DEEMED SAVINGS TECHNICAL ASSUMPTIONS

Product: Water Heating - CO

Description:

Residential natural gas customers receive a cash rebate for purchasing high-efficiency natural gas water heating equipment. Residential electric customers with standard electric water heaters can receive a rebate for replacing it with a heat pump water heater.

Equations:

Hot_Water_Energy (Tank-type)	= Qty x Hot_Water_Demand x Water_Heater_Delta_T x Days_Per_Year x Water_Density x Proposed_Tank_Size / Std_Tank_Size
Hot_Water_Energy (Tankless)	= Qty x Hot_Water_Demand x Water_Heater_Delta_T x Days_Per_Year x Water_Density
Water_Heater_Delta_T	= Water_Heater_Temperature - City_Mains_Temperature

Gas Equations:

Customer_Dth	= Baseline_Dth - Proposed_Dth
Baseline_Dth	= Hot_Water_Energy / Baseline_Eff_Gas / 1,000,000
Proposed_Dth	= Hot_Water_Energy / Proposed_Eff / 1,000,000
Baseline Efficiency Gas-Fired Storage WH	= coef1 - (coef2 x Proposed_Tank_Size)

Electric Equations:

Customer kWh	= Baseline_kWh - Proposed kWh + Cooling_Benefit_kWh + Heating_Penalty_kWh
Baseline_kWh	= HP_Hot_Water_Energy / Baseline_Eff_Electric / 3,412
Proposed_kWh	= HP_Hot_Water_Energy / Proposed_Eff / 3,412
Baseline_Eff_Electric	= coef1 - (coef2 x ~~Proposed_Tank_Size~~ HP_baseline_tank_size)
Customer kW	= ~~Baseline_kW - Proposed_kW~~ Baseline_kWh/8760 + Cooling_Benefit_kWh / Cooling_Hours - Proposed_kWh/8760
~~Baseline_kW~~	~~= Standard_Water_Heater_kW + Cooling_Benefit / Cooling_Hours~~
~~Proposed_kW~~	~~= Standard_Water_Heater_kW - (Baseline_kWh - Proposed_kWh) / 8760~~
Customer_PCkW	= Customer_kW x Coincidence_Factor
HP_Hot_Water_Energy	= Qty x HP_Hot_Water_Demand x Water_Heater_Delta_T x Days_Per_Year x Water_Density
Heating_Penalty_kWh	= -1 * (HP_Hot_Water_Energy / Proposed_Eff) / Heating_Eff * Heating Hours / 8760 / 3,412
Heating_Penalty_Dth	= -1 * (HP_Hot_Water_Energy / Proposed_Eff) / Heating_Eff * Heating Hours / 8760 / 1,000,000
Cooling_Benefit_kWh	= (HP_Hot_Water_Energy / Proposed_Eff) / (Cooling_SEER * 1000 / 3,412) * Cooling_Hours / 8760 / 3,412
Heat Penalty Energy O&M	= Heating_Penalty_Dth * Heating Energy O&M Rate

DEEMED SAVINGS TECHNICAL ASSUMPTIONS

Variable ID	Value	Description
Hot_Water_Demand	64.3	Average gallons per day of hot water use. (Reference 1)
HP_Hot_Water_Demand	See Table 6	Average gallons per day for Heat Pump Water Heater hot water use. (Reference 13)
Water_Heater_Temperature	135	Water heater setpoint temperature °F. (Reference 1)
City_Mains_Temperature	51.4	Water temperature of city water entering the water heater °F. (Reference 2)
Conversion from Btu to Dth	1,000,000	1 Dth = 1,000,000 Btuh
Conversion from Btu to Therm	100,000	1 Therm = 100,000 Btuh
Conversion from Btu to kWh	3,412	1 kWh = 3,412 Btuh
Specific Heat of Water	1	Btu/lb/°F
Water_Density	~~8.33~~ 8.34	lb/gal H20
Conversion from kW to Watts	1,000	1 kW = 1,000 Watts
Days_Per_Year	365	Days per Year
Standard_Water_Heater_kW	~~4.5~~ See Table 5	Assumed kW for a typical electric resistance water heater.
Quantity_Baseline_ERWH	See Table 5	Quantity of Baseline Electric Resistance Water Heaters at the allowable baseline tank size to meet required first hour draw requirements. The quantity and the ERWH baseline kW are used together to set the total baseline kW.
Cooling_Hours	957	Number of hours in a TMY3 year above the cooling enable temp of 77°F.
Hours per Year	8760	total hours in a year
Heating Hours	6154	Hours in the year at or below the heating enable temp of 62 F
Coincidence_Factor	100%	We are using the average water heater savings over the summer hours.
Coeff1	See Table 4	Code based forumula for calculation of Baseline efficiency based on water heater type and draw pattern provided by customer
Coeff2	See Table 4	Code based forumula for calculation of Baseline efficiency based on water heater type and draw pattern provided by customer
HP_baseline_tank_size	See Table 5	Baseline Electric Resistance Water Heater tank size based on ability to deliver required first hour draw requirements. The tank size is used to calculate the baseline unit efficiency along with the determined draw pattern required for the number of bedrooms in the home.
Heating_Eff	78%	Gas heating system efficiency in homes with gas fired heat for calculating HPWH O&M heating penalty
Air Source Heat Pump Heating System Efficiency	8.20	Heating efficiency in HSPF for homes with ASHP heating systems for calculating HPWH heating penalty. Answer provided in kWh.
Electric Resistance Heating Efficiency	100%	Heating efficiency for homes with electric resistance heat. Used in calculating the HPWH heating penalty in kWh.
Cooling_SEER	13.0	Cooling System Efficiency (SEER) of the typical home with refrigerated DX cooling systems for calculating HPWH O&M Cooling benefits
Heating Energy O&M Rate	6.09	Cost per Dtherm for gas heating penalty due to Heat Pump Water Heater opearting during heating season. (Assumed Energy Cost provided at the time of this filing).
Proposed_Tank_Size	Customer Input	DOE Rated Storage Volume ~~capacity~~ for tank type water heaters.
Type of Proposed Water Heater	Customer Input	Type of proposed water heater. (i.e. Storage, Tankless, Heat Pump)
Home Heating and Cooling Type for HP Water Heaters	Customer Input	Source for the home's heating and cooling. See Table 1.
Proposed_Eff	Customer Input	Uniform Efficiency Factor for proposed water heater.
Water Heater Draw Pattern	Customer Input	Manufacturer's rated draw pattern for proposed water heater.
Qty	Customer Input	Equipment Quantity
Measure Life	See Table 2	Lifetime of water heaters. (Reference 3)

Incremental Costs	See Table 2	Incremental cost of efficient technology over baseline technology.
NTG	See Table 2	Net to Gross
~~coef1~~	~~See Table 3~~	~~Code-based formula coefficients to determine baseline energy use~~
~~coef2~~	~~See Table 3~~	~~Code-based formula coefficients to determine baseline energy use~~
Std_Tank_Size	45.0	Reference tank volume storage capacity based on historical program participation.
Water Heater Self-Installation Rate	52%	Percent of Water Heaters that self-installed after retail purchase (Reference 9)

~~Table 1 - Secondary Cooling and Heating Benefits (References 6, 7)~~

~~Heating Type~~	~~Cooling Type~~	~~Cooling_Benefit kWh~~	~~Heating_Penalty kWh~~	~~O&M $~~
~~Natural Gas~~	~~Refrigerant Based~~	~~89.3~~	~~0~~	~~$ (42.44)~~
~~Electric Resistance~~	~~Refrigerant Based~~	~~89.3~~	~~1,593~~	~~$ -~~
~~Heat Pump~~	~~Refrigerant Based~~	~~89.3~~	~~706~~	~~$ -~~
~~Natural Gas~~	~~Non-Refrigerant Based~~	~~0.0~~	~~0~~	~~$ (42.44)~~
~~Electric Resistance~~	~~Non-Refrigerant Based~~	~~0.0~~	~~1,593~~	~~$ -~~
~~Heat Pump~~	~~Non-Refrigerant Based~~	~~0.0~~	~~706~~	~~$ -~~

Table 2 - Incremental Cost, Lifetime, NTG - References 3, 10, 11

Water Heater Type	Size	Draw Pattern	Baseline Cost	Incremental Cost	Lifetime	NTG
High Efficiency Tank-Type Water Heater	Volume <= 40 Gallon	MEDIUM	$ 906.99	$ 142.42	13	90%
High Efficiency Tank-Type Water Heater	Volume <= 40 Gallon	HIGH	$ 833.02	$ 260.86	13	90%
High Efficiency Tank-Type Water Heater	Volume > 40 Gallon	MEDIUM	$ 714.09	$ 119.30	13	90%
High Efficiency Tank-Type Water Heater	Volume > 40 Gallon	HIGH	$ 958.42	$ 382.64	13	90%
High Efficiency Tankless Water Heater	N/A	MEDIUM	$ 975.06	$ 783.49	20	90%
High Efficiency Tankless Water Heater	N/A	HIGH	$ 1,071.37	$ 860.63	20	90%
Air Source Heat Pump Water Heater	N/A	NA	$ 958.62	$ 611.45	12	100%

~~Table 3 - Baseline Efficiency Coefficients Reference 8 (>= 20gal & <= 55 gal)~~

~~Draw Pattern~~	~~Gas (Storage)~~		~~Elec (Storage)~~	
	~~coef1~~	~~coef2~~	~~coef1~~	~~coef2~~
~~Medium~~	~~0.6483~~	~~0.0017~~	~~0.9307~~	~~0.0002~~
~~High~~	~~0.6920~~	~~0.0013~~	~~0.9349~~	~~0.0001~~

Table 4 Gas Fired Storage Water Heater and Heat Pump Water Heater Baseline Efficiency Calculation Parameters (Reference 8)

	First Hour Rating to Define Draw Pattern		Electric Storage Water Heater >=20 Gallon and <=55 Gallon Baseline Efficiency Coefficients		Gas Storage Water Heater ≥20 gal and ≤55 gal Baseline Efficiency Coefficients	
Draw Pattern	min (>=Gallons)	max (< Gallons)	coef1	coef2	coef1	coef2
Very Small	1	18	0.8808	0.0008	0.3456	0.0020
Low	18	51	0.9254	0.0003	0.5982	0.0019
Medium	51	75	0.9307	0.0002	0.6483	0.0017
High	75	No Upper Limit	0.9349	0.0001	0.6920	0.0013

Table 5: 2019 ASHRAE HVAC Applications Chapter 51 Service Water Heating: "Table 4 HUD-FHA Minimum Water Heater Capacities for One- and Two-Family Living Units (Reference 12)"

Water Heater Type \ Number of BEDROOMS:	1	2	3	4	5	6
Baseline Quantity Electric Storage Tanks	1	1	1	2	2	2
Baseline Tank Volume Electric Storage Tanks	30	40	55	30	30	40
Baseline Wattage per Electric Storage Tank	3.8	4.5	4.5	4.5	4.5	4.5

Table 6 Water Usage per Day by Number of Bedrooms (Reference 13)

Home Type \ Number of BEDROOMS:	1	2	3	4	5	6
Single Family total HW usage per day	34	48	60	72	84	96
Multi-Family total HW usage per day	41	53	63	73	83	92

References:

1. Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters; United States Department of Energy; http://www.gpo.gov/fdsys/pkg/FR-1998-05-11/pdf/98-12296.pdf

2. Denver Water's 2006 Treated Water Quality Summary Report;
http://www.denverwater.org/docs/assets/9A12FBC5-BCDF-1B42-D1BC5F0B1CE3B115/TreatedWQSummaryReport20061.pdf
3. Energy Star Residential Water Heaters -Final Criterial Analysis, April 2008.
http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/WaterHeaterAnalysis_Final.pdf
4. Not Used
5. US Department of Energy; Residential Heat Pump Water Heaters;
http://energy.gov/eere/femp/covered-product-category-residential-heat-pump-water-heaters
6. US Department of Energy; Residential Air Conditioners and Heat Pumps; http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75
7. US Department of Energy; Residential Furnace Standards. https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/72#standards
8.US Department of Energy, Residental Water Heater Standards 10 CFR 430.32(d):
https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8
9. EnergyStar - http://aceee.org/sites/default/files/files/pdf/conferences/hwf/2016/Ryan_Session1C_HWF16_2.22.16_0.pdf
10. Equipment Manufacturer Retail Price Information Request (Q4 - 2017)
11. NREL - National Residential Efficiency Measure Database, https://remdb.nrel.gov/measures.php?gId=6&ctId=270
12. 2019 ASHRAE HVAC Applications manual Chapter 51 Service Water Heating

13 Florida Solar Energy Center paper "Estimating Daily Domestic Hot Water Use in North American Homes. https://fsec.ucf.edu/en/publications/pdf/FSEC-PF-464-15.pdf Table 5 on Page 11.