FLORIDA SOLAR ENERGY CENTER®

Creating Energy Independence

New RESNET Hot Water Heating Calculations

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Why Did RESNET Make This Change?

- Long term criticism by energy efficiency partner programs (EEP) because RESNET standards do not consider hot water distribution system losses
- Builder partners' interest in additional opportunities to reduce energy use through smarter design and enhanced product choices
- Recent research on hot water use in homes and hot water distribution systems points to significant opportunities for improved models.

Some Acknowledgements

RESNET could not have developed an effective proposal on hot water systems without:

- The dedicated efforts of the SDC300 Calculation Subcommittee led by Dave Roberts
- The substantive subject matter expertise and commitment of Gary Klein, Gerald Van Decker and Marc Hoeschele
- And the recent research results and analysis on hot water systems by Parker, Fairey and Lutz; Henderson and Wade; and Troy Sherman.

The Question Everyone Will Ask

- How much will my HERS Index scores change as a result of this Standard change?
  - As a function of my home's efficiency?
  - As a function of my water heater's efficiency?
  - As a function of my climate?
- A small study to answer these questions has been accomplished.

Home Scenarios Evaluated

- Evaluated 2,400 ft2, 2-story, 3-bedroom homes on crawlspace foundations with natural gas water heating systems, assuming three home efficiency scenarios:
  1. Modern efficiency home meeting the minimum envelope requirements of the 2012 IECC with minimum standard HVAC equipment
  2. HERS Reference home
  3. Typical existing home

Climates Evaluated

- Duluth, MN – a cold climate with large heating loads, small cooling loads and large water heating loads
- San Francisco, CA – a mild marine climate with moderate heating loads, small cooling loads and typical water heating loads
- Miami, FL – a hot humid climate with small heating loads, large cooling loads and small hot water loads.

Duluth Results

Scenarios	gas WH EF	Duluth		
		Old HERS	New HERS	Δ HERS
Scenario 1	0.53	68.63	67.90	-0.73
	0.59	65.56	65.13	-0.43
	0.67	62.41	62.29	-0.12
	range	6.22	5.61	0.62
Scenario 2	0.53	103.10	102.79	-0.31
	0.59	100.00	100.00	0.00
	0.67	96.81	97.12	0.32
	range	6.29	5.67	0.62
Scenario 3	0.53	130.20	130.26	0.06
	0.59	127.10	127.47	0.36
	0.67	123.91	124.59	0.68
	range	6.29	5.67	0.62

San Francisco Results

Scenarios	gas WH EF	San Francisco		
		Old HERS	New HERS	Δ HERS
Scenario 1	0.53	73.50	71.80	-1.69
	0.59	68.84	67.87	-0.97
	0.67	64.08	63.85	-0.23
	range	9.41	7.95	1.46
Scenario 2	0.53	104.71	103.98	-0.73
	0.59	100.00	100.00	0.00
	0.67	95.18	95.93	0.75
	range	9.52	8.04	1.48
Scenario 3	0.53	130.85	131.00	0.15
	0.59	126.15	127.03	0.89
	0.67	121.32	122.96	1.64
	range	9.52	8.04	1.48

Miami Results

Scenarios	gas WH EF	Miami		
		Old HERS	New HERS	Δ HERS
Scenario 1	0.53	70.54	69.34	-1.20
	0.59	68.78	68.14	-0.64
	0.67	67.00	66.92	-0.08
	range	3.55	2.42	1.12
Scenario 2	0.53	101.78	101.21	-0.56
	0.59	100.00	100.00	0.00
	0.67	98.18	98.76	0.57
	range	3.59	2.46	1.14
Scenario 3	0.53	130.77	130.86	0.09
	0.59	128.99	129.64	0.65
	0.67	127.18	128.40	1.22
	range	3.59	2.46	1.14

Conclusions

- New hot water procedures will:
  - Reduce HERS Index scores in high-performance homes
  - Increase HERS Index scores in low-performance homes
- Sensitivity to change is largely a function of the Reference Home hot water load as a percentage of the Reference Home total load:
  - San Francisco = 14.5% (all other loads are moderate)
  - Duluth = 9.5% (large space heating load)
  - Miami = 4.0% (large cooling load and small hot water load).

Current Models

- Current models consider only tested EF data and mains water temperatures in calculating hot water energy consumption
- Current models do not consider:
  - Hot water distribution system effectiveness, which plays a significant role in wasted hot water use and hot water energy consumption
  - Mixed water temperatures at fixtures, which are a major determinant of the quantity of hot water use due to climatic differences in local mains water temperatures.

Recent Research

- Hot water system set point temperatures
  - Lutz and Melody (2012) report that median average measured hot water tank outlet temperatures in 105 California homes was 123 °F
  - Parker (1999) reports that median average measured hot water tank outlet temperatures in a 149 Central Florida homes was 127 °F
- The RESNET Addendum splits the difference and establishes hot water thermostat temperatures at 125 °F.

Recent Research (Cont'd)

- Parker, et al. (2014), in a manuscript submitted for publication in *ASHRAE Transactions*, found that the daily quantity of water use (gpd) is well correlated to the number of home occupants and the potable water supply temperature
- A daily hot water quantity equation, based on the number of home occupants, the temperature of the potable water supply entering the residence and a mixed water fixture delivery temperature is supported by the research data.

New Hot Water Use (gallons per day)

Estimate of daily hot water quantity from best available measured data (Parker, et al. 2014):

$$\mathbf{HWgpd = Appl + (22 * Occ) * F_{mix}}$$

where:

HWgpd = total hot water gallons per day

Appl = appliance gallons per day = DWgpd + CWgpd

Occ = number of home occupants

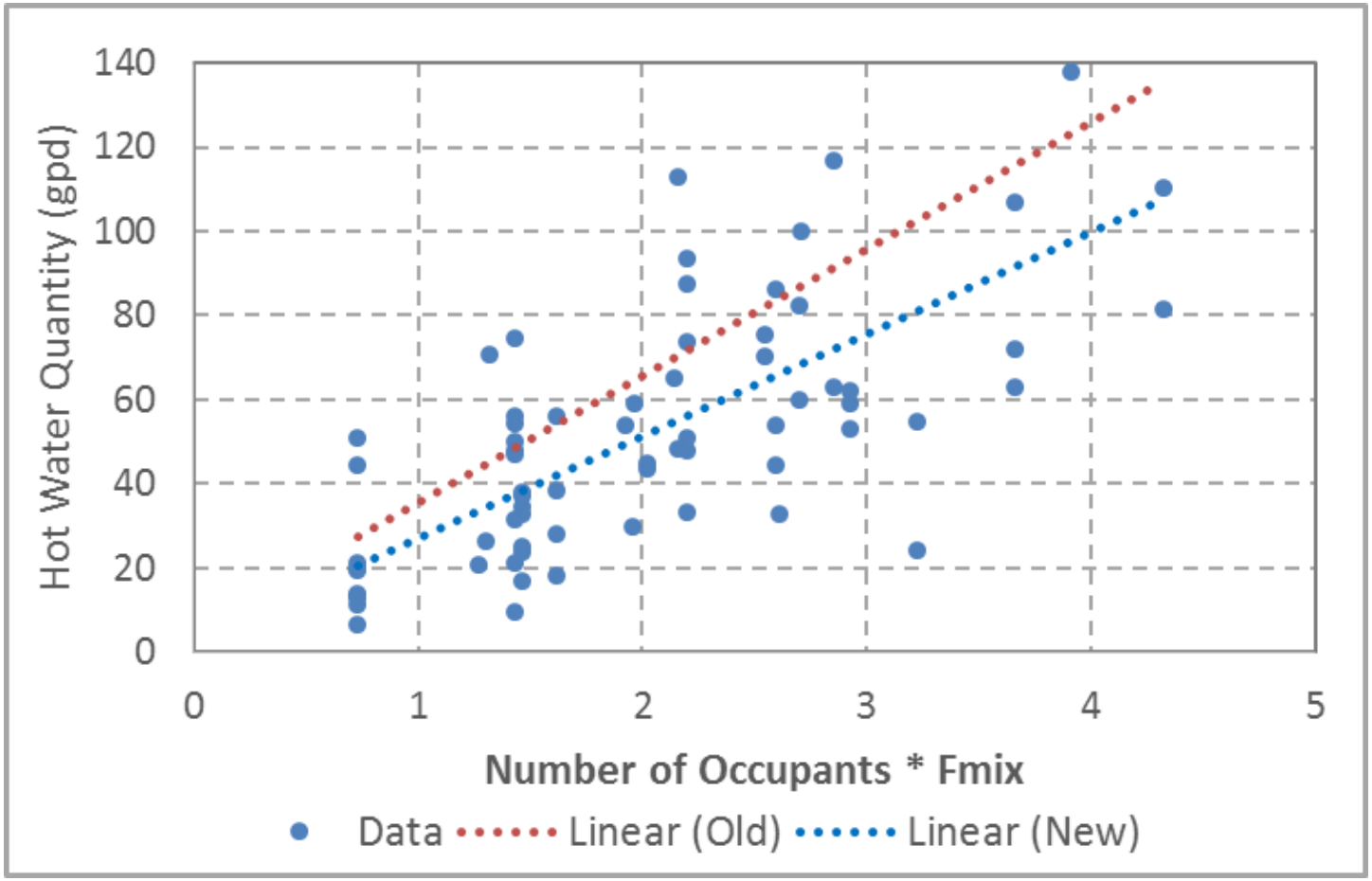
$F_{mix} = 1 - (T_{set} - T_{use}) / (T_{set} - T_{mains})$ = the mix fraction of hot water required to achieve T_{use}

T_{set} = hot water set point temperature (125 ^{o}F)

T_{use} = mixed water fixture temperature (105 ^{o}F)

T_{mains} = temperature of potable water supply

Hot Water Use Equation: Old vs New



Occupants and Bedrooms

Number of occupants per bedroom from RECS 2009 data (Parker, et al. 2014):

Occupants per Bedroom

Nbr	Occ
2	2.17
3	2.71
4	3.25
5	3.79

Occ = 1.09 + 0.54 * Nbr

Wasted Hot Water

- Estimated by Klein, Lutz, and Van Decker to be 20-25% in typical standard hot water systems (measured by Henderson and Wade to be 22%)
- Dependent on number of home occupants
  - More occupants = less time between instances
  - Less time between instances = less pipe heat loss
- Occupant vs. %waste estimate from Van Decker:

Occ	%waste
1	24.0%
2	22.4%
3	20.8%
4	19.2%
5	17.6%
6	16.0%

%waste = 0.256 - 0.016 * Occ

Computed Hot Water Quantities

Nbr	Occ	Appl	Fmix	HWgpd	%waste	Wgpd	Fgpd
1	1.63	5.5	0.676	29.7	23.0%	6.83	17.42
2	2.17	6.8	0.676	39.1	22.1%	8.66	23.63
3	2.71	8.2	0.676	48.5	21.3%	10.32	30.01
4	3.25	9.6	0.676	57.9	20.4%	11.82	36.54
5	3.79	11.0	0.676	67.4	19.5%	13.16	43.24
6	4.33	12.3	0.676	76.8	18.7%	14.33	50.10
7	4.87	13.7	0.676	86.2	17.8%	15.35	57.12
8	5.41	15.1	0.676	95.6	16.9%	16.20	64.31
9	5.95	16.5	0.676	105.0	16.1%	16.88	71.65

Appl = Appliance use = DWgpd + CWgpd

F_{mix} = for average climate (T_{mains} = 63.2 °F)

HWgpd = Total hot water use (Parker and Lutz 2014)

Wgpd = Wasted hot water use (Van Decker 2014)

Fgpd = Fixture hot water use = HWgpd - Wgpd - Appl

Reference Home Hot Water Use

From the above data, the equation for Reference Home hot water use (refHWgpd) is written:

refHWgpd = ((refFgpd + refWgpd) * F_{mix} + refCWgpd + refDWgpd) * Ndu

where:

refFgpd (fixture use) = 14.6 + 10.0 * Nbr

refWgpd (waste use) = 9.8 * $Nbr^{0.43}$

$F_{mix} = 1 - (T_{set} - T_{use}) / (T_{set} - T_{mains})$

refCWgpd = reference clothes washer use

refDWgpd = reference dishwasher use

Ndu = number of dwelling units

Note that because this equation stems from measured field data, it a priori includes average measured values for wasted water use and piping length.

Rated Homes

- Rated Home hot water quantity (gpd) may be impacted by a number of distribution system characteristics
  - Hot water piping length
  - Hot water piping insulation
  - Low-flow fixtures
  - Hot water recirculation systems
  - Drain Water Heat Recovery (DWHR) systems
- Rated Home hot water energy consumption (EC) (kWh/y or MBtu/y) may be impacted by these same distribution system characteristics.

Rated Home Quantity Equation

$HWgpd = (DWgpd + CWgpd + F_{eff} * adjF_{mix} * (refFgpd + oWgdp + sWgpd * WD_{eff})) * Ndu$

where:

F_{eff} = fixture flow effectiveness (standard or low-flow)

$adjF_{mix} = F_{mix} = 1 - (T_{set} - T_{use}) / (T_{set} - WH_{in}T)$

where

$WH_{in}T = T_{mains} + WH_{in}T_{adj}$ for DWHR systems (more later)

$= T_{mains}$ for all other systems

$oWgpd = refWgpd * oFrac * (1\text{-}oCD_{eff})$ = operational waste quantity

where

oFrac = 0.25 (operational hot water waste fraction)

oCD_{eff} = 0.0 (until operational hot water waste control devices are tested and approved)

Rated Home Quantity Equation (Cont'd)

$$HWgpd = (DWgpd + CWgpd + F_{eff} * adjF_{mix} * (refFgpd + oWgdp + sWgpd * WD_{eff})) * Ndu$$

sWgpd = (refWgpd – refWgpd * oFrac) * pRatio * SysFactor = structural waste quantity

where

oFrac = 0.25 (operational hot water waste fraction)

pRatio = piping length ratio (rated/reference)

SysFactor = distribution system insulation factor

WD_{eff} = water distribution system effectiveness (accounts for recirculation systems)

Ndu = number of dwelling units

DWHR Impact on Hot Water Use

DWHR system hot water quantity (gpd) is accounted for in the Rated Home equation through $adjF_{mix}$

$$HWgpd = (DWgpd + CWgpd + F_{eff} * adjF_{mix} * ((refFgpd + bWgdp + sWgpd * WD_{eff})) * Ndu$$

where:

$$adjF_{mix} = 1 - ((T_{set} - T_{use}) / (T_{set} - WH_{in}T))$$

and where:

for DWHR systems

$$WH_{in}T = T_{mains} + WH_{in}T_{adj}$$

for all other systems

$$WH_{in}T = T_{mains}$$

DWHR Heat Exchange

$WH_{in}T_{adj}$ = **Ifrac * ($DWHR_{in}T$ - T_{mains}) * $DWHR_{eff}$ * PLC * LocF * FixF**

where:

$WH_{in}T_{adj}$ = water heater inlet temperature adjustment

Ifrac = 0.90*(refFgpd / refHWgpd) = fraction of reference hot water quantity impacted by DWHR system

$DWHR_{in}T$ = 97 ^{o}F = temperature of the drain water entering the DWHR heat exchanger

$DWHR_{eff}$ = labeled efficiency of the DWHR heat exchanger

PLC = potable supply water piping loss coefficient

LocF = location factor for DWHR system (A, B or C)

FixF = fixture factor (indicating number of DWHR systems installed)

Additional Resources

- Justification and Background for Addendum A, ANSI/RESNET 301-2014

  http://www.resnet.us/standards/Just-Back_CMP_DHW_PD-03-rev.pdf

- Addendum A, ANSI/RESNET 301-2014

  http://www.resnet.us/standards/BSRRESNET_301-2014_Addendum_A-201x_FD-01_%282%29.pdf

Questions?