Implementing the Hot Water Provisions in the RESNET ANSI Standard

2016 RESNET Building Performance Conference
Scottsdale, Arizona

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March 2, 2016

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New Hot Water Provisions

- Addendum A to ANSI/RESNET/ICC 301-2014
- Modifies the hot water use profile in homes
  - Closely tied to local climate conditions
  - Generally lower hot water use than previous models
- Adds opportunities for improved performance
  - Hot water distribution system design credits
  - Low-flow fixtures
  - Drain water heat recovery systems
  - Water-efficient appliances

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Why Change Models?

- Concerns by energy efficiency partner programs (EEP) because previous RESNET standards did not consider hot water distribution systems
- Not able to adjust hot water use as a function of the distribution system, climate and fixtures
- 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.

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Current Models

- Current models consider only standard EF test data and mains water temperatures in calculating hot water energy consumption
  - Daily quantity of hot water use (gpd) is constant throughout the year and across the nation
  - ***Use (gpd) = 30 + 10 * Nbr***

    (This simplified daily use equation is replaced by 5 pages of new procedures and equations)

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What's Missing?

- Current models **do not** consider:
  - **Hot water distribution system effectiveness**, which plays a significant role in wasted hot water and thus, in hot water use quantity and energy consumption
  - **Mixed water temperatures at fixtures**, which, due to seasonal and climatic differences in mains water temperatures, are a major determinant of daily hot water use.

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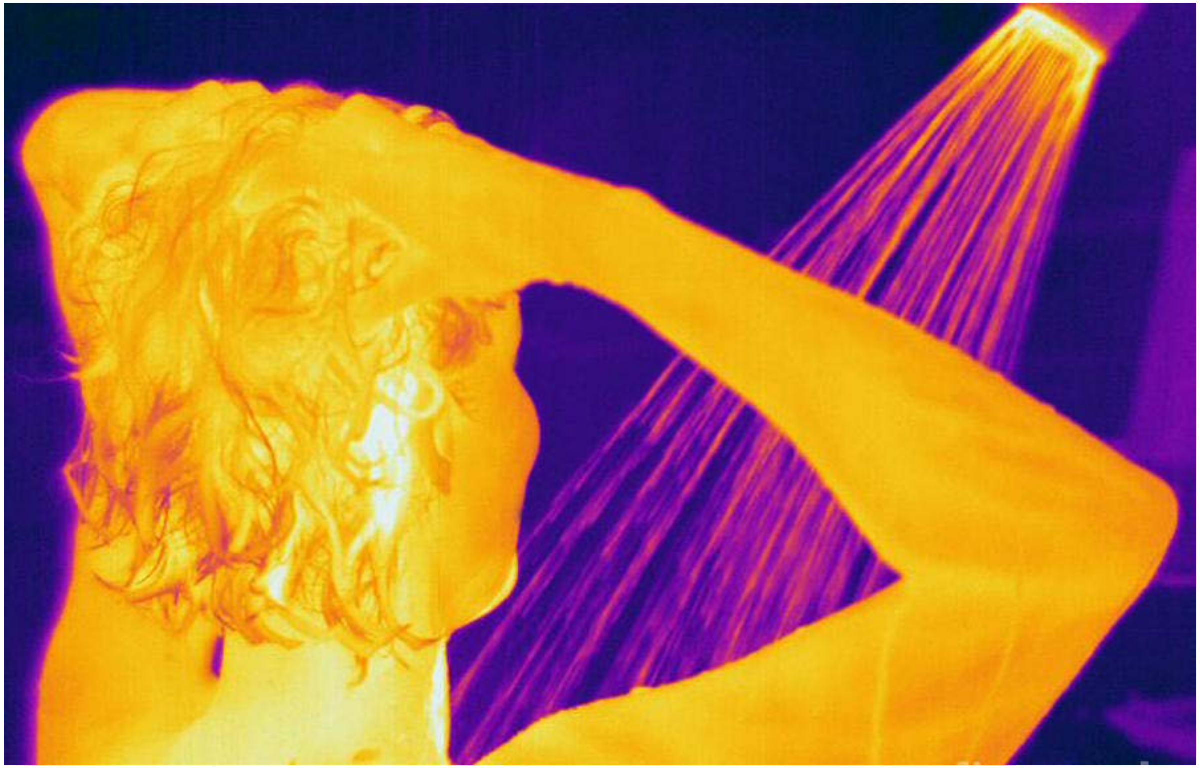
Fixture Hot Water Use

Mains Water @ 60 F → *Mixed Water @ 105 F* ← *Hot Water @ 125 F*



Body @ 98.6 F

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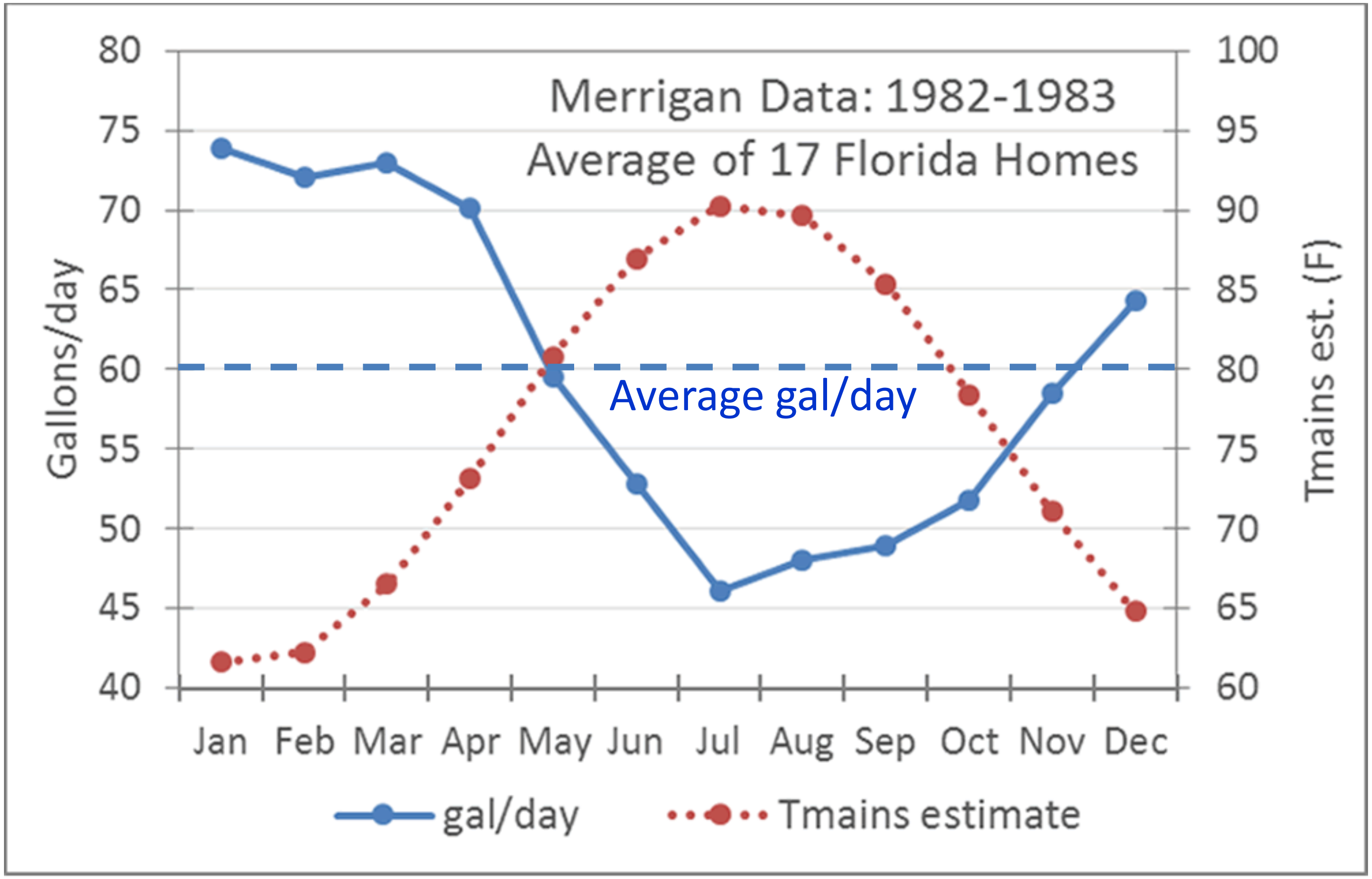
Hot Water Use Varies a Lot by Month



Recent Research

- Parker, et al. (2015) found that the daily quantity of hot water use (gpd) is well correlated to the demographics of home occupancy and the potable water mains temperature
- A daily hot water use equation, based on the number of home occupants, the temperature of the potable mains water and a fixture mixed water delivery temperature is well supported by the research data.

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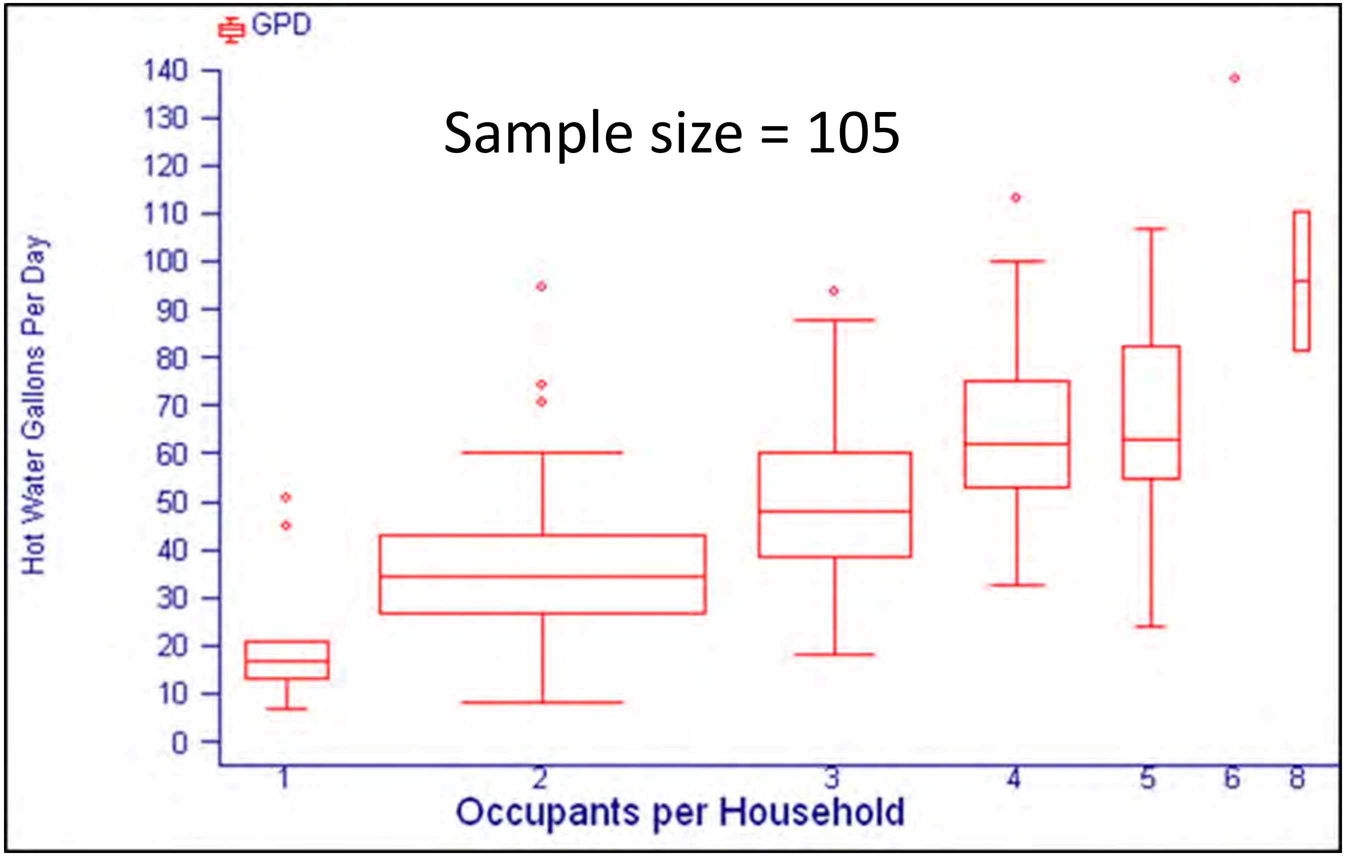
Hot Water Use is Function of Occupancy



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Hot Water Use Equation

Estimate of daily hot water use from best available measured data (Parker, et al. 2015):

$$\textbf{HWgpd} = \textbf{APL} + (\textbf{22} * \textbf{Occ}) * F_{mix}$$

where:

HWgpd = total hot water gallons per day (gpd)

APL = appliance gallons per day (DWgpd + CWgpd)

Occ = number of occupants

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

T_{set} = hot water system set point temperature (125 °F)

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

T_{mains} = temperature of potable mains water

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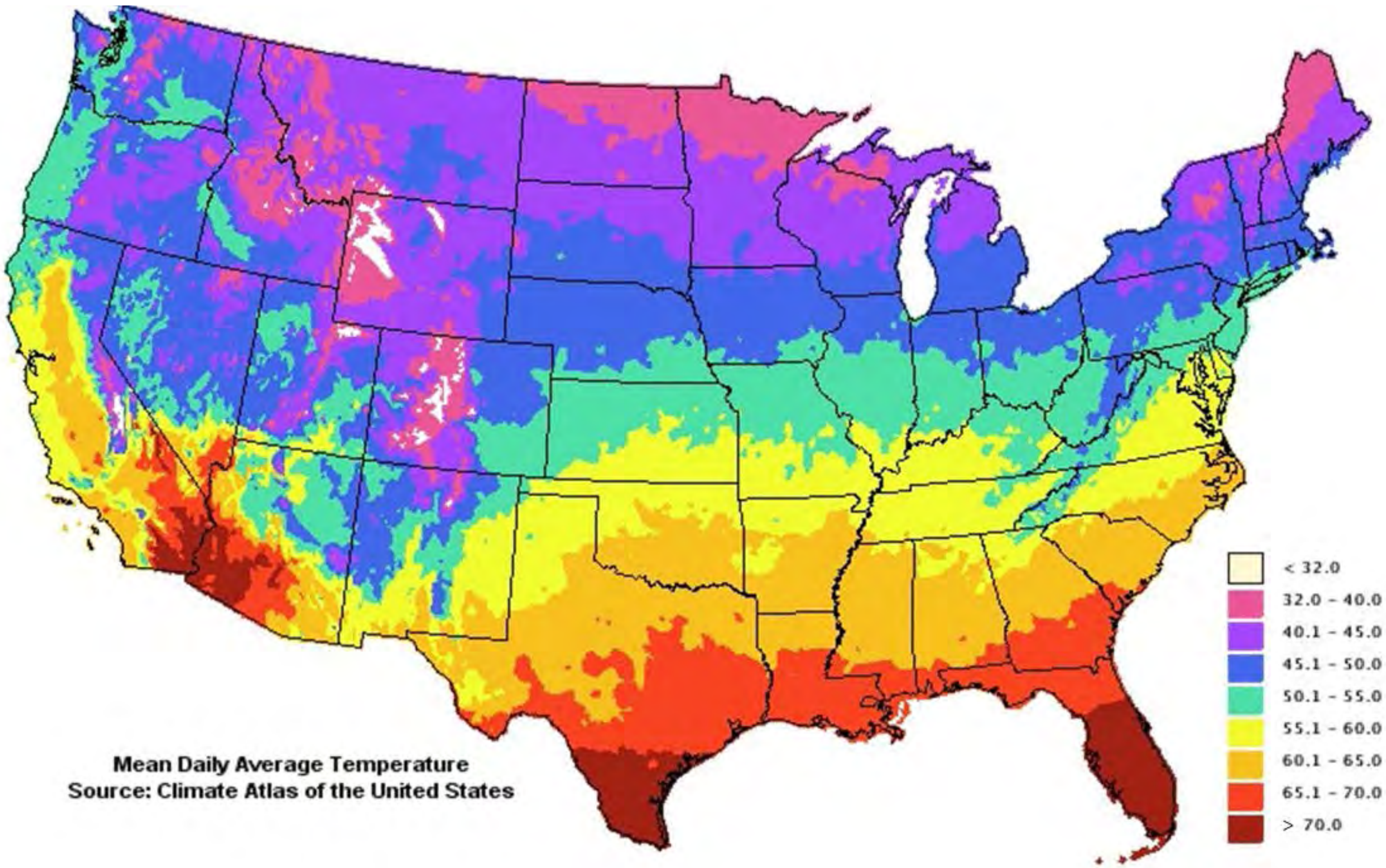
Mains Water Temperatures Vary A Lot



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Impact of T_{mains} on Daily Use (gpd)

- Assume 2.7 occupants (average for 3 bedroom home)
- APL = 8.2 gpd (standard clothes washer & dishwasher)
- Hot climate gallons per day
  - Tmains = 82 F (Miami, FL)
  - HWgpd = 8.2 + (2.7 * 22) * (1 - ((125 - 105) / (125 - 82)))

    = 40.0 gpd
- Cold climate gallons per day
  - Tmains = 45 F (Duluth, MN)
  - HWgpd = 8.2 + (2.7 * 22) * (1 - ((125 - 105) / (125 - 45)))

    = 52.8 gpd
- Climate induced difference = **12.8 gallons per day**

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Hot Water Use Equation Basis

- Hot water use equation is based on detailed measured annual data from 69 homes across U.S. with well known occupant demographics (ages)
  - 50% of data variance is explained when occupant ages are not considered
  - 70% of data variance is explained when occupant ages are considered (surprise - teenagers use significantly more hot water!)
- **Note:** measured data a priori includes typical distribution system piping and hot water waste.

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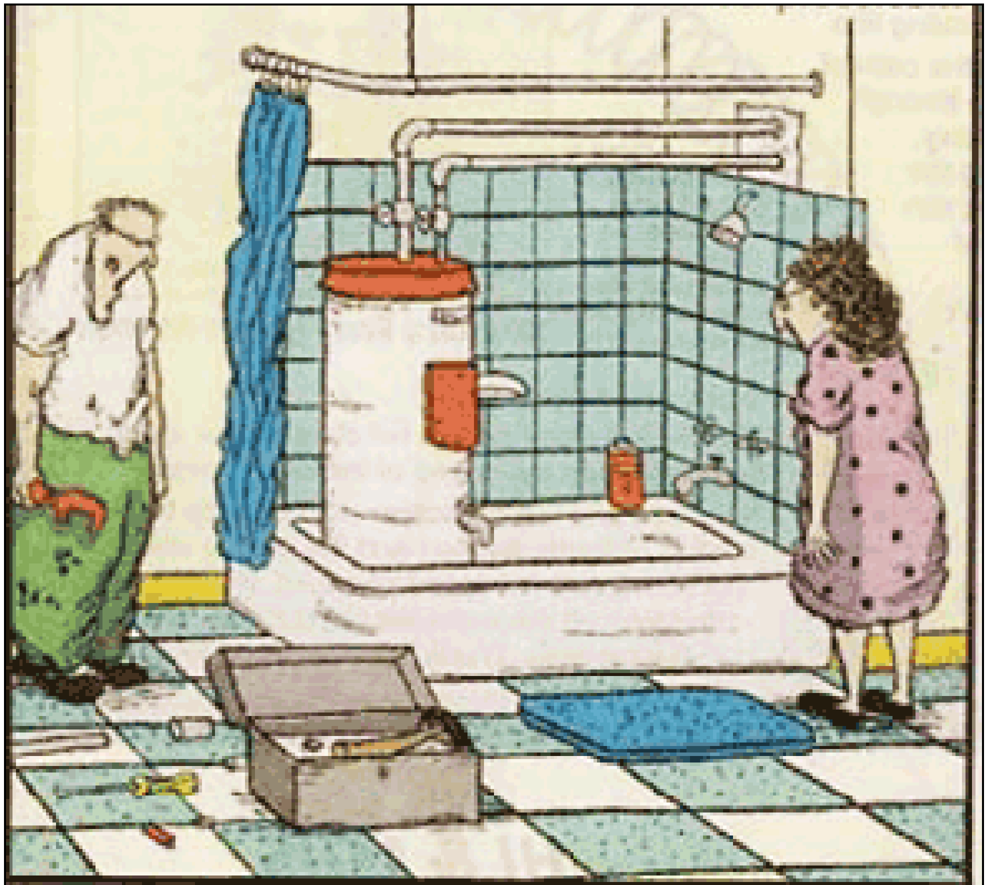
Hot Water Waste



"OK, there! I don't want to hear anyone whining about how long it takes for the water to get hot!"

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Structural Hot Water Waste

- **Mechanism:** Hot water remaining in hot water distribution system piping loses its embodied heat to its surroundings following hot water events
- Thus . . . hot water waste depends on:
  - Length and diameter of hot water piping (volume)
  - Hot water piping insulation (heat loss rate)
  - Elapsed time between hot water events (residual hot water availability in piping).

Wasted Hot Water

- Estimated by Lutz (2004), Klein (2012), and Van Decker (2014) to be 20-25% for typical standard hot water systems
- Measured by Henderson and Wade (2014) to be 22%
- Dependent on number of home occupants
  - More occupants = less time between hot water events
  - Less time between events = less overall piping heat loss
- Estimated by Van Decker (2014) to vary linearly from 24% for one occupant to 16% for six occupants.

$$\%waste = (0.256 - 0.016 * Occ) * 100$$

How Many Occupants per Bedroom?

$$HWgpd = APL + (22 * \color{red}{Occ}) * F_{mix}$$

Number of occupants per bedroom is derived from 2009 RECS single-family data (Parker, et al. 2015):

Occupants per Home

Nbr	Occ
2	2.17
3	2.71
4	3.25
5	3.79

$$Occ = 1.09 + 0.54 * Nbr$$

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Computed Uses by Number of Bedrooms

Nbr	Occ	APL	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

APL = Appliance use = DWgpd + CWgpd

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

HWgpd = Total hot water use (Parker, et al. 2015)

Wgpd = Waste hot water use (Van Decker 2014)

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

Climate-Normalized Uses

Daily hot water uses for Waste (Wgpd) and Fixture (Fgpd) uses are climate-normalized by dividing Computed Uses by F_{mix}

Nbr	Occ	Wgpd	Fgpd	(W+F)gpd
1	1.63	10.1	25.8	35.9
2	2.17	12.8	34.9	47.7
3	2.71	15.3	44.4	59.6
4	3.25	17.5	54.0	71.5
5	3.79	19.5	63.9	83.4
6	4.33	21.2	74.1	95.3
7	4.87	22.7	84.5	107.1
8	5.41	23.9	95.1	119.0
9	5.95	25.0	105.9	130.9

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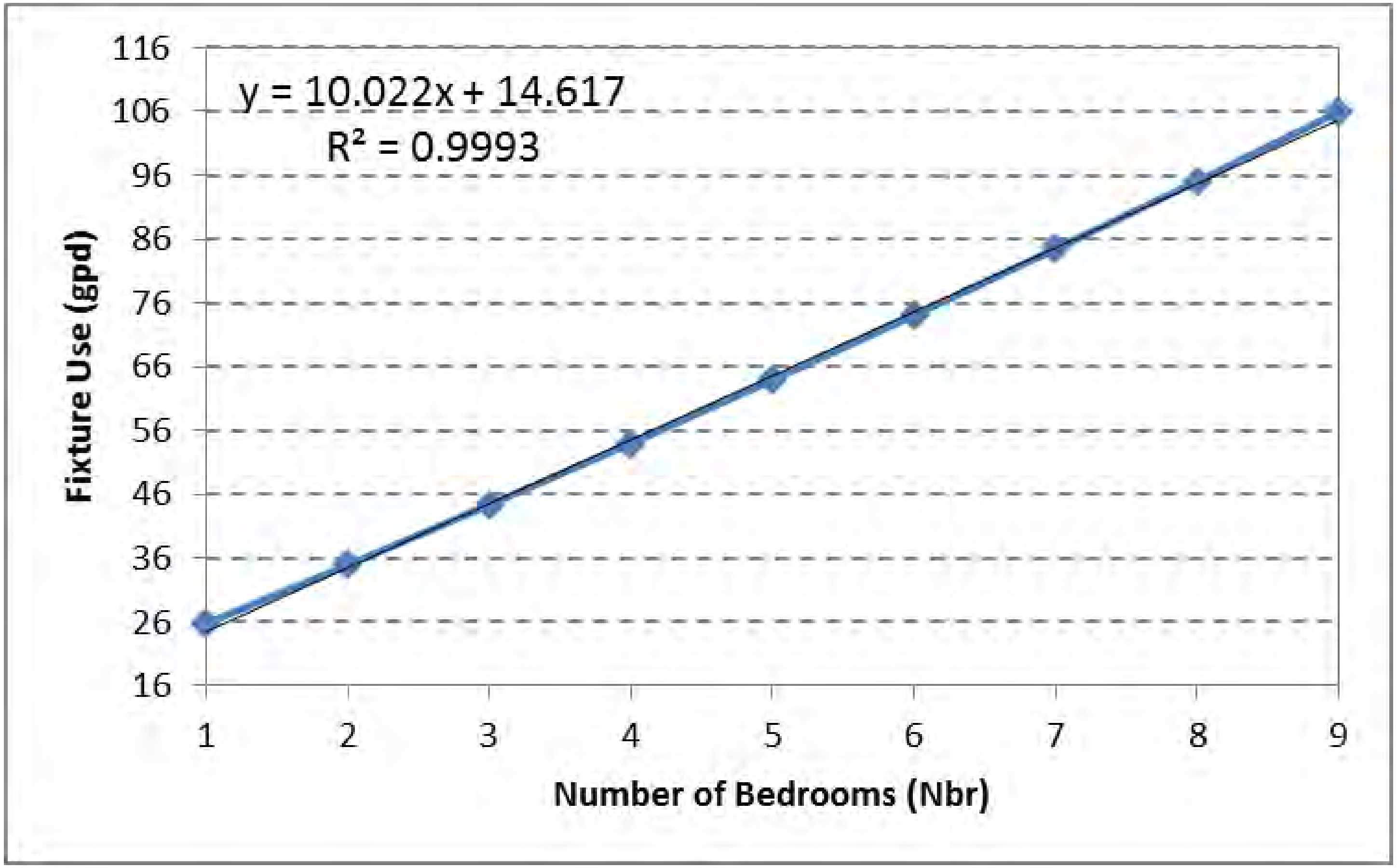
quantity annualcorrelatedexplained study total occupant homes demographics hot data daily any water use energy consumption heating climate factors accounting findings estimate actual climates distribution evaluate component efficiency estimating

Climate-Normalized Fgpd vs. Bedrooms



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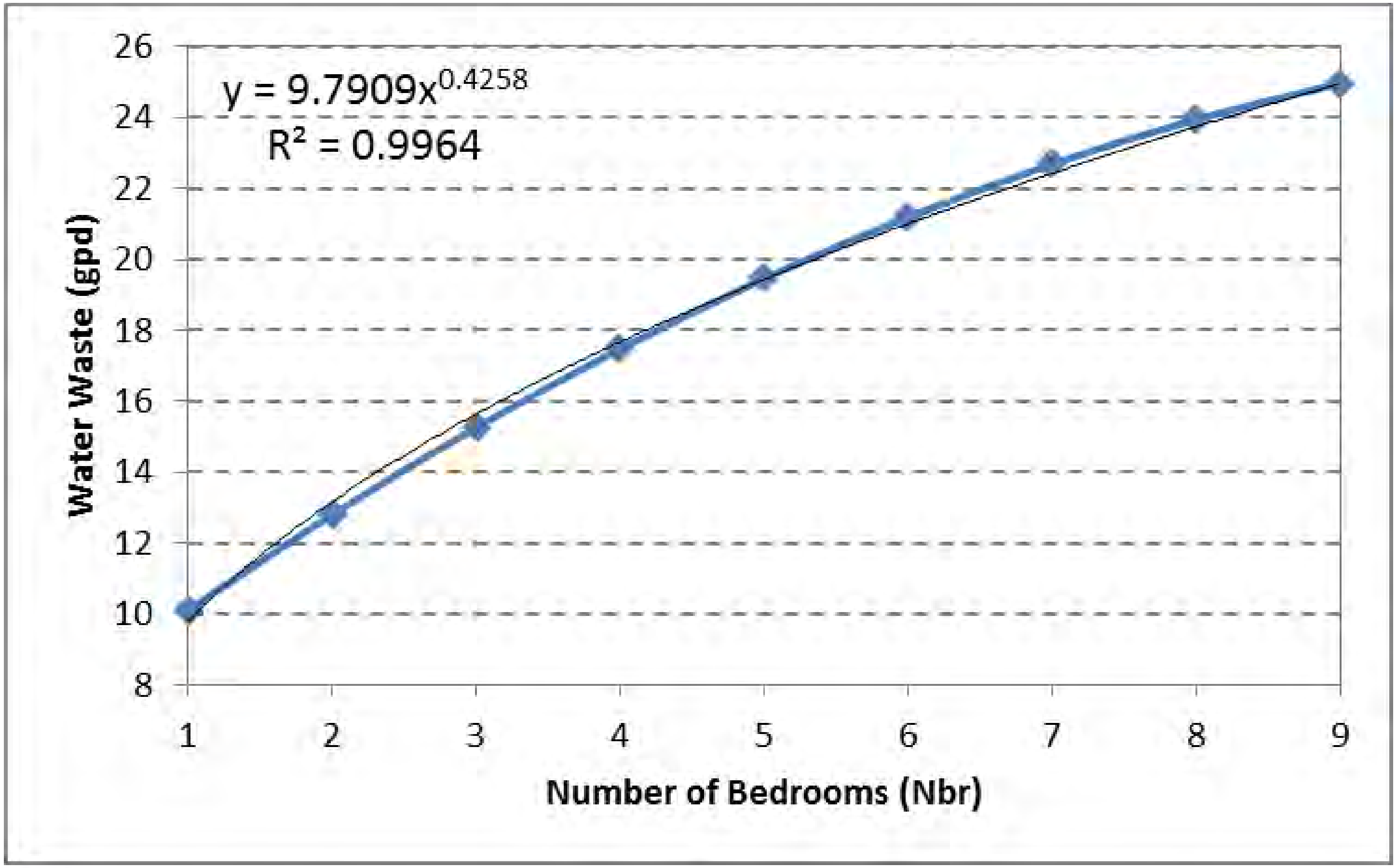
Climate-Normalized Wgpd vs. Bedrooms



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Reference Home Hot Water Use

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

$$\textbf{refHWgpd} = (\textbf{refFgpd} + \textbf{refWgpd}) * F_{mix} + \textbf{refCWgpd} + \textbf{refDWgpd}$$

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

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

HERS Rating Opportunities

- Improved hot water distribution system plumbing designs receives significant hot water use credit
- Piping insulation is explicitly credited
- Low-flow fixtures are explicitly credited
- Drain Water Heat Recovery (DWHR) systems are credited
- High-performance clothes washers and dishwashers receive hot water use credits
- Recirculation systems are properly accounted.

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Hot Water Savings Calculations

- EnergyGauge® USA v.5.0 results
- **Everything matters!** Energy uses based on 2,400 ft^2, 2-story, 3-bedroom homes with IECC 2012 envelopes and standard equipment, lighting and appliances
- Only 3 bounding climates are considered
  - Miami, FL: hot climate with large cooling energy use and small hot water use (40 gpd - 4% of Reference Home Load)
  - San Francisco, CA: mild climate with relatively small heating and cooling energy uses and average hot water use (49 gpd - 14.5% of Reference Home Load)
  - Duluth, MN: cold climate with large heating energy use and large hot water use (53 gpd - 9.5% of Reference Load).

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Hot Water Gallons per Day Savings

Gallons of Hot Water Savings per Day (gpd)			
Improvement	**Miami**	**San Fran**	**Duluth**
50% piping length	3.1	4.0	4.4
R-3 piping insulation	0.6	0.8	0.9
Recirc. (man) + R-3 pipe	5.8	7.4	8.2
Low-flow fixtures	1.6	2.1	2.3
ENERGY STAR clothes washers	2.7	2.7	2.7
ENERGY STAR dishwashers	2.0	2.0	2.0
DWHR	3.4	4.1	4.0
All of the above	**14.7**	**17.4**	**18.2**

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% Hot Water Gallons per Day Savings

% Gallons per Day of Hot Water Savings (% gpd)			
Improvement	**Miami**	**San Fran**	**Duluth**
50% piping length	7.7%	8.1%	8.3%
R-3 piping insulation	1.5%	1.6%	1.7%
Recirc. (man) + R-3 pipe	14.5%	15.1%	15.4%
Low-flow fixtures	4.0%	4.3%	4.3%
ENERGY STAR clothes washers	6.7%	5.5%	5.1%
ENERGY STAR dishwashers	5.0%	4.1%	3.8%
DWHR	8.5%	8.4%	7.5%
All of the above	**36.7%**	**35.4%**	**34.1%**

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Hot Water Therm Savings per Year

Therms of Hot Water Savings per Year			
Improvement	**Miami**	**San Fran**	**Duluth**
50% piping length	13	22	29
R-3 piping insulation	3	5	7
Recirc. (man) + R-3 pipe	17	30	41
Low-flow fixtures	2	5	7
ENERGY STAR clothes washers	4	6	9
ENERGY STAR dishwashers	4	5	6
DWHR	12	29	44
All of the above	**36**	**66**	**92**

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% Hot Water Therm Savings per Year

% Hot Water Therm Savings per year			
Improvement	**Miami**	**San Fran**	**Duluth**
50% piping length	12.0%	12.9%	13.4%
R-3 piping insulation	2.8%	2.9%	3.2%
Recirc. (man) + R-3 pipe	15.7%	17.6%	18.9
Low-flow fixtures	1.9%	2.9%	3.2%
ENERGY STAR clothes washers	3.7%	3.5%	4.1%
ENERGY STAR dishwashers	2.8%	2.9%	2.8%
DWHR	11.1%	17.1%	20.3%
All of the above	**33.3%**	**38.8%**	**42.4%**

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HERS Rating Outcomes

Estimated HERS Index Change			
Improvement	**Miami**	**San Fran**	**Duluth**
50% piping length	-0.6	-2.2	-1.6
R-3 piping insulation	-0.1	-0.5	-0.4
Recirc. (man) + R-3 pipe	-0.8	-3.0	-2.3
Low-flow fixtures	-0.1	-0.5	-0.4
ENERGY STAR clothes washers	-0.4	-0.7	-0.5
ENERGY STAR dishwashers	-0.3	-0.7	-0.5
DWHR	-0.6	-2.9	-2.5
All of the above	**-2.0**	**-6.9**	**-5.3**

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Hot Water Recirculation Systems

- Hot water recirculation systems do reduce hot water use
- However, . . . energy consumption in hot water recirculation systems is heavily influenced by the recirculation loop control strategy
  - No control (loop charged 24/7) results in very significant pump energy uses and recirculation loop heat losses
  - Temperature control results in significant but less severe pump energy uses and recirculation loop heat losses
  - Sensor demand control results in much reduced recirculation loop energy losses and modest overall energy savings (principally due to hot water use reductions)
  - Manual demand control results in small recirculation loop losses and moderate overall energy savings

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Recirculation System H_2O Savings

H_2O Savings are independent of control method

Recirculation System Hot Water Savings (gpd)*			
System Controls	**Miami**	**San Fran**	**Duluth**
None/timer	5.8	7.4	8.2
Temperature	5.8	7.4	8.2
Demand (sensor)	5.8	7.4	8.2
Demand (manual)	5.8	7.4	8.2

* Including code-required R-3 piping insulation

Recirculation System Therm Savings

Significant dependence on control method

Recirculation System Therm Savings (R-3 piping)			
System Controls	**Miami**	**San Fran**	**Duluth**
None/timer	-75	-112	-138
Temperature	-49	-72	-88
Demand (sensor)	11	21	29
Demand (manual)	17	30	41

% Recirculation System Therm Savings

Significant dependence on control method

% Recirculation System Therm Savings (R-3 piping)			
System Controls	**Miami**	**San Fran**	**Duluth**
None/timer	-69.4%	-65.9%	-63.6%
Temperature	-45.4%	-42.4%	-40.6%
Demand (sensor)	10.2%	12.4%	13.4%
Demand (manual)	15.7%	18.8%	18.9%

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Recirculation System HERS Outcomes

Significant dependence on control method

Estimated HERS Index Change (R-3 piping)			
System Controls	**Miami**	**San Fran**	**Duluth**
None/timer	3.7	12.1	8.2
Temperature	2.2	7.4	5.0
Demand (sensor)	-0.5	-2.1	-1.6
Demand (manual)	-0.8	-3.0	-2.3

DWHR IDR

- Drain Water Heat Recovery (DWHR) system Innovative Design Request (IDR)
  - Approved by SDC 300 and RESNET Standards Management Board (SMB)
  - http://www.resnet.us/professional/standards/innovative_design_requests
- Spreadsheet application that can be used to credit DWHR systems until ANSI/RESNET/ICC 301-2014 Addendum A becomes required in accredited software (July 1, 2016).

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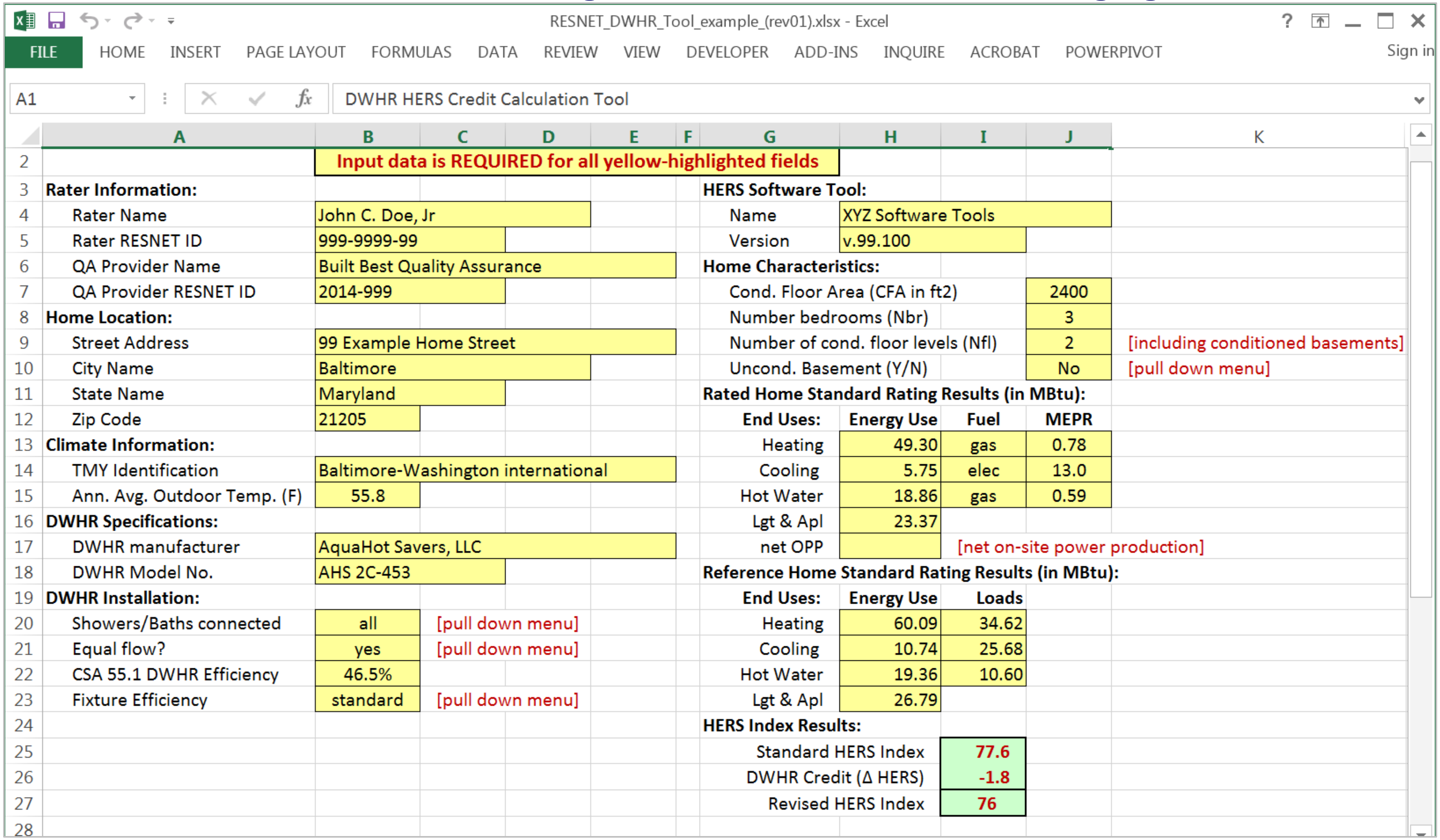
DWHR Spreadsheet App



	A	B	C–E	G	H	I	J	K
2		Input data is REQUIRED for all yellow-highlighted fields						
3	**Rater Information:**			**HERS Software Tool:**				
4	Rater Name	John C. Doe, Jr		Name	XYZ Software Tools			
5	Rater RESNET ID	999-9999-99		Version	v.99.100			
6	QA Provider Name	Built Best Quality Assurance		**Home Characteristics:**				
7	QA Provider RESNET ID	2014-999		Cond. Floor Area (CFA in ft2)			2400	
8	**Home Location:**			Number bedrooms (Nbr)			3	
9	Street Address	99 Example Home Street		Number of cond. floor levels (Nfl)			2	[including conditioned basements]
10	City Name	Baltimore		Uncond. Basement (Y/N)			No	[pull down menu]
11	State Name	Maryland		**Rated Home Standard Rating Results (in MBtu):**				
12	Zip Code	21205		**End Uses:**	**Energy Use**	**Fuel**	**MEPR**	
13	**Climate Information:**			Heating	49.30	gas	0.78	
14	TMY Identification	Baltimore-Washington international		Cooling	5.75	elec	13.0	
15	Ann. Avg. Outdoor Temp. (F)	55.8		Hot Water	18.86	gas	0.59	
16	**DWHR Specifications:**			Lgt & Apl	23.37			
17	DWHR manufacturer	AquaHot Savers, LLC		net OPP		[net on-site power production]		
18	DWHR Model No.	AHS 2C-453		**Reference Home Standard Rating Results (in MBtu):**				
19	**DWHR Installation:**			**End Uses:**	**Energy Use**	**Loads**		
20	Showers/Baths connected	all	[pull down menu]	Heating	60.09	34.62		
21	Equal flow?	yes	[pull down menu]	Cooling	10.74	25.68		
22	CSA 55.1 DWHR Efficiency	46.5%		Hot Water	19.36	10.60		
23	Fixture Efficiency	standard	[pull down menu]	Lgt & Apl	26.79			
24				**HERS Index Results:**				
25				Standard HERS Index		77.6		
26				DWHR Credit (Δ HERS)		-1.8		
27				Revised HERS Index		76		
28								

DWHR HERS Credit Report

DWHR HERS Credit Calculation Output Report

Home Address:
99 Example Home Street
Baltimore, Maryland
21205

Certified Rater:
Name: John C. Doe, Jr
ID: 999-9999-99

DWHR Specifications:
Manufacturer: AquaHot Savers, LLC
Model No: AHS 2C-453

DWHR Installation:

Showers/Baths connected	all
Equal Flow?	yes
DWHR Efficiency	46.5%
Fixture Efficiency	standard

Rated Home Standard Rating Results:

Home End Use	Energy (MBtu)	Fuel Type	MEPR
Heating	49.30	gas	0.78
Cooling	5.75	elec	13.0
Hot Water	18.86	gas	0.59
Lgt & Apl	23.37	n/a	n/a
net OPP	0.00		

DWHR Energy Savings:

Hot water energy savings	21.1%
Whole home energy saving	3.3%

HERS Credit Calculation Results:

Standard HERS Index score	77.6
DWHR HERS Index credit	-1.8
Revised HERS Index score	**76**

TMY Location:
Baltimore-Washington international
Annual Average Outdoor Temperature
55.8 F

RESNET QA Provider:
Name: Built Best Quality Assurance
ID: 2014-999

HERS Software Tool:
Name: XYZ Software Tools
Version: v.99.100

Rated Home Characteristics:

Conditioned Floor Area	2400
Number of Bedrooms	3
Conditioned Floor Levels	2
Unconditioned Basement	No

Reference Home Standard Rating Results:

Home End Use	Energy (MBtu)	Loads (MBtu)
Heating	60.09	34.62
Cooling	10.74	25.68
Hot Water	19.36	10.60
Lgt & Apl	26.79	26.79

Certification:
I hereby certifiy that the information submitted in this report is accurate to the best of my knowledge.

John C. Doe, Jr

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For Further Information

- Addendum A
  - http://www.resnet.us/blog/wp-content/uploads/2016/01/BSR_RESNET-301-2014-Addendum-A-2015-dated1-16-15.pdf
- Parker, et al. ASHRAE paper on hot water use in North American homes:
  - http://fsec.ucf.edu/en/publications/pdf/FSEC-PF-464-15.pdf

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quantity
occupant
homes
demographics
annual correlated explained
study
total
hot
data
daily
any
water
use
consumption
energy
heating
climate factors accounting findings estimate
actual climates distribution
evaluate
component
efficiency
estimating

Questions?