18.5 Residential Furnaces & Boilers

Algorithms

$$Customer\ DTh = Qty\_Prop\_Equip * \left(\left(Size_{Heat} \times \frac{EFF_{proposed}}{EFF_{baseline}}\right) - Size_{Heat}\right) \times 1/(1 + Oversize\ Factor) \times (1 - Altitude\ Factor) \times \frac{EFLH_{heating}}{1{,}000{,}000}$$

Variables

EFLH Heating	See Table 18.0.1	Equivalent Full Load Heating Hours assumed for installed high efficiency furnace and boiler equipment
Incremental Cost	See Table 18.5.1	Incremental costs of efficient equipment
Baseline Efficiency	See Table 18.5.2	Efficiency of baseline code minimum boiler (Reference 10) or furnace (Reference 1) Efficiency of Existing Equipment receiving Tune-up.
Proposed Efficiency	See Table 18.5.2	Proposed Efficiency of existing equipment after Tune-up.
Altitude_Factor	See Table 18.0.1	Deemed Altitude adjustment factor for derating sea level rated equipment (4% / 1000 Feet above sea level)
Boiler Oversize Factor	25%	Deemed Oversize Safety Factor for all new boiler heating equipment and all Income Qualified Single Family Weatherization Boiler Tune-up products
Furnace Oversize Factor	20%	Deemed Oversize Safety Factor for all new furnace heating equipment and all Income Qualified Single Family Weatherization Furnace Tune-up products
Lifetime	See Table 18.5.1	
Conversion from Btu to Dth	1,000,000	1 Dth = 1,000,000 Btuh
Conversion from Btu to Therms	100,000	1 Therm = 100,000 Btuh

Customer Inputs	**M&V Verified**	
Qty Prop Equip	Yes	Quantity of units of the same size
$Size\_Heat$	Yes	For new furnace or boiler AHRI rated Input BTUH. Provide data on customer rebate form. For Tune-up Measure on existing furnace or boiler Nameplate Input BTUH rating for existing equipment getting the tune-up measure. Provided data on customer rebate form.
Proposed Efficiency	Yes	AHRI rated efficiency of the proposed new equipment.
County	Yes	County where the new equipment is installed or Tune-up is being performed.

Table 18.5.1	**Measure Life (Reference 2)**	**Incremental Cost (Reference 4 for Furnaces, IQ Boilers and Tune-ups) (Reference 7 for all other High Efficiency Boilers)**
High Efficiency Furnace	18	$1,138.00
IQ-SFW Boiler	20	$1,446.00
IQ-SFW Boiler/Furnace Tune-up	2	$250.00
~~High Efficiency Boiler 90%~~	~~20~~	~~$817.48~~
High Efficiency Boiler 95%	20	$1,330.61

Table 18.5.2	Baseline EFF	Proposed EFF	Lifetime
High Efficiency Furnace	80%	Customer Input	18
High Efficiency Boiler	84%	Customer Input	20
IQ SFW - Furnace Tune-up	75%	80%	2
IQ SFW - Boiler Tune-up	75%	80%	2

References:

1. US Department of Energy; Residential Furnaces and Boilers; http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/72
2. 2015 ASHRAE Handbook - HVAC Applications; Comparison of Service Life Estimates; Page 37.3, Table 4
3. ECM Furnace Impact Assessment Report https://focusonenergy.com/sites/default/files/emcfurnaceimpactassessment_evaluationreport.pdf
4. Xcel program data from 2017 program year
5. Cost information from "2010 - 2012 W0017 Ex Ante Measure Cost Study Final Report.", Itron, May 2014.
6. DOE incremental cost for EC motors https://www.regulations.gov/document?D=EERE-2010-BT-STD-0011-0117
7. Xcel Minnesota Program Cost Data

Changes from Recent Filing:

1. Updated format of the deemed sheet to be able to reference the variables in the rest of the document
2. Changed Reference 2 to be IECC 2015 because ASHRAE 2015 does not exist
3. Updated costs for EC motors
4. Updated Program data to include the furnaces rebated in 2017
5. Split climate zone 3 into two climate zones to better represent the very high altitude mountain communities
6. added high efficiency boilers.

18.13 Residential Cold Climate Air Source Heat Pumps

Algorithms

$$Customer\ kW\ Savings = Customer\ kW_{EqCooling} + Customer\ kW_{QICooling}$$

$$Customer\ Coincident\ kW\ Savings = Customer\ Coincident\ kW_{Equipment} + Customer\ Coincident\ kW_{QI}$$

ASHP Baseline Cooling Only:

$$Customer\ kWh\ Savings = Customer\ kWh_{EqCooling} + Customer\ kWh_{QICooling}$$

Electric Resistance Heat Baseline:

$$Customer\ kWh\ Savings = Customer\ kWh_{EqCooling} + Customer\ kWh_{QICooling} + Customer\ kWh_{EQHeating} + Customer\ kWh_{QIHeating}$$

Dual Fuel Gas Heat Baseline

Customer kWh Savings = Customer kWh$_{EqCooling}$ + Customer kWh$_{QICooling}$ + Customer kWh_Heating Penalty

Customer Dtherm Savings = Customer DTherms_EQ Heating + Customer DTherm_QI Heating

$$EER_{baseline} = iCoef0 * (SEER^2_{baaseline}) + iCoef1 * SEER_{baseline}$$

$$Customer\ kW_{EqCooling} = Qty_{prop} \times \frac{\frac{Full\ Load\ Cool}{12{,}000}}{(1 - Sizing\ Loss)} \times \left(\left(\frac{12}{EER_{baseline}}\right) - \left(\frac{12}{EER_{proposed}}\right)\right)$$

$$Customer\ kW_{QICooling} = Qty\_Prop * \frac{Full\ Load\ Cool}{12{,}000} * 12/(EER\_proposed) * ((\frac{1}{1 - Loss_{NoQI}}) - \left(\frac{1}{1 - Loss_{Uncorr}}\right))$$

$$Customer\ kWh_{EqCooling} = Qty_{Prop} * \frac{\left(\frac{Full\ Load\ Cool}{12{,}000}\right)}{1 - Sizing\ Loss} * EFLH_{cooling} * ((\frac{12}{SEER_{baseline}}) - \left(\frac{12}{SEER_{proposed}}\right))$$

$$Customer\ kWh_{QICooling} = Qty_{Prop} * \frac{Full\_Load\_Cool}{12{,}000} * EFLH_{cooling} * \frac{12}{SEER_{proposed}} * ((\frac{1}{1 - Loss_{NoQI}}) - \left(\frac{1}{1 - Loss_{Uncorr}}\right))$$

$$Customer\ Coincident\ kW_{equipment} = Qty_{Prop} * Coincidence\ Factor * \frac{Full\ Load\ Cool}{12{,}000} * \frac{1}{1 - Sizing\ Loss} * (\left(\frac{12}{EER_{baseline}}\right) - \left(\frac{12}{EER_{Proposed}}\right))$$

$$Customer\ Coincident\ kW_{QI} = Qty_{Prop} * Coincidence\ Factor * \frac{12}{EER_{Cooling}} * \frac{Full\ Load\ Cool}{12{,}000} * ((\frac{1}{1 - Loss_{NoQI}}) - \left(\frac{1}{1 - Loss_{Uncorr}}\right))$$

$$Incremental\ Capital\ Cost_{Equipment} = ASHP\ Cost\ per\ Ton_{EQ} * \frac{\cancel{Size\_Heat\_}Size\_Heat\_47}{12{,}000} - \text{Cost Per Ton Baseline} * \frac{Size\_Cool}{12{,}000}$$

$$Incremental\ Capital\ Cost_{QI}\ New\ Home = Inc\ Cost_{QI}$$

$$Incremental\ Capital\ Cost_{QI}\ E\ Home = MAX(75, Inc\ Cost_{QI} - \frac{\cancel{Size\_Heat\_}Size\_Heat\_47}{12{,}000} * (\left(\frac{1}{1 - Sizing\ Loss}\right) - 1) * Cost\ per\ Ton_{baseline}))$$

ccASHP Heating Energy Savings

*Load_Heat = -1 * Size_Heat * 1/(1 + Oversize_Factor)*

m_load_profile = (balance pt load - Load_Heat) / (balance pt temp - Des_OAT)

*b_load_profile = Load_Heat - (m_load_profile * Des_OAT)*

*Full Load Cool = m_load_profile * Max_OAT + b_load_profile*

*Full_Load_Heat = m_load_profile * Min_OAT + b_load_profile*

Electric Resistance Heat Baseline:

*Customer kWh$_{EQHeating}$ = -1 * Full_Load_Heat * EFLH_Heating_HP * (1 / (HSPF_Baseline * HSPF_Adj_Factor) - 1 / (HSPF_Proposed * HSPF_Adj_Factor)) / 1000*

*Customer kWh$_{QIHeating}$ = -1 * Full_Load_Heat * EFLH_Heating_HP * 1 / (HSPF_Proposed * HSPF_Adj_Factor) * (1 / (1- loss_No_QI) - 1/Loss_uncorr) / 1000*

Dual Fuel Gas Heat Baseline

*Customer DTherms_EQ Saved = (-1 * Full_Load_Heat * EFLH_Heating_HP) / Furnace_Eff / 1,000,000*

*Customer kWh_Heating Penalty = Furnace_Fan_kW * EFLH_Heating_HP - Full_Load_Heat * EFLH_cc_HP_Heat * (0 - (1 / (HPSF_Proposed*HSPF_Adj_Factor))) / 1000*

*Customer DTherms_QI = Full_Load_Heat * (EFLH_Heat - EFLH_cc_HP_Heat) / Furnace_Eff * (1 / (1 - Loss_DuctLeakage) - 1 / (1 - Uncorr_Loss)) / 1,000,000*

Variables

$ASHP\ Cost\ per\ Ton\_EQ$	See Table 18.13.1	Capital Cost per Ton of new ccASHP.
$Cost\ per\ Ton\_baseline$	See Table 18.13.1	Baseline capital cost per ton for new AC equipment.
EER baseline	See Table 18.0.3	Baseline EER as calculated for residential equipment from the code required SEER.
SEER baseline	See Table 18.0.3	IECC 2012 identified code minimum SEER
Sizing Loss	See Table 18.0.4	
$Loss\_NoQI$	See Table 18.0.4	
$Loss\_Uncorr$	See Table 18.0.4	
$Inc\ Cost\_QI$	See Table 18.0.4	
Coincidence Factor_EQ	See Table 18.0.3	
Coincidence Factor_QI	See Table 18.0.3	
$iCoef0$	-0.02	coefficient used in polynomial conversion for AC or ASHP EER derived from known SEER.
$iCoef1$	1.12	coefficient used in polynomial conversion for AC or ASHP EER derived from known SEER.
Oversize_Factor__c	20%	Deemed Oversize Safety Factor for heating equipment.
EFLH cooling	See Table 18.0.1	Effective Full Load Hours for cooling load energy savings
EFLH_Heat	See Table 18.0.1	Effective Full Load Hours for heating load QI energy savings
EFLH_ccHP_Heat	See Table 18.0.1	Effective Full Load Hours for Cold Climate Heat Pump at and above cutoff temperature
Balance Pt Temp	See Table 18.0.6	Outdoor Ambient Temperature at which residential cooling and heating loads are zero BTUH
Max_OAT	See Table 18.0.6	Maximum Outdoor Ambient Temperature used in building load profile
Min_OAT	See Table 18.0.6	Minimum Outdoor Ambient Temperature used in building load profile
Des OAT	5	Low Outdoor Ambient Temperature for caluclating heating load Profile. Based on Low Temp Rating from NEEP QPL Data Sheets. Deemed to be 5 F.
Electric Resistance Heat HSPF	3.412	Electric resistance heat assumed heating season performance factor based on a COP of 1. no climate zone correction required.
Balance Pt Load	See Table 18.0.6	Heating and cooling loads are zero at the balance point outdoor ambient temperature
Furnace_Fan_kW	0.357	Furnace Fan EC Motor kW demand for baseline energy calculations for ASHP.
ASHP operating temperature cutoff	5	Outdoor Ambient Temperature below which heat pump operation ceases and gas furnace or electric resistance backup heating begins.
Furnace Eff	95%	This is the assumed furnace efficiency for the backup gas fired heat (Baseline Heat Type equals Gas Furnace) in a dual fuel ASHP system application.
HSPF_Adj_Factor	See Table 18.0.1	Adjustment factor for correcting HSPF from published data in AHRI's Climate Zone IV to AHRI's Climate Zone V. The HSPF_Adjustment_Factor for Electric Resistance Heat will be 1.
HSPF_Basline	See Table 18.0.3	Heating season performance factor of baseline equipment. For electric resistance heat baseline, a COP of 1 is assumed with no climate zone correction required.
NTG	100.0%	Net-to-gross for ccASHP units
Measure Life - Matched Split-System Air -Source Heat Pump	See Table 18.0.3	Reference 16
Measure Life - Quality Installation	18	Reference 16
Conversion Factors	See Table 18.0.5	

Customer Inputs	**M&V Verified**	
Size_Cool	Yes	NEEP QPL Data Sheet Rated Cooling Capacity at 95 F
Size_Heat_5	Yes	NEEP QPL Data Sheet Max Heating Capacity at 5 F
Size_Heat_47	Yes	NEEP QPL Data Sheet Rated Heating Capacity at 47 F
EER proposed	Yes	NEEP QPL Data Sheet rated full load Cooling Efficiency
SEER proposed	Yes	NEEP QPL Data Sheet rated part load Cooling Efficiency
HSPF Proposed	Yes	NEEP QPL Data Sheet rated Heating HSPF
Home Type	Yes	Single Family or Multi-Family home
County	Yes	Location of the home for determining weather zones.
Baseline Heat Type	Yes	baseline heating type; gas furnace or electric resistance backup heat
Home Category	Yes	New Home or Existing Home

Table 18.13.1. Incremental Capital Costs - New Construction (Plan A) - Reference 6

SEER	ASHP Cost per Ton	ccASHP Incremental Cost per Ton (compared to Res AC at 14 SEER)	Baseline Cost per Ton (Res AC)
13 SEER	N/A	N/A	N/A
14/14.5 SEER	$ 777.64	N/A	$ 514.98
15 SEER	$ 960.40	$ 445.42	N/A
16 SEER	$ 1,143.16	$ 628.18	N/A
17/18+ SEER	$ 1,325.93	$ 810.95	N/A

DEEMED SAVINGS TECHNICAL ASSUMPTIONS

References:

1. Building America, Research Benchmark Definitions, 2010. (see p. 10) http://www.nrel.gov/docs/fy10osti/47246.pdf
2. ASHRAE, 2019, Applications Handbook, Ch. 38, table 4, Comparison of Service Life Estimates
3. DOE Appliance Standards Website, Residential Central Air Conditioners and Heat Pumps. https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75
4. Neme, Proctor, Nadel, ACEEE, 1999. Energy Savings Potential From Addressing Residential Air Conditioner and Heat Pump Installation Problems, http://aceee.org/research-report/a992
5. State of Minnesota Technical reference Manual For Energy Conservation Improvement Programs, Version 3.1 https://mn.gov/commerce/industries/energy/utilities/cip/technical-
6 ENERGY STAR Quality Installation standards (ESVI). https://www.energystar.gov/index.cfm?c=hvac_install.hvac_install_index
7. NREL 2011 Measure Guideline Sealing and Insulating Ducts in Existing Homes. http://www.nrel.gov/docs/fy12osti/53494.pdf
8. State of Illinois Technical Reference Manual Version 8, dated 2020
9. For explanation of duct sealing requirements for new homes see "Significant Changes to the 2015 Minnesota Residential Codes (MR 1303, 1309 and 1322)". http://www.ci.minneapolis.mn.us/www/groups/public/@regservices/documents/webcontent/wcms1p-142763.pdf
10. Incremental costs for MSHPs were determined from the NEEP Incremental Cost Study Phase 2 Report
11. MSHP equipment life is from Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures; http://library.cee1.org/content/measure-life-report-residential-and-commercialindustrial-lighting-and-hvac-measures
12. For estimated life of GSHP see http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12640 (indoor components up to 25 years; ground loop =50 years)
13. Costs obtained from "2010-2012 WO017 Ex Ante Measure Cost Study Final Report", by Itron, May 2014. These are used in the DEER 2016 database.
14.For assumptions on losses related to overcharge or undercharge on refrigerant see "Sensitivity Analysis of Installation Faults on Heat Pump Performance", by P. Domanski, et. al., Sept 2014, http://www.acca.org/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=f02c1f61-4d1d-4a24-971d-cc9ea3e626b2&forceDialog=0
15. ENERGY STAR Connected Thermostat Key Product Criteria, Version 1.0, Rev. Jan 2017 -
16. Code of Federal Regulations Title 10: Energy PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS Subpart C—Energy and Water
17: "Measure Life Report - Residential and Commercial/Industrial Lighting and HVAC Measures", dated June 2007 for The New England State Program Working Group prepared
18. Assumptions on EC fan operating modes. Center for Energy and Environment Comments to Docket Number EERE-2010-BT-STD-0011-0022, July 27, 2010
19. ECM Furnace Impact Assessment Report https://focusonenergy.com/sites/default/files/emcfurnaceimpactassessment_evaluationreport.pdf
20. Xcel Energy, January 2019. Typical MN Residential Smart Switch Load Relief 2011-2015.
21. Xcel Energy, January 2019. Saver's Switch Control History.
22. Xcel Energy. January 2006. Residential Saver's Switch 2005 Impact Evaluation.
23. http://wpb-radon.com/radon_fan_performance.html33:5032:50A33:50
24. Information from manufacturer and contractors (Radonaway)
25. https://www.radonaway.com/products/radon-fans/rp140-pro.php
26. Energy Information Administration's (EIA) 2009 Residential Energy Consumption Survey (RECS)
27. Bin analysis using RECS data for thermostat operation and typical CO home cooling and heating conditions.

Changes from Recent Filing:

added dual fuel heating baseline
modified heating savings methodology to incorporate cut-off temperature for both dual fuel and electric resistance baselines
incorporated HSPF addjustments based on AHRI climate zones

18.14 Cold Climate Mini-Split Heat Pumps

Algorithms

$Customer\ kW\ Savings = Customer\ kW_{EqCooling}$

$Customer\ Coincident\ kW\ Savings = Customer\ Coincident\ kW_{Equipment}$

Electric Resistance Heat Baseline:

$Customer\ kWh\ Savings = Customer\ kWh_{EqCooling} + Customer\ kWh_{EQHeating}$

Dual Fuel Gas Heat Baseline:

$Customer\ kWh\ Savings = Customer\ kWh_{EqCooling} + Customer\ \ kWh\_Heating\ Penalty$

$Customer\ Dtherm\ Savings = Customer\ DTherms\_EQ\ Heating$

$$EER_{baseline} = (\ iCoef0\_c * (SEER\_Base\ /\ \frac{Size_{Cool}}{12{,}000})\ ^\wedge 3 + iCoef1\_c * (SEER\_Base\ /\ \frac{Size_{Cool}}{12{,}000})\ ^\wedge 2 + iCoef2\_c * (SEER\_Base\ /\ \frac{Size_{Cool}}{12{,}000}) + iCoef3\_c\ ) * (\frac{Size_{Cool}}{12{,}000})$$

$$Customer\ kW_{EqCooling} = Qty_{prop} * \frac{Full\_Load\_Cool}{12{,}000} * \left(\left(\frac{12}{EER_{baseline}}\right) - \left(\frac{12}{EER_{proposed}}\right)\right)$$

$$Customer\ kWh_{EqCooling} = Qty_{Prop} * \frac{Full\_Load\_Cool}{12{,}000} * EFLH_{cooling} * ((\frac{12}{SEER_{baseline}}) - \left(\frac{12}{SEER_{proposed}}\right))$$

$$Customer\ Coincident\ kW_{equipment} = Qty_{Prop} * Coincidence\ Factor * \frac{Full\_Load\_Cool}{12{,}000} * (\left(\frac{12}{EER_{baseline}}\right) - \left(\frac{12}{EER_{Proposed}}\right))$$

$$Incremental\ Capital\ Cost_{Equipment} = Qty_{Prop} * Inc\ Cost\ per\ Ton_{EQ} * \frac{\cancel{Size_{Cool}}Size\_Heat\_47}{12{,}000}$$

cc*MSHP Heating Energy Savings*

*Load_Heat = -1 * Size_Heat_5 * 1/(1 + Oversize_Factor)*

m_load_profile = (balance pt load - Load_Heat) / (balance pt temp - Des_OAT)

*b_load_profile = Load_Heat - (m_load_profile * Des_OAT)*

*Full Load Heat = m_load_profile * Min OAT + b_load_profile*

*Full Load Cool = m_load_profile * Max OAT + b_load_profile*

*HSPF_Baseline_Adj = HSPF_Baseline * HSPF_Adjustment_Factor*

*HSPF_Proposed_Adj = HSPF_Proposed * HSPF_Adjustment_Factor*

$Customer\ kWh_{EQHeating}$ *= Qty_{Prop} * (-1 * Full_Load_Heat * EFLH_ccHP_Heat * (1 / HSPF_Baseline_Adj - 1 / HSPF_Proposed_Adj) / 1000*

*Customer DTherms_EQ Saved = (-1 * Full_Load_Heat * EFLH_ccHP_Heat)/ Furnace_Eff / 1,000,000*

*Customer kWh_Heating Penalty = - 1 * Full_Load_Heat * EFLH_ccHP_Heat * (0 - (1 / (HPSF_Proposed*HSPF_Adj_Factor))) / 1000*

Variables

Inc Cost per Ton_EQ	See Table 18.4.2	Deemed Plan A Incremental Capital Cost per Ton, Based On Unit Efficiency (New Construction)
Cost per Ton_baseline	See Table 18.4.2	Baseline capital cost per ton for equipment
EER baseline	See Table 18.0.3	Baseline EER as calculated for residential equipment from the code required SEER.
SEER baseline	See Table 18.0.3	IECC 2012 identified code minimum SEER
HSPF_Baseline	See Table 18.0.3	Baseline heating season performance factor for code minimum MSHP. For Electric Resistance Heat Baseline the HSPF will be 3.412 based on a COP of 1 and does not require climate zone correction.
Coincidence Factor	See Table 18.0.3	
iCoef0	See Table 18.4.1	MSHP SEER to EER Conversion Coefficient
iCoef1	See Table 18.4.1	MSHP SEER to EER Conversion Coefficient
iCoef2	See Table 18.4.1	MSHP SEER to EER Conversion Coefficient
iCoef3	See Table 18.4.1	MSHP SEER to EER Conversion Coefficient
EFLH_Cooling	See Table 18.0.1	Effective Full Load Hours for cooling load energy savings
EFLH_Heating_HP	See Table 18.0.1	Effective Full Load Hours for Heat Pump impacted energy savings
EFLH_ccHP_Heat	See Table 18.0.1a	Effective Full Load Hours for Cold Climate Heat Pump impacted energy savings
ASHP / MSHP operating temperature cutoff	5	Outdoor Ambient Temperature below which heat pump operation ceases and electric resistance heating begins
Balance Pt Temp	See Table 18.0.6	Outdoor Ambient Temperature at which residential cooling and heating load profiles equal zero BTUH
Max OAT	See Table 18.0.6	Maximum Outdoor Ambient Temperature used in building ASHP load profile; TMY3 basis
Min OAT	See Table 18.0.6	Minimum Outdoor Ambient Temperature for caluclating full load heating; TMY3 Basis.
Des OAT	5	Low Outdoor Ambient Temperature for caluclating heating load Profile. Based on Low Temp Rating from NEEP QPL Data Sheets. Deemed to be 5 F.
HSPF_Adj_Factor	See Table 18.0.1	Adjustment factor for correcting HSPF from published data in climate zone IV to Minnesota Climate zone V. The HSPF_Adjustment_Factor for Electric Resistance Heat will be 1.
Balance Point Load	See Table 18.0.6	BTUH - Heating and cooling loads are zero at the balance point outdoor ambient
m_load_profile	Calculated	load profile slope (m)
b_load_profile	Calculated	load profile y intercept (b)
Full Load Heat	Calculated	Calculated full load heating BTUH based on the calculated load profile using the minimum Outside Air Temperature for the selected ccMSHP equipment. The load served is assumed to not be the whole load for the home.

Full Load Cool	Calculated	Calculated full load cooling BTUH based on the calculated load profile using the maximum Outside Air Temperature for the selected ccMSHP equipment. The load served is assumed to not be the whole load for the home.
Furnace Eff	95%	Furnace efficiency for backup heating deemed to be condensing type furnace with 95% efficiency
Oversize_Factor__c	20%	Deemed Oversize Safety Factor for heating equipment.
Lifetime	See Table 18.0.3	Measure Lifetime for ccMSHPs are the same as for MSHPs found in referenced table.
Minimum Qualifying Efficiency	See Table 18.0.2	

Customer Inputs	**M&V Verified**	
Size_Cool	Yes	NEEP QPL Data Sheet Rated Cooling Capacity at 95 F
Size_Heat_5	Yes	NEEP QPL Data Sheet Max Heating Capacity at 5 F
Size_Heat_47	Yes	NEEP QPL Data Sheet Rated Heating Capacity at 47 F
EER proposed	Yes	NEEP QPL Data Sheet rated full load Cooling Efficiency
SEER proposed	Yes	NEEP QPL Data Sheet rated part load Cooling Efficiency
HSPF Proposed	Yes	NEEP QPL Data Sheet rated Heating HSPF
Quantity proposed equipment	Yes	
Home Type	Yes	Single Family or Multi-Family home
County	Yes	Location of the home for determining weather zones.
Baseline Heat Type	Yes	Baseline heating type; gas furnace or electric resistance backup heat

Table 18.14.1: SEER Conversion Coefficients

Equipment type	Coef0	Coef1	Coef2	Coef3	Notes
MSHP - SEER to EER	-0.0002600	0.0101270	0.5263880	-0.0233300	Xcel Derivation

Table 18.14.2 Incremental Capital Costs - Cold Climate Mini-Split Heat Pump (Reference 8)

Mini-Split Heat Pump	Baseline Cost per ton Heating	Incremental cost per ton ~~Cooling~~ Heating
ccMSHP (18+ SEER, 11+ EER, 10.5 HSPF)	$ 3,266.64	$ 555.94

References:

See 18.1 Residential AC references

Changes from Recent Filing:

added dual fuel heating baseline
modified heating savings methodology to incorporate cut-off temperature for both dual fuel and electric resistance baselines
incorporated HSPF addjustments based on AHRI climate zones

18.0 Residential HVAC Deemed Tables

Table 18.0.1: Effective Full Load Hours, Altitude	EFLH Cooling		EFLH Heat		EFLH_Heating_HP (Heat Pump Impacted heating hours) ****			
	Single Family	**Multi-Family**	**Single Family**	**Multi-Family**	**Single Family**	**Multi-Family**	**Altitude Adjustment Factor**	**HSPF Climate Zone Adjustment Factor**
Zone 1 - CO Front Range *	590	699	1,825	1,409	1,409	1,088	0.177 ~~0.212~~	100%
Zone 2 - CO Western Slope **	837	992	1,971 ~~1,739~~	1,522 ~~1,343~~	1,495 ~~668~~	1,154 ~~516~~	0.163 ~~0.194~~	100%
Zone 3 - CO Mountain Areas ***	210	249	2,104	1,625	920	710	0.244 ~~0.301~~	85%
Zone 4 - CO Very High Altitude Areas *****	0	0	2,739	2,115	1,360	1,050	0.303	85%

* Zone 1 (Front Range as represented by Denver International Airport TMY3 data);
** Zone 2 (Western Slope as represented by Grand Junction TMY3 Data)
*** Zone 3 (Mountain Areas as represented by Alamosa TMY3 Data)
**** the heat pump impacted hours are determined at a cutoff temperature of ~~35~~ 25 F.
*** Zone 4 (Very High Altitude Areas as represented by Lake CO Airport TMY3 Data)

Table 18.0.1a: Effective Full Load Hours Cold Climate Heat Pumps	EFLH_ccHP_Heat (Cold Climate Heat Pump Impacted heating hours) *****	
	Single Family	**Multi-Family**
Zone 1 - CO Front Range	1,809	1,397
Zone 2 - CO Western Slope	1,971	1,522
Zone 3 - CO Mountain Areas	1,748	1,349
Zone 4 - CO Very High Altitude Areas	2,521	1,946

**** the cold climate heat pump impacted hours are determined at a cutoff temperature of 5 F.

Table 18.0.2: Minimum Qualifying Efficiency	Code Minimum						
Measure	**SEER**	**EER**	**HSPF**	**Heating COP**	**Minimum Qualifying SEER**	**Minimum Qualifying EER**	**Minimum qualifying HSPF / Full Load COP**
High Efficiency Air Conditioner - Split System	13.00	11.18	N/A	N/A	15.00		N/A
High Efficiency Air Conditioner - Packaged System	14.00	11.76	N/A	N/A	15.00		N/A
Air Source Heat Pump - Split System	14.00	11.76	8.20	N/A	15.00		9.00
Air Source Heat Pump - Packaged System	14.00	11.76	8.00	N/A	15.00		9.00
Mini-Split & Multi-Split Heat Pumps	14.00	11.76	8.20	N/A	16.00		9.00
Cold Climate Air Source Heat Pumps	14.00	11.76	8.00	N/A	18.00		10.50
Cold Climate Mini-Split & Multi-Split Heat Pumps	14.00	11.76	8.20	N/A	18.00		10.50
Gorund Source Heat Pump **	14.10	14.10	N/A	3.20	~~16.00~~	16.00	3.30 ~~4.00~~

** Ground Loop Brine to Air with entering temperatures of 77 F cooling mode and 32 F heating mode

Table 18.0.3: Coincidence Factors, Baseline Efficiencies and Lifetimes

Equipment Type	**Deemed Equipment Coincidence Factor**	**Deemed QI Coincidence Factor**	**SEER Baseline**	**EER Baseline**	**HSPF Baseline**	**Baseline Heating COP (Gas Fired)**	**Lifetime**	**Notes**
High Efficiency Air Conditioner - Split System *	90%	100%	13.00	11.18	N/A	N/A	18	(Reference 17)
Air Source Heat Pump - Split System	90%	100%	14.00	11.76	8.20	0.80	18	(Reference 17)
Mini-Split & Multi-Split Heat Pumps	90%	N/A	14.00	Varies	8.20	0.80	15	
Cold Climate Air Source Heat Pump - Split System	90%	100%	14.00	11.76	8.20	0.80	18	(Reference 17)
Cold Climate Mini-Split & Multi-Split Heat Pumps	90%	N/A	14.00	Varies	8.20	0.80	15	
Gorund Source Heat Pump **	90%	100%	13.00	11.18	N/A	0.80	20	

** Baseline for GSHP is Code minimum AC and Gas Fired Furnace.

Table 18.0.4: QI Factors (Reference 4, Reference 6, Reference 7, Reference 14)

Home Type - equipment type	**Sizing Loss**	**Refrigeration Charge**	**Improper Airflow**	**Duct Leakage**	**Loss NO Field QI**	**Loss_Uncorr**
New Home - AC/ASHP	0%	7.0%	2.0%	0.0%	9.00%	0.0%
Existing Home - AC/ASHP	2.0%	7.0%	2.0%	8.3%	17.30%	3.7%
New Home - GSHP	0%	0.0%	2.0%	0.0%	2.00%	0.0%
Existing Home - GSHP	2.0%	0.0%	2.0%	8.3%	10.30%	3.7%
New Home MSHP	0.0%	0.0%	0.0%	0.0%	0.00%	0.0%
Existing Home MSHP	0.0%	0.0%	0.0%	0.0%	0.00%	0.0%

Table 18.0.5: Conversion Factors and Constants

Conversion Factor from BTUH to kW	3,412	BTU/kW-hr
Btu to Dth	1,000,000	BTU/Dth
Therm to Dth	10	Therm/Dth
Btu to Therm	100,000	Btu/Therm
Convert from Btu/wh to kW/ton	12	Btu/wh per kW/ton
Conversion between Watts and kiloWatts	1,000	watts/kilowatt
Conversion between BTU/h and tons	12,000	BTUh / ton
Water Lb/gallon	8.34	lb/gal
Water_h_fg	1,059	BTU/lb (Evaporative energy / lb water)

Table 18.0.6: Cooling & Heating Weather Data for Load Estimates	**Maximum Outside Air Temperature (F)**	**Mimimum Outside Air Temperature (F)**	**Balance Point OSA Temperature (F)**	**Balance Point Load (BTUH)**		
Zone 1 - CO Front Range	104	-3	60	0		
Zone 2 - CO Western Slope	99	7	60	0		
Zone 3 - CO Mountain Areas	87	-26	60	0		
Zone 4 - CO Mountain Areas	81	-17	60	0		

20.1 Gas Water Heaters

Algorithms

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

$$Hot\_Water\_Energy = Qty \; x \; Hot\_Water\_Consumption \; x \; Water\_Heater\_Delta\_T \; x \; Days\_Per\_Year \; x \; Water\_Density$$

Water Heater Delta T = Water_Heater_Temperature - City_Mains_Temperature

For Storage Water Heaters:

Baseline_Efficiency_Gas= coef1 - (coef2 x Proposed_Tank_Size)

For Instantaneous and Indirect Water Heaters:

Baseline_Efficiency_Gas= coef1 - (coef2 x Baseline_Tank_Size)

For Indirect Water Heaters:

$$Proposed\_Dth = \left(Hot\_Water\_Energy / Eff_{P,Boiler} + \frac{UA_{P,DHW}}{Eff_{P,Boiler}} \times Ambient\_dT \times HoursPerYear \right) / 1{,}000{,}000$$

$$Ambient\_dT = Water\_Heater\_Temperature - Ambient\_Temperature$$

$$UA_{P,DHW} = \frac{SL_{P,DHW}}{70} \times Proposed\ Tank\ Size \times Water\_Density \times SpecificHeat_{Water}$$

Incremental Cost = Proposed Cost - Baseline Cost

Variables

Hot_Water_Consumption	See Table 20.1.4	Gallons of Water per day based on number of Bedrooms and Home Type
Water Heater Temperature	120.0	Water Heater Tank Temperature
City Mains Temperature	51.4	Water Main temperature average over the year
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 kW to Watts	1,000	1 kW = 1,000 Watts
Conversion from Btu to kWh	3,412	1 kW = 3,412 Btuh
Specific Heat of Water	1	Btu/lb/°F
Water_Density	8.34	lb/gal H20
Days_Per_Year	365	Days per Year
HoursPerYear	8,760	Hours per Year
Coef1	See Table 20.1.1 See Table 20.1.2	Code based forumula for calculation of Baseline efficiency based on water heater type and Proposed Tank Size
Coef2	See Table 20.1.1 See Table 20.1.2	Code based forumula for calculation of Baseline efficiency based on water heater type and draw pattern
Baseline_Tank_Size	See Table 20.1.3	For Instantaneous Water Heaters the baseline tank size will be based on the deemed First Hour Rating and the number of bedrooms.
Water Heater Self-Installation Rate	52%	Percent of Water Heaters that self-installed after retail purchase (Reference 9). Zero percent for heat pump water heaters.
Ambient_Temperature	70	Deemed ambient air temperature of the space where the Indirect Water Heater is installed.
SL_P,DHW	See Table 20.1.7	Standby loss factor for the proposed Indirect Water Heater, in °F/h. Deemed from Averages of AHRI database.
Indirect Water Heater Baseline Cost	See Table 20.1.6	Baseline cost of Indirect Water Heater, based on number of bedrooms
Indirect Water Heater Draw Pattern	See Table 20.1.6	Draw Pattern of baseline water heater for Indirect Water Heater measure based on number of bedrooms
Indirect Water Heater Proposed Cost	See Table 20.1.7	Proposed cost of Indirect Water Heater based on the proposed nominal tank size.
Measure Life for Indirect Water Heater	13	Indirect Water Heater measure life is equivalent to a gas fired storage water heater.

Customer Inputs	M&V Verified	
Number of Bedrooms	Yes	total number of bedrooms in the home where a new water heater is being installed
Proposed Eff	Yes	Proposed water heater AHRI Certified Uniform Energy Factor (UEF)
First Hour Rating	Yes	AHRI certified First Hour Rating in gallons per hour (GPH)
Quantity Proposed Equipment	Yes	
Instantaneous Water Heater Max GPM Rating	Yes	AHRI Certified GPM Rating
Proposed Tank Size	Yes	DOE Rated Storage Volume for tank type water heaters
Type of Proposed Water Heater	No	Type of proposed water heater. (i.e. Storage, Tankless, Heat Pump)
Water Heater Draw Pattern	No	Usage Bin identified on AHRI Certificate
$Eff\_P,Boiler$	Yes	Proposed Boiler Percent AFUE for boiler equipment associated with operation of the indirect water heater.

Table 20.1.1 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 WH >20 Gallon and <=55 Gallon Baseline Efficiency Coefficients		Gas Storage WH >55 Gallon and <=100 Gallon Baseline Efficiency Coefficients	
Draw Pattern	min (>=Gallons)	max (< Gallons)	coef1	coef2	coef1	coef2	coef1	coef2
Very Small	1	18	0.8808	0.0008	0.3456	0.0020	0.6470	0.0006
Low	18	51	0.9254	0.0003	0.5982	0.0019	0.7689	0.0005
Medium	51	75	0.9307	0.0002	0.6483	0.0017	0.7897	0.0004
High	75	No Upper Limit	0.9349	0.0001	0.6920	0.0013	0.8072	0.0003

Table 20.1.2 Instantaneous Gas Fired Water Heater baseline Efficiency calculation parameters (Reference 8)

	Instantaneous Gas-Fired Water Heater <2 gal and >50,000 Btu/h GPM Drawn	
Draw Pattern	Minimum (>=GPM)	Maximum (< GPM)
Very Small	0	1.7
Low	1.7	2.8
Medium	2.8	4
High	4	No Upper Limit

Table 20.1.3 Estimated Baseline Gas Storage Water Heater Tank Size for Instantaneous and Indirect Water Heaters - 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
Average Gas Storage First Hour Draw (Reference 12)	43	60	67	77	90	92
Instantaneous Water Heater Baseline Tank Size	20	30	35	40	50	50
Indirect Water Heater Baseline Tank Size	20	30	35	40	50	50

Table 20.1.4 Water Usage per Day by Number of Bedrooms

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

Table 20.1.5: Inc Costs for Income Qualifed Single Family Weatherization Program

	Incrmental Cost
High Efficiency Tank-Type Gas Fired Water Heater	$374.00
High Efficiency Tankless Gas Fired Water Heater	$1,100.27

Table 20.1.6: Baseline Water Heater Deemed Information for Indirect Water Heaters

No. of Bedrooms \ Cost & Draw Pattern	Baseline Cost	Deemed Draw Pattern
1	$719.04	Low
2	$719.04	Medium
3	$719.04	Medium
4	$719.04	High
5	$773.07	High

Table 20.1.7: Proposed Indirect Water Heater Standby Loss Factor (Reference 7), Equipment Cost

Indirect Nominal Tank Size (Proposed Tank Size)	Standby Loss, °F/h	Indirect WH Equip Cost	Minimum Tank Size	Maximum Tank Size
30	1.1286	$1,130.14	25	33
35	0.9538	$1,192.44	33	38
40	0.9957	$1,361.20	38	45
50	0.7304	$1,497.25	45	55

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. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs; https://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/72c23decff52920a85257f1100671bdd/$FILE/TRM%20Version%206%20-%20January%202019.pdf
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; Consumer Water Heaters; https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=32
7. AHRI Directory of Certified Product Performance for Indirect Water Heaters; https://www.ahridirectory.org/NewSearch?programId=28&searchTypeId=3
8.US Department of Energy,Energy and water conservation standards and their compliance dates: 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.

Changes from Recent Filing:

changed method for determining baseline tank size for instantaneous water heaters
changed method for determining hot water consumption
Added Indirect Water Heaters installed with a high efficiency boiler
Added Tankless Water Heater cost for Income Qualified Single Family Weatherization