Requirements.

[60] (Informative Reference) Table 3A from detailed reports listed at http://www.bls.gov/cpi/cpi_dr.htm

5.1.1. General. The Energy Rating for a home shall be determined in accordance with Sections 5.1.1.1 through 5.1.1.4.

5.1.1.1. For an existing home, required data shall be collected on site.

5.1.1.2. For a new, to-be-built home, the procedures of Section 4.5 shall be used to collect required data.

5.1.1.3. The collected data shall be used to estimate the annual Purchased Energy consumption for heating, cooling and water heating, lighting and appliances for both the Rated Home and the Reference Home as specified by Section 4.2.

5.1.1.4. Estimates completed using Sections 5.1.1.3 shall comply with Sections 5.1.1.4.1 through 5.1.1.4.3.

5.1.1.4.1. All estimates shall assume the standard operating conditions of Section 4.4.

5.1.1.4.2. All estimates shall be based on the Minimum Rated Features of Section 4.5.

5.1.1.4.3. All estimates shall be calculated using an Approved Software Rating Tool.

5.1.2. Savings Estimates.

5.1.2.1. Energy Cost Savings. Where determined, the energy cost savings for the Rated Home shall be calculated in accordance with Sections 5.1.2.1.1 and 5.1.2.1.2.

5.1.2.1.1. Energy Prices. Energy costs for all homes shall be calculated using state-wide, Revenue-Based Price rate data published annually by the U.S. Department of Energy (DOE), Energy Information Administration (EIA).[61]

5.1.2.1.2. Energy Cost Savings. Energy cost saving estimates of the Rated Home[62] for Confirmed, Sampled, and Projected Ratings shall be calculated in accordance with Sections 5.1.2.1.2.1 through 5.1.2.1.2.4.

5.1.2.1.2.1. Energy Rating Reference Home energy costs shall be determined by fuel type, applying the energy price rates to the individual fuel types of the Energy Rating Reference Home.

5.1.2.1.2.2. Rated Home energy costs shall be determined by fuel type, applying the same energy price rates used for the Energy Rating Reference Home.

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[61] (Informative Note) RESNET will compile and publish state-wide, revenue-based electricity price data that can be used in accordance with this section by Approved Software Rating Tools for the calculation of electricity costs.

[62] (Informative Note) Depending on the metering configuration for the Dwelling Unit, the energy cost savings for the Rated Home may be realized by the occupant or by the building owner.

5.1.2.1.2.3. Estimated energy cost savings with respect to the Energy Rating Reference Home shall be the difference between the estimated energy costs for the Energy Rating Reference Home and the estimated energy costs for the Rated Home.

5.1.2.1.2.4. Estimated energy cost savings with respect to the Typical Existing Home shall be determined in accordance with Sections 5.1.2.1.2.4.1 and 5.1.2.1.2.4.2.

5.1.2.1.2.4.1. For each fuel type, the Energy Rating Reference Home costs shall be multiplied by 1.3 to determine the Typical Existing Home estimated energy costs by fuel type.

5.1.2.1.2.4.2. Estimated energy cost savings with respect to the Typical Existing Home shall be the difference between the estimated energy costs of the Typical Existing Home and the estimated energy costs of the Rated Home.

5.1.2.2. Pollution Emission Savings. Where determined, the pollution emission savings for the Rated Home shall be calculated in accordance with Sections 5.1.2.2.1 and 5.1.2.2.2.

5.1.2.2.1. Pollution Emissions. Pollution emissions for all homes shall be calculated in accordance with Sections 5.1.2.2.1.1 and 5.1.2.2.1.2.

5.1.2.2.1.1. For electricity use, data for the sub-region annual total output emission rates published by Environmental Protection Agency's 2012 eGrid database[63] for electricity generation shall be used to calculate emissions.[64]

5.1.2.2.1.2. For fossil fuel use, pollution emissions shall be calculated using the emission factors given in Table 5.1.2(1).

Table 5.1.2(1) National Average Emission Factors for Household Fuels[65]

Fuel Type	Units	MBtu per Unit	CO_2 lb/MBtu	NOx lb/MBtu	SO_2 lb/MBtu
Natural Gas	Therm	0.1000	117.6	93.0	0.0000
Fuel Oil #2	Gallon	0.1385	159.4	127.8	0.5066
Liquid Petroleum Gas (LPG)	Gallon	0.0915	136.4	153.4	0.0163

[63] (Informative Reference) http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html
[64] (Informative Note) RESNET will compile and publish annual total output pollution rate data for NOx, SO_2 and CO_2 in accordance with the provisions of this section that can be used by Approved Software Rating Tools for the calculation of emissions.
[65] (Informative Note) Developed from the U.S. DOE National Impact Analysis AHAM2 report (appendix 15A) http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/aham2_dfr_app-15a_environmentalemissionfactors_2011-04-13.pdf

5.1.2.2.2. Pollution Emission Savings. Estimated pollution emission savings for the Rated Home shall be calculated in accordance with Sections 5.1.2.2.2.1 through 5.1.2.2.2.3.

5.1.2.2.2.1. The Energy Rating Reference Home pollution emissions shall be determined by fuel type by applying the pollution emissions determined in accordance with Section 5.1.2.2.1 to the individual fuel types of the Energy Rating Reference Home.

5.1.2.2.2.2. The Rated Home pollution emissions shall be determined by fuel type by applying the same pollution emission data used for the Energy Rating Reference Home in Section 5.1.2.2.2.1 above.

5.1.2.2.2.3. For Confirmed, Sampled and Projected Ratings, estimated pollution emission savings shall be calculated in accordance with Sections 5.1.2.2.2.3.1 and 5.1.2.2.2.3.2.

5.1.2.2.2.3.1. Estimated pollution emission savings with respect to the Energy Rating Reference Home shall be the difference between the pollution emissions of the Energy Rating Reference Home and the pollution emissions of the Rated Home.

5.1.2.2.2.3.2. Estimated pollution emission savings with respect to the Typical Existing Home shall be determined in accordance with Sections 5.1.2.2.2.3.2.1 and 5.1.2.2.2.3.2.2.

5.1.2.2.2.3.2.1. For each fuel type, multiply the Energy Rating Reference Home pollution emissions by 1.3 to determine the Typical Existing Home pollution emissions by fuel type.

5.1.2.2.2.3.2.2. Estimated pollution emission savings with respect to the Typical Existing Home shall be the difference between the pollution emissions of the Typical Existing Home and the pollution emissions of the Rated Home.

5.1.3. Reports. All reports generated by an Approved Software Rating Tool shall, at a minimum, contain the information specified by Sections 5.1.3.1 through 5.1.3.6.

5.1.3.1. The property location, including city, state, zip code and either the street address or the Community Name and Plan Name for the Rating.

5.1.3.2. The name of the Certified Rater conducting the Rating.

5.1.3.3. The name of the Approved Rating Provider under whose auspices the Certified Rater is certified.

5.1.3.4. The date the Rating was conducted.

5.1.3.5. The name and version number of the Approved Software Rating Tool used to determine the Rating.

5.1.3.6. The following statement in no less than 10-point font, "The Energy Rating Disclosure for this home is available from the Approved Rating Provider." At a minimum, this statement shall also include the Approved Rating Provider's mailing address and phone number.

5.1.4. Rating Types. There shall be four Rating types in accordance with Sections 5.1.4.1 through 5.1.4.45.

5.1.4.1. Confirmed Rating. A Rating type that encompasses one individual Dwelling Unit and is conducted in accordance with Sections 5.1.4.1.1 through 5.1.4.1.33.

5.1.4.1.1. All Minimum Rated Features of the Rated Home shall be verified through inspection and testing in accordance with Section 4.5.

5.1.4.1.2. All verified Minimum Rated Features of the Rated Home shall be entered into the Approved Software Rating Tool that generates the Energy Rating. The Energy Rating shall report the Energy Rating Index that comports with these inputs.

5.1.4.1.3. Confirmed Ratings shall be subjected to Quality Assurance requirements adopted by an Approved Rating Provider.

5.1.4.2. Projected Rating. A Rating type that encompasses one individual Dwelling Unit and is conducted in accordance with Sections 5.1.4.2.1 through 5.1.4.2.6.

5.1.4.2.1. All Minimum Rated Features of the Rated Home shall be determined from architectural drawings, Threshold Specifications, and the planned location and orientation for a new home or from a site audit and Threshold Specifications for an existing home that is to be improved. For a new home, if the proposed orientation is unknown, the home shall be analyzed facing each of the four cardinal directions, North, South, East and West, and the orientation resulting in the largest Energy Rating Index shall be used.

5.1.4.2.2. Projected Ratings shall use either the envelope leakage rate specified as the required performance by the construction documents, code or program requirements, the site-measured envelope leakage rate, or the air exchange rate specified for the Energy Rating Reference Home in Table 4.2.2(1).

5.1.4.2.3. Projected Ratings shall use either the Distribution System Efficiency specified as the required performance by the construction documents, code or program requirements, the site-measured Distribution System Efficiency, or the thermal Distribution System Efficiency value specified for the Energy Rating Reference Home in Table 4.2.2(1).

5.1.4.2.4. Projected Ratings shall use either the Ventilation airflow specified as the required performance by the construction documents, code or program requirements, the site-measured Ventilation airflow, or the Ventilation airflow specified for the Energy Rating Reference unit in Table 4.2.2(1).

5.1.4.2.5. The Minimum Rated Features of Rated Homes that were determined in Sections 5.1.4.2.1 through 5.1.4.2.4 shall be entered into the Approved Software Rating Tool that generates the Energy Rating. The Energy Rating shall report the Energy Rating Index that comports with these inputs.

5.1.4.2.6. Projected Rating reports shall contain the following text in no less than 14-point font at the top of the first page of the report: "Projected Rating Based on Plans – Field Confirmation Required."

5.1.4.3. Sampled Ratings for Detached Dwelling Units. A Rating type that encompasses a set of Dwelling Units that is conducted in accordance with Sections 5.1.4.3.1 through 5.1.4.3.3. Sampled Ratings are only permitted if Approved for use by the authority having jurisdiction.

5.1.4.3.1. For the set of Rated Homes, all Minimum Rated Features shall be field-verified through inspection and testing of a single Dwelling Unit in the set, or distributed across multiple Dwelling Units in the set, in accordance with Approved requirements[66].

5.1.4.3.2. The Threshold Specifications from the Worst-Case Analysis for the Minimum Rated Features of the set of Rated Homes shall be entered into the Approved Software Rating Tool that generates the Energy Rating. The Energy Rating shall report the Energy Rating Index that comports with these inputs.

5.1.4.3.3. Sampled Ratings shall be subjected to Quality Assurance requirements adopted by an Approved Rating Provider.

5.1.4.4. Sampled Ratings for Attached Dwelling Units. A Rating type that encompasses a set of Dwelling Units that is conducted in accordance with Sections **Error! Reference source not found.** through **Error! Reference source not found.**. Sampled Ratings are only permitted if Approved for use by the authority having jurisdiction.

5.1.4.4.1. Selecting unit types. A Projected Rating shall be performed on each unique Dwelling Unit type, in accordance with Section 5.1.4.2. Dwelling Units with the same construction type, same envelope systems, same number of Bedrooms, same number of stories within the unit, same window area (±10%), same Conditioned Floor Area (±10%, not to exceed ±100 ft2), and same ceiling height (±0.5 ft) are permitted to be the same unit type. Dwelling Units that satisfy these criteria, but differ in other criteria, are not required to be modeled as the same unit type.

[66] (Informative Note) Section 600 of the RESNET *Mortgage Industry National Home Energy Rating Standards* or equivalent may be used as criteria for inspection and testing Minimum Rated Features of a sample set of Rated Homes.

5.1.4.4.2. Worst-case Configuration. For each unique Dwelling Unit type, the Threshold Specifications resulting from the Worst-Case Analysis for the Minimum Rated Features of that Dwelling Unit type shall be entered into the Approved Software Rating Tool that generates the Energy Rating. The worst-case configuration of that unit type must then be determined using the various boundary conditions, orientations, and levels within the building to determine the worst-case configuration that results in the largest Energy Rating Index for that Dwelling Unit type. The Projected Rating for each unique Dwelling Unit type must be based on this Worst-Case Analysis and configuration. This Projected Rating then applies to all Dwelling Units of that same unit type, regardless of the actual exposure, orientation, level, or features of the actual Dwelling Unit.

5.1.4.4.2.1. Exception: A Dwelling Unit type is permitted to have a subtype, if boundary conditions, orientation, or level within the building results in a change to the Energy Rating Index of the Dwelling Unit type. The additional Projected Rating for the subtype then applies to all Dwelling Units of the same type and configuration of that subtype.

5.1.4.4.3. Threshold Specifications. In each Projected Rating, values for envelope leakage rate, Distribution System Efficiency, and Ventilation airflow, shall be normalized by volume or square footage and entered into the Approved Software Rating Tool that generates the Energy Rating. The Energy Rating shall report the Energy Rating Index that comports with these inputs. These values are permitted to differ by Dwelling Unit type. If applying Sampling to inspections or testing is permitted by the authority having jurisdiction, these values are the Threshold Specifications that establish the limits for Failures for each Sampled Feature. These values are permitted to be revised based upon the results of inspections or testing in accordance with Section **Error! Reference source not found.**.

5.1.4.4.4. Verification. All Minimum Rated Features for each unit shall be verified through inspection and testing, in accordance with Section 4.5.

5.1.4.4.4.1. Exception: If applying Sampling to inspections or testing is permitted by the authority having jurisdiction, each instance of each Sampled Feature is not required to be directly verified. For the set of Attached Dwelling Units, all Minimum Rated Features shall be field-verified through inspection and testing of a single Dwelling Unit in the set, or distributed across multiple Dwelling Units in the set, in accordance with Approved requirements.[67]

5.1.4.4.5. Application of Verification. Once all units in the Sampled Project have been verified, a Sampled Rating for each Dwelling Unit is created using the Projected Rating for that Dwelling Unit type and updating the Threshold Specifications of the Minimum Rated Features to reflect the poorest performance for each Minimum Rated Feature that has been verified through inspections and testing in that Dwelling Unit.

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[67] (Informative Note) Section 600 of the RESNET *Mortgage Industry National Home Energy Rating Standards* or equivalent may be used as criteria for inspection and testing Minimum Rated Features of a sample set of Rated Homes.

The final Energy Rating for this Dwelling Unit shall report the Energy Rating Index that comports with these inputs.

5.1.4.4.5.1. Exception: If applying Sampling to inspections or testing is permitted by the authority having jurisdiction, once verification is complete, the Threshold Specifications of the Minimum Rated Features in each Projected Rating must be updated in the Approved Software Rating Tool that generates the Energy Rating to reflect the worst performance values of each Sampled Feature that has been verified through inspections or testing.[68] The final Energy Rating for each Dwelling Unit type shall report the Energy Rating Index that comports with these inputs.

5.1.4.4.5.1.1. If any Failures occur for Minimum Rated Features, only the final performance is used when determining the worst performance value for that Minimum Rated Feature.

5.1.4.4.5.1.2. Every Dwelling Unit in the Sampled Project is represented by one of the Projected Ratings performed. A Sampled Rating for each unit is created using the final Energy Rating for that unit type and shall be assigned the same Energy Rating Index as determined by the final Rating for that unit type.

5.1.4.4.6. Labeling. Every unit in the Sampled Project shall be provided with a label in accordance with Section 5.3, which shall additionally contain one of the following statements as applicable:

5.1.4.4.6.1. "This unit has not been fully inspected or tested and has received a Sampled Rating in accordance with Section 5.1.4.4 of ANSI Standard 301."

5.1.4.4.6.2. "This unit has been fully inspected and tested and has received a Confirmed Rating in accordance with Section 5.1.4.1 of ANSI Standard 301."

5.1.4.4.7. Quality Assurance. Sampled Ratings shall be subjected to Quality Assurance requirements adopted by an Approved Rating Provider.

5.1.4.5. Threshold Ratings. A rating type that encompasses one individual Dwelling Units that is conducted in accordance with Sections 5.1.4.5.1 through 5.1.4.5.3.

5.1.4.5.1. The Threshold Specifications used in the Worst-Case Analysis of the Minimum Rated Features of Threshold Ratings shall be entered into the Approved Software Rating Tool that generates the Energy Rating. The Energy Rating shall report the Energy Rating Index that comports with these inputs.

[68] (Normative Note) A Sampled Rating, where a specific Minimum Rated Feature was directly verified in each unit and not verified using Sampling, is permitted to use the verified performance rather than the worst value for that feature.

5.1.4.5.2. All Minimum Rated Features shall be field-verified through inspection and testing of each Dwelling Unit in accordance with Section 4.4 to meet or exceed the Threshold Specifications. The field inspection and testing data shall not be used to modify Threshold Ratings.

5.1.4.5.3. Threshold Ratings shall be subjected to Quality Assurance requirements equivalent to Section 900 of the Mortgage Industry National Home Energy Rating Systems Standard.

5.1.5. Average Dwelling Unit Energy Rating Index. A single Energy Rating Index for a building with multiple units shall not be calculated by performing an Energy Rating on that building. If a single Energy Rating Index is needed to represent the residential portions of a building or a group of multiple Detached Dwelling Units for code compliance or other programmatic reason, that substitute Energy Rating Index must be calculated using an average of the Energy Rating Index values from all the individual Dwelling Units in the building or group. A Confirmed or Sampled Rating for each Dwelling Unit in the building or group shall be performed prior to this calculation.

5.2. Innovative Design Requests.

5.2.1. Petition. Approved Rating Providers can petition for adjustment to the Energy Rating Index for a Rated Home with features or technologies not addressed by Approved Software Rating Tools or this Standard. Innovative Design Requests (IDRs) shall be submitted to an Approved IDR authority and shall include, at a minimum, the following:

5.2.1.1. A Rating generated from Approved Software Rating Tool for Rated Home without feature(s) that cannot be modeled in the software tool.

5.2.1.2. Written description of feature(s) not included in Rating generated from software.

5.2.1.3. Manufacturer's technical or performance specifications for feature(s) not included in the Rating generated from the Approved Software Rating Tool.

5.2.1.4. Estimated energy impact. Calculations or simulation results estimating the energy impact of feature(s) not included in the Rating generated from an Approved Software Rating Tool and documentation to support the calculation methodology or describe the modeling approach used.

5.2.1.5. Estimated adjustment to Energy Rating Index. Calculations shall follow procedures of Sections 4.1 and 4.2.

5.2.2. Approval. IDRs shall be Approved on a case by case basis. The Approved IDR review authority shall accept or reject the IDR as submitted or request additional information. The Approved IDR review authority shall assign a unique identifier to each IDR and maintain a database of IDRs. If the IDR is Approved, the Approved Rating Provider is authorized to issue a supplemental report that adjusts the Energy Rating Index as Approved.

5.3. Labeling. Energy Rating labels shall, at a minimum, contain the information specified by Sections 5.3.1 through 5.3.6.

5.3.1. Real property physical address of the home, including city and state or territory

5.3.2. Energy Rating Index of the home

5.3.3. Projected annual site energy use of the home by fuel type

5.3.4. Projected annual energy cost of the home,[69] calculated in accordance with energy price rate provisions of Section 5.1.2.1.1

5.3.5. Name and address of the Approved Rating Provider

5.3.6. Date of the Energy Rating

[69] (Informative Note) The projected energy cost shown on the label might not reflect the projected energy costs to be paid by the occupant as metering configurations can result in certain energy costs and end-uses being paid by the building owner.

6. Normative References.

ACCA, "Manual B Balancing and Testing Air and Hydronic Systems", Air Conditioning Contractors of America, Arlington, VA.

ACCA, "Manual D Residential Duct Systems", [ANSI/ACCA 1 Manual D-2016], Air Conditioning Contractors of America, Arlington, VA.

ACCA, "Manual J Residential Load Calculation," 8th Edition, [ANSI/ACCA 2 Manual J-2016]. Air Conditioning Contractors of America, Arlington, VA.

ACCA, "Manual S Residential Heating and Cooling Equipment Selection", 2nd Edition, [ANSI/ACCA 3 Manual S-2014]. Air Conditioning Contractors of America, Arlington, VA.

ASHRAE *Handbook of Fundamentals*, 2017. American Society of Heating Refrigerating and Air Conditioning Engineers, Atlanta, GA.

ANSI/ASHRAE 62.2-2016, "Ventilation and Acceptable Indoor Air Quality in Low Rise Buildings." American Society of Heating, Refrigerating, and Air Conditioning Engineers, Atlanta, GA, 2016.

ANSI/CRRC S100-2016, "Standard Test Methods for Determining Radiative Properties of Materials," Cool Roof Rating Council, Oakland, CA. www.coolroofs.org

ANSI/RESNET/ICC 380-2019, "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" and ANSI Approved Addenda. Residential Energy Services Network, Oceanside, CA.

ASTM C177-13, "Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus." ASTM International, West Conshohocken, PA.

ASTM C518-17, "Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus." ASTM International, West Conshohocken, PA.

ASTM C976-96, "Thermal Performance of Building Assemblies by Means of a Calibrated Box." ASTM International, West Conshohocken, PA.

ASTM C1114-06(2013), "Standard Test Method for Steady-State Thermal Transmission Properties by Means of The Thin-Heater Apparatus." ASTM International, West Conshohocken, PA.

ASTM C1363-11, "Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus." ASTM International, West Conshohocken, PA.

CSA B55.1-12, (2012). "Test method for measuring efficiency and pressure loss of Drain Water Heat Recovery Units." CSA Group, Mississauga, Ontario, Canada L4W 5N6.

CSA B55.2-12, (2012). "Drain Water Heat Recovery Units." CSA Group, Mississauga, Ontario, Canada L4W 5N6.

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IECC, 2018 International Energy Conservation Code. International Code Council, 500 New Jersey Avenue, NW, Washington, DC.

IRC, 2018 International Residential Code. International Code Council, 500 New Jersey Avenue, NW, Washington, DC.

United States Congress, *National Appliance Energy Conservation Act (NAECA).* First passed in 1975 (Public Law 100-12) and amended in 1987 (Public Law 100-357), 1992 (Public Law 102-486) and 2005 (Public Law 109-58).

7. Informative References.

American National Standards Institute, (ANSI) http://www.ansi.com

Bureau of Labor Statistics, http://www.bls.gov/CPI/#tables

Bureau of Labor Statistics, Table 3A from detailed reports listed at http://www.bls.gov/cpi/cpi_dr.htm

Duffie, J.A. and W.A. Beckman, 1980. *Solar Engineering of Thermal Processes*, pp. 381-406, John Wylie & Sons, Inc., New York, NY.

Environmental Protection Agency, http://www.energystar.gov/index.cfm?c=clotheswash.pr_clothes_washers

Environmental Protection Agency, http://www.epa.gov/compliance/resources/publications/monitoring/caa/woodstoves/certifiedwood.pdf

International Code Council, http://www.iccsafe.org

RESNET, January 2013, *Mortgage Industry National Home Energy Rating Systems Standards.* Residential Energy Services Network, Oceanside CA.

Residential Energy Services Network, Inc., P.O. Box 4561, Oceanside, CA 92052-4561 (http://www.resnet.us)

Normative Appendix A

Insulation Grading

A-1. Insulation

In order to meet the requirements of a Grade I or Grade II insulation rating, the insulation material shall be installed in accordance with the minimum installation requirements of this Appendix and the requirements specified by ASTM standards C727, C1015, C1743, C1320, C1321 and ASTM C1848 as described below in the insulation grading section.

Installations not complying with the minimum installation requirements of this Appendix, the relevant ASTM standard for the type insulation, or not the Grade I or Grade II coverage requirements shall be considered Grade III installations. Grade III installations shall be recorded and shall be modeled as specified by Section 4.2.2.2.2 of this Standard.

A-1.1 Minimum General Installation Requirements:

PART 1 - Insulation shall be installed to manufacturers' recommendations.
PART 2 - No air spaces shall be allowed between different insulation types or systems.

Exception: When claiming the R-Value of an enclosed reflective airspace in accordance with the ASHRAE Handbook of Fundamentals, Chapter 26, table 3 or the ASHRAE 90.1-2016 Section A9-4 (or addendum ac to the 2013 edition) or ASTM C 1224.

PART 3 - Insulation shall be installed to the required density and thickness necessary to achieve the labeled R-Value.
PART 4 - Insulation shall fill around obstructions including, but not limited to, framing, blocking, wiring, pipes, etc. without substantial gaps or voids.

A-1.2 Minimum Specific Application Requirements:

1. Insulation installed in framed floor assemblies shall be in substantial and permanent contact with the subfloor.

   Exception: The floor framing-cavity insulation shall be permitted to be in contact with the topside of sheathing or continuous insulation installed on the bottom side of floor framing where combined with insulation that meets or exceeds the minimum wood frame wall R-Value in Table 402.1.2 of the International Energy Conservation Code (IECC) and that extends from the bottom to the top of all perimeter floor framing members.

   The cavity insulation between floor joists, beams or other horizontal floor supports that create cavities under the subfloor shall be permitted to be in direct contact with any additional continuous insulation attached to the underside of the horizontal supports. The combination of both cavity and continuous insulation shall meet or exceed the minimum required floor R value in Table 402.1.2 of the International Energy Conservation Code, (IECC). Instances of reflective insulation system installed beneath hydronic floors are not required to meet this standard.

2. For rim or band joist applications, insulation shall be in substantial and permanent contact with rim or band joist framing and tightly fitted to intersecting solid floor joists, wood i-joists or extend continuously through open web floor trusses; interior sheathing or air barrier is not required provided there is an air barrier on the exterior side or the insulation material is installed as an air barrier material.

3. Air permeable insulation installed in ventilated attics and vented sloped roofs shall have an effective air barrier (wind block, air chute, or eave baffle) securely fastened and installed at the eave or soffit edge vent of every cavity. The effective air barrier shall extend up and beyond the surface of the insulation or to the ridge vent.

A-1.3 Minimum Specific Material Requirements:

A-1.3.1 Insulated Sheathing:

1. If used as an air barrier, edges and joints shall be taped or otherwise air sealed in accordance with the manufacturer's recommendations.
2. Edges not supported directly on sheathing or framing shall be tightly fitted to one another without substantial gaps.
3. Sheathing shall be carefully fitted and taped or otherwise air sealed around obstructions in accordance with the manufacturer's recommendations.
4. When two or more layers of insulation are installed the joints shall be staggered. Only the joints of one of the layers shall be required to be taped or otherwise air sealed where that layer is designated to be an air-barrier.
5. Where used as an Approved water-resistive barrier (WRB), sheathing joints, Fenestration, and service penetrations shall be taped or otherwise air sealed in accordance with the manufacturer's installation instructions.

A-1.3.2 Fibrous Batt Insulation:

1. Insulation shall fill the cavity being insulated side to side, top to bottom.
2. Insulation shall be enclosed on all six sides with durable materials.

Exceptions:

a. Insulation installed in attics above ceilings shall not require an air barrier on the exterior side.
b. Insulation installed under floors directly above an unvented crawl space shall not require an air barrier on the exterior side.
c. Insulation installed in rim or band joists located in conditioned space shall not require an air barrier on the interior side.

d. Insulation installed on conditioned basement and crawlspace walls where an air barrier material meeting code requirements for exposed applications and tested in accordance with ASTM E2178 is installed on the interior side.

3. Faced batts shall be stapled to the face of the studs or side stapled to the studs with no buckling of the stapling tabs or the tabs shall be permitted to be left unstapled. Faced batt products without tabs and friction fit products shall not be required to be stapled when installed in walls. Compression of face stapled batts shall be graded in accordance with the criteria outlined in sections A-2.1.1.1, A-2.1.2.1, or A-2.1.3.
4. When side stapled, compression is permitted only along edges to the depth of the stapling tab.
5. Insulation shall be closely fitted around obstructions including, but not limited to, framing, blocking, wiring, pipes, etc. to avoid substantial gaps, voids or compression.

A-1.3.3 Blown or Sprayed Fibrous Loose Fill Insulation:

1. Insulation containment fabric or system that is side stapled shall not be stapled more than ½ inch back from the face of the stud.
2. Insulation shall be rolled or trimmed flat to allow installation and contact with interior sheathing or finish material.
3. Insulation shall fill the cavity being insulated, side to side, and top to bottom.
4. Blown insulation shall meet the manufacturer's stated recommendations for density and coverage in order to meet the required R value and to minimize or prevent settling.
5. Insulation shall be enclosed on all six sides with durable materials.

   Exceptions:
   a. Air permeable insulation installed on the top side of the ceiling in unconditioned attics shall not require an air barrier on the exterior.
   b. Insulation installed under floors that are directly above an unvented crawl space shall not require an air barrier on the exterior side.
   c. Insulation installed in rim or band joists located in conditioned space shall not require an air barrier on the interior side.

6. Insulation shall be installed around obstructions including, but not limited to, framing, blocking, wiring, pipes, etc. as to avoid substantial gaps, voids or compression.

A-1.3.4 Open-Cell Spray Polyurethane Foam (SPF) Insulation:

1. Installers shall meet the manufacturer's recommended training requirements and shall complete the online health and safety training for SPF provided by the Center for Polyurethanes Industry.
2. Spray foam shall be well-bonded to the substrate, including framing and sheathing.
3. Insulation, installed at a minimum thickness to be air impermeable per E2178 (air permeance less than 0.04 cfm/ft^2) and in-contact with the substrate shall be permitted to serve as the air barrier.
4. When insulation extends beyond the wall cavity it shall be trimmed to allow installation and contact with interior sheathing or finish material.

5. Insulation shall fill the cavity to within at least ½ inch of the face of the studs.

   Exception: The cavity fill requirement is met when the required R-Value is achieved using a thickness that is less than the cavity depth.

A-1.3.6 Closed-Cell Spray Polyurethane Foam (SPF) Insulation:

Installers shall meet the manufacturer's recommended training requirements and shall complete the online health and safety training for SPF provided by the Center for Polyurethanes Industry.

1. Spray foam shall be well-bonded to the substrate, including framing and sheathing.
2. Closed-cell insulation, installed at a minimum thickness of 1.5 inches and in contact with the substrate, shall be permitted to serve as a component of the continuous air barrier.

   Exception: Thicknesses less than 1.5 inches considered air-impermeable with appropriate ASTM E2178 data (air permeance less than 0.04 cfm/ft^2) from manufacturer data sheet or code evaluation report prepared by an organization accredited for product certification per ISO-17065 or other source approved by an authority having jurisdiction.

A-2. Insulation Grading

A-2.1 Grading Criteria for Batt, Loose-fill, Open and Closed Cell Polyurethane Spray Foam Insulation and Insulated Sheathing

A-2.1.1 Grade I (Minor Defects)

Shall meet ASTM-specified installation requirements in the applicable standards C1015, C1320 and ASTM C1848, and shall meet the following appropriate material installation grading requirements:

A-2.1.1.1 Batt or Loose-fill Insulation
When installing batt, or loose-fill insulation, no more than 2% of the total insulated area shall be compressed below the thickness required to attain the labeled R-Value or contain gaps or voids in the insulation. These areas shall not be compressed more than 3/4 inch of the specified insulation thickness in any given location. Voids extending from the interior to exterior of the intended insulation areas shall not be permitted.

A-2.1.1.2 Open-Cell Polyurethane Spray Foam Insulation (cavity not filled and not trimmed)
When installing open-cell polyurethane spray foam the average of all thickness measurements shall be greater than the specified thickness required to obtain the specified R-Value. No more than 2% of the insulated area shall contain voids or be more than ¾ inch below the specified thickness. The minimum installed thickness

shall not be less than 1 inch below the specified thickness at any point. Voids extending from the interior to the exterior of the intended insulation areas shall not be permitted.

A-2.1.1.3 Open-Cell Polyurethane Spray Foam Insulation (cavity filled and trimmed)
When installing open-cell polyurethane spray foam, no more than 2% of the total insulated area (cavity) shall be below the thickness required to attain the specified thickness or contain gaps or voids in the insulation. The minimum installed thickness shall not be less than 1/2 inch below the specified thickness at any point. Voids extending from the interior to exterior of the intended insulation areas shall not be permitted.

A-2.1.1.4 Closed-Cell Polyurethane Spray Foam
When installing closed-cell polyurethane spray foam the average of all thickness measurements shall be greater than the specified thickness required to obtain the specified R-Value. No more than 2% of the insulated area shall contain voids or be greater than ½ inch less than the specified thickness. The minimum installed thickness shall not be less than ¾ inch below the specified thickness at any point. Voids extending from the interior to exterior of the intended insulation areas shall not be permitted.

A-2.1.1.5 Insulated Sheathing
Insulated sheathing insulation installations meeting the minimum installation, application, and material requirements above. Voids exceeding 1/8" through interior to exterior of the intended insulation areas shall not be permitted. Joints and other gaps or separations in sheathing used as an air barrier, vapor retarder or drainage plane shall be taped or sealed.

A-2.1.2 Grade II (Moderate Defects)
Installations not complying with the minimum installation requirements in ASTM standards C1015, C1320, and ASTM C1848, and the appropriate Grade I material installation grading requirements shall be considered a Grade II or Grade III installation in accordance with their level of defect.

A-2.1.2.1 Batt or Loose-fill Insulation
When installing batt, or loose-fill insulation, no more than 15% of the total insulated area (cavity) shall be compressed or contain gaps or voids in the insulation. These areas shall not be missing or compressed more than 3/4 inch of the specified insulation thickness in any given location. Inset staples are allowed for batt insulation. Voids through interior to exterior of the intended insulation areas shall not be permitted.

A-2.1.2.2 Open-Cell Polyurethane Spray Foam Insulation (cavity not filled and not trimmed)
When installing open-cell polyurethane spray foam the average of all thickness measurements shall be greater than the specified thickness required to obtain the specified R-Value. No more than 15% of the insulated area shall contain voids. The

minimum thickness shall not be less than 3/4 inch below the specified thickness at any point. Voids extending from the interior to the exterior of the intended insulation areas shall not be permitted.

A-2.1.2.3 Open-Cell Polyurethane Spray Foam Insulation (cavity filled and trimmed)
When installing open-cell polyurethane spray foam, no more than 15% of the total insulated area (cavity) shall be below the thickness required to attain the specified thickness or contain gaps or voids in the insulation. The minimum installed thickness shall not be less than 1/2 inch below the specified thickness at any point. Voids extending from the interior to exterior of the intended insulation areas shall not be permitted.

A-2.1.2.4 Closed-Cell Polyurethane Spray Foam
When installing closed-cell polyurethane spray foam the average of all thickness measurements shall be greater than the specified thickness required to obtain the specified R-Value. No more than 15% of the insulated area shall contain voids. The minimum thickness shall not be less than 3/4 inch below the specified thickness at any point. Voids extending from the interior to exterior of the intended insulation areas shall not be permitted.

A-2.1.3 Grade III (Substantial Defects)
Installations not complying with the minimum installation requirements in ASTM standards C1015, C1320 and C1848, and the appropriate Grade I or Grade II material installation grading requirements shall be considered a Grade III installation.

Grade III installations shall be recorded and shall be modeled as specified by Section 4.2.2.2.2 of this Standard.

A-2.2 Structural Insulated Panels (SIPs) Grading Criteria

1. Sealing of panel joints shall meet the manufacturer's requirements. Where the manufacturer does not have specific joint sealing details SIPA's typical joint sealing details shall be used. SIPA details are available at www.sips.org.
2. Use spray foam to seal penetrations through the SIP panels.
3. Any damaged area shall be repaired.
4. All gaps and penetrations through SIPs including windows, doors, and foundation or roof connections shall be air-sealed with expanding foam compatible with the SIP materials.

A-2.2.1 Grade I (Minor Defects)
Shall meet the minimum installation requirements for SIP products above and the following requirements:

1. SIP panels shall be properly aligned and unsealed penetrations extending from the interior to exterior of the panels shall not be permitted.

2. 2% or less of the total area of the SIPS panels have damage which is unrepaired, including but not limited to cutouts for electrical boxes, pipes and other penetrations.

A-2.2.2 Grade II (Moderate to Frequent Defects)
Shall meet the minimum installation requirements for SIPS products above and the following:

1. Greater than 2% and less than 5% of the total area of the SIP panels have damage which is unrepaired, including but not limited to cutouts for electrical boxes, pipes and other penetrations.
2. SIP panels shall be properly aligned and unsealed penetrations extending from the interior to exterior of the panels shall not be permitted.

A-2.2.3 Grade III (Major Defects)
SIP panel installations not complying with the minimum installation requirements and Grade I or Grade II requirements above shall be considered a Grade III installation.

Grade III installations shall be recorded and shall be modeled as specified by Section 4.2.2.2.2 of this Standard.

A-2.3 Reflective/Radiant Grading Criteria

Regarding thermal performance claims or R-Values:

1. R-Value claims for the airspace adjacent to a reflective insulation product shall be based on average cavity depth (where not less than ½”), heat flow direction which represents the application (wall, ceiling or floor), temperature of the airspace surfaces relative to the specific wall assembly, location of the airspace in the assembly, and design climate conditions.
2. When utilizing R-Values claims for the airspace adjacent to a reflective insulation product, the airspace shall be a totally enclosed and unventilated cavity that minimizes airflow into or out of it in accordance with ASTM C727.
3. Where utilizing R-Values based on testing in accordance with ASTM C1224, the reflective insulation product shall be installed as tested. R-Value claims for the assembly including the airspace shall be based on ASTM C1224 or per the current FTC Rule 460 requirements. The assembly that is tested for thermal resistance shall be representative of the field assembly.
4. Reflective airspaces behind cladding or otherwise located to the exterior side of the air barrier layer for the assembly shall not claim R-Values based on having an airspace except where the cladding and the perimeter of the airspace creates a totally enclosed and unventilated cavity.

A-2.3.1 Reflective Insulation in Ceilings, Walls and Floors
Reflective insulation products include types with multiple layers, reflective bubble, and reflective foam – refer to the manufacturer’s instructions for the product’s installation details.

1. The products shall be permitted to be either face or side (inset) stapled and shall be permanently attached to the framing member;
2. When side or inset stapled, reflective insulation shall be installed at the depth in the cavity to attain the required airspace(s). Refer to manufacturer's installation details for the specific application, including required airspace dimensions. Where the cavity is partitioned to provide two or more airspaces that are each claimed for R-Value contribution, the attachment of the reflective material separating the spaces shall be installed against the framing without any gaps in order to minimize air leakage between the airspaces;
3. When face-stapled, the material width shall match the framing width (e.g. 16" wide material is used for 16" on-center framing).

   Exception: Nonstandard cavity widths.

4. When face-stapled, the staple tabs shall be aligned with the direction of the framing;
5. When reflective insulation is to serve as a vapor retarder, the tabs are over-lapped or taped when face-stapled. When inset stapled, the edges shall be attached to the sides, top and bottom of the framing.
6. Reflective insulation and radiant barriers (sheet type) materials shall not be laid directly on top of the attic floor or insulation materials installed above the ceiling.
7. Reflective insulation and radiant barriers installed under slabs shall not claim R-Values based on having an airspace.
8. Reflective airspaces behind cladding or otherwise located to the exterior side of the air barrier layer for the assembly shall not claim R-Values based on having an air-space except where the cladding and perimeter of the airspace creates a totally enclosed and unventilated cavity.

A-2.3.1.1 Grade I (Minor Defects)
Shall meet the minimum installation requirements in ASTM standard C727 and shall also the following area coverage requirements:

2% or less of the area is not insulated such that the building envelope exterior sheathing (wall) is visible from the building's interior.

A-2.3.1.2 Grade II (Moderate to Frequent Defects)
Shall meet the minimum installation requirements in ASTM standard C727 and shall also the following area coverage requirements:

Greater than 2% and less than 10% of the area which is available for insulation is not insulated such that the building envelope exterior sheathing (wall) is visible from the building's interior.

A-2.3.1.3 Grade III (Substantial Defects)
Installations not complying with the minimum installation requirements in ASTM standard C727 and Grade I or Grade II area coverage requirements above shall be considered a Grade III installation.

Grade III installations shall be recorded and shall be modeled as specified by Section 4.2.2.2.2 of this Standard.

A-2.3.2 Attic Radiant Barriers
Minimum Requirements:

1. Attic radiant barriers shall be installed with an airspace adjacent to the low emittance (metallic) surface(s);
2. When the radiant barrier only has one low emittance surface, it shall be on the bottom side (in the direction of the ceiling);
3. Attic and/or roof ventilation shall be maintained. Roof, gable and soffit vents shall not be covered.
4. The radiant barrier shall be installed on gable ends.
5. The radiant barrier shall be firmly secured.

Attic radiant barriers shall be permitted to be installed using one of the following three methods

RB Method 1: Deck applied – aluminum faced oriented strand board or plywood; radiant barriers applied in this manner shall be perforated.
RB Method 2: Draped – radiant barrier draped over the trusses or rafters;
RB Method 3; Truss applied – radiant barrier stapled to the bottom of the top cord of the roof truss or rafter.

A-2.3.2.1 Grade I (Minor Defects)
Shall meet the minimum installation requirements in ASTM C1743 and shall also meet the following area coverage requirements:

1. 2% or less of the roof is bare wood or does not include low-emittance.
2. 2% or less of the surface has contaminates, particles or ink on the surface (e.g. dirt, printing of product identification, etc.) reduces effectiveness.
3. Radiant barrier is installed to cover the face of the rafter (Method 3 only).

A-2.3.2.2 Grade II (Moderate to Frequent Defects)
Shall meet the minimum installation requirements in ASTM C1743 and shall also meet the following area coverage requirements:
.
1. 3% or greater and 10% or less of the roof is bare or does not include the radiant surface.
2. 3% or greater and 10% or less of the surface has contaminates, particles or printed information on the .
3. Radiant barrier is inset stapled (Method 3 only).

A-2.3.2.3 Grade III (Substantial Defects)
Installations not complying with the minimum installation requirements in ASTM C1743 and Grade I or Grade II area coverage requirements above shall be considered a Grade III installation.

Grade III installations shall be recorded and shall be modeled as specified by Section 4.2.2.2.2 of this Standard.

Additionally, radiant barrier installations which have the following issues shall be deemed to be Grade III:

1. Radiant barrier is not permanently attached;
2. Radiant barrier is not perforated (RB Method 1 only).

A-2.3.3 Interior Attic Radiation Control Coatings (IRCCs)
IRCC materials are a liquid applied with an emittance of 0.25 or less.

Application Requirements:

1. The IRCCS shall be in permanent contact with the underside of the roof deck and should cover the underside of all roof deck and gable surface s.
2. The coating shall render the application surface to an overall metallic finish that in some cases retains the texture characteristics of the wood surface.
3. The coating surface shall be dry to the touch.

A-2.3.3.1 Grade I (Minor Defects)
Shall meet the minimum installation requirements in ASTM C1321 and shall also meet the following area coverage requirements:

Less than 2% of the surface is bare wood or discolored.

A-2.3.3.2 Grade II (Moderate to Frequent Defects)
Shall meet the minimum installation requirements in ASTM C1321 and shall also meet the following area coverage requirements:

Greater than 2% and equal to or less than 10% of the surface is bare wood or discolored.

A-2.3.3.3 Grade III (Substantial Defects)
Installations not complying with the minimum installation requirements in ASTM C1321 and Grade I or Grade II area coverage requirements above shall be considered a Grade III installation.

Grade III installations shall be recorded and shall be modeled as specified by Section 4.2.2.2.2 of this Standard.

A-3. Normative References:

FTC Rule 460, 16 CFR Part 460, "Labeling and Advertising of Home Insulation: Trade Regulation Rule." Federal Trade Commission, Washington, D.C.

ANSI/ASHRAE 90.1-2016, "Energy Standard for Buildings Except of Low Rise Residential Buildings." American Society of Heating, Refrigerating, and Air Conditioning Engineers, Atlanta, GA, 2012.

ASHRAE *Handbook of Fundamentals*, 2017. American Society of Heating Refrigerating and Air Conditioning Engineers, Atlanta, GA.

ASTM Installation Standards for Building Insulation Products. ASTM International, West Conshohocken, PA.

ASTM C727: Standard Practice for Installation and Use of Reflective Insulation in Building Constructions

ASTM C1015 – 06 (2011)e1: Standard Practice for Installation of Cellulosic and Mineral Fiber Loose-Fill Thermal Insulation

ASTM C1224, "Standard Specification for Reflective Insulation for Building Applications." ASTM International, West Conshohocken, PA.

ASTM C1743 – 12: Standard Practice for Installation and Use of Radiant Barrier Systems (RBS) in Residential Building Construction

ASTM C1320 – 10 (2016): Standard Practice for Installation of Mineral Fiber Batt and Blanket Thermal Insulation for Light Frame Construction

ASTM C1321 - 15 Standard Practice for Installation and Use of Interior Radiation Control Coating Systems (IRCCS) in Building Construction

ASTM C1848 - 17a Standard Practice for Installation of High-Pressure Spray Polyurethane Foam Insulation for the Building Enclosure

IECC, 2018 International Energy Conservation Code. International Code Council, 500 New Jersey Avenue, NW, Washington, DC.

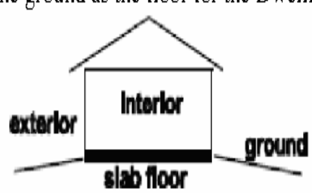
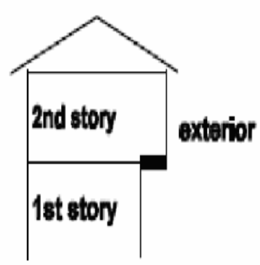
Normative Appendix B

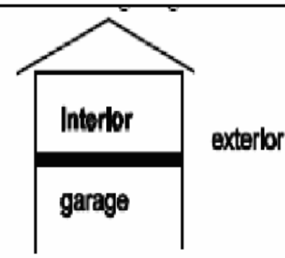
Inspection Procedures for Minimum Rated Features

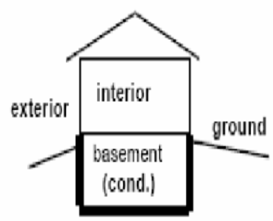
Contents

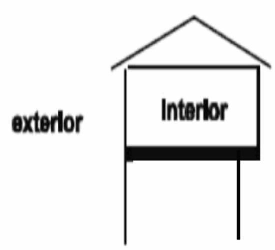
General		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Applies to relevant Minimum Rated Features (MRF) from Table 4.5.2(1)	Record field inspections and performance tests by digital/electronic means All records shall be kept for a minimum of 3 years	Clearly document the following: - The date and time of the inspection/test - The name of the Certified Rater, Approved Inspector, or Approved Tester conducting the inspection/test - The Dwelling Unit being inspected/tested containing sufficient detail to indicate the location of the inspection, including the address or unit number of the inspected/tested Dwelling Unit - If included in the Energy Rating and present in the Dwelling Unit, a minimum of one representative photo of items #2 (Wall Assembly); #3 (Roof/Ceiling Assembly); and either #11 (Heating Equipment), #12 (Cooling Equipment), or #14 (Service Hot Water Equipment) from Table 4.5.2(1) that reflect the reported data - If testing is conducted in the Dwelling Unit, a photo of the recorded test results or a report generated by automated software that communicates with the testing device showing the test result Each photo and/or report shall be time/date stamped and geotagged.

Building Element: Floor/Foundation Assembly		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Gross Area and perimeter	Measure floor/foundation dimensions	For floors and slabs, measure dimensions of floor to calculate area. For slab-on-grade, also calculate total perimeter and perimeter exposed to other conditioned spaces. For conditioned basements and crawlspaces, measure dimensions of walls and floor to calculate area. Divide walls into above and below grade sections. Dimensions shall be measured and rounded to the nearest ½ foot, and the square footage calculated and rounded to the nearest square foot. Dimensions shall use exterior measurements starting at the exterior finished surface of the outside wall. Openings to the floor below shall not be included in the square footage calculation, except for stairways; stairways and associated landings are counted as square footage on both the starting and ending levels. The "footprint" of protruding chimneys or bay windows shall not be included. The "footprint" of other protrusions like a cantilever when it includes finished floor area shall be included. For Detached Dwelling Units, the square footage of separate finished areas that are connected to the main body of the house by conditioned hallways or stairways shall be included. Each unique floor exposure, construction type, and R-Value combination shall be calculated separately.
Foundation type	Determine whether foundation is a crawlspace or basement, and if it meets the criteria for Conditioned Space Volume, Unconditioned Space Volume, Unrated Conditioned Space, and/or Infiltration Volume.	Use the definitions in Section 3 to determine whether a crawlspace or basement is Conditioned Space Volume, Unconditioned Space Volume, Unrated Conditioned Space, and/or Infiltration Volume.

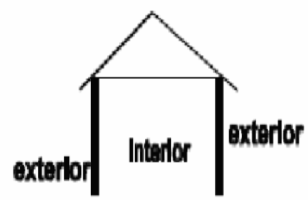
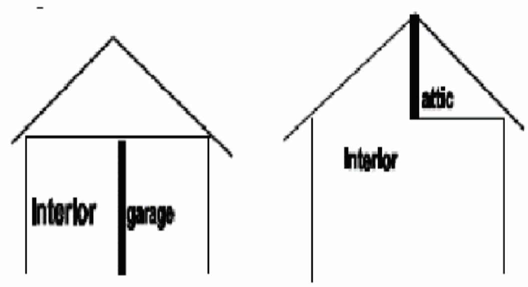
Building Element: Floor/Foundation Assembly		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Floor type	Identify floor over crawlspace	A crawlspace is a foundation condition with a vertical dimension between the floor joists and ground or slab that is 6 feet or less. Vented crawlspaces have some form of vent or louver in the crawlspace walls or are constructed in a manner such that air moves freely from outside the walls to inside the crawlspace. Unvented crawlspaces are constructed without any form of vents or louvers in the wall and are constructed to exclude air from outside the walls to inside the crawlspace. Unvented crawlspaces may also be Conditioned Space Volume.
	Identify slab-on-grade floor/foundation	A slab-on-grade is recognized by the absence of either a crawlspace or basement. A slab-on-grade is constructed by pouring a concrete slab directly on the ground as the floor for the Dwelling Unit. 
	Identify floor over full basement	A full basement has characteristics like a crawlspace, except that the clear vertical dimension is greater than 6 feet.
	Identify walkout basement	A walkout basement is a basement where a portion of the slab floor is on-grade and a portion is below grade.
	Identify floor over exterior space	A floor that extends horizontally beyond the story below and is exposed to the exterior underneath is considered floor to exterior. 
	Identify floor over garage	Identify floors over a garage.

Building Element: Floor/Foundation Assembly		
Rated Feature	**Task**	**On-Site Inspection Protocol**
		
	Identify floor of Attached Dwelling Unit over garage	Where the floor of an Attached Dwelling Unit is exposed to a garage space beneath it that is not shared with other Dwelling Units, that garage space shall be considered Unconditioned Space Volume. Otherwise, that floor of the Attached Dwelling Unit is facing one of the space types described in the next entry.
	Identify floor of Attached Dwelling Unit over Multifamily Buffer Boundary, Unrated Conditioned Space, Unrated Heated Space, or Non-Freezing Space	*Floor above Multifamily Buffer Boundary* – The space directly below the Dwelling Unit has no heating or cooling system or the space is not designed to maintain space conditions at 78 °F (26 °C) ± 5°F for cooling and 68 °F (20 °C) ± 5°F for heating. *Floor above Unrated Conditioned Space* – The space directly below the Dwelling Unit is serviced by a heating or cooling system designed to maintain space conditions at 78 °F (26 °C) ± 5°F for cooling and 68 °F (20 °C) ± 5°F for heating. *Floor above Unrated Heated Space* – The space directly below the Dwelling Unit is outside of the Conditioned Space Volume, and only interacts with the Rated Home via the shared services located within. This space is not cooled. *Non-Freezing Space* – the temperature of the space directly below the Dwelling Unit varies with outside temperature but is heated as necessary to stay at or aboveli40°F.

Building Element: Floor/Foundation Assembly		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Framing members	Determine the size of the framing members for all framed floors	Determine the framing member size and spacing for framed floors at each floor exposure. When framing cannot be directly observed, check the framing by looking for an access through another part of the building or by looking at the rim space from the outside.
Interior surface condition	Determine if the inside surface condition of floor is exposed or covered	*Covered* - Floors covered with wall-to-wall carpet are considered covered. Floors with only area rugs are not considered covered. *Exposed* - Floors covered with tile, linoleum, vinyl, or wood are considered exposed.
Foundation insulation	Determine type, grade, location, and thickness of foundation insulation and resultant R-Value	Use the inspection procedures in Normative Appendix A to determine the type and grade. Visually confirm location as interior or exterior, record R-value, and measure thickness. Visually confirm whether insulation product is installed for 100% of required area/perimeter and visually confirm and record R-value. If insulation is observed without a labeled R-Value, the manufacturer's data sheet shall be used to determine the R-Value based on installed thickness.  If 100% of the area/perimeter of the foundation insulation cannot be visually confirmed, inspect according to the protocol below: Visually confirm insulation product is installed for a minimum of 25% of the area/perimeter of the foundation insulation specified for insulation, and

Building Element: Floor/Foundation Assembly		
Rated Feature	**Task**	**On-Site Inspection Protocol**
		visually confirm and record R-value. Where R-Value cannot be determined during site observation, the manufacturer's data sheet shall be used. Use the inspection procedures in Normative Appendix A to determine the grade of insulation. The grade of the visually confirmed area shall be applied to the rest of the area unless photos show any additional deficiencies, in which case the grade recorded shall be the worst case documented. Collect photos to confirm installation at several site locations and in sufficient detail to confirm thickness, type, and grade of the insulation installation.-If foundation insulation cannot be visually verified immediately after installation, it may be verified through comprehensive photographs that comply with the requirements given above.
Floor insulation	Determine type, grade, and thickness of floor insulation and resultant R-Value	Use the inspection procedures in Normative Appendix A to determine the type and grade of floor insulation. For loose fill applications, multiply the thickness of the insulation in inches by the appropriate R-Value per inch based on the insulation type in order to calculate the total floor insulation R-value. 
Slab-on-grade insulation	Determine type, grade, location, and thickness of slab-on-grade insulation and resultant R-value	Slab perimeter insulation is installed vertically, either on the outside of the slab extending above and/or below grade or between the foundation wall and the slab itself. Under slab insulation is installed horizontally, either along the slab perimeter or underneath the entire slab.

Building Element: Floor/Foundation Assembly		
Rated Feature	**Task**	**On-Site Inspection Protocol**
		Use the inspection procedures in Normative Appendix A to determine the type and grade. Visually confirm location as horizontal or vertical, record R-Value, and measure thickness. Visually confirm whether insulation product is installed for 100% of required area/perimeter and visually confirm and record R-Value. If insulation is observed without a labeled R-Value, the manufacturer's data sheet shall be used to determine the R-Value based on installed thickness. If 100% of the area/perimeter of the slab insulation cannot be visually confirmed, inspect according to the protocol below: Visually confirm insulation product is installed for a minimum of 25% of the area/perimeter of the slab specified for insulation and visually confirm and record R-value. If insulation is observed without a labeled R-Value, the manufacturer's data sheet shall be used to determine the R-Value based on installed thickness. Use the inspection procedures in Normative Appendix A to determine the grade of insulation. The grade of the visually confirmed area shall be applied to the rest of the area unless photos show any additional deficiencies, in which case the grade recorded shall be the worst case documented. Collect photos to confirm installation at several site locations and in sufficient detail to confirm thickness, type, and grade of the insulation installation. If slab insulation cannot be visually verified immediately after installation, it may be verified through comprehensive photographs that comply with the requirements given above.

Building Element: Wall Assembly		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Gross Area	Determine surface area of all walls	Measure linear perimeter of the walls and round to the nearest ½ foot. Measure the interior wall height of the walls and round to the nearest ½ foot. Use these measurements to calculate surface area and round to the nearest square foot. Each unique wall exposure, construction type, and R-Value combination shall be calculated separately.
Wall exposure	Determine whether walls border exterior, Unconditioned Space Volume, Multifamily Buffer Boundary, Unrated Conditioned Space, Unrated Heated Space, Non-Freezing Space, or adjacent building	*Wall to exterior* – Walls border exterior space.  *Wall to Unconditioned Space Volume* – Walls border Unconditioned Space Volume, as defined in Section 3.  *Wall to Multifamily Buffer Boundary* – The space adjacent to the Dwelling Unit wall has no heating or cooling system or the space is not designed to maintain space conditions at 78 °F (26 °C) ± 5°F for cooling and 68 °F (20 °C) ± 5°F for heating. *Wall to Unrated Conditioned Space Volume* – The space adjacent to the Dwelling Unit wall is serviced by a heating or cooling system designed to

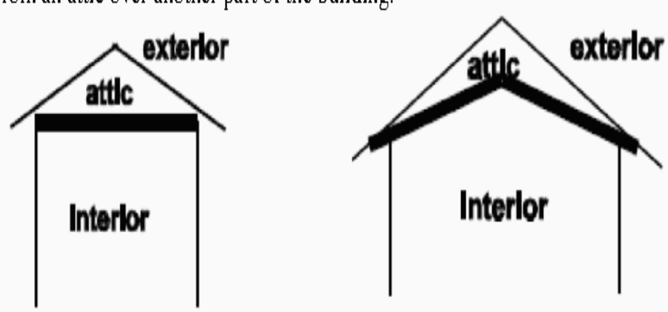
Building Element: Wall Assembly		
Rated Feature	**Task**	**On-Site Inspection Protocol**
		maintain space conditions at 78 °F (26 °C) ± 5°F for cooling and 68 °F (20 °C) ± 5°F for heating. *Wall to Unrated Heated Space* – The space adjacent to the Dwelling Unit wall is outside of the Conditioned Space Volume, and only interacts with the Rated Home via the shared services located within. This space is not cooled. *Wall to Non-Freezing Space* – The temperature of the space directly adjacent to the Dwelling Unit wall varies with outside temperature but is heated as necessary to stay at or above 40°F. *Wall to Adjacent Building* – When a Dwelling Unit is directly adjacent to another building, the walls adjacent to that other building shall be considered exterior walls. However, if there is no air space present between the two buildings and the building that is adjacent is inspected and determined to meet the definition of Conditioned Space Volume, then the wall shall be considered adiabatic.
Construction type	Determine the structural system of walls	*Wood framing* – Wood studs are typically located at 16" or 24" on center along the wall. Measure and record the on-center spacing of the studs. *Metal framing* – Steel studs are more common in construction over 5 stories. *Masonry walls* – Masonry walls are load-bearing walls constructed of concrete or brick. A wood framed wall with brick veneer is not a masonry wall. Also record the siding or finish material on the exterior of the wall and if interior framing is present, record whether it is wood or metal. *Foam core walls* – Foam core walls are a sandwich panel consisting of a foam center with outer layers of structural sheathing, gypsum board, or outer finish materials. Foam core panels may be structural or non-structural. Structural

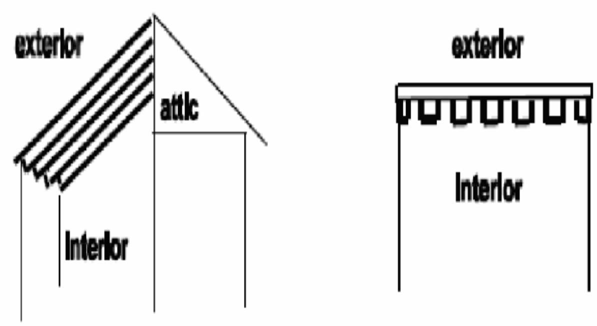
Building Element: Wall Assembly		
Rated Feature	**Task**	**On-Site Inspection Protocol**
		panels are also known as structural insulated panels (SIPs). Non-structural panels are frequently used in post and beam construction. *Log walls* – Log walls are solid wood walls, using either milled or rough logs or solid timbers. Some homes have the appearance of solid log walls, yet are actually wood frame walls with siding that looks like solid logs inside and out. Some log walls are manufactured with insulated cores. Assume no added insulation exists in a log wall unless manufacturer's data sheet and/or a visual inspection confirms insulation type and thickness.
Framing members	Determine the size of the framing members for all framed walls	Where framing is visible: If insulation is in place, carefully probe depth using tape measure, wire probe, or foam insulation depth gauge while disturbing as little of the assembly as possible. Where framing is not visible: Measure the width of the window or door jambs; Subtract the widths of the wall coverings and sheathing materials[70]; Compare the remaining width to 3.5" for a 2x4 wall or 5.5" for a 2x6 wall; Where exposed garage walls exist, examine them for reference, although they will not always be the same as other walls; Where a wall does not come close to the framing width of a 2x4 or 2x6, inspect for continuous insulation on the inside or outside of the walls or look for "double stud" or "strapped" walls or other factors that account for a thickness greater than 5.5". For brick veneer walls, assume 4.5" - 5" for brick, airspace, and sheathing material.

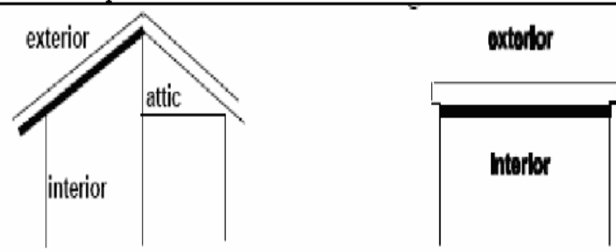
[70] (Informative Note) Approximately 0.25" to 1.0" for stucco, 0.5" to 0.6" for interior sheetrock, and 0.5" to 0.75" for other exterior siding materials.

Building Element: Wall Assembly		
Rated Feature	**Task**	**On-Site Inspection Protocol**
		Check the framing member size on all sides of the Dwelling Unit. When an addition has been added, be sure to check the walls of the addition separately. Where the Dwelling Unit has more than one story, check the framing member size for each floor.
Wall insulation installation	Determine type, grade, and thickness of framed wall insulation and resultant R-Value	Use the inspection procedures in Normative Appendix A to verify the insulation type and grade of the insulation installed in the framed wall stud cavity. Visually confirm and record R-Value and measure thickness. If insulation is observed, but the R-Value cannot be determined during site observation, the manufacturer's data sheet shall be used.
	Determine type, grade, and thickness of continuous exterior insulation and resultant R-Value	Use the inspection procedures in Normative Appendix A to determine the insulation type and grade. Visually confirm whether insulation product is installed for 100% of area specified for insulation and visually confirm and record R-Value and measure thickness. If insulation is observed without a labeled R-Value, the manufacturer's data sheet shall be used to determine the R-Value based on installed thickness. If 100% of the area of the exterior insulation cannot be visually confirmed, inspect according to the protocol below: Visually confirm insulation product is installed for a minimum of 25% of the area specified for insulation and visually confirm and record R-Value and measure thickness. If insulation is observed without a labeled R-Value, the manufacturer's data sheet shall be used to determine the R-Value based on installed thickness. Use the inspection procedures in Normative Appendix A to determine the type and grade of insulation. The grade of the visually confirmed area shall be applied to the rest of the area unless photos show any additional deficiencies, in which case the grade recorded shall be the worst case documented.

Building Element: Wall Assembly		
Rated Feature	**Task**	**On-Site Inspection Protocol**
		Photos to confirm installation at several site locations and in sufficient detail to confirm thickness, type, and grade of the insulation installation. a. If exterior insulation cannot be visually verified immediately after installation, it may be verified through comprehensive photographs that comply with the requirements given above.
Existing insulation in walls	Determine if wall insulation exists in existing Dwelling Unit	Check at plumbing outlet under sink or, in order of preference, remove cable outlet plate, telephone plate, electrical switch plates and/or electrical outlet plates on exterior walls. Probe the cavity around the exposed plate with a non-metal device. Determine type of insulation. Inspect outlets/switch plates on each side of the Dwelling Unit to verify that all walls are insulated. Multiply the wall framing member size in inches by the R-Value per inch. Use 3.5" for 2x4 walls and 5.5" for 2x6 walls constructed after 1945. When an addition has been added, check the walls of the addition separately. Where the Dwelling Unit has one more than one story, check each floor.
Color	Determine the color of the exterior walls	Identify the color of the walls as light, medium, or dark.
Thermal mass	Determine type and thickness of all mass walls	Where the Dwelling Unit's walls are constructed of concrete, masonry, or brick (other than brick veneer), determine their type and thickness. Solid concrete walls (poured) Measure the thickness of the poured concrete wall in inches. Concrete Masonry Unit Measure the thickness of the wall in inches. Inspect for vermiculite or perlite insulation or other additional insulation.

Building Element: Roof/Ceiling Assembly		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Gross Area	Obtain measurements of all roof/ceiling areas	Measure the linear perimeter of the ceiling area and round to the nearest ½ foot and use these measurements to calculate surface area of the ceiling and round to the nearest square foot. When a ceiling area is vaulted, it is necessary to calculate dimensions geometrically. Each unique roof/ceiling exposure, construction type, and R-Value combination shall be calculated separately.
Ceiling exposure	Determine ceiling exposure	Identify the ceiling as one of the four following types. 1. Ceiling to attic When the ceiling has attic space above, even when the ceiling is vaulted, as in a scissor truss, it is considered "ceiling to attic." Compare the vaulted ceiling angle against the angle of the roof. Where the ceiling angle is lower, there is attic space above the ceiling. Also check for an attic access, either separate or from an attic over another part of the building.  2. Ceiling to exterior When the ceiling has no attic space above, even when the ceiling is flat, it is considered "ceiling to exterior." 3. Ceiling to Multifamily Buffer Boundary

Building Element: Roof/Ceiling Assembly		
Rated Feature	**Task**	**On-Site Inspection Protocol**
		When the ceiling of the Attached Dwelling Unit has non-exterior, non-attic space directly above that has no heating or cooling system or the space is not designed to maintain space conditions at 78 °F (26 °C) ± 5°F for cooling and 68 °F (20 °C) ± 5°F for heating, it is considered "ceiling to Multifamily Buffer Boundary." 4. Ceiling to Unrated Conditioned Space When the ceiling of the Attached Dwelling Unit has unrated space directly above, which may be another Dwelling Unit or another conditioned space in the building, that is conditioned by a heating or cooling system designed to maintain space conditions at 78 °F (26 °C) ± 5°F for cooling and 68 °F (20 °C) ± 5°F for heating, it is considered "ceiling to Unrated Conditioned Space."
Construction type	Determine ceiling construction type	Framed ceilings fall into two categories. *Roof on exposed beams or rafters* – when you look up from inside the room, you will see exposed beams or rafters.  *Finished framed ceiling* – when a ceiling is framed, but you cannot see the framing because the ceiling is finished with drywall, plaster, or paneling, record it as a finished framed ceiling.

Building Element: Roof/Ceiling Assembly		
Rated Feature	**Task**	**On-Site Inspection Protocol**
		
Framing members	Determine the size of the framing members for all framed ceilings	Determine the framing member size and spacing for framed ceilings at each ceiling exposure. When framing cannot be directly observed, check the framing by looking for an access through an attic over another part of the building or by looking at the rafters from the outside.
Ceiling insulation	Determine type, grade, and thickness of insulation in framed ceiling and/or attic and resultant R-value	Determine the insulation R-Value that exists in the attic/ceiling, unless it is ceiling to Unrated Conditioned Space. Use the following method for calculating the overall ceiling R-value: • Use the inspection procedures in Normative Appendix A to determine the type and grade of the ceiling insulation present; • Record when the insulation is a combination of more than one type; • In the attic, measure the average depth in four places. Record whether the cavity insulation leaves the framing elements exposed, or covers them; when covered, record the thickness that covers the framing; • Multiply the R-Value of the material by the depth of the insulation. When there is no access to the attic or framed ceiling, a default R-Value shall be used based on current and historical local building practice and building code.
Roof construction type	Determine roof construction type	Identify the type of roofing surface. Some common types include asphalt shingle, pebble/gravel built-up roof, tile roof, wood shingle roof, rubber roof/roof coating, or metal roof.
Roof color	Determine the color of the roof	Identify the color of the roof as light, medium, or dark. Also check for any reflective roof coating.

Building Element: Roof/Ceiling Assembly		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Roof deck insulation	Determine type, grade, and thickness of roof deck insulation and resultant R-value	Use the inspection procedures in Normative Appendix A to verify the insulation type and grade. Visually confirm whether insulation product is installed for 100% of required area and visually confirm and record R-Value and measure thickness. If insulation is observed without a labeled R-Value, the manufacturer's data sheet shall be used to determine the R-Value based on installed thickness. If 100% of the roof area cannot be visually confirmed, inspect according to the protocol below: Visually confirm insulation product is installed for a minimum of 25% of the area specified for insulation and visually confirm and record R-Value and measure thickness. If insulation is observed without a labeled R-Value, the manufacturer's data sheet shall be used to determine the R-Value based on installed thickness. Use the inspection procedures in Normative Appendix A to determine the grade of insulation. The grade of the visually confirmed area shall be applied to the rest of the area unless photos show any additional deficiencies, in which case the grade recorded shall be the worst case documented. Collect photos to confirm installation at several site locations and in sufficient detail to confirm thickness, type, and grade of the insulation installation. If roof deck insulation cannot be visually verified immediately after installation, it may be verified through comprehensive photographs that comply with the requirements given above.

Building Element: Rim/Band Joists or Floor Perimeters		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Rim/band joist insulation installation	Inspect rim/band/floor perimeter insulation of Dwelling Unit during installation	In wood-framed buildings, the rim joist is the band joist around the perimeter of the floor joists over a basement or crawlspace, or between 2 stories of the building. In other taller multistory buildings, these intermediate floor perimeters may be metal-framed or solid concrete. Use the inspection procedures in Normative Appendix A to determine the insulation type and grade of insulation. Measure the depth of insulation at the rim/band joist and between stories in a multistory building. If insulation is observed without a labeled R-Value, the manufacturer's data sheet shall be used to determine the R-Value based on installed thickness.
Existing insulation in rim/band joists	Determine if rim/band insulation exists in existing Dwelling Unit	Crawlspace or Basement From the basement or crawlspace, visually identify and measure the depth of insulation at the rim joist. Use the inspection procedures in Normative Appendix A to determine the grade of insulation. Between Stories Look for access to the area from a garage or a utility access trap door. Visually identify and measure insulation where it exists. If no access is found, insulation is only assumed to exist at the rim joist between stories when: • Insulation was found at the rim joist at the top of the crawlspace or basement in the same building; and/ or • Insulation is found in the walls of the same building. Otherwise, assume no rim joist insulation exists.

Building Element: Doors		
Rated Feature	**Task**	**On-Site Inspection Protocol**

Area	Determine area of doors	Measure the linear perimeter of the door and round to the nearest inch. Use these measurements to calculate the area of the door(s) and round to the nearest tenth of a square foot. Each unique door type and R-Value combination shall be calculated separately.
Construction type	Determine construction type of doors	Determine whether the door(s) is fiberglass, metal, or wood by making a close inspection of its texture, inspecting its side view, or lock cut out. Alternatively, confirm by examining the door for a descriptive label or review the product manufacturer's data sheet.
Insulation	Determine doors insulation value	Determine the door(s) insulation U-factor value and, if applicable, SHGC by examining the door for a descriptive label or review the product manufacturer's data sheet. Where insulation cannot be determined, default values shall be based on the local building code in effect at the time of construction.
Presence of a door seal	Inspect for the presence of a door seal on the door where the blower door is installed	Identify the door where the blower door is to be setup for the airtightness test. Inspect for the presence of a door seal installed to minimize air leakage between the door and door frame. Document the presence, installation, quality, and condition of the door seal.

Building Element: Windows		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Area	Determine area of windows	Measure the width and height of the rough opening for the window and round to the nearest inch. Use these measurements to calculate window area, and round to the nearest tenth of a square foot. For existing homes or where the rough opening cannot be measured, window dimensions shall be measured from the outside edge of the window framing and include the width of the window frame. Each unique window type and U-value combination shall be calculated separately.
Construction type	Determine window material and Glazing characteristics	Material Examine each window frame to determine the type of material used. Visually confirm whether the frame is made of metal, wood, or vinyl. Alternatively, confirm by examining the window for a descriptive label or review the product manufacturer's data sheet. Where a metal framed dual- or multiple-paned window is installed, determine if a thermal break is present by looking for two separated metal extrusions connected by a rubber spacer. Alternatively, confirm by reviewing the product manufacturer's data sheet. Determine and record the window cladding type. Check both the inside and outside, since some windows will have cladding on one side only. Glazing Type Determine and record whether the windows are single-paned, double-paned or multiple-paned. Determine and record whether Glazing has a tint or low-e coating.

Building Element: Windows		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Orientation	Determine orientation of all windows	Determine orientation of all windows and record orientation to the nearest cardinal/ordinal points. When using a compass while standing in front of a window inside the Dwelling Unit, record orientation while facing the exterior and adjust for magnetic deviation. When using a compass while standing outside the Dwelling Unit, record orientation while standing with back to the window and adjust for magnetic deviation.
Shading	Determine permanent, fixed shading of windows	Identify permanent, fixed shading devices attached to the building. Fins and overhangs shall be considered fixed shading devices. Window screens, security bars, balcony railings, movable awnings, roller shades, and shade from adjacent buildings, trees and shrubs shall not be considered fixed shading devices. Projections and Overhangs The shading impact of a projection or overhang is found by measuring the length of the overhang from the exterior wall surface, the distance between the top of the window and the bottom edge of the overhang, and the distance between the bottom of the window and the bottom edge of the overhang. Measure the length of the overhangs over each exterior wall, to the nearest inch. Measure the distance between both the top of the window and the bottom of the window to the bottom edge of the overhang, to the nearest inch.
Solar heat gain coefficient	Determine solar heat gain coefficient of Glazing	Look for an NFRC label on new windows; it will display SHGC. Where no label is found, identify window in NFRC Certified Products Directory to determine SHGC or consult manufacturer's data sheet. If no SHGC is identified from window label, product literature, or NFRC directory, use the known window characteristics to select the SHGC from Table 10 in the ASHRAE Handbook of Fundamentals.

Building Element: Windows		
Rated Feature	**Task**	**On-Site Inspection Protocol**
U-value	Determine window U-value	Look for an NFRC label on new window; it will display full window U-value. Where no label is found, identify window in NFRC Certified Products Directory to determine U-value or consult manufacturer's data sheet. If no U-value is identified from window label, product literature, or NFRC directory, use the known window characteristics to select the U-value from Table 4 in ASHRAE Handbook of Fundamentals.
Natural Ventilation	Determine whether or not there are operable windows in the Dwelling Unit	Inspect all windows located in the Dwelling Unit and document which are operable and which are not.

Building Element: Skylights		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Area	Determine area of skylights	See windows.
Construction type	Determine framing and Glazing characteristics of skylights	See windows.
Orientation	Determine orientation of skylights	Determine the orientation of the lower edge of the skylight. Use this direction as the orientation of the skylight.
Shading	Determine shading of skylights	See windows.
Solar heat gain coefficient	Determine solar heat gain coefficient of skylights	See windows.
U-value	Determine skylight U-value	See windows.
Tilt	Determine tilt of skylights	Measure the tilt of the skylight relative to horizontal. This may be done with a level and angle finder instrument, or geometrically with a protractor. If the pitch of the roof is known or can be measured, and if the skylight is in line with the roof, then the roof pitch may also be considered the tilt of the skylights.

Building Element: Passive Solar System		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Direct gain	Identify system type and determine solar aperture orientation and aperture area	Through proper sizing, placement, orientation, and/or control of windows, skylights, shading devices, and solar storage mass within the building, a solar direct gain system is designed to reduce heating, cooling, and lighting energy requirements. To determine aperture area, measure width and height of south-facing Glazing and indicate tilt angle. Record glass type(s) and presence of night insulation, when present. Determine orientation to the nearest cardinal/ordinal point. Determine the type of thermal mass, its thickness, and its dimensions. Determine whether the mass will be lit by direct solar rays between the hours of 9:00 a.m. and 3:00 p.m. during the winter. Record any trees or other obstructions to solar gain.
Greenhouse or solarium	Identify system type and determine solar aperture orientation, aperture area, and information about thermal mass	A greenhouse or solarium creates a South-glazed buffer zone between the Dwelling Unit and the exterior to help heat the living area. See Direct gain, above, for specific inspection items.
Thermal storage mass	Identify system type and determine solar aperture orientation, aperture area, and information about thermal mass	Thermal mass systems consist of solar-exposed heavyweight materials with high heat capacitance and relatively high conductance or high thermal diffusivity, that are placed in the same zones(s) as the solar collection area(s). Determine and record whether these elements are integral with the building or distinct elements within the building. Distinct components: *Trombe wall* - uses a heat storage mass placed between the glass and the space to be heated. Measure area of storage mass, determine material, thickness, and capacitance.

Building Element: Passive Solar System		
Rated Feature	**Task**	**On-Site Inspection Protocol**
		Water wall - replaces the existing wall, or parts of it, with containers that hold water.
Thermosiphon Air Panel (TAP)	Identify system type	*Thermosiphon air panel (TAP)* - has one or more Glazing layers made of glass or plastic, an air space, an absorber, another air space, and (often) an insulated backing. These are similar in appearance to active flat-plate collectors, often mounted vertically on walls, or ground-mounted, so that the living space is higher than the collector to facilitate convection from the TAP to the building. See Greenhouse, above, for specific inspection items.

Building Element: Air Leakage		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Blower door test	Determine airtightness from a blower door test	Follow Procedure for Measuring Airtightness of Building or Dwelling Unit Enclosure in ANSI/RESNET/ICC 380.
Infiltration Volume	Determine Infiltration Volume of Rated Home	Determine the Infiltration Volume by adding the Conditioned Space Volume and Unconditioned Space Volume in the Dwelling Unit, in accordance with the definitions.
Compartmentalizatio n Boundary	Determine Compartmentalization Boundary	Determine the Compartmentalization Boundary by calculating the surface area that bounds the Infiltration Volume.

Building Element: Heating and Cooling Distribution System

Rated Feature	Task	On-Site Inspection Protocol
System type	Identify type of distribution system used to provide space heating and cooling	*Forced air* - a fan unit or air handler connected to ducts that supply heated or cooled air to multiple rooms in the Dwelling Unit. Forced air systems have supply and/or return ductwork. *Unit heater/air conditioner* - heating or cooling is supplied directly from a heating or cooling device located within the space it serves. Unitary equipment[2]~~1~~ has no supply or return ductwork. *Forced hot water* - heated water is pumped through a series of radiator elements to supply heat. Identify and record the radiator elements as conventional radiators, baseboard "fin tube" radiators, cast iron baseboards, or radiant hot water panels located at the baseboards or on walls or ceilings. *Hot water radiant system* - heated water is circulated through plastic or metal tubing that is installed in a concrete slab or finished floor or, occasionally, in walls or ceilings. *Steam heating* - steam systems utilize a distribution system with cast iron radiators connected to a boiler that creates steam. The steam rises into the radiators through one set of pipes, condenses into water, and drains back to the boiler. There are 2 common system types: One Pipe Steam - radiators have only one pipe connected with a shut off valve. There will also be an air vent on the opposite end of the radiator from the pipe connection. Two Pipe Steam - radiators will have a larger steam supply pipe and a smaller condensate return pipe. There will be a control valve on the steam side and a steam trap on the condensate side.

[2] (Informative Note) Examples of unitary equipment include window air conditioners, package terminal heat pumps (PTHP), packaged terminal air conditioners (PTAC), and ductless minisplits. Where unitary equipment has any amount of ductwork, they are forced air systems.

Building Element: Heating and Cooling Distribution System		
Rated Feature	**Task**	**On-Site Inspection Protocol**
		Electric radiant system - electric cables are installed in concrete floor slabs or in the ceiling. Electric current is passed through the cables, causing them to heat up, heating the floor, individual radiant wall panels, or the ceiling assembly, which radiates heat to the space. *Baseboard electric resistance* - electric elements are installed in baseboard enclosures. Electric current is passed through the electric element to provide heat to the space. *Electric unit heaters* - electric elements are enclosed in a cabinet with a blower that is suspended from the ceiling or mounted in a ceiling cavity, wall cavity, under a kitchen or bath cabinet (kickplate) or other areas. In multifamily buildings, look for these units in stairwells, storage rooms, mechanical rooms, water meter closets or any space with a small or low heating load.
Location of air ducts	Determine the location of ducts	Locate and differentiate between supply and return ducts. The location of air ducts shall be recorded as in attic space, crawlspace, basement, or other conditioned or unconditioned space. Use the definitions in Section 3 to classify the locations as Infiltration Volume, Conditioned Space Volume, Unconditioned Space Volume, or Unrated Conditioned Space. Approximate the percentage of both the supply and return ductwork in each area when supply/return ducts are located in more than one area.
Insulation	Determine the R-Value of distribution system insulation	Inspect the ducts or pipes to confirm they are insulated and look for labeling printed on the insulation by the manufacturer. Record R-value. Where insulation is not marked with the R-value, identify type and measure the thickness of the insulation to determine R-value.
Leakage of air ducts	Determine air leakage from ducts	Follow Procedure for Measuring Airtightness of Duct Systems in ANSI/RESNET/ICC 380. The air handler shall be installed prior to testing.

Building Element: Heating and Cooling Distribution System		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Circulation pumps	Determine the energy use of the distribution pumps	Record the horsepower and model number of any primary and secondary pumps associated with the distribution circulation loop, excluding any pumps on standby. Use the model number of the pumps to determine the pump motor efficiency from the manufacturer's data sheet. The number of Dwelling Units served by the circulation loop shall also be determined.

Building Element: Heating and Cooling Equipment		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Equipment class	Identify Class of equipment for heating and/or cooling	*Individual* - standalone equipment serving a single Dwelling Unit, often located within the Dwelling Unit. These units heat and/or cool the space and, other than electric connections to power the fans, controls, or compressors, are not connected to circulating fluids from a central boiler or Chiller. *Terminal* - individual equipment that heats and/or cool the space and are connected to boilers, Chillers, Variable Refrigerant Flow Multi-Split Air Conditioning and Heat Pump Equipment, and/or Cooling Towers. Fan coils and Water Loop Heat Pumps often indicate the use of a remote central boiler and/or Chiller. However, some terminal equipment appears similar to individual equipment and yet relies on a remote energy source to function. Look for insulated water pipes, refrigerant tubing, or control valves and confirm that there is no in-unit heating or cooling equipment or equipment in adjacent spaces that solely serves the terminal equipment of the Dwelling Unit that may be outside of the Dwelling Unit. *Central* - larger heating or cooling equipment that serves more than one Dwelling Unit, and possibly common spaces, using a conveyance to deliver and receive a circulating energy transfer medium to heat and/or cool the Dwelling Units through their terminal equipment. The circulation conveyance may be water piping or refrigerant tubing and likely will be insulated. Water loops will have circulating pumps. See Central Equipment below for details.
Location	Determine the location of heating and cooling equipment	Record whether individual, terminal, and central systems are in Conditioned Space Volume, Unrated Conditioned Space, Unrated Heated Space, or Unconditioned Space Volume.
Control system	Identify the control system for the heating and cooling system(s)	Determine the type of control systems and look for separate controls for the heating and cooling systems.

Building Element: Heating and Cooling Equipment		
Rated Feature	**Task**	**On-Site Inspection Protocol**
		Determine and record whether the Dwelling Unit thermostat controls are programmable, understanding that not all digital thermostats are programmable.
Efficiency	Determine the heating and cooling equipment efficiency and capacity	Look for the equipment nameplates and product literature. Record the manufacturer and model number, capacity, and, if listed directly on the nameplate, the efficiency rating. If not listed, use the model number to identify the efficiency rating in the AHRI directory. Where the nameplate information is not available or not accessible, use manufacturer's data sheet, equipment directories, or age-based defaults from Section 4.5.2 to determine and record an appropriate efficiency. SEER is used to measure the cooling efficiency of central air conditioning and Air Source Heat Pump systems. EER is used to determine the cooling efficiency of room air conditioners, VRF, Water Loop Heat Pumps, and Ground Source Heat Pumps. EER can be calculated from the nameplate information by dividing Btu output by Watt input. Chillers are rated in kW/ton. HSPF or COP is used to measure the heating efficiency of Air Source Heat Pumps, VRF, Water Loop Heat Pumps, and Ground Source Heat Pumps. AFUE or Thermal Efficiency is used to measure the efficiency of furnaces and boilers.
Heating and cooling energy source	Determine fuels used for heating and cooling	Heating systems use natural gas, propane, oil, electricity, or some other fuel. Most cooling systems are driven by electricity, however some cooling equipment uses natural gas or propane.

Building Element: Heating and Cooling Equipment		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Individual Heating and Cooling Equipment	Identify type(s) of individual equipment for heating and/or cooling of a single Dwelling Unit	Determine the individual heating/cooling type that is present in each Dwelling Unit. Typical unit types are defined below: *Boiler* – this device creates hot water or steam, powered by any fuel type, and can be used with forced air distribution, in conjunction with a fan coil unit or PTAC where the fan blows air over the hot water coil to provide heating, or distributed by forced hot water, steam, or a hot water radiant slab system. *Direct evaporative cooler* - is used primarily in very dry climates. Evaporative coolers work by blowing air over a damp pad or by spraying a fine mist of water into the air. Direct evaporative coolers add moisture to the home. *Furnace* - comprised of a combustion chamber and heat exchanger or an electric resistance element and a fan that forces air across the heat exchanger or resistance element to provide heat in a forced air system. *Ground Source Heat Pumps* - are coupled to the ground through the use of a water well. In Attached Dwelling Units, confirm and record when a circulation loop is shared amongst multiple Dwelling Units. See Central Equipment below for details. *Packaged terminal air conditioner (PTAC)* - a factory-selected wall sleeve and separate un-encased combination of heating and cooling components, assemblies, or sections. It may include heating capability by hot water, steam, or electricity and is intended for mounting through the wall to serve a single room or zone. If a hot water coil is present, determine if the boiler is individual or central. *Packaged terminal Heat Pump (PTHP)* - a PTAC capable of using the refrigerating system in a reverse cycle or Heat Pump mode to provide heat.

Building Element: Heating and Cooling Equipment		
Rated Feature	**Task**	**On-Site Inspection Protocol**
		Split system Air Source Heat Pump - move energy from one location to another using the vapor compression cycle. They are electrically driven and provide heating in winter and cooling in summer by reversing the direction of heat flow. Split system Heat Pumps consist of an outdoor unit and an indoor air handling unit, resembling a furnace. These systems require ductwork for air distribution. Most Air Source Heat Pumps incorporate electric resistance supplemental heat in the indoor section. However, some Heat Pump systems use a fossil fuel furnace for supplemental heating. These are known as "dual fuel" or add-on systems. *Split system air conditioner* - similar to a split system Air Source Heat Pump. Consists of an outdoor unit and a coil in the forced air distribution system. These systems are electrically powered and provide cooling. *Through-the-wall ductless Air Source Heat Pump* - a single packaged Air Source Heat Pump installed without a distribution system. Provides both heating and cooling and is installed through an exterior wall. *Unitary space heater* - these are fossil fuel burning heaters that have individual controls and no distribution system. Determine and record when the system is equipped with a fan for forcing air circulation over a heat exchanger or uses simple convective forces. These heaters are mounted on outside walls to facilitate venting and use natural gas, kerosene, propane, or other types of fossil fuel. *Variable-speed Mini-Split and Multi-Split Heat Pumps* - these systems are listed under "residential" in the AHRI Directory and have multiple configurations, depending on whether the system is "single-port" or "multi-

Building Element: Heating and Cooling Equipment		
Rated Feature	**Task**	**On-Site Inspection Protocol**
		port" and whether it is ducted, non-ducted, or a mix. They are considered individual systems when they serve only one Dwelling Unit[34]. *Window/through-the-wall air conditioner* – is a single packaged ductless air conditioner designed to be installed without a distribution system and without a factory-selected sleeve. *Electric resistance heater* – these are electric heaters that typically have individual controls and no distribution system. They are typically either electric baseboard heaters, electric wall heaters, or electric bathroom heaters.

[3] (Informative Note) The term "mini-split" generally refers to a non-ducted, "single-port" Heat Pump.

Building Element: Heating and Cooling Equipment		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Terminal Heating and Cooling Equipment	Identify type(s) of terminal equipment served by centralized systems for heating and/or cooling in each Dwelling Unit	Determine the terminal heating/cooling type that is present in each Dwelling Unit. Typical terminal unit types are defined below: *Fan coil unit* – hot/chilled water from a central boiler/Chiller is circulated through a coil. A fan blows air over the coil to provide heating/cooling. *Hot Water Packaged Terminal Air Conditioner (HW PTAC)* – a PTAC that includes a hot water coil connected to a central boiler. *Hydronic/radiant or convectors* – hot water from a central boiler is pumped through a series of radiator elements to supply heat. Conventional radiator elements are radiators, baseboard "fin tube" radiators, cast iron baseboards, or radiant hot water panels located at the baseboards or on the walls or ceilings. *Variable Refrigerant Flow Multi-Split Air Conditioning and Heat Pump terminal units* – refrigerant flows at a variable rate from one or more central outdoor condensing units to evaporator units located in the Dwelling Units. Styles of VRF terminal units include wall mounted, ceiling cassette, ceiling suspended, and are either ducted, non-ducted, or mixed. *Water Loop Heat Pumps* – hot/cold water from a centralized boiler and Cooling Tower is circulated through a Heat Pump in each Dwelling Unit.

Building Element: Heating and Cooling Equipment		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Central Heating and Cooling Equipment	Identify type(s) of central equipment serving terminal units in each Dwelling Unit	*Absorption cooler* – this is a gas air conditioner. Look for a Cooling Tower, an exhaust pipe, a gas burner to evaporate refrigerant, and a heat exchanger similar to an electric air conditioner. *Boiler* – this device creates hot water or steam, may be powered by any fuel type, and can be used with forced air distribution, in conjunction with a fan coil unit or PTAC where the fan blows air over the hot water coil to provide heating, or distributed by forced hot water, steam, or a hot water radiant slab system. Record whether the boiler also provides service hot water. *Chiller* – Vapor compression cooling equipment that uses the outdoor air or water circulated through a Cooling Tower as a heat sink for cooling and absorbs heat from conditioned space by means of a hydronic cold water distribution system. Determine whether the Chiller is a DX Chiller, water-cooled, or absorption. *Cooling Tower* – A heat rejection device that rejects heat to the atmosphere. Record the fan horsepower from the nameplate data of the Cooling Tower fan located inside the Cooling Tower. Record the horsepower and model number of the sprayer pump located inside the Cooling Tower. Alternatively, record the model number from the nameplate data of the Cooling Tower to determine the fan and sprayer pump data from manufacturer's data sheet. *Ground Source Heat Pump* – shared vapor compression heating and cooling equipment that uses the ground or ground water as the heat source or sink for heat. *Rooftop Make-Up Air Unit (MAU) or Dedicated Outdoor Air System (DOAS)* – large rooftop equipment that provides outdoor air or make-up air, with or without heating or cooling. In multifamily buildings, these systems may provide ducted air directly to the Dwelling Units or to other

Building Element: Heating and Cooling Equipment		
Rated Feature	**Task**	**On-Site Inspection Protocol**
		common spaces. *Single packaged air conditioner* - similar to single packaged Air Source Heat Pumps, these systems provide cooling only. In multifamily buildings, these systems may provide ducted air directly to the Dwelling Units or to other common spaces. *Single package Air Source Heat Pump* - a single package Heat Pump is similar to a split system, except it combines the functions of the indoor and outdoor units into one cabinet, mounted on the roof or on the ground. In multifamily buildings, these systems may provide ducted air directly to the Dwelling Units or to other common spaces. *Variable Refrigerant Flow Multi-Split Air Conditioning and Heat Pump outdoor units* – refrigerant flows at a variable rate from one or more central outdoor condensing units to evaporator units located in the Dwelling Units.

Building Element: Service Hot Water (SHW) Equipment		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Equipment class	Identify class of equipment for Service Hot Water (SHW)	*Individual* - standalone service hot water system serving a single Dwelling Unit. *Central* - shared service hot water system serving more than one Dwelling Unit. These shared systems may also provide service hot water to common spaces and shared laundry rooms. *Laundry* - service hot water system providing hot water for shared clothes washers that does not provide other service hot water to the Dwelling Unit.
Location	Determine location of service hot water equipment	Determine whether the water heater is in Conditioned or Unconditioned Space Volume, Unrated Heated Space, or Unrated Conditioned Space.
Efficiency	Determine the Energy Factor, Uniform Energy Factor, or thermal efficiency of the service hot water equipment	Look for the water heater's nameplate and product literature. Record the manufacturer, model number, and if listed directly on the nameplate, the efficiency rating. Search for the model number in an appropriate efficiency rating directory to determine and record the EF, UEF, or thermal efficiency rating. When thermal efficiency is recorded, also record the standby loss if available. When the efficiency rating cannot be determined, approximate the age of the unit and use a default efficiency.
Extra tank insulation value	Determine the insulation value of any exterior wrap	Visually determine whether the water heater is or is not wrapped with exterior insulation. When insulation is present, measure the thickness of the wrap and determine and record the R-Value.
Individual service hot water equipment type	Determine type, capacity, and fuel source of standalone water heater serving single Dwelling Unit	Identify whether the equipment is storage or instantaneous, identify its fuel source, and record storage tank capacity in gallons. Also record whether the SHW equipment is supplemented by a desuperheater and/or if it is integrated with the space heating system. .

Building Element: Service Hot Water (SHW) Equipment

Rated Feature	Task	On-Site Inspection Protocol
Central service hot water equipment type	Determine type, capacity, fuel source, and pump power of shared service hot water equipment serving more than one Dwelling Unit	Identify if equipment is a boiler or water heater, residential or commercial grade, its fuel source, pump power, and record storage tank capacity in gallons. Also record whether the SHW equipment is integrated with the space heating system and how many Dwelling Units it serves. *Central boiler with indirect fired storage tanks* – Record the number of boilers and tanks. Record the fuel source and the model number, capacity, and insulation value, when present, of the unfired storage tanks. *Central service hot water heater* – Record the number of water heaters, the fuel source, capacity, and insulation value, when present. *Central pump power* - in addition, record the horsepower and model number of all primary and secondary pumps that are associated with the service hot water distribution loop, excluding any pumps on standby. If not listed on the nameplate, use the pump model number to determine the pump motor efficiency from the manufacturer's data sheet.
Laundry service hot water equipment type	Determine type, capacity, and fuel source of laundry SHW equipment	Where a separate service hot water system provides hot water to clothes washers, but does not provide other service hot water to the Dwelling Unit, follow guidance for individual service hot water systems above to identify system type, capacity, and fuel source.
Drain Water Heat Recovery (DWHR)	Determine efficiency and performance factors	Where DWHR units are installed and serve the Rated Home, record the model number of the DWHR unit, its efficiency, and the number of showers in the Rated Home that are connected to the unit. A performance factor shall be determined based on its installation location. Determine if the DWHR unit supplies pre-heated water to the cold water piping, hot water heater potable supply piping, or to both.

Building Element: Service Hot Water Distribution		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Hot water pipe length	Determine hot water distribution pipe length	The hot water distribution pipe length from the water heater to the farthest hot water fixture shall be measured horizontally and vertically along its length, assuming the hot water piping does not run diagonally. For Dwelling Units being served by a Central SHW with a recirculation loop, begin the pipe length measurement from the shared recirculation loop rather than the water heater. The measured pipe length shall be inspected during construction and re-calculated if it did not conform to the designed plan layout.
Pipe insulation	Determine R-Value of pipe insulation	Inspect the hot water piping for the presence of insulation and record the percentage of piping that is insulated. Measure the thickness of the insulation and identify material to determine its R-Value.
Recirculation system	Determine the hot water recirculation type, control strategy, and branch length	Inspect the hot water distribution system to determine whether the system is a standard system or a recirculation system. A standard system shall be used for Attached Dwelling Units unless the recirculation system is entirely within the Rated Home. When a recirculation system is entirely within the Rated Home, then the control strategy shall be documented as one of the following strategies. *Uncontrolled* – the pump runs continuously *Timer*– the pump is controlled by a timer *Temperature control* – the pump runs based on monitoring temperature at some point in the system *Demand (presence sensor)* – the pump only runs when a sensor detects someone is present at the faucet

Building Element: Service Hot Water Distribution		
Rated Feature	**Task**	**On-Site Inspection Protocol**
		Demand (manual) – the pump only runs when a user presses a button indicating they are about to use hot water The branch hot water pipe length from the recirculation loop to the farthest hot water fixture from the recirculation loop shall be measured longitudinally, assuming the branch hot water piping does not run diagonally.
Flow rates of faucets and showerheads	Determine gpm of faucets and showerheads	Record the rated gpm printed on all showerheads and faucets. When the gpm rate is not visible, collect documentation showing the model number of the plumbing fixtures and use manufacturer's data sheet to determine and record the rated gpm.

Building element: Solar Domestic Hot Water Equipment		
Rated Feature	**Task**	**On-Site Inspection Protocol**
System type	Determine type of solar systems	Determine whether a solar domestic hot water system exists. These systems collect and store solar thermal energy for domestic water heating applications. When a solar water heating system exists, determine system type. For systems manufactured after January 1, 1995, system type, Energy Factor (EF), and other performance characteristics shall be determined from the SRCC label and by referring to SRCC literature. For systems lacking an SRCC label, Energy Factor and other performance characteristics are determined using a certified energy modeling tool or appropriate default values. Identify as passive or active. Base your evaluation on these criteria: *Passive* - No purchased electrical energy is required for recirculating water through a passive solar collector. Three types of passive systems are integrated collector storage (ICS), thermosiphon systems and self-pumped systems. *Integrated Collector Storage (ICS)* - consists of a single unit that incorporates both collector and water storage[42]. *Thermosiphon* - consists of a flat-plate solar collector and hot water storage tank. Instead of using a pump, circulation of the fluid is achieved by natural convection action. The storage tank must be located above the collector, and can be inside or outside the Conditioned Space Volume. *Self-pumped* - circulates fluid from storage to collectors without purchased electrical energy. Photovoltaic and percolating systems are self-pumped systems. The storage tank can be inside or outside the Conditioned Space Volume. *Active* -Also known as pumped systems. *Pumped* -purchased electrical energy input is required for operation of pumps or other components. The storage tank can be inside or outside the Conditioned Space Volume.

[42] (Informative Note) An example is the common "bread box" design. Storage is usually outside the Conditioned Space Volume.

Building element: Solar Domestic Hot Water Equipment		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Solar collector type	Identify type of solar collector	Identify the type of solar collector by checking for the SRCC label or manufacturer's data sheet.
Collector details	Determine area, orientation, and tilt of collector	Determine the area of the collector. Determine the orientation of the solar collector to the nearest cardinal/ordinal point in the direction toward which the collector faces. To determine the tilt of the collector use either geometric calculations based on horizontal length and vertical height measurements or a site selection and angle finder instrument.
Efficiency	Determine efficiency of solar system	Search for SRCC label. Check for SRCC system and component nameplates. Refer to the Directory of SRCC Certified Solar Collector and Water Heating System Ratings, or other SRCC literature for Energy Factor (EF) and other performance data.
Storage tank size and location	Determine the capacity of the storage tank and location	To determine the size of the storage tank, refer to documentation or a label indicating the tank capacity. Determine and record whether the storage tank is in Conditioned or Unconditioned Space Volume, Unrated Heated Space, or Unrated Conditioned Space.
Extra tank insulation value	Determine the insulation value of any exterior wrap	See Service Hot Water, above.
Pipe insulation value	Determine the insulation value of the pipes	Determine the R-Value of insulation installed on pipes.

Building Element: Light Fixtures		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Number of Qualifying and non-qualifying Light Fixtures	Calculate percentage of Qualifying Light Fixtures by dividing the part by the whole	For each of the three categories of lighting locations (ie. Interior, Exterior, and Garage), record whether the Qualifying Light Fixtures are or are not installed at the time of the inspection.

Building Element: Light Fixtures		
Rated Feature	**Task**	**On-Site Inspection Protocol**
		If the Qualifying Light Fixtures are installed at the time inspection, then determine if they are Tier I or Tier II. For each of the three categories of lighting locations (i.e. Interior, Exterior, and Garage), record the ratio of Qualifying Tier I Light Fixtures to all light fixtures in Qualifying Light Fixture Locations and the ratio of Qualifying Tier II Light Fixtures to all light fixtures in Qualifying Light Fixture Locations. This ratio is calculated by fixture and not by light bulb.

Building Element: Refrigerator(s)		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Total annual consumption of refrigerator	Determine total annual consumption of refrigerator	Record whether the refrigerator is or is not installed at the time of the inspection. If the refrigerator is installed at the time of inspection, then record the model number of the refrigerator and determine the total annual consumption from either the refrigerator Energy Guide Label, the California Energy Commission Appliance Database, the age-based defaults from Table 4.2.2.5.2.5(1) of ANSI 301, the EPA ENERGY STAR website, or another reputable source. Record the location of the refrigerator, whether it is in the Conditioned Space Volume of the Dwelling Unit, Unrated Heated Space, or Unrated Conditioned Space. If there are refrigerators and/or freezers and/or wine coolers in multiple locations within the Dwelling Unit or building, then use the location that represents the majority of power consumption. Total consumption for refrigerators is additive. It shall include all the power consumed by all the refrigerators and/or freezers for use by the occupants of the Dwelling Unit.

Building Element: Dishwasher(s)		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Total annual consumption of dishwasher	Determine the Energy Factor or total annual consumption of dishwasher	Record whether the dishwasher is or is not installed at the time of the inspection. When the dishwasher is installed at the time of inspection, record the model number of the dishwasher and determine the total annual consumption or Energy Factor from either the dishwasher Energy Guide Label, the California Energy Commission Appliance Database, the EPA ENERGY STAR website, or another reputable source. In addition, determine and record the place setting capacity. Record the location of the dishwasher, whether it is in the Conditioned Space Volume of the Dwelling Unit, Unrated Heated Space, or Unrated Conditioned Space. If there are dishwashers in multiple locations within the Dwelling Unit or building, then use the location that represents the majority of power consumption.

Building Element: Range/Oven		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Total annual consumption of range/oven	Determine the total annual consumption of range/oven	Record whether the range/oven is or is not installed at the time of the inspection. When the range/oven is installed at the time inspection, o Determine and record the fuel source for cooking. If different fuels are used, select the fuel for the range. o Determine and record if the range is an induction range ▪ Use model number to search for manufacturer's data sheet or other reputable source o Determine and record whether the oven is a convection oven or not ▪ Use model number to search for manufacturer's data sheet or other reputable source

<table>
<tr><th colspan="3">Building Element: Clothes Washer</th></tr>
<tr><th>Rated Feature</th><th>Task</th><th>On-Site Inspection Protocol</th></tr>
<tr><td>Total annual consumption of clothes washer</td><td>Determine the total annual consumption of clothes washer</td><td>Record whether the clothes washer is or is not installed at the time of the inspection.

When the clothes washer is installed at the time inspection,
o Record clothes washer model number.
o Record the location of the clothes washer, whether it is in the Conditioned Space Volume of the Dwelling Unit, Unrated Heated Space, or Unrated Conditioned Space.
o Determine the capacity in cubic feet and Modified Energy Factor (MEF) or the Integrated Modified Energy factor (IMEF) of the clothes washer from
▪ the manufacturer's data sheet,
▪ the California Energy Commission Appliance Database,
▪ the EPA ENERGY STAR website, or another reputable source.

When the clothes washers are located outside of the Dwelling Unit, in addition to the information above, record the number of clothes washers. To model performance credit for common area clothes washers, a minimum of one clothes washer per eight Dwelling Units is required.

If a water heater separate from the one serving the Rated Home provides hot water to the clothes washer, record the nameplate data of the service hot water heating system that provides hot water to the clothes washers. See Service Hot Water heating section for the information required.</td></tr>
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<table>
<tr><th colspan="3">Building Element: Clothes Dryer</th></tr>
<tr><th>Rated Feature</th><th>Task</th><th>On-Site Inspection Protocol</th></tr>
<tr><td>Total annual consumption of clothes dryer</td><td>Determine the total annual consumption of clothes dryer</td><td>Record whether the clothes dryer is or is not installed at the time of the inspection.

When the clothes dryer is installed at the time inspection,
o Record clothes dryer model number.
o Determine the fuel type of the dryer.
o Determine whether the clothes dryer is moisture sensing or not.
o Record the location of the clothes dryer, whether it is in the Conditioned Space Volume of the Dwelling Unit, Unrated Heated Space, or Unrated Conditioned Space.
o Determine the Efficiency Factor or Combined Energy Factor of the clothes dryer from:
▪ the manufacturer's data sheet,
▪ the California Energy Commission Appliance Database,
▪ the EPA ENERGY STAR website, or another reputable source.

When the clothes dryers are located outside of the Dwelling Unit, in addition to the information above, record the number of clothes dryers.</td></tr>
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Building Element: Ceiling Fans		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Total annual consumption of ceiling fan	Determine the total annual consumption of ceiling fan	Record whether ceiling fans are or are not installed at the time of the inspection. When ceiling fans are installed at the time of the inspection, o Record the number of ceiling fans in the Dwelling Unit. For ceiling fans to be modeled, there must be one fan per Bedroom plus one more elsewhere in the Dwelling Unit. o Record the model number for all ceiling fans. o Record the average efficiency for the fans installed (cfm/W) at medium speed.

Building Element: Dwelling Unit Mechanical Ventilation System(s)		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Centralized system equipment type	Data collection for centralized Dwelling Unit Mechanical Ventilation systems that serve more than one Dwelling Unit	*Centralized exhaust fans* – Record the model number from the nameplate data of each fan being utilized to provide Dwelling Unit Mechanical Ventilation. Use the fan model number to determine the fan cfm and wattage or horsepower from the manufacturer's data sheet. *Centralized supply or balanced system fans* – Record the model number from the nameplate data of each fan being utilized to provide ventilation air, directly or indirectly, to the Dwelling Unit. Record the percent of outdoor air in the supply air and whether the supply air is heated or cooled. If conditioned, record capacity and efficiency ratings of heating and cooling systems. Use the fan model number to determine the fan cfm and wattage or horsepower from the manufacturer's data sheet. For balanced systems, also record the sensible recovery efficiency and total recovery efficiency.
Individual system equipment type	Data collection for individual Dwelling Unit Mechanical Ventilation systems that serve a single Dwelling Unit	*Individual exhaust fans* – Record the fan wattage and model number from the nameplate data of the exhaust fan being utilized to provide Dwelling Unit Mechanical Ventilation. Use the fan model number to determine the fan wattage from the manufacturer's data sheet or HVI Directory. Where the fan is equipped with a timer, document the run time for the fan. If the fan is set to run continuously, then document the run time as 24 hours. In Attached Dwelling Units, it shall be determined whether there is supply air provided to the Dwelling Unit, directly or indirectly from adjacent corridor. See Corridor Ventilation section for guidance. *Individual supply fans* - Record the fan wattage and model number from the nameplate data of the supply fan being utilized to provide Dwelling Unit Mechanical Ventilation. Use the fan model number to determine the fan wattage from the manufacturer's data sheet or HVI Directory. If the fan is equipped with a timer, document the run time for the fan. If the fan is set to run continuously then document the run time as 24 hours. Record whether the supply fan is separate or integrated with the space conditioning system.

Building Element: Dwelling Unit Mechanical Ventilation System(s)		
Rated Feature	**Task**	**On-Site Inspection Protocol**
		Individual Balanced Ventilation Fans – These are commonly known as energy recovery ventilators (ERV) or heat recovery ventilators (HRV). Record model number from the nameplate data of the ERV/HRV. Use the model number to determine the fan wattage, sensible recovery efficiency, and total recovery efficiency from the manufacturer's data sheet or HVI Directory. If the fan is equipped with a timer, document the run time for the fan. If the fan is set to run continuously, then document the run time as 24 hours. *Central Fan Integrated Supply (CFIS) Ventilation System* – A central fan integrated Supply Ventilation System is a specific type of supply-only ventilation that includes a duct running from the outside into the return plenum of the heating/cooling system, a mechanical damper, and controls that ensure the system provides ventilation air even when there is no demand for heating or cooling. For these systems, record the central fan model number from the nameplate data of the air handler fan and whether or not it is equipped with an ECM motor. Use the fan model number to determine the fan cfm and either horsepower or wattage from the manufacturer's data sheet. Where fan wattage is not provided, use (HP x 746)/0.90 to calculate fan wattage. Where the fan has multiple speeds, use values associated with the high-speed setting to select or calculate the fan wattage. *Unit ventilator* – Similar to the CFIS system, a fan coil unit can be designed to provide both space conditioning and mechanical ventilation to the space that it is serving. Classify as a ventilation system only if the unit operates continuously with the outside air damper open or if the damper is controlled to allow the supply of ventilation air when there is no call for heating or cooling.
Dwelling Unit Mechanical Ventilation rate	Measure exhaust and supply airflow	Ventilation airflows in the Dwelling Unit shall be measured following the procedures in ANSI/RESNET/ICC 380.

Building Element: Corridor Ventilation		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Supply Ventilation	Determine whether a corridor ventilation system is used to directly or indirectly supply the adjacent Dwelling Units with ventilation air	Document whether or not weatherstripping and a door sweep are installed on the Dwelling Unit entry door. Document whether or not there is a Supply Ventilation System serving the adjacent common corridor. If there is a Supply Ventilation System serving the adjacent common corridor, then record the model number from the nameplate of that system. Use the model number to determine if the ventilation air is being heated or cooled, the percent of outdoor air supplied, the fan power, and heating/cooling efficiencies.

Building Element: On-Site Power Production		
Rated Feature	**Task**	**On-Site Inspection Protocol**
Annual electricity generation for On-Site Power Production (OPP) systems	Data collection for On-Site Power Production systems	*On-Site Power Production systems* – Collect documentation that shows the annual kWh/y generated. For combined heat and power systems, the documentation shall include the annual gas use in addition to kWh/y generated. *Photovoltaic Systems* – in situations where the Approved Software Rating Tool calculates electricity generation from photovoltaic systems, determine the following: - the orientation of the photovoltaic array to the nearest cardinal/ordinal point, in the direction the array faces. - the tilt of the array. Use an angle finder instrument or geometric calculation. - the area of the array and the peak power using the information on the SRCC label or manufacturer's data sheet. - the efficiency of the inverter using the manufacturer's data sheet.

Annex X – ECM Guidelines (Informative)

General Guidelines for Determining Energy Conservation Measure (ECM)
Service Lifetimes and Maintenance Fractions

	RESNET Energy Rating Standard (March 2012)[1]	Database for Energy Efficient Resources[2]	California Measurement Advisory Council[3]	American Council for an Energy-Efficient Economy[4]	Navigant[5]	National Association of Home Builders[6]	RESNET Standards Committee Estimate[7]	Range (years)
Duct Sealing	20	18						18-20
Air Sealing	30		10					10-30
Attic, Ventilation	30					"lifetime"		30
Attic, Radiant Barrier	30							30
Color, Roof Shingles	15	15						15
Color, Wall Paint	10	6				15		6-15
HVAC, Replacement	15	15	18	10-20	14	10-16		10-20
Furnace, Replacement	20	20	18		15-20	15-20		15-20
Hot Water, Heat Pump Water Heater	15	10	13	13	14			10-15
Hot Water, Heat Recovery	15							15
Hot Water, Pipe Insulation	15	12						12-15
Hot Water, Tank Wrap	12		10					10-12
Hot Water, Solar, Direct	40	15		13	20			13-40
Hot Water, Solar, ISC	40	15		13	20			13-40
Hot Water, Solar, Indirect	40	15		13	20			13-40
Hot Water, Standard System	12	15	13-15	13	9-15	10		9-15
Hot Water, Tankless Gas Water Heater	12	20		13	20	20		12-20
Insulation, Block Wall	40		25			"lifetime"		25-40
Insulation, Ceiling Insulation	40	20	25			"lifetime"		20-40
Insulation, Frame Wall Insulation	40	20	25			"lifetime"		20-40
High Efficiency Fluorescent Lamps	5	3.9-10.6						3.9-10.6
High Efficiency LED							15	15
Pool Pump, High Efficiency	15	10						10-15
Refrigerator Replacement	15	14	18		14-18	13		13-18
Low Flow Showerhead	15	10	6-8.9			"lifetime"		6-15
Window Replacement	40	20	25			15-30		15-40

Window Film or Tint	15	10				10		10-15
Window Solar Screens	15	10						10-15

1. Residential Energy Service Network (RESNET). "Mortgage Industry National Home Energy Rating Systems Standards, March 2, 2012
2. Database for Energy Efficient Resources (DEER). "DEER 2008 for 09-11 Planning/Reporting." 2008. http://www.deeresources.com May, 10, 2012
3. California Measurement Advisory Council (CALMAC): CALMAC Protocols. "Appendix F: Effective Useful Life Values for Major Energy Efficiency Measures." 1994-2007. http://www.calmac.org/events/APX _F.pdf May 10, 2012
4. American Council for an Energy-Efficient Economy (ACEE): "Consumer Resources by Measure Type" January 2011. www.acee.org May 10, 2012
5. Navigant Consulting. "EIA – Technology Forecast Updates – Residential and Commercial Building Technologies – Reference Case Second Edition (Revised)." Sept 2007.
6. National Association of Home Builders (NAHB): "National Association of Home Builders/Bank of America Home Equity Study of Life Expectancy of Home Components." February 2007. http://www.nahb.org/fileUpload_details.aspx?contentID=99359 May 10, 2012.
7. Residential Energy Service Network (RESNET). Standard Development Committee estimate for Standard 301. June 2012.

Performance Compliance Stringency Increase Comparison from Mod 7597 Reference Water Heater Efficiency Increase

Comparing sample Tampa project *EnergyGauge USA* run #1 below with run #2 (same project with 1.99 EF water heater, which would be the reference EF for 50 gallon electric water heaters under Mod 7597) shows the 1.99 EF water heater to reduce the total performance compliance e-Ratio by 0.07. This e-Ratio reduction is approximately equivalent to increasing the heat pump efficiency for this project from baseline SEER 14 / HSPF 8.2 to SEER 15.4 / HSPF 8.5 (run #3), or to reducing the window SHGC from 0.25 to 0.14 (run #4). [Differences between run #1 and all other runs highlighed in red.]

1) Tampa Single-family w/ 50 gallon 0.945 EF WH, 0.25 SHGC Glass, SEER 14 / HSPF 8.2 HP, and Leak Free (Qn_{out}= 0.03) Attic Ducts

Florida Code Performance Summary 2017

	Std. Reference	Proposed	e-Ratio
Heating:	3.91	3.73	0.95
Cooling:	52.50	52.62	1.00
Hot Water:	7.61	7.61	1.00
Total:	64.03	63.97	1.00

Glass/Floor Area: 0.160

PASS

View Multiple Reports | View Report(R405) | Print Multiple Reports | Close

2) Tampa Single-family w/ 50 gallon 1.99 EF WH, 0.25 SHGC Glass, SEER 14 / HSPF 8.2 HP, and Leak Free (Qn_{out}= 0.03) Attic Ducts

Florida Code Performance Summary 2017

	Std. Reference	Proposed	e-Ratio
Heating:	3.91	3.73	0.95
Cooling:	52.50	52.57	1.00
Hot Water:	7.61	3.54	0.47
Total:	64.03	59.84	0.93

Glass/Floor Area: 0.160

PASS

View Multiple Reports | View Report(R405) | Print Multiple Reports | Close

3) Tampa Single-family w/ 50 gallon 0.945 EF WH, 0.25 SHGC Glass, SEER 15.4 / HSPF 8.5 HP, and Leak Free (Qn_{out}= 0.03) Attic Ducts

Florida Code Performance Summary 2017

	Std. Reference	Proposed	e-Ratio
Heating:	3.91	3.61	0.92
Cooling:	52.50	48.60	0.93
Hot Water:	7.61	7.61	1.00
Total:	64.03	59.82	0.93

Glass/Floor Area: 0.160

PASS

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4) Tampa Single-family w/ 50 gallon 0.945 EF WH, 0.14 SHGC Glass, SEER 14 / HSPF 8.2 HP, and Leak Free (Qn_{out}= 0.03) Attic Ducts

Florida Code Performance Summary 2017

	Std. Reference	Proposed	e-Ratio
Heating:	3.91	4.28	1.10
Cooling:	52.50	47.64	0.91
Hot Water:	7.61	7.61	1.00
Total:	64.03	59.54	0.93

Glass/Floor Area: 0.160

PASS

View Multiple Reports | View Report(R405) | Print Multiple Reports | Close

EN8002

Date Submitted	12/12/2018	**Section**	403.3	**Proponent**	Joseph Belcher for FHBA
Chapter	4	**Affects HVHZ**	Yes	**Attachments**	No
TAC Recommendation	No Affirmative Recommendation				
Commission Action	Pending Review				

Comments

General Comments **No** **Alternate Language** **Yes**

Related Modifications

R403.3.7 and R403.3.7.1

Summary of Modification

Additional method for energy code compliance.

Rationale

Reason: The proposal, in addition to allowing ducts to be installed within ceiling insulation, also provides additional effective insulation credit for ducts deeply buried (more than 3 1/2" under insulation) to claim an effective R-value of R-25. This value is based on peer reviewed research conducted by Steven Winters and Associates (Griffiths) and similar language has been incorporated into California's Title 24 residential energy code (CEC).

This will be a valuable, energy equivalent, alternative for many builders that have difficulty designing ducts within the building.

Bibliography: Insulation Buried Attic Ducts: Analysis and Field Evaluation Findings, Griffiths, D et. al., 2008, (page 1-123) https://aceee.org/files/proceedings/2004/data/papers/SS04_Panel1_Paper11.pdf

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

May lead to cost reduction.

Impact to industry relative to the cost of compliance with code

NAHB estimates an average cost reduction of $599.

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

NAHB estimates an average cost reduction of $599.

Requirements

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

The change impacts public health and safety by allowing an additional alternate method for demonstrating energy compliance.

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

The change improves the code by allowing an additional alternate method for demonstrating energy compliance.

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 upgrades the effectiveness of the code.

2nd Comment Period

8002-A2

Proponent Joseph Belcher **Submitted** 5/26/2019 **Attachments** Yes

Rationale

TAC members mentioned a concern about moisture with buried ducts. The additional insulation for Climate Zones 1A and 2A along with the requirement to provide a vapor retarder or foam encapsulation will address the issue. The study Reducing Thermal Losses and Gains With Buried and Encap[sulated Ducts in Hot-Humid Climates" (See uploaded file.) indicates buried ducts with encapsuation "...shows no potential for condensation..." : The proposal, in addition to allowing ducts to be installed within ceiling insulation, also provides additional effective insulation credit for ducts deeply buried (more than 3 1/2" under insulation) to claim an effective R-value of R-25. This value is based on peer reviewed research conducted by Steven Winters and Associates (Griffiths) and similar language has been incorporated into California's Title 24 residential energy code (CEC). This will be a valuable, energy equivalent, alternative for many builders that have difficulty designing ducts within the building

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

NAHB estimates an average cost reduction of $599.

Impact to industry relative to the cost of compliance with code

NAHB estimates an average cost reduction of $599.

Impact to Small Business relative to the cost of compliance with code

NAHB estimates an average cost reduction of $599.

Requirements

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

The change impacts public health and safety by allowing an additional alternate method for demonstrating energy compliance.

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

The change improves the code by allowing an additional alternate method for demonstrating energy compliance.

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 upgrades the effectiveness of the code.

1st Comment Period History

EN8002-G1

Proponent pete quintela **Submitted** 1/14/2019 **Attachments** No

Comment:

May cause condensation in Zone 1, 18" insulation covering a 12" duct is not possible in many attics, consider an Exception for Zone 1.

1st Comment Period History

EN8002-G2

Proponent Jeff Sonne for FSEC **Submitted** 2/18/2019 **Attachments** No

Comment:

The Florida Solar Energy Center is providing a separate alt language mod for 8002, but also adds the following regarding such a mod which was first noted in a 2018 Florida Building Commission funded 2018 IECC vs. 2017 Florida Energy Code comparison report by the Center (http://publications.energyresearch.ucf.edu/wp-content/uploads/2018/07/FSEC-CR-2085-18.pdf):

- Adding the buried duct section to the FEC will provide clarification and will not reduce the stringency of the code, but condensation questions remain in our Florida climate for some cases.

R403.3 Ducts. Ducts and air handlers shall be installed in accordance with Sections R403.3.1 through ~~R403.3.5~~ R403.3.7R403.3.6 ~~7~~.

R403.3.6 ~~7~~ Ducts buried within ceiling insulation Supply and return ducts shall be permitted to be installed partially, or fully buried within ceiling insulation provided they meet the following requirements:

1. Supply and return ducts shall be insulated to a minimum of R-8;

2. At all points along the duct, the sum of the ceiling insulation above the top of the duct and below the bottom of the duct shall be a minimum of R-19 excluding the duct R-value;

3. In *climate zone*s 1A and 2A where supply ducts are fully buried within ceiling insulation, the supply ducts shall be insulated to minimum R-18 and in accordance with the vapor retarder requirements in Chapter 16 (M1601.4.6) of the *Florida Building Code-Residential* or Chapter 6 (604.11) of the *Florida Building Code-Mechanical*

Exception: Sections of supply ducts less than 3 feet from the supply outlet.

R403.3.6.1 Deeply buried duct effective R-value. Sections of ducts installed in accordance with Section R403.3.6 and directly on or within 5.5 inches of the ceiling board and surrounded with blown attic insulation of R-30 or greater and the top of the duct is buried a minimum of 3.5 inches below the insulation shall be permitted to claim an effective duct insulation of R-25 for the deeply buried section of the duct when using a simulated energy performance analysis.

RENUMBER REMAINDER OF SECTION

Revise as follows:

R403.3 Ducts. Ducts and air handlers shall be installed in accordance with Sections R403.3.1 through ~~R403.3.5~~ R403.3.7.

R403.3.7 Ducts buried within ceiling insulation Supply and return ducts shall be permitted to be installed partially, or fully buried within ceiling insulation provided they meet the following requirements:

1. Supply and return ducts shall be insulated to a minimum of R-8;
2. At all points along the duct, the sum of the ceiling insulation above the top of the duct and below the bottom of the duct shall be a minimum of R-19 excluding the duct R-value;
3. In *climate zone*s 1A and 2A where supply ducts are fully buried within ceiling insulation, the supply ducts shall be insulated to minimum R-18 and in accordance with the vapor retarder requirements in Chapter 16 (M1601.4.6) of the *Florida Building Code-Residential* or Chapter 6 (604.11) of the *Florida Building Code-Mechanical*

Exception: Sections of supply ducts less than 3 feet from the supply outlet.

Add new text as follows:

R403.3.7.1 Deeply buried duct effective R-value. Sections of ducts installed in accordance with Section R403.3.6 and directly on or within 5.5 inches of the ceiling board and surrounded with blown attic insulation of R-30 or greater and the top of the duct is buried a minimum of 3.5 inches below the insulation shall be permitted to claim an effective duct insulation of R-25 for the deeply buried section of the duct when using a simulated energy performance analysis.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

BUILDING TECHNOLOGIES PROGRAM

Reducing Thermal Losses and Gains With Buried and Encapsulated Ducts in Hot-Humid Climates

C. Shapiro, A. Magee, and W. Zoeller
Consortium for Advanced Residential Buildings

February 2013

Building America
U.S. Department of Energy

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U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Reducing Thermal Losses and Gains with Buried and Encapsulated Ducts in Hot-Humid Climates

Prepared for:
The National Renewable Energy Laboratory
On behalf of the U.S. Department of Energy's Building America Program
Office of Energy Efficiency and Renewable Energy
15013 Denver West Parkway
Golden, CO 80401
NREL Contract No. DE-AC36-08GO28308

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Prepared under Subcontract No. KNDJ-0-40342-00

February 2013

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U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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List of Tables

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Definitions

ACCA	Air Conditioning Contractors of America
ACEEE	American Council for an Energy-Efficient Economy
ACH_{50}	Air changes per hour at 50 Pascal
AHU	Air-handling unit
Apparent R-value	R-value of ductwork including heat transfer between the duct and conditioned space
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CARB	Consortium for Advanced Residential Buildings
ccSPF	Closed-cell polyurethane spray foam
CDD_{75}	Cooling degree days at base 75°F
CEC	California Energy Commission
cfm	Cubic foot per minute
DE	Delivery effectiveness
DOE	U.S. Department of Energy
dof	Degrees of freedom
DSE	Distribution system efficiency
Effective R-value	R-value of ductwork excluding heat transfer between the duct and conditioned space
EIA	Energy Information Administration
HDD_{65}	Heating degree days at base 65°F
ICC	International Code Council
kW	Kilowatt
kWh	Kilowatt-hour
LBNL	Lawrence Berkeley National Laboratory
LMTD	Log mean temperature difference
NCDC	National Climactic Data Center
NREL	National Renewable Energy Laboratory
Pa	Pascal

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Executive Summary

Thermal losses and gains from ductwork installed in unconditioned spaces—such as attics, crawl spaces, and garages—can contribute significantly to the overall heating and cooling loads of single-family residential buildings, with estimated duct losses ranging from 10%–45 %.[1] The impact is particularly severe in hot climates where air conditioning dominates and extensive duct systems are typically located in hot attics. The duct system inefficiencies are greatest at peak demand conditions when the attic is hottest and run times are the highest. The thermal losses and gains at the three single-story houses in Florida monitored in this study accounted for 15%–35% of the annual pre-retrofit heating and cooling energy use and 6%–25% of the total pre-retrofit annual utility bill.

Even though a number of existing methods can effectively move ducts into the conditioned space, they are not currently being widely implemented. Physically locating the ducts within the conditioned space is most often applicable only to new construction projects and requires planning during design. Attics can be insulated at the roof deck with closed-cell polyurethane foam (ccSPF) to reduce duct losses and infiltration rates, but this method has high up-front costs and the potential to increase loads on the building enclosure. In hot-dry climates, attic duct systems can be buried under loose-fill insulation at a significantly lower cost to reduce thermal loads. In hot-humid climates, however, condensation on the duct jacket can occur when the humidity in the attic is high.

Figure 1. Traditional ductwork hung from attic rafters

Figure 2. Ducts being encapsulated with ccSPF

There are almost 3.9 million houses in Florida alone (U.S. Department of Commerce 2003), most with ducts located in vented attics (Figure 1). A feasible and cost-effective retrofit strategy is needed to reduce duct losses in existing homes in hot-humid climates. Through past research, the Consortium for Advanced Residential Buildings has demonstrated the benefits of buried ducts and buried and encapsulated ducts in new construction applications. The buried and encapsulated duct strategy, which utilizes ccSPF to address condensation concerns (Figure 2), was developed specifically for hot-humid climates.

Buried and encapsulated ducts have the potential to substantially improve the thermal performance of existing ductwork and reduce duct air leakage rates. A second variation of the

[1] The range cited here is based on an extensive literature review described further in Section 1.

concept, just encapsulating the ducts without burying them, evolved during this research in response to site constraints. Encapsulating the ducts without burying them beneath loose-fill insulation results in a lower duct R-value, but the trade-offs are lower up-front costs and additional advantages in coordination and installation.

To evaluate the buried duct concept in a retrofit scenario for a hot-humid climate, encapsulated and buried and encapsulated ducts were installed and their performance was monitored in three Jacksonville homes. Ease of installation was also examined as a key factor in this study. Encapsulating ductwork in ccSPF increased the thermal resistance of the existing ductwork and decreased duct leakage rates. Burying these encapsulated ducts beneath loose-fill insulation further increased the R-value of the encapsulated ductwork.

A multifaceted approach—field monitoring, computer modeling and simulation, and numerical analysis—was used to develop a comprehensive view of encapsulated and buried and encapsulated ducts. The primary goals were to quantify the associated energy savings, cost effectiveness, and condensation potential of this retrofit measure. To calculate energy savings and condensation potential, the researchers performed computer modeling and analysis. Data from field testing were used to validate these conclusions and determine cost effectiveness.

This report begins with a comprehensive overview of the buried duct research that has been conducted to date, including the analysis approaches used to support previous research (Sections 1 and 2). In Section 3, detailed information is presented on the retrofit methodology used to install and test the three existing duct systems, including short- and long-term data collection. Section 4 evaluates the retrofit methodology.

After the methods used to retrofit the systems are explained, Section 5 summarizes the results of the field evaluation. The performance testing results are given, and the thermal performance and condensation potential of buried ducts are discussed qualitatively using the data collected during the monitoring period. Changes in the mechanical and distribution system configuration and operation at each house created challenges for interpreting long-term field monitoring and performance testing data. Despite these challenges, the data offered interesting insights into duct system performance and served to validate the system performance calculations.

Building on the qualitative findings from the field demonstration, a combination of analytical calculations and modeled analysis was used to determine the potential energy savings and cost effectiveness of the retrofit strategy. Section 6 outlines the analytical methodology used to develop the effective and apparent R-values for each strategy of duct insulation. Due to added system complexity, a finite-element heat transfer analysis was required to calculate these values for the buried duct strategy. The finite-element heat transfer model showed that encapsulating the ductwork in 1.5 in. of ccSPF (R-6.7 h-ft^2-°F/Btu-in.) can improve the existing R-4.2 flexible ductwork to values between R-9 and R-13, depending on the size of the duct. Burying the encapsulated ductwork (to create buried and encapsulated ducts) will further increase the effective R-values to between R-16 and R-31.

Using the R-values calculated in Section 6, the effective and apparent heat transfer coefficients (UA values) for the duct systems of the three Jacksonville homes were calculated, and are presented in Section 7. This analysis was validated by comparing the results with test data for each home. The reduction in apparent UA values, based on field data, correlated well with the theoretical UA value reduction as the analysis in Section 6 shows. The values were found to be within 10% of each other, which is a reasonable error given that the calculation assumes steady-state operation.

The heat transfer coefficients developed in Sections 6 and 7 were then used to determine the efficiency of the thermal distribution systems, based on the ASHRAE Standard 152-2004 methodology (ASHRAE 2004). This is covered in Section 8. Both delivery effectiveness and distribution system efficiency were calculated. The calculations showed that duct leakage has a significant impact on delivery effectiveness, as a result of the direct relationship between duct leakage and duct losses.

Duct leakage rates were substantially reduced through encapsulation with ccSPF. For the houses with an air-handling unit in the living space, duct leakage to the outdoors was reduced to rates typical for houses with ducts in the living space. For the house with an air-handling unit in the garage, the duct leakage rates were dramatically reduced, but not to levels associated with ducts in the living space.

In Section 9, the condensation potential of buried and encapsulated ducts is explored further using modeling. For this analysis, the steady-state two-dimensional thermal model developed in Section 6 was combined with a one-dimensional, dynamic, hygrothermal model to predict the potential for condensation on the surface of the duct. This analysis was conducted for both buried and buried and encapsulated ducts using the worst case configurations. The results from the analysis predict condensation issues for the buried ducts without additional ccSPF insulation, which was observed by Griffiths et al. (2002). The analysis did not predict a condensation issue for the buried and encapsulated ducts as specified.

Finally, Section 10 presents information on the predicted energy savings associated with this retrofit and an assessment of cost effectiveness. Predicted energy savings were based on a calibrated Building Energy Optimization model. The modeled energy savings, which range from 5%–20% of total energy use for the three houses, appear reasonable in comparison to the predicted cooling and heating energy savings derived from the ASHRAE 152 delivery system efficiencies (ASHRAE 2004). These savings show that nearly all of the thermal losses and gains from the pre-retrofit duct systems were mitigated through these strategies. A cost-effectiveness analysis determined that the buried and encapsulated duct retrofit achieved $10 in annualized savings. The encapsulated-only strategy yields $141 in annualized savings. The higher annualized savings of the encapsulated-only strategy is due, in part, to avoiding the material and labor requirements associated with duct reconfiguration and blown-in insulation.

Based on this research study, encapsulated and buried and encapsulated ducts were found to dramatically improve the distribution efficiency of existing ductwork. Pre- and post-retrofit distribution system efficiencies were calculated using ASHRAE Standard 152-2004. The best case scenario estimates a post-retrofit distribution system efficiency of 97%–98%. Potential energy savings of 8%–20% per year were predicted through simulation. The predicted total energy savings are consistent with mitigating the majority of the duct losses from the homes. Energy savings associated with thermal losses and gains for these houses had a strong correlation with duct leakage to the outdoors, resulting in a significant range of potential energy savings. Encapsulated and buried and encapsulated ducts were found to be cost effective.

This research has been incorporated into the U.S. Department of Energy (DOE) Challenge Home National Program Requirements (DOE 2012). Although forced-air ducts are typically required to be inside the home's thermal and air barrier boundary, Section 10(c) of DOE (2012) allows an exception for buried and encapsulated ducts. Under this exception ductwork must be encapsulated with at least 1.5 in. of ccSPF and buried under 2 in. of blown-in insulation.

Acknowledgments

Steven Winter Associates, Inc., acknowledges the U.S. Department of Energy Building America Program for funding and supporting the development of this technical report and previous research that informed the report. A special thanks to BASF for financial and technical support. In addition, the authors thank First Choice Supply, Inc., Rix Mechanical, Inc., and the participating homeowners.

1 Introduction

Heat gains and losses from ductwork installed in unconditioned spaces—such as attics, crawl spaces, and garages—can contribute significantly to the overall heating and cooling loads of single-family residential buildings. Unfortunately, installing ductwork in unconditioned spaces is a common construction practice throughout the United States. In the early 1990s, approximately 35% of American single-family homes contained ductwork installed in unconditioned spaces (Modera 1993). Over the past two decades, the number of homes with ductwork has increased considerably. Nearly all new single-family houses have ducted distribution systems; during the late 1990s, the percentage was estimated at 96% (National Association of Home Builders Research Center 1999). As a result, the percentage of housing units containing central forced-air cooling and/or heating systems has increased significantly, from 66% in 1993 (Energy Information Administration [EIA] 1993) to 76% in 2009 (EIA 2009).[2]

Although most studies emphasize the degree of duct losses in unconditioned spaces, estimates of these losses differ greatly, ranging from 10% to 45% (EPA 2009; Siegel et al. 2003; Vineyard et al. 2003; Jump et al. 1996; Palmiter and Francisco 1994; Modera 1993; Andrews and Modera 1992).[3] Duct leakage rates to the outside, which commonly vary from as little as 3% to more than 20%, are compounded by large temperature differentials between the conditioned air inside the duct and the air in the unconditioned space. During the cooling season, 55°F conditioned supply air can be separated from 120°F ambient attic air by duct insulation with a rated thermal resistance as low as R-4.2 (h-ft^2-°F/Btu). During the heating season, this temperature differential can be even higher, with 110°F conditioned air passing through an attic with a 20°F ambient temperature.

The wide range of duct loss estimates cited here demonstrates that duct losses can be reduced substantially for very leaky and underinsulated systems by properly sealing and insulating ductwork. (See Aldrich and Puttagunta 2011 for proper techniques.) Even when properly sealed and insulated, however, the duct losses of traditional duct systems commonly account for

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[2] The authors calculated these percentages using the Public Use Microdata Files furnished by the EIA for the 1993 and 2009 Residential Energy Consumption Surveys.

[3] ASHRAE 152-2004 (See 2004; Section 8) defines duct losses in various ways, depending on the use of the duct loss term. Delivery effectiveness (DE) includes both thermal losses and duct leakage losses. Thermal losses represent the heat transfer through the duct material and any insulation. Duct leakage occurs when the conditioned air escapes through gaps and cracks in the ductwork. The physical location of the ductwork, duct insulation level, and duct sealing all affect the magnitude of the DE. Distribution system efficiency (DSE) includes DE, but also accounts for system cycling, fan power, thermal regain, equipment capacity, and air infiltration. Each term is calculated for heating and cooling design and seasonal conditions. Design conditions represent the efficiency under peak loads; seasonal conditions represent the losses over the entire heating or cooling season. The cited studies calculate duct losses in various ways and do not necessarily correspond to the definitions given in ASHRAE 152-2004. Because DE and DSE are typically similar under both design and seasonal conditions, the values given in these studies are directly compared to demonstrate the magnitude of the duct losses. In this report, the term duct loss is used generically for DE and DSE under design, seasonal, or other conditions. DSE and DE are used when they directly correspond to the conditions defined under ASHRAE 152-2004. Design and seasonal conditions are noted if applicable.

approximately 10% of the heating and cooling loads.[4] As a result, more aggressive strategies are needed to further reduce duct thermal losses. The primary methods, which are discussed in Sections 1.1 and 1.2, involve placing ducts within the thermal enclosure and burying ducts beneath loose-fill insulation. The encapsulated and buried and encapsulated duct strategies seek to achieve similar benefits. Although this report focuses on using these strategies as a retrofit methodology for existing homes, these methods can be employed with minimal changes in new construction.

1.1 Ducts in Conditioned Space: Current Practice

With proper planning and careful attention to detail, the thermal losses associated with ductwork can be eliminated in new construction by placing ducts within the thermal enclosure. In new construction applications, ductwork can be placed within the thermal enclosure using one of four methods: (1) expanding the thermal enclosure to incorporate the unconditioned space (e.g., insulating attics at the roof deck and insulating basements at the basement walls); (2) installing ductwork in a soffit or dropped ceiling; (3) installing ductwork between floors; and (4) using a modified truss to create a plenum for ductwork in the attic (Roberts and Winkler 2010; Hendrick 2003; Consortium for Advanced Residential Buildings [CARB] 2000).

New construction strategies for placing ducts in conditioned space cannot always be applied to existing homes. In retrofit applications, Methods 2 through 4 are typically impractical. Method 1, incorporating the unconditioned space into the thermal enclosure, is a more common retrofit strategy, but it can have significant disadvantages associated with lower energy savings, higher costs, and increased moisture. For ducts placed in attics, which is the principal subject of this report, Method 1 results in insulating the attic at the roof deck and incorporating an unvented attic into the design. Insulating the attic at the roof deck increases the thermal enclosure surface area, which results in larger space-conditioning loads from the enclosure (Hendrick 2003). Although this penalty can be overcome by savings from ductwork thermal losses, the net energy savings (duct savings minus increased enclosure loads) might be less than those achieved with other methods of placing ducts within the thermal enclosure.

Furthermore, building codes require minimum levels of air-impermeable insulations (International Code Council [ICC] 2009), and insulation must be installed so that it does not become dislodged from the roof deck assembly. As a result, closed-cell spray polyurethane foam (ccSPF) insulation is typically used to insulate buildings at the roof deck. Achieving the equivalent R-value at the roof deck using ccSPF is significantly more expensive than installing loose-fill insulation along the ceiling plane. The larger surface area of the roof deck results in higher costs compared to ceiling insulation, and ccSPF is comparatively more expensive than loose-fill insulation. Insulating the building at the roof deck using ccSPF, however, does yield greater air sealing benefits than typical ceiling insulation methods.

Additionally, the moisture dynamics of insulation at the roof deck must be carefully addressed to prevent serious moisture-related problems. Minimum values of air-impermeable insulation are required by Table R806.5 of the *International Residential Code for One- and Two-Family*

[4] This figure is an approximate number derived from the data presented in the literature (EPA 2009; Siegel et al. 2003; Vineyard et al. 2003; Jump et al. 1996; Palmiter and Francisco 1994; Modera 1993; Andrews and Modera 1992). These might apply to DE and DSE under both design and seasonal conditions generally as an approximate value.

Dwellings to prevent condensation on the inside surface of the insulation during the heating season (ICC 2009). Solar radiation can drive moisture from wetted asphalt shingles into the structural sheathing during the cooling season, causing shingle buckling and sheathing deterioration (Lstiburek 2006; Hendrick 2003).

1.2 Buried Ducts: Past Research and Current Practice

Given the many barriers associated with retrofitting the building to include existing ducts within the thermal enclosure and the resistance of some builders to carefully plan for ducts in conditioned space, other methods are needed to address ductwork thermal losses in new and existing homes. Burying ductwork beneath a layer of loose-fill insulation (Figure 3) has been proposed as a comparable alternative to ducts in conditioned space. This method has received significant attention under the Building America Program and has been shown to substantially reduce duct thermal losses (Griffiths and Zuluaga 2004; Griffiths et al. 2004; Vineyard et al. 2004; Griffiths et al. 2002).

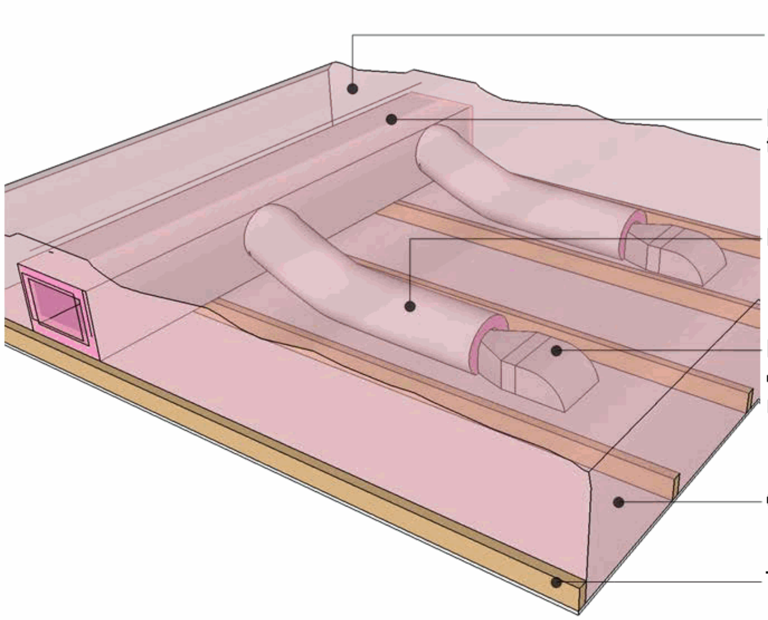


Figure 3. Detail of buried ducts

For new construction projects, the ductwork is installed as close to the ceiling plane as possible to maximize insulation coverage. The ducts are covered with insulation, which provides thermal resistance for the ductwork and boosts the R-value of the existing ceiling insulation. Although buried ducts do not eliminate duct losses entirely, the energy savings can be similar to those achieved by implementing Method 1 as discussed in Section 1.1, in which the attic is insulated at the roof deck. Some thermal losses will still be present with buried ducts, but these losses might be less than or equal to the increased thermal loads resulting from the increased enclosure area associated with Method 1.

The effective R-values of deeply buried ducts are between 25 and 31 (Griffiths et al. 2004). These values are greater than or equal to many attic insulation levels in existing homes. Although burying ducts deeply is uncommon and requires careful attention, the practice, when combined with proper duct sealing techniques, can reduce thermal losses substantially in comparison to traditional duct installations. Furthermore, in retrofit applications, the buried duct strategy can be implemented at a fraction of the cost associated with insulating the attic at the roof deck because the approach uses less expensive loose-fill insulation to cover the existing ductwork.

Buried ducts, however, are not well suited for hot-humid climates. After demonstrating buried duct benefits in hot-dry climates, Building America research was conducted to evaluate the strategy in hot-humid climates. After burial, duct jacket surface temperatures were observed to be lower than the dew point of the attic air; this creates a potential for condensation on the surface of the duct (Griffiths and Zuluaga 2004; Griffiths et al. 2004; Griffiths et al. 2002). As a result, a modified methodology to reduce the condensation potential was sought. Ductwork at a test home in Atlanta was encapsulated in a 1-in. layer of ccSPF insulation before being buried beneath loose-fill insulation. The buried and encapsulated duct strategy (Figure 4) implemented at this home successfully eliminated the condensation potential of buried ducts in a hot-humid climate (CARB 2003).

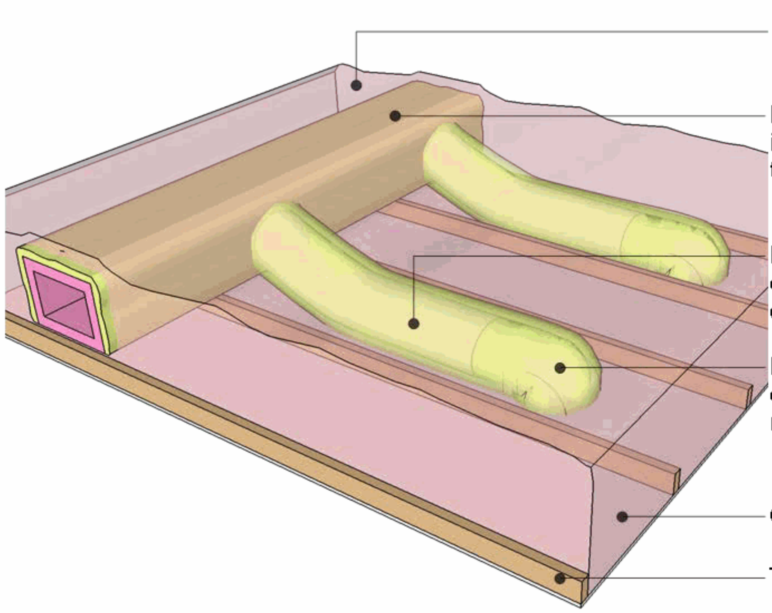


Figure 4. Detail of buried and encapsulated duct

The application of ccSPF, which has high R-values per inch and low vapor and air permeability, increases the thermal resistance of the duct insulation and reduces duct leakage by filling gaps and voids in the ductwork. Building on the buried duct concept, buried and encapsulated ducts start by encapsulating the ductwork before burying it beneath a layer of loose-fill mineral fiber insulation. In addition to the lower duct leakage rates expected from using ccSPF, installing additional insulation through the ccSPF and burying the ductwork beneath loose-fill insulation are expected to result in significantly higher R-values. Furthermore, the risk of condensation associated with buried ducts is expected to be eliminated by elevating the surface temperature of the outside vapor-impermeable layer of the duct above the dew point of the surrounding air.

1.3 Reducing Duct Losses in Existing Homes in Hot-Humid Climates

Recognizing that cost-effective and safe methods are needed to address thermal losses from ductwork in the current housing stock in hot-humid climates, it was clear that the feasibility of applying the buried and encapsulated duct strategy to existing homes warranted further research. Furthermore, more research was needed to validate the findings by CARB (2003) in hot-humid climates and quantify the energy savings potential of this strategy. The vast majority of single-family homes in the hot-humid climates in the United States have central forced-air cooling systems (see Table 1). Since conventional HVAC design manuals dictate that space-conditioning air in cooling-dominated climates be discharged from ceiling or high wall registers (Air Conditioning Contractors of America [ACCA] 1992) and living space is at a premium, the vast majority of these homes have ductwork installed in attics.

Table 1. Percentage of Households With Central, Ducted, Forced-Air Space-Conditioning Systems by Climate

Climate	Cooling (%)	Heating (%)	Heating and/or Cooling (%)
Very Cold/Cold	48.9	68.0	72.7
Hot-Dry/Mixed-Dry	60.6	67.1	73.0
Hot-Humid	82.5	79.4	86.1
Mixed-Humid	71.4	73.4	79.4
Marine	17.8	57.4	58.1
All Climates	61.3	70.9	76.3

Source: EIA (2009).

This report investigates the potential of two ductwork retrofit strategies employing ccSPF, buried and encapsulated ducts and encapsulated ducts alone. The encapsulated duct approach is a variation of the buried and encapsulated duct strategy that arose during the field retrofit because of feasibility limitations. Encapsulated ducts simply enhance the existing insulated ductwork by applying a layer of ccSPF. Requiring less modification and fewer contractors and materials, encapsulated ducts are expected to have higher R-values and lower duct leakage rates than existing ductwork. This study sought to explore the trade-offs in energy savings, installation cost, and installation ease between the two approaches.

When properly installed, these two duct insulation strategies are both compliant with the 2009 *International Residential Code for One- and Two-Family Dwellings* (ICC 2009). In general, the code allows spray-foam insulation to be applied to the exterior of ductwork (Section M1601.3) as long as the spray foam has a flame spread index no greater than 50 and a smoke developed index no greater than 450, is protected by an ignition barrier (Sections R316.5.3 and R316.5.4), and meets the general requirements for use in residential buildings (Section R316). As a result, buried and encapsulated ducts covered with at least 1.5 in. of mineral fiber insulation and installed in attics “entered only for purposes or repairs or maintenance” (meaning no storage or habitation allowed) meet these requirements (ICC 2009). Thermal barriers are not required for this type of attic, and 1.5 in. of fiberglass, which is considered mineral fiber insulation (ASTM 2011), meets the minimum requirements for ignition barriers.

Encapsulated ducts or buried and encapsulated ducts covered with less than 1.5 in. of fiberglass insulation can also be code compliant if the specific spray foam meets the broader requirements of Section M1601.3. Although not all ccSPF materials meet these requirements, the installed material has undergone testing to verify performance. Exposed applications of the spray foam used in this study are compliant with Section M1601.3, as described in the International Code Council Evaluation Service Report (International Code Council Evaluation Service 2012), and are therefore code compliant (International Code Council Evaluation Service 2010).

The primary goals of this study are to quantify the energy savings associated with encapsulated and buried and encapsulated ducts, along with their cost effectiveness and condensation potential. Although the field demonstration supplied valuable information about the installed performance of the distribution systems and important insights into the feasibility of this retrofit strategy, variations in field conditions necessitated supplemental data analysis. As with any field testing of occupied homes, quantifying energy savings is difficult because of the dramatic changes in occupant behavior and building system operation. Despite these difficulties, field evaluations are necessary to support other analytical methods with real-life data. In this report, computer modeling and analysis were used to calculate energy savings and condensation potential. Data from the field evaluation were used to validate these conclusions and determine cost effectiveness.

2 Previous Research

Previous research on buried ducts has focused on determining effective duct R-values, investigating the potential for condensation, and estimating associated energy savings in new construction applications. Unlike traditional hung ducts, the thermal resistance of buried ducts cannot be calculated by knowing the geometry of the duct insulation and its conductivity. To make an appropriate comparison with traditionally insulated duct R-values, effective R-values of buried ducts must be determined.

Using Algor FEA (Zoeller 2009), a two-dimensional, steady-state, finite-element heat transfer model, Griffiths and Zuluaga (2004) calculated effective R-values of ducts buried under various levels of loose-fill insulation. Effective R-values were defined as "the equivalent R-value that conventional hung ducts must be wrapped with to achieve the same thermal performance as buried ducts" (Griffiths and Zuluaga 2004; 723). Under this definition, effective R-values exclude the heat transfer between the conditioned space and the duct that results from burial in loose-fill insulation.

The primary driver of effective R-values was found to be the distance from the top of the insulation to the top of the duct, and the overall R-value of the attic insulation was found to be less important than the height of the insulation. Furthermore, the impact of insulation below the duct was minimal; effective R-values were unaffected by placing the ducts on the gypsum board ceiling surface, over loose-fill insulation, or over the lower truss cord. As a result, Griffiths and Zuluaga (2004) categorized buried duct insulation levels by the distance from the top of the insulation to the top of the duct. Ducts were defined as partially buried, fully buried, and deeply buried (see Figure 5).

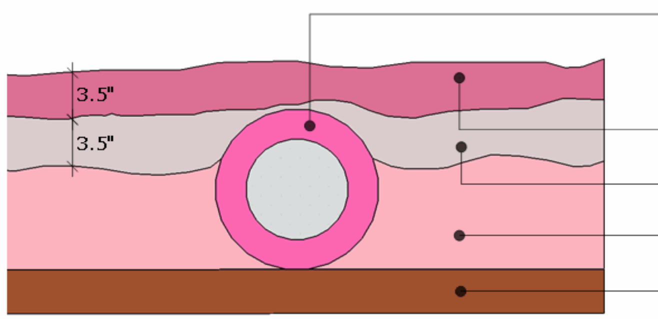


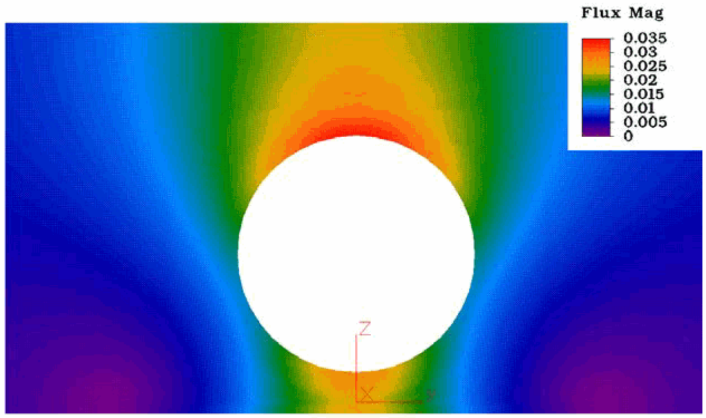
Figure 5. Categorization of duct insulation levels by burial class

For these levels of burial, effective R-values were calculated for fiberglass and cellulose attic insulation (Table 2). Although the effective R-values of ducts were found to be a function of the duct inner diameter, the listed R-values are an average of small and large duct simulations. These R-values became the basis of Table R3-38 of the *Residential Compliance Manual* (California Energy Commission [CEC] 2007; 2008).

Table 2. Effective R-values of Buried Ducts by Insulation Level and Type (h-ft^2-°F/Btu)

Loose-Fill Insulation Type	Deeply Buried	Fully Buried	Partially Buried
Fiberglass	R-25	R-13	R-9
Cellulose	R-31	R-15	R-9

Validating these theoretical effective R-values is difficult because the effective R-value explicitly excludes the nondetrimental heat transfer between the duct and the conditioned space (see Figure 6 for an image showing heat transfer). Validation has been attempted under laboratory conditions and in field testing (Griffiths et al. 2004; Vineyard et al. 2004), but the methods used in these validation studies do not exclude heat transfer between the duct and the conditioned space, resulting in a different definition of R-value. To address the conflation of these two R-value definitions in previous studies, this report distinguishes between effective R-values, which exclude heat transfer between the duct and conditioned space, and apparent R-values, which include heat transfer between the duct and conditioned space.



Source: CARB (2003)

Figure 6. Heat transfer between duct interior, conditioned space, and attic

Although apparent R-values are expected to be lower than effective R-values because they include all heat transfer across the surface of the duct, laboratory and field testing has not consistently supported this hypothesis. Griffiths et al. (2004) compared the performance of buried ducts against that of conventional hung ducts in two identical houses in Elk Grove, California. Apparent R-values determined through field testing were slightly higher than the effective R-values predicted by thermal modeling. Vineyard et al. (2004) used laboratory testing to calculate R-values and found apparent R-values slightly lower than the effective R-values found by Griffiths and Zuluaga (2004). The discrepancy between these results might be explained by the averaging used to calculate the effective R-values of buried ducts. For small or large ducts, the effective R-values could differ considerably from those shown in Table 2.

Research in Phoenix, Arizona, and Sacramento, California, successfully demonstrated that buried ducts do not have condensation issues in hot-dry climates. A demonstration in Melbourne, Florida, however, found a potential for condensation in a hot-humid climate. Even though the conditions supporting condensation were relatively short-lived and no damage was found, the condensation potential was possibly mitigated by leakage from the building enclosure and ductwork. In less leaky conditions, condensation could have been a greater problem (Griffiths et al. 2004; Griffiths et al. 2002). Chasar and Withers (2012) also observed condensation on the surface of buried ducts at a home in Cocoa, Florida. Laboratory testing determined that ducts cannot safely be fully buried in insulation when design dew point temperatures approach 80°F (Vineyard et al. 2004).

In a side-by-side evaluation of traditional ductwork and buried ducts, Griffiths et al. (2004) saw a measured improvement in distribution efficiency from 86% to 90%.[5] Under laboratory testing, Vineyard et al. (2004) reported seasonal distribution efficiency improvements ranging from 4% to 14% and design distribution efficiency improvements ranging from 5% to 31%. Seasonal distribution efficiency reductions represent annual energy savings; design distribution efficiency reductions represent potential space-conditioning system capacity reductions.

Field monitoring of buried and encapsulated ducts covered with 1 in. of ccSPF insulation saw no condensation potential during the monitored summer for a newly constructed home in Atlanta, Georgia. Observed ccSPF surface temperatures were safely above the attic dew point temperature. Although this study demonstrated the feasibility of buried and encapsulated ducts in new construction, no energy savings or distribution efficiency calculations to quantify the associated energy savings were reported (CARB 2003).

Most of the studies mentioned here have used temperature and relative humidity sensors to measure condensation potential. Using these sensors, the ambient air dew point is compared to the surface temperature of the ductwork. If the surface temperature is below the dew point of the surrounding air, there is a potential for condensation. Chasar and Withers (2012) used resistive moisture measuring strips in addition to temperature and relative humidity sensors. Both methods resulted in similar measures of condensation potential, validating both methods of measuring condensation potential.

[5] These values were measured over a period of time, and therefore do not correspond to either design or seasonal values.

3 Materials and Methods

In this study, three houses of similar size and vintage in Jacksonville, Florida, were monitored before and after duct retrofits during the summers of 2010 and 2011. These three test houses are single-story buildings that were constructed between 1980 and 1991 and built using typical Florida construction methods. Ductwork is constructed out of duct board or insulated flex duct and placed in vented attics with insulation at the ceiling plane. Air-handling units (AHUs) are located inside the house or in the garage.

System evaluations were performed through single-point performance testing at various project stages, long-term pre- and post-retrofit field monitoring, and house and system documentation. One house was retrofitted with encapsulated ducts, and the other two were retrofitted with buried and encapsulated ducts. This section summarizes the methodology used to monitor the pre- and post-retrofit performance of the duct systems in these three houses (Section 3.1) and the retrofitting methodology used to insulate the existing duct systems (Section 3.2). The performance testing and field monitoring methodologies were developed to gather as much information as possible about the temperature, relative humidity, and operation of the systems before and after duct insulation. Since encapsulated and buried and encapsulated ducts are a novel insulation strategy for ductwork in existing buildings, a retrofit methodology was developed to achieve the desired attributes of practical applications, to maximize energy savings, and to minimize condensation potential.

3.1 Monitoring Methodology

The performance of pre- and post-retrofit ductwork assemblies was measured using performance testing and long-term monitoring. To assess the long-term performance both before and after implementing the encapsulated duct and buried and encapsulated duct strategies, data loggers were placed at multiple distribution system locations. Measurements were taken at 1- or 2-min intervals. Operation of the space-conditioning equipment was measured at the AHU and condensing unit using state sensors, which have a Boolean output of either "on" or "off." Measurements were taken using the equipment listed in Table 3.

During the pre- and post-retrofit assessments, the following measurements were taken through performance testing:

- Pressure drop across the AHU and coil (Pa)
- Temperature change across the AHU and coil (°F)
- Total AHU supply and return airflows (cfm)
- Room airflows (cfm)
- Duct leakage—total and leakage to the outside, supply and return (cfm @ 25 Pa)
- Infiltration of building enclosure (ACH_{50})
- Power consumption of the AHU and condensing unit (W).

Table 3. Equipment Used for Performance Testing and Long-Term Monitoring

Measurement	Equipment Needed
Pressure Drop Across the AHU and Coil	DG-700 Digital Pressure and Flow Gauge
Temperature Change Across the AHU and Coil	HOBO U12-006 data logger with TMC6-HD Probe
Total AHU Supply and Return Airflows	True Flow Air Handler Flow Meter
Room Airflows	Alnor Low Flow Balometer
Duct Leakage—Total and Leakage to the Outside, Supply and Return	Minneapolis Duct Blaster System with DG-700 Digital Gauge
Infiltration of Building Enclosure	Minneapolis Blower Door System with DG-700 Digital Gauge
Infrared Thermal Imaging	Flir B50 Infrared Camera
Temperature of Airstream	HOBO U12-006 data logger with TMC6-HD Probe
Surface Temperature	HOBO U12-006 data logger with TMC6-HE Probe
Indoor/Attic Air Temperature and Relative Humidity	HOBO U12-011 data logger
Outdoor Air Temperature and Relative Humidity	HOBO U23-002 data logger
Relative Humidity of Airstream or Surface	HOBO U23-002 data logger
AHU and Condenser Run Times	HOBO U9-001 data logger with CSV-A8 Probe

At each of the three homes, temperature (°F) was measured at the following locations:

- Discharge airstream of longest run
- Discharge airstream of three typical runs
- AHU supply
- AHU return
- Surface of duct jacket at three typical runs
- Surface of ccSPF insulation at three typical runs (post-retrofit only)
- Surface of boots at three typical runs (pre-retrofit only for all houses and one boot per house post-retrofit)
- Attic ambient air
- Living space ambient air at two locations
- Outdoor ambient air.

Relative humidity (%) was measured at the following locations:

- Discharge airstream of longest run
- Discharge airstream of three typical runs
- AHU supply
- AHU return
- Surface of ccSPF insulation at three typical runs (post-retrofit only)
- Surface of boots at three typical runs (pre-retrofit only)
- Attic ambient air
- Living space ambient air at two locations
- Outdoor ambient air.

3.2 Retrofitting Methodologies

The methodologies for implementing the two ductwork retrofit strategies were influenced by concerns about maintaining quality installation, minimizing condensation, and streamlining the installation, along with practical concerns identified by the entire team. The team included the contractor responsible for applying the ccSPF insulation, the ccSPF manufacturer, the HVAC contractor, and the Building America researchers. The researchers were primarily concerned with ensuring that ductwork was placed as close as possible to the ceiling plane, the ccSPF application was consistent and of sufficient thickness to mitigate the possibility of condensation, and the installation was code compliant. The insulation contractor was primarily concerned with preventing leakage of ccSPF through the boots of the ductwork into the home and preventing blowback of fiberglass insulation during ccSPF application, which can affect visibility and insulation adherence to the ductwork.

Attic accessibility, temperature, and location of existing services (e.g., plumbing, television cable, security wires, and fireplace flues) also needed to be taken into account. Based on previous experience in Atlanta, a ccSPF thickness of 1.5 in. was selected to ensure that the ductwork would be covered in enough insulation to prevent condensation. This insulation level is slightly higher than that used in Atlanta because of the differences in climate.

Sections 3.2.1 and 3.2.2, respectively, describe the general strategy for encapsulated and buried and encapsulated duct retrofits. Although these methods serve as a general guideline for retrofitting existing ducts, differences between ductwork systems merit slightly different treatment, particularly when reconfiguring the existing system layout. The differences between the methods used at the three tested houses are discussed in Sections 3.2.3 through 3.2.5.

3.2.1 Buried and Encapsulated Ducts

For buried and encapsulated ducts, a four-phase methodology was employed. The insulation contractor removed the existing ceiling insulation, the HVAC contractor reconfigured the ducts, a trained installer applied the ccSPF, and the insulation contractor then installed the loose-fill insulation. This approach requires coordination between an insulation contractor and an HVAC contractor.

Additional coordination and home access was required for laborers to remove insulation and seal the register boots. The ccSPF contractor opted to remove all blown-in insulation and batt insulation as a precaution to eliminate any problems during ccSPF application. The following list explains and illustrates the steps taken during the buried and encapsulated ducts retrofit.

1. Remove existing insulation from around the ductwork by removing batt insulation and/or vacuuming out loose-fill insulation. Note: To minimize the number of site visits, laborers might be able to complete this step while the ccSPF equipment is being set up.

2. Seal around the boots with polyurethane-based insulating foam to prevent leakage into living space during encapsulation. Note: The blades of the interior diffusers were typically closed during ccSPF application for added protection.

3. Cut down or remove supports holding ductwork and plenum boxes above the truss bottom cords or gypsum board.[6] Varying degrees of reconfiguration could be appropriate, depending on the configuration of the ductwork and attic.[7] This work, including extending sections of ductwork, was done by an HVAC technician.

4. For ductwork that passes over soffits or other areas that have a large gap between the duct and the sheetrock, 1.5-in. rigid insulation board can be placed underneath the ductwork to ensure that the ductwork is entirely encapsulated in an air- and vapor-impermeable layer of insulation. It is preferable to seal the ductwork directly to the sheetrock but limited access for the ccSPF gun and gear must be considered.

[6] Ducts should be supported in compliance with local building codes and manufacturer specifications.

[7] Major reconfigurations might require duct sizing calculations using ACCA Manual D (ACCA 2009). For this project, duct reconfigurations were minor, and no efforts were made to rigorously size duct reconfigurations using Manual D.

5. Protect existing services, such as flues and pipes, from ccSPF using duct board or rigid insulation. The appropriate material will depend on the application.

6. Encapsulate ductwork in at least 1.5 in. of ccSPF. The minimum thickness must be maintained consistently on all sides to mitigate condensation concerns.

7. Bury encapsulated ductwork in loose-fill insulation. The insulation must cover the ductwork to be considered fully buried. Code requires a minimum of 1.5 in. of coverage over the ducts for ccSPF materials that do not meet the flame spread requirements. Coverage of 3.5 in. over the duct surface achieves a deeply buried rating.

3.2.2 Encapsulated Ducts

For one of the houses in this study, good duct burial could not be achieved even if significant duct reconfiguration had been undertaken. In addition, the project team was concerned that relocating the ductwork would significantly affect the room airflows. As a result, the team opted to evaluate the benefits of the encapsulated duct strategy.

For encapsulated ducts, the methodology is similar. This strategy, however, is simpler and requires no duct reconfiguration or loose-fill insulation. This is a single-contractor approach, requiring only ccSPF application. Selecting the appropriate method for each house will depend on cost, feasibility, ccSPF material code compliance, and energy performance goals. The following list describes and illustrates the encapsulated duct strategy.

1. Remove existing insulation from around the supply and return register boots by moving batt insulation or vacuuming out loose-fill insulation.

2. Seal ductwork with polyurethane-based insulating foam to prevent leakage into living space during encapsulation.

3. For ductwork that is not hung above the ceiling or does not have sufficient clearance below for proper ccSPF application, place 1.5-in.-thick rigid insulation board underneath the ductwork to ensure that the ductwork is entirely encapsulated in an air- and vapor-impermeable layer of insulation.

4. Encapsulate ductwork in at least 1.5 in. of ccSPF using a material that has the necessary ratings to demonstrate code compliance. Leave the ductwork exposed.

3.2.3 House 1 Retrofit

The existing ductwork in House 1 consisted of R-4.2 flexible ductwork configured with a primary trunk extending the length of the house and branch take-offs serving the spaces. The AHU is located inside the conditioned area and has a louvered door on the return, eliminating the need for return ductwork. Branches are connected to the primary supply trunk using plenum boxes constructed with R-4 fiberglass duct board, which are placed on plywood platforms. Duct runs are hung from the rafters with strapping and connected to sheet metal boots at the ceiling plane (Figure 7). This was the only home served by an AHU with a variable-speed fan motor.

Ductwork at House 1 was retrofitted with a buried and encapsulated duct strategy. Of the three, this house underwent the most significant duct reconfiguration. During the duct retrofit, the plywood platforms supporting the plenum boxes were removed to lower the main trunk closer to the ceiling plane. The straps supporting the ducts were removed, lowering them to the ceiling plane. Where possible, ductwork was reconfigured to minimize elbows and eliminate duct overlap. The reconfiguration resulted in approximately 21 linear feet of additional ductwork routed closer to the gypsum board. These modifications maximized duct burial to the greatest extent possible, but still primarily used the existing duct system.

Figure 7. Existing ductwork at House 1

3.2.4 House 2 Retrofit

Existing ductwork in House 2 consisted of a main rectangular supply trunk and rectangular branch supply take-offs. The AHU is located in the garage, near a wall adjacent to the conditioned space. All supply ductwork runs through the garage and into the attic. There are two returns, a central return entering the AHU return plenum through the partition wall, and a second return serving the far side of the house via a flex duct routed through the entire attic and garage. The supply ductwork consists of R-4 duct board rectangular ducts (Figure 8), and the return ductwork consists of a large R-4.2 flex duct (Figure 9).

House 2 was retrofitted with a buried and encapsulated duct strategy. During the retrofit, the majority of the supply ductwork was left in place because it was already resting on the lower truss cords. One exception was a supply duct that had been built to cross over the return duct (Figure 10). The duct board return had since been abandoned. The supply duct was replaced with a small flex duct using a side take-off, enabling this ductwork to drop low against the ceiling plane. In conjunction with this modification, the abandoned duct board return was removed and the majority of the return ductwork was relocated to the center of the attic and lowered to the truss cords (Figure 11). The abandoned return ductwork was removed and discarded.

Figure 8. Supply ductwork for House 2

Figure 9. Return ductwork for House 2

Figure 10. Supply ductwork jump over abandoned return ductwork

During removal of the ceiling insulation before encapsulation, a large opening in the far end of the supply trunk was discovered. This take-off protruded from the bottom of the trunk toward the ceiling, and was most likely meant to serve a register that was never installed. The supply air had been escaping to the attic since the system was installed. This opening was sealed before encapsulation. This problem was not discovered before pre-retrofit monitoring began. As shown in Figure 12, the ceiling in this home had a number of dropped areas for ceiling coffers. In these locations, the batt and the blown insulation were very deep. The insulation contractor removed much of this insulation and used rigid insulation as a substrate for the ccSPF application. Much of the batt insulation could have been left in place, but the open duct would not have been detected.

Figure 11. Duct reconfiguration at House 2

Figure 12. Open duct take-off at House 2

3.2.5 House 3 Retrofit

House 3 was similar to House 1 in ductwork specifications. Existing R-4.2 flexible ductwork was configured with a large main trunk running the length of the house and flex duct branch take-offs. The AHU is located inside the conditioned area and served by a louvered door on the return, eliminating the need for any return ductwork. Branches were connected to the supply trunk using plenum boxes constructed with R-4 fiberglass duct board, which were placed on plywood platforms. Duct runs were hung from the rafters and connected to sheet metal boots at the ceiling plane.

In this home, the main living room has a cathedral ceiling and the large duct trunk is suspended from the center of trusses for a long run (Figure 13). Even if this trunk were lowered, it would be resting on the angled cathedral ceiling plane. Under those conditions, burying the large duct would have been difficult and might have necessitated baffling at the perimeter to prevent insulation from blocking the limited attic vents. In addition, many of the branch ducts were resting on high raised platforms.

Lowering the ductwork would have resulted in severe duct bends, making burial challenging. The potential impact of the duct reconfiguration on room airflows was difficult to predict, but the project team opted to forgo duct reconfiguration in this house. As an alternative to burying the ductwork, the team considered wrapping the ducts with fiberglass duct wrap insulation or draping them with fiberglass batts. Either approach would have provided the minimum 1.5-in. coverage over the ccSPF and resulted in a minimal additional amount of insulating value. Ultimately, the manufacturer confirmed that the ccSPF could be left exposed, so no additional insulation was installed.

No reconfiguration was necessary at House 3 because it was retrofitted using the encapsulated duct strategy (see Figure 13 for finished retrofit). The ccSPF contractor was initially concerned that the raised ductwork would be difficult to insulate because of the high application pressures, but the installer was able to get access to all sides of the ductwork.

Figure 13. Finished encapsulated duct hung from roof deck

4 Retrofit Methodology Evaluation

Retrofitting these houses resulted in valuable information about the coordination issues, practicality, and difficulties associated with burial and/or encapsulation of the existing ductwork at the three test homes. Section 4.1 describes the lessons learned. Section 4.2 outlines some quality control issues experienced during the retrofit process.

4.1 Lessons Learned

During the retrofit process, many important details about the encapsulated and buried and encapsulated duct retrofit methodologies were uncovered. Even though the research team attempted to preemptively solve any problems that might arise, unforeseen issues were inevitably discovered during the installation. Furthermore, some of the actions taken to remove obstacles during the retrofits were potentially unnecessary. The following bullet points list potential areas of improved installation efficiency, as well as the issues that arose during the installation and potential solutions. As with any new building methodology, processes will become more streamlined as more installations take place.

- Baffling materials might be required to enable mounding of loose-fill insulation to achieve proper burial of vertical duct trunks and raised or larger diameter duct runs (Figure 14).
- Baffling might be necessary to partition off flues, chimneys, or other house components that should not be in contact with the ccSPF or loose-fill insulation. Foil-faced duct board was typically used because it is rated for use in attics, comes in narrow pieces that can be easily transferred to the attic, can be cut with a knife, and can be secured with metal tape (Figure 15).
- Venting for existing ventilation fans cannot be blocked by the added blown-in insulation. In one home, the fan was unducted and vented to the attic. Existing unducted ventilation fans should be ducted to an exterior termination.
- Attic venting at the ridge, gables, and perimeter should be assessed to ensure that added blown-in material will not block the airflow.
- Electrical, telephone, cable, security, and other wiring could be permanently spray foamed into place (Figure 16).
- Plumbing routed through the attic, such as the roof-mounted solar pool heating system installed in one test home, could be covered with foam.
- Access for installers can be difficult because of the cables, plumbing, and other equipment located in the attic.
- Can lighting, exhaust fans, and other electrical equipment located in the ceiling plane can get covered in foam and/or require baffling for protection during the retrofit.
- During the summer, high attic temperatures can be a safety concern for the ccSPF installers. The ccSPF material used in these installations is heated before spraying, further

increasing the attic temperature. In addition, installers must wear protective masks and suits. Forced ventilation air was used in the attics during these applications, although it was not cooled.

- Attic access for ccSPF installation must be considered. During screening of potential installation sites, houses with adequate access for hoses and equipment were selected. These houses all had attic access stairs located in the garage, eliminating the need to enter the house with hoses and ccSPF equipment.

- During the ccSPF installation, the HVAC system should be disabled. For all three houses, the AHUs were turned off during the application. The ccSPF contractor raised concerns about any odors escaping into the living space.

- Coordinating with occupants is important. If the AHU system will be disabled for a few hours, any pets or occupants should leave the house to avoid fumes and maintain comfort. Every attempt was made to minimize the number of times access to the house was required. To install sensors for this research project and conduct the performance testing, access to these houses was required more frequently than would be needed in a typical application.

- The need for boot sealing should be further evaluated. It might not be necessary, but in these homes it was left to the discretion of the contractor. If future investigations find that this is not required, it could result in lower costs.

- The need for insulation removal should be further evaluated. Fully removing the insulation might be unnecessary. Cutting it and rolling it back before applying the ccSPF might be sufficient. On the other hand, removing existing attic insulation offers an excellent opportunity for sealing the ceiling planes, which would result in even greater energy and comfort improvements.

- Sequencing of this retrofit application requires coordination to minimize costs and expedite the installation. Ideally, the ccSPF can be applied in a few hours in the morning and a second installer can follow behind with a truck to install the blown-in loose-fill insulation. For these houses, the same contractor performed both services, but with two separate crews. Additional time must be left for any insulation removal, boot sealing, and/or duct reconfiguration.

- Duct reconfiguration should be undertaken with care and evaluated for each home. For these retrofits, minimal duct changes were made and the pre- and post-retrofit airflows were verified by testing. Although airflow verifications might not be necessary for retrofits with minimal reconfigurations, the airflows could be affected if significant changes are made to ductwork. In this case, it might be necessary to install flow dampers and verify airflows after the retrofit is complete.

- Using an HVAC contractor for the duct reconfiguration is recommended. Typically, insulation contractors are not familiar with the impact of duct changes on the system airflows. Although the insulation contractor can do minimal duct reconfiguration (cutting down strapping, etc.), changes to the distribution system can void any contractor warranties associated with the installed duct system. Local codes can also require a licensed HVAC contractor to perform all work related to the HVAC system.

- The buried and encapsulated duct strategy is a multitrade effort. For these homes, Building American Program researchers coordinated with the contractors and homeowners. It is unlikely that a homeowner would be willing to serve as the point of coordination to implement this strategy. To offer this strategy as a package, two or three contractors would be required: a ccSPF installer, a blown-in insulation installer, and an HVAC installer (could be optional, if code allows). Ideally, a company that offers a full range of home retrofit services could furnish this package. As an alternative, organizations could partner to offer the package, with one contractor serving as a coordinator.

- The encapsulated duct strategy is a single-trade effort. It requires significantly less coordination, fewer periods of access to the home, only a single insulation material, and lower costs. Insulation contractors might need to be trained to recognize major distribution flaws that must be corrected by an HVAC contractor, such as the one discovered at House 2. An HVAC contractor might be required to consult on a case-by-case basis if concerns arise and the homeowner opts to pursue them.

- Careful attention must be paid to quality control of the ccSPF installation. This is discussed further in Section 4.2.

Figure 14. Baffling used to ensure proper burial of supply duct plenum (post-encapsulation and pre-burial)

Figure 15. Baffling used to prevent ccSPF application on flue duct

Figure 16. Electrical, telephone, and other wiring permanently spray foamed to the ceiling and ductwork during retrofit

4.2 Quality Control

The most important observation from the field demonstration was the inadequate application of ccSPF at several specific locations of the ductwork and the general difficulty with maintaining consistent insulation thickness. This observation is not intended as a critique of the installation contractors. The installers were challenged by extremely high attic temperatures, limited access for spraying, a tight project schedule, varying site conditions, the unique addition of devices and wiring for system performance monitoring, and minimal available information on the preferred installation details. Overall, all three installations were very successful, but it is important to document opportunities for future improvement.

At House 1, the top of the supply plenum box that extends vertically into the attic was not foamed (Figure 17). Even with baffling, this large vertical riser was difficult to bury beneath a deep fiberglass insulation. Although the lack of insulation reduces the R-value of this duct section and the overall distribution system efficiency, it is unlikely to create a condensation problem. Since this problem was not discovered until after the spray foaming was finished, the top of the plenum box was covered with R-4 rigid board and sealed with metal tape (see Figure 14). The supply plenum requires particularly close attention. Because it is closest to the AHU, the supply plenum has the highest system pressure and distributes the most extreme air temperatures.

Figure 17. Improperly spray-foamed plenum box at House 1

Furthermore, at several locations at House 1 where the ductwork runs perpendicular across the lower truss cords and other locations where the ductwork was slightly elevated, the underside of the ductwork was not completely covered in spray foam. The inadequate application of spray foam at the underside of the ductwork could create the potential for condensation because the duct jacket, which might be below the dew point of the surrounding air, was exposed.

Although somewhat difficult to see, Figure 18 and Figure 19 show the undersides of ductwork that were left exposed after the ccSPF was applied. Getting the spray nozzle low enough to apply foam in these locations was challenging. Two options could be used to solve this problem. The installer can cocoon the duct in ccSPF and directly seal it to the sheetrock (Figure 20). Alternatively, a piece of rigid insulation can be inserted under the ductwork to act as a substrate for the foam and ensure that a minimal insulation thickness is achieved on the underside of the ducts (Figure 21).

In addition, the insulation thickness varied considerably for these applications, as shown in Figure 20 through Figure 23. Achieving a consistent minimum thickness of ccSPF without wasting material is a difficult balance. For this demonstration, the installing contractors were asked to err on the side of too much insulation. Given the high cost of the material, this was often a counterintuitive request. As a mainstream practice, educating the installers on the importance of providing that minimum insulation thickness will be critical to ensure that condensation concerns are mitigated. Proper training and familiarity gained through performing more retrofits is expected to decrease waste and improve consistency.

Figure 18. Exposed duct jacket at the underside of duct

Figure 19. Exposed underside of ductwork not adequately covered with ccSPF

Figure 20. Ductwork well-sealed to sheetrock with ccSPF

Figure 21. Rigid insulation inserted under ductwork to serve as a substrate and provide insulating value

Figure 22. Varying thickness of ccSPF and interference from cross bracing

Figure 23. Varying application thicknesses shown on rectangular (left) and round (right) ducts

4.3 Retrofit Evaluation Summary

As noted in Sections 4.1 and 4.2, the attics in these existing houses were filled with electrical, telephone, and other wiring that crossed the ductwork in many locations. As a result, the wiring was permanently spray foamed to the ceiling and ductwork during the retrofit. If there is a problem with the existing wiring in the house, it might be difficult to service. For buried and encapsulated ducts, however, there might be no practical difference for service technicians trying to deal with wiring buried beneath fiberglass insulation and wiring spray foamed to ductwork. In practice, there was no way to avoid spray foaming over wiring because these wires were so haphazardly laid across the ceiling.

Although the retrofitting methodology included removing ceiling insulation from around the ductwork before applying the spray-foam insulation to the surface of the duct work, there appeared to be no issues with blowback of batt insulation during spray-foam application. Although the airborne fibers associated with blown-in insulation might pose a health and safety problem, the protective equipment worn by the installer is likely sufficient to minimize concern. The authors feel that removing batt insulation before ccSPF application seems unnecessary, except around boots and within a few feet of the ductwork.

A minimal amount of insulation must still be removed around boots to allow access for proper spray-foam adherence to the sheetrock. Similarly, batt insulation can be cut parallel to the ductwork and rolled back a few feet to open 1 to 2 ft of access adjacent to the ducts for proper adherence of the ccSPF to the sheetrock. Any fiberglass remaining below the ductwork can serve as a backer to minimize the amount of ccSPF required for encapsulation. Removing and/or rolling back the fiberglass insulation is unnecessary when a substrate, such as rigid insulation, is inserted beneath the ductwork. A vapor-impermeable insulation of the same insulation level as the spray foam must be used to prevent condensation underneath the duct.

With these strategies for removing existing insulation, it might be possible to minimize costs and site visits by using a two-person crew. While the ccSPF equipment is being set up, a second person can cut back the insulation and expose the boots. After the ccSPF application, the second technician can roll the insulation back into place and cover the boots. Furthermore, preapplying spray-foam insulation around the boots could be unnecessary for preventing leakage into the living space. More testing is needed to see if there is indeed a problem with leakage of ccSPF into the living space. Regardless, this could be undertaken fairly quickly during the field preparation work.

5 Field Monitoring and Performance Testing Results

Field monitoring and performance testing yielded valuable data on the performance of the distribution systems before and after ductwork retrofits. Building specifications obtained by observing the building system and performance testing are discussed and summarized in Section 5.1. Long-term monitoring of occupied buildings reveals valuable information about the thermal performance, as discussed in Section 5.2, and the condensation potential, as discussed in Section 5.3, of the distribution system.

5.1 Building Specifications

All three homes are single-family detached houses of similar vintage with vented attics, slab on grade construction, and attached garages. Table 4 shows building enclosure and mechanical equipment specifications for the three houses. The specifications in the table did not change over the pre- and post-retrofit period.

Pre- and post-retrofit duct, building, and system specifications for variables that change between the pre- and post-retrofit monitoring periods, such as duct leakage and R-value are shown in Table 5. Duct R-values were determined using the methodology outlined in Section 6. Total duct leakage and duct leakage to the outdoors were significantly reduced, and flows stayed relatively constant between the pre- and post-retrofit testing period. Building infiltration was reduced as well through duct sealing, air sealing around duct supply registers, and additional attic insulation.

The post-retrofit supply duct R-value for House 3 is approximately half of the values for the other two homes. The encapsulated duct strategy was used in House 3; houses 1 and 2 received buried and encapsulated ducts. House 3 has comparable post-retrofit duct leakage rates to those observed in House 1. Both have similar duct construction. At House 1, reconfiguration of the ductwork led to an increase in total duct surface area because the duct runs were lengthened to lower ductwork closer to the ceiling plane. At House 2, reconfiguration of the ductwork led to a reduction in supply duct surface area because a circuitous duct board run was replaced with a shorter flex duct run. The return duct surface area was increased because the return ductwork was lengthened to lower ductwork closer to the ceiling plane. All surface areas were measured at the inner duct dimensions.

The pre-retrofit duct leakage numbers for House 2 listed in Table 5 are not entirely accurate. The open duct take-off shown in Figure 12 caused issues with measuring duct leakage before the retrofit. The duct pressure during the total duct blaster test did not reach 25 Pa, and the results were extrapolated from the measured pressure of 15.3 Pa. During the duct leakage to the outside test, the duct and house pressures could not be equalized because of the disconnected duct. The duct leakage to the outside is not reported in Table 5, but for modeling efforts, the duct leakage to the outdoors was assumed to equal the total duct leakage.

Houses 1 and 3 have AHUs placed in the living space, but House 2 has leaky supply and return plenums connected to an AHU in the garage (see Figure 24). As a result, House 2 did not experience a reduction in duct leakage to the outdoors to the same extent as houses 1 and 3. Additional spray foaming of the supply and return ductwork in the garage would have further reduced duct leakages, but this retrofit was outside the scope of this project.

Table 4. Building Enclosure and Space-Conditioning Specifications of Monitored Houses

	House 1	House 2	House 3
Year Built	1991	~1980	1987
Area of Conditioned Space (ft^2)	2,133	2,100	1,876
Volume of Conditioned Space (ft^3)	20,800	18,900	16,289
Bedrooms	4	3	3
Bathrooms	2	2	2
Exterior Finish	Pink stucco	Light wood siding	Light wood siding
Wall Assembly	2 × 4 R-13	2 × 4 R-11	2 × 4 R-13
Ceiling Assembly	R-30 fiberglass batts	R-19 fiberglass batts + 1- to 3-in. blown-in mounds over kitchen	R-19 fiberglass batts
Windows	Double, clear	Single, clear	Double, clear
Skylights	None	Insulated clear, uninsulated light shaft	None
Doors	R-4	R-4	R-4
Main Roof	Dark asphalt 5:12	Light brown asphalt, 5:12	Light brown asphalt 5:12
Outdoor Unit Model Number	Payne PH15NB048-A	Tempstar NHP042AKAI	Payne PH10JA036-C
Outdoor Tonnage	4 tons	3.5 tons	3 tons
Indoor Unit Model Number	Payne PF4MNA061	Trane TWE042C1FC	PF1MNA036
Indoor Tonnage	5 tons	3.5 tons	3 tons
Rated Energy Efficiency Rating/Seasonal Energy Efficiency Ratio	12.0/14.5	8.8/10.0	9.05/10.00
Cooling Capacity (Btu/h)	47,500	39,500	34,000
High-Temperature Heating (Btu/h)	46,500	38,000	34,000
Low Temperature Heating (Btu/h)	29,200	22,000	20,600
Number of Compressor Speeds	1	1	1
Control Type	Thermostatic	Orifice	Orifice
AHU Fan Type	Permanent split capacitor	Permanent split capacitor	Electronically commutated motors

Table 5. Pre- and Post-Retrofit Duct, Building, and System Specifications

	House 1		House 2		House 3	
	Pre-Retrofit	Post-Retrofit	Pre-Retrofit	Post-Retrofit	Pre-Retrofit	Post-Retrofit
Supply Duct Surface Area (ft^2)[a]	339	374	384	369	214	214
Return Duct Surface Area (ft^2)[b]	N/A	N/A	163	194	N/A	N/A
Supply Duct Effective R-Value (h-ft^2-°F/Btu)	4.7	21.9	6.5	26.1	4.6	11.1
Return Duct Effective R-Value (h-ft^2-°F/Btu)	N/A	N/A	4.9	26.2	N/A	N/A
Flow at Operating Conditions (cfm)	1,562	1,469	1,144	1,138	949	976
Duct Leakage to Outdoors (cfm@25 Pa)	152	29	N/A[b]	162	88	22
Total Duct Leakage (cfm@25 Pa)	527	188	382[c]	290	227	117
Building Infiltration (cfm@50 Pa)	2,672	2,138	4,066	2,905	2,306	2,168

[a] Duct surface area is measured at the inner duct dimensions.
[b] Duct leakage to the outdoors could not be measured because of disconnected duct take-off.
[c] Total duct leakage was measured at 15.3 Pa and extrapolated to 25 Pa.

Figure 24. AHU at House 2 located in garage with leaky return and supply plenums

Using the data displayed in Table 4 and Table 5, pre- and post-retrofit building loads were calculated using ACCA's *Manual J: Residential Load Calculation* (2006), as shown in Figure 25 and Figure 26. At House 1, the building loads are similar to the installed capacity, and the HVAC system seems to be properly sized. At House 2, the installed capacity is drastically undersized compared to the calculated building loads. Monitoring revealed long run times for the equipment in House 2, supporting the calculation that the system is undersized. The large loads are primarily caused by the poor window system installed in the house. House 3 Manual J calculations show that the system is slightly oversized.

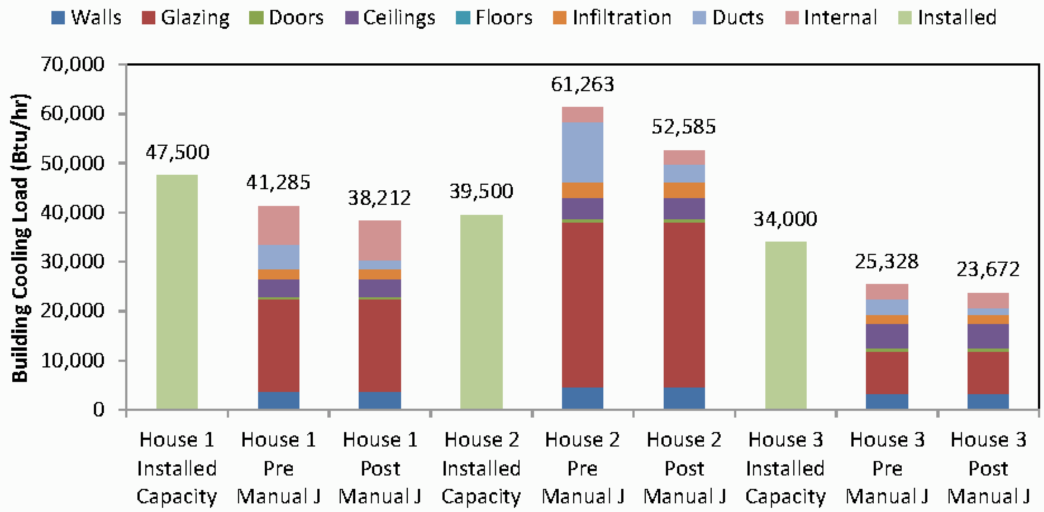


Figure 25. Pre- and post-retrofit Manual J building cooling loads compared to installed capacity

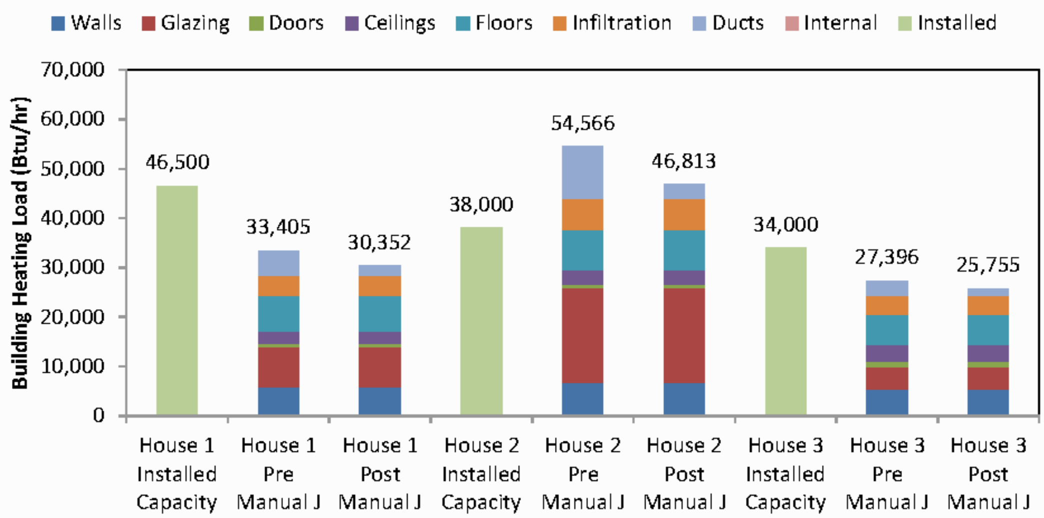


Figure 26. Pre- and post-retrofit Manual J building heating loads compared to installed capacity

5.2 Qualitative Discussion of Thermal Performance

Changes in the mechanical and distribution system configuration and operation at each house created challenges for interpreting long-term field monitoring and performance testing data. House 1 was unoccupied and the cooling system was set to a higher set-point temperature during the post-retrofit period. At House 2, a large hole in the ductwork was discovered during the retrofit, which complicated the comparison between pre- and post-retrofit performance. At House 3, the outdoor condensing unit was cleaned and recharged with refrigerant between the pre- and post-retrofit periods, which increased the system's efficiency. The ambient temperature sensor was placed too close to the condensing unit to measure temperatures accurately. Despite these challenges, the data shown in Figure 27 through Figure 32 give interesting insights into the benefits of buried ducts.

The graphs each show a 1-day period for a typical duct at each house over a typical summer day. The day selected starts at 4 a.m. on July 29 of the year during which the home was monitored. Two graphs are shown for each house, enabling a comparison of the pre- and post-retrofit performance of the same duct run. Periods of air-conditioning operation can be identified in these graphs by looking at the discharge airstream temperature (shown as the light blue line). During periods of air-conditioning operation, the discharge temperature drops significantly, typically to below 60°F. Table 6 lists the weather conditions for the two days graphed in this section using data available from the National Climactic Data Center (NCDC).

Table 6. Weather Conditions for Days Graphed in This Section

	July 29, 2010	July 29, 2011
High	96°F	94°F
Low	73°F	73°F
Dew Point	72°F	72°F
Clouds	Clear/partly cloudy with afternoon thunderstorms	Clear/partly cloudy with afternoon thunderstorms

Source: NCDC (2012).

The pre-retrofit graphs confirm that the equipment in houses 1 and 3 can satisfy the cooling loads because the systems cycle on and off. House 2, however, has an undersized system, and as a result, the cooling system runs constantly between 10:00 a.m. and 8:00 p.m. Post-retrofit run time cannot be assessed at House 1 because of a change in occupancy. The run time at House 3, however, shows an increase in cycling caused by a reduction in load corresponding to the retrofit. This increase in cycling, though, could be partially caused by the cleaning and recharging of the mechanical system that took place before the post-retrofit monitoring started. At House 2 with its undersized system, no reduction in load is observable through system run time.

As expected, the additional insulation applied to the ductwork results in a significant reduction in the temperature of the duct jacket surface. The temperature of the duct jacket surface during the pre-retrofit period decreased substantially when the air-conditioning system was running. By contrast, the surface temperature of the ccSPF surface during the post-retrofit period fluctuates only slightly during air-conditioner operation. This vast difference in temperature sensitivity of the ductwork surface points to a large increase in the R-value of the ductwork.

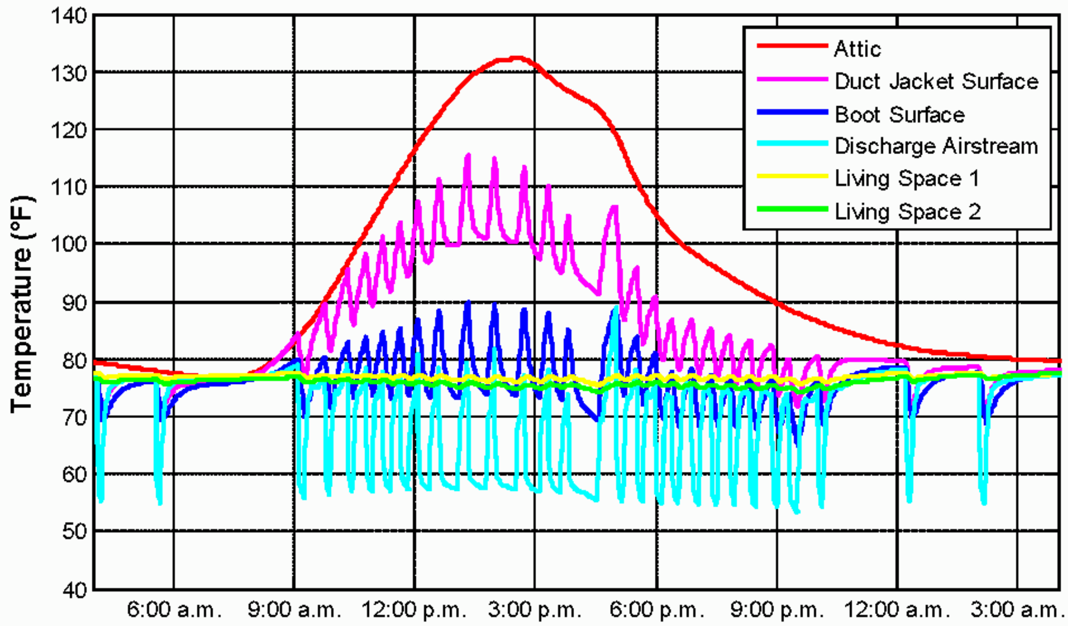


Figure 27. Pre-retrofit surface and air temperatures at duct run 2 in House 1

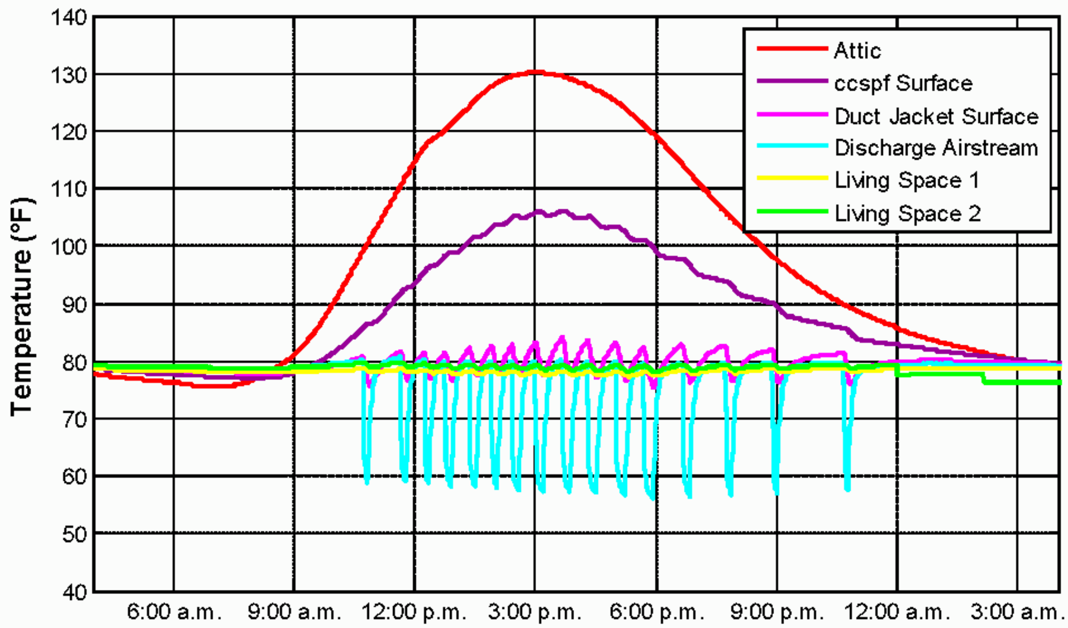


Figure 28. Post-retrofit surface and air temperatures at duct run 2 in House 1

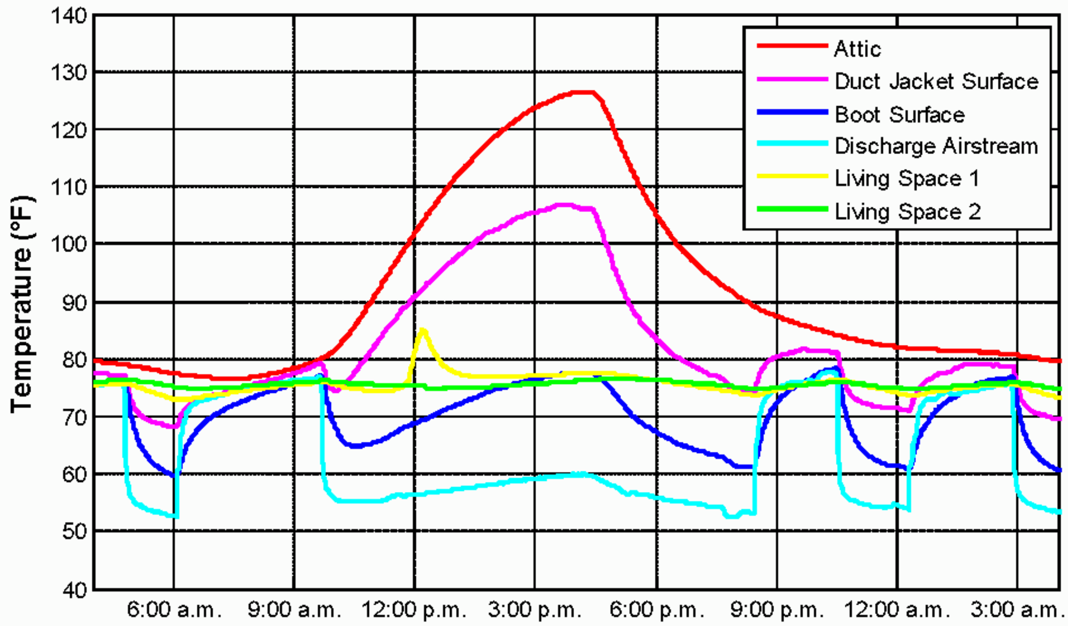


Figure 29. Pre-retrofit surface and air temperatures at duct run 3 in House 2

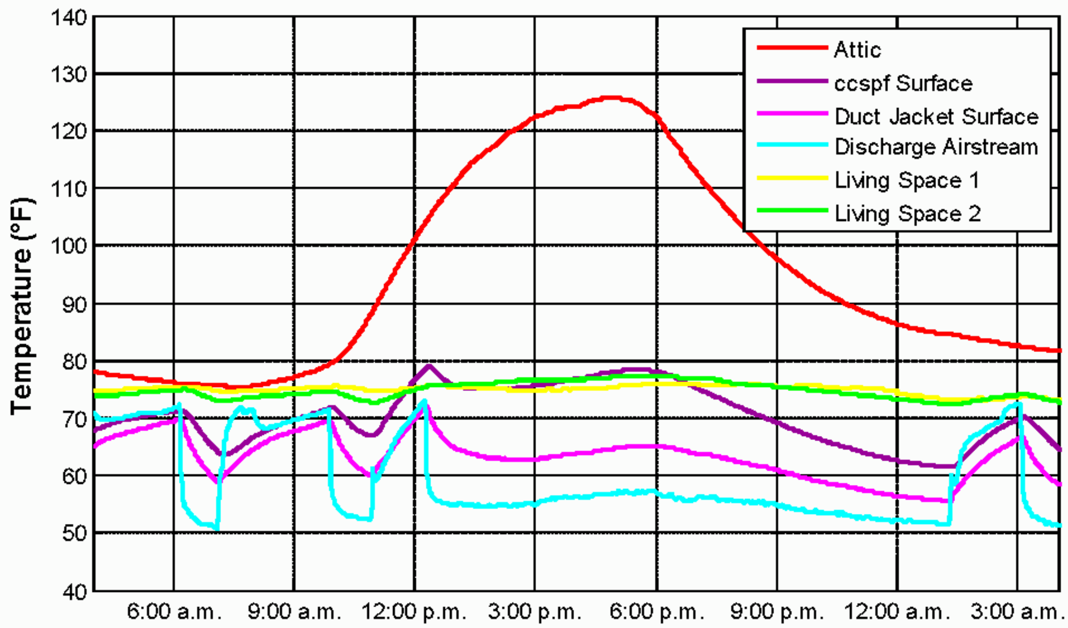


Figure 30. Post-retrofit surface and air temperatures at duct run 3 in House 2

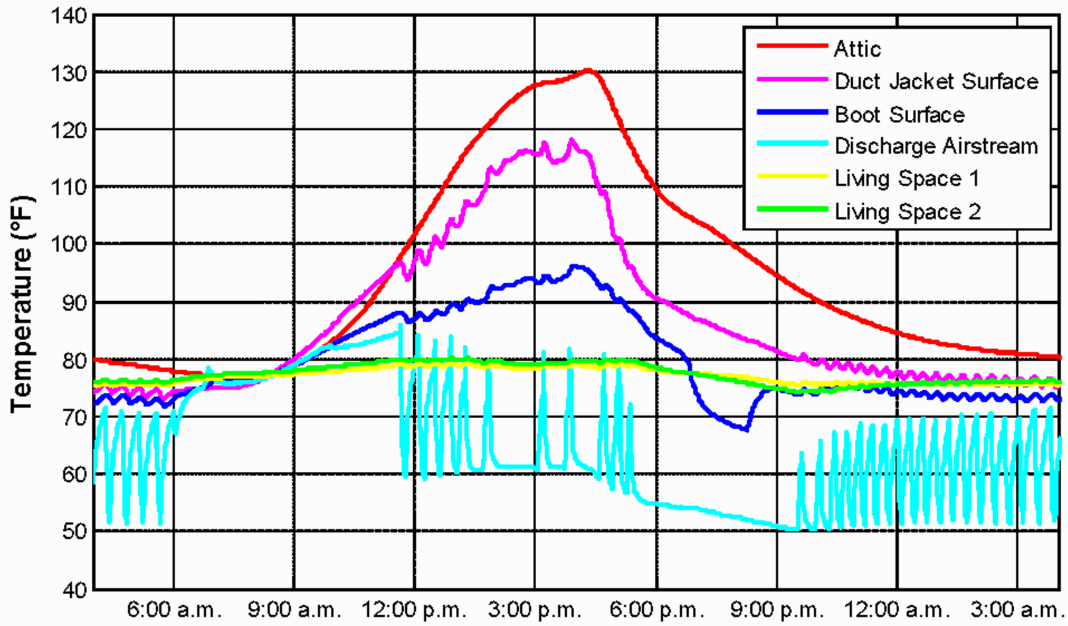


Figure 31. Pre-retrofit surface and air temperatures at duct run 2 in House 3

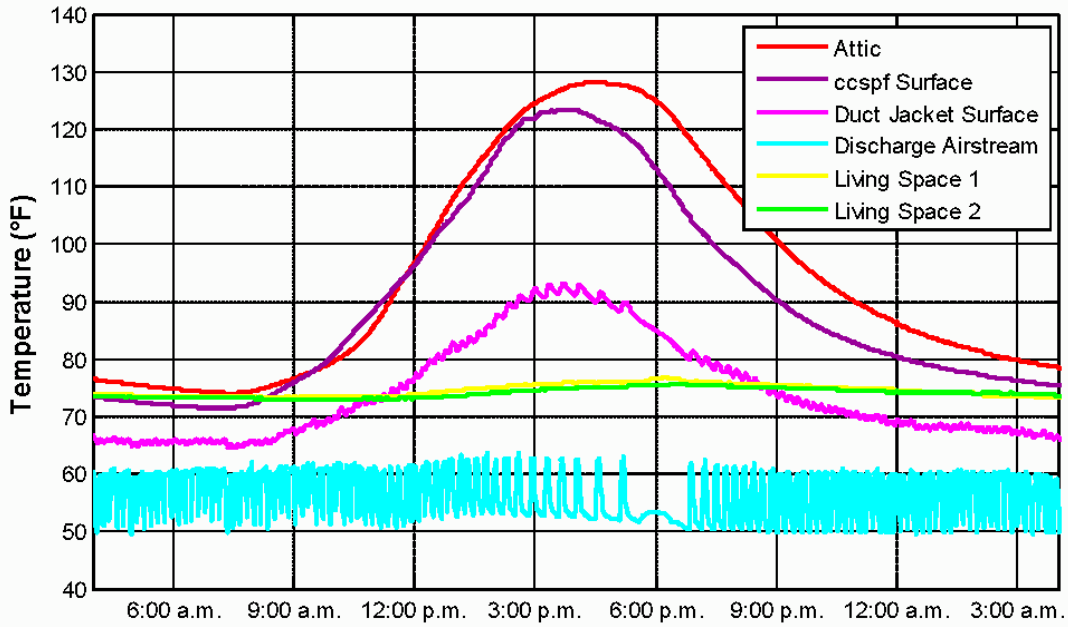


Figure 32. Post-retrofit surface and air temperatures at duct run 2 in House 3

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For House 3, the encapsulated ducts were not buried. Comparing the post-retrofit duct surfaces in House 3 to those of similar construction in House 1, duct jacket and ccSPF surface temperatures are much higher for the unburied case than for the buried case. Unlike the other two houses, the temperature of the duct jacket surface in House 1 remains coupled with the temperature of the attic. The pre- and post-retrofit comparison for House 1, however, shows a significant decrease in the duct jacket surface temperature. The ccSPF surface temperature profile is similar to that of the pre-retrofit duct surface but with far less variation related to system cycling.

Infrared thermal imaging of the pre- and post-retrofit ductwork further validates the large increases in duct R-values and reductions in duct leakage. Figure 33 and Figure 34 compare thermal images of the pre-retrofit ductwork at House 2 with the same ductwork after encapsulation but before burial. Large thermal losses occur in both cases.

With the AHU operating in cooling mode, the surface temperature of the ductwork before the retrofit was significantly lower than that of both the surrounding air and the encapsulated ductwork. The temperature of the exterior surface of the duct board was approximately 65°F in Figure 33. After encapsulation, the surface of the ccSPF is just under 100°F in Figure 34. As demonstrated by the previous graphs, the thermal imaging confirms the duct surface temperature has become nearly completely decoupled from the airstream temperature and more closely aligns with the ambient attic temperature.

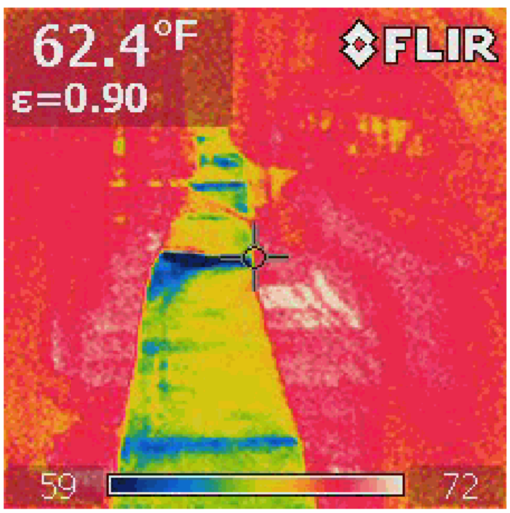

Figure 33. Pre-retrofit infrared thermal imaging at House 2

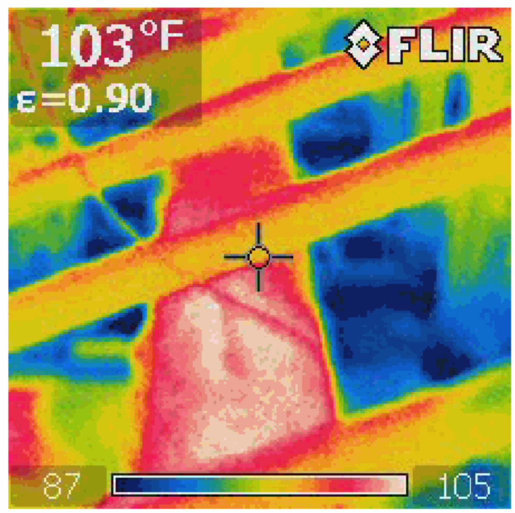

Figure 34. Infrared thermal imaging of encapsulated ductwork at House 2

This conclusion is further supported by less direct observations of the field monitoring data. During the pre-retrofit monitoring, the discharge airstream temperatures were observed to rise above the temperature of the living space during periods when the air conditioner was not running. As a consequence, when the air conditioner turned on, the volume of hot air inside the ductwork was pushed back into the living space, resulting in an increased load on the house.

Following the duct retrofits, the measured discharge air temperature was observed to stay at or below the living space temperature, eliminating this problem.

Pushing this volume of hot, unconditioned air into the living space undoubtedly increases the cooling load of the building, but quantifying the degree to which the cooling load is increased is difficult and cannot be accomplished using the data collected in this field study. Although monitoring was not conducted during the heating season, this retrofit is expected to also mitigate a similar heating load penalty. In new construction homes that use buried and encapsulated ducts, this peak load reduction benefit is typically accounted for by downsizing the equipment.

5.3 Qualitative Discussion of Condensation Potential

Graphs of duct surface temperatures and attic dew points reveal some interesting information about the condensation potential of the pre- and post-retrofit ductwork (Figure 35 through Figure 40). When the surface temperature of the duct falls below the dew point of the surrounding air, there is a potential for condensation on the duct. In practice, it is often difficult to accurately measure the relative humidity of the surrounding air, and the attic ambient air can be used as a proxy for the surrounding air. In reality, however, the dense insulation retards moisture transfer from the attic air to the duct surface. Although Chasar and Withers (2012) partially validated the use of attic dew point temperatures and duct surface temperatures to measure condensation potential, more detailed modeling of the hygrothermal performance of buried ducts was performed in this study to accurately evaluate the condensation potential of a buried duct installation (see Section 9).

The graphs in Figure 35 through Figure 40 reveal the change in condensation potential between the pre- and post-retrofit cases. The graphs show a 24-h period for each house for a typical summer day. These periods are identical to those shown in the graphs in Section 5.2. Two graphs are shown for each house, comparing the pre- and post-retrofit performance. In the pre-retrofit case, the attic dry bulb and dew point temperatures are plotted on each graph. This is overlaid with three boot surface temperature measurements on the left axis (solid lines) and three corresponding boot surface relative humidity measurements on the right axis (dashed lines). In the post-retrofit case, the surface temperatures and relative humidities are reported for the top surface of the ccSPF. The difference in graphed locations is caused by the selection of monitoring locations during the pre- and post-retrofit periods. The potential for condensation occurs when any of the three boot surface or ccSPF temperatures fall below the black line that represents the attic dew point temperature.

At first glance, the attic dew point temperatures fluctuate significantly compared to the outdoor dew point, raising questions about the validity of the attic dew point temperature measurements. Although the mean ambient dew point temperature corresponding to the 1% design temperature at Jacksonville Naval Air Station is 70°F (ASHRAE 2009), the dew points in these attics reach into the upper 80s. Furthermore, even though the ambient dew point is relatively constant throughout the day, the attic dew point in these houses drops to around 60°F during the night and rises rapidly into the upper 80s during the day. Although the behavior of the attic air is intriguing and cannot be easily explained, the attic dew point temperatures measured in this study do not seem to be inaccurate. The relative humidity sensors used in this study are accurate in the hot attic conditions, and the dew point calculations used in data postprocessing have been rigorously verified. Furthermore, a long-term monitoring study that included 20 houses in Florida (Arena et al. 2010) and a study of an early 1990s vintage home in Florida (Chasar and Wither 2012) found similar trends in attic dew point temperatures. Appendix A contains a more comprehensive discussion of this issue.

The pre-retrofit cases at all three houses showed a potential for condensation at the boot surface. Since significant amounts of condensation would likely stain the ceiling gypsum board, it was assumed that any accumulated condensation was minimal and/or able to dry out. Uncontrolled air leakage at the boot, which allows conditioned air to escape into the attic through unsealed gaps around the boot, could have resulted in the unintentional benefit of mitigating the condensation issues, similar to the results observed by Griffiths et al. (2002). The high potential of condensation observed in the pre-retrofit case is validated by the high relative humidities observed at the surface of the ductwork. These relative humidities approach saturation and the relative humidity sensors lose accuracy at these levels.

As anticipated, the post-retrofit case at houses 1 and 3 showed no condensation potential at the surface of the ccSPF applied directly over the entire boot. The surface temperatures were significantly higher than the attic dew point. The temperature sensors in the pre-retrofit case were placed on the boot and therefore represent the worst-case scenario. In the post-retrofit case, however, the sensors were usually placed at the top of the ductwork on the surface of the ccSPF, which raises some questions about the condensation potential at other points along the ductwork profile.

Surprisingly, the encapsulation and burial of the ductwork at House 2 did not mitigate the existing condensation potential of the pre-retrofit ductwork. As in the pre-retrofit case, it was assumed that any accumulated condensation was minimal and/or able to dry out because significant amounts of condensation would likely stain the ceiling gypsum board. Although the exact cause of the post-retrofit condensation potential is unknown, it is possible that the long run time of the undersized system resulted in lower surface temperatures.

Based on previous research, the 1.5 in. of ccSPF was applied to the ducts specifically to mitigate the condensation potential, regardless of the additional R-value provided by any additional insulation. The post-retrofit results for House 3, in which the ducts were not buried, can be contrasted with the results from the buried ducts in House 1. At House 3, the encapsulated duct surface temperature profiles aligned closely with the ambient attic conditions. At the boot locations shown in the figures, all measurements were taken beneath the layer of existing attic insulation. The temperature differential between the boot surface and attic ambient was larger in House 1, where blown-in insulation was added.

Before the retrofit, the low temperatures and high relative humidities at the boot surfaces in House 1 showed a high condensation potential. These issues appear to have been mitigated with the buried and encapsulated duct approach. At House 2, the boot surface temperatures were lower than the dew point of the attic air in the pre-retrofit case. The relative humidity of the air at the surface of the duct, however, was significantly below saturation, and as a result, the condensation potential was low. In the post-retrofit case, the condensation potential was not worsened by the further burial of the ductwork.

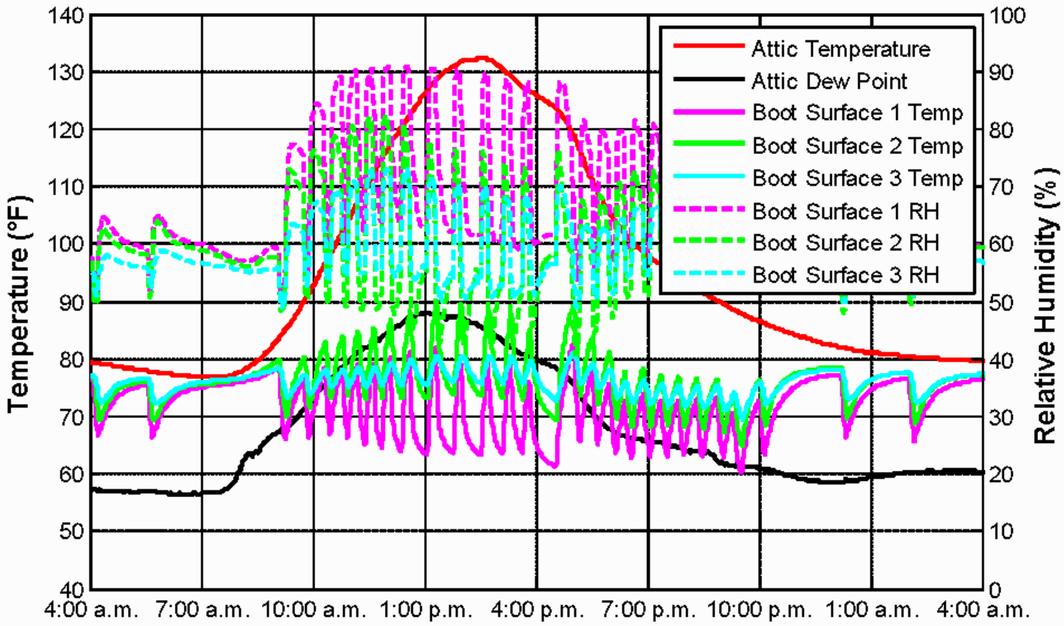

Figure 35. Pre-retrofit boot surface temperatures and attic dew point at House 1

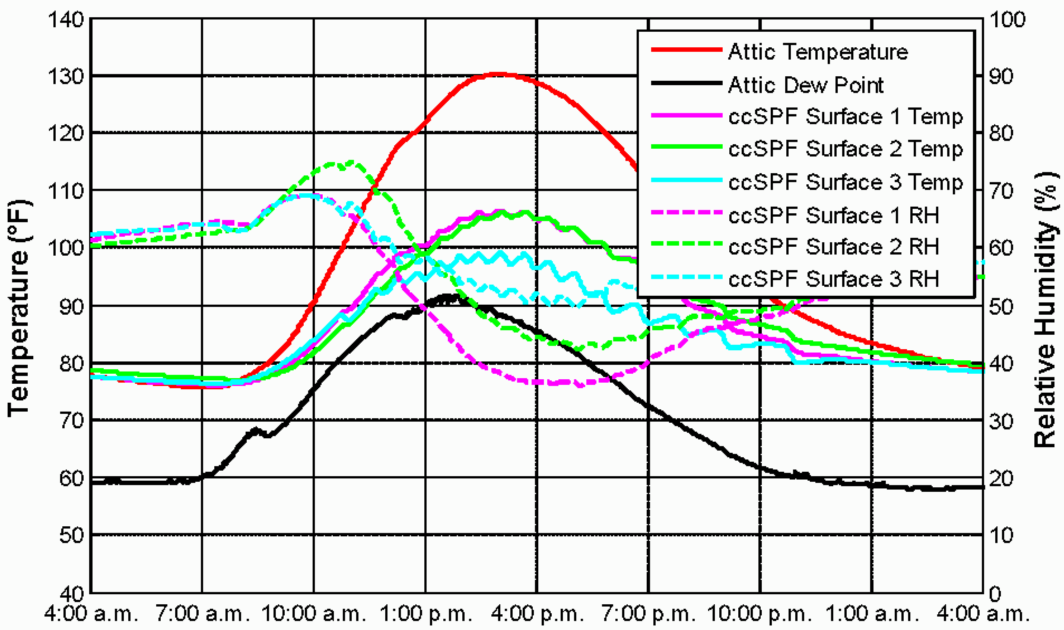

Figure 36. Post-retrofit ccSPF surface temperatures and attic dew point at House 1

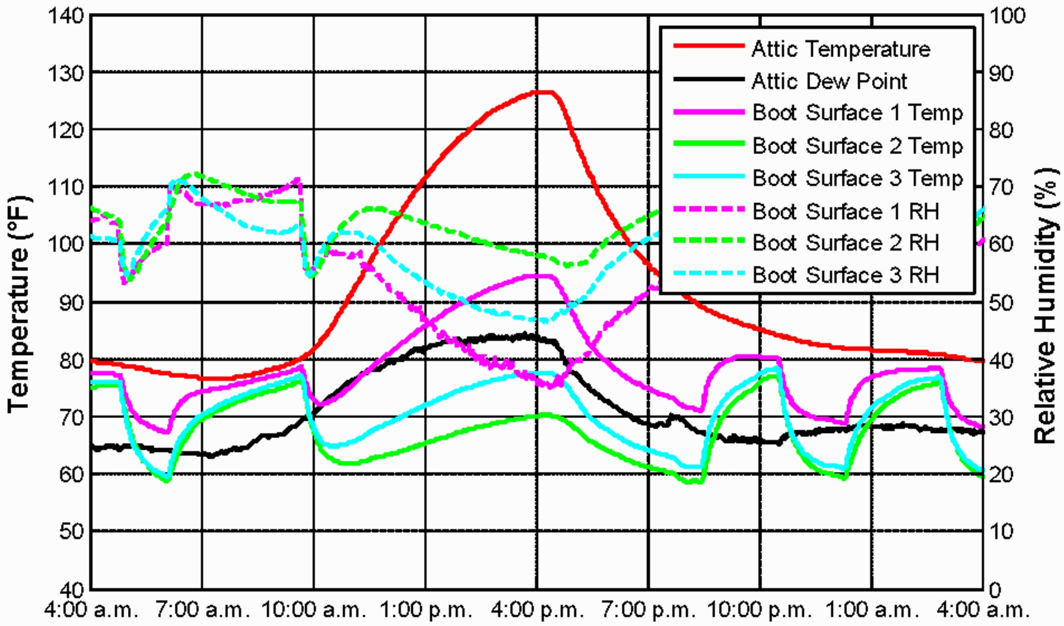

Figure 37. Pre-retrofit boot surface temperatures and attic dew point at House 2

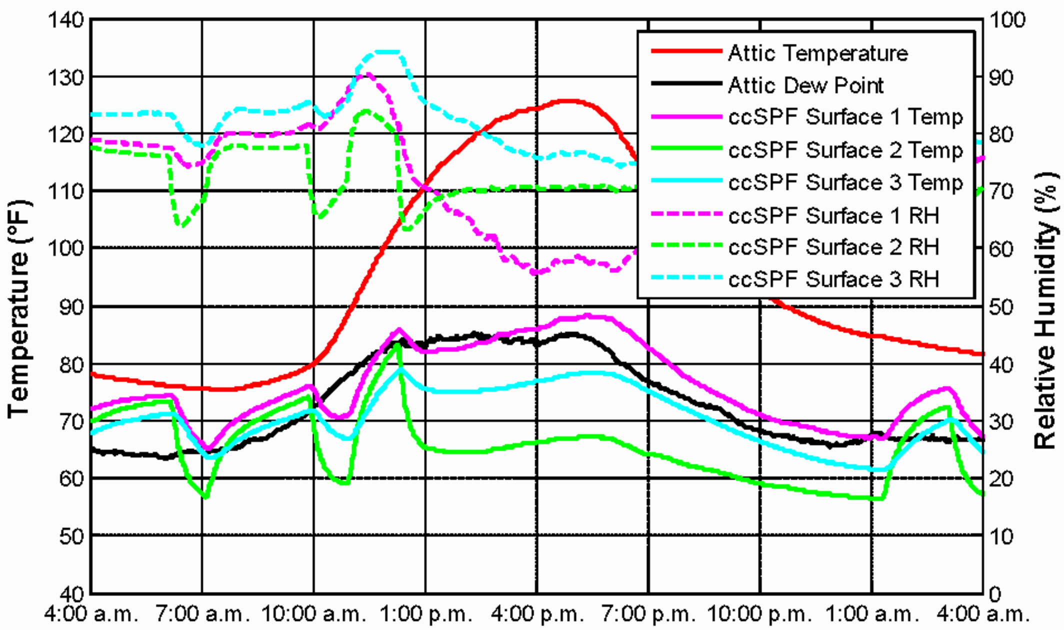

Figure 38. Post-retrofit ccSPF surface temperatures and attic dew point at House 2

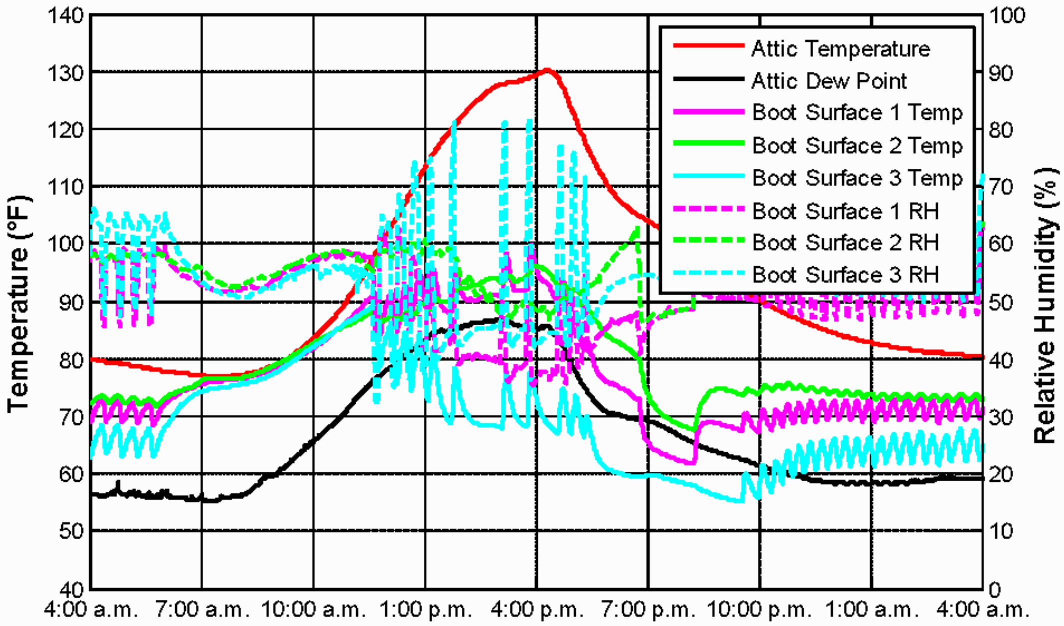

Figure 39. Pre-retrofit boot surface temperatures and attic dew point at House 3

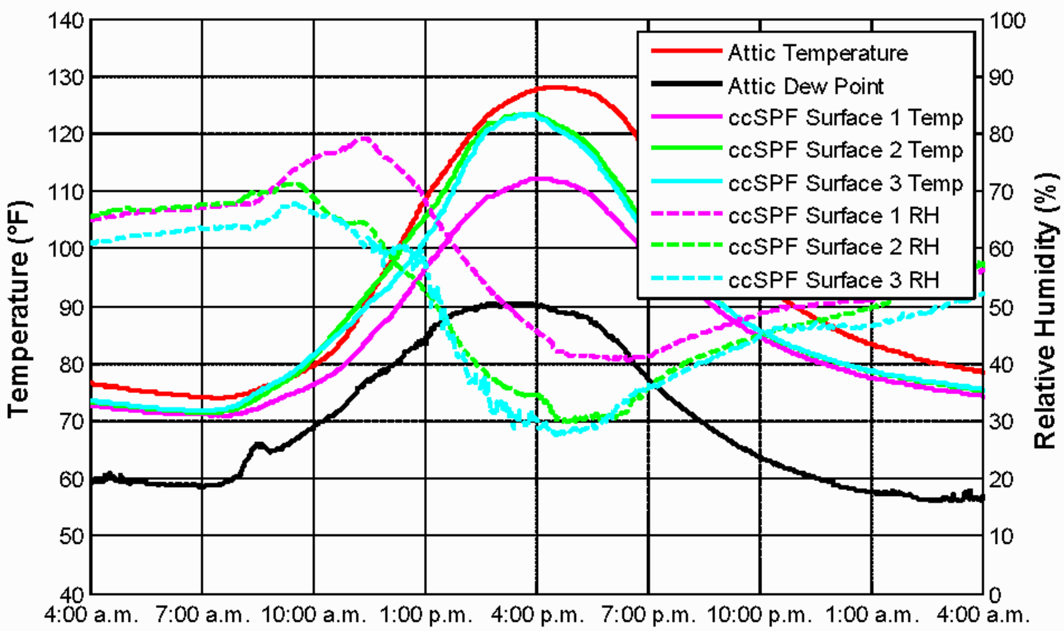

Figure 40. Post-retrofit ccSPF surface temperatures and attic dew point at House 3

6 Theoretical Effective and Apparent R-Values of Round Ductwork by Insulation Strategy

Observations of the field demonstration gave the team valuable insight into the feasibility of this retrofit strategy. As part of the field work, researchers identified barriers, collected performance data, and assessed concerns associated with condensation potential. Installed retrofit costs were also estimated based on the contractor costs for these retrofits (Section 10). The next critical step was to determine the potential energy savings and, ultimately, the cost effectiveness associated with the retrofit strategy. This was done through a combination of analytical calculations and modeled analysis.

Knowing effective R-values, which *exclude* heat transfer between the ductwork and the conditioned space, is necessary to calculate energy savings associated with encapsulated and buried and encapsulated ducts. Apparent R-values, which *include* heat transfer between the ductwork and the conditioned space, are also useful for comparing experimental results to theoretical calculations. Effective and apparent R-values can be calculated using Equations 1 and 2, respectively [8]

$$R_{effective} = \frac{2\pi r_i \Delta T}{Q_{attic \to duct}} \quad (1)$$

$$R_{apparent} = \frac{2\pi r_i \Delta T}{Q_{attic \to duct} + Q_{interior \to duct}} \quad (2)$$

where

$Q_{attic \to duct}$	=	the heat transfer between the attic and duct
$Q_{interior \to duct}$	=	the heat transfer between the interior space and duct
r_i	=	duct inner radius
ΔT	=	temperature difference between duct and attic.

Both effective and apparent R-values of round ductwork were calculated using either analytical or computational methods for four insulation strategies:

- **Traditionally insulated ducts** are insulated with traditional fiberglass duct wrap with rated R-values of 4.2, 6, and 8.
- **Encapsulated ducts** are traditionally insulated ducts encapsulated in a layer of ccSPF insulation. These ducts have higher R-values and lower leakage rates than traditionally insulated ducts.
- **Buried ducts** are traditionally insulated ducts buried beneath loose-fill insulation at the ceiling plane. These ducts have higher R-values, but only slightly lower leakage rates, than traditionally insulated ducts.

[8] In this report, all thermal resistance values *R* are given as totals of the entire depth of the application in units of h-ft^2-°F/Btu. Conductivities *k* are given as the reciprocal of the R-values per inch in units of Btu-in./h-ft^2-°F. As a result, R-values should be considered the total of the application, and conductivities are the values per inch of application.

- **Buried and encapsulated ducts** are traditionally insulated ducts encapsulated in a layer of ccSPF insulation and buried beneath loose-fill insulation at the ceiling plane.

R-values of traditionally insulated ducts were calculated to accurately compare pre- and post-retrofit performance using similar assumptions. R-values of buried ducts were calculated to compare the methodology used in this study to that of previous studies on buried ducts. The methodology used to calculate the traditional and buried duct insulation strategies also served as the basis for the R-value calculations of encapsulated and buried and encapsulated ducts.

Since traditionally unburied ducts do not experience heat transfer with the conditioned space, apparent and effective R-values are equivalent (i.e., the heat transfer between the duct interior and the attic will equal heat losses measured under laboratory or field testing). These R-values can be calculated analytically in a closed-form equation. Buried ducts have different effective and apparent R-values, which must be computed using numerical methods. The next two sections outline the analytical calculations of traditional and encapsulated ductwork, followed by two sections that outline the modeled analysis for buried and buried and encapsulated ducts.

6.1 Traditionally Insulated Round Ductwork

When installed over round ductwork, the effective R-value of the insulation application does not equal the nominal R-value of the insulation. R-values per inch are rated for a material lying flat, and when accounting for the cylindrical installation of the geometry, effective R-values can be significantly different from the nominal values. Furthermore, the nominal R-value excludes the inner and outer surface films of air (Palmiter and Kruse 2006). The effective R-value of the ductwork $R_{effective}$ in relation to the inner area of the ductwork is the sum of the inner surface film resistance R_{inner}, the actual R-value of the cylindrical insulation $R_{insulation}$, and the outer surface film resistance R_{outer}, corrected for the ratio of the outer diameter d_o to the inner diameter d_i.

$$R_{effective} = R_{inner} + R_{insulation} + \frac{d_i}{d_o} R_{outer} \tag{3}$$

Palmiter and Kruse (2006) found that the inner surface film resistance is dependent on duct inner diameter and the exterior surface film is independent of inner diameter. For this analysis, Palmiter and Kruse's inner surface film resistances (see Table 7) and a slightly different outer film heat transfer coefficient of 1.76 Btu/h-ft^2-°F, to be consistent with previous buried duct research, was used. Palmiter and Kruse further determined that the actual R-value of the ductwork can be found as a function of the rated R-value $R_{nominal}$, the inner diameter of the duct d_i, and the outer diameter of the duct d_o.

$$R_{insulation} = \frac{d_i}{d_o - d_i} R_{nominal} \ln\left(\frac{d_o}{d_i}\right) \tag{4}$$

Based on the modified outer surface film resistance, the effective R-values of round insulated ducts found for various insulation levels are shown in Table 8.

Table 7. Inner Surface Film Resistances by Duct Inner Diameter

Duct Inner Diameter (in.)	Inner Surface Film Heat Transfer Coefficient (Btu/h-ft²-°F)
4	2.22
6	2.04
8	1.92
10	1.85
12	1.79
14	1.72
16	1.69

Table 8. Effective R-Values of Round Insulated Flexible Ducts

Duct Inner Diameter (in.)	R-4.2 Thickness = 1.25 in.		R-6.0 Thickness = 1.79 in.		R-8.0 Thickness = 2.38 in.	
	$R_{insulation}$	$R_{effective}$	$R_{insulation}$	$R_{effective}$	$R_{insulation}$	$R_{effective}$
4	3.3	4.1	4.3	5.0	5.3	6.0
6	3.5	4.4	4.7	5.6	5.9	6.7
8	3.7	4.6	5.0	5.9	6.3	7.2
10	3.8	4.7	5.1	6.1	6.5	7.5
12	3.8	4.9	5.3	6.3	6.7	7.7
14	3.9	4.9	5.3	6.4	6.9	7.9
16	3.9	5.0	5.4	6.5	7.0	8.0

Source: Adapted from Palmiter and Kruse (2006).

A derivation of Equation 4 is given in Equation 5 because it is useful for deriving an equation for the thermal resistance of encapsulated ducts in Section 6.2. Assuming a homogenous material with cylindrical geometry, Fourier's law of conduction can be stated as

$$\dot{Q} = -Ak\frac{dT}{dr} \quad (5)$$

where

A = the surface area at radius r (ft^2)
k = the conductivity of the material (Btu-in./h-ft²-°F)
$\dot{Q}$ = the heat transfer rate (Btu/h)
$\frac{dT}{dr}$ = the rate of change of temperature with radius (°F/in.).

Since the area of heat flow at radius r is equal to the circumference of the circle $2\pi r$ times the length of the cylinder l, Equation 5 becomes

$$\dot{Q} = 2\pi r l k\frac{dT}{dr}. \quad (6)$$

The heat flow between any two radii, r_1 and r_2, of a homogenous material can be found by rearranging Equation 6 and integrating from r_1 to r_2.

$$\dot{Q}\int_{r_1}^{r_2}\frac{1}{r}dr = -2\pi lk\int_{T_1}^{T_2}dT \quad (7)$$

Performing the integration and solving for $\dot{Q}$, Equation 7 becomes

$$\dot{Q} = \frac{2\pi lk(T_1 - T_2)}{\ln\left(\frac{r_2}{r_1}\right)}, \quad (8)$$

which is the general form for heat transfer between two radii of a homogenous material with cylindrical geometry.

To apply Equation 8 to the case of round insulated flexible ductwork, let the heat transfer flow from the outer radius r_o to the inner radius r_i. This is equivalent to replacing r_1 to r_o and r_2 with r_i. Recognizing that the definition of thermal resistance of the insulation $R_{insulation}$ is equal to the surface area at radius r_i, multiplied by the temperature difference across the material, and divided by the heat transfer rate

$$R_{insulation} = \frac{2\pi lr_i(T_o - T_i)}{\dot{Q}}, \quad (9)$$

Equation 9 becomes

$$R_{insulation} = \frac{r_i \ln\left(\frac{r_i}{r_o}\right)}{k}. \quad (10)$$

The conductivity k is equal to the nominal thermal resistance divided by the thickness of the material

$$k = \frac{d_o - d_i}{2R_{nominal}}. \quad (11)$$

Replacing the radii terms with diameters and replacing the conductivity term with Equation 11, Equation 10 yields

$$R_{insulation} = \frac{d_i}{d_o - d_i}R_{nominal}\ln\left(\frac{d_i}{d_o}\right), \quad (12)$$

which is Equation 4.

6.2 Encapsulated Ducts

If the ccSPF is installed over existing fiberglass insulation, Equation 3 can be used to calculate the effective R-value of the insulation. Equation 4, however, is not valid because of the different conductivities of the materials. For a ccSPF-encapsulated insulated flexible duct, the heat flows through two concentric cylinders of homogenous insulations with different conductivities (Figure 41).

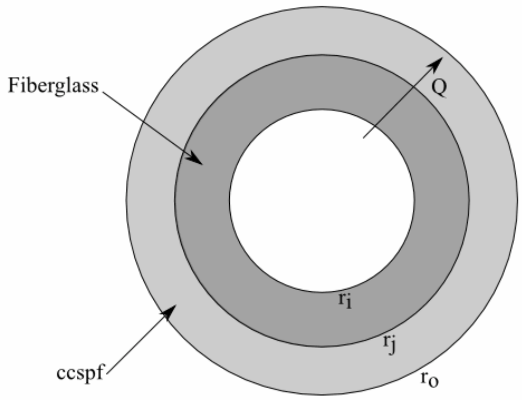

Figure 41. Flexible ductwork encapsulated in ccSPF

Since these materials are homogenous, the heat transfer from r_i to r_j can be found using Equation 8

$$\dot{Q} = \frac{2\pi l k_f (T_i - T_j)}{\ln\left(\frac{r_j}{r_i}\right)}, \tag{13}$$

where

k_f	=	conductivity of fiberglass (Btu-in./h-ft^2-°F)
r_i	=	inner radius of the duct (in.)
r_j	=	radius of the junction point between the fiberglass and ccSPF (in.)
T_i	=	temperature at r_i (°F)
T_j	=	temperature at r_j (°F).

Similarly, the heat transfer from r_j to r_o is

$$\dot{Q} = \frac{2\pi l k_c (T_j - T_o)}{\ln\left(\frac{r_o}{r_j}\right)}, \tag{14}$$

where

k_c	=	conductivity of ccSPF (Btu-in./h-ft^2-°F)
r_o	=	outer radius of the duct with insulation (in.)

T_o = temperature at r_o (°F).

Since steady state conduction, the heat transfer from r_i to r_j *is* equal to the heat transfer from r_j to r_o. Therefore, the heat transfer terms in Equations 13 and 14 are equivalent. Since the actual R-value of the duct is equal to

$$R_{insulation} = \frac{A_i(T_i - T_o)}{\dot{Q}}, \tag{15}$$

where A_i is the area of the duct at r_i. $R_{insulation}$ can be found by solving Equations 13 and 14 for the right-hand term of Equation 15. By solving Equation 14 for T_j

$$T_j = \frac{\dot{Q}\ln\left(\frac{r_o}{r_j}\right)}{2\pi l k_c} + T_o, \tag{16}$$

replacing T_j in Equation 13 with the right-hand term of Equation 16

$$\dot{Q}k_c \ln\left(\frac{r_j}{r_i}\right) = 2\pi l k_f k_c (T_i - T_o) - k_f \dot{Q} \ln\left(\frac{r_o}{r_j}\right), \tag{17}$$

and grouping like terms, Equation 17 becomes

$$\dot{Q}\left[k_c \ln\left(\frac{r_j}{r_i}\right) + k_f \ln\left(\frac{r_o}{r_j}\right)\right] = 2\pi l k_f k_c (T_i - T_o). \tag{18}$$

Since the area of the duct at the inner radius A_i is equal to

$$A_i = 2\pi r_i l, \tag{19}$$

$2\pi l$ in Equation 18 can be replaced with A_i/r_i

$$\dot{Q}r_i\left[k_c \ln\left(\frac{r_j}{r_i}\right) + k_f \ln\left(\frac{r_o}{r_j}\right)\right] = A_i k_f k_c (T_i - T_o). \tag{20}$$

Rearranging Equation 20 to solve for the right-hand term of Equation 15

$$\frac{A_i(T_i - T_o)}{\dot{Q}} = \frac{r_i\left[k_c \ln\left(\frac{r_j}{r_i}\right) + k_f \ln\left(\frac{r_o}{r_j}\right)\right]}{k_f k_c}, \tag{21}$$

and replacing the left-hand term for $R_{insulation}$, the equation for $R_{insulation}$ as a function of the conductivities and radii of the materials is

$$R_{insulation} = \frac{r_i\left[k_c \ln\left(\frac{r_j}{r_i}\right) + k_f \ln\left(\frac{r_o}{r_j}\right)\right]}{k_f k_c}. \tag{22}$$

To write Equation 22 in terms of the R-values of the insulations, the conductivity of fiberglass can be replaced with

$$k_f = \frac{r_j - r_i}{R_{f,nominal}}, \tag{23}$$

and the conductivity of ccSPF can be replaced with

$$k_c = \frac{r_o - r_j}{R_{c,nominal}}, \tag{24}$$

where $R_{f,nominal}$, and $R_{c,nominal}$ represent the nominal R-values of the insulation application typically reported. Rewriting Equation 22 in terms of the nominal R-values yields

$$R_{insulation} = r_i\left[\frac{R_{f,nominal}}{r_j - r_i}\ln\left(\frac{r_j}{r_i}\right) + \frac{R_{c,nominal}}{r_o - r_j}\ln\left(\frac{r_o}{r_j}\right)\right]. \tag{25}$$

Table 9 lists results for R-4.2, R-6, and R-8 round insulated ductwork encapsulated in 1- to 2.5-in of ccSPF. R-values in this table are given in h-ft^2-°F/Btu, where the surface area is based on the inner diameter of the duct. These results assume the same internal and external film resistances and fiberglass R-value (3.36/in.) from the previous section. The results also assume that closed-cell spray foam has an R-value of R-6.7/in.

Table 9. Effective R-Values of ccSPF Encapsulated Round Flexible Ducts by Insulation Thickness

	R-4.2 Flex Duct				R-6.0 Flex Duct				R-8.0 Flex Duct			
ccSPF Thickness (in.)	1	1.5	2	2.5	1	1.5	2	2.5	1	1.5	2	2.5
Nominal R-Value	10.9	14.3	17.6	21.0	12.7	16.1	19.4	22.8	14.7	18.1	21.4	24.8
4-in. Diameter	7.6	9.0	10.4	11.6	8.1	9.4	10.6	11.7	8.7	9.9	10.9	11.9
6-in. Diameter	8.6	10.4	12.0	13.6	9.3	11.0	12.5	13.9	10.1	11.6	13.0	14.3
8-in. Diameter	9.2	11.3	13.1	14.9	10.1	12.0	13.7	15.4	11.0	12.7	14.4	15.9
10-in. Diameter	9.7	11.9	13.9	15.9	10.6	12.7	14.7	16.5	11.7	13.6	15.4	17.1
12-in. Diameter	10.0	12.3	14.5	16.6	11.1	13.3	15.4	17.3	12.2	14.3	16.2	18.1
14-in. Diameter	10.2	12.7	15.0	17.2	11.4	13.7	15.9	18.0	12.6	14.8	16.9	18.9
16-in. Diameter	10.4	13.0	15.4	17.7	11.6	14.1	16.4	18.6	12.9	15.2	17.4	19.5

6.3 Buried Ducts

Unlike insulated and encapsulated round ductwork, the thermal resistance of buried ducts cannot be found analytically. Instead, a finite-element heat transfer model must be used to determine the effective R-value of buried ductwork. For this analysis, THERM 6.3, which is a two-dimensional heat-transfer modeling program developed by the Lawrence Berkeley National Laboratory (LBNL), was used to calculate effective and apparent R-values. A diagram of the buried duct modeling configuration is shown in Figure 42.

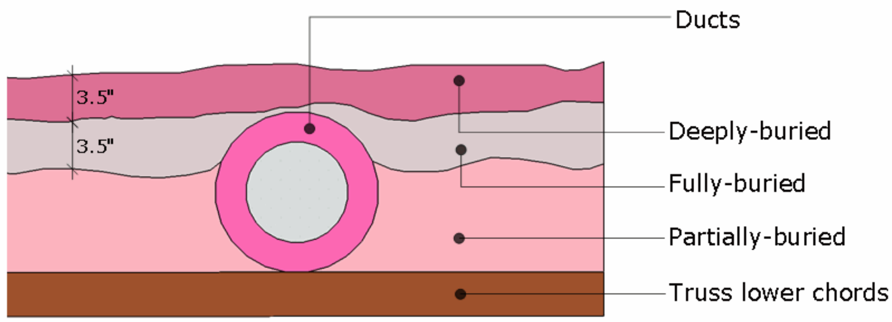

Figure 42. Diagram of buried duct modeling configuration

The conductivities and thicknesses of the materials used in this model (see Figure 43 for diagram of buried duct configuration) are shown in Table 10. All emissivities were set to 0.9, which is the default for all materials in the THERM library. Simulations were ended with a heat transfer error less than 3%.

Table 10. Material Conductivities and Thicknesses

Material	Conductivity *k* (Btu-in./h-ft^2-°F)	Thickness (in.)
Loose-Fill Fiberglass	0.4	Depends on configuration (see Figure 5 for depth of burial classes)
Insulating Duct Wrap	0.298	Depends on duct insulation
16-in. on Center Joists With Loose-Fill Fiberglass Insulation (Weighted Average of Framing and Insulation)	0.464	3.5
Gypsum Board	1.1	0.5

Table 11 gives boundary conditions, which include temperature and surface film resistance, for all surfaces. The film resistances for the different duct diameters are taken from Palmiter and Kruse (2006), and the attic and conditioned space film resistances are identical to those found in previous studies (CARB 2003; Griffiths and Zuluaga 2004), on buried ducts. Boundary conditions were implemented using THERM's simplified convection/linearized radiation model.

Table 11. Boundary Conditions

Boundary condition	Temperature (°F)	Surface film resistance (Btu/h-ft^2-°F)
Conditioned Space	75	1.76
Attic Air	120	1.76
4-in. Duct Interior	55	2.22
6-in. Duct Interior	55	2.04
8-in. Duct Interior	55	1.92
10-in. Duct Interior	55	1.85
12-in. Duct Interior	55	1.79
14-in. Duct Interior	55	1.72
16-in. Duct Interior	55	1.69

Apparent and effective R-values for buried round ductwork are shown in Table 12 and Table 13, respectively. Effective R-values for R-4.2 ducts are similar to those calculated by Griffiths and Zuluaga (2004). Differences between these numbers might be attributable to different simulation programs and the error levels of the simulation. Apparent R-values are similar to effective R-values for smaller, partially buried ducts, but become significantly smaller for larger, deeply buried ducts.

Table 12. Effective R-Values of Buried Round Ducts

	R-4.2 Ducts			R-6 Ducts			R-8 Ducts		
Burial Level	Partially	Fully	Deeply	Partially	Fully	Deeply	Partially	Fully	Deeply
4-in. Diameter	5.6	8.4	14.3	7.1	9.9	15.2	8.5	11.2	16.1
6-in. Diameter	6.9	10.4	17.8	8.7	12.2	19.0	9.3	13.9	20.1
8-in. Diameter	8.1	12.0	20.7	10.2	14.1	22.1	12.3	16.2	23.5
10-in. Diameter	9.0	13.4	23.1	11.4	15.8	24.7	13.7	18.1	26.3
12-in. Diameter	9.9	14.7	25.2	12.5	17.2	27.0	15.0	19.7	28.8
14-in. Diameter	10.7	15.8	27.1	13.4	18.5	29.0	16.2	21.2	31.1
16-in. Diameter	11.5	16.8	28.9	14.3	19.8	31.0	17.3	22.6	33.1

Table 13. Apparent R-Values of Buried Round Ducts

	R-4.2 Ducts			R-6 Ducts			R-8 Ducts		
Burial Level	Partially	Fully	Deeply	Partially	Fully	Deeply	Partially	Fully	Deeply
4-in. Diameter	5.6	8.3	13.3	7.1	9.7	14.3	8.5	11.0	15.3
6-in. Diameter	6.8	9.9	16.0	8.6	11.7	17.3	9.3	13.3	18.4
8-in. Diameter	7.8	11.3	18.1	9.9	13.2	19.6	11.8	15.1	21.0
10-in. Diameter	8.7	12.4	19.9	10.9	14.6	21.5	13.0	16.7	23.1
12-in. Diameter	9.4	13.4	13.4	11.8	15.7	23.2	14.1	18.0	24.9
14-in. Diameter	10.1	14.3	22.8	12.6	16.7	24.7	15.1	19.2	26.6
16-in. Diameter	10.7	15.1	24.1	13.3	17.8	26.1	16.0	20.3	28.1

6.4 Buried and Encapsulated Ducts

Effective and apparent R-values of buried and encapsulated ducts were similarly calculated using THERM. All boundary materials and conductivities were identical to the previous simulations, and the ccSPF insulation had a conductivity of 0.149 Btu-in./h-ft^2-°F and a thickness of 1.5 in. Figure 43 is a diagram of the buried and encapsulated duct configuration used in the modeling. Effective and apparent R-values for buried and encapsulated ducts are shown in Table 14 and Table 15, respectively. Partially, fully, and deeply buried ducts are defined in the same manner as in previous research, as shown in Figure 5 (Griffiths and Zuluaga 2004; Griffiths et al. 2004; Griffiths et al. 2002).

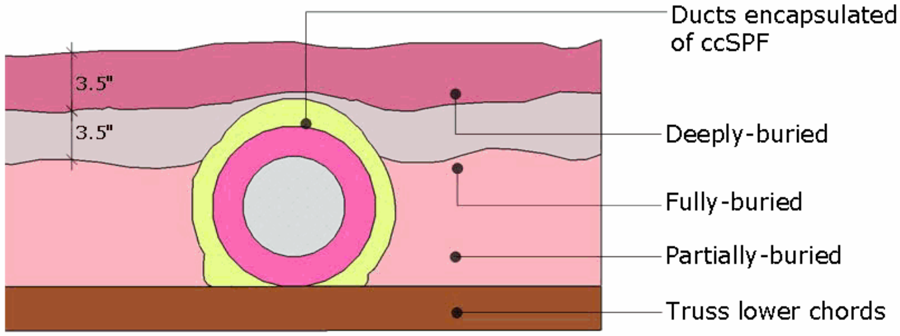

Figure 43. Diagram of buried and encapsulated ducts

As previously mentioned, the differences between the apparent and effective R-values are caused by heat transfer between the air inside the duct and the interior building air. As suggested by the relatively small differences between effective and apparent R-values, the vast majority of the heat transferred to the duct comes from the attic at design conditions, as shown in Figure 44. The color gradient in Figure 44 indicates magnitude, not direction. The area directly under the duct shows heat flux from the interior space to the duct. The areas to the far right and left of the duct show heat flux from the attic to the interior space, and the areas in between have small heat magnitudes as the heat flux direction changes.

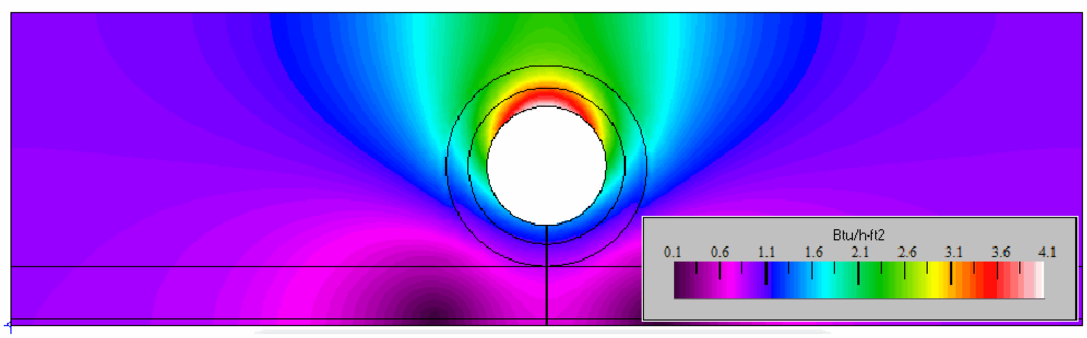

Figure 44. Heat flux magnitude through encapsulated and fully buried 8-in. diameter duct

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Table 14. Effective R-Values of Buried and Encapsulated Round Ducts

	R-4.2 Ducts			R-6 Ducts			R-8 Ducts		
Burial Level	Partially	Fully	Deeply	Partially	Fully	Deeply	Partially	Fully	Deeply
4-in. Diameter	12.8	15.7	20.4	13.6	16.3	20.7	14.4	17.0	21.1
6-in. Diameter	15.8	19.5	25.5	16.9	20.4	26.0	18.0	21.5	26.6
8-in. Diameter	18.4	22.6	29.6	19.7	23.8	30.3	21.0	25.0	31.1
10-in. Diameter	20.6	25.3	33.0	22.0	26.6	34.0	23.6	28.0	35.0
12-in. Diameter	22.5	27.5	36.0	24.1	29.0	37.1	25.8	30.6	38.3
14-in. Diameter	24.2	29.5	38.7	26.0	31.3	39.9	27.9	33.0	41.3
16-in. Diameter	25.8	31.4	41.1	27.7	33.2	42.5	29.7	35.2	44.0

Table 15. Apparent R-Values of Buried and Encapsulated Round Ducts

	R-4.2 Ducts			R-6 Ducts			R-8 Ducts		
Burial Level	Partially	Fully	Deeply	Partially	Fully	Deeply	Partially	Fully	Deeply
4-in. Diameter	12.8	15.6	19.7	13.6	16.2	20.1	14.4	16.8	20.4
6-in. Diameter	15.7	18.9	23.9	16.7	19.8	24.5	17.7	20.8	25.1
8-in. Diameter	17.8	21.4	27.1	19.1	22.5	27.9	20.3	23.6	28.7
10-in. Diameter	19.7	23.5	29.7	21.0	24.8	30.7	22.5	26.1	31.7
12-in. Diameter	21.2	25.3	31.9	22.7	26.7	33.0	24.3	28.2	34.2
14-in. Diameter	22.6	26.9	33.9	24.3	28.5	35.2	26.0	30.1	36.5
16-in. Diameter	23.8	28.3	35.6	25.7	30.0	37.0	27.5	31.8	38.5

Since the ductwork of the homes tested in this report were buried under a mound of loose-fill insulation, not buried under a plane of insulation, effective and apparent R-values of encapsulated ducts buried under a mound of insulation were also computed. Mounded-buried ducts are defined for the purpose of modeling as bounded by an arc that peaks 1 in. above the duct and meets the line tangent to the bottom with a distance of three times the duct's outer diameter, $3d_o$, between the edges of the fiberglass (Figure 45).

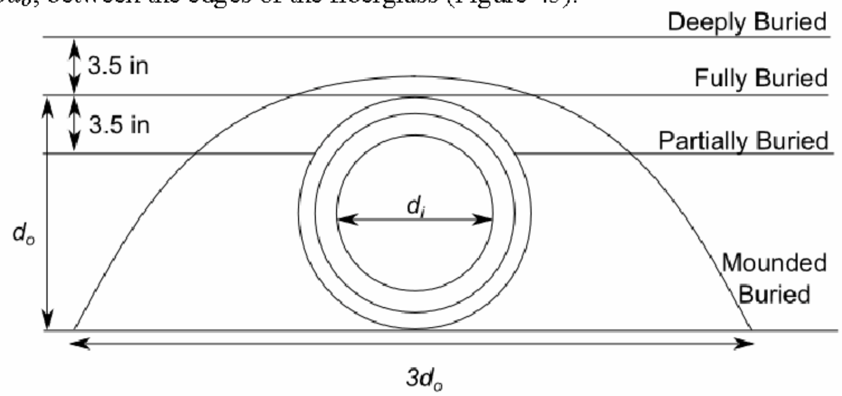

Figure 45. Definition of mounded-buried ducts

Table 16 contains effective and apparent R-values for mounded-buried encapsulated ducts. These R-values are surprisingly similar to fully buried encapsulated duct R-values. The slight reduction in R-value for mounded ducts is attributable to the increased heat transfer through the sides of the duct. A large amount of this heat transfer increase is offset by an increase in the amount of insulation above the duct (1 in. of insulation was assumed to cover the top of the duct for the mounded case, and no insulation was assumed for the fully buried case).

Table 16. R-Values of Mounded-Buried R-4.2 Ducts Encapsulated in 1.5 in. of ccSPF

Duct Inner Diameter (in.)	$R_{effective}$	$R_{apparent}$
4	15.2	15.2
6	18.7	18.5
8	21.6	20.9
10	24.1	22.9
12	26.2	24.6
14	28.1	26.2
16	29.8	27.5

R-values of buried and encapsulated ducts increase dramatically with increased inner diameter (Figure 46). The direct relationship between effective R-value and duct diameter could be caused by two properties of the insulation geometry. First, increasing the duct size also increases the total depth of the fiberglass insulation, which reduces the heat transfer from the bottom of the duct toward the attic. Second, just as the R-values of traditionally insulated ducts change with duct inner diameter because of the cylindrical geometry of round ductwork, the R-values of buried and encapsulated round ductwork will be affected by inner diameter. Since the impact of inner diameter is greater for buried and encapsulated ducts than for traditionally insulated round ductwork, the increased R-values are likely caused by a combination of these factors.

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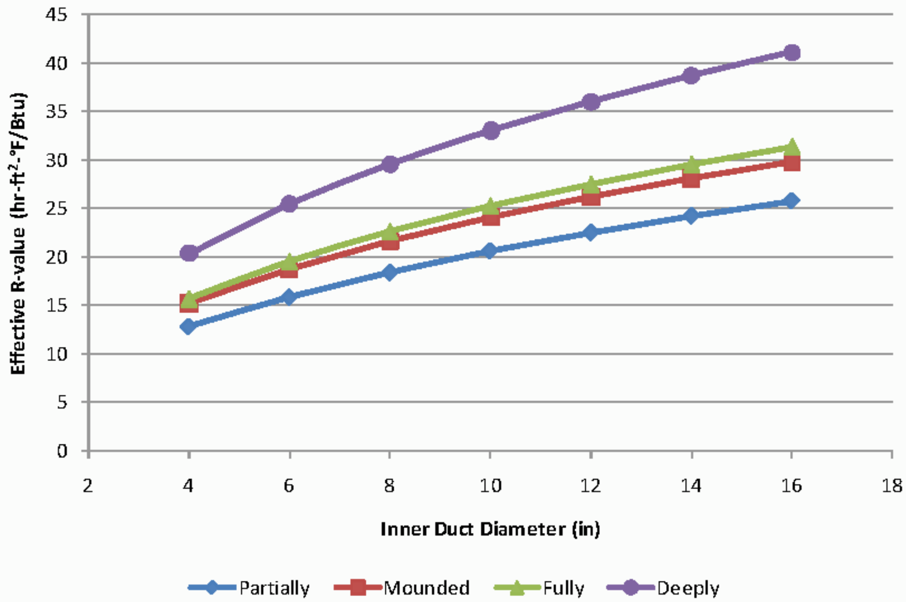

Figure 46. Effective R-values of R-4.2 buried and encapsulated ducts

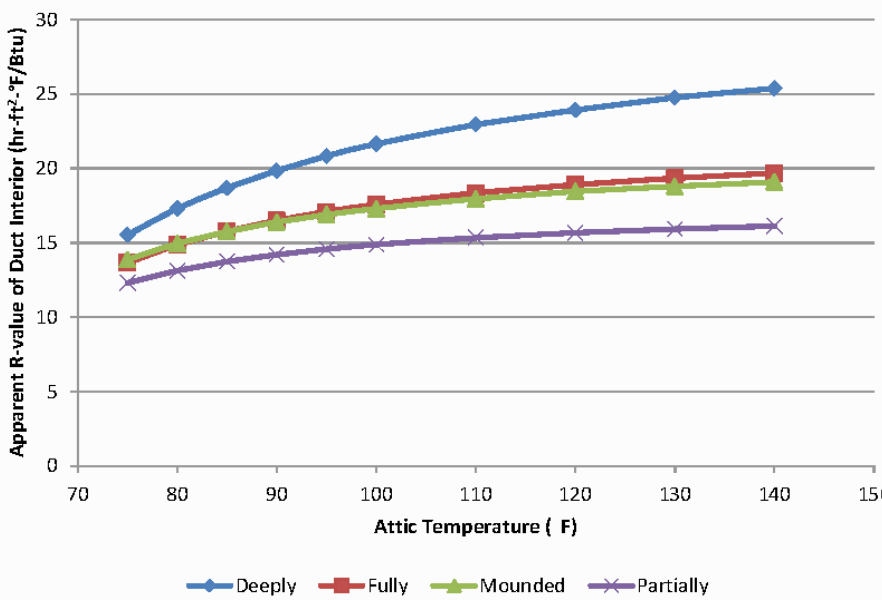

Figure 47. Apparent R-values of 6-in. buried ducts encapsulated in ccSPF by attic temperature

Finite-element modeling showed that effective R-values are independent of boundary condition temperatures, but apparent R-values are highly dependent on boundary condition temperature.

The large insulation levels, coupled with the location of the ducts in relation to the interior space, mean that heat gains or losses are dependent on both the interior temperature and the attic temperature. As a result, changes in the attic temperature, duct interior temperature, or interior temperature will result in a change in the heat flow through the cross-section and a change in apparent R-value. Figure 47 shows the effect of attic temperature on the R-value of a 6-in. buried and encapsulated duct. The temperature change causes a large change in apparent R-value, particularly for deeply buried ducts. In this case, the apparent R-value dropped by almost 40% when the temperature changed from 120°F to 75°F. Table 17 summarizes effective R-values of an 8-in. duct by insulation strategy.

Table 17. Summary of Duct Effective R-Values for 8-in. Duct by Insulation Strategy

Duct Configuration	R-4.2 Ducts	R-6 Ducts	R-8 Ducts
Traditional Hung Ducts	4.6	5.9	7.2
Hung Ducts Encapsulated in 1.5 in. of ccSPF	11.3	12.0	12.7
Partially Buried	8.1	10.2	12.3
Fully Buried	12.0	14.1	16.2
Deeply Buried	20.7	22.1	23.5
Encapsulated in 1.5 in. of ccSPF and Partially Buried	18.4	19.7	21.0
Encapsulated in 1.5 in. of ccSPF and Fully Buried	22.6	23.8	25.0
Encapsulated in 1.5 in. of ccSPF and Deeply Buried	29.6	30.3	31.1

7 Effective Heat Transfer Coefficients of Test Home Ductwork and R-Value Validation

Using the R-values calculated in Section 6, the overall effective and apparent UA values of the ductwork in the three Jacksonville houses were calculated and are shown in Table 18. For plenum boxes used to connect trunks and branches together, the R-value cannot be modeled in THERM because of the three-dimensional nature of the geometry. Instead, these boxes were assigned an R-value equal to the R-value of a round duct of a similar size. Although not exact, this method should give an approximate result for these boxes. For House 2, which has rectangular ductwork, each of the duct sizes were modeled in THERM. The existing configuration was already partially buried as a result of the configuration of the ductwork and the fiberglass blown-in insulation (see Figure 8 and Figure 10). The fiberglass insulation was assumed to be installed at a level 3 in. above the bottom of the duct. Post-retrofit ducts were assumed to have mounded burial with a configuration similar to that shown in Figure 45, and the dimension d_o equals the outer width of the duct parallel to the ceiling.

Table 18. Theoretical UA Values for Monitored Jacksonville Houses

	Pre-Retrofit			Post-Retrofit			Reduction in Apparent UA (%)	Reduction in Effective UA (%)
	Area (ft^2)	Apparent UA (Btu/h-°F)	Effective UA (Btu/h-°F)	Area (ft^2)	Apparent UA (Btu/h-°F)	Effective UA (Btu/h-°F)		
House 1	339.3	72.1	72.1	374.4	17.4	17.1	75.9	76.3
House 2	546.1	91.9	90.3	563.1	24.5	21.6	73.3	76.1
House 3	214.4	46.2	46.2	214.4	19.3	19.3	58.2	58.2

The values shown in Table 18 can be validated using test data collected during field monitoring. When the space-conditioning system is running in steady-state operation, the heat transfer between the conditioned air inside the duct and the attic temperature can be simplified as a heat exchanger. Using this simplification, the heat transfer between the duct and the attic is governed by

$$UA = \frac{\dot{Q}}{LMTD} \tag{26}$$

where

$\dot{Q}$ = the heat transfer rate between the duct and attic (Btu/h), as defined by Equation 28

U = the heat transfer coefficient (Btu/h-ft^2-°F)

A = interior surface area of duct (ft^2), and

$LMTD$ = log mean temperature difference (°F), as defined by Equation 27.

The $LMTD$ is the logarithmic mean between two ends, A and B, of a heat exchanger.

$$LMTD = \frac{\Delta T_A - \Delta T_B}{\ln \frac{\Delta T_A}{\Delta T_B}} \qquad (27)$$

In this application, stream *A* is the supply temperature of the duct, where

$$\Delta T_A = T_{supply} - T_{attic},$$

and stream *B* is the discharge temperature, where

$$\Delta T_B = T_{discharge} - T_{attic}.$$

The heat transfer rate is

$$\dot{Q} = 1.08 \times \dot{V} \times \left(T_{supply} - T_{discharge}\right), \qquad (28)$$

where $\dot{V}$ is the volumetric flow rate (ft^3/min).

For typical trunk and branch distribution systems, however, the overall heat transfer coefficient of the system will not equal the sum of each discharge because multiple discharges will share the same branch. Instead, each heat transfer rate and *LMTD* must be calculated independently. The *LMTD*s must be weighted as a fraction of the total airflow. The overall UA is the ratio of the summed heat transfer rates and weight *LMTD*s. This equation is defined as

$$UA = \frac{\sum \dot{Q}_i}{\sum w_i LMTD_i}, \qquad (29)$$

where i represents the index of the discharge register and w_i is the airflow fraction $\dot{V}_i / \dot{V}$ for discharge i.

To ensure that these calculations are valid, periods of operation that appear to be largely steady state were isolated from the monitored data. Since apparent R-values vary with temperature, periods with attic temperature near 120°F, which is the boundary condition used in the finite element modeling, were used. The entire UA of the system cannot be effectively calculated because only four duct discharge temperatures were measured. Instead, the percent change in UA after the retrofit can be calculated from the relative apparent UAs calculated using the method described previously.

Table 19 lists mean apparent UA values and standard deviations from the steady-state period identified in the data. The removal of the large hole in the ductwork at House 2 led to changes in the airflows of this system, which resulted in difficulties in measuring UA. The post-retrofit UAs for House 2 were significantly higher than the pre-retrofit UAs and the House 2 data was deemed useless for this analysis.

Table 19. Relative Apparent UAs as Measured in Test Houses

House	Pre-Retrofit					Post-Retrofit					Reduction in Apparent UA (%)
	N	Apparent UA		T_{attic}		N	Apparent UA		T_{attic}		
		Mean	Std.	Mean	Std.		Mean	Std.	Mean	Std.	
1	8	13.4	0.6	120.8	4.0	3	2.51	0.72	120.7	5.4	81.3
3	6	34.1	0.01	120.6	2.4	4	11.2	0.4	121.3	3.7	67.2

The apparent UA reductions listed in Table 18 and Table 19 are relatively close, with UA reductions varying by no more than 10%. Given that the UAs calculated theoretically cannot account for plenum boxes and the issues with measuring apparent UA using a method that assumes steady-state operation, the team concluded that these values reflect a reasonable level of agreement.

8 ASHRAE 152 Distribution System Efficiencies

The heat transfer coefficients calculated in Sections 6 and 7 are necessary for calculating the efficiency of the thermal distribution systems. The efficiency of thermal distribution systems can be estimated using ASHRAE Standard 152, which determines "the efficiency of space heating and/or cooling thermal distribution systems under seasonal and design conditions" (ASHRAE 2004; 2). Standard 152 provides a methodology for calculating the delivery effectiveness (DE) and distribution system efficiency (DSE) of a thermal distribution system.

The DE is defined as "the ratio of the thermal energy transferred to or from the conditioned space to the thermal energy transferred at the equipment distribution system heat exchanger" (ASHRAE 2004; 2). The DSE includes losses calculated in the DE and adds losses associated with the impact of unbalanced leakage on building infiltration, energy recovery from losses to buffer zones, and losses associated with space-conditioning system cycling. The DSE is

$$DSE = DE_{corr} F_{equip} F_{load} \left(1 - F_{cycloss}\right), \qquad (30)$$

where

F_{equip}	=	equipment factor
F_{load}	=	infiltration factor
$F_{cycloss}$	=	equipment cycling factor
DE_{corr}	=	DEs corrected for regain.

All DE and DSE calculations were performed in compliance with ASHRAE Standard 152-2004, except where explicitly noted. A spreadsheet developed by LBNL in this analysis (LBNL 2003). To calculate the corrected DE, regain factors for supply and return ducts are needed. Airflow between the attic and conditioned space was not measured, so these values cannot be calculated explicitly. Instead, the default regain factors of 0.1 used in LBNL's ASHRAE 152 spreadsheet were used in this analysis.

Calculation of the infiltration factor requires effective leakage area L_n. Blower door tests were performed at 50 Pa, and L_n was calculated using an approximately equivalent expression for single-story homes (Sherman 1986), which is shown in Equation 31. See ASTM (1987), ASHRAE (1993), and ASHRAE (1998) for detailed information about calculating L_n exactly.

$$L_n \approx \frac{ACH_{50}}{20} \qquad (31)$$

Input values used in the ASHRAE 152 calculation are taken from Table 4 and Table 5. ASHRAE 152 DEs, corrected DEs, and DSEs are summarized in Table 20 through Table 22. As the summary tables show, the retrofit resulted in a dramatic increase, typically 12% or greater, in DE in all three homes. Similarly, the retrofit resulted in DSE increases. The cooling seasonal DSE increased by 11% in House 1, by 25% in House 2, and by 10% in House 3.

The similar DE improvements in House 1, in which the ducts were encapsulated and buried, and House 3, in which the ducts were only encapsulated, could be explained by several factors. First, the improvements in duct leakage will have a larger impact in R-value because duct leakage has a one-to-one direct relationship with duct losses. Second, the ductwork was lengthened in House 1, which will reduce the impact of the R-value increase. The remaining DE improvements are associated with the increased R-value.

Table 20. Pre- and Post-Retrofit ASHRAE 152 DE and DSEs for House 1

	Pre-Retrofit			Post-Retrofit		
	DE (%)	Corrected DE (%)	DSE (%)	DE (%)	Corrected DE (%)	DSE (%)
Heating Design	83	85	84	96	96	98
Heating Seasonal	84	86	85	96	97	97
Cooling Design	80	82	82	95	96	97
Cooling Seasonal	85	86	86	97	97	97

Table 21. Pre- and Post-Retrofit ASHRAE 152 DE and DSEs for House 2

	Pre-Retrofit			Post-Retrofit		
	DE (%)	Corrected DE (%)	DSE (%)	DE (%)	Corrected DE (%)	DSE (%)
Heating Design	61	64	58	84	85	84
Heating Seasonal	66	69	65	86	87	86
Cooling Design	43	47	39	77	78	73
Cooling Seasonal	59	62	54	83	84	79

Table 22. Pre- and Post-Retrofit ASHRAE 152 DE and DSEs for House 3

	Pre-Retrofit			Post-Retrofit		
	DE (%)	Corrected DE (%)	DSE (%)	DE (%)	Corrected DE (%)	DSE (%)
Heating Design	84	85	85	95	95	95
Heating Seasonal	85	86	85	95	96	95
Cooling Design	82	84	79	94	94	90
Cooling Seasonal	86	87	81	95	96	91

9 Condensation Potential of Encapsulated and Buried Ducts

As noted in Section 5.3, condensation will occur on the surface of the duct if the surface temperature is below the dew point of the surrounding air. Although the attic air temperature and relative humidity were monitored during the field testing, the dew point of the air surrounding specific points on the duct profile cannot be determined because of the complex process of vapor transport. The steady-state, two-dimensional, thermal modeling outlined in previous sections was combined with one-dimensional, dynamic, hygrothermal modeling to predict the potential for condensation on the surface of the duct.

The hygrothermal modeling program WUFI Pro 5 was used to simulate the movement of water vapor through the attic assembly. The hygrothermal modeling was used to determine the dew point of the air through the depth of the attic insulation assembly. These dew points were then compared to the surface temperatures of the duct at each depth, as calculated using two-dimensional steady-state modeling.

This analysis was conducted for buried ducts and buried and encapsulated ducts using the worst case of the modeling configurations described previously, a 4-in. R-4.2 duct deeply buried beneath attic insulation. Attic temperatures and relative humidities from one of the houses monitored in the research were used to simulate the conditions of an attic in a hot-humid climate. A constant temperature of 75°F and a relative humidity of 50% were applied to the interior conditions. The supply duct air was not explicitly modeled because of the geometric limitations of WUFI Pro 5. The maximum dew points along the depth of the duct corresponded to the highest attic temperatures monitored in this study. The resulting air dew points were compared to the steady-state surface temperatures predicted by THERM for the boundary attic condition of 130°F.

The results from the analysis (Figure 48) predict condensation issues for the buried ducts without additional ccSPF insulation, which was observed by Griffiths et al. (2002). Figure 48 shows the potential for condensation across the entire surface area of the duct under these conditions. The surface temperature of the duct, marked as black isotherms, is lower than the dew point of the surrounding air, which is marked in red. This case is more severe than the conditions observed by Griffiths et al. (2002) because it ignores the effects of leakage from the interior and the duct. As a result, this case can be viewed as the worst case potential for condensation.

A similar analysis of a buried and encapsulated duct shows no potential for condensation (Figure 49). The surface temperature is lower than the dew point of the air across the entire depth of the insulation. These results validate that the potential for condensation can be mitigated by encapsulating buried ducts in a layer of 1.5-in. ccSPF insulation. The closeness of duct surface temperature and the dew point of the surrounding air at the bottom of the duct emphasizes that 1.5 in. of ccSPF should be the minimum insulation level applied to R-4.2 ducts. For ductwork with higher existing R-values, lower ccSPF thicknesses might be possible, although consistently applying lower thicknesses might not be possible.

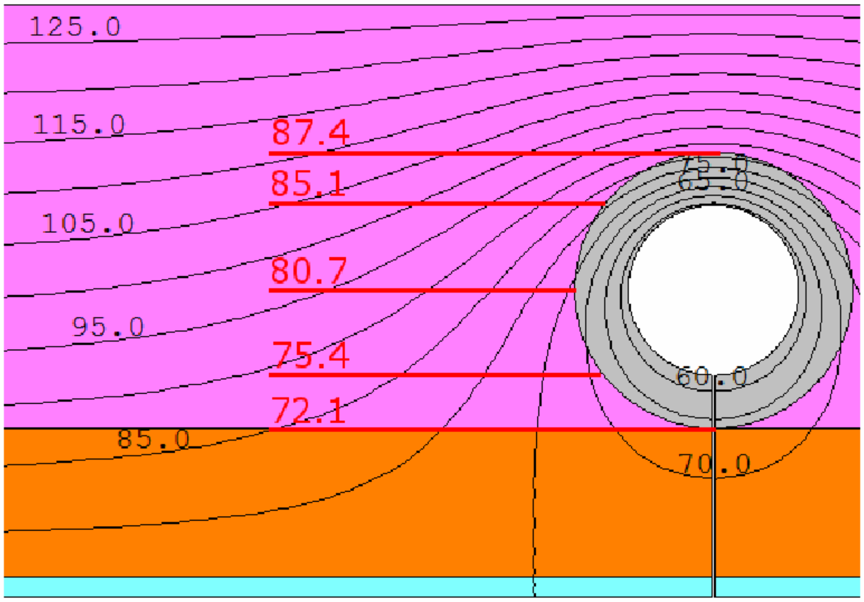

Figure 48. R-4.2 duct (4 in.) deeply buried in fiberglass insulation. Isotherms from the steady state model (in black) are compared to the dew point of the air at several key locations (in red).

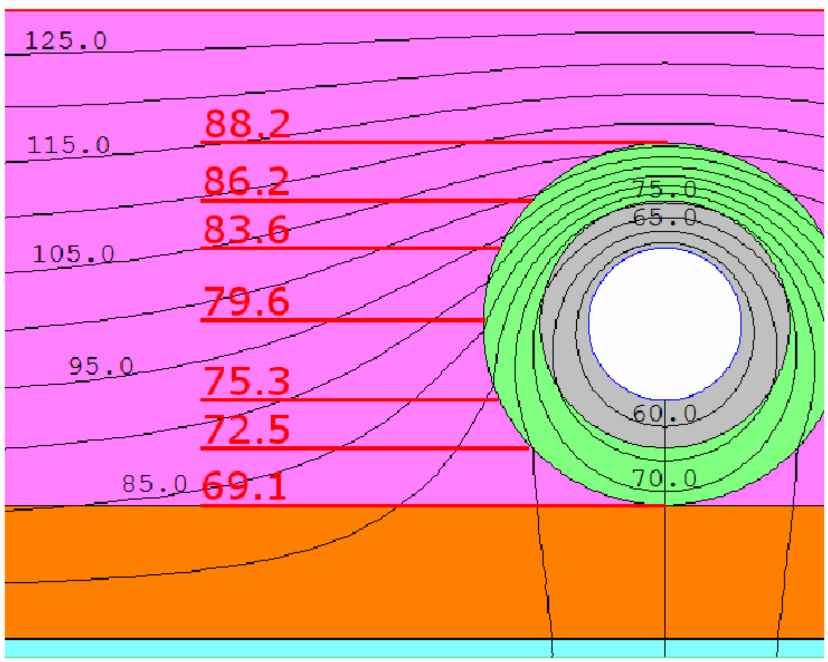

Figure 49. R-4.2 duct (4 in.) deeply buried in fiberglass insulation and encapsulated in 1.5 in. of ccSPF. Isotherms from the steady-state model (in black) are compared to the dew point of the air at several key locations (in red).

10 Predicted Energy and Cost Savings

Energy savings were predicted in Building Energy Optimization (BEopt)E+ 1.2 using the specifications given in Table 4 and Table 5. The pre-retrofit BEopt models were calibrated using utility bill data collected for 20 months before the start of the retrofit. Heating and cooling set-point temperatures and miscellaneous electric load multipliers were modified to match the observed utility bills. A utility bill analysis was used to match modeled and observed utility bills and account for differences between the observed temperatures and the typical meteorological year. The utility analysis was performed using a multivariate, linear, least-squares regression of the form

$$E = \beta_1 N_{days} + \beta_2 CDD_{75} + \beta_3 HDD_{65}, \qquad (32)$$

where

E	=	electricity use during the billing period (kWh)
N_{days}	=	number of days in the billing period
CDD_{75}	=	cooling degree days at base 75°F
HDD_{65}	=	heating degree days at base 65°F
β_1, β_2, and β_2	=	regression coefficients.

This methodology is similar to that used by the PRISM model, but employs a fixed base for the CDD and HDD calculations (Fels 1986). Table 23 shows the regression statistics—including the coefficient value, t-statistic, and p-value—for the pre-retrofit utility bills collected for 20 months before the retrofits began. The resulting regression coefficients were statistically significant at the 95% confidence level. At House 3, the initial regression found a negative coefficient for the HDD variable that was statistically insignificant at the 95% confidence level. The resulting coefficient was thus forced to zero and ignored in this analysis.

Table 23. Regression Statistics for Pre-Retrofit Utility Bills

	House 1 $R^2 = 0.974$ N = 20, dof[a] = 17			House 2 $R^2 = 0.985$ N = 20, dof = 17			House 3 $R^2 = 0.989$ N = 20, dof = 18		
	coef.	t	p	coef.	t	p	coef.	t	p
N_{days}	16.3	5.15	7.97×10^{-5}	50.8	11.8	1.28×10^{-9}	54.25	30.0	8.14×10^{-5}
CDD_{75}	4.02	4.95	1.21×10^{-4}	7.40	6.86	2.77×10^{-6}	4.52	7.34	8.12×10^{-5}
HDD_{65}	2.56	8.91	8.20×10^{-8}	1.06	2.70	1.54×10^{-2}	N/A	N/A	N/A

[a]Degrees of freedom

Table 24 shows identical statistics for the weather data used in and the energy predictions by BEopt. The coefficients are all statistically significant at the 95% confidence level and match the coefficients in Table 23 far better than typical energy models. Because these retrofits were completed relatively recently, insufficient data are available to use utility bill analysis to compare pre- and post-retrofit energy savings. To visualize these results, the resulting pre-retrofit predicted utility bills are compared in Figure 50 to a 1-year period as observed at the Jacksonville houses.

Table 24. Regression Statistics for Pre-Retrofit Energy Predictions (BEoptE+ 1.2)

	House 1 $R^2 = 0.999$ N = 12, dof = 9			House 2 $R^2 = 0.999$ N = 12, dof = 9			House 3 $R^2 = 0.997$ N = 12, dof = 10		
	coef.	t	p	coef.	t	p	coef.	t	p
N_{days}	25.0	24.7	1.38×10^{-9}	52.5	25.9	9.34×10^{-10}	49.8	39.7	2.43×10^{-12}
CDD_{75}	2.79	11.5	1.11×10^{-6}	8.11	16.6	4.61×10^{-8}	4.41	11.5	4.37×10^{-7}
HDD_{65}	1.63	10.1	3.81×10^{-6}	1.14	3.53	6.42×10^{-3}	N/A	N/A	N/A

For the houses with buried and encapsulated ducts, two scenarios were investigated: adding blown-in insulation only around the ductwork, and adding blown-in insulation over the entire attic plane. In the first scenario, the additional insulation was ignored and the attic insulation was modeled at the same level as the pre-retrofit case. For the second scenario, 12 in. of additional blown-in attic insulation was assumed for an additional insulation level of R-30. At House 2, where the ducts were already partially buried, the additional insulation raises the R-value only from the existing R-24 to R-25.

The energy savings are relatively robust at 8% to 20% of total annual energy. These scenarios are compared to the alternative method of reducing duct losses by converting the attic to an unvented attic. House 2 was not modeled using this method because the location of the AHU precludes an accurate estimate of the duct losses. Without actually installing this configuration, duct leakage cannot be estimated.

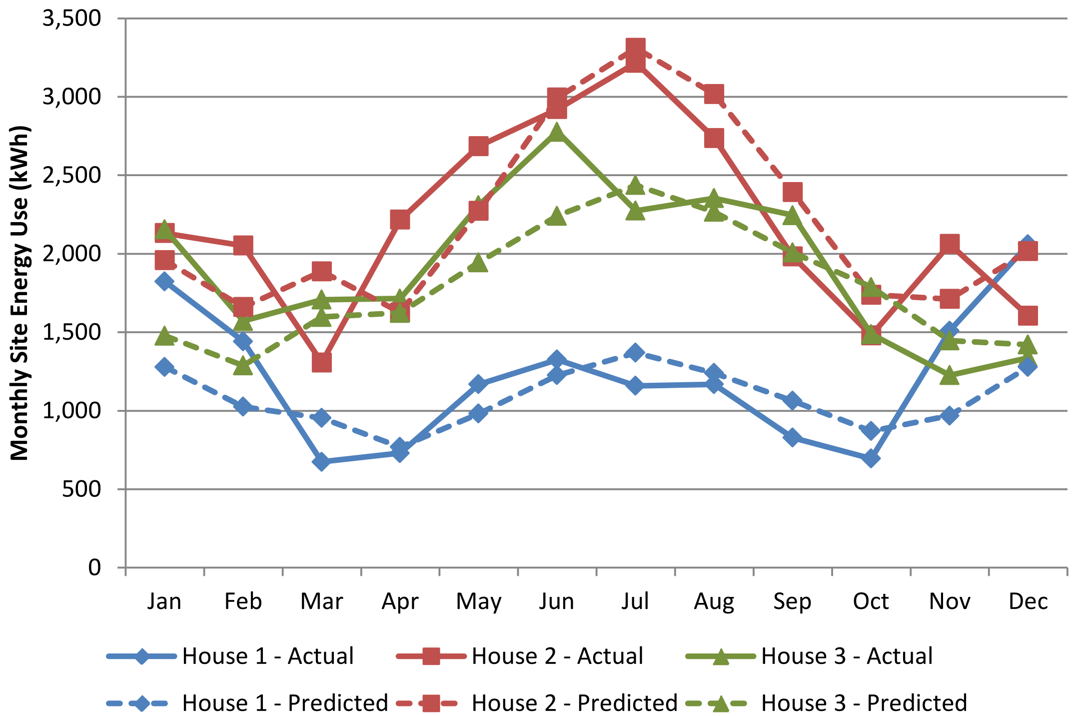

Figure 50. Predicted versus actual pre-retrofit energy use

These savings are reasonable in comparison to the predicted cooling and heating energy savings derived from the ASHRAE 152 seasonal delivery system efficiencies (Table 26). The predicted energy savings level from BEopt is consistently higher than that predicted by ASHRAE 152. Since these methods are both analytical estimates of the savings, it is difficult to determine which is more accurate.

Table 25. Predicted Energy Savings From BEoptE+ 1.2

	House 1			House 2		House 3	
	Encap-sulated + Mounded Buried	Encap-sulated + Fully Buried	R-30 Unvented Attic	Encap-sulated + Mounded Buried	Encap-sulated + Fully Buried	Encap-sulated	R-30 Unvented Attic
Annual Site Energy Savings (kWh)	1,013	1,365	777	4,566	5,203	1,032	1,190
% Savings Over Existing	8	10	6	17	20	5	5
Annual Utility Bill Savings Over Existing ($)	127	171	97	571	650	129	149

Table 26. Comparison of Predicted Savings Between BEopt and ASHRAE 152 (Duct Retrofit Only)

	Percent Predicted Energy Savings from ASHRAE 152 (Seasonal DSE)		Percent Predicted Energy Savings from BEopt	
	Cooling	Heating	Cooling	Heating
House 1	10.99	10.53	14.21	11.88
House 2	21.52	19.77	23.34	26.36
House 3	11.34	12.37	12.43	17.07

[a] This includes the added duct R-value of burying ducts at houses 1 and 2, but it excludes the additional R-value of the ceiling assembly after burial.

Table 27 shows the installed costs of the retrofits. These costs were derived from the HVAC and insulation contractor invoices for labor and materials, with the exception of the ccSPF insulation. The ccSPF costs are based on material and equipment data found in RSMeans (2011). The ccSPF was donated by the manufacturer, a partner in this project. As a result, actual ccSPF costs were not available but data on ccSPF quantities were used.

Table 27. Installed Cost of Encapsulated and Buried and Encapsulated Ducts at Houses

	House 1	House 2	House 3
Ductwork Area (ft^2)	483	719	280
Attic Insulation Area (ft^2)	521	521	N/A
Installed Cost ($)	2,990	3,806	956

The costs given in Table 27 represent the costs associated with this demonstration project. Not having undertaken this retrofit before, the contractor pricing is assumed to reflect time needed for training, setup, and coordination. These costs, however, do not include time required for coordination among the contractors and with the homeowners, which was carried out by the Building America team.

For the cost analysis, the researchers assumed that the installed costs will decrease as this becomes a widespread practice. The cost estimates for the measures shown in Table 28 assume that this retrofit is a mature building practice and processes are streamlined. The cost estimates are derived from the National Renewable Energy Laboratory's (NREL's) National Residential Efficiency Measures Database, RSMeans (2011), and the invoices from the contractors that performed the installation for this project. Again, no costs associated with coordination were included in these estimates.

Costs for the duct spray foam were taken from RSMeans and multiplied by 1.75 to account for the increased difficulty of the installation, material waste, and greater inconsistency of the application. Contractor invoices were used for comparison, but the cost estimates reflect average pricing and assume that the process has been streamlined. The projected costs, rather than the actual, were used for the cost-effectiveness analysis calculations.

Annualized returns were calculated assuming a 30-year analysis period, a 3% inflation rate, a 3% real discount rate, and a 7% 5-year loan. The lifetimes of the ducts and insulation were assumed to be 30 years. The cost savings are shown in Table 29. Encapsulated and buried and encapsulated ducts were shown to be cost effective; converting the attic to an unvented attic, though, was not cost effective. Generally, the added benefit of completely covering the attic plane with loose-fill insulation was not more cost effective than mounded burial of the ducts.

Houses 1 and 3 have no return ducting, which is common for Florida houses. Many Florida houses have AHUs in mechanical rooms with louvered doors with the bottom of the AHU open. Another alternative is that the AHU sits on top of a return plenum with a return grille directly below a closet door. As a result, the total costs and benefits of the measure are reduced for this case. House 2 presents the alternative where there is return ducting, leading to greater energy savings at a higher cost.

Table 28. Cost Estimates for Duct Retrofits

	House 1			House 2		House 3	
	Encapsulated + Mounded Buried	Encapsulated + Fully Buried	R-30 Unvented Attic	Encapsulated + Mounded Buried	Encapsulated + Fully Buried	Encapsulated	R-30 Unvented Attic
Ductwork Area (ft^2)	483	483	483	719	719	280	280
Attic Insulation Area (ft^2)	521	2,097	2,541	521	2,086	N/A	2,315
Duct Spray Foam ($1.89/$ft^2$) (RSMeans × 1.75)	$912	$912	N/A	$1,358	$1,358	$530	N/A
Blown-in Insulation ($0.63/$ft^2$) (NREL 2012)	$328	$1,321	N/A	$328	$1,314	N/A	N/A
Roof Deck Spray Foam ($3.58/$ft^2$) (NREL 2012)	N/A	N/A	$9,096	N/A	N/A	N/A	$8,287
Remove Blown-in Insulation (Contractor Cost)	N/A	N/A	N/A	$756	$756	N/A	N/A
Seal Boots and Place Rigid Insulation (Contractor Cost)	$63	$63	N/A	$84	$84	$63	N/A
Duct Reconfiguration (Contractor Cost)	$426	$426	N/A	$864	$864	N/A	N/A
Total Cost ($)	**$1,730**	**$2,722**	**$9,096**	**$3,391**	**$4,376**	**$530**	**$8,287**

Table 29. Annualized Savings by Retrofit Measure and House ($)

	House 1			House 2		House 3	
	Encapsulated + Mounded Buried	Encapsulated + Fully Buried	R-30 Unvented Attic	Encapsulated + Mounded Buried	Encapsulated + Fully Buried	Encapsulated	R-30 Unvented Attic
Total Cost	1,730	2,722	9,096	3,391	4,376	530	8,287
Utility Bill Savings	127	171	97	571	650	129	149
Annualized Savings	10	–28	–821	513	209	141	–655

11 Conclusion

This report takes a multifaceted approach, including field testing and analytical methods, to evaluate the cost effectiveness, energy savings potential, and condensation potential of encapsulated and buried and encapsulated ducts. Although field testing yielded valuable information about the installed system performance, variations in field conditions necessitated further analysis. As with any field testing of occupied homes, quantifying energy savings was difficult because of the dramatic changes in occupant behavior and building system performance. Despite these difficulties, field testing was necessary to establish data-driven support for other analytical methods. The following sections summarize the conclusions for each of the key sections of the report.

11.1 Retrofit Methodology and Lessons Learned

The retrofitting methodology used in this study was evaluated in terms of effectiveness, feasibility, and safety. Although the implemented methodology was effective, several issues must be more carefully considered in future installations, such as protecting existing materials, ensuring proper spray foam coverage, and coordinating among trades. Section 4 covers these topics in greater detail.

First, can lighting, exhaust fans, flues, security wire, plumbing, and other services located in or along the ceiling plane can get covered in foam and/or require baffling for protection during the retrofit. Second, training is required to emphasize the importance of ensuring that the minimum application thickness of the ccSPF (1.5 in. at R-6.7 h-ft^2-°F/Btu-in.) is consistently achieved to mitigate the potential for condensation. In areas where applying ccSPF is difficult, such as the undersides of ductwork too low to reach with the spray nozzle, ensuring proper installation is important. Two options can be used to solve this problem. The installer can cocoon the duct in ccSPF and directly seal it to the sheetrock. Alternatively, a piece of rigid insulation can be inserted under the ductwork to serve as a substrate for the foam and ensure that the minimal insulation thickness is achieved on the underside of the ducts.

Finally, coordination between trades must be considered. The buried and encapsulated duct strategy is a multitrade effort. To offer this strategy as a package, two or three contractors would be required: a ccSPF installer, a blown-in insulation installer, and an HVAC installer. (The latter might be optional depending on local codes). This strategy requires a significant amount of coordination, and this role should be assigned early in the process. The encapsulated duct strategy, on the other hand, is a single-trade effort, requiring significantly less coordination and fewer periods of access to the home. In addition, this strategy uses a single insulation material and costs less.

11.2 Field Evaluation

Changes in the mechanical and distribution system configuration and operation at each house created challenges for interpreting long-term field monitoring and performance testing data. Despite these challenges, the data gave interesting insights into duct system performance and validated the calculated system performance. These topics are discussed in greater detail in Section 5.

Field testing and monitoring showed promising improvements in system performance. Duct leakage rates were reduced considerably. At the same time, airflows remained relatively constant in both pre- and post-retrofit testing. The R-value of the encapsulated-only ductwork was approximately half that of the buried and encapsulated ductwork. A qualitative analysis of the monitoring data showed a large improvement in duct R-values and no worsening of any existing condensation potential.

11.3 Effective and Apparent R-Values

In order to calculate heat transfer gains and losses from ductwork in unconditioned attics, effective and apparent R-values were calculated using several techniques. Section 6 provides greater detail on these calculations. Analytical calculations were used to determine the effective and apparent R-values of traditional ductwork and encapsulated ducts. Because buried and buried and encapsulated ducts are more complex than traditional insulation systems, a finite-element heat transfer analysis was required to calculate these values for the buried duct strategy.

The resulting R-values from both methods matched existing literature well and showed large improvements in R-values for encapsulated and buried and encapsulated ducts. The calculations found that, by encapsulating the ductwork in 1.5 in. of ccSPF (R-6.7 h-ft^2-°F/Btu-in.), the existing R-4.2 flexible ductwork can be improved to values between R-9 and R-13, depending on the size of the duct. Comparable buried and encapsulated ducts will have a significantly higher increase in R-values, ranging between R-16 and R-31.

11.4 Effective Heat Transfer Coefficients

The calculated R-values listed in Section 6 were validated using field monitoring data in Section 7. The reduction in apparent UA values, based on field data, correlated well with the theoretical UA value reduction that was developed based on the analysis in Section 6. The values were found to be within 10% of one another, which is a reasonable alignment given that the calculation assumes steady-state operation.

11.5 ASHRAE Standard 152 Distribution System Efficiency

Based on the field monitoring and analytical tools used in Section 6 and validated in Section 7, both DE and DSE were calculated for the three test homes. The calculations show that duct leakage has a significant impact on DE, resulting from the direct relationship between duct leakage and duct losses. Duct leakage rates were substantially reduced through encapsulation with ccSPF. Duct leakage to the outdoors was reduced to minimal rates typical for houses with AHUs in the living space. For the house with an AHU in the garage, the duct leakage rates were dramatically reduced, but still significant.

The heating and cooling seasonal DSEs for the best-performing buried and encapsulated duct home were 97% post-retrofit, compared to pre-retrofit percentages of 85% and 86%, respectively. The heating and cooling seasonal DSEs for the home with the encapsulated-only system were 95% and 91%, respectively, after the retrofit. These values were compared to 85% and 81% pre-retrofit, respectively. The pre-retrofit seasonal DSEs for the two homes with flexible ductwork were similar (85%–87%). Post-retrofit, the heating seasonal DSE was 2% higher when the ducts were buried. Similarly, the cooling seasonal distribution system efficiency was 6% greater in the home where the ducts are buried.

The pre-retrofit seasonal DSE for the home with ductwork constructed primarily of duct board was 65% for heating and 54% for cooling. This is roughly 20% lower than the flexible duct systems. This is reasonable, based on the condition of the existing ductwork, the presence of an unsealed duct opening, and the high duct leakage rates. Post-retrofit, the heating seasonal DSE was 21% higher when the duct board system was encapsulated and buried. Similarly, the cooling seasonal DSE was 25% greater after the retrofit and duct repair.

11.6 Condensation Potential of Buried and Encapsulated Ducts

In Section 9, the steady-state two-dimensional thermal model developed in Section 6 was combined with one-dimensional dynamic hygrothermal model to predict the potential for condensation on the surface of the duct. This analysis was conducted for buried ducts and buried and encapsulated ducts using the worst case configurations. The results from the analysis predict condensation issues for the buried ducts without additional ccSPF insulation. Griffiths et al. (2002) observed these issues as well. The closeness of duct surface temperature and the dew point of the surrounding air at the bottom of the duct confirmed the need for a minimum insulation level of 1.5 in. of ccSPF on ducts with R-4.2 insulation.

11.7 Predicted Energy and Cost Savings

In Section 10, predicted energy savings were based on a calibrated BEopt model. The BEopt energy savings, which ranged from 5%–20% of total energy use for the three houses, appear reasonable in comparison to the predicted cooling and heating energy savings derived from the ASHRAE 152 DEs (ASHRAE 2004). A cost-effectiveness analysis determined that the buried and encapsulated duct retrofit achieved $10 in annualized savings, making it cost effective (greater than zero). The encapsulated-only strategy has $141 in annualized savings. The higher cost effectiveness of the encapsulated-only strategy is due, in part, to avoiding the material and labor requirements associated with duct reconfiguration and blown-in insulation. Although the encapsulated duct strategy was the most cost effective, the buried and encapsulated duct strategy has the largest amount of predicted energy savings.

11.8 Summary

Based on this research study, encapsulated and buried and encapsulated ducts were found to dramatically improve the DSE of existing ductwork. Pre- and post-retrofit DSEs were calculated using ASHRAE 152. The best case scenario estimates a DSE range of 97%–98%. Potential energy savings ranging from 5% to 20% per year were predicted through simulation. Both encapsulated and buried and encapsulated ducts were found to be cost effective.

Encapsulated ducts were found to be more cost effective than buried and encapsulated ducts to reduce energy costs associated with ductwork delivery losses. The encapsulated method is less expensive to install than buried and encapsulated ducts because it does not require an HVAC contractor to cut down and reconfigure the ductwork, nor does it require labor and material associated with loose-fill insulation for duct burial. Eliminating the need to reconfigure the ductwork also mitigates concerns about affecting the airflows in the home.

As a single-trade method, encapsulation requires fewer visits to the home and no coordination with other contractors. This is significant because a multitrade method requires sales coordination among differing trades to market the service, as well as field coordination for implementation. Encapsulated ducts, though, do require an appropriately fire-rated ccSPF to be code compliant, and the predicted energy savings are slightly lower. For new construction projects and gut rehab projects that include duct replacement, a buried and encapsulated duct strategy can result in additional energy savings with minimal additional effort. In these scenarios, the incremental installation costs are lower and more trades will already be involved in the project.

This research has been incorporated into the U.S. Department of Energy (DOE) Challenge Home National Program Requirements (DOE 2012). Under Section 10(c), buried and encapsulated ducts are exempt from the requirement that forced-air ducts be inside the home's thermal and air barrier boundary. Under this exception ductwork must be encapsulated with at least 1.5 in. of ccSPF and buried under 2 in. of blown-in insulation.

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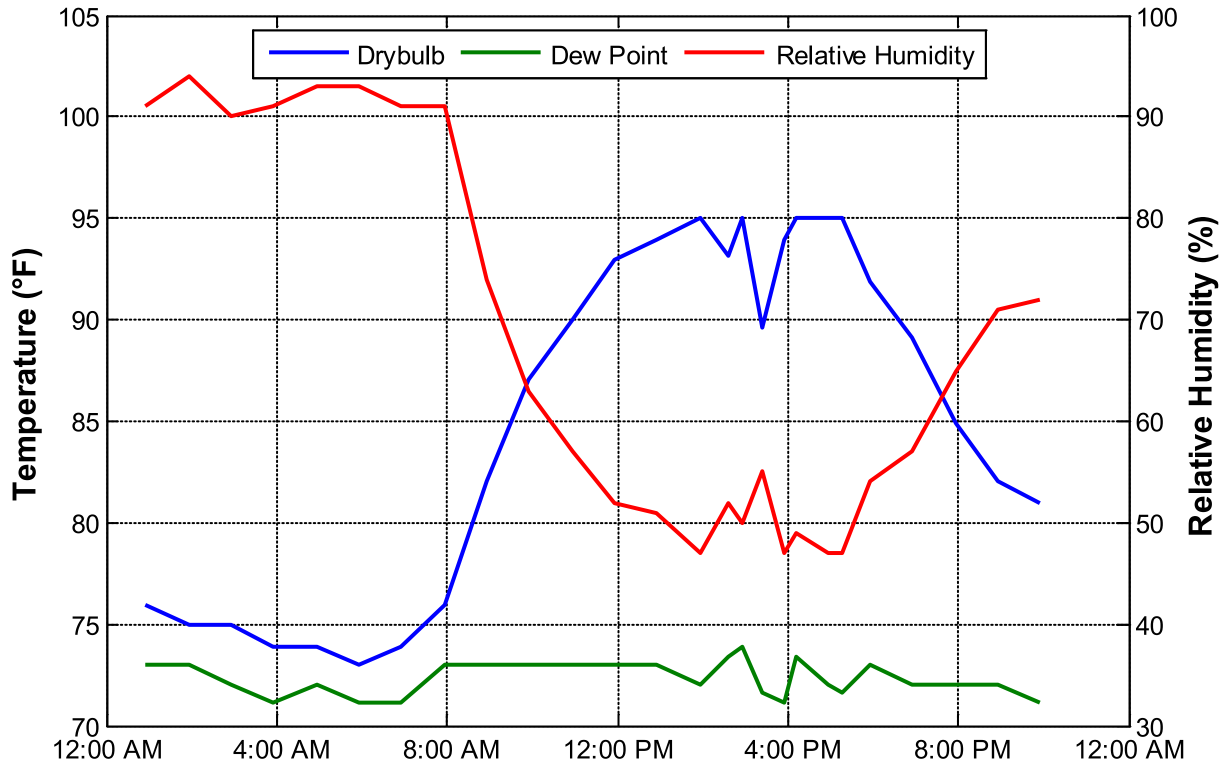
Appendix A: Attic Dew Point Temperature

This study yielded some intriguing insights into the moisture performance of attics in hot-humid climates. The dew point temperatures of the attics do not seem to track to outdoor dew points. Although the mean ambient dew point temperature corresponding to the 1% design temperature at Jacksonville Naval Air Station is 70°F (ASHRAE 2009), the attic dew point in these houses reached into the upper 80s. Furthermore, the ambient dew point was relatively constant throughout the day, but the attic dew point in these houses dropped to around 60°F during the night. Figure 51 shows the ambient conditions in Jacksonville, Florida, on July 29, 2010, using data from NCDC. On that day the dew point temperature remained relatively constant between 70°F and 75°F. The attic dew points, though, fluctuated at a much larger interval, 50°F to 90°F, as shown in Figure 52 through Figure 53



Source: NCDC (2012)

Figure 51. Ambient conditions in Jacksonville, Florida, on July 29, 2010

This might be surprising at first glance, but the attic dew point temperatures measured in this study do not seem inaccurate. The relative humidity sensors used in the study have a rated accuracy of ±2.5% in an operating range of –40°F to 158°F. Although dew point is more sensitive to errors in relative humidity measurement at higher dry bulb temperatures, the rated inaccuracy does not account for the dew point trends. A long-term monitoring study conducted for the U.S. Department of Housing and Urban Development that included 20 houses in Florida found similar trends in attic dew point temperatures (Arena et al. 2010). Explaining the cause of the changing dew point temperatures in the attics of these houses is outside the scope of this study, but possible explanations include solar moisture drive, along with moisture storage and evaporation in the building components, especially wood. Figure 52 and Figure 53 show the temperature and relative humidity of the attic and ambient air at one house monitored in this study and one house monitored by Arena et al. (2010), respectively.

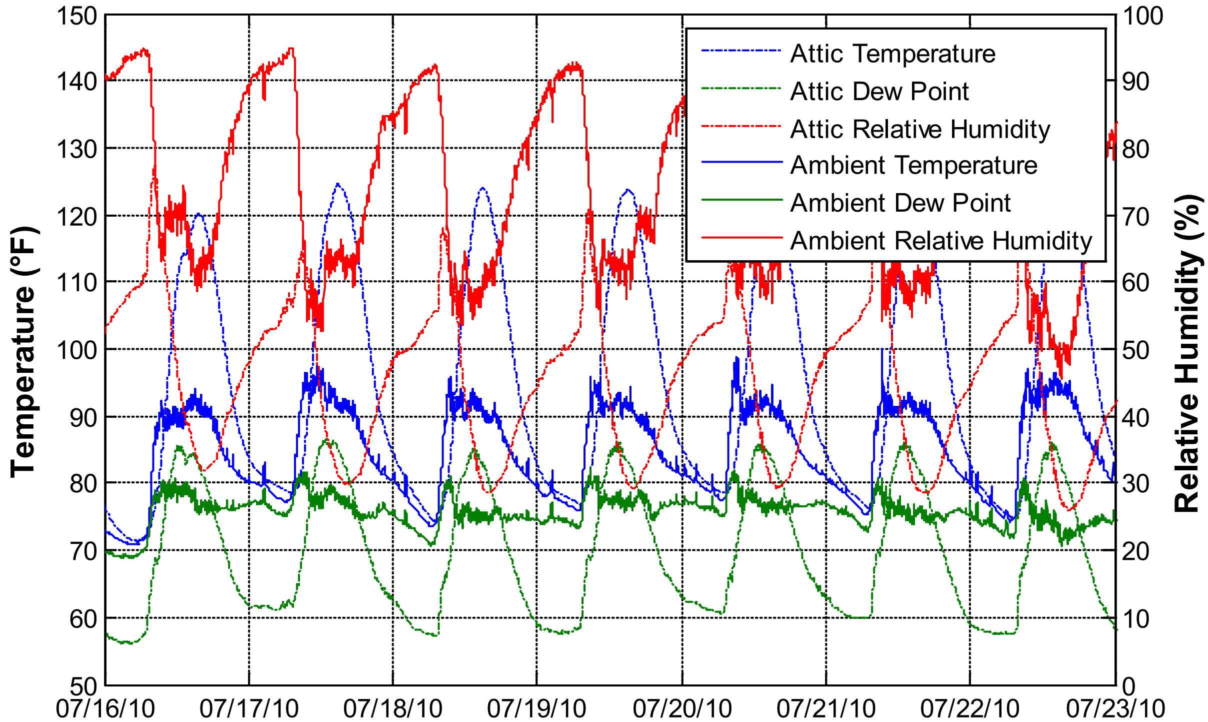


Figure 52. Pre-retrofit ambient and attic conditions at House 1

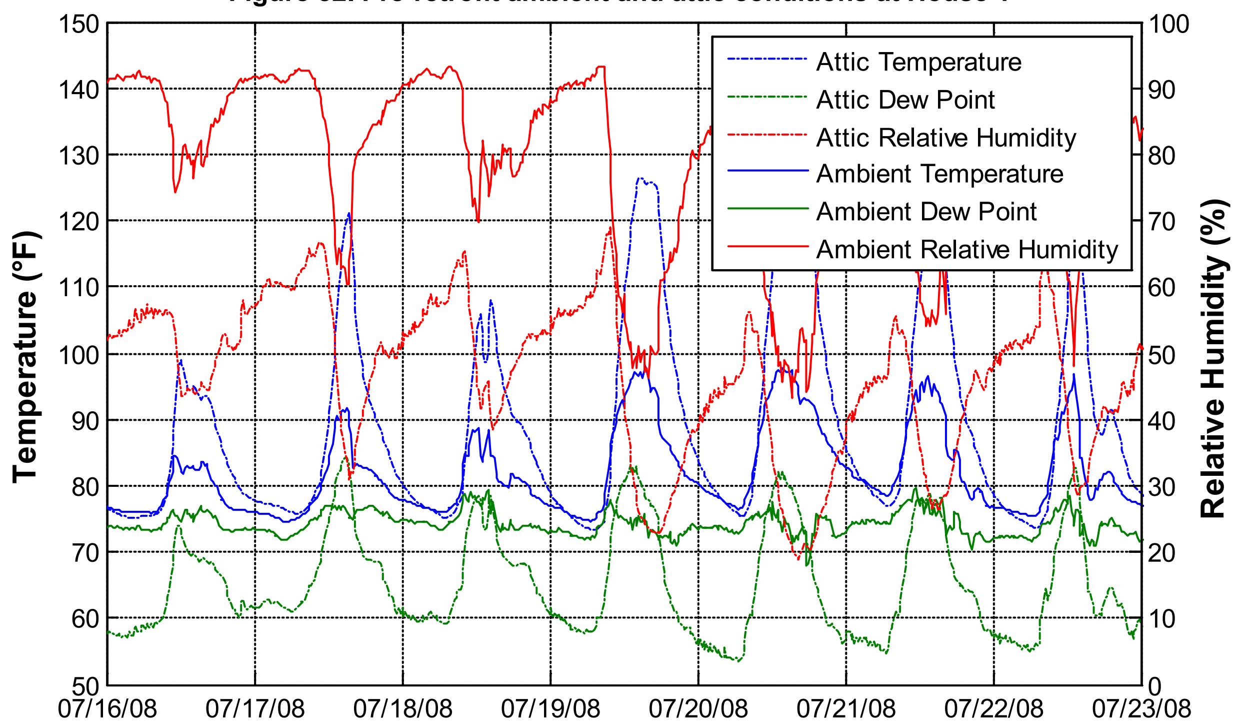


Figure 53. Ambient and attic conditions at U.S. Department of Housing and Urban Development Study House 4

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EN8129

Date Submitted	12/14/2018	**Section**	405	**Proponent**	Eric Lacey
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	No Affirmative Recommendation				
Commission Action	Pending Review				

Comments

General Comments **No** **Alternate Language** **Yes**

Related Modifications

8127

Summary of Modification

Provides a reasonable efficiency trade-off backstop for the performance path.

Rationale

See attached file.

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

No significant impact on cost of compliance. The proposed backstop is well short of the code's baseline requirements.

Impact to industry relative to the cost of compliance with code

No significant impact on industry relative to cost of compliance. The proposed backstop is well short of the code's baseline requirements.

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

No significant impact on small businesses.

Requirements

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

Directly connected to the health, safety, and welfare of the general public. An ability/inability to pay monthly utility bills has a profound effect on homeowner health, safety, and welfare.

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

Improves the code by adding a critical backstop for trade-offs.

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

Does not discriminate against any products. Any combination of materials or products can be used to achieve compliance.

Does not degrade the effectiveness of the code

Improves the code.

2nd Comment Period

8129-A3

Proponent Jay Murdoch **Submitted** 5/26/2019 **Attachments** Yes

Rationale

This proposal is offered only where the Commission does not accept EN8127 (HVAC trade-offs) and EN8129 (envelope backstop). This proposal is limited to wood frame walls and calls for cavity insulation values to be set at a minimum value (R-13 and correlating U-factor of 0.084). We feel that the HVAC trade off against the envelope is not in the interests of Florida's new home buyers and subsequent owners/renters, and we support establishing mandatory minimums for the thermal envelope. If the Commission rejects EN8127 and EN8129, we propose that mandatory minimum insulation values be established, at least for wood frame walls. It is remarkable that with all the incremental improvements to the energy codes over the last two decades that R11 is still permitted in Florida code and used widely. According the builder practice data from the Home Innovation Research Lab, which is affiliated with NAHB, Florida is the sole state where R11 is used to meet the energy code in significant volume. This data is supported by insulation manufacturing data. While the use of R13 in wood frame walls was mainstreamed in builder practice by the mid-2000s, generally, Florida and the manufactured housing industry are the last remaining users of R11 today. It should be noted that the federal HUD Code, covering manufactured housing, was drafted in the early 1990s and became effective in 1994, twenty-five years ago. If the Commission will not move the code forward, by eliminating the HVAC equipment and aligning it with the IECC and other States, or establishing mandatory minimums for the envelope, then we urge that it take an incremental step by establishing R13 as a mandatory minimum for wood frame walls.

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

Where R11 is still being used, the improvement to R13 will save property owners, renters and consumers over the useful life of the home.

Impact to industry relative to the cost of compliance with code

R13 is readily available through multiple channels and manufacturers. Further, increased envelope insulations allows builders to save costs on HVAC, hot water heating, and other energy efficiency measures.

Impact to Small Business relative to the cost of compliance with code

No significant impact on small businesses.

Requirements

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

Thermal envelope insulation can help improve comfort in homes and buildings, and reduce the loads on HVAC equipment. Improved energy efficiency connects with the healthy and welfare of the general public.

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

Improves the code as it closes a gap permitted by allowance of trade-offs against the envelope.

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

This change does not discriminate as all insulations are capable of meeting this. R13 has been prescribed as the minimum since the 1990s - except in FL where R11 still remains in use.

Does not degrade the effectiveness of the code

This does not degrade the effectiveness of the code, rather it enhances it's effectiveness.

1st Comment Period History

EN8129-G1

Proponent David Mann **Submitted** 2/14/2019 **Attachments** Yes

Comment:

Please see attached supporting comment.

1st Comment Period History

EN8129-G2

Proponent Jeff Sonne for FSEC **Submitted** 2/15/2019 **Attachments** No

Comment:

The Florida Solar Energy Center opposes this mod. We feel that the additional performance compliance method stringency that this mod proposes is overly restrictive; the performance method is intended to allow "trade-offs" which account for less efficient components. It appears this mod would not allow glazed fenestration with an average SHGC over 0.30 to be used for performance compliance (compared with the 0.50 average SHGC allowed for performance compliance in the current code).

Revise Section R405.2 as follows, only if the Commission rejects EN8127 and EN8129.

R405.2 Mandatory requirements. Compliance with this section requires that the mandatory provisions identified in Section R401.2 be met. The wood frame wall R-values shall be equal to or greater than the levels specified in Table 402.1.2 of 402.1.4. Supply and return ducts not completely inside the building thermal envelope shall be insulated to an R-value of not less than R-6.

Revise Section R405.2 as follows:

R405.2 Mandatory requirements. Compliance with this section requires that the mandatory provisions identified in Section R401.2 be met. The *building thermal envelope* shall be greater than or equal to levels of efficiency and *Solar Heat Gain Coefficients* in Table 402.1.1 or 402.1.3 of the 2009 *International Energy Conservation Code.* Supply and return ducts not completely inside the *building thermal envelope* shall be insulated to an *R*-value of not less than R-6.

American Chemistry Council

February 13, 2019

RE: ACC Comments Supporting Florida Building Code 7th Edition Update Energy Proposal #8129

I am writing on behalf of the American Chemistry Council (ACC) to support proposal #8129. This proposal applies the same thermal envelope trade-off backstop to the performance path that currently applies to the Energy Rating Index in Section R406.2 of the 6th Edition Florida Building Code. While both the ERI and the performance path allow builders to trade off a considerable amount of efficiency, we believe it is vitally important to include some limitation to help ensure a reasonable amount of efficiency in the thermal envelope given the equipment trade-offs currently allowed. Strong thermal envelope requirements enhance energy efficiency, drive materials and product innovation, and support continued economic and job growth.

About ACC and Building Energy Codes

ACC members apply the science of chemistry to make innovative products and services that make people's lives better, healthier and safer. The business of chemistry is a $526 billion enterprise and a key element of the nation's economy. Chemistry companies are among the largest investors in research and development, investing $91 billion in 2016. In the state of Florida, chemical manufacturing is a $9B industry employing over 15,000 people and another 26,000 in related jobs.

Florida's energy code impacts ACC's members and their employees. The chemical industry supplies many products and materials to the building and construction value chain, including those that deliver energy efficiency throughout the entire structure. ACC's members are also large users of energy so the responsible use of energy is important to the industry's economic health and competitiveness. Energy efficiency is the lowest cost option for meeting energy demand. Energy efficient buildings create economic opportunities for businesses and industry by promoting new energy efficient technologies and reducing energy waste.

ACC has extensive knowledge regarding building code development. ACC is a partner in recent building science research, including projects with the Department of Energy and Home Innovation Research Labs. ACC representatives serve on the ICC, ASHRAE, ASTM, AAMA, and other code and standard setting bodies.

Please contact me at (404) 242-5016 or Michael_Power@AmericanChemistry.com if we can be of any further assistance.

Regards,
Michael Power
Senior Director, Southern Region
American Chemistry Council

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RECA Proposal to Add Safety Net for Consumers in Performance Path

This proposal establishes a crucial trade-off "efficiency safety net" for Florida homeowners. It would require that the thermal envelope components at least meet the 2009 IECC prescriptive values as a backstop, just like Section R406 does for the new ERI compliance option. We recommend adopting this proposal in any event, but especially if the Commission decides to continue to permit equipment trade-offs in Section R405.

As we explain in a separate proposal to eliminate the equipment trade-offs from Section R405, trade-offs between equipment and envelope components allow an unnecessary weakening of the overall efficiency of the home and can leave homeowners saddled with higher energy bills over the lifetime of the home. We believe that the most sensible solution is to follow the model of the IECC and eliminate these trade-offs, but if the Commission decides to allow equipment trade-offs in the 7th Edition code, we offer the above proposal in order to ensure at least a minimal efficiency level in the thermal envelope. This proposal would apply the same mandatory requirements, including envelope requirements at least as efficient as those specified in the 2009 IECC, in section R405 that are required in the Energy Rating Index compliance option (Section R406). We believe it is reasonable to require a sensible minimum efficiency level for the thermal envelope components, irrespective of other trade-offs.

EN7243

Date Submitted	11/12/2018	**Section**	503.1.4	**Proponent**	Bryan Holland
Chapter	5	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	No Affirmative Recommendation				
Commission Action	Pending Review				

Comments

General Comments **Yes** **Alternate Language** **Yes**

Related Modifications

Summary of Modification

This proposed modification

Rationale

In this proposed modification, 50% is changed to 10% for alterations to residential lighting systems to correlate and match the 10% exception for commercial lighting systems in Section C503.6.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This 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

This proposed modification will not change the cost of compliance to building and property owners.

Impact to industry relative to the cost of compliance with code

This proposed modification will increase the cost of construction for alterations where greater than 10% of the lighting is replaced.

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

This proposed modification will not change the cost of compliance or impact small business

Requirements

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

This proposed modification is directly connected to the health, safety, and welfare of the general public by increasing the overall efficacy of lighting in residential buildings.

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

This proposed modification improves and strengthens the code by harmonizing the requirements in both residential and commercial construction and by lowering the threshold where lower efficacy lighting can remain in use during alterations.

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.

Does not degrade the effectiveness of the code

This proposed modification enhances the effectiveness of the code.

Alternate Language

2nd Comment Period

7243-A1

Proponent Jeff Sonne for FSEC **Submitted** 5/20/2019 **Attachments** Yes

Rationale

Same as original; only changes the exception from original mod's 10% of luminaires to 20% to overcome objection that 10% is too strict.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Same as original; no impact.

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

Only slight impact to building and property owners; high efficacy lamps are now readily available, affordable, and highly cost effective as indicted in a 2018 FBC funded code comparison report by FSEC: http://publications.energyresearch.ucf.edu/wp-content/uploads/2018/07/FSEC-CR-2085-18.pdf.

Impact to industry relative to the cost of compliance with code

Will slightly increase the cost of compliance.

Impact to Small Business relative to the cost of compliance with code

This proposed modification will not change the cost of compliance or impact small business

Requirements

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

Same as original mod; benefits public by increasing the overall efficacy of lighting in residential buildings.

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

Same as original mod; improves and strengthens the code by harmonizing the requirements in both residential and commercial construction and by lowering the threshold where lower efficacy lighting can be used for alterations.

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

Same as original mod; does not discriminate.

Does not degrade the effectiveness of the code

Same as original mod; enhances the effectiveness of the code.

2nd Comment Period

EN7243-G3

Proponent Bryan Holland **Submitted** 5/21/2019 **Attachments** No

Comment:

Please reconsider this proposed modification for approval. This code change aligns the residential provisions for lighting alterations with those in C503.6 for commercial occupancies. The 10% threshold provides allowance for low-efficacy lamps in appliances, legacy lighting products, and other special-use applications. This code change will ensure that general lighting used for occupancy of an altered space will meet the lighting efficacy requirements in R404.1.

2nd Comment Period

EN7243-G4

Proponent Jeff Sonne for FSEC **Submitted** 5/22/2019 **Attachments** No

Comment:

The Florida Solar Energy Center again supports this mod.

High efficacy lamps are now readily available, affordable, and highly cost effective as indicated in a 2018 FBC funded code comparison report by FSEC: http://publications.energyresearch.ucf.edu/wp-content/uploads/2018/07/FSEC-CR-2085-18.pdf.

1st Comment Period History

EN7243-G1

Proponent pete quintela **Submitted** 1/14/2019 **Attachments** No

Comment:

This proposed mod changes the current code exception for residential alterations that replace less than 50% of luminaries in a space to 10%. It is my opinion that 10% is extremely restrictive.

1st Comment Period History

EN7243-G2

Proponent	Jeff Sonne for FSEC	**Submitted**	2/18/2019	**Attachments**	No

Comment:

The Florida Solar Energy Center supports this mod which is highly cost effective for Florida citizens.

R503.1.4 Lighting. New lighting systems that are part of the alteration shall comply with Section R404.1.

Exception: Alterations that replace less than ~~50~~ 20 percent of the luminaires in a space, provided that such alterations do not increase the installed interior lighting power.

R503.1.4 Lighting. New lighting systems that are part of the alteration shall comply with Section R404.1.

Exception: Alterations that replace less than ~~50~~ <u>10</u> percent of the luminaires in a space, provided that such alterations do not increase the installed interior lighting power.

EN7330

Date Submitted	11/19/2018	**Section**	503.1	**Proponent**	Bryan Holland
Chapter	5	**Affects HVHZ**	No	**Attachments**	No

TAC Recommendation No Affirmative Recommendation
Commission Action Pending Review

Comments

General Comments Yes **Alternate Language** No

Related Modifications

Summary of Modification

This proposed modification deletes an unintended and unnecessary exception for alterations.

Rationale

This proposed modification deletes exception #7 related to lighting alterations as was originally intended by the authors of this Section in the 2015 IECC. The current rule in Section C503.6 is the correct requirement for lighting alterations. This modification removes the conflict between the two parts of the same section.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This 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

This proposed modification will not change the cost of compliance to building and property owners.

Impact to industry relative to the cost of compliance with code

This proposed modification will not change the cost of compliance or impact industry.

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

This proposed modification will not change the cost of compliance or impact small business.

Requirements

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

This proposed modification is directly connected to the health, safety, and welfare of the general public by correcting the code for proper use and enforcement.

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

This proposed modification improves and strengthens the code by removing an exception that is conflict the correct requirement in another part of the same section.

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.

Does not degrade the effectiveness of the code

This proposed modification enhances the effectiveness of the code.

2nd Comment Period

EN7330-G2

Proponent Bryan Holland **Submitted** 5/21/2019 **Attachments** No

Comment:

Please reconsider this proposed modification for approval. C503.1, Exception #7 is an ERROR. It was never supposed to be included in the code upon the addition of C503.6 that covers lighting alterations. This ERROR has been corrected in the 2018 IBC and needs to be corrected in the 2020 FBC. The continuance of this incorrect exception is in direct conflict with the correct rule in C503.6.

2nd Comment Period

EN7330-G3

Proponent Jennifer Privateer **Submitted** 5/22/2019 **Attachments** No

Comment:

agree with deletion as proposed

2nd Comment Period

EN7330-G4

Proponent Harold Barrineau **Submitted** 5/25/2019 **Attachments** No

Comment:

I agree with this modification

1st Comment Period History

EN7330-G1

Proponent pete quintela **Submitted** 1/14/2019 **Attachments** No

Comment:

I do not agree with this mod, I think it is extremely restrictive. This code section exceptions address common types of alterations where the need for upgrading to the new code requirements are not warranted.

C503.1 General. Alterations to any building or structure shall comply with the requirements of the code for new construction. Alterations shall be such that the existing building or structure is no less conforming to the provisions of this code than the existing building or structure was prior to the alteration. Alterations 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 portions of the existing building or building system to comply with this code. Alterations shall not create an unsafe or hazardous condition or overload existing building systems.

Alterations complying with ANSI/ASHRAE/IESNA 90.1. need not comply with Sections C402, C403, C404 and C405.

Exception: The following alterations need not comply with the requirements for new construction, provided the energy use of the building is not increased:

1. Storm windows installed over existing fenestration.

2. Surface-applied window film installed on existing single-pane fenestration assemblies reducing solar heat gain, provided the code does not require the glazing or fenestration to be replaced.

3. Existing ceiling, wall or floor cavities exposed during construction, provided that these cavities are filled with insulation.

4. Construction where the existing roof, wall or floor cavity is not exposed.

5. Roof recover.

6. Air barriers shall not be required for roof recover and roof replacement where the alterations or renovations to the building do not include alterations, renovations or repairs to the remainder of the building envelope.

~~7. Alterations that replace less than 50 percent of the luminaires in a space, provided that such alterations do not increase the installed interior lighting power.~~

EN7726

26

Date Submitted	12/6/2018	**Section**	806.5	**Proponent**	Ann Russo1
Chapter	8	**Affects HVHZ**	No	**Attachments**	No

TAC Recommendation No Affirmative Recommendation
Commission Action Pending Review

Comments

General Comments **Yes** **Alternate Language** **No**

Related Modifications

Summary of Modification

Editorial improvement.

Rationale

This is an editorial improvement, which makes the code clearer. There is no change in the requirements.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No negative impact to local entity relative to enforcement of code.

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

Will not increase the cost of construction.

Impact to industry relative to the cost of compliance with code

Will not increase the cost of construction.

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

Will not increase the cost of construction.

Requirements

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

This proposal is simply an editorial improvement which makes the code clearer.

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

This proposal will make to code clearer which will improve the application of the code.

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

This proposal will not discriminate against materials, products, methods or systems of construction.

Does not degrade the effectiveness of the code

This proposal will not degrade the effectiveness of the code.

2nd Comment Period

EN7726-G1

Proponent ashley ong **Submitted** 5/13/2019 **Attachments** No

Comment:

As stated in the summary, this modification is only editorial. It does allow air permeable insulation as an option. This modification will NOT discriminate other materials allowed in the code. Please support this editorial change.

2nd Comment Period

EN7726-G2

Proponent	Jennifer Privateer	**Submitted**	5/23/2019	**Attachments**	No

Comment:

agreed

2nd Comment Period

EN7726-G3

Proponent	Harold Barrineau	**Submitted**	5/25/2019	**Attachments**	No

Comment:

I agree with this modification

Revise as follows to make the code clearer:

R806.5 Unvented attic and unvented enclosed rafter assemblies.

(no change to the text in between)

5.1.2 Where air-permeable insulation is ~~provided inside the building thermal envelope, it shall be installed in accordance withSection 5.1.1. In addition to the air-permeable insulation~~ installed directly below the structural sheathing, rigid board or sheet insulation shall be installed directly above the structural roof sheathing in accordance with the R-values in Table R806.5 for condensation control.

(no change to the text below)