18.1 Residential Air Conditioning

Algorithms

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

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

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

Customer Dth_QI Existing Home = Dth Heat_NoQI Existing Home_Eff - Dth Heat_QI Existing Home_Eff

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

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

$$Customer\ kW_{QICooling} = Qty\_Prop * \frac{Size\_Cool}{12{,}000} * \frac{12}{EER_{proposed}} * \left(\left(\frac{1}{1 - Loss_{NoQI}}\right) - \left(\frac{1}{1 - Loss_{Uncorr}}\right)\right)$$

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

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

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

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

$$Incremental\ Capital\ Cost_{Equipment} = Qty_{Prop} * Inc\ Cost\ per\ Ton_{EQ} * \frac{Size\_Cool}{12{,}000}$$

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

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

AC with Furnace Heating Savings

Customer Dth_QI Existing Home = Dth Heat_NoQI Existing Home_Eff - Dth Heat_QI Existing Home_Eff

*Dth Heat_NoQI Existing Home_Eff = Size_Heat * (1 - Oversize Factor) * (1 - Altitude_Adj_Factor) * EFLH_Heat * 1/(Furnace_Eff * (1 - Loss_DuctLeakage)) / 1,000,000*

*Dth Heat_QI Existing Home_Eff = Size_Heat * (1 - Oversize Factor) * (1 - Altitude_Adj_Factor) * EFLH_Heat * 1 / (Furnace_Eff * (1 - Uncorr_Loss)) / 1,000,000*

*Estimated Furnace Size_Heat = Const_a * Size_Cool + Const_b* *NOTE: only if actual furnace capacity is not available*

Variables

$Inc\ Cost\ per\ Ton\_EQ$	See Table 18.1.1	Deemed Plan A Incremental Capital Cost per Ton, Based On Unit Efficiency (New Construction)
$Cost\ per\ Ton\_baseline$	See Table 18.1.2	Baseline capital cost per ton for equipment
$Inc\ Cost\_QI$	See Table 18.1.2	Deemed incremental cost for 'quality install' installtion effort.
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	
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.
Conversion Factors	See Table 18.0.5	for all conversion factors
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_Heating_HP	See Table 18.0.1	Effective Full Load Hours for Heat Pump impacted energy savings
$uCoef0$	1.70223	formula constant (slope) for use in estimating furnace size from nameplate cooling capacity for
$uCoef1$	24779	constant for use in estimating furnace size from nameplate cooling capacity for a furnace
Furnace_Eff	Derived from Inputs	Contractor to provide the associated furnace efficiency if known. If the furnace efficiency is unknown, the Furnace Type (Condensing or Non-Condensing) will determine the deemed furnace efficiency to be used in the calculations. Condensing furnaces = 95% efficiency and for Non-Condensing = 80% effiiciency. If Furnace Type is unknown we will assume Condensing.
NTG	73% ~~67.6%~~	Net-to-gross for AC units which is calculated from High Efficiency AC Program Evaluation conducted in 2021 ~~2012~~.
Measure Life - Matched Split-System Air Conditioner (Plan A)	See Table 18.0.3	Reference 16
Measure Life - Quality Installation	18	Reference 16

Customer Inputs	**M&V Verified**	
Size Cool	Yes	AHRI rating of total cooling equipment BTUH (sensible plus latent)
Qty Prop	Yes	Quantity of proposed equipment
EER proposed	Yes	AHRI rated full load energ efficiency ratio
SEER proposed	Yes	AHRI rated seasonal energy efficiency ratio
Home Type	No	customer home type; new or existing
County	No	Location of the installed new equipment
Size Heat	No	Namplate of existing furnace
Furnace Type	No	Contractor to determine if the new AC equipment is associated with a furnace that has a Condensing or Non-Condensing burner / heat exchanger.

Table 18.1.1 Incremental Capital Costs - New Construction (Plan A) - Reference 6

SEER	AC Cost per Ton	AC Incremental Cost per Ton
13 SEER	$ 422.85	N/A
14/14.5 SEER	$ 514.98	N/A
15 SEER	$ 607.10	$ 184.25
16 SEER	$ 699.23	$ 276.38
17/18+ SEER	$ 791.36	$ 368.51

Table 18.1.2 Incremental Capital Costs - Quality Install (Reference 6)

Measures	**New Home**	**Existing Home***
Quality Installation	$ 103.56	$ 259.80

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:

Updated Net to Gross with 2021 program evaluation data