Table of Revisions/Changes

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
2-20-1	R	2/28/2020	2/28/2020	R/MF Heat Pump Water Heater (HPWH) – Air Source	Revised to align with updated baseline guidance/fuel-switching provisions consistent with other heat pump technologies	Pg. 72
2-20-2	R	2/28/2020	2/28/2020	R/MF Heat Pump - Air Source (ccASHP)	Revised to align with updated baseline guidance/fuel-switching provisions consistent with other heat pump technologies; Revisions applied reflecting the findings of recent ASHP white paper	Pg. 146
2-20-3	R	2/28/2020	2/28/2020	R/MF Heat Pump – Water-to-Air Ground Source (GSHP)	Revised to align with updated baseline guidance/fuel-switching provisions consistent with other heat pump technologies; Revisions applied reflecting the findings of recent ASHP white paper	Pg. 150
2-20-4	A	2/28/2020	2/28/2020	R/MF Air Conditioner and Heat Pump – Packaged Terminal	New Measure	Pg. xx
2-20-5	A	2/28/2020	2/28/2020	C/I Heat Pump – Air Source (ccASHP)	New Measure	Pg. xx
2-20-6	R	2/28/2020	2/28/2020	C/I Heat Pump – Water-to-Air Ground Source (GSHP)	New Measure	Pg. xx
2-20-7	R	2/28/2020	2/28/2020	C/I Air Conditioner and Heat Pump – Packaged Terminal	Revised to align with updated baseline guidance/fuel-switching provisions consistent with other heat pump technologies; Added compliance efficiency of 10% better than code	Pg. 336
2-20-8		2/28/2020	2/28/2020	C/I Heat Pump – Water Source (WSHP)	No revisions applied – measure marked for removal from TRM	Pg. 379
2-20-9		2/28/2020	2/28/2020	C/I Variable Refrigerant Flow (VRF) System	No revisions applied – measure marked for removal from TRM	Pg. 400

Note: Revisions and additions to the measures listed above were undertaken by the Joint Utilities Technical Resource Manual (TRM) Management Committee between January 1, 2020 – February 28, 2020

DOMESTIC HOT WATER

HEAT PUMP WATER HEATER (HPWH) – AIR SOURCE

Measure Description

This measure covers the installation of electric storage tank water heaters that use heat pump technology to move heat from the air (inside or outside the building) to the water storage tank and are designed to heat and store potable water at a thermostatically controlled temperature of less than 180°F. It is not intended for equipment delivering process or space heating hot water. It applies to electric heat pump water heaters with a maximum current rating of 24 amperes at a voltage no greater than 250 volts and with a rated storage tank capacity of 120 gallons or less.[1,2]

This measure applies to new construction/major renovation projects and replacement of existing water heaters and assumes baseline to be a minimally code compliant storage type water heater.

This measure applies to residential applications as well as residential-duty water heaters installed in commercial settings. In the latter case, this methodology shall be employed utilizing typical GPD values as defined in the "Gallons per Day (GPD)" section of the Commercial Storage Tank Water Heater measure detailed in this document.

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \left(\frac{F_{eDHW}}{UEF_{baseline}} - \frac{1}{UEF_{ee} \times F_{derate}}\right) + \Delta kWh_{cooling} - \Delta kWh_{heating}$$

$$\Delta kWh_{cooling} = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \frac{1}{UEF_{ee}} \times F_{Loc} \times \frac{F_{Cool}}{SEER/3.412}$$

$$\Delta kWh_{heating} = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{3{,}412} \times \frac{1}{UEF_{ee}} \times F_{Loc} \times F_{ElecHeat} \times \frac{F_{Heat}}{HSPF/3.412}$$

Peak Coincident Demand Savings

$$\Delta kW = units \times (\Delta kW/unit)$$

[1] ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters, Eligibility Criteria Version 3.2, September 2017
[2] 10 CFR 430.2

Annual Fossil Fuel Energy Savings

$$\Delta therms = units \times \frac{GPD \times 365 \times 8.33 \times \Delta T_{main}}{100{,}000} \times \left[\frac{F_{FFDHW}}{UEF_{baseline}} + \frac{F_{BoilerDHW}}{AFUE} - \left(\frac{1}{UEF_{ee}} \times F_{loc} \times F_{FFHeat} \times \frac{F_{Heat}}{AFUE}\right)\right]$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
Δtherms	= Annual fossil fuel savings
$\Delta kWh_{cooling}$	= Annual electric cooling energy savings as a result of interactivity with the building's HVAC system (electric cooling bonus)
$\Delta kWh_{heating}$	= Annual electric heating energy savings as a result of interactivity with the building's HVAC system (electric heating penalty)
units	= Number of measures installed under the program
GPD	= Gallons per day
ΔT_{main}	= Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
F_{eDHW}	= Electric water heating factor, used to exclude baseline electric water heating consumption if no baseline electric water heating is present
F_{FFDHW}	= Fossil fuel water heating factor, used to exclude baseline fossil fuel water heating consumption if no baseline fossil fuel fired direct water heating is present
$F_{BoilerDHW}$	= Fossil fuel water heating factor, used to exclude baseline fossil fuel water heating consumption if no baseline fossil fuel fired boiler-driven indirect water heating is present
baseline	= Baseline condition or measure
ee	= Energy efficient condition or measure
UEF	= Uniform energy factor
F_{derate}	= Efficiency derating factor used to account for the degradation of heat pump performance present in systems installed in unconditioned spaces
F_{Loc}	= Installation location factor, used to exclude interactive HVAC impacts for systems installed in unconditioned spaces
F_{Cool}	= Cooling factor, used to account for the percentage of heat extracted from ambient air by the heat pump water heater that reduces space cooling load
F_{Heat}	= Heating factor, used to account for the percentage of heat extracted from ambient air by the heat pump water heater that increases space heating load
$F_{ElecHeat}$	= Electric heating factor, used to exclude electric heating penalty if no electric heating is present
F_{FFHeat}	= Fossil fuel heating factor, used to exclude fossil fuel heating penalty if no fossil fuel heating is present
SEER	= Seasonal average energy efficiency ratio over the cooling season, BTU/watthour, (used for average U.S. location/region)
HSPF	= Heating seasonal performance factor, BTU/watt-hour, total heating output (supply heat) in BTU (including electric heat) during the heating season / total electric energy heat pump consumed (in watt-hour)

AFUE = Annual fuel utilization efficiency, seasonal energy efficiency for fuel heating equipment
(ΔkW/unit) = Deemed peak coincident demand savings per measure
365 = Days in one year
8.33 = Energy required (BTU) to heat one gallon of water by one degree Fahrenheit
3,412 = Conversion factor, one kWh equals 3,412 BTU
3.412 = Conversion factor, one watt-hour equals 3.412 BTU
100,000 = Conversion factor (BTU/therm), one therm equals 100,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
GPD	17.2 X # of people	Calculated based on number of people served by the system. If unknown, use 46 GPD.[3]
ΔT_{main}	T_{set} - T_{main}	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F).
T_{set}	140	Water heater set point temperature (°F).[4]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
F_{eDHW}		Use a value of 1.0 if the water was previously heated with electricity or if it is a new construction home with no gas access. Otherwise, use 0.0.
F_{FFDHW}		Use a value of 1.0 if the water was previously heated directly with fossil fuels or if it is a new construction home with gas access. Otherwise, use 0.0.
$F_{BoilerDHW}$		Use a value of 1.0 if the water was previously heated indirectly with fossil fuels through the boiler system. Otherwise, use 0.0.
$UEF_{baseline}$		Uniform Energy Factor of the baseline condition. See Baseline Efficiencies… section below for details regarding derivation of this input.
UEF_{ee}		Uniform Energy Factor of the energy efficient measure, from application.
F_{derate}		For equipment installed in unconditioned spaces, lookup in Derate Factor table below based on installation location and nearest city. For equipment installed in conditioned spaces, a value of 1.0 shall be used.

[3] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016, p. 5; 17.2 GPD equated from the report findings indicating an average 2.65 people per household and 45.5 GPD per household.
[4] Per OSHA recommendations for prevention of Legionalla bacterial growth (https://www.osha.gov/dts/osta/otm/legionnaires/hotwater.html)

Variable	Value	Notes
F_{Loc}		Use a value of 1.0 if the water heater is installed in a conditioned space. Otherwise, use 0.0.
F_{Cool}		Lookup in HVAC Interactivity table below based on nearest city.
F_{Heat}		Lookup in HVAC Interactivity table below based on nearest city.
$F_{ElecHeat}$		Use a value of 1.0 if the building is electrically heated. Otherwise, use 0.0.
F_{FFHeat}		Use a value of -1.0 if the building is fossil fuel heated. Otherwise, use 0.0.
SEER	13	Assumed efficiency of existing air conditioning system, based on a minimally code compliant, 3-ton, split system AC.[5]
HSPF	Heat Pump – 8.2 Electric Resistance – 3.412	Assumed efficiency of electric heating system, based on a COP of 1.0 for electric resistance heating and a minimally code compliant, 3-ton split system HP for heat pumps.[6]
AFUE	80%	Assumed efficiency of fossil fuel heating system, based on a minimally code compliant, 80 MBH gas furnace.[7]
(ΔkW/unit)	0.17	Deemed Summer Peak Coincident Demand Savings[8]

Cold Water Inlet Temperature (T_{main})

Supply water main temperatures vary according to climate, and are approximately equal to the annual average outdoor temperature plus 6°F.[9] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[10] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

[5] ECCCNYS 2016, Table C403.2.3(1) & NYCECC 2016, Table C403.2.3(1)
[6] ECCCNYS 2016, Table C403.2.3(2) & NYCECC 2016, Table C403.2.3(2)
[7] 10 CFR 430.32 (e) (2) (i) (A)
[8] "Field Testing of Pre-Production Prototype Heat Pump Water Heaters" Federal Energy Management Program, DOE/EE-0317, May 2007.
[9] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory
[10] Average annual outdoor temperatures taken from NCDC 1981-2010 climate normals

Derate Factor

Standard testing conditions for rating of heat pump water heaters require a dry bulb temperature of 67.5°F ± 1°F and a relative humidity of 50% ±2%.[11] The reported efficiency of heat pump water heaters is established at these conditions; however, heat pump efficiency degrades at lower ambient temperatures. The Derate Factor is established to adjust the published efficiency of the qualifying heat pump water heater when the system is installed in semi-conditioned or unconditioned spaces, namely, garages and basements. The values shown below were derived from Table 10 of Residential Heat Pump Water Heater Evaluation: Lab Testing & Energy Use Estimates published by Bonneville Power Administration in 2011[12] and verified via comparison with results from the 2013 NEEA Heat Pump Water Heater Field Study Report.[13] Average values from northwest heating zones 1 (<6,000 HDD), 2 (6,000 – 7,500 HDD) and 3 (>7,500 HDD)[14] from this analysis and comparison were then mapped to representative NY climate regions as shown below.

City	F_{derate} (Unconditioned Basement Installation)	F_{derate} (Garage Installation)
Albany	0.80	0.78
Binghamton	0.80	0.78
Buffalo	0.80	0.78
Massena	0.75	0.69
NYC	0.86	0.83
Poughkeepsie	0.80	0.78
Syracuse	0.80	0.78

HVAC Interactivity

Because heat pump water heaters operate via the transfer of heat from the ambient air to the water in the storage tank, systems installed in conditioned spaces will interact with the building's HVAC system. The values shown in the table below reflect the percentage of heat extracted from the ambient air by the heat pump that either decreases the building's cooling load (F_{Cool}) or increases the building's heating load (F_{Heat}). These values were derived from Table 12 of Residential Heat Pump Water Heater Evaluation: Lab Testing & Energy Use Estimates published by Bonneville Power Administration in 2011[15] and key operating assumptions specified therein. Average values from northwest heating zones 1 (<6,000 HDD), 2 (6,000 – 7,500 HDD) and 3 (>7,500 HDD)[16] were then mapped to representative NY climate regions and scaled linearly based on regional HDD and CDD. The HDD and CDD values are based on 30-year averages of U.S annual climate normals between 1981 and 2010 using base 65° F.[17]

[11] 10 CFR 430 Subpart B Appendix E

[12] Residential Heat Pump Water Heater Evaluation: Lab Testing & Energy Use Estimates, Bonneville Power Administration, November 2011

[13] NEEA Heat Pump Water Heater Field Study Report, Fluid Market Strategies, October 2013

[14] NW Council Heating/Cooling zone maps

[15] Residential Heat Pump Water Heater Evaluation: Lab Testing & Energy Use Estimates, Bonneville Power Administration, November 2011

[16] NW Council Heating/Cooling zone maps

[17] HDD/CDD taken from NCEI 1981-2010 climate normals

City	CDD	F_{Cool}	HDD	F_{Heat}
Albany	597	0.26	6,680	0.70
Binghamton	382	0.17	7,193	0.76
Buffalo	544	0.24	6,617	0.70
Massena	363	0.16	8,196	0.84
Poughkeepsie	671	0.29	6,210	0.65
NYC	1,160	0.51	4,671	0.49
Syracuse	570	0.25	6,651	0.70

Coincidence Factor (CF)

The recommended value for the coincidence factor is N/A. Deemed demand savings values incorporate system peak coincidence considerations.

Baseline Efficiencies from which Savings are Calculated

The baseline for a non-fuel switching normal replacement at end of the appliance effective useful life (EUL), in new construction, or substantial renovation scenarios is the minimally-compliant state or municipal energy code or federal standard, that is applicable to the measure or system being installed.

The baseline for a fuel switching installation at the end of the appliance effective useful life is the minimally-compliant, state or municipal energy code or federal standard, that is applicable to the measure or system, similar to the existing measure or system, that the consumer would have had installed without the influence of the energy efficiency program.

The baseline for a system being installed prior to the end of useful life of the existing on-site equipment may be considered as an Early Replacement; consistent with methods described in Appendix M, *Guidelines for Early Replacement* of this TRM. The non-fuel switching and fuel switching baselines detailed above shall be considered where applicable when calculating Remaining Useful Life (RUL).

$UEF_{baseline}$ shall be calculated as a function of qualifying equipment tank volume (v_t) per federal standards[18] as shown in the table below, using the qualifying equipment capacity and draw pattern. Draw pattern can be established based on the proposed equipment First Hour Rating (FHR), rated in gallons. See First Hour Rating vs. Draw Pattern table below. If FHR is unknown, a Medium draw pattern should be assumed for equipment with rated storage capacity ≤50 gallons and a High draw pattern should be assumed otherwise.[19]

[18] 10 CFR 430.32(d)

[19] Based on review of typical usage bins for AHRI certified residential water heating equipment (https://www.ahridirectory.org/ahridirectory/pages/home.aspx)

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	$UEF_{baseline}$
Electric Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.8808 - (0.0008 x v_t)
		Low	0.9254 - (0.0003 x v_t)
		Medium	0.9307 - (0.0002 x v_t)
		High	0.9349 - (0.0001 x v_t)
	> 55 gal and ≤ 120 gal	Very Small	1.9236 - (0.0011 x v_t)
		Low	2.0440 - (0.0011 x v_t)
		Medium	2.1171 - (0.0011 x v_t)
		High	2.2418 - (0.0011 x v_t)
Gas-Fired Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.3456 – (0.0020 x v_t)
		Low	0.5982 – (0.0019 x v_t)
		Medium	0.6483 – (0.0017 x v_t)
		High	0.6920 – (0.0013 x v_t)
	> 55 gal and ≤ 100 gal	Very Small	0.6470 – (0.0006 x v_t)
		Low	0.7689 – (0.0005 x v_t)
		Medium	0.7897 – (0.0004 x v_t)
		High	0.8072 – (0.0003 x v_t)
Oil-Fired Storage Water Heater	≤ 50 gal	Very Small	0.2509 – (0.0012 x v_t)
		Low	0.5330 – (0.0016 x v_t)
		Medium	0.6078 – (0.0016 x v_t)
		High	0.6815 – (0.0014 x v_t)

*v_t = tank volume in gallons

First Hour Rating vs. Draw Pattern[20]

First Hour Rating	Draw Pattern
<18 gallons	Very Small
≥18 and <51 gallons	Low
≥51 and <75 gallons	Medium
≥75 gallons	High

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a heat pump water heater meeting minimum performance requirements specified in ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters, Eligibility Criteria Version 3.2.[21] Per that specification, heat pump water heaters with ≤55 gallon storage capacity must have a UEF ≥ 2.00 and heat pump water heaters with >55 gallon storage capacity must have UEF ≥2.20.

Operating Hours

Water heater run hours are not utilized in the estimation of energy or demand savings, but water heater is assumed to be available for operation 8,760 hours per year.

[20] 10 CFR 429.17

[21] ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters, Eligibility Criteria Version 3.2, September 2017

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Heat pump water heaters installed in conditioned spaces will result in an increase in space heating load due to the extraction of heat from the ambient air. This interactivity is addressed in the prescribed methodology.

Ancillary Electric Savings Impacts

Heat pump water heaters installed in conditioned spaces will result in an increase in space heating load and a decrease in cooling load due to the extraction of heat from the ambient air. This interactivity is addressed in the prescribed methodology.

References

1. ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters, Eligibility Criteria Version 3.2, September 2017
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11. NOAA National Centers for Environmental Information – NCEI 1981-2010 Climate Normals
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12. 10 CFR 430 Subpart B – Test Procedures, Appendix E – Uniform Test Method for Measuring the Energy Consumption of Water Heaters
Available from: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=9624a8ba0987aaae248454c49194a661&mc=true&n=pt10.3.430&r=PART&ty=HTML#ap10.3.430_127.e
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Available from: http://neea.org/docs/default-source/reports/heat-pump-water-heater-field-study-report.pdf?sfvrsn=5
15. NW Council Heating/Cooling Zone Maps
Available from:
https://www.bpa.gov/EE/Sectors/Residential/Documents/PNWHeatingandCoolingClimateZoneAssignmentsbyCounty.pdf
16. 10 CFR 429.17 Water heaters.
Available from: https://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=10:3.0.1.4.17#se10.3.429_117

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
6-13-3	6/30/2013
11-13-2	11/26/2013
12-17-7	12/31/2017
12-18-3	12/31/2018
2-20-1	2/28/2020

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Heating, Ventilation and Air Conditioning (HVAC)

Heat Pump – Air Source (ccASHP)

Measure Description

This measure covers the installation of cold climate Air Source Heat Pumps (ccASHP) systems that provides heating and cooling for space conditioning in a residential home.[22,23] An air source heat pump is a product, other than a packaged terminal heat pump, which is powered by single phase electric current, air cooled, rated below 65,000 BTU/h, not contained within the same cabinet as a furnace with rated capacity above 225,000 BTU/h, and operates as a heat pump in both heating and cooling mode. This ASHP analysis shall be associated with single zone split-systems with ductless indoor units that may be wall-mounted, floor-mounted, or ceiling-mounted; and multi-zone split systems with one outdoor section and multiple indoor sections. These indoor sections may be a combination of ductless or compact ducted units; or a central ducted split-system similar to a traditional ducted central air conditioner system.

This measure is based on several assumptions consistent with best practice design for a quality ASHP installation:

- Residential NYS and NYC code and Federal Standard (ECCCNYS 2016, NYCECC 2016, Code of Federal Regulations 10 CFR 430.32) or local legislation applicable at the time of installation should be referenced for correct baseline system and efficiency values.

- Systems shall be sized in accordance with ACCA Manual S based on building design loads calculated in accordance with ACCA Manual J or other approved heating and cooling calculation methodologies.[24,25,26]

- The building design heating load in New York typically exceeds the design cooling load, therefore it is assumed that the ASHP is sized for the building or zone heat load.

The applicability of this measure for a whole-house application is limited to an ASHP system that is sized and installed to provide between 90% and 125% of the design heating load.[27] For a whole house application scenario, when the system is sized such that supplemental electric resistance heat is included within the heat pump to help meet the design heating load, the efficiency of the resistance heating is assumed to be equal to 1 in this analysis. Smaller system sizes are allowable

[22] NEEP Cold Climate Air Source Heat Pump (ccASHP) Specification (Version 3.0) effective January 1, 2019

[23] "Residential homes" means detached one- and two-family dwellings and townhouses not more than three stories above-grade in height with a separate means of egress and their accessory structures, and one-family dwellings converted to bed and breakfast dwellings.

[24] ECCCNYS 2016, Section R403.7

[25] 2016 NYCECC, Section R403.7

[26] ECCCNYS 2016 and 2016 NYCECC require that systems serving multiple dwelling units follow Sections C403 and C404 of the respective codes.

[27] Code reference above. The 90% minimum does not include supplemental heat. Note that Manual S allows use of *low-speed* cooling capacity to determine the cooling size limit of 115% of design total cooling load.

for heating displacement applications in conformance with the NEEP *Guide to Sizing & Selecting Air-Source Heat Pumps in Cold Climates*[28].

The ASHP efficiency must meet the Northeast Energy Efficiency Partnerships (NEEP) Cold Climate Air Source Heat Pump (ccASHP) Specification (Version 3.0) effective January 1, 2019. The specification uses AHRI-certified performance ratings and manufacturer reported data to describe the efficiency and capacity of the unit under full and part load conditions. This equipment is rated under ANSI/AHRI 210/240.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating} - kWh_{heating,supplemental,ee}$$

$$\Delta kWh = units \times \Bigg(\left(BCL \times \frac{1}{1{,}000} \times \left(\frac{F_{CEC}}{SEER_{baseline}} - \frac{1}{EER_{season,ee}} \right) \times BEFLH_{cooling} \times F_{load,cooling} \right) + \left(BHL \times \frac{1}{1{,}000} \times \left(\frac{F_{EH}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}} \right) \times \frac{1}{3.412} \times BEFLH_{heating} \times F_{load,heating} \right) - \left(BHL \times \frac{1}{1{,}000} \times F_{EH,new} \times \frac{1}{3.412} \times BEFLH_{heating} \times \left(1 - F_{load,heating}\right) \right) \Bigg)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times BCL \times \frac{1}{1{,}000} \times \left(\frac{F_{CEC}}{EER_{baseline}} - \frac{1}{EER_{ee}} \right) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta therms = BHL \times \frac{1}{100{,}000} \times \frac{F_{FFH}}{AFUE_{baseline}} \times BEFLH_{heating} \times F_{load,heating}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Summer peak coincident demand savings
Δtherms	= Annual fossil fuel savings
AFUE	= Annual fuel utilization efficiency, seasonal efficiency for fuel heat equipment
baseline	= Baseline condition or measure
BCL	= Building Cooling Load at design conditions (BTU/h)
$BEFLH_{cooling}$	= Cooling equivalent full-load hours based on building design load
$BEFLH_{heating}$	= Heating equivalent full-load hours based on building design load
BHL	= Building Heating Load at design conditions (BTU/h)
CF	= Coincidence Factor

[28] neep.org/sites/default/files/Sizing & Selecting ASHPs In Cold Climates.pdf

$_{cooling}$ = Used to identify operation of equipment in cooling mode
COP = Coefficient of performance for heating, ratio of output energy/input energy
COP_{season} = Seasonally adjusted average coefficient of performance
$_{ee}$ = Energy efficient condition or measure
EER = Energy efficiency ratio under peak conditions
EER_{season} = Seasonally adjusted average energy efficiency
F_{CEC} = Central electric cooling flag; used to account for the presence or absence of a central electric cooling system
F_{EH} = Electric heating flag; used to account for the presence or absence of an electric heating system in the baseline case
$F_{EH,new}$ = Electric heat flag; used to account for when a new heat pump with supplemental resistance heating is installed
F_{FFH} = Fossil fuel heating flag; used to account for the presence or absence of a fossil fuel-fired heating system in the baseline case
$F_{load,cooling}$ = Adjustment factor to account for the portion of the seasonal[29] cooling load met by the heat pump
$F_{load,heating}$ = Adjustment factor to account for the portion of the seasonal[30] heating load met by the heat pump
$_{heating}$ = Used to identify operation of equipment in heating mode
$_{heating,supplemental,ee}$ = Used to identify operation of supplemental electric resistance heat
kWh = Electric energy consumption
SEER = Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour, used for average U.S. location/region
units = Number of units installed under the program
3.412 = Conversion factor, one watt-hour equals 3.412 BTU
1,000 = Conversion factor, one kilowatt equals 1,000 watts
100,000 = Conversion factor, (BTU/therm), one therm equals 100,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$AFUE_{baseline}$		Annual fuel utilization efficiency, seasonal energy efficiency for fuel heating equipment. See Baseline Efficiency section below for details.
BCL		Building cooling load at design conditions.
$BEFLH_{cooling}$		Lookup based on building type, vintage and location from table below.
$BEFLH_{heating}$		Lookup based on building type, vintage and location from table below.
BHL		Building heating load at design conditions.
$COP_{season,baseline}$		Seasonal Coefficient of Performance of the baseline equipment. The assumed efficiency of an electric resistance heating system is 1.

29 Fraction of annual (vs. design) cooling load served by the equipment as shown in the Cooling Load Factor table.
30 Fraction of annual (vs. design) heating load served by the equipment as shown in the Heating Load Factor table.

Variable	Value	Notes
$COP_{season,ee}$		Seasonally adjusted Coefficient of Performance of the efficient equipment. See Compliance Efficiency section below for details.
$EER_{baseline}$		Electric cooling energy efficiency rating of baseline equipment. See Baseline Efficiencies section below for details.
EER_{ee}		Electric cooling energy efficiency rating of efficient equipment. See Compliance Efficiency section below for details.
$EER_{season,ee}$		Seasonally adjusted energy efficiency ratio of the efficient equipment. See Compliance Efficiency section below for details.
F_{CEC}		If a central electric cooling system is present, set equal to 1. Otherwise, set equal to 0.
F_{EH}		Used to account for when a fossil fuel system is replaced with a heat pump with supplemental resistance heating. If a central electric heating system is present, set equal to 1. Otherwise, set equal to 0.
$F_{EH,new}$		If the efficient heat pump system relies on supplemental electric resistance heat to meet the peak load, set equal to 1. Otherwise, set equal to 0.
F_{FFH}		If a fossil fuel-fired heating system is present, set equal to 1. Otherwise, set equal to 0.
$F_{load,cooling}$		Lookup based on equipment sizing and control parameters from table below.
$F_{load,heating}$		Lookup based on equipment sizing and control parameters from table below.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[31]

Baseline Efficiencies from which Energy Savings are Calculated

The baselines used in this measure are determined by the type of equipment that would have been installed without the influence of the program supporting the installation of this measure. This allows for an analysis that does not depend on a typical ‘like-for-like’ replacement scenario.

An ASHP system can be considered a normal replacement scenario for electric resistance heating (with or without a central electric cooling system), an (ASHP) system (that provides space heating

[31] Based on BG&E ‘Development of Residential Load Profile for Central Air Conditioners and Heat Pumps’ research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available but is referenced by the Mid-Atlantic TRM Version 7.0 published May 2017 and by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus.

and cooling), or a fossil fuel fired heating system (with or without a central electric cooling system).

Tables are provided below to show the baseline efficiencies for appropriate Electric Heating and Cooling System Baseline Efficiencies, and appropriate Fossil Fuel Fired Heating System Baseline Efficiencies.

Electric Cooling and Heating System Baseline Efficiencies

Product Class	Seasonal Energy Efficiency Ratio (SEER)[32]	Energy Efficiency Ratio (EER)	Heating Seasonal Performance Factor (HSPF)[33]
Split System – Air Conditioner (<45 kBTU/h)	13.0	11.2	N/A
Split System – Air Conditioner (≥45 and <65 kBTU/h)	13.0	11.2	N/A
Single Package – Air Conditioner	14.0	11.8	N/A
Split System – Heat Pump (<45 kBTU/h)	14.0	11.8	8.2
Split System – Heat Pump (≥45 and < 65 kBTU/h)	14.0	11.8	8.2
Single Package – Heat Pump (<65 kBTU/h)	14.0	11.8	8.0

Fossil Fuel Fired Heating System Baseline Efficiencies

Systems Serving Single-Family Homes or Single Units[34]

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Non-weatherized oil-fired furnaces (not including mobile home furnaces)	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.82 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.82 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.84 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.82 AFUE

32 10 CFR 430.32(c)(1)
33 10 CFR 430.32(c)(1)
34 10 CFR 430.32(e)

Systems Serving Multiple Dwelling Units

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.78 AFUE or 0.80 Et
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.75 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.75 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et

Compliance Efficiency from which Incentives are Calculated

ASHP are rated under ANSI/AHRI 210/240. Cold climate ASHPs must meet the Northeast Energy Efficiency Partnerships (NEEP) Cold Climate Air Source Heat Pump (ccASHP) Specification (Version 3.0) effective January 1, 2019. The specification uses AHRI-certified performance ratings and manufacturer reported data to describe the efficiency and capacity of the unit under full and part load condition

The average seasonal heating efficiency for an ASHP with a two stage or variable speed compressor is calculated as:

$$COP_{season,ee} = a + b \; x \; HSPF \; x \; \frac{1}{3.412}$$

The average seasonal cooling efficiency for a ccASHP with a variable speed compressor is calculated as:

$$EER_{season,ee} = c + d \; x \; SEER$$

where:

a & b = Offset and slope coefficients from Tables below for heating (select based on city and scenario)
c & d = Offset and slope coefficients from Tables below for cooling (select based on city and scenario)
HSPF = Rated Heating Season Performance Factor from AHRI
SEER = Rated Seasonal Energy Efficiency Ratio from AHRI
3.412 = Conversion factor, one watt-hour equals 3.412 BTU

Summary of Variables and Data Sources

Variable	Value	Source
a & b		Coefficients to represent offset and slope from the table below to determine seasonal heating efficiency ($COP_{season,ee}$) from HSPF. Depends on city and scenario.
c & d		Coefficients to represent offset and slope from the table below to determine seasonal cooling efficiency ($EER_{season,ee}$) from SEER. Depends on city and scenario.
HSPF		Rated heating season performance factor from AHRI.
SEER		Rated seasonal energy efficiency ratio from AHRI.

Definitions of Whole House and Displacement Scenarios (considering ccASHP sizing, equipment type, and controls)

The scenarios shown in the first column below represent various specific applications of heat pumps, with heat pump type, sizing, and control strategy shown. These scenarios may be considered "sub-measures" of this measure[35]. Assigning applicable scenario(s) to program participants or participant groups is the responsibility of program designers and implementers. Where participants fall between the numeric values in the column "HP Sizing," use the scenario with the lower of the values in the column. "Single-zone ductless" means the equipment is single-zone (1-to-1 indoor to outdoor units). There may be multiple single-zone systems to achieve the HP sizing shown. The scenario "displace/replace an existing heating zone" applies only when integrated controls are configured with ductless system(s) that effectively distribute heating to an entire pre-existing zone (thermostat). It also applies when ductless mini-splits are installed in homes heated by electric resistance baseboards with room-level thermostats.

Scenario	Description	ASHP Type	Application	Controls	HP Sizing Ratio
1a	Central ASHP with different controls	Central, Ducted	Whole	Integrated/ Modulating	0.9
1b				Integrated/ Fixed capacity	
1c				DF/Either HP or Furnace	
1d				Integrated/ Modulating	1.0
2a	Ductless Mini-spilt sized at 30%, 50%, 70% and 90/100%	Single-zone Ductless	Displace	Separate	0.3
2b					0.5
2c					0.7
2d				Integrated/ Fixed Capacity	0.3
2e					0.5
2f					0.7
2g			Whole	Integrated/ Modulating	0.9
2h					1.0
3a	Ductless MULTI-split sized to 70% and 90/100%	Multi-zone Ductless	Displace	Separate	0.7
3b			Whole	Integrated/ Modulating	0.9
3c					1.0
4a			Displace	Separate	0.5

[35] Detailed descriptions of these scenarios and their parameters are found in the white paper *Savings Calculations for Residential Air Source Heat Pumps: The Basis for Modifying EFLH and Seasonal Efficiency Factors for "Whole House" and "Displacement" Applications*, Tables 2 and 3, and the associated narrative.

Scenario	Description	ASHP Type	Application	Controls	HP Sizing Ratio
4b	Compact Ducted Mini-split sized to 50% ,70% and 90/100%	Single-zone Compact Ducted	Whole	Integrated/ Modulating	0.7
4c					0.9
4d					1.0

The HP sizing should be determined using the maximum heating capacity at 5°F from the NEEP Cold Climate Heat Pump List ($QH_{5,max}$) and design heating load for the home:

$$\text{HP Sizing Ratio} = QH_{5,max} / BHL$$

The HP Sizing corresponds to the column in the table above. Choose an appropriate scenario, then use the coefficients from the tables below to determine the seasonal efficiencies and load factors.

Coefficients for Seasonal Heating Efficiency: $COP_{season,ee}$ = a + b × HSPF/3.412														
Scenario	**Albany**		**Binghamton**		**Buffalo**		**Massena**		**New York**		**Poughkeepsie**		**Syracuse**	
	a	B	a	b	a	b	a	b	a	b	a	b	a	b
1a	-0.010	0.880	0.113	0.854	0.219	0.842	-0.185	0.838	0.919	0.738	0.333	0.796	0.124	0.860
1b	-0.040	0.891	0.092	0.863	0.197	0.851	-0.168	0.830	0.888	0.750	0.301	0.813	0.093	0.871
1c	0.056	0.906	0.220	0.870	0.310	0.849	-0.057	0.922	0.945	0.741	0.579	0.802	0.183	0.875
1d	-0.117	0.902	-0.003	0.879	0.081	0.876	-0.259	0.847	0.844	0.752	0.237	0.815	-0.007	0.890
2a	2.552	0.197	2.532	0.202	2.645	0.181	2.304	0.204	2.457	0.303	2.620	0.177	2.565	0.195
2b	2.351	0.256	2.419	0.243	2.644	0.188	2.011	0.290	2.453	0.315	2.470	0.228	2.500	0.217
2c	2.441	0.228	2.480	0.224	2.619	0.198	2.358	0.203	2.617	0.271	2.459	0.239	2.550	0.206
2d	2.615	0.113	2.637	0.113	2.702	0.108	2.312	0.150	2.998	0.105	2.725	0.104	2.655	0.107
2e	2.574	0.125	2.601	0.124	2.647	0.122	2.335	0.143	2.896	0.137	2.654	0.119	2.631	0.116
2f	2.458	0.160	2.493	0.155	2.546	0.153	2.322	0.145	2.892	0.139	2.588	0.135	2.513	0.154
2g	2.351	0.172	2.382	0.169	2.440	0.161	2.125	0.178	2.826	0.143	2.424	0.162	2.415	0.163
2h	2.336	0.179	2.386	0.169	2.422	0.168	2.030	0.205	2.827	0.147	2.372	0.177	2.414	0.168
3a	-3.334	1.993	-3.307	1.991	-3.485	2.065	-2.938	1.810	-3.710	2.205	-3.093	1.929	-3.339	2.006
3b	-2.683	1.735	-2.637	1.728	-2.720	1.770	-2.004	1.446	-3.241	2.010	-2.306	1.624	-2.710	1.757
3c	-2.823	1.775	-2.783	1.769	-2.832	1.800	-1.991	1.436	-3.311	2.025	-2.395	1.645	-2.861	1.800
4a	-0.333	1.141	-0.305	1.138	-0.251	1.137	-0.852	1.263	0.373	1.026	-0.407	1.194	-0.308	1.140
4b	-0.402	1.155	-0.393	1.160	-0.300	1.147	-0.865	1.261	0.225	1.057	-0.390	1.175	-0.385	1.160
4c	-0.166	1.004	-0.019	0.963	0.018	0.961	-0.234	0.972	0.282	0.972	0.121	0.926	-0.006	0.962
4d	-0.240	1.024	-0.102	0.983	0.027	0.950	-0.321	0.993	0.224	0.984	0.110	0.920	-0.127	1.001

Coefficients for Seasonal Cooling Efficiency: $EER_{season,ee}$ = c + d × SEER														
Scenario	**Albany**		**Binghamton**		**Buffalo**		**Massena**		**New York**		**Poughkeepsie**		**Syracuse**	
	c	D	c	d	c	d	c	d	c	d	c	d	c	d
1a	4.98	0.640	8.20	0.468	4.93	0.661	6.06	0.574	4.61	0.663	4.87	0.641	5.08	0.636
1b	4.98	0.640	8.20	0.468	4.93	0.661	6.06	0.574	4.61	0.663	4.87	0.641	5.08	0.636
1c	4.98	0.640	8.20	0.468	4.93	0.661	6.06	0.574	4.61	0.663	4.87	0.641	5.08	0.636
1d	4.50	0.677	6.67	0.546	4.56	0.689	5.10	0.630	3.87	0.712	4.31	0.684	4.83	0.658
2a	11.59	0.110	11.58	0.114	11.72	0.118	11.59	0.114	11.60	0.108	11.57	0.107	11.62	0.113
2b	11.72	0.113	11.66	0.114	11.81	0.118	11.64	0.111	11.84	0.108	11.65	0.111	11.77	0.112
2c	11.81	0.126	11.75	0.117	11.98	0.128	11.81	0.116	12.06	0.122	11.91	0.121	11.85	0.124
2d	11.59	0.110	11.58	0.114	11.72	0.118	11.59	0.114	11.60	0.108	11.57	0.107	11.62	0.113
2e	11.72	0.113	11.66	0.114	11.81	0.118	11.64	0.111	11.84	0.108	11.65	0.111	11.77	0.112
2f	11.81	0.126	11.75	0.117	11.98	0.128	11.81	0.116	12.06	0.122	11.91	0.121	11.85	0.124
2g	12.09	0.139	11.83	0.125	12.11	0.147	11.90	0.130	12.11	0.150	12.17	0.137	11.97	0.140
2h	12.08	0.154	11.90	0.130	12.12	0.159	11.96	0.138	12.09	0.168	12.14	0.158	12.04	0.150
3a	7.52	0.283	2.92	0.530	3.75	0.492	5.72	0.378	3.69	0.532	3.11	0.555	6.46	0.342
3b	3.46	0.565	5.30	0.402	8.13	0.276	6.81	0.343	3.82	0.574	2.21	0.655	2.88	0.593
3c	3.47	0.595	7.69	0.282	4.59	0.507	3.33	0.565	7.53	0.371	7.06	0.386	2.70	0.625
4a	-6.75	1.106	-5.49	1.040	-5.96	1.074	-5.92	1.058	-7.61	1.149	-6.96	1.111	-6.49	1.095
4b	-8.59	1.214	-6.84	1.117	-8.07	1.198	-7.59	1.155	-10.01	1.291	-9.26	1.246	-8.25	1.198
4c	-11.15	1.366	-8.27	1.200	-10.44	1.341	-9.54	1.271	-11.71	1.395	-11.70	1.392	-10.36	1.324
4d	-11.27	1.377	-8.87	1.236	-9.76	1.303	-10.41	1.322	-12.11	1.420	-11.42	1.380	-11.63	1.400

Note that several scenarios are the same since control approach and UR do not apply for cooling (i.e. 1a,1b and 1c are all the same, 2a is the same as 2d, etc.)

Heating Load Factor

Factors in the table below ($F_{load,heating}$) are used to determine the fraction of the annual load that is met by the ASHP unit.

Fraction of Heating Load met by the ASHP ($F_{load,heating}$)							
Scenario	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**New York**	**Poughkeepsie**	**Syracuse**
1a	0.998	0.995	0.999	0.979	0.999	0.972	0.997
1b	0.994	0.987	0.994	0.957	0.997	0.948	0.991
1c	0.859	0.862	0.892	0.691	0.980	0.819	0.901
1d	0.999	0.998	1.000	0.985	1.000	0.981	0.998
2a	0.250	0.247	0.246	0.231	0.281	0.247	0.243
2b	0.389	0.384	0.389	0.368	0.442	0.388	0.379
2c	0.562	0.550	0.559	0.551	0.608	0.541	0.552
2d	0.544	0.534	0.532	0.513	0.590	0.509	0.535
2e	0.742	0.728	0.730	0.712	0.772	0.692	0.737
2f	0.862	0.854	0.851	0.820	0.889	0.810	0.859
2g	0.979	0.967	0.971	0.942	0.980	0.921	0.978
2h	0.990	0.984	0.988	0.955	0.989	0.940	0.989
3a	0.719	0.710	0.698	0.673	0.767	0.667	0.717
3b	0.956	0.941	0.937	0.918	0.963	0.899	0.953
3c	0.975	0.965	0.961	0.940	0.977	0.922	0.976
4a	0.430	0.423	0.434	0.421	0.488	0.429	0.419
4b	0.590	0.579	0.584	0.563	0.637	0.564	0.582
4c	0.973	0.962	0.966	0.936	0.978	0.918	0.975
4d	0.992	0.988	0.994	0.960	0.994	0.947	0.991

Cooling Load Factor

Factors in the table below ($F_{load,cooling}$) are used to determine the fraction of the annual load that is met by the ASHP unit.

Fraction of Cooling Load met by the ASHP ($F_{load,cooling}$)							
Scenario	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**New York**	**Poughkeepsie**	**Syracuse**
1a	0.953	0.862	0.956	0.909	0.978	0.983	0.948
1b	0.953	0.862	0.956	0.909	0.978	0.983	0.948
1c	0.953	0.862	0.956	0.909	0.978	0.983	0.948
1d	0.969	0.899	0.977	0.937	0.988	0.993	0.971
2a	0.521	0.415	0.520	0.463	0.575	0.549	0.508
2b	0.741	0.607	0.740	0.672	0.801	0.777	0.723
2c	0.879	0.756	0.877	0.816	0.923	0.912	0.864
2d	0.521	0.415	0.520	0.463	0.575	0.549	0.508
2e	0.741	0.607	0.740	0.672	0.801	0.777	0.723
2f	0.879	0.756	0.877	0.816	0.923	0.912	0.864
2g	0.949	0.857	0.952	0.905	0.977	0.980	0.945
2h	0.968	0.895	0.975	0.935	0.988	0.992	0.968
3a	0.880	0.759	0.879	0.818	0.923	0.913	0.867
3b	0.950	0.860	0.953	0.906	0.978	0.981	0.946
3c	0.968	0.896	0.974	0.935	0.988	0.992	0.969
4a	0.730	0.594	0.727	0.659	0.792	0.767	0.712
4b	0.871	0.744	0.869	0.808	0.919	0.906	0.855
4c	0.947	0.848	0.947	0.899	0.976	0.978	0.940
4d	0.966	0.888	0.970	0.930	0.987	0.991	0.965

Note that several scenarios are the same since control approach and UR do not apply for cooling (i.e. 1a,1b and 1c are all the same, 2a is the same as 2d, etc.)

Operating Hours

The Building Equivalent Full Load Hours for heating ($BEFLH_{heating}$) and for cooling ($BEFLH_{cooling}$) in the tables below represent equivalent full load operating hours for HVAC equipment based on 1% design temperature, TMY3 weather data, and the design heating load. For heating, hours from the summer period (June through September) were excluded. For Cooling, the values of EFLH from Appendix G were multiplied by a factor of 1.25 to convert to BEFLH.

Single-Family Detached Cooling $BEFLH_{cooling}$ by Vintage and City

City	Old	Average	New
Albany	403	388	349
Binghamton	249	246	198
Buffalo	418	403	345
Massena	323	313	263
NYC	838	811	788
Poughkeepsie	620	588	580
Syracuse	388	370	335

Multi-Family Low-Rise Cooling $BEFLH_{cooling}$ by Vintage and City

City	Prior to 1979	From 1979 Through 2006	From 2007 Through Present
Albany	358	369	349
Binghamton	271	274	263
Buffalo	338	343	320
Massena	288	285	273
NYC	634	688	703
Poughkeepsie	496	529	526
Syracuse	331	355	371

Single-Family Detached Heating $BEFLH_{heating}$ by Vintage and City

City	Old	Average	New
Albany	1,878	1,763	1,643
Binghamton	2,060	1,935	1,804
Buffalo	2,080	1,952	1,819
Massena	1,986	1,880	1,772
NYC	1,636	1,485	1,329
Poughkeepsie	2,044	1,912	1,776
Syracuse	1,960	1,842	1,720

Multi-Family Low-Rise Heating $BEFLH_{heating}$ by Vintage and City

City	Pre-war uninsulated brick	Prior to 1979	From 1979 Through 2006	From 2007 Through present
Albany	1,889	1,751	1,720	1,239
Binghamton	2,375	2,244	2,117	1,528
Buffalo	2,178	2,072	2,066	1,501
Massena	2,436	2,220	2,254	1,639
NYC	1,698	1,287	1,229	855
Poughkeepsie	1,457	1,520	1,476	1,047
Syracuse	2,372	1,998	2,050	1,437

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

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Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
12-17-8	12/31/2017
9-18-4	9/28/2018
2-20-2	2/28/2020

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HEATING, VENTILATION AND AIR CONDITIONING (HVAC)

HEAT PUMP – WATER-TO-AIR GROUND SOURCE (GSHP)

Measure Description

This measure covers the installation of an ENERGY STAR® certified Ground Source Heat Pump (GSHP) system with a closed loop heat exchanger field, which provides heating and cooling for space conditioning by the water to air transference of ground temperatures through a typical air-duct distribution system in a residential home.[36] These systems can optionally have an integrated desuperheater or a dedicated Domestic Hot Water (DHW) water-to-water heat pump that supplements domestic hot water heating in conjunction with space conditioning. Methods for calculating annual DHW energy savings are presented below.

This measure applies to GSHPs in residential applications, and where each GSHP unit has its own dedicated loop pump. It does not apply to large GSHP systems with multiple heat pump units with centralized ground loop pumping.

The GSHP analysis associated with this measure is based on several assumptions consistent with best practice design for a quality GSHP installation:

- Current Residential code and Federal standard (Code of Federal Regulations 10 CFR 430.32, ECCCNYS 2016, NYCECC 2016 or local legislation) applicable to the installation should be referenced for correct baseline system and efficiency values.

- Systems shall be sized in accordance with ACCA Manual S based on building loads calculated in accordance with ACCA Manual J.[37,38,39]

- The building peak heating load in New York typically exceeds the peak cooling load, therefore it is assumed that the GSHP runs at part-load during peak cooling hours.

- The ground loop heat exchanger is adequately sized and installed properly to allow the GSHP to meet the peak heating load without electric resistance auxiliary heat.

- The GSHP is equipped with either a two stage or variable-speed compressor system, a variable speed or constant speed ground loop circulator pump, and a variable-speed blower distribution fan. This is a compliance requirement for application of this measure.

[36] "Residential homes" means detached one- and two-family dwellings and townhouses not more than three stories above-grade in height with a separate means of egress and their accessory structures, and one-family dwellings converted to bed and breakfast dwellings.
[37] ECCCNYS 2016, Section R403.7
[38] 2016 NYCECC, Section R403.7
[39] ECCNYS 2016 and 2016 NYCECC require that systems serving multiple dwelling units follow Sections C403 and C404 of the respective codes.

- The GSHP efficiency is rated in accordance with ISO 13256-1, and AHRI-certified performance ratings are provided by the manufacturer showing the efficiency and capacity of the unit under full and part load conditions.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Note: The algorithms below address energy impacts associated with space conditioning load only. See the Methods for Calculating Annual Domestic Hot Water Energy Savings from an Integrated Desuperheater or Dedicated Water Source Heat Pump Water Heater (WSHPWH) section of this measure for estimating savings associated with installation of a desuperheater or water source heat pump water heater.

Annual Electric Energy Savings

$$\Delta kWh = \left[\frac{BCL}{1{,}000} \times \left(\frac{F_{CEC}}{SEER_{baseline}} - \frac{1}{EER_{season,ee}}\right) \times BEFLH_{cooling}\right] + \left[\frac{BHL}{3{,}412} \times \left(\frac{F_{EH}}{COP_{baseline}} - \frac{1}{COP_{season,ee}}\right) \times BEFLH_{heating}\right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{BCL}{1{,}000} \times \left(\frac{F_{CEC}}{EER_{baseline}} - \frac{1}{EER_{GLHP,full,ee}}\right) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta therms = \frac{BHL}{100{,}000} \times \frac{F_{FFH}}{AFUE_{baseline}} \times BEFLH_{heating}$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Summer Peak Coincident Demand Savings
Δtherms = Annual fossil fuel savings
AFUE = Annual fuel utilization efficiency, seasonal efficiency for fuel heat equipment
$_{baseline}$ = Baseline condition or measure
BCL = Building Cooling Load at design conditions (BTU/h)
$BEFLH_{cooling}$ = Cooling equivalent full-load hours based on building design load
$BEFLH_{heating}$ = Heating equivalent full-load hours based on building design load
BHL = Building Heating Load at design conditions (BTU/h)
CF = Coincidence Factor
COP = Coefficient of performance, ratio of output energy/input energy
COP_{season} = Coefficient of performance on a seasonal basis. Adjusted to account for fan and pump power.
$_{ee}$ = Energy efficient condition or measure
EER = Energy efficiency ratio (BTU/watt-hour)

$EER_{GLHP, full}$ = Full load energy efficiency ratio (BTU/watt-hours)
EER_{season} = Energy efficiency ratio (BTU/watt-hour) at part-load seasonally-adjusted for fan and pump power
F_{CEC} = Central electric cooling factor flag; used to account for the presence or absence of a central electric cooling system
F_{EH} = Electric heating factor flag; used to account for the presence or absence of an electric heating system
F_{FFH} = Fossil fuel heating flag; used to account for the presence or absence of a fossil fuel-fired heating system
SEER = Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour,(used for average U.S. location/region)
3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000 = Conversion factor, one kW equals 1,000 Watts
100,000 = Conversion factor, (BTU/therm), one therm equals 100,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
BCL		Building cooling load at design conditions, from application. Building cooling load calculated in accordance with ACCA Manual J.
BHL		Building heating load at design conditions, from application. Building heating load calculated in accordance with ACCA Manual J.
F_{CEC}		If a central electric cooling system is present, set equal to 1. Otherwise, set equal to 0.
F_{EH}		If a central electric heating system is present, set equal to 1. Otherwise, set equal to 0.
F_{FFH}		If a fossil fuel-fired heating system is present, set equal to 1. Otherwise, set equal to 0.
$SEER_{baseline}$		Seasonal electric cooling energy efficiency rating of baseline equipment. See Baseline Efficiency section below for details.
$EER_{baseline}$		Electric cooling energy efficiency rating of baseline equipment. See Baseline Efficiency section below for details.
$EER_{season,ee}$		Energy efficiency ratio from the manufacturer's catalog data AHRI ratings adjusted to account for applied fan and pump power. See Compliance Efficiency section below for details.
$EER_{GLHP,full}$		Full load energy efficiency ratio at AHRI rated conditions. Corresponds to fluid temperature of 77ºF
$AFUE_{baseline}$		Annual fuel utilization efficiency, seasonal energy efficiency for fuel heating equipment. See Baseline Efficiency section below for details.
$COP_{baseline}$		Electric heating energy efficiency rating of baseline equipment. See Baseline Efficiency section below for details.

Variable	Value	Notes
$COP_{season,ee}$		Coefficient of performance (ratio of heat delivered to energy input to the compressor) from the manufacturer's catalog data adjusted to account for applied fan and pump power. See Compliance Efficiency section below for details.
$BEFLH_{cooling}$		Lookup based on building type, vintage and location from table below.
$BEFLH_{heating}$		Lookup based on building type, vintage and location from table below.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[40]

Baseline Efficiencies from which Energy Savings are Calculated

The baselines used in this measure are determined by the type of equipment that would have been installed without the influence of the program supporting the installation of this measure. This allows for an analysis that does not depend on a typical 'like-for-like' replacement scenario.

A GSHP system can be considered a normal replacement scenario for electric resistance heating (with or without a central electric cooling system), an Air Source Heat Pump (ASHP) system (that provides space heating and cooling), or a fossil fuel fired heating system (with or without a central electric cooling system).

Tables are provided below to show the baseline efficiencies for appropriate Electric Heating and Cooling System Baseline Efficiencies, and appropriate Fossil Fuel Fired Heating System Baseline Efficiencies.

Electric Cooling and Heating System Baseline Efficiencies

Product Class	Seasonal Energy Efficiency Ratio (SEER)[41]	Energy Efficiency Ratio (EER)	Heating Seasonal Performance Factor (HSPF)[42]
Split System – Air Conditioner (<45 kBTU/h)	13.0	11.2	N/A
Split System – Air Conditioner (≥45 and <65 kBTU/h)	13.0	11.2	N/A
Single Package – Air Conditioner	14.0	11.8	N/A

[40] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps' research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, however is referenced by the Mid-Atlantic TRM Version 7.0 published May 2017 and by M. M. Straub, using available information from Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus.

[41] 10 CFR 430.32 (c)(1)

[42] 10 CFR 430.32 (c)(1)

Product Class	Seasonal Energy Efficiency Ratio (SEER)[41]	Energy Efficiency Ratio (EER)	Heating Seasonal Performance Factor (HSPF)[42]
Split System – Heat Pump (<45 kBTU/h)	14.0	11.8	8.2
Split System – Heat Pump (≥45 and < 65 kBTU/h)	14.0	11.8	8.2
Single Package – Heat Pump (<65 kBTU/h)	14.0	11.8	8.0

Fossil Fuel Fired Heating System Baseline Efficiencies
(Systems Serving Single-Family Homes or Single Units)[43]

Equipment Type	Size Range	ECCCNYS and NYCECC Minimum Efficiency for Climate Zones 4, 5, and 6
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Non-weatherized oil-fired furnaces (not including mobile home furnaces)	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.82 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.80 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.84 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.82 AFUE

For scenarios where the baseline heating system is electric resistance heat, the baseline efficiency is assumed to be a COP of 1.0.

For scenarios where there is new construction or substantial renovation, the baseline is assumed to be a gas fired warm air furnace with a central air conditioning system when natural gas service is available at the project site, and an ASHP system when natural gas service is not available at the project site.

For scenarios where the baseline heating system is an ASHP, additional consideration is given to account for the significant difference between the rating conditions for HSPF and the typical operating conditions in New York State, as shown below:

The HSPF is the AHRI-rated heating seasonal average efficiency expressed in terms of BTU/watt-hour. A seasonally-adjusted $COP_{baseline}$ of an air-source heat pump is used in the above equations. This adjusted baseline COP shall be calculated as:

$$COP_{baseline} = \frac{HSPF \times F_{HSPF}}{3.412}$$

where:

HSPF = Heating seasonal performance factor of the baseline system

[43] 10 CFR 430.32(e)

F_{HSPF} = HSPF Climate Adjustment Factor, from table below
3.412 = Conversion factor, one watt-hour equals 3.412 BTU

HSPF Climate Adjustment Factor (F_{HSPF})

City	HSPF < 8.5	HSPF ≥ 8.5
Albany	0.70	0.67
Binghamton	0.68	0.65
Buffalo	0.73	0.70
Massena	0.59	0.56
NYC	0.80	0.78
Poughkeepsie	0.62	0.59
Syracuse	0.69	0.66

For scenarios where the baseline cooling system is an Air Source Heat Pump (ASHP), no additional consideration is given to account for the difference between the rating conditions for SEER and the typical operating conditions in New York State, because the differences between the rating conditions and the typical operating conditions are small.

Replacement of room air conditioners is not addressed in this analysis. To capture savings associated with removal of room air conditioners, refer to the Air Conditioner – Room (RAC) Recycling measure in the Single and Multi-Family Residential Measures section of this TRM.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® certified GSHP heat pump system as defined in the Measure Description section above.

The average seasonal cooling efficiency for a GSHP with a two-stage or variable speed compressor is calculated as:

$$EER_{season,ee} = \Big(\big(F_{full} \times EER_{GLHP,full} \times 1.09 \times F_{pump,full}\big) + \big(F_{part} \times EER_{GLHP,part} \times F_{pump,part}\big)\Big) \times F_{dist,c}$$

The average seasonal heating efficiency for a GSHP with a two stage or variable speed compressor is calculated as:

$$COP_{season,ee} = \Big(\big(F_{full} \times COP_{GLHP,full} \times 1.08 \times F_{pump,full}\big) + \big(F_{part} \times COP_{GLHP,part} \times F_{pump,part}\big)\Big) \times F_{dist,h}$$

where:
$COP_{GLHP,full}$ = Rated COP of the unit at GLHP full load heating conditions
$COP_{GLHP,part}$ = Rated COP of the unit at GLHP part load heating conditions
$EER_{GLHP,full}$ = Rated EER of the unit at GLHP full load cooling conditions
$EER_{GLHP,part}$ = Rated EER of the unit at GLHP part load cooling conditions

$F_{dist,c}$ = Factor to adjust the cooling efficiency to account for additional fan power
$F_{dist,h}$ = Factor to adjust the heating efficiency to account for additional fan power
F_{full} = Seasonal weighting factor for full load efficiency
F_{part} = Seasonal weighting factor for part load efficiency
$F_{pump, part}$ = Factor to adjust part load efficiency to account for additional pumping power
$F_{pump,full}$ = Factor to adjust full load efficiency to account for additional pumping power
1.09 = Correction for change in EER[44]
1.08 = Correction for change in COP[45]

Summary of Variables and Data Sources

Variable	Value	Source
$COP_{GLHP,full}$		The rated COP of the unit at GLHP full load (or standard) heating conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 32°F.
$COP_{GLHP,part}$		The rated COP of the unit at GLHP part load heating conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 41°F.
$EER_{GLHP,full}$		The rated EER of the unit at GLHP full load (or standard) cooling conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 77°F.
$EER_{GLHP,part}$		The rated EER of the unit at GLHP part load cooling conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 68°F.
$F_{dist,c}$		Factor to adjust the cooling efficiency to account for additional fan power that would be required, beyond the fan power corresponding to zero static in rated COP. Choose the appropriate factor from the Distribution Correction Factors table below.
$F_{dist,h}$		Factor to adjust the heating efficiency to account for additional fan power that would be required, beyond the fan power corresponding to zero static in rated COP. Choose the appropriate factor from the Distribution Correction Factors table below.
F_{full}	0.25	Seasonal weighting factor for full load efficiency = 0.25. Based in part on observed mix of low and high stage operation from field testing.[46]

44 Correction for 9% change in EER as the entering fluid temperature decreases from 77°F to 68°F. The 1% per °F was observed from published performance data as well as in the IGSHPA Design Manual.

45 Correction for 8% change in COP as the entering fluid temperature increases from 32°F to 40°F. The 1% per °F was observed from published performance data as well as in the IGSHPA Design Manual.

46 New York State Energy Research and Development Authority (NYSERDA) 2017 "Analysis of Water Furnace Geothermal Heat Pump Sites in New York State with Symphony Monitoring System," NYSERDA Report Number 18-03. Prepared by CDH Energy Corp., Cazenovia, NY. nyserda.ny.gov/publications.

Variable	Value	Source
F_{part}	0.75	Seasonal weighting factor for part load efficiency = 0.75. Based in part on observed mix of low and high stage operation from field testing.[47]
$F_{pump,full}$		Factor to adjust the full load efficiency to account for additional pumping power used by the system. Choose the appropriate factor from Pumping Power Adjustment Factor table below.
$F_{pump,part}$		Factor to adjust the part load efficiency to account for additional pumping power used by the system. Choose the appropriate factor from Pumping Power Adjustment Factor table below.

Loop Pumping Power Correction Factor ($F_{pump,full}$ and $F_{pump,part}$)

A correction factor for pumps ($F_{pump,full}$ and $F_{pump,part}$) is required because the rated efficiency values only include the pumping energy associated with the water-side pressure drop through the heat pump unit (typically about 5-10 Watts per nominal ton). Actual pumping power is much higher. The ASHRAE GSHP Design Guide (Kavanaugh and Rafferty 2015) developed a grading system that assigns scores based on the amount of pumping power per installed ton. For instance, it gives a grade of "A" to system that uses 45 Watts per nominal ton and a grade of "B" to a system that uses 60 Watts per nominal ton.

Analysis of observed pumping power from 45 to 90 Watts/ton was performed to determine the impact of loop pumping power on efficiency. Results are shown in the Pumping Factors table below.[48]

Pumping Power Adjustment Factors

Different factors are required for different loop pumping power levels and loop pump control strategies. For part load performance there are multiple ways to control the pump at low stage:

- the pump can maintain constant flow regardless of compressor stage.
- the pump stages flow in proportion to the compressor capacity.
- the pump can be variable speed and modulate with the variable speed compressor.

A constant speed loop pump results in poor performance since the pump power becomes a relatively larger portion of total power at low stage. Variable speed pumping with a variable speed compressor results in the best performance. The penalty for constant speed pumping is highest for units with variable speed compressors. The last consideration is the low-to-high capacity ratio (CR), which can be calculated as follows:

$$CR = \frac{QC_{GLHP,part}}{QC_{GLHP,full}}$$

[47] Ibid.

[48] Henderson, H.I., 2019. White Paper Savings Calculations for Residential Ground Source Heat Pumps: The Basis for Equivalent Full Load Hours (EFLH) and Seasonal Efficiency Factors. Prepared for the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Public Service.

where:

CR = Capacity ratio of part-load cooling capacity to full-load heating capacity.
$QC_{GLHP,part}$ = Part-load cooling capacity rating from AHRI certificate.
$QC_{GLHP,full}$ = Full-load heating capacity rating from AHRI certificate.

The values of QC are the rated full and part load performance values from AHRI. Units with two stage compressors typically have a value of CR of approximately 0.75. Units with variable speed compressors typically have a CR of approximately 0.40.

The table below presents the values of $F_{pump,full}$ and $F_{pump,part}$ that correspond to each loop pump arrangement (e.g. pumping control strategy, CR, and pumping power). The full load pumping factors are typically 0.89 to 0.94. Part load factors can range from 0.69 to 0.94 depending on the pumping control strategy, the capacity ratio of the heat pump, and the pumping power. The factor closest to the actual situation should be used.

Pumping Factors ($F_{pump,full}$ and $F_{pump,part}$)

Pumping Control Strategy	**Capacity Ratio (CR)**	**Pumping Power**							
		45 Watts/ton		60 Watts/ton		75 Watts/ton		90 Watts/ton	
		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
Full load ($F_{pump,full}$)		0.94	0.94	0.93	0.92	0.91	0.90	0.89	0.89
Part load – constant flow pumping ($F_{pump,part}$)	0.75	0.89	0.91	0.86	0.89	0.83	0.86	0.80	0.84
Part load – constant flow pumping ($F_{pump,part}$)	0.40	0.81	0.85	0.77	0.81	0.72	0.77	0.69	0.74
Part load – staged pumping ($F_{pump,part}$)	0.75	0.92	0.94	0.89	0.91	0.87	0.89	0.84	0.87
Part load – staged pumping ($F_{pump,part}$)	0.40	0.92	0.94	0.89	0.91	0.87	0.89	0.84	0.87
Part load – variable pumping ($F_{pump,part}$)	0.40	0.94	0.95	0.92	0.93	0.90	0.92	0.88	0.90

Distribution Power Correction

For GSHP systems with an air-duct distribution system, the fan power included in the rated efficiencies corresponds to zero external static pressure and therefore is smaller than would be expected for an actual application. The indoor fan power included in the ISO 13256-1 test procedure is estimated to be approximately 0.15 Watts/cfm for permanent split-capacitor fan motors and 0.11 Watts/cfm for electrically commutated fan motors.[49]

[49] Ibid.

The purpose of the distribution (i.e., fan or pump) correction factor, $F_{dist,h}$ and $F_{dist,c}$ is to determine the equivalent amount of distribution power for the baseline system, such as a fuel fired furnace or boiler, or a heat pump. The correction factor considers the differential distribution power between the GSHP and the baseline system. The Distribution Correction Factors to correct GSHP Seasonal Efficiency for typical baseline scenarios summarized in the table below:

Distribution Correction Factors ($F_{dist,h}$ and $F_{dist,c}$)

	If baseline system is a Furnace with conventional air conditioning	If baseline system is a Boiler with conventional air conditioning	If baseline system is a Central air source heat pump
Heating ($F_{dist,h}$)	0.96	0.96	0.97
Cooling ($F_{dist,c}$)	0.95	0.95	0.95

Note: Based on furnace and boiler ancillary power of 137 Watts

Operating Hours

The Building Equivalent Full Load Hours for heating ($BEFLH_{heating}$) and for cooling ($BEFLH_{cooling}$) in the tables below represent equivalent full load operating hours for HVAC equipment based on 1% design temperature, TMY3 weather data, and the design heating load. For heating, hours from the summer period (June through September) were excluded. For Cooling, the values of EFLH from Appendix G were multiplied by a factor of 1.25 to convert them to BEFLH.

Single-Family Detached Cooling $BEFLH_{cooling}$ by Vintage and City

City	Old	Average	New
Albany	403	388	349
Binghamton	249	246	198
Buffalo	418	403	345
Massena	323	313	263
NYC	838	811	788
Poughkeepsie	620	588	580
Syracuse	388	370	335

Multi-Family Low-Rise Cooling $BEFLH_{cooling}$ by Vintage and City

City	Prior to 1979	From 1979 Through 2006	From 2007 Through Present
Albany	358	369	349
Binghamton	271	274	263
Buffalo	338	343	320
Massena	288	285	273
NYC	634	688	703
Poughkeepsie	496	529	526
Syracuse	331	355	371

Single-Family Detached Heating $BEFLH_{heating}$ by Vintage and City

City	Old	Average	New
Albany	1,878	1,763	1,643
Binghamton	2,060	1,935	1,804
Buffalo	2,080	1,952	1,819
Massena	1,986	1,880	1,772
NYC	1,636	1,485	1,329
Poughkeepsie	2,044	1,912	1,776
Syracuse	1,960	1,842	1,720

Multi-Family Low-Rise Heating $BEFLH_{heating}$ by Vintage and City

City	Pre-war uninsulated brick	Prior to 1979	From 1979 Through 2006	From 2007 Through present
Albany	1,889	1,751	1,720	1,239
Binghamton	2,375	2,244	2,117	1,528
Buffalo	2,178	2,072	2,066	1,501
Massena	2,436	2,220	2,254	1,639
NYC	1,698	1,287	1,229	855
Poughkeepsie	1,457	1,520	1,476	1,047
Syracuse	2,372	1,998	2,050	1,437

Methods for Calculating Annual Domestic Hot Water Energy Savings from an Integrated Desuperheater or Dedicated Water Source Heat Pump

GSHP systems can reduce DHW energy consumption by two optional methods: 1) using a GSHP unit with an optional desuperheater or 2) installing an additional water-to-water heat pump (WWHP) dedicated to meeting the DHW load.

When a desuperheater is installed with a GSHP system, the energy consumed by a typical DHW appliance can be reduced. The waste heat from the compressor of the GSHP system is transferred through a heat exchanger to heat or preheat water that is delivered to a storage tank-type water heater. The benefit of the desuperheater varies throughout the year and depends on whether the system is operating in heating mode or cooling mode, and the duration of compressor operation. In the cooling mode, waste heat from the compressor is transferred to heat domestic hot water instead of the to the closed loop heat exchanger field. In the heating mode water heating is supplied at the heating COP of the heat pump. A desuperheater only heats DHW when the GSHP unit runs to meet the space heating or cooling load.

When a WWHP that is dedicated to DHW is added to the ground loop, the dedicated WWHP operates in response to the DHW loads, independent of GSHP unit operation to meet space loads. Therefore, the energy savings are more consistent across the year.

In this analysis, installation of a desuperheater is assumed to displace a percentage of the total DHW load, depending on the size of the DHW load. The dedicated WWHP more consistently displaces a larger portion of the DHW load. Electric demand impacts are not considered at this time.

$$\Delta therms_{GSHP-DHW} = \frac{Q_{GSHP-DHW}}{100{,}000} \times \frac{F_{FFDHW}}{UEF_{baseline}}$$

$$\Delta kWh_{GSHP-DHW} = \frac{Q_{GSHP-DHW}}{3{,}412} \times \left(\frac{F_{EDHW}}{UEF_{baseline}} - \frac{1}{COP_{GSHP-DHW}}\right)$$

$$Q_{GSHP-DHW} = F_{GSHP-DHW} \times GPD \times 365 \times 8.33 \times \Delta T_{main}$$

For a desuperheater

$$F_{GSHP-DHW} = F_{desup}$$

$$COP_{GSHP-DHW} = \frac{COP_{desup}}{F_{desup,htg\ mode}}$$

For a dedicated WWHP

$$F_{GSHP-DHW} = 0.95$$

$$COP_{GSHP-DHW} = COP_{AHRI,GLHP} \times 0.9$$

where:

$\Delta therms_{GSHP-DHW}$	= Fossil fuel energy displaced by a desuperheater or dedicated WWHP
$\Delta kWh_{GSHP-DHW}$	= Electricity displaced by desuperheater or dedicated WSHPWH operation, considering that desuperheater operation in the heating mode increases energy use
$COP_{AHRI,GLHP}$	= Rated COP for a per ISO13256-2 at GLHP conditions (32°F source, 104°F load)
COP_{desup}	= Overall annual COP of desuperheater (average across summer and winter)
$COP_{GSHP-DHW}$	= Overall annual COP of desuperheater or dedicated WWHP
F_{desup}	= Fraction of annual DHW load served by a desuperheater
$F_{desup,htg\ mode}$	= Fraction of desuperheater operation that occurs in heating mode
F_{EDHW}	= Flag indicating that baseline DHW system is electric
F_{FFDHW}	= Flag indicating that baseline DHW system is fossil fuel fired
$F_{GSHP-DHW}$	= Fraction of annual DHW load served by a desuperheater or dedicated WWHP
GPD	= Gallons per day per each unit
$Q_{GSHP-DHW}$	= Annual DHW load served by desuperheater or dedicated WWHP, BTU
$UEF_{baseline}$	= Uniform energy factor of baseline DHW appliance (gas or electric)
ΔT_{main}	= Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F)
0.9	= Correction factor from AHRI rated conditions to 40°F source, 115°F load.
0.95	= Fraction of annual DHW load served by dedicated WWHP
8.33	= Energy required (BTU) to heat one gallon of water by one-degree Fahrenheit

365	= Days in one year
3,412	= Conversion factor, one kWh equals 3,412 BTU
100,000	= Conversion factor (BTU/therm), one therm equals 100,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
COP_{desup}		From application
F_{desup}		Choose annual desuperheater fraction from table as function of water use (GPD). Fraction of total DHW load met by desuperheater. If no desuperheater is present, set equal to 0.
$F_{desup,htg\ mode}$	0.72 for NY 0.86 for other cities	Fraction of desuperheater operation that occurs in the heating mode
F_{EDHW}	1 for electric DHW	Flag indicating baseline DHW is electric
F_{FFDHW}	1 for gas-fired DHW	Flag indicating baseline DHW is fossil fuel-fired
GPD	17.2 × # of people	Calculated based on number of people served by the system. If unknown, use 46 GPD.
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{set}	130	Water heater set point temperature (°F).
$UEF_{baseline}$		Uniform Energy Factor of the baseline condition. See Baseline Efficiencies section for details regarding derivation of this input.
ΔT_{main}	T_{set} - T_{main}	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F).

Desuperheater Annual Load Fraction

GPD	Fraction of DHW Load met by Desuperheater (F_{desup}, %)[50]
35	36%
45	30%
55	26%
65	22%

Note: Based on DHW set point of 130°F.

[50] Based on an analysis using results from Carlson (1997) combined with bin data for NY cities, as shown in Appendix E of the GSHP White Paper (Henderson 2019). These factors consider the net impact on DHW system, after distribution losses from desuperheater piping. A Geolink report for Albany implied a fraction of 50% with usage of 54 gal/day, ignoring distribution losses.

Cold Water Inlet Temperature (T_{main})
Supply water main temperatures vary according to climate and are approximately equal to the annual average outdoor temperature plus 6°F.[51] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[52] (°F)	T_{main} (°F)
Albany	48.3	54.3
Binghamton	46.3	52.3
Buffalo	48.3	54.3
Massena	43.5	49.5
NYC	55.4	61.4
Poughkeepsie	49.8	55.8
Syracuse	48.3	54.3

Baseline Efficiencies from which Energy Savings are Calculated
The baseline condition is a minimally code compliant water heater of type (storage-type or instantaneous) equivalent to the existing water heater and with tank volume (where applicable), input capacity and draw pattern equivalent to the efficient water heater. For new construction, the baseline condition is a minimally code compliant storage-type water heater with tank volume, input capacity and draw pattern equivalent to the efficient water heater. $UEF_{baseline}$ shall be calculated as a function of qualifying equipment tank volume (vt) for storage type water heaters. A Medium draw pattern should be assumed for storage type water heaters with rated storage capacity ≤ 50 gallons and a High draw pattern should be assumed otherwise.[53]

Residential Water Heaters[54]

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	Uniform Energy Factor
Gas-Fired Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.3456 - (0.0020 x vt*)
		Low	0.5982 - (0.0019 x vt)
		Medium	0.6483 - (0.0017 x vt)
		High	0.6920 - (0.0013 x vt)
	> 55 gal and ≤ 100 gal	Very Small	0.6470 - (0.0006 x vt)
		Low	0.7689 - (0.0005 x vt)
		Medium	0.7897 - (0.0004 x vt)
		High	0.8072 - (0.0003 x vt)

[51] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory
[52] Average annual outdoor temperatures taken from NCEI 1981-2010 climate normals.
[53] Based on review of typical usage bins for AHRI certified residential water heating equipment. (https://www.ahridirectory.org/ahridirectory/pages/home.aspx)
[54] 10 CFR 430.32(d)

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	Uniform Energy Factor
Electric Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.8808 - (0.0008 x vt)
		Low	0.9254 - (0.0003 x vt)
		Medium	0.9307 - (0.0002 x vt)
		High	0.9349 - (0.0001 x vt)
	> 55 gal and ≤ 120 gal	Very Small	1.9236 - (0.0011 x vt)
		Low	2.0440 - (0.0011 x vt)
		Medium	2.1171 - (0.0011 x vt)
		High	2.2418 - (0.0011 x vt)

*v_t = tank volume in gallons

First Hour Rating vs. Draw Pattern (Storage Type Only)[55]

First Hour Rating	Draw Pattern
< 18 gallons	Very Small
≥ 18 and < 51 gallons	Low
≥ 51 and < 75 gallons	Medium
≥ 75 gallons	High

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. 10 CFR 430.32 Energy and water conservation standards and their compliance dates. Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
2. BG&E: Development of Residential Load Profile for Central Air Conditioners and Heat Pumps, via *Mid-Atlantic Technical Reference Manual Version 6.0*, May 2016 Available from: http://www.neep.org/mid-atlantic-technical-reference-manual-v6

[55] 10 CFR 429.17

3. Building America House Simulation Protocols, Robert Hendron and Cheryn Engebrecht, National Renewable Energy Laboratory, October 2010 Available from: https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/house_simulation_revised.pdf
4. Carlson, S. 1997. "Geothermal Heat Pump Performance in Heating Dominated Climates." Presented at Heat Pumps in Cold Climates, 3rd International Technical Conference. August 11-12. Wolfville, Nova Scotia.
5. ECCCNYS, 2016, per IECC 2015; Section R403.7 Available from: https://codes.iccsafe.org/public/document/IECC2015NY-1/chapter-4-re-residential-energy-efficiency
6. Fairey, P., D. Parker, B Wilcox, M Lombardi. *Climate Impacts on Heating Seasonal Performance Factor (HSPF) and Seasonal Energy Efficiency Ratio (SEER) for Air Source Heat Pumps*, ASHRAE Transactions, 110(2): 178-88.
7. *Guide to Geothermal Heat Pumps* (February 2011) U. S. Department of Energy, Energy Efficiency and Renewable Energy, DOE/EE-0385
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10. Kavanaugh, S and Rafferty, K (2015): *Geothermal Heating and Cooling, Design of Ground-Source Heat Pump Systems* RP-1674, Atlanta, GA. ASHRAE Inc.
11. *Manual J Residential Load Calculation*, Arlington, VA. Air Conditioning Contractors Association
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13. M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 Available from: https://www.sciencedirect.com/science/article/pii/S1040619011001941
14. Monitored data from geothermal heat pump systems installed in New York State submitted August 2015 by the New York Geothermal Energy Organization and reviewed by NYS DPS Staff.
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16. Rudd, A., H.I. Henderson, D. Bergey & D. Shirey, 2013. 'Energy Efficiency and Cost Assessment of Humidity Control Options for Residential Buildings.' ASHRAE Research Report RP1449, April. Table 5.
17. *Water Source Heat Pumps – Testing and Rating for Performance – Part 1: Water to Air and Brine to Air Heat Pumps* (2012) Arlington, VA. ANSI/ASHRAE/ISO Standard 13256-1:1998 (RA 2012), AHRI, 2012.

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
4-16-1	3/31/2016
6-17-6	6/30/2017
3-18-11	3/29/2018
2-20-3	2/28/2020

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HEATING, VENTILATION AND AIR CONDITIONING (HVAC)

AIR CONDITIONER AND HEAT PUMP – PACKAGED TERMINAL

Measure Description

This measure covers the installation of high efficiency packaged terminal air conditioners and heat pumps in residential and multifamily applications.

Packaged Terminal Air Conditioner (PTAC)
A wall sleeve and a separate un-encased combination of heating and cooling assemblies specified by the manufacturer and intended for mounting through the wall. It includes refrigeration components, separable outdoor louvres, forced ventilation, and heating availability by purchaser's choice of, at least, hot water, steam, or electrical resistance heat.

Note: *Models designated as "cooling only" units need not include heating elements if the physical characteristics and arrangement of the refrigeration system are identical to those of models with heating availability.*[56]

Packaged Terminal Heat Pump (PTHP)
A separate un-encased refrigeration system installed in a cabinet having a function and configuration similar to that of a packaged terminal air-conditioner. It uses reverse cycle refrigeration as its prime heat source and should have other supplementary heat source(s) available to purchasers with the choice of, at least, hot water, steam, or electric resistance heat.[57,58]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \left[\begin{array}{c}\left(\frac{kBTU/h_{cooling}}{unit} \times \left(\frac{F_{CEC}}{EER_{baseline}} - \frac{1}{EER_{ee}}\right) \times EFLH_{cooling}\right) \\ + \\ \left(\frac{kBTU/h_{heating}}{unit \times 3.412} \times \left(\frac{F_{EH}}{COP_{baseline}} - \frac{1}{COP_{ee}}\right) \times EFLH_{heating}\right)\end{array}\right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \left[\frac{kBTU/h_{cooling}}{unit} \times \left(\frac{F_{CEC}}{EER_{baseline}} - \frac{1}{EER_{ee}}\right) \times CF\right]$$

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[56] AHRI Standard 310/380 – 2014
[57] Ibid.
[58] Replacement unit shall be factory labeled as follows: "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY: NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS." Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406 mm) in height and less than 42 inches (1067 mm) in width.

Annual Fossil Fuel Energy Savings

$$\Delta therms = units \times \left(\frac{kBTU/h_{heating}}{unit} \times \frac{F_{FFH}}{Eff_{heating,baseline}} \times \frac{EFLH_{heating}}{100} \right)$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
Δtherms	= Annual fossil fuel savings
units	= Number of measures installed under the program
$_{baseline}$	= Baseline condition or measure
$_{ee}$	= Energy efficient condition or measure
$kBTU/h_{cooling}$	= Output cooling capacity in kBTU/h (at AHRI standard rating conditions)
$kBTU/h_{heating}$	= Output heating capacity in kBTU/h (at AHRI standard high-temperature rating conditions)
F_{CEC}	= Central electric cooling flag; used to account for the presence or absence of a central electric cooling system
F_{EH}	= Electric heating flag; used to account for the presence or absence of an electric heating system in the baseline case
F_{FFH}	= Fossil fuel heating flag; used to account for the presence or absence of a fossil fuel-fired heating system in the baseline case
EER	= Energy efficiency ratio, measurement of cooling capacity for a unit (in BTU/hour) / electrical energy used (watts) (at AHRI standard rating conditions)
COP	= Coefficient of performance, ratio of output energy/input energy (at AHRI standard high-temperature rating conditions)
$Eff_{heating}$	= Fuel heating energy efficiency rating of equipment.
$EFLH_{cooling}$	= Cooling equivalent full-load hours
$EFLH_{heating}$	= Heating equivalent full-load hours
CF	= Coincidence factor
3.412	= Conversion factor, one watt-hour equals 3.412 BTU
100	= Conversion factor, one therm equals 100 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
$kBTU/h_{cooling}$		From application
$kBTU/h_{heating}$		From application
F_{CEC}		If a central electric cooling system is present, set equal to 1. Otherwise, set equal to 0.
F_{EH}		If a central electric heating system is present, set equal to 1. Otherwise, set equal to 0.
F_{FFH}		If a fossil fuel-fired heating system is present, set equal to 1. Otherwise, set equal to 0.
$EER_{baseline}$		Calculate from Baseline Efficiencies table below based on equipment type, size category and capacity.
EER_{ee}		From application

Variable	Value	Notes
$COP_{baseline}$		Calculate from Baseline Efficiencies table below based on equipment type, size category and capacity.
COP_{ee}		From application
$Eff_{,heating,baseline}$		From Fossil Fuel Fired Heating System Baseline Efficiencies table below.
$EFLH_{cooling}$		From application. If unknown, lookup based on building type, vintage and location from Appendix G.
$EFLH_{heating}$		From application. If unknown, lookup based on building type, vintage and location from Appendix G.
CF	0.69	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[59]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline for a non-fuel switching normal replacement at end of the appliance effective useful life (EUL), in new construction, or substantial renovation scenarios is the minimally-compliant state or municipal energy code or federal standard, that is applicable to the measure or system being installed. The baseline efficiencies are calculated based on rated equipment input capacity in BTU/h and are defined by International Energy Conservation Code[60] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) and the New York City Energy Conservation Code[61] (NYCECC) as shown below. The formulas in the rightmost column shall be used to establish the baseline efficiency in the units specified (EER or COP).

[59] Based on BG&E 'Development of Residential Load Profile for Central Air Conditioners and Heat Pumps' research, the Maryland Peak Definition coincidence factor is 0.69. This study is not publicly available, but is referenced by the Mid-Atlantic TRM Version 7.0 published May 2017 and by M. M. Straub, Using Available Information for Efficient Evaluation of Demand-Side Management Programs, Electricity Journal, September 2011 and supported by research conducted by Cadmus on behalf of the TRM Management Committee.
[60] ECCCNYS 2016, Table C403.2.3(3)
[61] NYCECC 2016, Table C403.2.3(3)

Electric Cooling and Heating System Baseline Efficiencies

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency ECCCNYS and NYCECC[62]
PTAC (Cooling Mode) Standard Size	All Capacities	95°F db Outdoor Air	EER = 14.0 - (0.300 × Cap/1,000)
PTAC (Cooling Mode) Replacements/ Nonstandard Size[63]	All Capacities	95°F db Outdoor Air	EER = 10.9 - (0.213 × Cap/1,000)
PTHP (Cooling Mode) Standard Size	All Capacities	95°F db Outdoor Air	EER = 14.0 - (0.300 × Cap/1,000)
PTHP (Cooling Mode) Replacements/ Nonstandard Size	All Capacities	95°F db Outdoor Air	EER = 10.8 - (0.213 × Cap/1,000)
PTHP (Heating Mode) Standard Size	All Capacities	—	NYS: COP = 3.2 – (0.026 × Cap/1,000) NYC: COP = 3.7 – (0.052 × Cap/1,000)
PTHP (Heating Mode) Replacements/ Nonstandard Size	All Capacities	—	COP = 2.9 - (0.026 × Cap/1,000)

The baseline for a fuel switching installation at the end of the appliance effective useful life is the minimally-compliant, state or municipal energy code or federal standard, that is applicable to the measure or system, similar to the existing measure or system, that the consumer would have had installed without the influence of the energy efficiency program. The baseline efficiency for residential furnaces, boilers, and unit heaters ($\eta_{baseline}$) is defined by the Code of Federal Regulations and subsequently adopted by the Energy Conservation Code of New York State, and the New York City Energy Conservation Code as shown below.

[62] "Cap" = The rated cooling capacity of the project in BTU/h. If the unit's capacity is less than 7,000 BTU/h, use 7,000 BTU/h in the calculation. If the unit's capacity is greater than 15,000 BTU/h, use 15,000 BTU/h in the calculations."

[63] Replacement/Nonstandard size units must be factory labeled as follows: "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS." Replacement/Nonstandard size efficiencies apply only to units being installed in existing sleeves having an external wall opening of less than 16 in. high or less than 42 in. wide and having a cross-sectional area less than 670 in.

Fossil Fuel Fired Heating System Baseline Efficiencies

Systems Serving Single-Family Homes or Single Units[64]

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Non-weatherized oil-fired furnaces (not including mobile home furnaces)	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.82 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.82 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.84 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.82 AFUE

Systems Serving Multiple Dwelling Units

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.78 AFUE or 0.80 Et
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.75 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.75 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et

The baseline for a system being installed prior to the end of useful life of the existing on-site equipment may be considered as an Early Replacement; consistent with methods described in Appendix M, *Guidelines for Early Replacement* of this TRM. The non-fuel switching and fuel switching baselines detailed above shall be considered where applicable when calculating Remaining Useful Life (RUL).

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a high efficiency packaged terminal air conditioner or heat pump system as defined in the Measure Description section above meeting or exceeding an efficiency rating of 10% better than code, as outlined in the Baseline Efficiencies section.

Operating Hours

Equipment heating and cooling equivalent full load hours shall be taken from the application. If unknown, default EFLH by facility type, vintage and location can be found in Appendix G.

64 10 CFR 430.32(e)

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

References

1. AHRI Standard 310/380 – 2014: Standard for Packaged Terminal Air-Conditioners and Heat Pumps
   Available from:
   http://www.ahrinet.org/App_Content/ahri/files/STANDARDS/AHRI/AHRI_Standard_310_380-2014_CSA_C744-14.pdf
2. BG&E, Development of Residential Load Profile for Central Air Conditioners and Heat Pumps, via Mid-Atlantic Technical Reference Manual Version 7.0, May 2017 (accessed October 26, 2017)
   Available from:
   http://neep.org/sites/default/files/resources/Mid_Atlantic_TRM_V7_FINAL.pdf
3. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
   Available from: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
4. ECCCNYS 2016, per IECC 2015; Table C403.2.3(3): Minimum Efficiency Requirements: Electrically Operated Unitary Packaged Terminal Air Conditioners, Packaged Terminal Heat Pumps, Single-Package Vertical Air Conditioners, Single Vertical Heat Pumps, Room Air Conditioners and Room Air Conditioner Heat Pumps, Table C403.2.3(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements & Table C403.2.3(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers.
   Available from: https://codes.iccsafe.org/public/document/IECC2015NY-1/chapter-4-ce-commercial-energy-efficiency

5. NYCECC 2016; Table C403.2.3(3): Minimum Efficiency Requirements: Electrically Operated Unitary Packaged Terminal Air Conditioners, Packaged Terminal Heat Pumps, Single-Package Vertical Air Conditioners, Single Vertical Heat Pumps, Room Air Conditioners and Room Air Conditioner Heat Pumps, Table C403.2.3(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements & Table C403.2.3(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers
Available from:
https://www1.nyc.gov/assets/buildings/apps/pdf_viewer/viewer.html?file=2016ECC_CHC4.pdf&section=energy_code_2016

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1	10/15/2010
1-17-6	12/31/2016
12-17-14	12/31/2017
2-20-4	2/28/2020

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Heating, Ventilation and Air Conditioning (HVAC)

Heat Pump – Air Source (ccASHP)

Measure Description

This measure covers the installation of cold climate Air Source Heat Pumps (ccASHP) systems[65] that provides heating and cooling for space conditioning in a commercial application including high rise multifamily buildings of four or more stories[66] or with an occupied floor located more than 75 feet above the lowest level of fire department vehicle access.[67] An air source heat pump is a product, other than a packaged terminal heat pump, which is powered by single phase electric current, air cooled, rated below 65,000 BTU/h, not contained within the same cabinet as a furnace with rated capacity above 225,000 BTU/h, and operates as a heat pump in both heating and cooling mode. This ASHP analysis shall be associated with single zone split-systems with ductless indoor units that may be wall-mounted, floor-mounted, or ceiling-mounted; and multi-zone split systems with one outdoor section and multiple indoor sections. These indoor sections may be a combination of ductless or compact ducted units; or a central ducted split-system similar to a traditional ducted central air conditioner system.

For non-cold climate ASHP systems and for systems with cooling capacity ≥ 65,000 BTU/h, please refer to the Commercial Air Conditioner and Heat Pump – Unitary & Applied measure in the current effective version of the NY TRM.

This measure is based on several assumptions consistent with best practice design for a quality ASHP installation:

- NYS and NYC code and Federal Standard (ECCCNYS 2016, NYCECC 2016, Code of Federal Regulations 10 CFR 430.32, 431.77, 431.87) or local legislation applicable at the time of installation should be referenced for correct baseline system and efficiency values.

- Building heating and cooling loads shall be calculated, and systems shall be sized, in accordance with applicable federal, state, local and municipal codes and standards.

- When the building peak heating load for a small commercial building in New York State exceeds the peak cooling load, it is assumed that the ASHP runs at part-load during peak cooling hours. For installation scenarios where the building load is cooling dominant a custom analysis is required.

The ASHP efficiency must meet the Northeast Energy Efficiency Partnerships (NEEP) Cold Climate Air Source Heat Pump (ccASHP) Specification (Version 3.0) effective January 1, 2019. The specification uses AHRI-certified performance ratings and manufacturer reported data to describe the efficiency and capacity of the unit under full and part load conditions. This equipment is rated under ANSI/AHRI 210/240.

[65] NEEP Cold Climate Air Source Heat Pump (ccASHP) Specification (Version 3.0) effective January 1, 2019
[66] NYSERDA, Mid- and High-Rise Multifamily Buildings
[67] IBC 2015; Chapter 2 Definitions: High-Rise Building

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating} - kWh_{heating,supplemental,ee}$$

$$\Delta kWh = units \times \Bigg(\bigg(BCL \times \frac{1}{1{,}000} \times \bigg(\frac{F_{CEC}}{SEER_{baseline}} - \frac{1}{EER_{season,ee}}\bigg) \times EFLH_{cooling} \times F_{load,cooling}\bigg) + \bigg(BHL \times \frac{1}{1{,}000} \times \bigg(\frac{F_{EH}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}}\bigg) \times \frac{1}{3.412} \times EFLH_{heating} \times F_{load,heating}\bigg) - \bigg(BHL \times \frac{1}{1{,}000} \times F_{EH,new} \times \frac{1}{3.412} \times EFLH_{heating} \times (1 - F_{load,heating})\bigg)\Bigg)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times BCL \times \frac{1}{1{,}000} \times \left(\frac{F_{CEC}}{EER_{baseline}} - \frac{1}{EER_{ee}}\right) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta therms = BHL \times \frac{1}{100{,}000} \times \frac{F_{FFH}}{Eff_{heating\ baseline}} \times EFLH_{heating} \times F_{load,heating}$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Summer Peak Coincident Demand Savings
Δtherms = Annual fossil fuel savings
baseline = Baseline condition or measure
BCL = Building Cooling Load at design conditions (BTU/h)
BHL = Building Heating Load at design conditions (BTU/h)
CF = Coincidence Factor
cooling = Used to identify operation of equipment in cooling mode
COP = Coefficient of performance for heating, ratio of output energy/input energy
COP_{season} = Seasonally adjusted average coefficient of performance
ee = Energy efficient condition or measure
EER = Energy efficiency ratio under peak conditions
EER_{season} = Seasonally adjusted average energy efficiency
Eff = Energy efficiency (0-100%)
$EFLH_{cooling}$ = Cooling equivalent full-load hours
$EFLH_{heating}$ = Heating equivalent full-load hours
F_{CEC} = Central electric cooling flag; used to account for the presence or absence of a central electric cooling system
F_{EH} = Electric heating flag; used to account for the presence or absence of an electric heating system in the baseline case
$F_{EH,new}$ = Electric heat flag; used to account for when a new heat pump with supplemental resistance heating is installed
F_{FFH} = Fossil fuel heating flag; used to account for the presence or absence of a fossil

fuel-fired heating system in the baseline case

$F_{load,cooling}$ = Adjustment factor to account for the portion of the seasonal[68] cooling load met by the heat pump

$F_{load,heating}$ = Adjustment factor to account for the portion of the seasonal[69] heating load met by the heat pump

$_{heating}$ = Used to identify operation of equipment in heating mode

$_{heating,supplemental,ee}$ = Used to identify operation of supplemental electric resistance heat

kWh = Electric energy consumption

SEER = Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour, used for average U.S. location/region

units = Number of units installed under the program

3.412 = Conversion factor, one watt-hour equals 3.412 BTU

1,000 = Conversion factor, one kilowatt equals 1,000 watts

100,000 = Conversion factor, (BTU/therm), one therm equals 100,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
BCL		Building cooling load at design conditions.
BHL		Building heating load at design conditions.
$COP_{season,baseline}$		Seasonal Coefficient of Performance of the baseline equipment. The assumed efficiency of an electric resistance heating system is 1.
$COP_{season,ee}$		Seasonally adjusted Coefficient of Performance of the efficient equipment. See Compliance Efficiency section below for details.
$EER_{baseline}$		Electric cooling energy efficiency rating of baseline equipment. See Baseline Efficiencies section below for details.
EER_{ee}		Electric cooling energy efficiency rating of efficient equipment. See Compliance Efficiency section below for details.
$EER_{season,ee}$		Seasonally adjusted energy efficiency ratio of the efficient equipment. See Compliance Efficiency section below for details.
$Eff_{baseline}$		Baseline established by applicable energy conservation code, climatic zone, equipment type and size, fuel source, and system configuration. See Baseline Efficiency section below.
$EFLH_{cooling}$		From application. If unknown, lookup based on building type and location from Appendix G.
$EFLH_{heating}$		From application. If unknown, lookup based on building type and location from Appendix G.

[68] Fraction of annual (vs. design) cooling load served by the equipment as shown in the Cooling Load Factor table.
[69] Fraction of annual (vs. design) heating load served by the equipment as shown in the Heating Load Factor table.

Variable	Value	Notes
F_{CEC}		If a central electric cooling system is present, set equal to 1. Otherwise, set equal to 0.
F_{EH}		Used to account for when a fossil fuel system is replaced with a heat pump with supplemental resistance heating If a central electric heating system is present, set equal to 1. Otherwise, set equal to 0.
$F_{EH,new}$		If the efficient heat pump system relies on supplemental electric resistance heat to meet the peak load, set equal to 1. Otherwise, set equal to 0.
F_{FFH}		If a fossil fuel-fired heating system is present, set equal to 1. Otherwise, set equal to 0.
$F_{load,cooling}$		Lookup based on equipment sizing and control parameters from table below.
$F_{load,heating}$		Lookup based on equipment sizing and control parameters from table below.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.80.[70]

Baseline Efficiencies from which Energy Savings are Calculated

The baselines used in this measure are determined by the type of equipment that would have been installed without the influence of the program supporting the installation of this measure. This allows for an analysis that does not depend on a typical ‘like-for-like’ replacement scenario.

An ASHP system can be considered a normal replacement scenario for electric resistance heating (with or without a central electric cooling system), an (ASHP) system (that provides space heating and cooling), or a fossil fuel fired heating system (with or without a central electric cooling system).

Tables are provided below to show the baseline efficiencies for appropriate Electric Heating and Cooling System Baseline Efficiencies, and appropriate Fossil Fuel Fired Heating System Baseline Efficiencies.

Electric Cooling and Heating System Baseline Efficiencies

Product Class	Seasonal Energy Efficiency Ratio (SEER)[71]	Energy Efficiency Ratio (EER)	Heating Seasonal Performance Factor (HSPF)[72]
Split System – Air Conditioner (<65 kBTU/h)	13.0	11.2	N/A

[70] *No source specified – update pending availability and review of applicable references.*
[71] 10 CFR 430.32 (c)(1)
[72] 10 CFR 430.32 (c)(1)

Product Class	Seasonal Energy Efficiency Ratio (SEER)[71]	Energy Efficiency Ratio (EER)	Heating Seasonal Performance Factor (HSPF)[72]
Single Package – Air Conditioner	14.0	11.8	N/A
Split System – Heat Pump (<65 kBTU/h)	14.0	11.8	8.2
Single Package – Heat Pump (<65 kBTU/h)	14.0	11.8	8.0

Fossil Fuel Fired Heating System Baseline Efficiencies

Systems Serving Single-Family Homes or Single Units[73]

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Non-weatherized oil-fired furnaces (not including mobile home furnaces)	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.82 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.82 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.84 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.82 AFUE

Systems Serving Multiple Dwelling Units

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.78 AFUE or 0.80 Et
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.75 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.75 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et

Compliance Efficiency from which Incentives are Calculated

ASHP are rated under ANSI/AHRI 210/240. Cold climate ASHPs must meet the Northeast Energy Efficiency Partnerships (NEEP) Cold Climate Air Source Heat Pump (ccASHP) Specification (Version 3.0) effective January 1, 2019. The specification uses AHRI-certified performance ratings and manufacturer reported data to describe the efficiency and capacity of the unit under full and part load condition

[73] 10 CFR 430.32(e)

The average seasonal heating efficiency for an ASHP with a two stage or variable speed compressor is calculated as:

$$COP_{season,ee} = a + b \; x \; HSPF \; x \; \frac{1}{3.412}$$

The average seasonal cooling efficiency for a ccASHP with a variable speed compressor is calculated as:

$$EER_{season,ee} = c + d \; x \; SEER$$

where:

a & b = Offset and slope coefficients from Tables below for heating (select based on city and scenario)
c & d = Offset and slope coefficients from Tables below for cooling (select based on city and scenario)
HSPF = Rated Heating Season Performance Factor from AHRI
SEER = Rated Seasonal Energy Efficiency Ratio from AHRI
3.412 = Conversion factor, one watt-hour equals 3.412 BTU

Summary of Variables and Data Sources

Variable	Value	Source
a & b		Coefficients to represent offset and slope from the table below to determine seasonal heating efficiency ($COP_{season,ee}$) from HSPF. Depends on city and scenario.
c & d		Coefficients to represent offset and slope from the table below to determine seasonal cooling efficiency ($EER_{season,ee}$) from SEER. Depends on city and scenario.
HSPF		Rated heating season performance factor from AHRI.
SEER		Rated seasonal energy efficiency ratio from AHRI.

Total and Partial Load Displacement Scenarios (considering ccASHP sizing, equipment type, and controls)

The scenarios shown in the first column below represent various specific applications of heat pumps, with heat pump type, sizing, and control strategy shown. These scenarios may be considered “sub-measures” of this measure[74]. Assigning applicable scenario(s) to program participants or participant groups is the responsibility of program designers and implementers. Where participants fall between the numeric values in the column “HP Sizing,” use the scenario with the lower of the values in the column. “Single-zone ductless” means the equipment is single-zone (1-to-1 indoor to outdoor units). There may be multiple single-zone systems to achieve the HP sizing shown. The scenario “displace/replace an existing heating zone” applies

[74] Detailed descriptions of these scenarios and their parameters are found in the white paper *Savings Calculations for Residential Air Source Heat Pumps: The Basis for Modifying EFLH and Seasonal Efficiency Factors for “Whole House” and “Displacement” Applications*, Tables 2 and 3, and the associated narrative.

only when integrated controls are configured with ductless system(s) that effectively distribute heating to an entire pre-existing zone (thermostat). It also applies when ductless mini-splits are installed in homes heated by electric resistance baseboards with room-level thermostats.

Scenario	Description	ASHP Type	Application	Controls	HP Sizing Ratio
1a	Central ASHP with different controls	Central, Ducted	Whole	Integrated/ Modulating	0.9
1b				Integrated/ Fixed capacity	
1c				DF/Either HP or Furnace	
1d				Integrated/ Modulating	1.0
2a	Ductless Mini-spilt sized at 30%, 50%, 70% and 90/100%	Single-zone Ductless	Displace	Separate	0.3
2b					0.5
2c					0.7
2d				Integrated/ Fixed Capacity	0.3
2e					0.5
2f					0.7
2g			Whole	Integrated/ Modulating	0.9
2h					1.0
3a	Ductless MULTI-split sized to 70% and 90/100%	Multi-zone Ductless	Displace	Separate	0.7
3b			Whole	Integrated/ Modulating	0.9
3c					1.0
4a	Compact Ducted Mini-split sized to 50% ,70% and 90/100%	Single-zone Compact Ducted	Displace	Separate	0.5
4b					0.7
4c			Whole	Integrated/ Modulating	0.9
4d					1.0

The HP sizing should be determined using the maximum heating capacity at 5°F from the NEEP Cold Climate Heat Pump List ($QH_{5,max}$) and design heating load for the home:

$$\text{HP Sizing Ratio} = QH_{5,max} / BHL$$

The HP Sizing corresponds to the column in the table above. Choose an appropriate scenario, then use the coefficients from the tables below to determine the seasonal efficiencies and load factors.

Coefficients for Seasonal Heating Efficiency: $COP_{season,ee} = a + b \times HSPF/3.412$														
Scenario	**Albany**		**Binghamton**		**Buffalo**		**Massena**		**New York**		**Poughkeepsie**		**Syracuse**	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b
1a	-0.010	0.880	0.113	0.854	0.219	0.842	-0.185	0.838	0.919	0.738	0.333	0.796	0.124	0.860
1b	-0.040	0.891	0.092	0.863	0.197	0.851	-0.168	0.830	0.888	0.750	0.301	0.813	0.093	0.871
1c	0.056	0.906	0.220	0.870	0.310	0.849	-0.057	0.922	0.945	0.741	0.579	0.802	0.183	0.875
1d	-0.117	0.902	-0.003	0.879	0.081	0.876	-0.259	0.847	0.844	0.752	0.237	0.815	-0.007	0.890
2a	2.552	0.197	2.532	0.202	2.645	0.181	2.304	0.204	2.457	0.303	2.620	0.177	2.565	0.195
2b	2.351	0.256	2.419	0.243	2.644	0.188	2.011	0.290	2.453	0.315	2.470	0.228	2.500	0.217
2c	2.441	0.228	2.480	0.224	2.619	0.198	2.358	0.203	2.617	0.271	2.459	0.239	2.550	0.206
2d	2.615	0.113	2.637	0.113	2.702	0.108	2.312	0.150	2.998	0.105	2.725	0.104	2.655	0.107
2e	2.574	0.125	2.601	0.124	2.647	0.122	2.335	0.143	2.896	0.137	2.654	0.119	2.631	0.116
2f	2.458	0.160	2.493	0.155	2.546	0.153	2.322	0.145	2.892	0.139	2.588	0.135	2.513	0.154
2g	2.351	0.172	2.382	0.169	2.440	0.161	2.125	0.178	2.826	0.143	2.424	0.162	2.415	0.163
2h	2.336	0.179	2.386	0.169	2.422	0.168	2.030	0.205	2.827	0.147	2.372	0.177	2.414	0.168
3a	-3.334	1.993	-3.307	1.991	-3.485	2.065	-2.938	1.810	-3.710	2.205	-3.093	1.929	-3.339	2.006
3b	-2.683	1.735	-2.637	1.728	-2.720	1.770	-2.004	1.446	-3.241	2.010	-2.306	1.624	-2.710	1.757
3c	-2.823	1.775	-2.783	1.769	-2.832	1.800	-1.991	1.436	-3.311	2.025	-2.395	1.645	-2.861	1.800
4a	-0.333	1.141	-0.305	1.138	-0.251	1.137	-0.852	1.263	0.373	1.026	-0.407	1.194	-0.308	1.140

Coefficients for Seasonal Heating Efficiency: $COP_{season,ee} = a + b \times HSPF/3.412$

Scenario	Albany		Binghamton		Buffalo		Massena		New York		Poughkeepsie		Syracuse	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b
4b	-0.402	1.155	-0.393	1.160	-0.300	1.147	-0.865	1.261	0.225	1.057	-0.390	1.175	-0.385	1.160
4c	-0.166	1.004	-0.019	0.963	0.018	0.961	-0.234	0.972	0.282	0.972	0.121	0.926	-0.006	0.962
4d	-0.240	1.024	-0.102	0.983	0.027	0.950	-0.321	0.993	0.224	0.984	0.110	0.920	-0.127	1.001

Coefficients for Seasonal Cooling Efficiency: $EER_{season,ee} = c + d \times SEER$

Scenario	Albany		Binghamton		Buffalo		Massena		New York		Poughkeepsie		Syracuse	
	c	d	c	d	c	d	c	d	c	d	c	d	c	d
1a	4.98	0.640	8.20	0.468	4.93	0.661	6.06	0.574	4.61	0.663	4.87	0.641	5.08	0.636
1b	4.98	0.640	8.20	0.468	4.93	0.661	6.06	0.574	4.61	0.663	4.87	0.641	5.08	0.636
1c	4.98	0.640	8.20	0.468	4.93	0.661	6.06	0.574	4.61	0.663	4.87	0.641	5.08	0.636
1d	4.50	0.677	6.67	0.546	4.56	0.689	5.10	0.630	3.87	0.712	4.31	0.684	4.83	0.658
2a	11.59	0.110	11.58	0.114	11.72	0.118	11.59	0.114	11.60	0.108	11.57	0.107	11.62	0.113
2b	11.72	0.113	11.66	0.114	11.81	0.118	11.64	0.111	11.84	0.108	11.65	0.111	11.77	0.112
2c	11.81	0.126	11.75	0.117	11.98	0.128	11.81	0.116	12.06	0.122	11.91	0.121	11.85	0.124
2d	11.59	0.110	11.58	0.114	11.72	0.118	11.59	0.114	11.60	0.108	11.57	0.107	11.62	0.113
2e	11.72	0.113	11.66	0.114	11.81	0.118	11.64	0.111	11.84	0.108	11.65	0.111	11.77	0.112
2f	11.81	0.126	11.75	0.117	11.98	0.128	11.81	0.116	12.06	0.122	11.91	0.121	11.85	0.124
2g	12.09	0.139	11.83	0.125	12.11	0.147	11.90	0.130	12.11	0.150	12.17	0.137	11.97	0.140
2h	12.08	0.154	11.90	0.130	12.12	0.159	11.96	0.138	12.09	0.168	12.14	0.158	12.04	0.150
3a	7.52	0.283	2.92	0.530	3.75	0.492	5.72	0.378	3.69	0.532	3.11	0.555	6.46	0.342
3b	3.46	0.565	5.30	0.402	8.13	0.276	6.81	0.343	3.82	0.574	2.21	0.655	2.88	0.593
3c	3.47	0.595	7.69	0.282	4.59	0.507	3.33	0.565	7.53	0.371	7.06	0.386	2.70	0.625
4a	-6.75	1.106	-5.49	1.040	-5.96	1.074	-5.92	1.058	-7.61	1.149	-6.96	1.111	-6.49	1.095
4b	-8.59	1.214	-6.84	1.117	-8.07	1.198	-7.59	1.155	-10.01	1.291	-9.26	1.246	-8.25	1.198
4c	-11.15	1.366	-8.27	1.200	-10.44	1.341	-9.54	1.271	-11.71	1.395	-11.70	1.392	-10.36	1.324
4d	-11.27	1.377	-8.87	1.236	-9.76	1.303	-10.41	1.322	-12.11	1.420	-11.42	1.380	-11.63	1.400

Note that several scenarios are the same since control approach and UR do not apply for cooling (i.e. 1a,1b and 1c are all the same, 2a is the same as 2d, etc.)

Heating Load Factor

Factors in the table below ($F_{load,heating}$) are used to determine the fraction of the annual load that is met by the ASHP unit.

Fraction of Heating Load met by the ASHP ($F_{load,heating}$)

Scenario	Albany	Binghamton	Buffalo	Massena	New York	Poughkeepsie	Syracuse
1a	0.998	0.995	0.999	0.979	0.999	0.972	0.997
1b	0.994	0.987	0.994	0.957	0.997	0.948	0.991
1c	0.859	0.862	0.892	0.691	0.980	0.819	0.901
1d	0.999	0.998	1.000	0.985	1.000	0.981	0.998
2a	0.250	0.247	0.246	0.231	0.281	0.247	0.243
2b	0.389	0.384	0.389	0.368	0.442	0.388	0.379
2c	0.562	0.550	0.559	0.551	0.608	0.541	0.552
2d	0.544	0.534	0.532	0.513	0.590	0.509	0.535
2e	0.742	0.728	0.730	0.712	0.772	0.692	0.737
2f	0.862	0.854	0.851	0.820	0.889	0.810	0.859
2g	0.979	0.967	0.971	0.942	0.980	0.921	0.978
2h	0.990	0.984	0.988	0.955	0.989	0.940	0.989
3a	0.719	0.710	0.698	0.673	0.767	0.667	0.717
3b	0.956	0.941	0.937	0.918	0.963	0.899	0.953
3c	0.975	0.965	0.961	0.940	0.977	0.922	0.976
4a	0.430	0.423	0.434	0.421	0.488	0.429	0.419
4b	0.590	0.579	0.584	0.563	0.637	0.564	0.582
4c	0.973	0.962	0.966	0.936	0.978	0.918	0.975
4d	0.992	0.988	0.994	0.960	0.994	0.947	0.991

Cooling Load Factor

Factors in the table below ($F_{load,cooling}$) are used to determine the fraction of the annual load that is met by the ASHP unit.

Fraction of Cooling Load met by the ASHP ($F_{load,cooling}$)							
Scenario	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**New York**	**Poughkeepsie**	**Syracuse**
1a	0.953	0.862	0.956	0.909	0.978	0.983	0.948
1b	0.953	0.862	0.956	0.909	0.978	0.983	0.948
1c	0.953	0.862	0.956	0.909	0.978	0.983	0.948
1d	0.969	0.899	0.977	0.937	0.988	0.993	0.971
2a	0.521	0.415	0.520	0.463	0.575	0.549	0.508
2b	0.741	0.607	0.740	0.672	0.801	0.777	0.723
2c	0.879	0.756	0.877	0.816	0.923	0.912	0.864
2d	0.521	0.415	0.520	0.463	0.575	0.549	0.508
2e	0.741	0.607	0.740	0.672	0.801	0.777	0.723
2f	0.879	0.756	0.877	0.816	0.923	0.912	0.864
2g	0.949	0.857	0.952	0.905	0.977	0.980	0.945
2h	0.968	0.895	0.975	0.935	0.988	0.992	0.968
3a	0.880	0.759	0.879	0.818	0.923	0.913	0.867
3b	0.950	0.860	0.953	0.906	0.978	0.981	0.946
3c	0.968	0.896	0.974	0.935	0.988	0.992	0.969
4a	0.730	0.594	0.727	0.659	0.792	0.767	0.712
4b	0.871	0.744	0.869	0.808	0.919	0.906	0.855
4c	0.947	0.848	0.947	0.899	0.976	0.978	0.940
4d	0.966	0.888	0.970	0.930	0.987	0.991	0.965

Note that several scenarios are the same since control approach and UR do not apply for cooling (i.e. 1a,1b and 1c are all the same, 2a is the same as 2d, etc.)

Operating Hours

Equipment heating and cooling equivalent full load hours shall be taken from the application. If unknown, default EFLH by facility type and location can be found in Appendix G.

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

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Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
12-17-8	12/31/2017
9-18-4	9/28/2018
2-20-5	2/28/2020

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Heating, Ventilation and Air Conditioning (HVAC)

Heat Pump – Water-to-Air Ground Source (GSHP)

Measure Description

This measure covers the installation of an ENERGY STAR® certified ground source heat pump (GSHP) system installed in a commercial setting with a closed loop heat exchanger field, which provides heating and cooling for space conditioning by the water to air transference of ground temperatures through a typical air-duct distribution system in a small commercial building not more than three stories above-grade in height.

This measure applies to individual GSHP units in small commercial applications, and where each GSHP unit has its own dedicated loop pump It does not apply to large GSHP systems with multiple heat pump units served by centralized ground loop pumping. The GSHP analysis associated with this measure is based on several assumptions consistent with best practice design for a quality GSHP installation:

- Building heating and cooling loads shall be calculated, and systems shall be sized in accordance with applicable federal, state, local and municipal codes and standards.
- When the building peak heating load for a small commercial building in New York State exceeds the peak cooling load, it is assumed that the GSHP runs at part-load during peak cooling hours. For installation scenarios where the building load is cooling dominant a custom analysis is required.
- The ground loop heat exchanger is adequately sized and installed properly to allow the GSHP to meet the peak heating load without electric resistance auxiliary heat.
- The GSHP is equipped with either a two stage or variable-speed compressor system, a variable speed or constant speed ground loop circulator pump, and a variable-speed blower distribution fan.
- The GSHP efficiency is rated in accordance with ISO 13256-1, and AHRI-certified performance ratings are provided by the manufacturer showing the efficiency and capacity of the unit under full and part load conditions.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \left[\frac{BCL}{1{,}000} \times \left(\frac{F_{CEC}}{SEER_{baseline}} - \frac{1}{EER_{season,ee}}\right) \times EFLH_{cooling}\right] + \left[\frac{BHL}{3{,}412} \times \left(\frac{F_{EH}}{COP_{baseline}} - \frac{1}{COP_{season,ee}}\right) \times EFLH_{heating}\right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{BCL}{1{,}000} \times \left(\frac{F_{CEC}}{EER_{baseline}} - \frac{1}{EER_{GLHP,full,ee}} \right) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta therms = \frac{BHL}{100{,}000} \times \frac{F_{FFH}}{Eff_{baseline}} \times EFLH_{heating}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Summer Peak Coincident Demand Savings
Δtherms	= Annual fossil fuel savings
baseline	= Baseline condition or measure
BCL	= Building Cooling Load at design conditions (BTU/h)
BHL	= Building Heating Load at design conditions (BTU/h)
CF	= Coincidence Factor
COP	= Coefficient of performance, ratio of output energy/input energy
COP_{season}	= Coefficient of performance on a seasonal basis. Adjusted to account for fan and pump power.
ee	= Energy efficient condition or measure
EER	= Energy efficiency ratio (BTU/watt-hour)
$EER_{GLHP, full}$	= Full load energy efficiency ratio (BTU/watt-hours)
EER_{season}	= Energy efficiency ratio (BTU/watt-hour) at part-load seasonally-adjusted for fan and pump power
Eff	= Energy efficiency (0-100%)
$EFLH_{cooling}$	= Cooling equivalent full-load hours
$EFLH_{heating}$	= Heating equivalent full-load hours
F_{CEC}	= Central electric cooling factor flag; used to account for the presence or absence of a central electric cooling system
F_{EH}	= Electric heating factor flag; used to account for the presence or absence of an electric heating system
F_{FFH}	= Fossil fuel heating flag; used to account for the presence or absence of a fossil fuel-fired heating system
SEER	= Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour,(used for average U.S. location/region)
3.412	= Conversion factor, one watt-hour equals 3.412 BTU
1,000	= Conversion factor, one kW equals 1,000 Watts
100,000	= Conversion factor, (BTU/therm), one therm equals 100,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
BCL		Building cooling load at design conditions, from application. Building load calculated in accordance with ASHRAE Standard 183.
BHL		Building heating load at design conditions, from application. Building load calculated in accordance with ASHRAE Standard 183.
$COP_{baseline}$		Electric heating energy efficiency rating of baseline equipment. See Baseline Efficiency section below for details.
$COP_{season,ee}$		Coefficient of performance (ratio of heat delivered to energy input to the compressor) from the manufacturer's catalog data adjusted to account for applied fan and pump power. See Compliance Efficiency section below for details.
$EER_{baseline}$		Electric cooling energy efficiency rating of baseline equipment. See Baseline Efficiency section below for details.
$EER_{GLHP,full}$		Full load energy efficiency ratio at AHRI rated conditions. Corresponds to fluid temperature of 77ºF
$EER_{season,ee}$		Energy efficiency ratio from the manufacturer's catalog data AHRI ratings adjusted to account for applied fan and pump power. See Compliance Efficiency section below for details.
$Eff_{baseline}$		Baseline established by applicable energy conservation code, climatic zone, equipment type and size, fuel source, and system configuration. See Baseline Efficiency section below.
$EFLH_{cooling}$		From application. If unknown, lookup based on building type and location from Appendix G.
$EFLH_{heating}$		From application. If unknown, lookup based on building type and location from Appendix G.
F_{CEC}		If a central electric cooling system is present, set equal to 1. Otherwise, set equal to 0.
F_{EH}		If a central electric heating system is present, set equal to 1. Otherwise, set equal to 0.
F_{FFH}		If a fossil fuel-fired heating system is present, set equal to 1. Otherwise, set equal to 0.
$SEER_{baseline}$		Seasonal electric cooling energy efficiency rating of baseline equipment. See Baseline Efficiency section below for details.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.80.[75]

Baseline Efficiencies from which Energy Savings are Calculated

The baselines used in this measure are determined by the type of equipment that would have been installed without the influence of the program supporting the installation of this measure. This allows for an analysis that does not depend on a typical 'like-for-like' replacement scenario.

[75] *No source specified – update pending availability and review of applicable references.*

A GSHP system can be considered a normal replacement scenario for electric resistance heating (with or without a central electric cooling system), an Air Source Heat Pump (ASHP) system (that provides space heating and cooling), or a fossil fuel fired heating system (with or without a central electric cooling system).

Tables are provided below to show the baseline efficiencies for appropriate Electric Heating and Cooling System Baseline Efficiencies, and appropriate Fossil Fuel Fired Heating System Baseline Efficiencies.

Electric Cooling and Heating System Baseline Efficiencies

Product Class	Seasonal Energy Efficiency Ratio (SEER)[76]	Energy Efficiency Ratio (EER)	Heating Seasonal Performance Factor (HSPF)[77]
Split System – Air Conditioner (<65 kBTU/h)	13.0	11.2	N/A
Single Package – Air Conditioner	14.0	11.8	N/A
Split System – Heat Pump (<65 kBTU/h)	14.0	11.8	8.2
Single Package – Heat Pump (<65 kBTU/h)	14.0	11.8	8.0

Fossil Fuel Fired Heating System Baseline Efficiencies

Systems Serving Single-Family Homes or Single Units[78]

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Non-weatherized oil-fired furnaces (not including mobile home furnaces)	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.82 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.82 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.84 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.82 AFUE

[76] 10 CFR 430.32 (c)(1)
[77] 10 CFR 430.32 (c)(1)
[78] 10 CFR 430.32(e)

Systems Serving Multiple Dwelling Units

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.78 AFUE or 0.80 Et
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.75 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.75 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et

For scenarios where the baseline heating system is electric resistance heat, the baseline efficiency is assumed to be a COP of 1.0.

For scenarios where there is new construction or substantial renovation, the baseline is assumed to be a gas fired warm air furnace with a central air conditioning system when natural gas service is available at the project site, and an ASHP system when natural gas service is not available at the project site.

For scenarios where the baseline heating system is an ASHP, additional consideration is given to account for the significant difference between the rating conditions for HSPF and the typical operating conditions in New York State, as shown below:

The HSPF is the AHRI-rated heating seasonal average efficiency expressed in terms of BTU/watt-hour. A seasonally-adjusted $COP_{baseline}$ of an air-source heat pump is used in the above equations. This adjusted baseline COP shall be calculated as:

$$COP_{baseline} = \frac{HSPF \times F_{HSPF}}{3.412}$$

where:

HSPF = Heating seasonal performance factor of the baseline system
F_{HSPF} = HSPF Climate Adjustment Factor, from table below
3.412 = Conversion factor, one watt-hour equals 3.412 BTU

HSPF Climate Adjustment Factor (F_{HSPF})

City	HSPF < 8.5	HSPF ≥ 8.5
Albany	0.70	0.67
Binghamton	0.68	0.65
Buffalo	0.73	0.70
Massena	0.59	0.56
NYC	0.80	0.78

City	HSPF < 8.5	HSPF ≥ 8.5
Poughkeepsie	0.62	0.59
Syracuse	0.69	0.66

For scenarios where the baseline cooling system is an Air Source Heat Pump (ASHP), no additional consideration is given to account for the difference between the rating conditions for SEER and the typical operating conditions in New York State, because the differences between the rating conditions and the typical operating conditions are small.

Replacement of room air conditioners is not addressed in this analysis. To capture savings associated with removal of room air conditioners, refer to the Air Conditioner – Room (RAC) Recycling measure in the Single and Multi-Family Residential Measures section of this TRM.

Compliance Efficiency from which Incentives are Calculated

Ground source heat pumps are rated according to ISO 13256-1. The rated efficiencies in the standard account for the compressor energy as well as the supply fan and pump energy required to overcome air and fluid pressure drops internal to the unit. The fan energy required to distribute air through the duct system and the pump energy required to move the heat transfer fluid through the ground loop is accounted for separately in this analysis.

The seasonal average cooling and heating efficiencies are estimated from AHRI performance ratings with the adjustments described below.

The average seasonal heating efficiency for a GSHP with a two stage or variable speed compressor is calculated as:

$$COP_{season,ee} = \Big(\big(F_{full} \times COP_{GLHP,full} \times 1.08 \times F_{pump,full}\big) + \big(F_{part} \times COP_{GLHP,part} \times F_{pump,part}\big)\Big) \times F_{dist,h}$$

The average seasonal cooling efficiency for a GSHP with a dual-stage or variable speed compressor is calculated as:

$$EER_{season,ee} = \Big(\big(F_{full} \times EER_{GLHP,full} \times 1.09 \times F_{pump,full}\big) + \big(F_{part} \times EER_{GLHP,part} \times F_{pump,part}\big)\Big) \times F_{dist,c}$$

where:

$COP_{GLHP,full}$ = Rated COP of the unit at GLHP full load heating conditions
$COP_{GLHP,part}$ = Rated COP of the unit at GLHP part load heating conditions
$EER_{GLHP,full}$ = Rated EER of the unit at GLHP full load cooling conditions
$EER_{GLHP,part}$ = Rated EER of the unit at GLHP part load cooling conditions
$F_{dist,c}$ = Factor to adjust the cooling efficiency to account for additional fan power
$F_{dist,h}$ = Factor to adjust the heating efficiency to account for additional fan power

F_{full} = Seasonal weighting factor for full load efficiency
F_{part} = Seasonal weighting factor for part load efficiency
$F_{pump,full}$ = Factor to adjust full load efficiency to account for additional pumping power
$F_{pump, part}$ = Factor to adjust part load efficiency to account for additional pumping power
1.08 = Correction for change in COP[79]
1.09 = Correction for change in EER[80]

Summary of Variables and Data Sources

Variable	Value	Source
$COP_{GLHP,full}$		The rated COP of the unit at GLHP full load (or standard) heating conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 32°F.
$COP_{GLHP,part}$		The rated COP of the unit at GLHP part load heating conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 41°F.
$EER_{GLHP-,full}$		The rated EER of the unit at GLHP full load (or standard) cooling conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 77°F.
$EER_{GLHP-,part}$		The rated EER of the unit at GLHP part load cooling conditions from ASHRAE/ISO 13256-1. This value is certified by AHRI and is available in the product directory. It corresponds to an entering loop temperature of 68°F.
$F_{dist,c}$		Factor to adjust the cooling efficiency to account for additional fan power that would be required, beyond the fan power corresponding to zero static in rated COP. Choose the appropriate factor from the Distribution Correction Factors table below.
$F_{dist,h}$		Factor to adjust the heating efficiency to account for additional fan power that would be required, beyond the fan power corresponding to zero static in rated COP. Choose the appropriate factor from the Distribution Correction Factors table below.
F_{full}	0.25	Seasonal weighting factor for full load efficiency = 0.25. Based in part on observed mix of low and high stage operation from field testing.[81]
F_{part}	0.75	Seasonal weighting factor for part load efficiency = 0.75. Based in part on observed mix of low and high stage operation from field testing.[82]

[79] Correction for 8% change in COP as the entering fluid temperature increases from 32°F to 40°F. The 1% per °F was observed from published performance data as well as in the IGSHPA Design Manual.
[80] Correction for 9% change in EER as the entering fluid temperature decreases from 77°F to 68°F. The 1% per °F was observed from published performance data as well as in the IGSHPA Design Manual.
[81] New York State Energy Research and Development Authority (NYSERDA). 2017. "Analysis of Water Furnace Geothermal Heat Pump Sites in New York State with Symphony Monitoring System," NYSERDA Report Number 18-03. Prepared by CDH Energy Corp., Cazenovia, NY. nyserda.ny.gov/publications.
[82] Ibid.

Variable	Value	Source
$F_{pump,full}$		Factor to adjust the full load efficiency to account for additional pumping power used by the system. Choose the appropriate factor from Pumping Power Adjustment Factor table below.
$F_{pump,part}$		Factor to adjust the part load efficiency to account for additional pumping power used by the system. Choose the appropriate factor from Pumping Power Adjustment Factor table below.

Loop Pumping Power Correction Factor ($F_{pump,full}$ and $F_{pump,part}$)

A correction factor for pumps ($F_{pump,full}$ and $F_{pump,part}$) is required because the rated efficiency values only include the pumping energy associated with the water-side pressure drop through the heat pump unit (typically about 5-10 Watts per nominal ton). Actual pumping power is much higher. The ASHRAE GSHP Design Guide (Kavanaugh and Rafferty 2015) developed a grading system that assigns scores based on the amount of pumping power per installed ton. For instance, it gives a grade of “A” to system that uses 45 Watts per nominal ton and a grade of “B” to a system that uses 60 Watts per nominal ton.

Analysis of observed pumping power from 45 to 90 Watts/ton was performed to determine the impact of loop pumping power on efficiency. Results are shown in the Pumping Factors table below.[83]

Pumping Power Adjustment Factors

Different factors are required for different loop pumping power levels and loop pump control strategies. For part load performance there are multiple ways to control the pump at low stage:

- the pump can maintain constant flow regardless of compressor stage.
- the pump stages flow in proportion to the compressor capacity.
- the pump can be variable speed and modulate with the variable speed compressor.

A constant speed loop pump results in poor performance since the pump power becomes relatively larger portion of total power at low stage. Variable speed pumping with a variable speed compressor results in the best performance. The penalty for constant speed pumping is highest for units with variable speed compressors. The last consideration is the low-to-high capacity ratio (CR), which can be calculated as follows:

$$CR = \frac{QC_{GLHP,part}}{QC_{GLHP,full}}$$

where:

CR = Capacity ratio of part-load cooling capacity to full-load heating capacity.
$QC_{GLHP,part}$ = Part-load cooling capacity rating from AHRI certificate.
$QC_{GLHP,full}$ = Full-load heating capacity rating from AHRI certificate.

[83] Henderson, H.I., 2019. *White Paper Savings Calculations for Residential Ground Source Heat Pumps: The Basis for Equivalent Full Load Hours (EFLH) and Seasonal Efficiency Factors.* Prepared for the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Public Service.

The values of QC are the rated full and part load performance values from AHRI. Units with two stage compressors typically have a value of CR of approximately 0.75. Units with variable speed compressors typically have a CR of approximately 0.40.

The table below presents the values of $F_{pump,full}$ and $F_{pump,part}$ that correspond to each loop pump arrangement (e.g. pumping control strategy, CR, and pumping power). The full load pumping factors are typically 0.89 to 0.94. Part load factors can range from 0.69 to 0.94 depending on the pumping control strategy, the capacity ratio of the heat pump, and the pumping power. The factor closest to the actual situation should be used.

Pumping Factors ($F_{pump,full}$ and $F_{pump,part}$)

Pumping Control Strategy	**Capacity Ratio (CR)**	**Pumping Power**							
		45 Watts/ton		60 Watts/ton		75 Watts/ton		90 Watts/ton	
		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
Full load ($F_{pump,full}$)		0.94	0.94	0.93	0.92	0.91	0.90	0.89	0.89
Part load – constant flow pumping ($F_{pump,part}$)	0.75	0.89	0.91	0.86	0.89	0.83	0.86	0.80	0.84
Part load – constant flow pumping ($F_{pump,part}$)	0.40	0.81	0.85	0.77	0.81	0.72	0.77	0.69	0.74
Part load – staged pumping ($F_{pump,part}$)	0.75	0.92	0.94	0.89	0.91	0.87	0.89	0.84	0.87
Part load – staged pumping ($F_{pump,part}$)	0.40	0.92	0.94	0.89	0.91	0.87	0.89	0.84	0.87
Part load – variable pumping ($F_{pump,part}$)	0.40	0.94	0.95	0.92	0.93	0.90	0.92	0.88	0.90

Distribution Power Correction

For GSHP systems with an air-duct distribution system, the fan power included in the rated efficiencies corresponds to zero external static pressure and therefore is smaller than would be expected for an actual application. The indoor fan power included in the ISO 13256-1 test procedure is estimated to be approximately 0.15 Watts/cfm for permanent split-capacitor fan motors and 0.11 Watts/cfm for electrically commutated fan motors.[84]

The purpose of the distribution (i.e., fan or pump) correction factor, $F_{dist,h}$ and $F_{dist,c}$ is to determine the equivalent amount of distribution power for the baseline system, such as a fuel fired furnace or boiler, or a heat pump. The correction factor considers the differential distribution power between the GSHP and the baseline system. The Distribution Correction Factors to correct GSHP Seasonal Efficiency for typical baseline scenarios summarized in the table below:

[84] Ibid.

Distribution Correction Factors ($F_{dist,h}$ and $F_{dist,c}$)

	If baseline system is a Furnace with conventional air conditioning	If baseline system is a Boiler with conventional air conditioning	If baseline system is a Central air source heat pump
Heating ($F_{dist,h}$)	0.96	0.96	0.97
Cooling ($F_{dist,c}$)	0.95	0.95	0.95

Note: Based on furnace and boiler ancillary power of 137 Watts

Operating Hours

Equipment heating and cooling equivalent full load hours shall be taken from the application. If unknown, default EFLH by facility type and location can be found in Appendix G.

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

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Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
4-16-1	3/31/2016
6-17-6	6/30/2017
3-18-11	3/29/2018
2-20-6	2/28/2020

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Heating, Ventilation and Air Conditioning (HVAC)

Air Conditioner and Heat Pump – Packaged Terminal

Measure Description

This measure covers the installation of high efficiency packaged terminal conditioners heat pumps in commercial applications.

Packaged Terminal Air Conditioner (PTAC)

A wall sleeve and a separate un-encased combination of heating and cooling assemblies specified by the manufacturer and intended for mounting through the wall. It includes refrigeration components, separable outdoor louvres, forced ventilation, and heating availability by purchaser's choice of, at least, hot water, steam, or electrical resistance heat.

Note: *Models designated as "cooling only" units need not include heating elements if the physical characteristics and arrangement of the refrigeration system are identical to those of models with heating availability.*[85]

Packaged Terminal Heat Pump (PTHP)

A separate un-encased refrigeration system installed in a cabinet having a function and configuration similar to that of a packaged terminal air-conditioner. It uses reverse cycle refrigeration as its prime heat source and should have other supplementary heat source(s) available to purchasers with the choice of, at least, hot water, steam, or electric resistance heat.[86,87]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \left[\begin{array}{c} \left(\frac{kBTU/h_{cooling}}{unit} \times \left(\frac{F_{CEC}}{EER_{baseline}} - \frac{1}{EER_{ee}} \right) \times EFLH_{cooling} \right) \\ + \\ \left(\frac{kBTU/h_{heating}}{unit \times 3.412} \times \left(\frac{F_{EH}}{COP_{baseline}} - \frac{1}{COP_{ee}} \right) \times EFLH_{heating} \right) \end{array} \right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \left[\frac{kBTU/h_{cooling}}{unit} \times \left(\frac{F_{CEC}}{EER_{baseline}} - \frac{1}{EER_{ee}} \right) \times CF \right]$$

85 AHRI Standard 310/380 – 2014

86 Ibid.

87 Replacement unit shall be factory labeled as follows: "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY: NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS." Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406 mm) in height and less than 42 inches (1067 mm) in width.

Annual Fossil Fuel Energy Savings

$$\Delta therms = units \times \left(\frac{kBTU/h_{heating}}{unit} \times \frac{F_{FFH}}{Eff_{heating,baseline}} \times \frac{EFLH_{heating}}{100}\right)$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
Δtherms	= Annual fossil fuel savings
units	= Number of measures installed under the program
$_{baseline}$	= Baseline condition or measure
$_{ee}$	= Energy efficient condition or measure
$kBTU/h_{cooling}$	= Output cooling capacity in kBTU/h (at AHRI standard rating conditions)
$kBTU/h_{heating}$	= Output heating capacity in kBTU/h (at AHRI standard high-temperature rating conditions)
F_{CEC}	= Central electric cooling flag; used to account for the presence or absence of a central electric cooling system
F_{EH}	= Electric heating flag; used to account for the presence or absence of an electric heating system in the baseline case
F_{FFH}	= Fossil fuel heating flag; used to account for the presence or absence of a fossil fuel-fired heating system in the baseline case
EER	= Energy efficiency ratio, measurement of cooling capacity for a unit (in BTU/hour) / electrical energy used (watts) (at AHRI standard rating conditions)
COP	= Coefficient of performance, ratio of output energy/input energy (at AHRI standard high-temperature rating conditions)
$Eff_{heating}$	= Fuel heating energy efficiency rating of equipment.
$EFLH_{cooling}$	= Cooling equivalent full-load hours
$EFLH_{heating}$	= Heating equivalent full-load hours
CF	= Coincidence factor
3.412	= Conversion factor, one watt-hour equals 3.412 BTU
100	= Conversion factor, one therm equals 100 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
$kBTU/h_{cooling}$		From application
$kBTU/h_{heating}$		From application
F_{CEC}		If a central electric cooling system is present, set equal to 1. Otherwise, set equal to 0.
F_{EH}		If a central electric heating system is present, set equal to 1. Otherwise, set equal to 0.
F_{FFH}		If a fossil fuel-fired heating system is present, set equal to 1. Otherwise, set equal to 0.
$EER_{baseline}$		Calculate from Baseline Efficiencies table below based on equipment type, size category and capacity.
EER_{ee}		From application

Variable	Value	Notes
$COP_{baseline}$		Calculate from Baseline Efficiencies table below based on equipment type, size category and capacity.
COP_{ee}		From application
$Eff_{,heating,baseline}$		From Fossil Fuel Fired Heating System Baseline Efficiencies table below.
$EFLH_{cooling}$		From application. If unknown, lookup based on building type and location from Appendix G.
$EFLH_{heating}$		From application. If unknown, lookup based on building type and location from Appendix G.
CF	0.8	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[88]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline for a non-fuel switching normal replacement at end of the appliance effective useful life (EUL), in new construction, or substantial renovation scenarios is the minimally-compliant state or municipal energy code or federal standard, that is applicable to the measure or system being installed. The baseline efficiencies are calculated based on rated equipment input capacity in BTU/h and are defined by International Energy Conservation Code[89] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) and the New York City Energy Conservation Code[90] (NYCECC) as shown below. The formulas in the rightmost column shall be used to establish the baseline efficiency in the units specified (EER or COP).

[88] *No source specified – update pending availability and review of applicable references.*
[89] ECCCNYS 2016, Table C403.2.3(3)
[90] NYCECC 2016, Table C403.2.3(3)

Electric Cooling and Heating System Baseline Efficiencies

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency ECCCNYS and NYCECC[91]
PTAC (Cooling Mode) Standard Size	All Capacities	95°F db Outdoor Air	EER = 14.0 - (0.300 × Cap/1,000)
PTAC (Cooling Mode) Replacements/ Nonstandard Size[92]	All Capacities	95°F db Outdoor Air	EER = 10.9 - (0.213 × Cap/1,000)
PTHP (Cooling Mode) Standard Size	All Capacities	95°F db Outdoor Air	EER = 14.0 - (0.300 × Cap/1,000)
PTHP (Cooling Mode) Replacements/ Nonstandard Size	All Capacities	95°F db Outdoor Air	EER = 10.8 - (0.213 × Cap/1,000)
PTHP (Heating Mode) Standard Size	All Capacities	—	NYS: COP = 3.2 – (0.026 × Cap/1,000) NYC: COP = 3.7 – (0.052 × Cap/1,000)
PTHP (Heating Mode) Replacements/ Nonstandard Size	All Capacities	—	COP = 2.9 - (0.026 × Cap/1,000)

The baseline for a fuel switching installation at the end of the appliance effective useful life is the minimally-compliant, state or municipal energy code or federal standard, that is applicable to the measure or system, similar to the existing measure or system, that the consumer would have had installed without the influence of the energy efficiency program. The baseline efficiency for commercial furnaces, boilers, and unit heaters ($\eta_{baseline}$) is defined by the Code of Federal Regulations (CFR) and subsequently adopted by the Energy Conservation Construction Code of New York State and the New York City Energy Conservation Code as shown below.

[91] "Cap" = The rated cooling capacity of the project in BTU/h. If the unit's capacity is less than 7,000 BTU/h, use 7,000 BTU/h in the calculation. If the unit's capacity is greater than 15,000 BTU/h, use 15,000 BTU/h in the calculations."

[92] Replacement/Nonstandard size units must be factory labeled as follows: "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS." Replacement/Nonstandard size efficiencies apply only to units being installed in existing sleeves having an external wall opening of less than 16 in. high or less than 42 in. wide and having a cross-sectional area less than 670 in.

Fossil Fuel Fired Heating System Baseline Efficiencies[93,94]

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.78 AFUE or 0.80 Et
	≥ 225 kBTU/h	0.80 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.75 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired, Natural Draft	< 300 kBTU/h	0.75 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et

The baseline for a system being installed prior to the end of useful life of the existing on-site equipment may be considered as an Early Replacement; consistent with methods described in Appendix M, *Guidelines for Early Replacement* of this TRM. The non-fuel switching and fuel switching baselines detailed above shall be considered where applicable when calculating Remaining Useful Life (RUL).

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a high efficiency packaged terminal air conditioner or heat pump system as defined in the Measure Description section above meeting or exceeding an efficiency rating of 10% better than code, as outlined in the Baseline Efficiencies section.

Operating Hours

Equipment heating and cooling equivalent full load hours shall be taken from the application. If unknown, default EFLH by facility type and location can be found in Appendix G.

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Ancillary fossil fuel savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

Ancillary Electric Savings Impacts

Ancillary electric savings impacts, if appropriate, will be researched and incorporated into this measure algorithm in future revisions to the TRM.

[93] ECCCNYS 2016, Table C403.2.3(4) and Table C403.2.3(5)
[94] NYCECC 2016; Table C403.2.3(4) and Table C403.2.3(5)

References

1. AHRI Standard 310/380 – 2014: Standard for Packaged Terminal Air-Conditioners and Heat Pumps
Available from:
http://www.ahrinet.org/App_Content/ahri/files/STANDARDS/AHRI/AHRI_Standard_310_380-2014_CSA_C744-14.pdf
2. ECCCNYS 2016, per IECC 2015; Table C403.2.3(3): Minimum Efficiency Requirements: Electrically Operated Unitary Packaged Terminal Air Conditioners, Packaged Terminal Heat Pumps, Single-Package Vertical Air Conditioners, Single Vertical Heat Pumps, Room Air Conditioners and Room Air Conditioner Heat Pumps, Table C403.2.3(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements & Table C403.2.3(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers.
Available from: https://codes.iccsafe.org/public/document/IECC2015NY-1/chapter-4-ce-commercial-energy-efficiency
3. NYCECC 2016; Table C403.2.3(3): Minimum Efficiency Requirements: Electrically Operated Unitary Packaged Terminal Air Conditioners, Packaged Terminal Heat Pumps, Single-Package Vertical Air Conditioners, Single Vertical Heat Pumps, Room Air Conditioners and Room Air Conditioner Heat Pumps, Table C403.2.3(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements & Table C403.2.3(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers
Available from:
https://www1.nyc.gov/assets/buildings/apps/pdf_viewer/viewer.html?file=2016ECC_CHC4.pdf&section=energy_code_2016

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