FLORIDA SOLAR ENERGY CENTER™
Creating Energy Independence

**Date: February 15, 2017**

# Report for the period thru February 15, 2017
# Submitted to
## Department of Business and Professional Regulations
## Office of Codes and Standards

| | | | |
|---|---|---|---|
| *Grantee Name:* | University of Central Florida/Florida Solar Energy Center | | |
| *Grantee Address:* | 1679 Clearlake Road, Cocoa, FL 32922 | | |
| *Grantee's Grant Manager:* | Robin K. Vieira | *Telephone No:* | 321-638-1404 |
| | | | |
| *Reporting Period:* | Through February 15, 2017 (Interim) | | |
| *Project Number and Title:* | **Improved Hot Water Code Calculation** | | |
| | | | |

***Provide a summary of Project accomplishments to date. (Include comparison of actual accomplishments to the objectives established for the period. If goals were not met provide reasons why.***

<u>Project Overview</u>

The purpose of this research project is to characterize hot water waste sources, characterize the implications of the climatic differences on hot water use and characterize the energy impacts of hot water recirculation systems and controls with respect to energy consumption in Florida homes and recommend Florida-specific methods that can be employed in the Florida Energy code for residential hot water use and energy consumption calculations.

The study will include a literature review, research report and recommendations suitable for consideration by the Florida Building Commission in determining the most appropriate Florida-specific methods, procedures and calculations for determining the energy use effectiveness, including the hot water distribution system effectiveness, of domestic hot water systems in the Florida Energy Code for Residential Buildings.

## Interim Progress Report

**Activities Summary**

Work on the project to this point has focused on the Task 1 literature review and Task 2 calculation procedure development. Specific activities have included:

- Literature review of NREL, LBNL, ASHRAE, DOE Building America databases and general search of "hot water distribution" and "energy" key words: A listing of documents reviewed for this task is included in the Appendix; a summary of the literature review findings will be included in the final report
- Draft calculations procedures: A draft interactive hot water energy consumption calculation spreadsheet and draft proposed code changes are provided with this report.

**Proposed Code Changes**

Domestic Hot Water (DHW) systems research shows that a number of significant factors impinging on hot water energy use are not considered by standard DHW energy use calculations in building energy codes, including the Florida Building Code for Energy Conservation. There are three principal factors that are not adequately considered by standard building energy code hot water calculations:

- The fact that service water temperatures ($T_{mains}$) vary from climate location to climate location is not adequately considered in determining the quantity of hot water use (gallons per day) by standard models
- The fact that domestic hot water distribution system design significantly impacts both the hot water use quantity (hot water waste) and hot water energy consumption (piping heat loss) is not adequately considered by standard models
- The fact that devices like hot water recirculation pumps, which can reduce the quantity of hot water use (by up to 15%), can dramatically increase hot water energy use (by up to 250%) is not adequately considered by standard models.

Measurement of hot water energy use in the field shows a distinct climatic influence on hot water energy use. The field research consistently shows that seasons and locations with lower outdoor temperatures have larger hot water energy use and seasons and locations with higher outdoor temperatures have smaller hot water energy use. Figure 1 presents an example from research conducted by Merrigan in Florida between 1982 and 1983.[1] As illustrated in Figure 1, the estimated service water

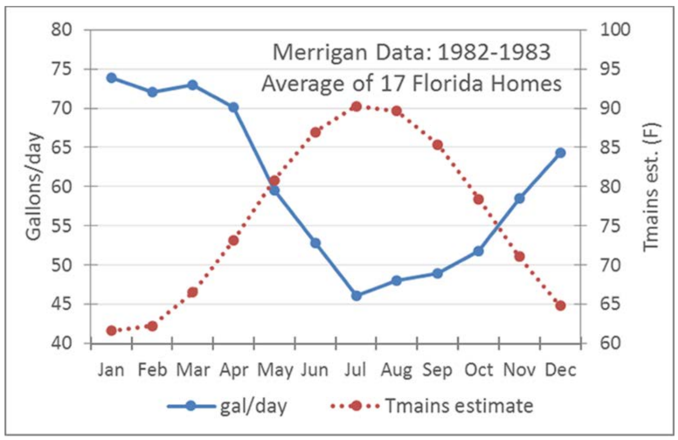

Figure 1. Measured DHW gallons per day in 17 Florida Homes from research conducted in 1982-1983.

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[1] Merrigan, T.J., 1988. "Residential Hot Water Use in Florida and North Carolina." ASHRAE Transactions, Vol. 94, Part 1.

temperature ($T_{mains}$) varies inversely with the amount of hot water needed to produce a use temperature commensurate with showering and other human needs ($T_{use} \approx 105$ F). Thus, as illustrated in Figure 1, when $T_{mains}$ temperatures are high, it takes much less hot water to reach this $T_{use}$ temperature than when $T_{mains}$ temperatures are low.

DHW research also shows that hot water use includes significant wasted hot water use due to DHW system distribution system losses. Typical hot water distribution system losses are estimated to be about 20% of typical hot water energy consumption or about 10 gallons per day as a national average. The quantity of hot water waste that a distribution system experiences is dependent on three principle factors:

- The length and diameter of the hot water piping between the hot water heater and the point of hot water use (i.e. the volume of hot water that can be left in the piping)
- The amount of insulation on the hot water piping
- The elapsed time between multiple hot water events that use the same piping.

The first two of these factors are self-evident but the third factor can be more difficult to grasp. The time interval between multiple hot water events that use the same piping is important because it determines the quantity of heat that will be lost from the piping between hot water events. If two hot water events follow one another within a very short time period (e.g. two showers, one right after another), the hot water waste quantity will be very similar to a single event. However, if sufficient time elapses between and following two events, then all of the residual hot water left in the piping following both events will be lost to the surroundings.

As noted above, hot water recirculation systems can reduce the quantity of hot water used but can also dramatically increase energy use depending on if or how they are controlled. It is therefore important that both the benefits and potential drawbacks of these systems also be accounted for in code calculation procedures.

Based on latest research and industry standards, the draft interactive hot water energy consumption calculation spreadsheet and draft proposed code change language delivered with this report provide a comprehensive means of including climate, circulation system design and insulation in performance code hot water energy use calculations.

*EnergyGauge* USA code software already accounts for solar thermal and heat recovery (desuperheater) systems “upstream” of the new draft calculation procedures, so if either of these conservation technologies are employed, estimated savings from their use will automatically be included in the new simulation results.

**Remaining Tasks**

Completion of the sample home energy use comparison spreadsheet (Task 3) and compilation of the sample home energy code performance scores (Task 4) are planned for March and April. A final report, including summary of literature review and recommendations for consideration by the Florida Building Commission will be submitted by June 1, 2017.

## Deliverables Update

Deliverable #1 Interim Report

Completed with submission of this February 15, 2017 interim report.

Deliverable #2 Draft of Calculation Procedures (Task 2)

Completed with submission of this February 15, 2017 interim report.

Deliverable #3 Sample Home Energy Use Comparison Spreadsheet (Task 3)

To be submitted with final report.

Deliverable #4 Report Documenting Sample Home Energy Code Performance Scores (Task 4)

To be submitted with final report.

Deliverable #5 Final Report

Due June 1, 2017.

A. ***Provide an update on the estimated time for completion of the project and an explanation for any anticipated delays.***

No delays in meeting deliverable due dates are anticipated at this time.

B. ***Provide any additional pertinent information including, when appropriate, analysis and explanation of cost overruns or high unit cost***

No cost overruns are anticipated.

C. ***Identify below, and attach copies of, any relevant work products being submitted for the project for this reporting period (e.g. report data sets, links to on-line photographs, etc.)***

Work products submitted with this report include a literature review documents list, draft hot water energy consumption calculation spreadsheet and draft proposed code change language.

D. ***Hours and budget update***

Not available at this time.

This report is submitted in accordance with the reporting requirements of Work Authorization for $21,990 dated November 2, 2016.

Rob Vieira

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Signature of the Grantee's Grant Manager
Robin K. Vieira

February 15, 2017

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Date

APPENDIX

- Literature Review Listing

- Draft Proposed Code Change Language

## Hot Water Distribution and Energy Literature Review Listing

**Review Database**

| # | Author | Title | Year | Organization |
|---|---|---|---|---|
| | **National Renewable Energy Laboratory (NREL)** | | | |
| | - Search: "hot water distribution" and "energy" together (reviewed first 10 pgs) | | | |
| 1 | Henderson, H. and J Wade | Disaggregating Hot Water Use and Predicting Hot Water Waste in Five Test Homes | 2014 | NREL |
| 2 | Burch, J. and J. Thornton | A Realistic Hot Water Draw Specification for Rating Solar Water Heaters | 2013 | NREL |
| 3 | Cassard, H. et al. | Break-even Cost for Residential Solar Water Heating in the United States: Key Drivers and Sensitivities | 2013 | NREL |
| | **Lawrence Berkely National Laboratory (LBNL)** | | | |
| | - Search: "hot water distribution" and "energy" together (reviewed first 3 pgs) | | | |
| 1 | Lutz, J. | Water and Energy Wasted During Residential Shower Events: Findings from a Pilot Field Study of Hot Water Dist | 2011 | LBNL |
| 2 | Lutz, J. et al. | Hot Water Draw Patterns in Single-Family Houses: Findings from Field Studies | 2011 | LBNL |
| 3 | Lutz, J. | Water Heaters and Hot Water Distribution Systems | 2008 | LBNL/CEC |
| 4 | Lutz, J. | Feasibility Study and Roadmap to Improve Residential Hot Water Distribution Systems | 2004 | LBNL |
| 5 | Lutz, J. et al. | Residential Hot Water Distribution Systems: Roundtable Session | 2002 | ACEEE |
| 6 | Lutz, J. | Estimating Energy and Water Losses in Residential Hot Water Distribution Systems | 2005 | LBNL |
| 7 | Liao, A. et al. | Performance Monitoring of Residential Hot Water Distribution Systems | 2014 | LBNL/ ACEEE |
| 8 | N/A | Home Energy Saver & Score: Engineering Documentation | N/A | LBNL |
| | **ASHRAE** | | | |
| | - Search: "hot water distribution" and "energy" together (reviewed first 5 pgs) | | | |
| | [None found in first 50 links provided by search] | | | |
| | **DOE Building America** | | | |
| | - Search: "hot water distribution" and "energy" together (reviewed first 3 pgs) | | | |
| 1 | Shein, J. | ZERH Webinar: Efficient Hot Water Distribution: You Know that Hot Water Distribution is Important | 2016 | EERE |
| 2 | Klein, G. | DOE ZERH Webinar: Efficient Hot Water Distribution I: What's at Stake | 2014 | EERE |
| 3 | Klein, G. | DOE ZERH Webinar: Efficient Hot Water Distribution II: How to Get it Right | 2014 | EERE |
| 4 | Dentz, J. and E. Ansanelli | Energy-Efficient Controls for Multifamily Domestic Hot Water | 2015 | ARIES Collaborative |
| 5 | | Zero Energy Ready Home and the Challenge of Hot Water on Demand | 2016 | EERE |

**DOE Building America (cont.)**

| | | | | |
|---|---|---|---|---|
| 1 | | ENERGY STAR® Hot Water Systems for High Performance Homes | 2011 | EERE |
| 2 | | Model Simulating Real Domestic Hot Water Use - Building America Top Innovation | N/A | EERE |

**General Google Search**

- Search: "hot water distribution" and "energy" together (reviewed first 4 pgs)

| | | | | |
|---|---|---|---|---|
| 1 | Klein, G. | Saving Water and Energy in Residential Hot Water Distribution Systems | N/A | CEC |
| 2 | | LEED BD+C: Homes v4 Efficient hot water distribution system requirements | N/A | USGBC |
| 3 | | EPA WaterSense® Guide for Efficient Hot Water Delivery Systems | 2014 | EPA |
| 4 | Ayala, G. and D. Zobrist | Best Practices for Efficient Hot Water Distribution in Multifamily Buildings | 2012 | ACEEE |
| 5 | | Hot water Distribution: Distribution Designs and On-Demand Systems | 2014 | Southface |
| 6 | Acker, L. and G. Klein | Benefits of Demand-Controlled Pumping | 2006 | Home Energy |
| 7 | Klein, G. | Hot Water Distribution Research | 2006 | IAPMO |
| 8 | Hoeschele, M. and E. Weitzel | Hot Water Distribution System Model Enhancements | 2012 | NREL |
| 9 | Maguire, J. et al. | An Analysis Model for Domestic Hot Water Distribution Systems | 2011 | NREL |
| 10 | Weitzel, E. and M. Hoeschele | Evaluating Domestic Hot Water Distribution System Options with Validated Analysis Models | 2014 | NREL |
| 11 | | Domestic Hot Water System Piping Insulation: Analysis of Benefits and Cost | 2010 | NAHB |
| 12 | Gu, L. | A Simplified Hot Water Distribution System Model | 2007 | FSEC |

**Other**

| | | | | |
|---|---|---|---|---|
| 1 | | ANSI/RESNET 301-2014 Addendum A-2015: Amendment on Domestic Hot Water Systems | 2015 | ANSI/RESNET |
| 2 | | Florida Building Code 5th Edition (2014) Energy Conservation | 2015 | ICC |
| 3 | | 2015 International Energy Conservation Code | 2014 | ICC |
| 4 | Parker, D. et al. | Estimating Daily Domestic Hot-Water Use in North American Homes | 2015 | FSEC |
| 5 | | California Building Energy Efficiency Standards - 2013 Residential Compliance | 2014 | CEC |
| 6 | | 2001 California Title 24 Residential Manual: Chapter 6 Water Heating Calculations | 2001 | CEC |
| 7 | Burch, J. and C. Christensen | Towards development of an algorithm for mains water temperature. | 2007 | NREL |
| 8 | Klein, G. | Comparing the Energy Requirements of Hot Water Circulation System Control Strategies: Preliminary Results | 2015 | ACEEE/Klein |
| 9 | Lutz, J. and M. Melody | Typcial Hot Water Draw Patterns Based on Field Data | 2012 | LBNL |
| 10 | Masiello, J. and D. Parker | Factors Influencing Water Heating Energy Use and Peak Demand in a Large Scale Residential Monitoring Study | 2002 | ACEEE |
| 11 | Wiehagen, J., and J.L. Sikora | Performance Comparison of Residential Hot Water Systems | 2003 | NREL |
| 12 | Wendt, R. et al. | Evaluation of Residential Hot Water Distribution Systems by Numeric Simulation | 2004 | ORNL |

## PROPOSED DOMESTIC HOT WATER SYSTEM CHANGES

***TABLE R405.5.2(1)— SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS. Modify as follows:***

**TABLE R405.5.2(1)**
**SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS**

| BUILDING COMPONENT | STANDARD REFERENCE DESIGN | PROPOSED DESIGN |
|---|---|---|
| Service water Heating[d, e, f, g] | ~~As proposed~~ Fuel Type: Same as proposed<br>Use (gal/day): ~~same as proposed design~~ determined in accordance with Appendix #<br><br>Efficiency: in accordance with prevailing Federal minimum standards<br>Energy Consumption: determined in accordance with Appendix #. | Fuel Type: As proposed<br>Use (~~G~~gal/day):~~= 30 + (10 × $N_{br}$)~~ determined in accordance with Appendix #<br><br>Efficiency: As proposed<br><br>Energy Consumption: determined in accordance with Appendix #. |

[All other parts of the table to remain unchanged.]

***Add new Appendix # to read as follows:***

### *APPENDIX #*

### *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** **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 (ºF)
$T_{amb,avg}$ = annual average ambient air temperature (ºF)
$\Delta T_{amb,max}$ = maximum difference between monthly average ambient air temperatures (e.g., $T_{amb,avg,july} - T_{amb,avg,january}$) (ºF)
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 + $F_{eff}$ * adj$F_{mix}$ * (refFgpd + oWgpd + sWgpd * $WD_{eff}$)) * Ndu** **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 ºF = water heater set point temperature
$T_{use}$ = 105 ºF = 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** **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.

**$EC_{HW} = stdEC_{HW} * (E_{waste} + 128) / 160$ Eq. #-7**

where $E_{waste}$ is calculated in accordance with equation #-8.

**$E_{waste} = oEW_{fact} * (1-oCD_{eff}) + sEW_{fact} * pEratio$ 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 |