Table of Revisions/Changes

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
6-24-2	C	7/8/2024	7/8/2024	R/MF Attic Access Insulation & Sealing	Updated baseline R-value for uninsulated surfaces and corresponding source. Corrected single-family dwelling default boiler baseline.	Pg. x
6-24-6	C	7/8/2024	7/8/2024	R/MF Insulation – Opaque Shell	Revised language in Measure Description section to clarify eligible applications. Corrected single-family dwelling default boiler baseline. Updated baseline R-values for various building vintages and shell components.	Pg. 99
6-24-15	C	7/8/2024	7/8/2024	R/MF Air Conditioner – Room (RAC) Cover and Gap Sealer	Updated boiler baseline efficiency for systems serving single units.	Pg. 81
6-24-16	C	7/8/2024	7/8/2024	R/MF Window	Updated boiler baseline efficiency for systems serving single units.	Pg. 108
6-24-17	C	7/8/2024	7/8/2024	R/MF Heat Pump Water Heater (HPWH) – Air Source	Updated boiler baseline efficiency for systems serving single units.	Pg. 136
6-24-18	C	7/8/2024	7/8/2024	R/MF Air Conditioner and Heat Pump – Packaged Terminal	Updated boiler baseline efficiency for systems serving single units.	Pg. 198
6-24-19	C	7/8/2024	7/8/2024	R/MF Boiler, Furnace and Unit Heater	Updated boiler baseline efficiency for systems serving single units.	Pg. 206
6-24-20	C	7/8/2024	7/8/2024	R/MF Boiler and Furnace – Combination (Combi) Boiler and Furnace	Updated boiler baseline efficiency for systems serving single units.	Pg. 211
6-24-21	C	7/8/2024	7/8/2024	R/MF Energy and Heat Recovery Ventilator	Updated boiler baseline efficiency for systems serving single units.	Pg. 237
6-24-22	C	7/8/2024	7/8/2024	R/MF Heat Pump – Air Source (ccASHP)	Updated boiler baseline efficiency for systems serving single units.	Pg.249
6-24-23	C	7/8/2024	7/8/2024	R/MF Heat Pump – Air-toWater	Updated boiler baseline efficiency for systems serving single units.	Pg. 266
6-24-24	C	7/8/2024	7/8/2024	R/MF Water-to-Air Ground Source (GSHP)	Updated boiler baseline efficiency for systems serving single units	Pg. 279
6-24-25	C	7/8/2024	7/8/2024	C/I Heat Pump – Water-to-Air Ground Source (GSHPs) in Systems with Central Plumbing	Updated boiler baseline efficiency for systems serving single units	Pg. 791

Note: Revisions, Additions, Corrections and Removals to the measures listed above were undertaken by the Joint Utilities Technical Resource Manual (TRM) Management Committee between April 1, 2024 – June 28, 2024.

BUILDING ENVELOPE

ATTIC ACCESS INSULATION & SEALING

Measure Description

This measure is applicable to insulation and air sealing of attic access points, including hatches (also known as scuttle holes), knee walls and pull-down stairs. Thermal energy is contained within a home but transfer between conditioned and unconditioned spaces through uninsulated and/or poorly sealed areas including the entrance of the attic space can increase HVAC loads, reduce indoor air quality, and adversely impact occupant health and comfort. This measure entails installation of an insulated barrier paired with an air seal gasket to reduce conductive and convective heat transfer through the attic access. If the attic access point is within an uninsulated location such as a garage, savings are not applicable.[1] Savings are attributed to increased R-value and reduced air infiltration.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

$$\Delta kWh_{cooling} = \frac{\left[\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times CDD \times 24\right]}{1{,}000 \times SEER} \times F_{ElecCool}$$

$$\Delta kWh_{heating} = \left\{\frac{\left[\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times HDD \times 24\right]}{1{,}000 \times HSPF} + \frac{1.08 \times CFM/ft \times L \times HDD \times 24}{1{,}000 \times HSPF}\right\} \times F_{ElecHeat}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times F_{ElecCool}}{1{,}000 \times EER} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \left\{\frac{\left[\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times HDD \times 24\right]}{1{,}000{,}000 \times Eff_{FuelHeat}} + \frac{1.08 \times CFM/ft \times L \times HDD \times 24}{1{,}000{,}000 \times Eff_{FuelHeat}}\right\} \times F_{FuelHeat}$$

[1] Department of Energy: Technology Fact Sheet – Attic Access
https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/26447.pdf

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
$\Delta MMBtu$ = Annual fossil fuel energy savings
$\Delta kWh_{cooling}$ = Annual electric cooling energy savings
$\Delta kWh_{heating}$ = Annual electric heating energy savings
$R_{baseline}$ = R-value of existing insulation (ft^2-F°-h/BTU)
ΔR = Difference in R-value between installed insulation and existing insulation (ft^2-F°-h/BTU)
A = Uninsulated attic access area, in ft^2
CDD = Cooling Degree Days - The number of degrees that a day's average temperature is above some baseline temperature, which represents the temperature above which buildings need to be cooled. The baseline temperature is typically 65°F, but may vary based on application.
HDD = Heating Degree Days - The number of degrees that a day's average temperature is below some baseline temperature, which represents the temperature below which buildings need to be heated. The baseline temperature is typically 65°F, but may vary based on application.
SEER = Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour, used for average U.S. location/region
HSPF = Heating seasonal performance factor, BTU/watt-hour, total heating output (supply heat) in BTU (including supplemental heaters) during the heating season / total electric energy heat pump consumed (in watt-hour)
EER = Energy efficiency ratio under peak conditions (BTU/watt-hour)
$Eff_{FuelHeat}$ = Efficiency of fuel heating equipment (AFUE, Et, or Ec)
CFM/ft = Air leakage rate through unsealed attic access, in cubic feet of air per minute per linear foot of gap
L = Length of sealed attic access gap, in ft
$F_{ElecCool}$ = Electric cooling factor; used to account for the presence or absence of an electric cooling system
$F_{ElecHeat}$ = Electric heating factor, used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$ = Fossil fuel heating factor, used to account for the presence or absence of a fossil fuel heating system
1.08 = Specific heat of air × density of inlet air @ 70˚F × 60 min/hr[2]
24 = Hours in one day
1,000 = Conversion factor, 1,000 watts is equal to 1 kW
3,412 = Conversion factor, one kWh equals 3,412 Btu
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 Btu
CF = Coincidence factor

[2] The sensible heat constant at standard conditions of 1.08 is applied in accordance with standard HVAC industry practice. While the underlying assumptions are not representative characteristics of a NY heating season, the impacts to this value due to average heating season temperature and NY mean elevation offset such that the NY heating season specific value is approximately 1.08.

Summary of Variables and Data Sources

Variable	Value	Notes
$R_{baseline}$	4	Default R-value for uninsulated ceiling surface based on pre-war uninsulated brick vintage building.[3]
ΔR		From application.
A		From application.
CDD		Lookup based on location in Heating and Cooling Degree Days table below.
HDD		Lookup based on location in Heating and Cooling Degree Days table below.
SEER		From application. Use SEER2 rating if equipment has a SEER2 rating. If unknown use 13.4 SEER2, assuming a minimally code compliant, 3-ton, split system AC.[4]
HSPF		From application. For equipment rated in HSPF2, HSPF2 rating shall be used. If unknown use 7.5 HSPF2, assuming a 3-ton central ASHP system. [5] For electric resistance heating and electric furnaces, use 3.4 HSPF. If taken from application, COP must be converted to HSPF using the equivalency HSPF = COP x 3.412.
EER		From application. For equipment rated in EER2, EER2 rating shall be used. If unknown, baseline EER is established as follows[6]: $EER = (1.12 \times SEER) - (0.02 \times SEER^2)$
$Eff_{FuelHeat}$		From application. If unknown, lookup based on system size and type in Baseline Efficiencies from which Energy Savings are Calculated section below.
CFM/ft	1.0	Average air leakage rate per linear foot of crack.[7]
L		From application.
$F_{ElecCool}$		If an electric cooling system is present, set equal to 1. Otherwise, set equal to 0.
$F_{ElecHeat}$		Use a value of 1.0 if the building is electrically heated. Otherwise, use 0.0.
$F_{FuelHeat}$		Use a value of 1.0 if the building is fuel heated. Otherwise, use 0.0.
CF	0.69	

[3] Guidehouse, inc. (2024). Downstate New York Weatherization Program: Residential Sector Impact and Process Evaluation. Matter No.15-M-0252, item No. 158.
[4] 10 CFR 430.32(c)(5)
[5] Ibid.
[6] DOE, Building America House Simulation Protocols, October 2010; for equipment rated in SEER2, replace SEER with SEER2 and EER with EER2 in the derivation formula.
[7] Reflects the average value indicated for the Crack Method (Range 0.12 – 2.8 CFM/ft; Average: 1.0 CFM/ft) from https://hvac-eng.com/infiltration-rules-of-thumb/

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[8]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is an attic access point (hatch, pull-down stairs or knee wall) with no insulation or air sealing.

The baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is the nameplate efficiency of the existing equipment. If unknown, the baseline efficiency is defined by the Code of Federal Regulations as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[9]

Equipment Type	Size Range	CFR Minimum Efficiency
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.84 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.82 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.86 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.85 AFUE

The baseline efficiency for heating systems serving multiple dwelling units is the nameplate efficiency of the existing system. If unknown, the baseline efficiency is defined by International Energy Conservation Code[10] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: 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	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.81 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec

[8] 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 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.

[9] 10 CFR 430.32(e)(2)(iii)(A) <last reviewed 6/21/2024>

[10] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5).

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 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	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

Compliance Efficiency from which Incentives are Calculated

The compliance condition is insulation and air leakage sealing applied to an attic access meeting or exceeding applicable construction code requirements. The installed R-value must be captured and included in the program application.

Opaque shell insulation improvements performed under this measure shall be installed such that that all altered envelope components comply with all federal, state, local and municipal codes and standards applicable to alterations to existing buildings, including but not limited to Section R503.1 of ECCCNYS 2020[11] requiring all existing ceiling, wall, and floor cavities exposed during construction to be filled with insulation. Thermal envelope components not altered as part of this measure (e.g. continuous insulation in wood-framed buildings) are not required to meet code for compliance.

Operating Hours

Effective heating and cooling hours associated with benefits of opaque shell insulation are established via the Heating and Cooling Degree Days section below.

Heating and Cooling Degree Days[12]

City	HDD	CDD
Albany	6,391	721
Binghamton	7,200	383
Buffalo	6,502	607

[11] ECCCNYS 2020, Section R503 Building Thermal Envelope.
[12] HDD/CDD taken from NCEI 1991-2020 climate normal using a 65 °F balance point.

City	HDD	CDD
Massena	8,030	406
NYC	4,900	1017
Poughkeepsie	6,026	745
Syracuse	6,625	618

Example Calculation *(Not to be used as default)*

A residential customer applies R-20 insulation and air sealing to the pull-down stair attic access in their single-family home near Albany. The home is cooled with a 15 SEER, 12 EER central AC and heated with a gas fired warm air furnace with an efficiency of 0.80 AFUE. The attic access has dimensions of 25" x 54" (A = 25/12 x 54/12 = 9.375 ft^2; L = 25/12 x 2 + 54/12 x 2 = 13.2 ft).

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

$$\Delta kWh_{cooling} = \frac{\left[\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times CDD \times 24\right]}{1{,}000 \times SEER} \times F_{ElecCool}$$

$$\Delta kWh_{heating} = \left\{\frac{\left[\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times HDD \times 24\right]}{1{,}000 \times HSPF} + \frac{1.08 \times CFM/ft \times L \times HDD \times 24}{1{,}000 \times HSPF}\right\} \times F_{ElecHeat}$$

$$\Delta kW = \frac{\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times F_{ElecCool}}{1{,}000 \times EER} \times CF$$

$$\Delta MMBtu = \left\{\frac{\left[\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times HDD \times 24\right]}{1{,}000{,}000 \times Eff_{FuelHeat}} + \frac{1.08 \times CFM/ft \times L \times HDD \times 24}{1{,}000{,}000 \times Eff_{FuelHeat}}\right\} \times F_{FuelHeat}$$

$R_{baseline}$ = 4, from Summary of Variables and Data Sources table
ΔR = 16, from application
A = 9.375, from application
CDD = 721, from Heating and Cooling Degree Days table based on location
HDD = 6,391, from Heating and Cooling Degree Days table based on location
SEER = 15, from application
HSPF = N/A
EER = 12, from application
$Eff_{FuelHeat}$ = 0.80 AFUE, from application
CFM/ft = 1.0 from Summary of Variables and Data Sources table

L = 13.2, from application

$F_{ElecCool}$ = 1, from application
$F_{ElecHeat}$ = 0, from application
$F_{FuelHeat}$ = 1, from application
CF = 0.69, from Summary of Variables and Data Sources table

$$\Delta kWh_{cooling} = \frac{\left[\left(\frac{1}{4} - \frac{1}{4+16}\right) \times 9.375 \times 721 \times 24\right]}{1{,}000 \times 13} \times 1 = 2.16\ kWh$$

$$\Delta kWh_{heating} = \left\{\frac{\left[\left(\frac{1}{4} - \frac{1}{4+16}\right) \times 9.375 \times 6{,}391 \times 24\right]}{1{,}000 \times N/A} + \frac{1.08 \times 1.0 \times 13.2 \times 6{,}391 \times 24}{1{,}000 \times N/A}\right\} \times 0 = 0\ kWh$$

$$\Delta kW = \frac{\left(\frac{1}{4} - \frac{1}{4+16}\right) \times 9.375 \times 1}{1{,}000 \times 12} \times 0.69 = 0.0001\ kW$$

$$\Delta MMBtu = \left\{\frac{\left[\left(\frac{1}{4} - \frac{1}{4+16}\right) \times 9.375 \times 6{,}391 \times 24\right]}{1{,}000{,}000 \times 0.8} + \frac{1.08 \times 1.0 \times 13.2 \times 6{,}391 \times 24}{1{,}000{,}000 \times 0.8}\right\} \times 1$$
$$= 1.71\ MMBtu$$

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. Department of Energy: Technology Fact Sheet – Attic Access.
   Available from:
   https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/26447.pdf
2. Guidehouse, Inc. (2024). Downstate New York Weatherization Program: Residential Sector Impact and Process Evaluation. Matter No.15-M-0252, item No. 158.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402
3. BG&E: Development of Residential Load Profile for Central Air Conditioners and Heat Pumps.

4. ECCCNYS 2020 Section R402 Building Thermal Envelope.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402
5. ECCCNYS 2020 Section R403 Systems.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[re]-residential-energy-efficiency#NYSECC2020P1_RE_Ch04_SecR403
6. ECCCNYS 2020 Section R503 Alterations.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-5-re-existing-buildings.
7. Building America House Simulation Protocols, Robert Hendron and Cheryn Engebrecht, National Renewable Energy Laboratory, October 2010.
   Available from: https://www.nrel.gov/docs/fy11osti/49246.pdf
8. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=dfe00d44cfd9ab9ead4019d69702652a&mc=true&node=pt10.3.430&rgn=div5#se10.3.430_132
9. ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1.
10. NOAA National Centers for Environmental Information – NCEI 1991-2020 Climate Normals.
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
   DOE, Energy Saver, Insulation Materials.
   Available from: https://www.energy.gov/energysaver/weatherize/insulation/insulation-materials#fiberglass

Record of Revision

Record of Revision Number	Issue Date
9-23-1	10/30/2023
6-24-2	7/8/2024

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Insulation - Opaque Shell

Measure Description

This measure covers the installation of wall, ceiling, rim joist, and/or floor insulation to reduce the thermal conductance of the building envelope. Energy and demand savings are realized through reductions in the building's heating and cooling loads. Existing (baseline) and installed (qualifying) shell R-values must be captured or estimated to evaluate energy savings. This measure is only applicable to insulation of surfaces separating conditioned spaces from unconditioned spaces or the exterior of the building. Ceiling insulation is applicable to surfaces between the top conditioned floor and the roof. Insulation of a shared wall between two conditioned spaces or the floor/ceiling separating conditioned spaces is not eligible.

This measure includes, but is not limited to, blown-in insulation in walls and ceilings and application of rigid foam insulating boards or fiberglass to floors and rim joists. Cellulose is the most common blown-in insulation material; other materials include mineral fiber, loose-fill fiberglass, and Styrofoam pellets. Cellulose insulation is made from a cellular plant source, most commonly wood or paper, and treated with fire and pest resistant chemicals. Cellulose insulation is installed in three primary forms: loose-fill, stabilized and wall-cavity spray. Loose-fill insulation is a dry install that is blown into joist cavities in uninsulated attics or applied over existing batts. Stabilized cellulose is similar to loose-fill and applied in the same way but contains a moisture-activated adhesive that serves to increase the density of the cellulose and limit settling. Wall-cavity spray is typically applied prior to drywall installation in new construction, however insertion into existing walls is possible.

This measure is only applicable as a retrofit in existing single and multi-family buildings that are three-stories or less.

For applications involving insulation of multiple building envelope components (e.g., wall and ceiling), evaluate each component separately via the method below and sum together to determine total estimated energy savings.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times \left(1 - F_{framing}\right) \times CDD \times 24 \times F_{ElecCool}}{1{,}000 \times SEER}$$

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times \left(1 - F_{framing}\right) \times HDD \times 24 \times F_{ElecHeat}}{1{,}000 \times HSPF}$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{\Delta kWh_{cooling}}{EFLH_{cooling}} \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times \left(1 - F_{framing}\right) \times HDD \times 24 \times F_{FuelHeat}}{1{,}000{,}000 \times Eff_{FuelHeat}}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
$\Delta kWh_{cooling}$	= Annual electric cooling energy savings
$\Delta kWh_{heating}$	= Annual electric heating energy savings
$R_{baseline}$	= R-value of existing insulation (ft^2-F°-h/BTU)
ΔR	= Difference in R-value between baseline insulation and total post-implementation insulation (ft^2-F°-h/BTU)
A	= Area of insulated surfaces (ft^2)
$F_{framing}$	= Framing factor
$F_{ElecCool}$	= Electric cooling factor; used to account for the presence or absence of an electric cooling system
CDD	= Cooling Degree Days - The number of degrees that a day's average temperature is above some baseline temperature, which represents the temperature above which buildings need to be cooled. The baseline temperature is typically 65°F, but may vary based on application.
HDD	= Heating Degree Days - The number of degrees that a day's average temperature is below some baseline temperature, which represents the temperature below which buildings need to be heated. The baseline temperature is typically 65°F, but may vary based on application.
$F_{ElecHeat}$	= Electric heating factor, used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$	= Fossil fuel heating factor, used to account for the presence or absence of a fossil fuel heating system
SEER	= Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour, used for average U.S. location/region
HSPF	= Heating seasonal performance factor, BTU/watt-hour, total heating output (supply heat) in BTU (including supplemental heaters) during the heating season / total electric energy heat pump consumed (in watt-hour)
$Eff_{FuelHeat}$	= Efficiency of fuel heating equipment (AFUE, Et, or Ec)
$EFLH_{cooling}$	= Cooling equivalent full-load hours
CF	= Coincidence factor
24	= Hours in one day
1,000	= Conversion factor, one kW equals 1,000 watts

1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
$R_{baseline}$		From application. If unknown, follow guidance provided in the Baseline Efficiency section. Assume default for uninsulated surfaces to be R-4, per the pre-war uninsulated brick vintage values in the table below.
ΔR		From application.
A		From application.
$F_{framing}$	Walls: 0.25 Ceilings: 0.07 Rim Joists: 0.05 Floors: 0.12	ASHRAE.[13]
$F_{ElecCool}$		If an electric cooling system is present, set equal to 1. Otherwise, set equal to 0.
CDD		Lookup based on location in Heating and Cooling Degree Days table below.
HDD		Lookup based on location in Heating and Cooling Degree Days table below.
$F_{ElecHeat}$		Use a value of 1.0 if the building is electrically heated. Otherwise, use 0.0.
$F_{FuelHeat}$		Use a value of 1.0 if the building is fuel heated. Otherwise, use 0.0.
SEER		From application. Use SEER2 rating if equipment has a SEER2 rating. If unknown use 13.4 SEER2, assuming a minimally code compliant, 3-ton, split system AC.[14]
HSPF		From application. For equipment rated in HSPF2, HSPF2 rating shall be used. If unknown use 7.5 HSPF2, assuming a 3-ton central ASHP system. [15] For electric resistance heating and electric furnaces, use 3.4 HSPF. If taken from application, COP must be converted to HSPF using the equivalency HSPF = COP x 3.412.
$Eff_{FuelHeat}$		From application. If unknown, lookup based on system size and type in Baseline Efficiencies from which Energy Savings are Calculated section below.
$EFLH_{cooling}$		Lookup based on building type, vintage, and location from Appendix G.

[13] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1.
[14] 10 CFR 430.32(c)(5)
[15] Ibid.

Variable	Value	Notes
CF	0.69	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[16]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition is a building envelope with insulation levels that are not compliant with all current applicable construction code requirements. Because baseline for this measure is established using assumed or existing insulation levels that are based on outdated codes and standards, there is no distinction in the approach for baseline determination between market-rate and LMI applications. R-value of existing insulation shall come from application. Because efficacy of insulation is known to degrade over time, R-value adjustment factors are provided in the Insulation Derating Allowances table below. The appropriate value shall be determined based on visual inspection of the quality of existing insulation. If existing insulation cannot be visually inspected, an Insulation Quality of "Good" shall be assumed.

Insulation Derating Allowances[17]

Insulation Quality	Derate Factor
Good	0.82
Fair	0.60
Poor	0.23

In the case of removal of existing insulation, $R_{baseline}$ shall be set equal to the estimated existing insulation R-value while $R_{baseline} + \Delta R$ should be set equal to the sum of the new insulation R-value and the R-value of an uninsulated surface (i.e., R-4).

If existing insulation R-value is unknown, lookup in the Existing Building Envelope R-value: Walls and Ceilings table below based on building vintage and envelope component for walls and ceilings and in the Existing Building Envelope R-value: Floors and Rim Joists table below based on location and envelope component for floor and rim joist insulation. As an alternative to the defaults presented in the tables below, R-3.1 per inch of existing insulation may be applied.[18]

[16] 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 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.

[17] Values taken from U.S DOE Home Energy Score Insulation Derate Calculator (https://betterbuildingssolutioncenter.energy.gov/sites/default/files/Assessor%20Calculator%20v.020619.xlsx)

[18] DOE, Energy Saver, Insulation Materials. Assumes "low-density" fiberglass batts for 2 by 4 inch stud-framed wall (R-11/3.5 inch = R-3.1 per inch of insulation).

NYS (except NYC) Single Family and Multi-Family Low-Rise (3-stories or less) Default R-Values (for use when insulation cannot be observed) [19,20,21,22]

Vintage	Climate Zone	Wall	Ceiling	Rim Joist	Floor
Pre-war uninsulated brick	N/A	4	4	2	4
Prior to 1979	N/A	4.8	11	2	4
From 1979 through 2006	N/A	11	19	12	19
From 2007 through 2009	4	15	38	10	19
	5	21	38	10	30
	6	21	49	10	30
2010 through 2014	4	13	38	10	19
	5	20	38	10	30
	6	20	49	15	30
2015 through 2019	4 except Marine	20	49	10	19
	5 and Marine 4	20	49	15	30
	6	25	49	15	30
2020 through present	4 except Marine	20	49	10	19
	5 and Marine 4	20	49	15	30
	6	25	49	15	30

NYC Single Family and Multi-Family Low-Rise (3-stories or less) Default R-Values (for use when insulation cannot be observed) [23,24,25,26]

Vintage	Climate Zone	Wall	Ceiling	Rim Joist	Floor
Pre-war uninsulated brick	N/A	4	4	2	4
Prior to 1979	N/A	4.8	11	2	4
From 1979 through 2006	N/A	11	19	12	19
From 2007 through 2010	4	15	38	10	19
2011 through 2015	4	13	38	10	19
2016 through 2019	4 except Marine	25	49	15	30
	5 and Marine 4	20	49	15	30
2020 through present	4	25	49	15	30

The baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is the nameplate efficiency of the existing equipment. If unknown, the baseline efficiency is defined by the Code of Federal Regulations as shown in the table below.

[19] Guidehouse, inc. (2024). Downstate New York Weatherization Program: *Residential Sector Impact and Process Evaluation.* Matter No.15-M-0252, item No. 158.
[20] NYS construction codes from 2007 to 2020
[21] IECC Table R402.1.2 Insulation and Fenestration Requirements by Component
[22] "Implementation of Building Energy Standards in New York State", U-value of basement walls, pg 597
[23] Guidehouse, inc. (2024). Downstate New York Weatherization Program: *Residential Sector Impact and Process Evaluation.* Matter No.15-M-0252, item No. 158.
[24] NYC construction codes from 2007 to 2020
[25] IECC Table R402.1.2 Insulation and Fenestration Requirements by Component
[26] "Implementation of Building Energy Standards in New York State", U-value of basement walls, pg 597

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[27]

Equipment Type	Size Range	CFR Minimum Efficiency
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.84 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.82 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.86 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.85 AFUE

The baseline efficiency for heating systems serving multiple dwelling units is the nameplate efficiency of the existing system. If unknown, the baseline efficiency is defined by International Energy Conservation Code[28] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: 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	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.81 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 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	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

[27] 10 CFR 430.32(e)(2)(iii)(A) <last reviewed 6/21/2024>
[28] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5).

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a residential opaque building shell with increased insulation meeting or exceeding applicable construction code requirements. The installed R-value must be captured and included in the program application.

Opaque shell insulation improvements performed under this measure shall be installed such that all altered envelope components comply with all federal, state, local and municipal codes and standards applicable to alterations to existing buildings, including but not limited to Section R503.1 of ECCCNYS 2020[29] requiring all existing ceiling, wall, and floor cavities exposed during construction to be filled with insulation. Thermal envelope components not altered as part of this measure (e.g., continuous insulation in wood-framed buildings) are not required to meet code for compliance.

Operating Hours

Effective heating and cooling hours associated with benefits of opaque shell insulation are established via the Heating and Cooling Degree Days section below.

Heating and Cooling Degree Days[30]

City	HDD	CDD
Albany	6,391	721
Binghamton	7,200	383
Buffalo	6,502	607
Massena	8,030	406
NYC	4,900	1,017
Poughkeepsie	6,026	745
Syracuse	6,625	618

Example Calculation *(Not to be used as default)*

An existing residential customer in a single-family home located near Binghamton with R-12 roof insulation in fair condition, a gas fired warm air furnace with an efficiency of 0.80 AFUE and no cooling system is adding R-20 of blown-in loose fill cellulose insulation in 500 SF of attic space. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = \frac{\left(\frac{1}{R_{baseline}} - \frac{1}{R_{baseline} + \Delta R}\right) \times A \times \left(1 - F_{framing}\right) \times HDD \times 24 \times F_{FuelHeat}}{1{,}000{,}000 \times Eff_{FuelHeat}}$$

$R_{baseline}$ = 12 x 0.60 = 7.2, from application, adjusted based on Insulation Derating Allowance table from Baseline Efficiency section
ΔR = 20, from application
A = 500 SF, from application

[29] ECCCNYS 2020, Section R503 Building Thermal Envelope.
[30] HDD/CDD taken from NCEI 1991-2020 climate normal using a 65 °F balance point.

$F_{framing}$ = 0.07, from Summary of Variables and Data Sources table based on application
HDD = 7,200, from Heating Degree Day table based on location from application
$F_{FuelHeat}$ = 1.0, from Summary of Variables and Data Sources table from HVAC system from application
$Eff_{FuelHeat}$ = 0.80 AFUE, from application

$$\Delta MMBtu = \frac{\left(\frac{1}{7.2} - \frac{1}{7.2 + 20}\right) \times 500 \times (1 - 0.07) \times 7{,}200 \times 24 \times 1.0}{1{,}000{,}000 \times 0.80}$$
$$= 10.26\ MMBtu$$

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. Rim joist insulation may yield additional savings resulting from improved air sealing between the first floor and an unconditioned basement or crawlspace.

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. Rim joist insulation may yield additional savings resulting from improved air sealing between the first floor and an unconditioned basement or crawlspace.

References

1. BG&E: Development of Residential Load Profile for Central Air Conditioners and Heat Pumps.
2. ECCCNYS 2020 Section R402 Building Thermal Envelope.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402
3. ECCCNYS 2020 Section R403 Systems.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[re]-residential-energy-efficiency#NYSECC2020P1_RE_Ch04_SecR403
4. ECCCNYS 2020 Section R503 Alterations.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-5-re-existing-buildings.
5. 2015 International Residential Code
6. Available from: https://codes.iccsafe.org/content/IRC2015NY/chapter-11-re-energy-efficiency#IRC2015_Pt04_Ch11_SecN1102.1
7. 2016 NYCECC

Available from: https://www.nyc.gov/assets/buildings/apps/pdf_viewer/viewer.html?file=2016ECC_CHR4.pdf&section=energy_code_2016
8. ICC - ECCNYS 2010 Section 402
9. 2011 NYCECC
Available from: https://www.nyc.gov/assets/buildings/codes-pdf/energy_code_2011/2011ECC_CH4.pdf
10. ICC - ECCNYS 2007 Section 402
11. Building America House Simulation Protocols, Robert Hendron and Cheryn Engebrecht, National Renewable Energy Laboratory, October 2010.
Available from: https://www.nrel.gov/docs/fy11osti/49246.pdf
12. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=dfe00d44cfd9ab9ead4019d69702652a&mc=true&node=pt10.3.430&rgn=div5#se10.3.430_132
13. ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1.
14. NOAA National Centers for Environmental Information – NCEI 1991-2020 Climate Normals.
Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
15. DOE, Energy Saver, Insulation Materials.
Available from: https://www.energy.gov/energysaver/weatherize/insulation/insulation-materials#fiberglass
16. Guidehouse, Inc. (2024). Downstate New York Weatherization Program: Residential Sector Impact and Process Evaluation. Matter No.15-M-0252, item No. 158.
Available from: https://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?Mattercaseno=16-02180
17. 2018 International Energy Conservation Code (IECC) R402.1.2 Insulation and Fenestration Criteria
Available from: https://codes.iccsafe.org/content/iecc2018/chapter-4-re-residential-energy-efficiency
18. "Implementation of Building Energy Standards in New York State", Raymond J. Albrecht, P.E. and J. Delaine Jones, AlA
Available from: https://web.ornl.gov/sci/buildings/conf-archive/1979%20B1%20papers/042.pdf
19. U.S. DOE Home Energy Score for Insulation Deration adjustments.
Available from: https://betterbuildingssolutioncenter.energy.gov/sites/default/files/Assessor%20Calculator%20v.020619.xlsx

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
7-13-25	7/31/2013
7-13-38	7/31/2013
9-18-2	9/28/2018
3-19-2	3/29/2019
12-19-2	12/23/2019
12-20-2	12/31/2020
3-21-5	4/9/2021
7-21-5	8/30/2021
6-23-1	7/14/2023
6-24-6	7/8/2024

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BUILDING SHELL

AIR CONDITIONER – ROOM (RAC) COVER AND GAP SEALER

Measure Description

This measure covers the installation of a rigid, insulated cover installed on the inside of a room air conditioner (RAC) and a cover or sealing on the gap surrounding the unit. The cover is designed for permanently installed RAC units, which comprise window air conditioners and through-the-wall air conditioners, left in place throughout the heating season and reduces heating load by limiting the infiltration of cold outside air. To ensure persistence of savings, homeowner/building staff shall be instructed on proper annual removal and reinstallation. This measure assumes the cover is in place outside of the cooling season for the duration of the measure EUL.

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings (Electric Heating Equipment Only)

$$\Delta kWh = units \times \frac{1.08 \times CFM \times HDD \times 24}{Eff_{heating} \times 3{,}412}$$

Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings (Fossil Fuel Heating Equipment Only)

$$\Delta MMBtu = units \times \frac{1.08 \times CFM \times HDD \times 24}{Eff_{heating} \times 1{,}000{,}000}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
CFM	= Cubic foot per minute
HDD	= Heating degree day
$Eff_{heating}$	= Efficiency of heating system
1.08	= Specific heat of air × density of inlet air @ 70˚F × 60 min/hr[31]
24	= Hours in one day
3,412	= Conversion factor, one kWh equals 3,412 BTU
1,000,000	= Conversion factor, one MMBtu equals 1,000,000 BTU

[31] The sensible heat constant at standard conditions of 1.08 is applied in accordance with standard HVAC industry practice. While the underlying assumptions are not representative characteristics of a NY heating season, the impacts to this value due to average heating season temperature and NY mean elevation offset such that the NY heating season specific value is approximately 1.08.

Summary of Variables and Data Sources

Variable	Value	Notes
CFM	19	Based on a negative pressure differential of 10 Pa.[32,33]
HDD		Look up in Heating Degree Days section below based on location.
$Eff_{heating}$		From application, based on existing equipment nameplate efficiency. If unknown, look up in table below based on equipment type and size. For electric resistance heat, use a value of 1.0.

Heating Degree Days

The table below presents the heating degree days (HDD) for several NY cities throughout the heating season (October 1st through May 31st).[34] Heating degree days represent the annual summation of the number of degrees that each day's average temperature is below some baseline temperature. The values below are distinct from HDD values used elsewhere in this TRM because they exclude degree days that fall on cooler evenings during the cooling season when the cover would not be in place. The baseline temperature reflects the temperature below which it is assumed a building needs to be heated. The HDD values below are based on 30-year averages of U.S annual climate normals between 1991 and 2020 using a baseline temperature of 65° F.[35]

City	HDD
Albany	6,226
Binghamton	6,872
Buffalo	6,314
Massena	7,692
NYC	4,845
Poughkeepsie	5,873
Syracuse	6,423

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Savings are Calculated

The baseline condition is a room air conditioning unit in a multifamily building left in place through the heating season without a cover.

The baseline efficiency of the heating system is the nameplate efficiency of the existing equipment.

[32] Steven Winter Associates, There Are Holes in Our Walls, April 2011, pg. 13.
[33] TRANE Engineers Newsletter, Managing the Ins and Outs of Commercial Building Pressurization, 2002, pg. 6. A conservative estimation of building pressure differential throughout New York State during the heating season.
[34] NYC Department of Housing Preservation and Development, Residential Heat and Hot Water Requirements.
[35] HDD during heating season calculated from NOAA National Centers for Environmental Information.

If unknown, the baseline efficiency is that of a minimally code compliant system of type and capacity equivalent to the existing case.

If the existing equipment efficiency is unknown, the baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is defined by the Code of Federal Regulations as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[36]

Equipment Type	Size Range	CFR Minimum Efficiency
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.84 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.86 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.82 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.85 AFUE

If the existing equipment efficiency is unknown, the baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[37] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: 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	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.81 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Gas Fired,	< 300 kBTU/h	0.80 AFUE

[36] 10 CFR 430.32(e)(2)(iii)(A)
[37] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5).

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Natural Draft	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a room air conditioning unit in a multifamily building with a cover and/or sealing on the surrounding gap through the heating season (October 1st through May 31st).[38] Building staff shall be instructed on proper annual removal and reinstallation to ensure persistence of savings.

Operating Hours

Assumed equipment operating hours are embedded in Heating Degree Day values.

Example Calculation *(Not to be used as default)*

Two (2) covers are installed on room air conditioners in a multi-family residence located near Albany. The residence is equipped with electric resistance heat with an efficiency rating of 1.0 COP. Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are not applicable. Annual Electric Energy Savings are calculated as below.

$$\Delta kWh = units \times \frac{1.08 \times CFM \times HDD \times 24}{Eff_{heating} \times 3{,}412}$$

units = 2, from application
CFM = 19, from Summary of Variables and Data Sources table
HDD = 6,226, from Heating Degree Day table based on location from application
$Eff_{heating}$ = 1.0, from Summary of Variables and Data Sources table based on application

$$\Delta kWh = 2 \times \frac{1.08 \times 19 \times 6{,}226 \times 24}{1 \times 3{,}412} = 1{,}797\ kWh$$

Effective Useful Life (EUL)

See Appendix P.

[38] NYC Department of Housing Preservation and Development, Residential Heat and Hot Water Requirements.

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. There Are Holes in Our Walls; A Report Prepared for the Urban Green Building Council, by Steven Winter Associates, April 2011.
   Available from:
   https://urbangreencouncil.org/sites/default/files/there_are_holes_in_our_walls.pdf
2. TRANE Engineers Newsletter, Managing the ins and outs of Commercial Building Pressurization, Volume 31, No. 2, 2002.
   Available from: https://www.trane.com/content/dam/Trane/Commercial/global/products-systems/education-training/engineers-newsletters/airside-design/admapn003en_0502.pdf
3. ECCCNYS 2020 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.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC403
4. NOAA National Centers for Environmental Information – NCEI 1991-2020 Climate Normals.
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
5. NYC Department of Housing Preservation and Development, Residential Heat and Hot Water Requirements.
   Available from: https://www1.nyc.gov/nyc-resources/service/1815/residential-heat-and-hot-water-requirements
6. 10 CFR 430.32(e)(2)(iii)(A) Energy and water conservation standards and their compliance dates
   Available from: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32

Record of Revision

Record of Revision Number	Issue Date
6-14-1	6/19/2014
9-18-3	9/28/2018
3-19-3	3/29/2019
7-21-3	8/30/2021
6-24-15	7/8/2024

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WINDOW

Measure Description

This measure covers the installation of high efficiency windows with reduced thermal conductance and optimal solar heat gain coefficient based on the climate at the project location. For the purposes of this measure, a window is defined as an assembled unit consisting of a frame/sash component holding one or more pieces of glazing functioning to admit light and/or air into an enclosure and designed for a vertical installation in an external wall of a residential building.[39] This measure is only applicable to windows that serve as a barrier between conditioned spaces and outside air. This method does not take into consideration the reduction in infiltration, changes in convective heat transfer, or changes in solar heat gain. For a more holistic approach, a model-based savings calculation is more appropriate.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings[40]

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

$$\Delta kWh_{cooling} = \frac{(U_{baseline} - U_{ee}) \times SF}{Eff_{ElecCool} \times 1{,}000} \times CDD \times F_{ElecCool} \times 24$$

$$\Delta kWh_{heating} = \frac{(U_{baseline} - U_{ee}) \times SF}{HSPF \times 1{,}000} \times HDD \times F_{ElecHeat} \times 24$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{(U_{baseline} - U_{ee}) \times SF}{EER \times 1{,}000} \times F_{ElecCool} \times \Delta T \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{(U_{baseline} - U_{ee}) \times SF}{Eff_{FuelHeat} \times 1{,}000{,}000} \times HDD \times F_{FuelHeat} \times 24$$

where:

DkWh	= Annual electric energy savings
DkW	= Peak coincident demand electric savings
DMMBtu	= Annual fossil fuel energy savings
$U_{baseline}$	= Measure of heat loss through baseline window (BTU/h-ft^2-°F)
U_{ee}	= Measure of heat loss through energy efficient window (BTU/h-ft^2-°F)
SF	= Total glazing area of installed windows (ft^2)
$F_{ElecCool}$	= Electric cooling factor; used to account for the presence or absence of an

[39] ENERGY STAR® Product Specification Residential Windows, Doors, and Skylights, Eligibility Criteria, V6.0, January 2014.

[40] US DOE Energy Savings Windows Worksheet.

electric cooling system

CDD = Cooling Degree Days - The number of degrees that a day's average temperature is above some baseline temperature, which represents the temperature above which buildings need to be cooled. The baseline temperature is typically 65°F, but may vary based on application.

HDD = Heating Degree Days - The number of degrees that a day's average temperature is below some baseline temperature, which represents the temperature below which buildings need to be heated. The baseline temperature is typically 65°F, but may vary based on application.

$Eff_{ElecCool}$ = Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour, using either SEER (<65,000 BTU/h) or IEER (>65,000BTU/h)

HSPF = Heating seasonal performance factor, BTU/watt-hour, total heating output (supply heat) in BTU (including supplemental heaters) during the heating season / total electric energy heat pump consumed (in watt-hour)

EER = Energy efficiency ratio under peak conditions (BTU/watt-hour)

$Eff_{FuelHeat}$ = Efficiency of fossil fuel heating equipment (AFUE, Et, or Ec)

$F_{ElecHeat}$ = Electric heating factor, used to account for the presence or absence of an electric heating system

$F_{FuelHeat}$ = Fossil fuel heating factor, used to account for the presence or absence of a fossil fuel heating system

ΔT = Difference in outdoor season design temperature and indoor setpoint temperature

CF = Coincidence Factor

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

8,760 = Hours in one year

1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

24 = Conversion factor, one day equals 24 hours

Summary of Variables and Data Sources

Variable	Value	Notes
$U_{baseline}$		From application. If unknown, use 0.879 for single-pane and failed double-pane windows and 0.517 for intact double-pane windows.[41] For new construction and gut renovations, see Baseline Efficiencies section below.
U_{ee}		From application.
SF		From application.
CDD		Lookup based on location in Operation Hours section below.
HDD		Lookup based on location in Operation Hours section below.

[41] LBNL RESFEN6 Window Library. RESFEN6 programmed U-factors for single clear, non-metal frame and double clear, non-metal frame applied.

Variable	Value	Notes
$Eff_{ElecCool}$		From application. For equipment rated in SEER2, SEER2 rating shall be used. If unknown, use 13 SEER, assuming a minimally code compliant, <5.4 ton, split system AC.[42]
HSPF		From application. For equipment rated in HSPF2, HSPF2 rating shall be used. If unknown, use 8.2 HSPF, assuming a split system with <5.4 ton cooling capacity. [43] For electric resistance heating and electric furnaces, use 3.4 HSPF. If taken from application, COP must be converted to HSPF using the equivalency HSPF = COP x 3.412.
EER		From application. For equipment rated in EER2, EER2 rating shall be used. If unknown, baseline EER is established as follows[44]: $EER = (1.12 \times SEER) - (0.02 \times SEER^2)$
$Eff_{FuelHeat}$		From application. If unknown, lookup based on system size and type in Baseline Efficiencies section below.
$F_{ElecCool}$		If an electric cooling system is present, set equal to 1. Otherwise, set equal to 0.
$F_{ElecHeat}$		Use a value of 1.0 if the building is electrically heated. Otherwise, use 0.0.
$F_{FuelHeat}$		Use a value of 1.0 if the building is fossil fuel heated. Otherwise, use 0.0.
ΔT	20	Difference between cooling season design temperature (90ºF) and indoor set temperature (70ºF).
CF	0.69	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[45]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline characteristics of window replacement and new construction/gut renovation were determined using defaults presented in LBNL's RESFEN V6.0 software[46] and New York State

[42] ECCCNYS 2020, Table C403.3.2(1).
[43] Ibid.
[44] US DOE, Building America House Simulation Protocols, October 2010; for equipment rated in SEER2, replace SEER with SEER2 and EER with EER2 in the derivation formula.
[45] 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 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.
[46] LBNL RESFEN6 Window Library. RESFEN6 programmed U-factors for single clear, non-metal frame and double clear, non-metal frame applied.

code[47]. Because existing conditions may be used as baseline for this measure, there is no distinction in the approach for baseline determination between market-rate and LMI applications. The baseline for window replacements (excluding entire building gut renovation) is a building with windows having a U-value higher than the maximum code value based on climate zone.

For window replacement, existing conditions shall be used to determine baseline U-value and fossil fuel heating system efficiencies. If unknown, U-value and fossil fuel heating system efficiencies shall be established based on window type and heating equipment type/size, respectively, per the tables below and Summary of Variables and Data Sources above. For new construction, assume a code baseline window and the appropriate HVAC system type based on design specifications.

Window Type	U-Value
Single Pane/Failed Double Pane	0.879
Intact Double Pane	0.517
Code, Climate Zone 4	0.320
Code, Climate Zone 5	0.300
Code, Climate Zone 6	0.300

The baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is defined by the Code of Federal Regulations as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[48]

Equipment Type	Size Range	CFR Minimum Efficiency
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.84 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.86 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.82 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.85 AFUE

The baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[49] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Multiple Dwelling Units

[47] ECCCNYS 2020, Table R402.1.2.
[48] 10 CFR 430.32(e)(2)(iii)(A)
[49] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5).

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.81 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 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	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

Compliance Efficiency from which Incentives are Calculated

Installed windows must meet the minimum compliance criteria required by V6.0 of the ENERGY STAR® Residential Windows, Doors and Skylights Product Specification.[50]

Operating Hours

Effective heating and cooling hours associated with benefits of window upgrades are established from Heating and Cooling Degree Days. Lookup Heating Degree Days and Cooling Degree Days based on location from the table below.

Heating and Cooling Degree Days[51]

City	HDD	CDD
Albany	6,391	721
Binghamton	7,200	383

[50] ENERGY STAR® Product Specification Residential Windows, Doors, and Skylights, Eligibility Criteria, V6.0, January 2014.

[51] HDD/CDD taken from NCEI 1991-2020 climate normal using a 65 °F balance point.

City	HDD	CDD
Buffalo	6,502	607
Massena	8,030	406
NYC	4,900	1017
Poughkeepsie	6,026	745
Syracuse	6,625	618

Example Calculation *(Not to be used as default)*

An existing residential customer near Albany installs high efficiency windows with a total glazing area of 250 square feet and a U-value of 0.270, replacing single-pane windows with an assumed U-value of 0.879. The home is heated with a 100 kBTU/h gas furnace and is cooled via a split system AC with 13 SEER and 11 EER. Annual Electric Energy Savings, Annual Fossil Fuel Energy Savings and Summer Peak Coincident Demand Savings are calculated as below.

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

$$\Delta kWh_{cooling} = \frac{(U_{baseline} - U_{ee}) \times SF}{Eff_{ElecCool} \times 1{,}000} \times CDD \times F_{ElecCool} \times 24$$

$$\Delta kWh_{heating} = \frac{(U_{baseline} - U_{ee}) \times SF}{HSPF \times 1{,}000} \times HDD \times F_{ElecHeat} \times 24$$

$$\Delta kW = \frac{(U_{baseline} - U_{ee}) \times SF}{EER \times 1{,}000} \times F_{ElecCool} \times \Delta T \times CF$$

$$\Delta MMBtu = \frac{(U_{baseline} - U_{ee}) \times SF}{Eff_{FuelHeat} \times 1{,}000{,}000} \times HDD \times F_{FuelHeat} \times 24$$

$U_{baseline}$ = 0.879, based on existing single pane windows
U_{ee} = 0.270, from application
SF = 250, from application
CDD = 721, based on location
HDD = 6,391, based on location
$Eff_{ElecCool}$ = 13, from application
EER = 11, from application
$Eff_{FuelHeat}$ = 0.80, based on heating system type and capacity
$F_{ElecCool}$ = 1, from Summary of Variables and Data Sources table
$F_{ElecHeat}$ = 0, from Summary of Variables and Data Sources table
$F_{FuelHeat}$ = 1, from Summary of Variables and Data Sources table
ΔT = 20, from Summary of Variables and Data Sources table
CF = 0.69, from Summary of Variables and Data Sources table

$$\Delta kWh_{cooling} = \frac{(0.879 - 0.270) \times 250}{13 \times 1{,}000} \times 721 \times 1 \times 24 = 202.66\ kWh$$

$$\Delta kWh_{heating} = 0\ kWh$$

$$\Delta kWh = 202.66 + 0 = 202.66\ kWh$$

$$\Delta kW = \frac{(0.879 - 0.270) \times 250}{11 \times 1{,}000} \times 1 \times 20 \times 0.69 = 0.191\ kW$$

$$\Delta MMBtu = \frac{(0.879 - 0.270) \times 250}{0.80 \times 1{,}000{,}000} \times 6{,}391 \times 1 \times 24 = 29.19\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

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

Ancillary Electric Savings Impacts

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

References

1. ENERGY STAR® Product Specification Residential Windows, Doors, and Skylights, Eligibility Criteria, Version 6.0, January 2014.
   Available from: https://www.energystar.gov/sites/default/files/ES_Final_V6_Residential_WDS_Spec.pdf
2. U.S. Department Of Energy; Energy Savings Windows Worksheet.
   Available from: https://energy.gov/sites/prod/files/2014/01/f7/energy_savings_windows_worksheet.xls
3. BG&E: Development of Residential Load Profile for Central Air Conditioners and Heat Pumps.
4. LBNL RESFEN6 for Calculating the Heating and Cooling Energy Use of Windows in Residential Buildings, December 2012.
   Available from: https://windows.lbl.gov/sites/default/files/Downloads/resfen60-user-manual.pdf
5. ECCCNYS 2020, Table R402.1.2: Insulation and fenestration criteria.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-re-residential-energy-efficiency

6. 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
7. 10 CFR 430.32 Energy and water conservation standards and their compliance dates.
   Available from: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32
8. ECCCNYS 2020, Table C403.3.2(1): Minimum Efficiency Requirements: Electrically Operated Unitary Air Conditioners and Condensing Units, Table C403.3.2(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements & Table C403.3.2(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-ce-commercial-energy-efficiency
9. NOAA National Centers for Environmental Information – NCEI 1991-2020 Climate Normals.
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
10. 10 CFR 430.32(e)(2)(iii)(A) Energy and water conservation standards and their compliance dates
   Available from: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32

Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
6-17-1	6/30/2017
9-19-1	9/27/2019
12-21-3	12/31/2021
6-22-15	9/2/2022
6-24-16	7/8/2024

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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 (in conditioned or unconditioned spaces) 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 an input voltage 250 volts or less, and with a rated storage tank capacity of 120 gallons or less.[52,53]

This measure applies to new construction/major renovation projects and replacement of existing water heaters. Baseline equipment in new construction/major renovation shall be a minimally code compliant, gas-fired storage type water heater where gas service is available and a minimally code compliant, electric storage type water heater elsewhere. Baseline efficiency for replacement of equipment shall be a minimally code compliant system of the same type as the existing equipment. New construction projects in NYC must comply with the provisions of LL154 and reflect an electric baseline beginning in January 2024 in accordance with the LL154 Effectuation Schedule presented in the "New Construction Baselines - NYC Local Low 154 of 2021" section of this TRM’s Introduction.

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

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

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

[52] ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters, Eligibility Criteria Version 5.0, July 2022.
[53] 10 CFR 430.2.

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

Peak Coincident Demand Savings

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

Annual Fossil Fuel Energy Savings

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

where:

DkWh = Annual electric energy savings
DkW = Peak coincident demand electric savings
DMMBtu = Annual fossil fuel energy 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 households addressed by the program
GPD = Gallons per day of delivered hot water per person
PPH = Persons per household served by DHW system
DT_{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
$_{baseline}$ = Characteristic of baseline condition
$_{ee}$ = Characteristic of energy efficient condition
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

$F_{FuelHeat}$ = 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 = Specific heat of water; energy required (BTU), to heat one gallon of water by one degree Fahrenheit [BTU/(gal-F)]

3,412 = Conversion factor, one kWh equals 3,412 BTU

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

1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
GPD	17.2	Average daily hot water usage per person.[54]
PPH		From application. If unknown, use a value of 2.8 for single-family homes[55] and 2.0 for multifamily homes.[56] For sites with multiple water heating systems, PPH shall be allocated proportional to the input heating capacity of each water heater relative to the total input heating capacity of all water heaters.[57]
DT_{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}	125	Water heater set point temperature (°F).[58]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.

[54] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016, pg. 5; 17.2 GPD equated from the report findings indicating an average 2.65 people per household and 45.5 GPD per household.

[55] Residential Statewide Baseline Study of New York State, July 2015. Volume 1: Single-Family Report, Table 9.

[56] Residential Statewide Baseline Study of New York State, July 2015. Volume 2: Multifamily Report, Table 8.

[57] For example, if a home with 6 occupants contains two water heaters with 40 MBH and 50 MBH input capacities and the 40 MBH unit is being replaced with an equivalent capacity unit, the PPH value applied shall be PPH = 6 (occupants) x 40 (MBH) / (40 + 50) (MBH) = 2.7.

[58] 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.

Variable	Value	Notes
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.
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.
$F_{FuelHeat}$		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.[59]
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.[60]
AFUE		From application. If unknown, lookup from Baseline Efficiencies section based on existing equipment type. For new construction/gut rehab or if equipment type is unknown, assume an 80 MBH gas furnace.

[59] ECCCNYS 2020, Table C403.3.2(1).
[60] ECCCNYS 2020, Table C403.3.2(2).

Variable	Value	Notes
(ΔkW/unit)		Deemed Summer Peak Coincident Demand Savings. Use a value of 0.17 if the water was previously heated with electricity in replacement scenarios and if there is no gas service available in new construction/gut rehab scenarios.[61] Otherwise, use -0.17 for an electric penalty.[62]

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.[63] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[64] (°F)	T_{main} (°F)
Albany	49.4	55.4
Binghamton	46.8	52.8
Buffalo	49.1	55.1
Massena	45.1	51.1
NYC	54.7	60.7
Poughkeepsie	50.9	56.9
Syracuse	49.0	55.0

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%.[65] 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[66] and verified via comparison with results from the 2013 NEEA Heat Pump Water Heater Field Study Report.[67] Average values from northwest heating zones 1 (<6,000 HDD), 2 (6,000 – 7,500 HDD) and 3 (>7,500

[61] "Field Testing of Pre-Production Prototype Heat Pump Water Heaters" Federal Energy Management Program, DOE/EE-0317, May 2007.
[62] "CT HVAC and Water Heater Process and Impact Evaluation and CT Heat Pump Water Heater Impact Evaluation", West Hill Energy and Computing, Final Report R1614/R1613, July 19, 2018.
[63] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
[64] Average annual outdoor temperatures taken from NCDC 1991-2020 climate normals.
[65] 10 CFR 430 Subpart B Appendix E.
[66] Residential Heat Pump Water Heater Evaluation: Lab Testing & Energy Use Estimates, Bonneville Power Administration, November 2011.
[67] NEEA Heat Pump Water Heater Field Study Report, Fluid Market Strategies, October 2013.

HDD)[68] 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[69] 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)[70] 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.[71]

City	CDD	F_{Cool}	HDD	F_{Heat}
Albany	721	0.26	6,391	0.70
Binghamton	383	0.17	7,200	0.76
Buffalo	607	0.24	6,502	0.70
Massena	406	0.16	8,030	0.84
Poughkeepsie	1017	0.29	4,900	0.65
NYC	745	0.51	6,026	0.49
Syracuse	618	0.25	6,625	0.70

Coincidence Factor (CF)

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

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[68] NW Council Heating/Cooling zone maps.

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

[70] NW Council Heating/Cooling zone maps.

[71] HDD/CDD taken from NCEI 1991-2020 climate normals.

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. New construction projects in New York City (NYC) are required to adhere to the regulations outlined in Local Law 154 (LL154) and must apply an electric baseline in accordance with the phased effectuation of that legislation.. The LL154 Effectuation Schedule, as detailed in the "New Construction Baselines - NYC Local Law 154 of 2021" section of this TRM's Introduction, provides guidance for compliance.

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).

For LMI applications, existing condition baseline shall be established based on nameplate efficiency or efficiency measured through combustion analysis.

$UEF_{baseline}$ shall be calculated as a function of qualifying equipment tank volume (v_t) per federal standards[72] 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.[73]

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	$UEF_{baseline}$
Electric Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	$0.8808 - (0.0008 \times v_t)$
		Low	$0.9254 - (0.0003 \times v_t)$
		Medium	$0.9307 - (0.0002 \times v_t)$
		High	$0.9349 - (0.0001 \times v_t)$
	> 55 gal and ≤ 120 gal	Very Small	$1.9236 - (0.0011 \times v_t)$
		Low	$2.0440 - (0.0011 \times v_t)$
		Medium	$2.1171 - (0.0011 \times v_t)$
		High	$2.2418 - (0.0011 \times v_t)$

[72] 10 CFR 430.32(d).
[73] 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	$UEF_{baseline}$
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[74]

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

The baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is defined by the Code of Federal Regulations as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[75]

Equipment Type	Size Range	CFR Minimum Efficiency
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.84 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.86 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.82 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.85 AFUE

The baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[76] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Multiple Dwelling Units

[74] 10 CFR 429.17.
[75] 10 CFR 430.32(e)(2)(iii)(A)
[76] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5).

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.81 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 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	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

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 5.0.[77] The table below presents minimum UEF ratings for heat pump water heaters required by that standard.

Product Type	UEF
Integrated HPWH	≥ 3.30
Integrated HPWH, 120 Volt / 15 Amp Circuit	≥ 2.20
Split-System HPWH	≥ 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.

[77] ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters, Eligibility Criteria Version 5.0, July 2022.

Example Calculation *(Not to be used as default)*

A 40-gallon heat pump water heater replaces an existing gas-fired storage water heater in a single family detached home located near Albany with 3 residents. The heat pump water heater has a UEF of 3.5 and a first hour rating of 60 gallons per hour. The water heater is installed in the home's conditioned utility closet, and the home's gas heating system has an AFUE of 80%. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

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

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

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

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

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

units = 1, from application
GPD = 17.2 from Summary of Variables and Data Source table
PPH = 3, from application
$\Delta T_{main} = T_{set} - T_{main}$ = 125 – 55.4 = 69.6
    T_{set} from Summary of Variables and Data Sources table
    T_{main} from Cold Water Inlet Temperature lookup table based on location from application
F_{eDHW} = 0, from Summary of Variable and Data Sources table based on baseline DHW fuel source from application
UEF_{ee} = 3.5, from application
F_{derate} = 1, from Summary of Variable and Data Sources table based on location from application
F_{Loc} = 1, from Summary of Variable and Data Sources based on location from application
F_{cool} = 0.26, from HVAC Interactivity section based on location from application
SEER = 13, from Summary of Variable and Data Sources table

$F_{ElecHeat}$ = 0, from Summary of Variable and Data Sources table based on location from application
HSPF = N/A, from application
(ΔkW/unit) = -0.17, from Summary of Variables and Data Sources table based on existing water heating system fuel from application
F_{FFDHW} = 1, from Summary of Variables and Data Sources table based on existing water heating system from application
$UEF_{baseline}$ = 0.6483 – (0.0017 x v_t) = 0.6483 – (0.0017 x 40) = 0.5803
$UEF_{baseline}$ equation lookup from Baseline Efficiencies section based on Product Class from baseline application and Rated Storage Volume and Draw Pattern from compliance equipment from application, where Draw Pattern is determined by the First Hour Rating based on application
v_t from application of compliance equipment
$F_{BoilerDHW}$ = 0, from Summary of Variables and Data Sources table based on existing water heating system from application
F_{Heat} = 0.70, from HVAC Interactivity section based on location from application
AFUE = 0.80, from application

$$\Delta kWh_{cooling} = 1 \times \frac{17.2 \times 3 \times 365 \times 8.33 \times 69.6}{3{,}412} \times \frac{1}{3.5} \times 1 \times \frac{0.26}{13/3.412} = 62.40\ kWh$$

$$\Delta kWh_{heating} = 0$$

$$\Delta kWh = 1 \times \frac{17.2 \times 3 \times 365 \times 8.33 \times 69.6}{3{,}412} \times \left(0 - \frac{1}{3.5 \times 1}\right) + 62.40 - 0$$
$$= -851.97\ kWh$$

$$\Delta kW = 1 \times (-0.17) = -0.17\ kW$$

$$\Delta MMBtu = 1 \times \frac{17.2 \times 3 \times 365 \times 8.33 \times 69.6}{1{,}000{,}000} \times \left[\frac{1}{0.5803} + 0 - \left(\frac{1}{3.5} \times 1 \times 1 \times \frac{0.7}{0.8}\right)\right]$$
$$= 16.1\ MMBtu$$

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 5.0, July 2022.
   Available from: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Residential%20Water%20Heaters%20Version%205.0%20Specification%20and%20Partner%20Commitments.pdf
2. 10 CFR 430.2 Definitions.
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?rgn=div8&node=10:3.0.1.4.18.1.9.2
3. Water Research Foundation: "Residential End Uses of Water, Version 2: Executive Report", April 2016.
   Available from: https://www.waterrf.org/research/projects/residential-end-uses-water-version-2
4. Residential Statewide Baseline Study of New York State, July 2015.
   Available from: https://www.nyserda.ny.gov/About/Publications/Evaluation-Reports/Building-Stock-and-Potential-Studies/Residential-Statewide-Baseline-Study-of-New-York-State
5. 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=ap10.3.430_127.e&rgn=div9
6. AHRI Directory of Certified Product Performance.
   Available from: https://www.ahridirectory.org/ahridirectory/pages/home.aspx
7. ECCCNYS 2020 Table C403.3.2(1): Minimum Efficiency Requirements: Electrically Operated Unitary Air Conditioners and Condensing Units, Table C403.3.2(2): Minimum Efficiency Requirements: Electrically Operated Unitary and Applied Heat Pumps, Table C403.3.2(4): Warm-Air Furnaces and Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces and Unit Heaters, Minimum Efficiency Requirements, & Table C403.3.2(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-ce-commercial-energy-efficiency
8. 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
9. "Field Testing of Pre-Production Prototype Heat Pump Water Heaters" Federal Energy Management Program, DOE/EE-0317, May 2007.
   Available from: https://energy.gov/sites/prod/files/2014/01/f7/heat_pump_water_heater_testing.pdf

10. "CT HVAC and Water Heater Process and Impact Evaluation and CT Heat Pump Water Heater Impact Evaluation", West Hill Energy and Computing, Final Report R1614/R1613, July 19, 2018.
Available from: https://www.energizect.com/sites/default/files/R1614-1613_ResH-VAC_Report_Final_8.29.18.pdf
11. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
Available from: https://www.energystar.gov/ia/partners/prod_develop-ment/new_specs/downloads/water_heaters/AlgorithmForMainsWaterTemperature.pdf
12. NOAA National Centers for Environmental Information – NCEI 1991-2020 Climate Normals.
Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
13. 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/retriev-eECFR?gp=&SID=9624a8ba0987aaae248454c49194a661&mc=true&n=pt10.3.430&r=PART&ty=HTML#ap10.3.430_127.e
14. "Residential Heat Pump Water Heater Evaluation: Lab Testing & Energy Use Estimates", Bonneville Power Administration, November 2011.
Available from: http://citeseerx.ist.psu.edu/viewdoc/down-load?doi=10.1.1.401.3815&rep=rep1&type=pdf
15. NEEA Heat Pump Water Heater Field Study Report, Fluid Market Strategies, October 2013.
Available from: https://neea.org/img/uploads/heat-pump-water-heater-field-study-re-port.pdf
16. NW Council Heating/Cooling Zone Maps.
Available from: https://www.bpa.gov/EE/Sectors/Residential/Documents/PNWHeat-ingandCoolingClimateZoneAssignmentsbyCounty.pdf
17. 10 CFR 429.17 Water heaters.
Available from: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-429
18. 10 CFR 430.32(e)(2)(iii)(A) Energy and water conservation standards and their compliance dates
Available from: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32

Record of Revision

Record of Revision Number	Issue Date
0	10/15/2010
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12-18-3	12/31/2018
2-20-1	2/28/2020
7-21-7	8/30/2021
3-23-19	3/31/2023

12-23-1	1/5/2024
6-24-17	7/8/2024

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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.*[78]

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.[79,80]

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = units \times \begin{bmatrix} \left(kBTU/h_{cooling} \times \left(\frac{F_{ElecCool}}{EER_{baseline}} - \frac{1}{EER_{ee}} \right) \times EFLH_{cooling} \right) \\ + \\ \left(\frac{kBTU/h_{heating}}{3.412} \times \left(\frac{F_{ElecHeat}}{COP_{baseline}} - \frac{1}{COP_{ee}} \right) \times EFLH_{heating} \right) \end{bmatrix}$$

Summer Peak Coincident Demand Savings

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

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[78] AHRI Standard 310/380 – 2014.

[79] Ibid.

[80] 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

$$\Delta MMBtu = units \times \left(kBTU/h_{heating} \times \frac{F_{FuelHeat}}{Eff_{heating,baseline}} \times \frac{EFLH_{heating}}{1{,}000} \right)$$

where:

ΔkWh	= Annual electric energy savings
DkW	= Peak coincident demand electric savings
DMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
$kBTU/h_{cooling}$	= Output cooling capacity in kBTU/h per unit (at AHRI standard rating conditions)
$kBTU/h_{heating}$	= Output heating capacity in kBTU/h per unit (at AHRI standard high-temperature rating conditions)
$F_{ElecCool}$	= Electric cooling factor; used to account for the presence or absence of an electric cooling system
$F_{ElecHeat}$	= Electric heating factor; used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$	= Fossil fuel heating factor; used to account for the presence or absence of a fossil fuel heating system
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)
$Eff_{heating}$	= Fossil 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
1,000	= Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
$kBTU/h_{cooling}$		From application.
$kBTU/h_{heating}$		From application.
$F_{ElecCool}$		If an electric cooling system is present, set equal to 1. Otherwise, set equal to 0.
$F_{ElecHeat}$		If an electric heating system is present, set equal to 1. Otherwise, set equal to 0.
$F_{FuelHeat}$		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.[81]

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[82] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown below. The formulas in the rightmost column shall be used to establish the baseline efficiency in the units specified (EER or COP).

Electric Cooling and Heating System Baseline Efficiencies

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency ECCCNYS[83]
PTAC (Cooling Mode) Standard Size	All Capacities	95°F db Outdoor Air	EER = 14.0 - (0.300 × Cap/1,000)

[81] 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 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.

[82] ECCCNYS 2020, Table C403.3.2(3).

[83] "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."

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency ECCCNYS[83]
PTAC (Cooling Mode) Replacements/ Nonstandard Size[84]	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 installed without the influence of the energy efficiency program. The baseline efficiency for residential furnaces, boilers, and unit heaters is defined by the Code of Federal Regulations and subsequently adopted by the Energy Conservation Code of New York State.

The baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is defined by the Code of Federal Regulations as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[85]

Equipment Type	Size Range	CFR Minimum Efficiency
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.84 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.86 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.82 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.85 AFUE

[84] 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.

[85] 10 CFR 430.32(e)(2)(iii)(A)

The baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[86] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: 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	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.81 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 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	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 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.

[86] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5).

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.

Example Calculation *(Not to be used as default)*

Four standard size packaged terminal heat pump (PTHP) each fulfilling a cooling load of 17 kBTU/h and a heating load of 23 kBTU/h are installed in a two-story multifamily building located near Albany constructed in 1975. The PTHP has an EER of 10.4 and a COP of 3.2. The conditions prior to installation include an electric cooling system and a gas-fired warm air furnace. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

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

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

$$\Delta MMBtu = units \times \left(kBTU/h_{heating} \times \frac{F_{FuelHeat}}{Eff_{heating,baseline}} \times \frac{EFLH_{heating}}{1{,}000}\right)$$

units = 4
$kBTU/h_{cooling}$ = 17, from application
$F_{ElecCool}$ = 1, based on application
$EER_{baseline}$ = 14.0 – (0.300 x Cap/1,000) = 14.0 – (0.300 x 17,000/1,000) = 8.90
$EER_{baseline}$ equation from Electric Cooling and Heating System Baseline Efficiencies based on equipment type of compliance equipment from application
EER_{ee} = 10.4, from application
$EFLH_{cooling}$ = 286, from Appendix G based on housing type, building vintage, and location from application
$kBTU/h_{heating}$ = 23, from application
$F_{ElecHeat}$ = 0, based on application
$COP_{baseline}$ = 3.2 – (0.026 x cap/1,000) = 3.2 – (0.026 x 23,000/1,000) = 2.60
COP_{ee} = 3.2, from application
$EFLH_{heating}$ = 1,030, from Appendix G based on housing type, building vintage, and location from application
CF = 0.69, from Summary of Variables and Data Sources table
$F_{FuelHeat}$ = 1, based on application
$EFF_{heating,baseline}$ = 0.80 from Fossil Fuel Fired Heating System Baseline Efficiencies table based on equipment type and building type from application

$$\Delta kWh = 4 \times \left[\left(17 \times \left(\frac{1}{8.90} - \frac{1}{10.4}\right) \times 286\right) + \left(\frac{23}{3.412} \times \left(\frac{0}{2.60} - \frac{1}{3.2}\right) \times 1{,}030\right)\right]$$
$$= -8{,}364\ kWh$$

$$\Delta kW = 4 \times \left[17 \times \left(\frac{1}{8.90} - \frac{1}{10.4}\right) \times 0.69\right] = 0.76\ k$$

$$\Delta MMBtu = 4 \times \left(23 \times \frac{1}{0.80} \times \frac{1{,}030}{1{,}000}\right) = 118.5\ MMBtu$$

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: https://www.ahrinet.org/search-standards/ahri-310380-packaged-terminal-air-conditioners-and-heat-pumps-csa-c744-17
2. BG&E, Development of Residential Load Profile for Central Air Conditioners and Heat Pumps.
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 2020 Table C403.3.2(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 C403.3.22(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements & Table C403.3.2(5): Minimum Efficiency Requirements: Gas- And Oil-Fired Boilers.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-ce-commercial-energy-efficiency

5. 10 CFR 430.32(e)(2)(iii)(A) Energy and water conservation standards and their compliance dates
Available from: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32

Record of Revision

Record of Revision Number	Issue Date
2-20-4	2/28/2020
11-23-1	11/30/2023
6-24-18	7/8/2024

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HEATING, VENTILATION AND AIR CONDITIONING (HVAC)

BOILER, FURNACE, AND UNIT HEATER

Measure Description

This measure covers the installation of high efficiency fossil fuel-fired furnaces, boilers, and unit heaters used for space heating. The baseline case shall be minimally code compliant equipment of the same type and capacity as in the efficient case, which shall be sized in accordance with federal, state, local and municipal codes and standards.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times kBTU/h_{in} \times \left(\frac{Eff_{ee}}{Eff_{baseline}} - 1\right) \times \frac{EFLH_{heating}}{1{,}000}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
$kBTU/h_{in}$	= Fuel Input Rating per unit
Eff_{ee}	= Efficiency of energy efficient condition
$Eff_{baseline}$	= Efficiency of baseline condition
$EFLH_{heating}$	= Heating equivalent full-load hours
1,000	= Conversion factor, one MMBtu equals 1,000 kBTU

Summary of Variables and Data Sources

Variable	Value	Notes
$kBTU/h_{in}$		Nominal heating input capacity is the nameplate input rating of the unit in kBTU/h, from application.
$Eff_{baseline}$		Lookup based on equipment type, size and applicable energy conservation code from the Baseline Efficiency section below.
Eff_{ee}		From application.

Variable	Value	Notes
$EFLH_{heating}$		Lookup based on building type and location, Appendix G.

Efficiency is expressed as the ratio between the fuel input relative to the output. The efficiency of furnaces, boilers and unit heaters is customarily evaluated on the basis of one or more of three standards, and are referred to as Thermal Efficiency (E_t), Combustion Efficiency, (E_c) or Annual Fuel Utilization Efficiency (AFUE).

Presently, the AFUE value is only applicable to smaller units. For larger units, use thermal and combustion efficiencies referenced on manufacturer's nameplate data in accordance with nationally recognized standards and testing agencies.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline efficiency for residential furnaces, boilers, and unit heaters is defined by the Code of Federal Regulations and subsequently adopted by the Energy Conservation Code of New York State.

For LMI applications, existing condition baseline shall be established based on nameplate efficiency or efficiency measured through combustion analysis.

The baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is defined by the Code of Federal Regulations as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[87]

Equipment Type	Size Range	CFR Minimum Efficiency
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.84 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.86 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.82 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.85 AFUE

The baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[88] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Multiple Dwelling Units

[87] 10 CFR 430.32(e)(2)(iii)(A)

[88] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5).

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.81 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 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	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

Compliance Efficiencies from which Incentives are Calculated

The compliance condition is a furnace, boiler or unit heater with efficiency exceeding that of the baseline equipment.

Operating Hours

Heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical single and multi-family residential buildings. Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for commercial buildings in NY are shown in Appendix G.

Example Calculation *(Not to be used as default)*

A 120 kBTU/h warm air, gas fired furnace with 92% AFUE is installed in a single - family, detached home located near Albany constructed in 1995. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = units \times kBTU/h_{in} \times \left(\frac{Eff_{ee}}{Eff_{baseline}} - 1\right) \times \frac{EFLH_{heating}}{1{,}000}$$

units = 1, from application
$kBTU/h_{in}$ = 120, from application
Eff_{ee} = 0.92, from application
$Eff_{baseline}$ = 0.80, from Baseline Efficiencies section based on equipment type and size from application
$EFLH_{heating}$ = 978, from Appendix G based on housing type, building vintage, and location from application

$$\Delta MMBtu = 1 \times 120 \times \left(\frac{0.92}{0.80} - 1\right) \times \frac{978}{1{,}000} = 17.60\ MMBtu$$

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

High efficiency furnaces may be packaged with high efficiency cooling equipment and/or electronically commutated blower motors, which may provide electricity savings. Draft fans, when present, will increase electricity consumption.

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. ECCCNYS 2020 Table C403.3.2(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/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402
3. 2015 ASHRAE Handbook – HVAC Applications, Table 4: Comparison of Service Life Estimates.
4. 10 CFR 430.32(e)(2)(iii)(A) Energy and water conservation standards and their compliance dates
   Available from: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-

430/subpart-C/section-430.32

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1-16-2	12/31/2015
6-17-5	6/30/2017
12-19-3	12/23/2019
6-24-19	7/8/2024

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Boiler and Furnace - Combination ("Combi") Boiler and Furnace

Measure Description

This measure covers the installation of residential fossil fuel-fired combination or "combi" boilers and furnaces, which are defined as high-efficiency, instantaneous water heaters with a heating designation. Combi-boilers are all-in-one high-efficiency space heating systems with integrated capability for providing instantaneous domestic hot water, while combi-furnaces supply both domestic tankless hot water and forced air heating. These units realize energy savings through increased thermal efficiency and by taking cold water straight from the main supply and heating it as needed, which eliminates the need for a separate hot water storage tank and avoids standby losses. Qualifying equipment must be in accordance with ASHRAE Standard 124-2007 (RA 2016).[89] This measure only applies to systems with modulating/staging capability and no water storage tank.

This measure only captures the fossil fuel savings impacts of combi-boilers and combi-furnaces. While electric combi-boilers exist, more investigation and research are required before an approach for estimating associated energy savings can be developed.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = N/A$$

Summer Peak Coincident Demand Savings

$$\Delta kW = N/A$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \Delta MMBtu_{SH} + \Delta MMBtu_{DHW}$$

$$\Delta MMBtu_{SH} = units \times \frac{kBTU/h_{in}}{unit} \times \left(\frac{AFUE_{ee}}{AFUE_{baseline}} - 1\right) \times \frac{EFLH_{heating}}{1{,}000}$$

$$\Delta MMBtu_{DHW} = units \times \left[\frac{GPD \times PPH \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \left(\frac{1}{RE_{baseline}} - \frac{1}{AFUE_{ee}}\right) + \frac{UA_{baseline}}{RE_{baseline}} \times \frac{\Delta T_{amb}}{1{,}000{,}000} \times 8{,}760\right]$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings

[89] ASHRAE Standard 124-2007 (RA 2016) – Methods of Testing for Rating Combination Space-Heating and Water-Heating Appliances (ANSI Approved).

$\Delta MMBtu$ = Annual fossil fuel energy savings
$\Delta MMBtu_{DHW}$ = Annual domestic hot water savings associated with installation of a high-efficiency combi-boiler or combi-furnace
$\Delta MMBtu_{SH}$ = Annual space heating savings associated with installation of a high-efficiency combi-boiler or combi-furnace
units = Number of households addressed by the program
$kBTU/h_{in}$ = Space heating fuel input rating
baseline = Characteristic of baseline condition
ee = Characteristic of energy efficient condition
AFUE = Annual fuel utilization efficiency, seasonal energy efficiency for fossil fuel heating equipment
$EFLH_{heating}$ = Heating equivalent full-load hours
GPD = Gallons per day of delivered hot water per person
PPH = Persons per household served by DHW system
ΔT_{main} = Average difference between the cold inlet temperature and the hot water delivery temperature (°F)
RE = Recovery efficiency, a common metric specified by the residential gas-fired storage water heater rating/testing standard and is equivalent to thermal efficiency at standard rating conditions.
UA = Overall heat loss coefficient (BTU/h-°F)
ΔT_{amb} = Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F)
8.33 = Specific heat of water; energy required (BTU), to heat one gallon of water by one degree Fahrenheit [BTU/(gal-F)]
365 = Days in one year
1,000 = Conversion factor, one MMBtu equals 1,000 kBTU
8,760 = Hours in one year
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables & Data Sources

Variable	Value	Notes/References
$kBTU/h_{in}$		Nominal heating input capacity is the nameplate input rating of the unit in kBTU/h, from application.
$AFUE_{baseline}$		See Baseline Efficiencies section below.
$AFUE_{ee}$		From application.
$EFLH_{heating}$		Lookup based on building type and location in Appendix G.
GPD	17.2	Average daily hot water usage per person.[90]

[90] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016, pg. 5; 17.2 GPD equated from the report findings indicating an average 2.65 people per household and 45.5 GPD per household.

Variable	Value	Notes/References
PPH		From application. If unknown, use a value of 2.8 for single-family homes[91] and 2.0 for multifamily homes.[92] For sites with multiple water heating systems, PPH shall be allocated proportional to the input heating capacity of each water heater relative to the total input heating capacity of all water heaters.[93]
DT_{main}	$T_{set} - T_{main}$	Average temperature difference between water heater set point temperature and the supply water temperature in water main (°F).
DT_{amb}	55 $= T_{set} - T_{amb}$	Average temperature difference between water heater set point temperature and the surrounding ambient air temperature (°F).
T_{set}	125	Water heater set point temperature (°F).[94]
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{amb}	70	Surrounding ambient air temperature (°F).[95]
$RE_{baseline}$	0.75	Gas recovery efficiency.[96]
$UA_{baseline}$	7.85	Overall heat loss coefficient of the baseline condition (BTU/h-°F).[97]

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.[98] Supply main temperatures based on the annual outdoor temperature are shown below.

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[91] Residential Statewide Baseline Study of New York State, July 2015. Volume 1: Single-Family Report, Table 9.

[92] Residential Statewide Baseline Study of New York State, July 2015. Volume 2: Multifamily Report, Table 8.

[93] For example, if a home with 6 occupants contains two water heaters with 40 MBH and 50 MBH input capacities and the 40 MBH unit is being replaced with an equivalent capacity unit, the PPH value applied shall be PPH = 6 (occupants) x 40 (MBH) / (40 + 50) (MBH) = 2.7.

[94] 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.

[95] Water heaters are generally located in conditioned or partially conditioned spaces with a typical average temperature of 65°F to 70°F to avoid freezing. A value of 70°F is used for the purposes of estimating tank/ambient air temperature differential, which aligns with standby loss specification testing standards.

[96] Per 10 CFR 430, typical recovery efficiency of a fuel water heater, which is used for the purposes of this measure as a proxy for thermal efficiency, is 0.75. See for example, 10 CFR 430 Subpart B Appendix C1, 5.6.1.1.

[97] Based on computation of heat loss coefficients via conversion equations found in 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters. Heat loss coefficient was calculated for a minimally code compliant fuel storage water heater found to be the most typical in terms of storage and input capacity, representing storage type water heaters of between 20 and 55 gallon capacity (40 gallon, 40,000 BTU/h assumed). Results of heat loss coefficient evaluation for this assumed baseline is used to represent the $UA_{baseline}$ term.

[98] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.

City	Annual average outdoor temperature[99] (°F)	T_{main} (°F)
Albany	49.4	55.4
Binghamton	46.8	52.8
Buffalo	49.1	55.1
Massena	45.1	51.1
NYC	54.7	60.7
Poughkeepsie	50.9	56.9
Syracuse	49.0	55.0

Coincidence Factor (CF)

The prescribed value for the coincidence factor is N/A. This measure is not anticipated to have electric impacts.

Baseline Efficiencies from which Energy Savings are Calculated

Space Heating Component

The baseline efficiency for the space heating component of residential combi-boilers and combi-furnaces is defined by the Code of Federal Regulations and subsequently adopted by the Energy Conservation Code of New York State, as shown below.

For LMI applications, existing condition baseline shall be established based on nameplate efficiency or efficiency measured through combustion analysis.

The baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is defined by the Code of Federal Regulations as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[100]

Equipment Type	Size Range	CFR Minimum Efficiency
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.84 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.86 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.82 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.85 AFUE

The baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[101] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Multiple Dwelling Units

[99] Average annual outdoor temperatures taken from NCEI 1991-2020 climate normals.
[100] 10 CFR 430.32(e)(2)(iii)(A)
[101] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5).

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.81 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 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	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

<u>Domestic Hot Water Component</u>
The baseline condition is a standard efficiency 40-gallon storage type water heater with a recovery efficiency of 75%[102] and heat loss coefficient of 7.85 BTU/h-°F.[103]

For LMI applications, existing condition baseline shall be established based on nameplate efficiency or efficiency measured through combustion analysis.

Compliance Efficiency from which Incentives are Calculated

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[102] Per 10 CFR 430, typical recovery efficiency of a fuel water heater, which is used for the purposes of this measure as a proxy for thermal efficiency, is 0.75. See for example, 10 CFR 430 Subpart B Appendix C1, 5.6.1.1.
[103] Per 10 CFR 430, typical recovery efficiency of a fuel water heater, which is used for the purposes of this measure as a proxy for thermal efficiency, is 0.75. See for example, 10 CFR 430 Subpart B Appendix C1, 5.6.1.1.
[103] Based on computation of heat loss coefficients via conversion equations found in 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters. Heat loss coefficient was calculated for a minimally code compliant fuel storage water heater found to be the most typical in terms of storage and input capacity, representing storage type water heaters of between 20 and 55 gallon capacity (40 gallon, 40,000 BTU/h assumed). Results of heat loss coefficient evaluation for this assumed baseline is used to represent the $UA_{baseline}$ term.

The compliance condition is a combi-boiler unit with a heating designation efficiency of 90% AFUE or greater or a combi-furnace unit with a heating designation efficiency of 92% AFUE. Qualifying systems must be equipped with modulating/staging capability and no water storage tank. Units shall be in accordance with ASHRAE Standard 124-2007 (RA 2016).[104]

Operating Hours

Heating equivalent full-load hours were calculated from a DOE-2.2 simulation of prototypical single and multi-family residential buildings. Operating hour assumptions for the prototypical building models are described in Appendix A. The heating EFLH for residential buildings in NY are shown in Appendix G.

Domestic hot water heaters are assumed to be available for operation 8,760 hours per year, and it is assumed standby losses in the baseline case are incurred 8,760 hours per year.

Example Calculation *(Not to be used as default)*

A "combi" boiler with 199 kBTU/h and 90% AFUE is installed in a single - family, detached home with 5 residents located near Albany constructed in 1995. The conditions prior to installation include a gas-fired warm air furnace and gas storage tank water heater. Annual Electric Energy Savings and Summer Peak Coincident Demand Savings are not applicable. Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta MMBtu = \Delta MMBtu_{SH} + \Delta MMBtu_{DHW}$$

$$\Delta MMBtu_{SH} = units \times \frac{kBTU/h_{in}}{unit} \times \left(\frac{AFUE_{ee}}{AFUE_{baseline}} - 1\right) \times \frac{EFLH_{heating}}{1{,}000}$$

$$\Delta MMBtu_{DHW} = units \times \left[\frac{GPD \times PPH \times 365 \times 8.33 \times \Delta T_{main}}{1{,}000{,}000} \times \left(\frac{1}{RE_{baseline}} - \frac{1}{AFUE_{ee}}\right) + \frac{UA_{baseline}}{RE_{baseline}} \times \frac{\Delta T_{amb}}{1{,}000{,}000} \times 8{,}760\right]$$

units = 1, from application
$(kBTU/h_{in})$/unit = 199, from application
$AFUE_{ee}$ = 0.9, from application
$AFUE_{baseline}$ = 0.80, from Baseline Efficiencies section based on equipment type and size from application
$EFLH_{heating}$ = 978, from Appendix G based on housing type, building vintage, and location from application
GPD = 17.2, from Summary of Variables and Data Source table
PPH = 5, from application
$\Delta T_{main} = T_{set} - T_{main} = 125 - 55.4 = 69.6$

[104] ASHRAE Standard 124-2007 (RA 2016) – Methods of Testing for Rating Combination Space-Heating and Water-Heating Appliances (ANSI Approved).

T_{set} from Summary of Variables and Data Sources table
T_{main} from Cold Water Inlet Temperature lookup table based on location from application
$RE_{baseline}$ = 0.75, from Summary of Variables and Data Sources table
$UA_{baseline}$ = 7.85, from Summary of Variables and Data Sources table
ΔT_{amb} = 55, from Summary of Variables and Data Sources table

$$\Delta MMBtu_{SH} = 1 \times 199 \times \left(\frac{0.90}{0.80} - 1\right) \times \frac{978}{1{,}000} = 24.33\ MMBtu$$

$$\Delta MMBtu_{DHW} = 1 \times \left[\frac{17.2 \times 5 \times 365 \times 8.33 \times 69.6}{1{,}000{,}000} \times \left(\frac{1}{0.8} - \frac{1}{0.9}\right) + \frac{7.85}{0.75} \times \frac{55}{1{,}000{,}000} \times\ 8{,}760\right] = 7.57\ MMBtu$$

$$\Delta MMBtu = 24.33 + 7.57 = 31.90\ MMBtu$$

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

High efficiency furnaces may be packaged with high efficiency cooling equipment and/or electronically commutated blower motors, which may provide electricity savings. Draft fans, when present, will increase electricity consumption.

References

1. ASHRAE Standard 124-2007 (RA 2016) – Methods of Testing for Rating Combination Space-Heating and Water-Heating Appliances (ANSI Approved).
2. Water Research Foundation: "Residential End Uses of Water, Version 2: Executive Report", April 2016.
   Available from:
   https://www.circleofblue.org/wp-content/uploads/2016/04/WRF_REU2016.pdf
3. Residential Statewide Baseline Study of New York State, July 2015.
   Available from: https://www.nyserda.ny.gov/About/Publications/Evaluation-Reports/Building-Stock-and-Potential-Studies/Residential-Statewide-Baseline-Study-of-New-York-State

4. 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=ap10.3.430_127.e&rgn=div9
5. 10 CFR 430 Subpart B – Test Procedures, Appendix C1 - Uniform Test Method for Measuring the Energy Consumption of Dishwashers.
   Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=9acb5e05dd1d96230c64079cf0c03102&mc=true&node=pt10.3.430&rgn=div5#ap10.3.430_127.c1
6. 10 CFR 429, 430, and 431 Docket No. EERE-2015-BT-TP-0007, Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters.
   Available from: https://energy.gov/sites/prod/files/2016/08/f33/Water%20Heaters%20Test%20Procedure%20SNOPR.pdf
7. AHRI Directory of Certified Product Performance.
   Available from: https://www.ahridirectory.org/Search/SearchHome?ReturnUrl=%2f
8. Burch, Jay and Craig Christensen; "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
   Available from: https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/AlgorithmForMainsWaterTemperature.pdf
9. NOAA National Centers for Environmental Information – NCEI 1991-2020 Climate Normals.
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
10. ECCCNYS 2020 Table C403.3.2(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/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402
11. 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
12. 10 CFR 430.32(e)(2)(iii)(A) Energy and water conservation standards and their compliance dates
    Available from: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32

Record of Revision

Record of Revision Number	Issue Date
9-18-16	9/28/2018
12-23-4	1/5/2024

6-24-20	7/8/2024

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ENERGY AND HEAT RECOVERY VENTILATOR

Measure Description

This measure covers the installation of Energy Recovery Ventilator (ERV) and Heat Recovery Ventilator (HRV) equipment. ERVs and HRVs reduce heating and cooling loads while maintaining required ventilation rates by facilitating heat transfer between outgoing conditioned air and incoming outdoor air. ERVs and HRVs employ air-to-air heat exchangers to recover energy from exhaust air for the purpose of pre-conditioning outdoor air prior to supplying the conditioned air to the space, either directly or as part of an air-conditioning system.[105] This measure only applies in cases where ERV/HRV functionality is not required by federal, state, local or municipal codes or standards. For the purposes of this measure, ERVs and HRVs are distinguished as follows:

Energy Recovery Ventilator (ERV)
Transfers both sensible (heat content) and latent (moisture content) heat between supply and exhaust airstreams.

Heat Recovery Ventilator (HRV)
Transfers sensible heat only between supply and exhaust airstreams.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings (for ERVs)

Annual Electric Energy Savings

$$\Delta kWh = units \times (\Delta kWh_{cooling} + \Delta kWh_{heating} + \Delta kWh_{fan})$$

$$\Delta kWh_{cooling} = \frac{4.5 \times CFM \times \Delta H \times Eff_{hx,total}}{1{,}000 \times Eff_{ElecCool}} \times \frac{hrs/day}{24} \times F_{ElecCool}$$

$$\Delta kWh_{heating} = \frac{1.08 \times CFM \times HDD \times Eff_{hx,sens}}{1{,}000 \times Eff_{ElecHeat}} \times hrs/day \times F_{ElecHeat}$$

$$\Delta kWh_{fan} = \left[\left(\frac{CFM}{1{,}000 \times Eff_{fan,baseline}} \times hrs/day\right) - \left(\frac{W_{fan,ee}}{1{,}000}\right)\right] \times 365$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \left(\frac{\Delta kWh_{fan}}{8{,}760} + \frac{\Delta kWh_{cooling}}{EFLH_{cooling}}\right) \times CF$$

Annual Fossil Fuel Energy Savings

[105] AHRI GUIDELINE V (I-P)-2011 Calculating the Efficiency of Energy Recovery Ventilation and its Effect on Efficiency and Sizing of Building HVAC Systems.

$$\Delta MMBtu = \frac{1.08 \times CFM \times HDD \times Eff_{hx,sens}}{1{,}000{,}000 \times Eff_{FuelHeat}} \times hrs/day \times F_{FuelHeat}$$

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings (for HRVs)

Annual Electric Energy Savings

$$\Delta kWh = units \times (\Delta kWh_{cooling} + \Delta kWh_{heating} + \Delta kWh_{fan})$$

$$\Delta kWh_{cooling} = \frac{1.08 \times CFM \times CDD \times Eff_{hx,sens}}{1{,}000 \times Eff_{ElecCool}} \times hrs/day \times F_{ElecCool}$$

$$\Delta kWh_{heating} = \frac{1.08 \times CFM \times HDD \times Eff_{hx,sens}}{1{,}000 \times Eff_{ElecHeat}} \times hrs/day \times F_{ElecHeat}$$

$$\Delta kWh_{fan} = \left[\left(\frac{CFM}{1{,}000 \times Eff_{fan,baseline}} \times hrs/day\right) - \left(\frac{W_{fan,ee}}{1{,}000}\right)\right] \times 365$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \left(\frac{\Delta kWh_{fan}}{8{,}760} + \frac{kWh_{cooling}}{EFLH_{cooling}}\right) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{1.08 \times CFM \times HDD \times Eff_{hx,sens}}{1{,}000{,}000 \times Eff_{FuelHeat}} \times hrs/day \times F_{FuelHeat}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
units	= Number of measures installed under the program
baseline	= Property of the baseline or existing condition
ee	= Property of the efficient condition
heating	= Property of heating season
cooling	= Property of cooling season
fan	= Property of system fan
CFM	= Maximum rated CFM of the proposed ERV/HRV
ΔH	= Product of the difference between outdoor air and return air enthalpies (Btu/lb air) at each outdoor air enthalpy bin and the number of hours at each bin (Btu-h/lb)

$Eff_{hx,total}$ = Total Effectiveness of heat exchanger rated in accordance with AHRI Standard 1060[106] or Total Recovery Efficiency rated in accordance with HVI 920[107]

$Eff_{hx,sens}$ = Sensible Effectiveness of heat exchanger rated in accordance with AHRI Standard 1060[108] or Sensible Recovery Efficiency rated in accordance with HVI 920[109]

$Eff_{ElecCool}$ = Seasonal average energy efficiency of electric cooling equipment, BTU/watt-hour, using either SEER (<65,000 BTU/h) or IEER ($\geq$65,000 BTU/h)

$Eff_{ElecHeat}$ = Seasonal average energy efficiency of electric heating equipment. Heating Seasonal Performance Factor, BTU/watt-hour, total heating output (supply heat) in BTU (including resistance heating) during the heating season / total electric energy heat pump consumed (in watt-hour); if equipment efficiency is reported in COP, convert to HSPF using the equivalency HSPF = COP x 3.412

$Eff_{FuelHeat}$ = Efficiency of fossil fuel heating equipment (AFUE, Et, or Ec)

hrs/day = Average daily run time, in hours, when ERV/HRV is in recovery mode

$F_{ElecCool}$ = Electric cooling factor, used to account for the presence or absence of a central electric cooling system

$F_{ElecHeat}$ = Electric heating factor, used to account for the presence or absence of an electric heating system

$F_{FuelHeat}$ = Fossil fuel heating factor, used to account for the presence or absence of a fossil fuel heating system

$Eff_{fan,baseline}$ = Base case exhaust fan efficiency (CFM/W)

$W_{fan,ee}$ = Total rated wattage of ERV/HRV fans

HDD = Heating Degree Days. The number of degrees that a day's average temperature is below some baseline temperature, which represents the temperature below which buildings need to be heated. The baseline temperature is typically 65°F, but may vary based on application.

CDD = Cooling Degree Days. The number of degrees that a day's average temperature is above some baseline temperature, which represents the temperature above which buildings need to be cooled. The baseline temperature is typically 65°F, but may vary based on application.

$EFLH_{cooling}$ = Equivalent full-load cooling hours

CF = Coincidence Factor

4.5 = Density of inlet air at 70ºF x 60 min/hr, in lb-min/ft^3-hr

1.08 = Specific heat of air × density of inlet air @ 70˚F × 60 min/hr[110] in BTU/h-ºF-CFM

24 = Hours in a day

365 = Days in year

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[106] AHRI Standard 1060 for Performance Rating of Air-to-Air Exchangers for Energy Recovery Ventilation Equipment.

[107] HVI Publication 920 Product Performance Certification Procedure Including Verification and Challenge

[108] AHRI Standard 1060 for Performance Rating of Air-to-Air Exchangers for Energy Recovery Ventilation Equipment.

[109] HVI Publication 920 Product Performance Certification Procedure Including Verification and Challenge

[110] The sensible heat constant at standard conditions of 1.08 is applied in accordance with standard HVAC industry practice. While the underlying assumptions are not representative characteristics of a NY heating season, the impacts to this value due to average heating season temperature and NY mean elevation offset such that the NY heating season specific value is approximately 1.08.

8,760 = Hours in a year
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU
1,000 = Conversion factor, one kW equals 1,000 Watts

Summary of Variables and Data Sources

Variable	Value	Notes
CFM		From application.
ΔH		Lookup from Derivation of DH Values using Bin Analysis table below based on location.
$Eff_{hx,total}$		From application. If unknown, refer to ERV/HRV Defaults table below.
$Eff_{hx,sens}$		From application. If unknown, refer to ERV/HRV Defaults table below.
$Eff_{ElecCool}$		From application or use 14 SEER, assuming a 3-ton central ASHP system.[111] For equipment rated in SEER2, SEER2 rating shall be used.
$Eff_{ElecHeat}$		From application or use 8.2 HSPF, assuming a 3-ton central ASHP system.[112] For electric resistance heating and electric furnaces, use 3.4 HSPF. If taken from application, COP must be converted to HSPF using the equivalency HSPF = COP x 3.412. Use HSPF2 if equipment has an HSPF2 rating. For electric resistance heat, use 3.412 HSPF.
$Eff_{FuelHeat}$		From application, E_c, E_t, or AFUE shall be used, based on nameplate rating metric of existing equipment. If unknown, lookup in tables below based on equipment type and size.
hrs/day	19.2	See Operating Hours section below.
$F_{ElecCool}$		Use a value of 1.0 if the building has a central electric cooling system. Otherwise, use 0.0.
$F_{ElecHeat}$		Use a value of 1.0 if the building is electrically heated. Otherwise, use 0.0.
$F_{FuelHeat}$		Use a value of 1.0 if the building is fossil fuel heated. Otherwise use 0.0.
$Eff_{fan,baseline}$	2.8 CFM/W	Per IECC.[113]
$W_{fan,ee}$		From application. If unknown, refer to ERV/HRV Defaults table below.
HDD		From application. If unknown, lookup based on location in Heating and Cooling Degree Days table below.
CDD		From application. If unknown, lookup based on location in Heating and Cooling Degree Days table below.

[111] 10 CFR 430.32 (c)(1).
[112] Ibid.
[113] IECC 2018 Table R403.6.1

Variable	Value	Notes
$EFLH_{cooling}$		Lookup based on building type, vintage and location from Appendix G.
CF	0.69	

ERV/HRV Defaults[114]

Residence Type	CFM	$Eff_{hx,sens}$	$Eff_{hx,total}$	$W_{fan,ee}$
Single-family	153	0.73	0.56	52
Multi-family	64	0.67	0.48	38

Derivation of DH Values using Bin Analysis

To account for the full benefits of an ERV transferring sensible and latent heat between supply and exhaust airstreams, it is necessary to establish the aggregate enthalpy difference between outside air and return air (i.e., desired indoor air conditions) across the entire cooling season. To accomplish this, a bin analysis was conducted for each standard weather city to determine the number of hours the outside air dry bulb temperature fell within each 5°F bin and the average air enthalpy within each temperature bin. The results were then input into the below algorithm:

$$\Delta H = \sum (H_{OA} - H_{RA}) \times hrs_{bin}$$

where:

ΔH = Product of the difference between outdoor air and return air enthalpies (Btu/lb air) at each outdoor air enthalpy bin and the number of hours at each bin (Btu-h/lb)

H_{OA} = Average enthalpy at the outdoor air dry bulb temperature bin (per the Outdoor Air Temperature & Enthalpy table below)

H_{RA} = Enthalpy of the return air (assumed constant 25.3 Btu/lb based on 70°F and 50% RH indoor air conditions).

hrs_{bin} = Hours during which the outdoor air dry bulb temperature fell within the bin range (per the Bin Hours table below)

The resultant ΔH values for each standard weather city are presented in the table below.

City	ΔH
Albany	7,656
Binghamton	3,973
Buffalo	6,793
Massena	5,165
NYC	14,315
Poughkeepsie	9,599

[114] Table of ERV/HRV Default Values is based on all available ERV Certified Data from file 'HVIProd_ER.xlsx' published by Home Ventilating Institute (This table lists certified values of 387 models of ERVs. The default values above assume that Single-family residences will install ERVs with Heating CFM > 75 and Multi-family residences will install ERVs with Heating CFM <= 75 cfm. The respective default values represent arithmetic averages of the respective HVI ERV values separated into these two ERV CFM ranges.

City	ΔH
Syracuse	7,296

Outdoor Air Temperature & Enthalpy[115]

Outdoor air dry bulb temperature bins and corresponding average enthalpy by city across a typical climatological year is presented in the table below.

DB Temperature Range (°F)	Mid-Point (°F)	Albany (Btu/lb)	Binghamton (Btu/lb)	Buffalo (Btu/lb)	Massena (Btu/lb)	NYC (Btu/lb)	Poughkeepsie (Btu/lb)	Syracuse (Btu/lb)
95 to 100	97.5	24.30	24.26	24.26	24.26	24.26	24.26	24.26
90 to 95	92.5	23.06	23.06	23.06	23.06	23.06	23.06	23.06
85 to 90	87.5	21.86	21.86	21.86	21.86	21.86	21.86	21.86
80 to 85	82.5	20.66	20.66	20.66	20.66	33.96	32.91	32.59
75 to 80	77.5	30.88	30.24	30.56	30.69	32.24	30.99	30.84
70 to 75	72.5	28.75	28.65	28.88	28.72	30.54	29.07	28.73
65 to 70	67.5	27.06	26.70	27.08	26.67	27.22	27.27	27.19
60 to 65	62.5	24.27	24.79	24.33	24.82	23.80	24.42	24.53
55 to 60	57.5	21.07	21.60	21.31	21.74	20.81	21.29	21.35
50 to 55	52.5	18.56	18.82	18.76	18.99	18.32	18.72	18.80
45 to 50	47.5	16.28	16.50	16.47	12.88	15.98	16.28	16.52
40 to 45	42.5	14.19	14.36	14.40	14.45	13.90	14.24	14.40
35 to 40	37.5	12.25	12.37	12.50	12.52	11.92	12.14	12.47
30 to 35	32.5	10.37	10.59	10.66	10.68	10.33	10.35	10.55
25 to 30	27.5	8.73	8.85	8.95	8.83	8.85	8.85	8.88
20 to 25	22.5	7.19	7.31	7.43	7.19	6.23	7.32	7.31
15 to 20	17.5	5.77	5.90	5.03	5.68	5.03	5.03	5.90
10 to 15	12.5	3.83	3.83	3.83	4.23	3.83	3.83	3.83
5 to 10	7.5	2.63	2.64	2.64	2.64	2.64	2.64	2.64
0 to 5	2.5	1.43	1.43	1.43	1.43	1.43	1.43	1.43
-5 to 0	-2.5	0.23	0.23	0.23	0.23	0.23	0.23	0.23
-10 to -5	-7.5	-0.97	-0.97	-0.97	-0.97	-0.97	-0.97	-0.97
-15 to -10	-12.5	-2.17	-2.17	-2.17	-2.17	-2.17	-2.17	-2.17
-20 to -15	-17.5	-3.37	-3.37	-3.37	-3.37	-3.37	-3.37	-3.37
-25 to -20	-22.5	-4.57	-4.57	-4.57	-4.57	-4.57	-4.57	-4.57
-30 to -25	-27.5	-5.77	-5.77	-5.77	-5.77	-5.77	-5.77	-5.77
-35 to -30	-32.5	-6.97	-6.97	-6.97	-6.97	-6.97	-6.97	-6.97
-40 to -35	-37.5	-8.18	-8.18	-8.18	-8.18	-8.18	-8.18	-8.18

Bin Hours[116]

Number of hours the outdoor air dry bulb temperature falls within each bin range by city across a typical climatological year is presented in the table below.

DB Temperature Range (°F)	Mid-Point (°F)	Albany (hrs)	Binghamton (hrs)	Buffalo (hrs)	Massena (hrs)	NYC (hrs)	Poughkeepsie (hrs)	Syracuse
95 to 100	97.5	0	0	0	0	0	0	0
90 to 95	92.5	0	0	0	0	0	0	0
85 to 90	87.5	0	0	0	0	0	0	0
80 to 85	82.5	124	0	0	0	246	394	42
75 to 80	77.5	556	195	520	483	698	489	619
70 to 75	72.5	608	574	678	489	1115	578	561

[115] NCEI 1991-2020 Annual/Seasonal Climate Normals.

[116] Ibid.

DB Temperature Range (°F)	Mid-Point (°F)	Albany (hrs)	Binghamton (hrs)	Buffalo (hrs)	Massena (hrs)	NYC (hrs)	Poughkeepsie (hrs)	Syracuse
65 to 70	67.5	884	776	916	649	780	832	866
60 to 65	62.5	865	1071	859	959	717	876	893
55 to 60	57.5	659	735	622	714	707	663	648
50 to 55	52.5	624	648	645	615	735	636	623
45 to 50	47.5	617	636	635	584	746	667	630
40 to 45	42.5	621	626	652	582	882	643	626
35 to 40	37.5	675	670	715	550	1197	811	700
30 to 35	32.5	822	730	819	619	858	963	762
25 to 30	27.5	1056	1157	1246	571	79	839	1139
20 to 25	22.5	608	878	453	886	0	369	650
15 to 20	17.5	41	64	0	731	0	0	1
10 to 15	12.5	0	0	0	328	0	0	0

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[117]

Baseline Efficiencies from which Energy Savings are Calculated

The baseline condition for this measure is a single or multi-family dwelling with an ASHRAE 62.2-compliant exhaust fan system with no heat or energy recovery.

The baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is defined by the Code of Federal Regulations as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[118]

Equipment Type	Size Range	CFR Minimum Efficiency
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.84 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.86 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.82 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.85 AFUE

The baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[119] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Multiple Dwelling Units

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[117] 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 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 RM Management Committee.
[118] 10 CFR 430.32(e)(2)(iii)(A)
[119] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5).

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.81 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 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	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

Compliance Efficiency from which Incentives are Calculated

The compliance condition for this measure is a building with an ASHRAE 62.2-compliant exhaust fan system equipped with AHRI 1060 or HVI 920 certified ERV or HRV components.

Operating Hours

The equipment is oversized such that it is able to provide necessary ventilation on the design heating day despite having to run in defrost mode more often. The assumption made is that the system is oversized by 25% to achieve this and that this results in an average daily runtime over the course of the year of 19.2 hours/day (80% of 24 hours) to adequately ventilate the home.

Default HDD and CDD are presented in the table below for use in this methodology.

Heating and Cooling Degree Days[120]

City	HDD	CDD
Albany	6,391	721

[120] HDD/CDD taken from NCEI 1991-2020 climate normal using a 65 °F balance point.

City	HDD	CDD
Binghamton	7,200	383
Buffalo	6,502	607
Massena	8,030	406
NYC	4,900	1,017
Poughkeepsie	6,026	745
Syracuse	6,625	618

Example Calculation *(Not to be used as default)*

An ERV delivering 70 CFM is installed in a high-rise multifamily building built in 1970 with an existing ½ hp exhaust fan system of 70% efficiency located near Albany. The ERV has a sensible effectiveness of 88% and total effectiveness of 68%, and operates for 19.2 hours per day. The building is cooled by a central air conditioner with 13 SEER and heated by an 80% thermal efficient gas furnace. The ERV fan has a motor efficiency of 80%, a mechanical efficiency of 65% and a rated wattage of 90W. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = units \times (\Delta kWh_{cooling} + \Delta kWh_{heating} + \Delta kWh_{fan})$$

$$\Delta kWh_{cooling} = \frac{4.5 \times CFM \times \Delta H \times Eff_{hx,total}}{1{,}000 \times Eff_{ElecCool}} \times \frac{hrs/day}{24} \times F_{ElecCool}$$

$$\Delta kWh_{heating} = \frac{1.08 \times CFM \times HDD \times Eff_{hx,sens}}{1{,}000 \times Eff_{ElecHeat}} \times hrs/day \times F_{ElecHeat}$$

$$\Delta kWh_{fan} = \left[\left(\frac{CFM}{1{,}000 \times Eff_{fan,baseline}} \times hrs/day\right) - \left(\frac{W_{fan,ee}}{1{,}000}\right)\right] \times 365$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \left(\frac{kWh_{fan}}{8{,}760} + \frac{kWh_{cooling}}{EFLH}\right) \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{1.08 \times CFM \times HDD \times Eff_{hx,sens}}{1{,}000{,}000 \times Eff_{FuelHeat}} \times hrs/day \times F_{FuelHeat}$$

units = 1, from application
CFM = 70, from application
$Eff_{hx,total}$ = 0.68, from application
ΔH = 7,656, from Derivation of DH Values using Bin Analysis table
Hrs/day = 19.2 hours, from Summary of Variables and Data Sources table

HDD = 6,391, from Operating Hours Section
$Eff_{ElecCool}$ = 13, from application
$F_{ElecCool}$ = 1, from application
$Eff_{fan,baseline}$ = 2.8 CFM/W, from Summary of Variables and Data Sources table
$Eff_{hx,sens}$ = 0.88, from application
$Eff_{ElecHeat}$ = N/A, from application
$W_{fan,ee}$ = 90, from application
$F_{ElecHeat}$ = 0, from application
$EFLH_{cooling}$ = 686, from Appendix G based on building type, vintage and location
CF = 0.69, from Summary of Variables and Data Sources table
$Eff_{FuelHeat}$ = 0.80, from application
$F_{FuelHeat}$ = 1, from application

$$\Delta kWh = 1 \times (100.91 + 0 + 142.35) = 243.26\ kWh$$

$$\Delta kWh_{cooling} = \frac{4.5 \times 70 \times 7656 \times 0.68}{1{,}000 \times 13} \times \frac{19.2}{24} \times 1 = 100.91\ kWh$$

$$\Delta kWh_{heating} = 0\ kWh$$

$$\Delta kWh_{fan} = \left[\left(\frac{70}{1{,}000 \times 2.8} \times 19.2\right) - \left(\frac{90}{1{,}000}\right)\right] \times 365 = 142.35\ kWh$$

$$\Delta kW = \left(\frac{142.35}{8{,}760} + \frac{100.91}{686}\right) \times 0.69 = 0.11\ kW$$

$$\Delta MMBtu = \frac{1.08 \times 70 \times 6391 \times 0.88}{1{,}000{,}000 \times 0.80} \times 19.2 \times 1 = 10.20\ MMBtu$$

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

Employing ERVs in the winter may exchange latent heat decreasing the need to run a humidifier, but the impact is expected to be negligible and is not quantified in the prescribed estimation methodology for this measure at this time.

References

1. ECCCNYS 2020 Table C403.3.2(4): Warm-Air Furnaces And Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces And Unit Heaters, Minimum Efficiency Requirements.
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC403
2. 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
3. AHRI GUIDELINE V (I-P)-2011 Calculating the Efficiency of Energy Recovery Ventilation and its Effect on Efficiency and Sizing of Building HVAC Systems. Available from: https://www.ahrinet.org/system/files/2023-06/AHRI_Guideline_V_I-P_2011.pdf
4. AHRI Standard 1060 (I-P), 2018 Standard for Performance Rating of Air-to-Air Exchangers for Energy Recovery Ventilation Equipment.
   Available from: https://www.airxchange.com/wp-content/uploads/2020/10/AHRI_Standard_1060_I-P_2018.pdf
5. HVI Publication 920 Product Performance Certification Procedure Including Verification and Challenge, February 2020.
   Available from: https://www.hvi.org/hvi-certified-ratings-programs/hvi-certification-program-policies-and-procedures/
6. NOAA National Center for Environmental Information – NCEI 1991 – 2020 Annual/Seasonal Climate Normals.
   Available from: https://www.ncdc.noaa.gov/cdo-web/datatools/normals
7. BG&E: Development of Residential Load Profile for Central Air Conditioners and Heat Pumps.
8. International Energy Conservation Code 2018, table R403.6.1 Whole dwelling mechanical ventilation system efficacy.
   Available from: https://codes.iccsafe.org/content/iecc2018/chapter-4-re-residential-energy-efficiency
9. 10 CFR 430.32(e)(2)(iii)(A) Energy and water conservation standards and their compliance dates
   Available from: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32

Record of Revision

Record of Revision Number	Issue Date
7-20-2	7/31/2020
6-22-5	9/2/2022
3-23-8	3/31/2023
6-23-4	7/14/2023
6-24-21	7/8/2024

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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 Pump (ccASHP) systems[121] with total rated heating capacity less than 300,000 BTU/h that provide heating and cooling in for space conditioning in residential applications.[122] An air source heat pump is a product, other than a packaged terminal heat pump or single package vertical heat pump, which is powered by single phase electricity, air cooled, 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 measure applies to central ducted systems, 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.

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

- Residential NYS code and Federal Standard (ECCCNYS 2020, 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.[123,124]

- 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 120% of the design heating load.[125] 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 for heating displacement applications in conformance with the NEEP *Guide to Sizing & Selecting Air-Source Heat Pumps in Cold Climates*[126].

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[121] NEEP Cold Climate Air Source Heat Pump (ccASHP) Specification (Version 4.0) effective January 1, 2023

[122] "Residential application" 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.

[123] ECCCNYS 2020, Section R403.7.

[124] ECCCNYS 2020 requires that systems serving multiple dwelling units follow Sections C403 and C404.

[125] 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.

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

The ASHP efficiency must meet the Northeast Energy Efficiency Partnerships (NEEP) Cold Climate Air Source Heat Pump (ccASHP) Specification (Version 4.0) effective January 1, 2023. 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

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

Summer Peak Coincident Demand Savings

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

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = BHL \times \frac{1}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{AFUE_{baseline}} \times BEFLH_{heating} \times F_{load,heating} \times F_{ctrl}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
BCL	= Building Cooling Load at design conditions (BTU/h)
BHL	= Building Heating Load at design conditions (BTU/h)
$F_{ElecHeat}$	= Electric heating factor; used to account for the presence or absence of an electric heating system
$F_{ElecHeat,new}$	= New electric heating factor; used to account for a new heat pump's reliance on supplemental electric resistance heat to meet full heating load
$F_{FuelHeat}$	= Fossil fuel heating factor; used to account for the presence or absence of a fossil fuel heating system
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition
SEER	= Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour, used for average U.S. location/region
EER	= Full load energy efficiency ratio (BTU/watt-hour)

EER_{season} = Seasonally adjusted average energy efficiency (BTU/watt-hour)
COP = Coefficient of performance for heating, ratio of output energy/input energy
COP_{season} = Seasonally adjusted average coefficient of performance
AFUE = Annual fuel utilization efficiency, seasonal efficiency for fossil fuel heating equipment
$BEFLH_{cooling}$ = Cooling equivalent full-load hours based on building design load
$BEFLH_{heating}$ = Heating equivalent full-load hours based on building design load
$F_{load,cooling}$ = Adjustment factor to account for the portion of the seasonal[127] cooling load met by the heat pump
$F_{load,heating}$ = Adjustment factor to account for the portion of the seasonal[128] heating load met by the heat pump
F_{ctrl} = Factor to modify heating load fraction when optional control features are used.
CF = Coincidence Factor
3.412 = Conversion factor, one watt-hour equals 3.412 BTU
1,000 = Conversion factor, one kilowatt equals 1,000 watts
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
BCL		Building cooling load at design conditions, from application.
BHL		Building heating load at design conditions, from application.
$F_{ElecHeat}$		If the baseline heating system is an electric system, set equal to 1. Otherwise, set equal to 0.
$F_{ElecHeat,new}$		If the efficient case heat pump system relies on newly installed supplemental electric resistance heat capacity to meet the peak load, set equal to 1. Otherwise, set equal to 0.
$F_{FuelHeat}$		If the baseline heating system is a fossil fuel system, set equal to 1. Otherwise, set equal to 0.
$SEER_{baseline}$		Electric cooling seasonal energy efficiency rating of baseline equipment. See Baseline Efficiencies section below for details.
$EER_{baseline}$		Electric cooling full load energy efficiency rating of baseline equipment. See Baseline Efficiencies section below for details.
EER_{ee}		Electric cooling full load 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.

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

Variable	Value	Notes
$COP_{season,baseline}$		Seasonally adjusted Coefficient of Performance of the baseline equipment. The assumed COP of an electric resistance/electric furnace system is 1.0. If the baseline is a conventional ASHP[129], use the baseline calculations below.
$COP_{season,ee}$		Seasonally adjusted Coefficient of Performance of the efficient equipment. See Compliance Efficiency section below for details.
$AFUE_{baseline}$		Seasonal fuel energy efficiency of the baseline equipment. See Baseline Efficiency section below for details.
$BEFLH_{cooling}$		Lookup based on building type, vintage and location from the appropriate table in the Operating Hours section below.
$BEFLH_{heating}$		Lookup based on building type, vintage and location from the appropriate table in the Operating Hours section below.
$F_{load,cooling}$		Lookup based on equipment sizing and control parameters from the Cooling Load Factor table below.
$F_{load,heating}$		Lookup based on equipment sizing and control parameters from the Heating Load Factor table below.
F_{ctrl}		Lookup based on optional control features Control Factor table (equals 1 for default control)
CF	0.69	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[130]

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.

For LMI applications, existing condition baseline shall be established based on nameplate or measured efficiency.

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). The tables below provide baseline efficiencies for electric cooling and heating and fossil fuel fired heating systems.

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[129] In this context, "conventional ASHP" is defined as a minimally code-compliant non-NEEP listed ASHP with efficiency ratings as indicated in the Baseline Efficiencies section below.

[130] 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 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 RM Management Committee.

For scenarios where there is new construction or substantial renovation, the baseline is assumed to be a fossil fuel fired warm air furnace of the fuel type most likely to be installed at the project site without the influence of the program with a central air conditioning system.

The baseline efficiency for electric cooling and heating systems is defined by the Code of Federal Regulations as shown in the table below.

Electric Cooling and Heating System Baseline Efficiencies

Product Class	Seasonal Energy Efficiency Ratio (SEER)[131]	Energy Efficiency Ratio (EER)	Heating Seasonal Performance Factor (HSPF)[132]
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

The baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is defined by the Code of Federal Regulations as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[133]

Equipment Type	Size Range	CFR Minimum Efficiency
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.84 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.86 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.82 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.85 AFUE

[131] 10 CFR 430.32(c)(1).
[132] 10 CFR 430.32(c)(1).
[133] 10 CFR 430.32(e)(2)(iii)(A)

The baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[134] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Multiple Dwelling Units

Equipment Type	**Size Range**	**ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6**[135]
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.81 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 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	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

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

For scenarios where the baseline heating system is a conventional 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 a conventional air-source heat pump is used in the above equations. This adjusted baseline COP shall be calculated as:

[134] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5).

[135] AFUE: Annual Fuel Utilization Efficiency; Et: Thermal Efficiency; Ec: Combustion Efficiency

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

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}) for Conventional ASHP Used as a Baseline

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 a conventional ASHP, climate adjustment factors for cooling efficiency are not provided. Differences between SEER rating conditions and typical operating conditions in New York State and cooling load are anticipated to have negligible impact on predicted savings.

Compliance Efficiency from which Incentives are Calculated

ASHPs 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 4.0) effective January 1, 2023. 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 variable speed compressor is calculated as:

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

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

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

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 or derived based on guidance in Efficiency Conversion section below
SEER = Rated Seasonal Energy Efficiency Ratio from AHRI or derived based on guidance in Efficiency Conversion section below
3.412 = Conversion factor, one watt-hour equals 3.412 BTU

Note that the cooling efficiency adjustments are quite large for some ASHP units (mini-splits) but much smaller for central ducted ASHP units. For the baseline conventional ASHP we assume that no adjustment to SEER is required. Appendix F in the ASHP White Paper explains why some ASHP units require a cooling efficiency adjustment while others do not.

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 or derived based on guidance in Efficiency Conversion section below
SEER		Rated seasonal energy efficiency ratio from AHRI or derived based on guidance in Efficiency Conversion section below

Efficiency Conversion

For equipment with seasonal heating and cooling efficiency ratings in HSPF2 and SEER2 per AHRI, respectively, efficiency ratings shall be converted to HSPF and SEER as follows:

$$HSPF = HSPF2/F_{HSPF2}$$

$$SEER = SEER2/F_{SEER2}$$

Where F_{HSPF2} and F_{SEER2} are established based on equipment type per the table below.[136]

Equipment Type	F_{HSPF2}	F_{SEER2}
Ductless System[137]	0.90	1.00
Centrally Ducted Split System[138]	0.85	0.95

[136] Conversion factors developed by AHRI and adopted by RESNET, as published in Draft PDS-02 MINHERS® Addendum 71f, SEER/HSPF2 Conversions, RESNET, January 2023
[137] Applies to all scenarios labeled 2 and 3 (i.e., 2a – 2h and 3a – 3c) in the Whole Building and Displacement Scenarios table below
[138] Applies to all scenarios labeled 1 and 4 (i.e., 1a – 1d and 4a – 4d) in the Whole Building and Displacement Scenarios table below

Equipment Type	F_{HSPF2}	F_{SEER2}
Centrally Ducted Single Packaged System	0.84	0.95

The scenarios shown in the first column of the Whole Building and Displacement Scenarios table 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[139]. Assigning applicable scenario(s) to program participants or participant groups is the responsibility of program designers and implementers. For reference, the control strategies listed in the Whole Building and Displacement Scenarios table below are defined as follows:

- **Separate:** The ASHP and backup heating system are on separate thermostats and there is no effort to lock out the heat pump at cold temperatures when the backup system is running.
- **Integrated:** The ASHP and backup heating system are on the same thermostat. The backup heater can modulate (or cycle ON and OFF) to meet the load without limiting the ASHP from delivering its maximum capacity. Also called "Droop" control in the Clean Heat Program.

The Separate and Integrated control options in the table only apply to the Part Load or Displacement scenarios. The impact of optional control features for Whole Building or Full Load are accounted for by the control factor (F_{ctrl}) in the table below. "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. When multiple HPs are used, the capacity-weighted rated efficiencies (HSPF, SEER, and EER) for the installed units need to be determined. For both cooling and heating efficiencies, use the rated cooling capacity at 95°F for each unit to find the weighted average for HSPF, SEER and EER.

Whole Building and Displacement Scenarios

Scenario	Description	ASHP Type	Application	Controls	HP Sizing Parameter
1a – 1c	Central ASHP	Central, Ducted	Whole or Full Load	(see F_{ctrl} table)	0.9
1d					1.0
2a	Ductless Mini-Spilt sized at 30%, 50%, 70% and 90/100%	Single-Zone Ductless	Displace or Part Load	Separate	0.3
2b					0.5
2c					0.7
2d				Integrated	0.3
2e					0.5
2f					0.7
2g			Whole or Full Load	(see F_{ctrl} table)	0.9
2h					1.0
3a	Ductless Multi-Split sized to 70% and 90/100%	Multi-Zone Ductless	Displace or Part Load	Separate	0.7
3b			Whole or Full Load	(see F_{ctrl} table)	0.9
3c					1.0

[139] 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 Parameter
4a	Compact Ducted Mini-Split sized to 50% ,70% and 90/100%	Single-Zone Compact Ducted	Displace or Part Load	Separate	0.5
4b					0.7
4c			Whole or Full Load	(see F_{ctrl} table)	0.9
4d					1.0

The HP Sizing Parameter should be determined using the maximum heating capacity at 17°F ($QH_{17,max}$) for projects best represented by the New York City climate zone and maximum heating capacity at 5°F from the NEEP Cold Climate Heat Pump List ($QH_{5,max}$) otherwise. BHL is the design heating load for the home:

$$\text{HP Sizing Parameter} = (QH_{17,max} \text{ or } QH_{5,max}) / BHL$$

The HP Sizing Parameter corresponds to the rightmost column in the Whole Building and Displacement Scenarios table above. Choose an appropriate scenario, then use the coefficients from the tables below to determine the seasonal efficiencies and load factors. When the HP Sizing Parameter falls between the values in the column, use the scenario with the lower value.

Note that the HP Sizing Parameter is a factor of convenience for use in this section. It is not necessarily the same as the Actual Sizing Ratio that the participating installers must determine to comply with code and satisfy any requirements established for full load sizing.

$$\text{Actual HP Sizing} = QH \text{ @ } T_{des} / BHL \quad \neq \quad \text{HP Sizing Parameter}$$

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, 1b, 1c	-0.010	0.880	0.113	0.854	0.219	0.842	-0.185	0.838	0.817	0.781	0.333	0.796	0.124	0.860
1d	-0.117	0.902	-0.003	0.879	0.081	0.876	-0.259	0.847	0.876	0.760	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	2.631	0.255	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	2.401	0.329	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	2.366	0.342	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	3.002	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	2.946	0.122	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	2.888	0.141	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	2.836	0.134	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	2.814	0.146	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	-3.593	2.178	-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	-2.914	1.913	-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	-3.094	1.966	-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	0.282	1.070	-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	0.316	1.041	-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	0.432	0.924	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	0.369	0.940	0.110	0.920	-0.127	1.001

Note that the values for scenarios 1a, 1b and 1c are all the same because of revisions to the controls definitions.

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, 1b, 1c	-0.540	0.961	0.920	0.914	-1.370	1.035	-0.390	0.936	2.910	0.786	-0.510	0.965	-0.810	0.988
1d	-0.460	0.946	-0.140	0.966	-1.670	1.041	-0.210	0.916	1.520	0.859	-0.590	0.961	-0.890	0.982

Coefficients for Seasonal Cooling Efficiency: $EER_{season,ee} = c + d \times SEER$														
Scenario	**Albany**		**Binghamton**		**Buffalo**		**Massena**		**New York**		**Poughkeepsie**		**Syracuse**	
2a	12.330	0.118	11.950	0.116	12.240	0.130	12.360	0.135	11.070	0.165	12.100	0.111	12.180	0.123
2b	11.440	0.208	12.210	0.146	11.010	0.229	10.330	0.273	10.080	0.277	12.130	0.167	11.330	0.210
2c	9.810	0.306	10.940	0.232	9.590	0.302	9.160	0.321	9.440	0.323	10.310	0.282	9.740	0.308
2d	12.330	0.118	11.950	0.116	12.240	0.130	12.360	0.135	11.070	0.165	12.100	0.111	12.180	0.123
2e	11.440	0.208	12.210	0.146	11.010	0.229	10.330	0.273	10.080	0.277	12.130	0.167	11.330	0.210
2f	9.810	0.306	10.940	0.232	9.590	0.302	9.160	0.321	9.440	0.323	10.310	0.282	9.740	0.308
2g	9.400	0.314	9.950	0.300	8.130	0.366	8.500	0.351	8.670	0.353	9.080	0.328	9.080	0.327
2h	8.890	0.336	9.440	0.313	7.960	0.375	8.160	0.364	8.510	0.361	9.130	0.327	9.020	0.332
3a	17.760	-0.189	6.680	0.454	10.960	0.199	18.580	-0.218	11.600	0.196	16.240	-0.105	14.460	-0.008
3b	14.530	0.035	14.100	0.009	15.660	-0.060	11.420	0.204	16.950	-0.122	18.500	-0.205	17.260	-0.147
3c	10.850	0.255	17.070	-0.164	14.630	0.017	13.740	0.066	18.850	-0.246	15.270	-0.009	14.140	0.052
4a	-12.940	1.478	-12.220	1.433	-11.550	1.396	-13.560	1.520	-9.590	1.290	-12.690	1.456	-12.770	1.473
4b	-14.160	1.556	-13.060	1.493	-3.400	0.957	-14.370	1.569	-11.850	1.424	-14.010	1.547	-4.690	1.038
4c	-14.370	1.566	-4.310	1.019	-9.600	1.300	-14.650	1.576	-14.290	1.563	-14.680	1.586	-8.450	1.246
4d	-14.440	1.566	-4.690	1.041	-10.170	1.328	-14.700	1.572	-15.140	1.609	-14.790	1.590	-16.480	1.676

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 heating 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							
1b	1.00	1.00	1.00	0.98	0.99	0.97	1.00
1c							
1d	1.00	1.00	1.00	0.99	1.00	0.98	1.00
2a	0.25	0.25	0.25	0.23	0.24	0.25	0.24
2b	0.39	0.38	0.39	0.37	0.39	0.39	0.38
2c	0.56	0.55	0.56	0.55	0.54	0.54	0.55
2d	0.54	0.53	0.53	0.51	0.54	0.51	0.54
2e	0.74	0.73	0.73	0.71	0.72	0.69	0.74
2f	0.86	0.85	0.85	0.82	0.84	0.81	0.86
2g	0.98	0.97	0.97	0.94	0.97	0.92	0.98
2h	0.99	0.98	0.99	0.95	0.98	0.94	0.99
3a	0.72	0.71	0.70	0.67	0.70	0.67	0.72
3b	0.96	0.94	0.94	0.92	0.95	0.90	0.95
3c	0.97	0.96	0.96	0.94	0.97	0.92	0.98
4a	0.43	0.42	0.43	0.42	0.43	0.43	0.42
4b	0.59	0.58	0.58	0.56	0.55	0.56	0.58
4c	0.97	0.96	0.97	0.94	0.96	0.92	0.98
4d	0.99	0.99	0.99	0.96	0.98	0.95	0.99

Note that the values for scenarios 1a, 1b and 1c are all the same because of revisions to the controls definitions.

Cooling Load Factor

Factors in the table below ($F_{load,cooling}$) are used to determine the fraction of the annual cooling load that is met by the ASHP unit. The cooling sizing is determined using assumptions about the relative size of cooling loads (BCL) and heating loads (BHL) in NY based on climate.

Fraction of Cooling Load Met by the ASHP ($F_{load,cooling}$)							
Scenario	**Albany**	**Binghamton**	**Buffalo**	**Massena**	**New York**	**Poughkeepsie**	**Syracuse**
1a	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1b							
1c							
1d	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2a	0.90	0.79	0.90	0.95	0.91	0.88	0.89
2b	0.99	0.95	0.99	1.00	0.99	0.99	0.99
2c	1.00	0.99	1.00	1.00	1.00	1.00	1.00
2d	0.90	0.79	0.90	0.95	0.91	0.88	0.89
2e	0.99	0.95	0.99	1.00	0.99	0.99	0.99
2f	1.00	0.99	1.00	1.00	1.00	1.00	1.00
2g	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2h	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3a	1.00	0.99	1.00	1.00	1.00	1.00	1.00
3b	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3c	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4a	0.99	0.96	0.99	1.00	0.98	0.99	0.99
4b	1.00	0.99	1.00	1.00	1.00	1.00	1.00
4c	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4d	1.00	1.00	1.00	1.00	1.00	1.00	1.00

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.)

<u>Optional Control Features</u>

All the whole building or full load scenarios in the Whole Building and Displacement Scenarios table above correspond to separate control or default control of the ASHP systems. If the ASHP has optional control features, the control factors (F_{ctrl}) in the table below shall be used (otherwise F_{ctrl} is equal to 1.0 by default for separate control). The control factors increase (or decrease) the heating load met by the heat pump. Integrated control (droop control) brings on the backup heating source but still allows the heat pump to operate with the backup heat. This corresponds to a standard 2-stage thermostat and is the default control for Centrally Ducted systems (so F_{ctrl} = 1.0). Changeover controls switch from the heat pump to the backup heating source when the temperature is below the changeover threshold (design temperature plus 5°F, or T_{des}+5°**F**). This changeover temperature equates to 20°F in NYC and 3°F in Albany. Changeover controls are typical for dual-fuel central-ducted systems but are also found in other heat pump controls. With changeover control, the control factor is less than 1, indicating that the heating load and savings are reduced.

<u>Control Factors (Fctrl) for Optional Control Features (Fctrl = 1.0 for default controls)</u>

Whole or Full Load Scenarios	**HP Sizing Parameter**	**NYC**		**Other Cities**	
		Integrated Control	**Changeover T_{des}+5°F**	**Integrated Control**	**Changeover T_{des}+5°F**
Centrally Ducted (Scenarios 1a and 1d)	0.9 1.0	1.00 1.00	0.94 0.93	1.00 1.00	0.99 0.99
Ductless Mini-Spilt (Scenarios 2g and 2h)	0.9 1.0	1.03 1.02	0.96 0.96	1.02 1.01	0.98 0.99
Ductless Multi-Splits	0.9 1.0	1.05 1.04	0.93 0.95	1.05 1.03	0.94 0.97

Whole or Full Load Scenarios	HP Sizing Parameter	NYC		Other Cities	
		Integrated Control	Changeover T_{des}+5°F	Integrated Control	Changeover T_{des}+5°F
(Scenarios 3b and 3c)					
Compact Ducted Scenarios 4c and 4d)	0.9 1.0	1.04 1.02	0.99 0.94	1.03 1.01	0.97 0.97

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. All values have been adjusted to reflect 30-year NCEI climate normal from 1991 – 2020.

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

City	Old	Average	New
Albany	465	448	403
Binghamton	254	251	202
Buffalo	508	490	419
Massena	353	342	287
NYC	778	752	731
Poughkeepsie	758	718	709
Syracuse	431	411	373

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

City	Prior to 1979	From 1979 Through 2006	From 2007 Through Present
Albany	413	426	403
Binghamton	277	280	269
Buffalo	411	417	389
Massena	314	311	298
NYC	588	638	652
Poughkeepsie	606	646	643
Syracuse	368	395	413

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

City	Old	Average	New
Albany	1,791	1,681	1,567
Binghamton	2,072	1,947	1,815
Buffalo	2,016	1,892	1,763
Massena	1,957	1,852	1,746
NYC	1,595	1,448	1,296
Poughkeepsie	2,047	1,915	1,778
Syracuse	1,938	1,821	1,701

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	1,802	1,670	1,640	1,182
Binghamton	2,389	2,257	2,130	1,537
Buffalo	2,111	2,008	2,002	1,455
Massena	2,400	2,187	2,221	1,615
NYC	1,656	1,255	1,199	834
Poughkeepsie	1,459	1,522	1,478	1,048
Syracuse	2,345	1,976	2,027	1,421

Example Calculation *(Not to be used as default)*

A central ducted air source heat pump is installed in a single-family, detached home located near Albany constructed in 1965. The heat pump is rated at 20 SEER, 13 EER, and 12 HSPF with a total system heating capacity at 5ºF of 60 kBTU/h. The heat pump fully replaces the existing 3-ton central air conditioner and 80 kBTU/h gas fired furnace. The building cooling load is 36 kBTU/h and building heating load is 58 kBTU/h. The system includes supplemental electric resistance heat. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\begin{aligned}\Delta kWh = \Bigg(\Bigg(& BCL \times \frac{1}{1{,}000} \times \left(\frac{1}{SEER_{baseline}} - \frac{1}{EER_{season,ee}}\right) \times BEFLH_{cooling} \times F_{load,cooling}\Bigg) \\ & + \Bigg(BHL \times \frac{1}{1{,}000} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}}\right) \times \frac{1}{3.412} \times BEFLH_{heating} \\ & \times F_{load,heating} \times F_{ctrl}\Bigg) \\ & - \left(BHL \times \frac{1}{1{,}000} \times F_{ElecHeat,new} \times \frac{1}{3.412} \times BEFLH_{heating} \times \left(1 - F_{load,heating} \times F_{ctrl}\right)\right)\Bigg)\end{aligned}$$

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

$$\Delta MMBtu = BHL \times \frac{1}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{AFUE_{baseline}} \times BEFLH_{heating} \times F_{load,heating} \times F_{ctrl}$$

BCL = 36,000, from application

$SEER_{baseline}$ = 14.0, from Electric Cooling and Heating System Baseline Efficiencies table based on equipment type from application

$EER_{season,ee}$ = c + d x SEER = -0.460 + 0.946 x 20 = 18.46

$EER_{season,ee}$ equation from Compliance Efficiency section

c and d from Coefficients for Seasonal Cooling Efficiency table based on scenario and location from application. To determine scenario, the HP Sizing Parameter is calculated: $QH_{5,max}$ / BHL= 60/58 = 1.03. Thus c and d correspond to scenario 1d based on application conditions

SEER from application

$BEFLH_{cooling}$ = 465, from Operating Hours section tables based on housing type, city, and vintage from application

$F_{load,cooling}$ = 1, from Cooling Load Factor table based on scenario from application
BHL = 58,000, from application
$F_{ElecHeat}$ = 0, from application
$COP_{season,baseline}$ = N/A, from application
$COP_{season,ee}$ = a + b x HSPF x 1/3.412 = -0.117 + 0.902 x 12 x 1/3.412 = 3.14
$COP_{season,ee}$ equation from Compliance Efficiency section
a and b from Coefficients for Seasonal Heating Efficiency table based on scenario and location from application
HSPF from application
$BEFLH_{heating}$ = 1,791, from Operating Hours section tables based on housing type, city, and vintage from application
$F_{load,heating}$ = 1, from Heating Load Factor table based on scenario from application
F_{ctrl} = 1.0 from application for default controls
$F_{ElecHeat,new}$ =1, from application
$EER_{baseline}$ = 11.8, from Electric Cooling and Heating System Baseline Efficiencies table based on equipment type from application
EER_{ee} = 13, from application
CF = 0.69, from Coincidence Factor section
$F_{FuelHeat}$ = 1, from application
$AFUE_{baseline}$ = 0.80, from Baseline Efficiencies section based on equipment type and size from application

$$\Delta kWh = \left(\left(36{,}000 \times \frac{1}{1{,}000} \times \left(\frac{1}{14} - \frac{1}{18.46}\right) \times 465 \times 1\right) + \left(58{,}000 \times \frac{1}{1{,}000} \times \left(0 - \frac{1}{3.14}\right) \times \frac{1}{3.412} \times 1{,}791 \times 1 \times 1.0\right) - \left(58{,}000 \times \frac{1}{1{,}000} \times 1 \times \frac{1}{3.412} \times 1{,}791 \times (1 - 1 \times 1.0)\right)\right) = -9{,}406.94\ kWh$$

$$\Delta kW = 36{,}000 \times \frac{1}{1{,}000} \times \left(\frac{1}{11.8} - \frac{1}{13}\right) \times 1 \times 0.69 = 0.19\ kW$$

$$\Delta MMBtu = 58{,}000 \times \frac{1}{1{,}000{,}000} \times \frac{1}{0.80} \times 1{,}791 \times 1 \times 1.0 = 129.85\ MMBtu$$

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.
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. ECCCNYS 2020, Table C403.3.2(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/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402
5. Draft PDS-02 MINHERS® Addendum 71f, SEER/HSPF2 Conversions, RESNET, January 2023
   Available from: https://www.resnet.us/about/standards/minhers/draft-pds-02-minhers-addendum-71f-seer-hspf2-conversions/
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. Henderson, H.I., 2020. 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. Revised in June.
8. 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
9. *Manual J Residential Load Calculation*, Arlington, VA. Air Conditioning Contractors Association.
10. *Manual S Equipment Selection*, Arlington, VA. Air Conditioning Contractors Association.
11. 10 CFR 430.32(e)(2)(iii)(A) Energy and water conservation standards and their compliance dates
    Available from: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32

Record of Revision

Record of Revision Number	Issue Date

1	10/15/2010
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7-20-21	7/31/2020
3-23-9	3/31/2023
6-24-22	7/8/2024

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HEAT PUMP – AIR-TO-WATER

Measure Description

This measure covers residential space conditioning, single stage air-to-water heat pumps (AWHPs) that are installed with a buffer tank on the load-side of the heat pump unit to reduce compressor cycling rates, as well as variable speed AWHPs that may or may not require a buffer tank. These AWHP units distribute heat in the home using hydronic or hot water systems instead of ductwork. These heat pumps can be reversible and provide chilled water for cooling by rejecting heat to the outside air.

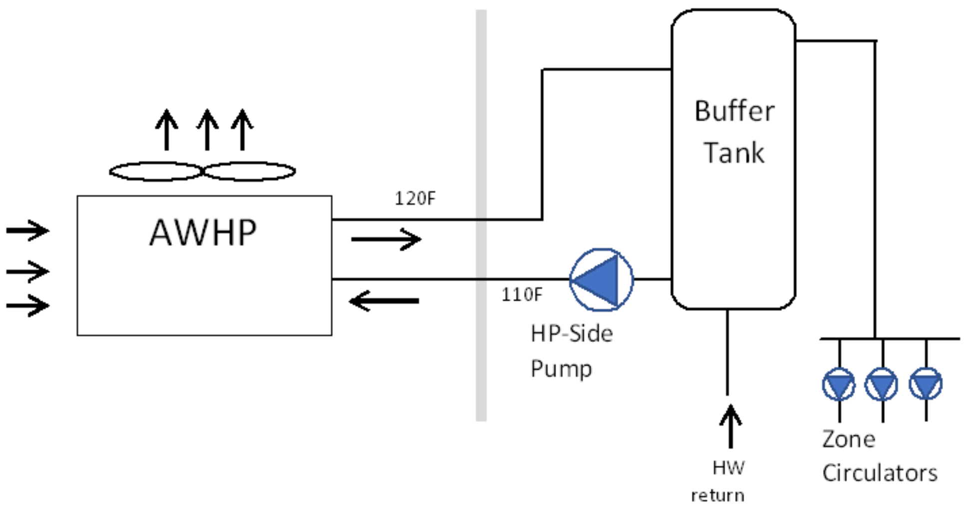

FIGURE 1. TYPICAL SCHEMATIC FOR AN AIR-TO-WATER HP SYSTEM FOR SPACE HEATING

AWHPs are not considered a drop-in replacement for boilers since significant hydronic system modifications are usually required. In many retrofit applications in existing homes the hydronic distribution system, or hot water baseboards, that were installed with the boiler must be adapted to use an AWHP. AWHPs generally cannot provide hot water at the same temperatures as boilers. Therefore, to keep hot water temperatures low, the house can be retrofitted to use additional heat emitters such as additional/larger baseboard heaters or hydronic air handler units (AHUs). Alternatively, buildings in which the envelope has been significantly improved such that heating loads are much smaller (e.g., a deep retrofit), it may be possible to use existing heat emitters to meet the heating load at lower hot water temperatures.

AWHP products appropriate for space conditioning applications typically operate over a range of leaving water temperatures (LWTs) from 90°F to 140°F in heating mode and 40°F to 50°F in cooling mode. These operating LWTs represent equipment operating parameter ranges used in the underlying analysis upon which this method is based. These units operate at flow rates to provide a water-side temperature rise in the range of 10 to 15°F. The efficiency and capacity of these systems are strongly affected by the LWT, as well as ambient air temperatures.

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

- Systems shall be sized in accordance with ACCA Manual S based on building design loads calculated in accordance with approved heating and cooling calculation methodologies.[140,141]

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

- The AWHP is sized to meet 100% of the evaluated design condition heating load.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \left(\left(BCL \times \frac{1}{1{,}000} \times \left(\frac{1}{EER_{season,baseline}} - \frac{1}{EER_{season,ee}}\right) \times BEFLH_{cooling} \times F_{ElecCool}\right) + \left(BHL \times \frac{1}{1{,}000} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}}\right) \times \frac{1}{3.412} \times BEFLH_{heating}\right)\right)$$

Summer Peak Coincident Demand Savings

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

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = BHL \times \frac{1}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{Eff_{FuelHeat,baseline}} \times BEFLH_{heating}$$

where:

ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
ΔMMBtu	= Annual fossil fuel energy savings
BCL	= Building Cooling Load at design conditions (BTU/h)
BHL	= Building Heating Load at design conditions (BTU/h)
$F_{ElecCool}$	= Electric cooling factor; used to toggle cooling savings depending on whether AWHP system is intended to provide cooling
$F_{ElecHeat}$	= Electric heating factor; used to account for the presence or absence of an electric heating system in the baseline case
$F_{FuelHeat}$	= Fossil fuel heating factor; used to account for the presence or absence of a fossil fuel heating system in the baseline case
$_{baseline}$	= Characteristic of baseline condition
$_{ee}$	= Characteristic of energy efficient condition

[140] ECCCNYS 2020, Section R403.7.

[141] ECCCNYS 2020 requires that systems serving multiple dwelling units follow Sections C403 and C404.

EER = Full load energy efficiency ratio (BTU/watt-hour)
EER_{season} = Seasonally adjusted average energy efficiency (BTU/watt-hour)
COP = Coefficient of performance for heating, ratio of output energy/input energy
COP_{season} = Seasonally adjusted average coefficient of performance
$Eff_{FuelHeat}$ = Efficiency of fuel heating equipment (AFUE, Et, or Ec)
$BEFLH_{cooling}$ = Cooling equivalent full-load hours based on building design load
$BEFLH_{heating}$ = Heating equivalent full-load hours based on building design load
CF = Coincidence Factor
3.412 = Conversion factor, one watt-hour equals 3.412 BTU
1,000 = Conversion factor, one kilowatt equals 1,000 watts
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
BCL		Building cooling load at design conditions, from application.
BHL		Building heating load at design conditions, from application.
$F_{ElecCool}$		If the AWHP system is intended to provide cooling, set equal to 1. Otherwise, set equal to 0.
$F_{ElecHeat}$		If the baseline heating system is an electric system, set equal to 1. Otherwise, set equal to 0.
$F_{FuelHeat}$		If the baseline heating system is a fossil fuel system, set equal to 1. Otherwise, set equal to 0.
$EER_{season,baseline}$		Electric cooling seasonal energy efficiency rating of baseline equipment (CEER or SEER). See Baseline Efficiencies section below for details.
$EER_{baseline}$		Electric cooling full load energy efficiency rating of baseline equipment (CEER or EER). See Baseline Efficiencies section below for details.
EER_{ee}		Manufacturer published electric cooling energy efficiency rating of efficient equipment at 95°F outdoor air and 45°F CHW (used as a proxy for full load system efficiency to estimate peak demand reduction).
$EER_{season,ee}$		Seasonally adjusted energy efficiency ratio of the efficient equipment. See Compliance Efficiency section below for details.
$COP_{season,baseline}$		Seasonally adjusted Coefficient of Performance of the baseline equipment. The assumed COP of an electric resistance or boiler system is 1.0.
$COP_{season,ee}$		Seasonally adjusted Coefficient of Performance of the efficient equipment. See Compliance Efficiency section below for details.
$Eff_{FuelHeat,baseline}$		Seasonal fuel energy efficiency of the baseline equipment. See Baseline Efficiency section below for details.
$BEFLH_{cooling}$		Lookup based on building type, vintage and location from the appropriate table in the Operating Hours section below.

Variable	Value	Notes
$BEFLH_{heating}$		Lookup based on building type, vintage and location from the appropriate table in the Operating Hours section below.
CF	0.69	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[142]

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.

For LMI applications, existing condition baseline shall be established based on nameplate or measured efficiency.

An AWHP system can be considered a normal replacement scenario for an electric resistance or boiler system with or without electric cooling or a fossil fuel fired heating system with or without electric cooling. The tables below provide baseline efficiencies for electric cooling and heating and fossil fuel fired heating systems.

For scenarios where there is new construction or substantial renovation, the baseline is assumed to be a fossil fuel fired hot water boiler of the fuel type most likely to be installed at the project site without the influence of the program with room air conditioners for cooling. Room air conditioners are considered the most suitable counterfactual for AWHP cooling due to expected absence of ductwork.

Baseline efficiency values shall be determined from the tables below based on the appropriately selected baseline system type.

<u>Room Air Conditioner (RAC) Baseline Efficiencies</u>
The CEER values listed in the table below reflect the minimum performance required by federal standards.[143]

Product Type	Product Class Capacity (BTU/h)	Federal Standard with Louvered Sides (CEER)	Federal Standard Without Louvered Sides (CEER)
RAC without Reverse Cycle	< 6,000	11.0	10.0
	6,000 to 7,999	11.0	10.0

[142] 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 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 RM Management Committee.
[143] 10 CFR 430.32(b).

Product Type	Product Class Capacity (BTU/h)	Federal Standard with Louvered Sides (CEER)	Federal Standard Without Louvered Sides (CEER)
	8,000 to 10,999	10.9	9.6
	11,000 to 13,999	10.9	9.5
	14,000 to 19,999	10.7	9.3
	20,000 to 27,999	9.4	9.4
	≥ 28,000	9.0	9.4
Casement Only	All	9.5	
Casement-Slider	All	10.4	

Electric Cooling and Heating System Baseline Efficiencies (SEER, EER, HSPF)

Product Class	Seasonal Energy Efficiency Ratio (SEER)[144]	Energy Efficiency Ratio (EER)	Heating Seasonal Performance Factor (HSPF)[145]
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

Electric Cooling and Heating System Baseline Efficiencies (SEER2, EER2, HSPF2)

Product Class	Seasonal Energy Efficiency Ratio 2 (SEER2)[146]	Energy Efficiency Ratio 2 (EER2)	Heating Seasonal Performance Factor 2 (HSPF2)[147]
Split System – Air Conditioner (<45 kBTU/h)	13.4	11.4	N/A

[144] 10 CFR 430.32(c)(1).
[145] 10 CFR 430.32(c)(1).
[146] 10 CFR 430.32(c)(5).
[147] 10 CFR 430.32(c)(5).

Product Class	Seasonal Energy Efficiency Ratio 2 (SEER2)[146]	Energy Efficiency Ratio 2 (EER2)	Heating Seasonal Performance Factor 2 (HSPF2)[147]
Split System – Air Conditioner (≥45 and <65 kBTU/h)	13.4	11.4	N/A
Single Package – Air Conditioner	13.4	11.4	N/A
Split System – Heat Pump (<45 kBTU/h)	14.3	11.9	7.5
Split System – Heat Pump (≥45 and < 65 kBTU/h)	14.3	11.9	7.5
Single Package – Heat Pump (<65 kBTU/h)	13.4	11.4	6.7

The baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is defined by the Code of Federal Regulations as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[148]

Equipment Type	Size Range	CFR Minimum Efficiency
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.84 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.86 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.82 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.85 AFUE

The baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[149] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Multiple Dwelling Units

[148] 10 CFR 430.32(e)(2)(iii)(A)
[149] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5).

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6[150]
Warm Air Furnace, Gas Fired	< 225 kBTU/h	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.81 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 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	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

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

Compliance Efficiency from which Incentives are Calculated

Technically, the rating standard for air-to-water heat pump equipment is AHRI 550/590. However, a search of the AHRI directory in late 2021 revealed that no products were using this standard for product certification. Only a few manufacturers appear to use these rating conditions in their product literature. As such, this method relies on manufacturer published COP ratings at 5°F and a LWT of 110°F and EER ratings at 95°F and 45°F CHW temperature adjusted to account for site-specific LWT, outdoor air conditions, piping configuration, defrost and cycling, pumping power and presence of load side temperature reset.

In order to establish seasonal heating and cooling efficiencies, the following information must first be collected/determined:

- the COP of the unit at 5°F and a LWT of 110°F

[150] AFUE: Annual Fuel Utilization Efficiency; Et: Thermal Efficiency; Ec: Combustion Efficiency

    - NOTE: A minimum COP_{A5W110} of 1.7 is required for compliance with this measure method.
- the EER of the unit at 95°F and 45°F CHW (if system is intended to provide cooling)
    - NOTE: A minimum EER_{A95W45} of 9.6 is required for compliance with this measure method and the evaluated $EER_{season,ee}$ must exceed the $EER_{season,baseline}$ to qualify.
- the pumping power per nominal heating ton
- the maximum leaving water temperature, accounting for impact of the piping arrangement
- the most appropriate weather city

Once this information is known, the average seasonal heating efficiency for an AWHP can be calculated as:

$$COP_{season,ee} = COP_{A5W110} \times SEF \times F_{defrost,cycle} \times F_{pump} \times F_{reset}$$

And the average seasonal cooling efficiency for an AWHP can be calculated as:

$$EER_{season,ee} = EER_{A95W45} \times F_{pump}$$

where:

COP_{A5W110} = Manufacturer published coefficient of performance at 5°F outdoor air temperature and 110°F LWT

EER_{A95W45} = Manufacturer published cooling energy efficiency rating at 95°F and 45°F CHW temperature

SEF = Seasonal efficiency factor depending on LWT and location

$F_{defrost,cycle}$ = Adjustment factor for defrost and cycling depending on AWHP unit characteristics

F_{pump} = Adjustment factor to account for pumping power

F_{reset} = Adjustment factor to account for presence or absence of load side temperature reset

<u>Summary of Variables and Data Sources</u>

Variable	Value	Source
COP_{A5W110}		From application
EER_{A95W45}		From application
SEF		Lookup based on location and system LWT from Seasonal Efficiency Factor table below.
$F_{defrost,cycle}$		Lookup based on AWHP system type from Defrost and Cycling Adjustment Factors table below.
F_{pump}		Lookup based on pump power (watts/ton) from Pumping Power Adjustment Factors table below.
F_{reset}		For AWHPs equipped with outdoor air temperature-based load side temperature reset, use a value of 1.1. Otherwise, use 1.0.[151]

[151] Henderson, H.I., 2022. White Paper: Savings Calculations for Residential Air-to-Water Heat Pumps for Space Heating, pg. 9

Seasonal Efficiency Factor[152]

City	Seasonal Efficiency Factor (SEF) Design Leaving Water Temperature (°F)					
	100	110	120	130	140	150
Albany	1.32	1.20	1.09	0.97	0.86	0.74
Binghamton	1.33	1.21	1.10	0.98	0.86	0.75
Buffalo	1.33	1.22	1.10	0.99	0.87	0.76
Massena	1.27	1.15	1.04	0.92	0.80	0.69
New York	1.42	1.30	1.19	1.07	0.96	0.84
Poughkeepsie	1.33	1.21	1.10	0.98	0.87	0.75
Syracuse	1.33	1.21	1.10	0.98	0.87	0.75

Defrost and Cycling Adjustment Factors[153]

AWHP System Type	Defrost/Cycling Adjustment Factor ($F_{defrost,cycle}$)
Constant Speed	0.80
Variable Speed	0.85
Variable Speed w/ Adaptive Defrost	0.90

Pumping Power Adjustment Factors[154]

Pumping Power (watts/ton heating)	Pumping Power Adjustment Factor (F_{pump})
20	0.994
40	0.989
60	0.984
80	0.978

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. All values have been adjusted to reflect 30-year NCEI climate normal from 1991 – 2020.

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

City	Old	Average	New
Albany	465	448	403
Binghamton	254	251	202

[152] Ibid, pg. 10
[153] Ibid, pg. 6
[154] Ibid, pg. 10

City	Old	Average	New
Buffalo	508	490	419
Massena	353	342	287
NYC	778	752	731
Poughkeepsie	758	718	709
Syracuse	431	411	373

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

City	Prior to 1979	From 1979 Through 2006	From 2007 Through Present
Albany	413	426	403
Binghamton	277	280	269
Buffalo	411	417	389
Massena	314	311	298
NYC	588	638	652
Poughkeepsie	606	646	643
Syracuse	368	395	413

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

City	Old	Average	New
Albany	1,791	1,681	1,567
Binghamton	2,072	1,947	1,815
Buffalo	2,016	1,892	1,763
Massena	1,957	1,852	1,746
NYC	1,595	1,448	1,296
Poughkeepsie	2,047	1,915	1,778
Syracuse	1,938	1,821	1,701

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	1,802	1,670	1,640	1,182
Binghamton	2,389	2,257	2,130	1,537
Buffalo	2,111	2,008	2,002	1,455
Massena	2,400	2,187	2,221	1,615
NYC	1,656	1,255	1,199	834
Poughkeepsie	1,459	1,522	1,478	1,048
Syracuse	2,345	1,976	2,027	1,421

Example Calculation *(Not to be used as default)*

A single-stage air-to-water heat pump is installed in a single - family, detached home located near Albany and constructed in 1995. The AWHP is installed as the primary space conditioning system, replacing a gas-fired hot water boiler system and several 10,000 BTUh window air conditioners with louvered sides serving an evaluated cooling load of 36 kBTUh and heating load of 58 kBTUh. The AWHP has an EER rating of 16.4 at 95°F outdoor air temperature and 45°F CHW and a COP of 2.8 at 5°F outdoor air temperature and 110°F LWT. The system pumping power is evaluated at 40 watts/ton and is designed to operate at 130°F LWT in heating mode. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \left(\left(BCL \times \frac{1}{1{,}000} \times \left(\frac{1}{EER_{season,baseline}} - \frac{1}{EER_{season,ee}}\right) \times BEFLH_{cooling} \times F_{ElecCool}\right) + \left(BHL \times \frac{1}{1{,}000} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}}\right) \times \frac{1}{3.412} \times BEFLH_{heating}\right)\right)$$

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

$$\Delta MMBtu = BHL \times \frac{1}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{Eff_{FuelHeat,baseline}} \times BEFLH_{heating}$$

BCL = 36,000, from application
$EER_{season,baseline}$ = 10.9, from Baseline Efficiencies section based on equipment type and size from application
$EER_{season,ee}$ = EER_{A95W45} x F_{pump} = 16.4 x 0.989 = 16.2
EER_{A95W45} from application
F_{pump} from Pumping Power Adjustment Factors table based on 40 watt/ton pumping power
$BEFLH_{cooling}$ = 448, from Operating Hours section tables based on housing type, city, and vintage from application
$F_{ElecCool}$ = 1, from application
BHL = 58,000, from application
$F_{ElecHeat}$ = 0, from Summary of Variables and Data Sources table based on existing HVAC from application
$COP_{seaseason,baseline}$ = N/A
$COP_{season,ee}$ = COP_{A5W110} x SEF x $F_{defrost,cycle}$ x F_{pump} x F_{reset}
= 2.8 x 0.97 x 0.8 x 0.989 x 1.0 = 2.15
COP_{A5W110} from application
SEF from Seasonal Efficiency Factor table based on location and design LWT
$F_{defrost,cycle}$ from Defrost and Cycling Adjustment Factors based on system type
F_{pump} from Pumping Power Adjustment Factors table based on 40 watt/ton pumping power
F_{reset} from Summary of Variables and Data Sources table
$BEFLH_{heating}$ = 1,681, from Operating Hours section tables based on housing type, city, and vintage from application
$EER_{baseline}$ = 10.9, from Baseline Efficiencies section based on equipment type and size from application
EER_{ee} = 16.4, from application
CF = 0.69, from Summary of Variables and Data Sources table
$F_{FuelHeat}$ = 1, from Summary of Variables and Data Sources table based on existing HVAC from application
$EFF_{FuelHeat,baseline}$ = 0.84, from Baseline Efficiencies section based on equipment type and size from application

$$\Delta kWh = \left(\left(36{,}000 \times \frac{1}{1{,}000} \times \left(\frac{1}{1.0.9} - \frac{1}{16.2}\right) \times 448 \times 1\right) + \left(58{,}000 \times \frac{1}{1{,}000} \times \left(\frac{0}{N/A} - \frac{1}{2.15}\right) \times \frac{1}{3.412} \times 1{,}681\right)\right) = 484.08 + (-13{,}290.72) = -12{,}806.64\ kWh$$

$$\Delta kW = 36{,}000 \times \frac{1}{1{,}000} \times \left(\frac{1}{10.9} - \frac{1}{16.4}\right) \times 0.69 = 0.764\ kW$$

$$\Delta MMBtu = 58{,}000 \times \frac{1}{1{,}000{,}000} \times \frac{1}{0.84} \times 1{,}681 = 116.1\ MMBtu$$

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.
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. ECCCNYS 2020, Table C403.3.2(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/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402

5. Henderson, H.I., 2023. White Paper: Savings Calculations for Residential Air-to-Water Heat Pumps for Space Heating, Guidance for AWHP systems that use Hydronic Distribution. Prepared for the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Public Service. Revised March 2022.
6. 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
7. *Manual J Residential Load Calculation*, Arlington, VA. Air Conditioning Contractors Association.
8. *Manual S Equipment Selection*, Arlington, VA. Air Conditioning Contractors Association.
9. 10 CFR 430.32(e)(2)(iii)(A) Energy and water conservation standards and their compliance dates
Available from: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32

Record of Revision

Record of Revision Number	Issue Date
6-23-6	7/14/2023
6-24-23	7/8/2024

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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 or an open loop ground water system as permissible by local environmental review.[155] The GSHP system provides heating and cooling for space conditioning by a water-to-air heat pump via a typical air-duct distribution system in a residential home.[156] These systems can optionally have an integrated desuperheater or a dedicated Domestic Hot Water (DHW) water-to-water heat pump (WWHP) that supplements domestic hot water heating in conjunction with space conditioning. Methods for calculating annual DHW energy savings are presented separately 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 2020 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.[157,158]
- 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.
- 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.

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[155] This measure section does not apply to a subset of open loop systems known as standing column wells, since operating temperatures are much different in these applications.
[156] "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.
[157] ECCCNYS 2020, Section R403.7.
[158] ECCNYS 2020 requires that systems serving multiple dwelling units follow Sections C403 and C404.

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-to-Water Heat Pump* section of this measure for estimating DHW savings associated with these systems.

Annual Electric Energy Savings

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

Summer Peak Coincident Demand Savings

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

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{BHL}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{AFUE_{baseline}} \times BEFLH_{heating}$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
ΔMMBtu = Annual fossil fuel energy savings
BCL = Building Cooling Load at design conditions (BTU/h)
BHL = Building Heating Load at design conditions (BTU/h)
$F_{ElecHeat}$ = Electric heating factor; used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$ = Fossil fuel heating factor; used to account for the presence or absence of a fossil fuel heating system
$_{baseline}$ = Characteristic of baseline condition
$_{ee}$ = Characteristic of energy efficient condition
EER_{season} = Energy efficiency ratio (BTU/watt-hour) at part-load seasonally adjusted for fan and pump power
EER_{peak} = Full load energy efficiency ratio (BTU/watt-hour)
$EER_{GSHP,full}$ = Full load energy efficiency ratio (BTU/watt-hour). Refers to Ground Loop Heat Pump (GLHP)-rated condition for closed loop GSHP systems or Ground Water Heat Pump (GWHP)-rated conditions for open loop systems.
COP_{season} = Coefficient of performance, seasonally adjusted for fan and pump power.
AFUE = Annual fuel utilization efficiency, seasonal efficiency for fossil fuel-fired heating equipment

$BEFLH_{cooling}$ = Cooling equivalent full-load hours based on building design load
$BEFLH_{heating}$ = Heating equivalent full-load hours based on building design load
CF = Coincidence Factor
3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000 = Conversion factor, one kW equals 1,000 Watts
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
BCL		Building cooling load at design conditions calculated in accordance with ACCA Manual J, from application.
BHL		Building heating load at design conditions calculated in accordance with ACCA Manual J, from application.
$F_{ElecHeat}$		If the baseline heating system is an electric system, set equal to 1. Otherwise, set equal to 0.
$F_{FuelHeat}$		If the baseline heating system is a fossil fuel system, set equal to 1. Otherwise, set equal to 0.
$EER_{season,baseline}$		Seasonal electric cooling energy efficiency rating of baseline equipment. See SEER values in Baseline Efficiency section below for details.
$EER_{peak,baseline}$		Electric cooling energy efficiency rating of baseline equipment. See EER values in Baseline Efficiency section below for details.
$EER_{season,ee}$		Energy efficiency ratio from the manufacturer's catalog data adjusted to account for applied fan and pump power. See Compliance Efficiency section below for details.
$EER_{GSHP,full,ee}$		Full load energy efficiency ratio at AHRI rated conditions. Corresponds to GLHP-rated condition with fluid temperature of 77°F for closed loop systems, or GWHP-rated condition with fluid temperature of 59°F for open loop systems.
$COP_{season,baseline}$		Electric heating energy efficiency rating of baseline equipment. See Baseline Efficiency section below for details.
$COP_{season,ee}$		Coefficient of performance from the manufacturer's catalog data adjusted to account for applied fan and pump power. See Compliance Efficiency section below for details.
$AFUE_{baseline}$		Seasonal fuel energy efficiency of the baseline equipment. See Baseline Efficiency section below for details.
$BEFLH_{cooling}$		Lookup based on building type, vintage and location from the appropriate table in the Operating Hours section below.
$BEFLH_{heating}$		Lookup based on building type, vintage and location from the appropriate table in the Operating Hours section below.
CF	0.69	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69.[159]

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.

For LMI applications, existing condition baseline shall be established based on nameplate or measured efficiency.

A GSHP 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). The tables below provide baseline efficiencies for electric cooling and heating and fossil fuel fired heating systems.

For scenarios where there is new construction or substantial renovation, the baseline is assumed to be a fossil fuel fired warm air furnace of the fuel type most likely to be installed at the project site without the influence of the program with a central air conditioning system.

The baseline efficiency for electric cooling and heating systems is defined by the Code of Federal Regulations as shown in the table below. Baseline efficiency ratings (SEER/SEER2, EER/EER2, HSPF/HSPF2) shall align with the efficiency rating of the efficient equipment.

Electric Cooling and Heating System Baseline Efficiencies (SEER, EER, HSPF)

Product Class	Seasonal Energy Efficiency Ratio (SEER)[160]	Energy Efficiency Ratio (EER)	Heating Seasonal Performance Factor (HSPF)[161]
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

[159] 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 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 RM Management Committee.

[160] 10 CFR 430.32(c)(1).

[161] 10 CFR 430.32(c)(1).

Product Class	Seasonal Energy Efficiency Ratio (SEER)[160]	Energy Efficiency Ratio (EER)	Heating Seasonal Performance Factor (HSPF)[161]
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

Electric Cooling and Heating System Baseline Efficiencies (SEER2, EER2, HSPF2)

Product Class	Seasonal Energy Efficiency Ratio 2 (SEER2)[162]	Energy Efficiency Ratio 2 (EER2)	Heating Seasonal Performance Factor 2 (HSPF2)[163]
Split System – Air Conditioner (<45 kBTU/h)	13.4	11.4	N/A
Split System – Air Conditioner (≥45 and <65 kBTU/h)	13.4	11.4	N/A
Single Package – Air Conditioner	13.4	11.4	N/A
Split System – Heat Pump (<45 kBTU/h)	14.3	11.9	7.5
Split System – Heat Pump (≥45 and < 65 kBTU/h)	14.3	11.9	7.5
Single Package – Heat Pump (<65 kBTU/h)	13.4	11.4	6.7

GSHP System Baseline Efficiencies

[162] 10 CFR 430.32(c)(5).
[163] 10 CFR 430.32(c)(5).

Product Application	Full-Load Rated Heating COP	Full-Load Rated Cooling EER	Adjusted Heating Efficiency ($COP_{season,base}$)	Adjusted Cooling Efficiency ($EER_{season,base}$)
Closed Loop, GLHP-rating	3.2	14.1	2.95	12.99
Open Loop, GWHP-rating	3.7	18.0	3.05	14.71

*Equipment < 135 kBTU/h cooling capacity rated by ISO/ANSI/ASHRAE 13256-1: Baseline system is assumed to be single stage.
**Adjusted values use corrections below for pumping and distribution losses assuming a pumping power of 90 Watts per ton for closed loop and 120 Watts per ton open loop.

The baseline efficiency for fossil fuel fired heating systems serving single-family homes and individual units is defined by the Code of Federal Regulations as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[164]

Equipment Type	Size Range	CFR Minimum Efficiency
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.84 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.86 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.82 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.85 AFUE

The baseline efficiency for heating systems serving multiple dwelling units is defined by International Energy Conservation Code[165] and subsequently adopted by the Energy Conservation Construction Code of New York State (ECCCNYS) as shown in the table below.

Fossil Fuel Fired Heating System Baseline Efficiencies: 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	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.81 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et

[164] 10 CFR 430.32(e)(2)(iii)(A)
[165] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5).

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 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	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

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

For scenarios where the baseline heating system is a conventional 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 a conventional air-source heat pump is used in the above equations. This adjusted baseline COP shall be calculated as:

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

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}) for Conventional ASHP Used as a Baseline

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 a conventional 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.

For scenarios where the baseline heating and cooling system is an existing GSHP, the seasonal heating and cooling efficiencies of the baseline equipment code minimum efficiencies that have been adjusted consistent with the methodology provided for efficient equipment described in the *Compliance Efficiency from Which Incentives are Calculated* section below.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is an ENERGY STAR® certified GSHP system as defined in the Measure Description section above. If the GSHP system is closed loop, use the following formulas with the COP and EER values from the GLHP ratings. If the GSHP system is an open loop system, use the following formulas with the COP and EER values from the GWHP ratings. The formulas adjust performance for closed loop systems to an average entering water temperature of approximately 40°F for heating and 77°F for cooling. The open loop formulas adjust performance to an average entering water temperature of 50°F for both heating and cooling[166].

The formulas determine the average seasonal cooling efficiency ($EER_{season,ee}$) and the average seasonal heating efficiency ($COP_{season,ee}$) for a GSHP system with a two-stage or variable speed compressor.

Closed Loop Systems (using GLHP ratings):

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

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

Open Loop Systems (using GWHP ratings):

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

[166] These entering temperatures were selected based on measured data from GSHP sites presented in NYSERDA Report 18-03.

$$COP_{season,ee} = \left(\left(F_{full} \times COP_{GWHP,full} \times F_{pump,full}\right) + \left(F_{part} \times COP_{GWHP,part} \times F_{pump,part}\right)\right) \times F_{dist,h}$$

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
$COP_{GWHP,full}$ = Rated COP of the unit at GWHP full load heating conditions
$COP_{GWHP,part}$ = Rated COP of the unit at GWHP part load heating conditions
$EER_{GWHP,full}$ = Rated EER of the unit at GWHP full load cooling conditions
$EER_{GWHP,part}$ = Rated EER of the unit at GWHP 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[167]
1.08 = Correction for change in COP[168]

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.

[167] 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. This factor also applies to the GWHP adjustment from 50°F to 59°F.
[168] 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.

Variable	Value	Source
$EER_{GLHP,part}$		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.
$COP_{GWHP,full}$		The rated COP of the unit at GWHP 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 water temperature of 50°F.
$COP_{GWHP,part}$		The rated COP of the unit at GWHP 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 water temperature of 50°F.
$EER_{GWHP,full}$		The rated EER of the unit at GWHP 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 water temperature of 59°F.
$EER_{GWHP,part}$		The rated EER of the unit at GWHP 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 water temperature of 59°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.[169]
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.[170]
$F_{pump,full}$		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.

[169] 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.

[170] Ibid.

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 120 Watts/ton was performed to determine the impact of loop pumping power on efficiency. Results are shown in the Pumping Factors table below.[171]

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:

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

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 0.86 to 0.94. Part load factors can range from 0.62 to 0.95 depending on the

[171] Henderson, H.I., 2020. 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. Revised in June.

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	Pumping Power											
		45 Watts/ton		60 Watts/ton		75 Watts/ton		90 Watts/ton		105 Watt/ton		120 Watts/ton	
		Clg	Htg	Clg	Htg	Clg	Htg	Clg	Htg	Clg	Htg	Clg	Htg
Full load ($F_{pump,full}$)		0.94	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87	0.86	0.86
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	0.78	0.82	0.75	0.80
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	0.65	0.71	0.62	0.68
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	0.82	0.86	0.80	0.84
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	0.82	0.86	0.80	0.84
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	0.86	0.89	0.84	0.87

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.[172]

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 fossil 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

[172] Ibid.

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 to BEFLH. All values have been adjusted to reflect 30-year NCEI climate normal from 1991 – 2020.

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

City	Old	Average	New
Albany	465	448	403
Binghamton	254	251	202
Buffalo	508	490	419
Massena	353	342	287
NYC	778	752	731
Poughkeepsie	758	718	709
Syracuse	431	411	373

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

City	Prior to 1979	From 1979 Through 2006	From 2007 Through Present
Albany	413	426	403
Binghamton	277	280	269
Buffalo	411	417	389
Massena	314	311	298
NYC	588	638	652
Poughkeepsie	606	646	643
Syracuse	368	395	413

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

City	Old	Average	New
Albany	1,791	1,681	1,567
Binghamton	2,072	1,947	1,815
Buffalo	2,016	1,892	1,763
Massena	1,957	1,852	1,746
NYC	1,595	1,448	1,296
Poughkeepsie	2,047	1,915	1,778
Syracuse	1,938	1,821	1,701

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	1,802	1,670	1,640	1,182
Binghamton	2,389	2,257	2,130	1,537
Buffalo	2,111	2,008	2,002	1,455
Massena	2,400	2,187	2,221	1,615
NYC	1,656	1,255	1,199	834

City	Pre-war uninsulated brick	Prior to 1979	From 1979 Through 2006	From 2007 Through present
Poughkeepsie	1,459	1,522	1,478	1,048
Syracuse	2,345	1,976	2,027	1,421

Example Calculation *(Not to be used as default)*

A closed loop water-to-air GSHP is installed in a single - family, detached home located near Albany and constructed in 1995. The heat pump has variable speed pump controls and a rated heating capacity of 60 kBTUh, with a full load EER of 19, part load EER of 25, full load COP of 3.5 and part load COP of 4.1. The GSHP has 60 watts/ton system pumping power. The home has a building cooling load of 36 kBTUh and the building heating load of 58 kBTUh, and existing HVAC equipment are a split system air conditioner and a gas fired furnace. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

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

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

$$\Delta MMBtu = \frac{BHL}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{AFUE_{baseline}} \times BEFLH_{heating}$$

BCL = 36,000, from application

$EER_{season,baseline}$ = 13.0, from Baseline Efficiencies section based on equipment type and size from application

$EER_{season,ee}$ = ((F_{full} x $EER_{GLHP,full}$ x 1.09 x $F_{pump,full}$) + (F_{part} x $EER_{GLHP,part}$ x $F_{pump,part}$)) x $F_{dist,c}$

= ((0.25 x 19 x 1.09 x 0.93) + (0.75 x 25 x 0.92)) x 0.95 = 20.96

$EER_{season,ee}$ equation from Compliance Efficiency section based on GSHP type

F_{full} from Compliance Efficiency section's Summary of Variables and Data Sources table

$EER_{GLHP,full}$ from application

$F_{pump,full}$ from Pumping Power Adjustment Factors table based on application

F_{part} from Compliance Efficiency section's Summary of Variables and Data Sources table

$EER_{GLHP,part}$ from application

$F_{pump,part}$ from Pumping Power Adjustment Factors table based on application

$F_{dist,c}$ from Distribution Correction Factors based on application

$BEFLH_{cooling}$ = 448, from Operating Hours section tables based on housing type, city, and vintage from application

BHL = 58,000, from application

$F_{ElecHeat}$ = 0, from Summary of Variables and Data Sources table based on existing HVAC from application

$COP_{seaseason,baseline}$ = N/A

$COP_{season,ee}$ = ((F_{full} x $COP_{GLHP,full}$ x 1.08 x $F_{pump,full}$) + (F_{part} x $COP_{GLHP,part}$ x $F_{pump,part}$)) x $F_{dist,h}$

= ((0.25 x 3.5 x 1.08 x 0.92) + (0.75 x 4.1 x 0.93)) x 0.96 = 3.58

$COP_{season,ee}$ equation from Compliance Efficiency section based on GSHP type

$COP_{GLHP,full}$ from application

$F_{pump,full}$ from Pumping Power Adjustment Factors table based on application

$COP_{GLHP,part}$ from application

$F_{pump,part}$ from Pumping Power Adjustment Factors table based on application

$F_{dist,h}$ from Distribution Correction Factors based on application

$BEFLH_{heating}$ = 1,681, from Operating Hours section tables based on housing type, city, and vintage from application

$EER_{peak,baseline}$ = 11.2, from Baseline Efficiencies section based on equipment type and size from application

$EER_{GSHP,full,ee}$ = 19, from application

CF = 0.69, from Summary of Variables and Data Sources table

$F_{FuelHeat}$ = 1, from Summary of Variables and Data Sources table based on existing HVAC from application

$AFUE_{baseline}$ = 0.8, from Baseline Efficiencies section based on equipment type and size from application

$$\Delta kWh = \left[\frac{36{,}000}{1{,}000} \times \left(\frac{1}{13} - \frac{1}{20.96}\right) \times 448\right] + \left[\frac{58{,}000}{3{,}412} \times \left(0 - \frac{1}{3.58}\right) \times 1{,}681\right] = -7{,}51\ kWh$$

$$\Delta kW = \frac{36{,}000}{1{,}000} \times \left(\frac{1}{11.2} - \frac{1}{19}\right) \times 0.69 = 0.91\ kW$$

$$\Delta MMBtu = \frac{58{,}000}{1{,}000{,}000} \times \frac{1}{0.8} \times 1{,}681 = 121.87\ MMBtu$$

Methods for Calculating Annual Domestic Hot Water Energy Savings from an Integrated Desuperheater or Dedicated Water-to-Water 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 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 DHW-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.

$$\Delta MMBtu_{GSHP-DHW} = \frac{Q_{GSHP-DHW}}{1{,}000{,}000} \times \frac{F_{FFDHW}}{UEF_{baseline}}$$

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

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

For a desuperheater:

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

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

For a dedicated DHW-WWHP:

When DHW tank has resistance elements,

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

OR, when DHW tank is over 80 gallons and has no resistance elements[173]

$$F_{GSHP-DHW} = 1.0$$

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

where:

$\Delta MMBtu_{GSHP-DHW}$ = Fossil fuel energy displaced by a desuperheater or dedicated DHW-WWHP

[173] Based on feedback from NY-GEO on current field practices, if a DHW-WWHP is installed with a large pre-heating tank (e.g., over 80 gallons) it does not need an electric resistance element and can therefore meet 100% of the DHW load.

$\Delta kWh_{GSHP\text{-}DHW}$ = Electricity displaced by desuperheater or dedicated DHW-WWHP 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 COP of desuperheater (same as space heating efficiency, use $COP_{season,ee}$ as calculated in Compliance Efficiency section above)
$COP_{GSHP\text{-}DHW}$ = Overall annual COP of desuperheater or dedicated DHW-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} = Factor indicating that baseline DHW system is electric
F_{FFDHW} = Factor indicating that baseline DHW system is fossil fuel fired
$F_{GSHP\text{-}DHW}$ = Fraction of annual DHW load served by a desuperheater or dedicated DHW-WWHP
GPD = Gallons per day of delivered hot water per person
PPH = Persons per household served by DHW system
$Q_{GSHP\text{-}DHW}$ = Annual DHW load served by desuperheater or dedicated DHW-WWHP, BTU
$UEF_{baseline}$ = Uniform energy factor of baseline DHW appliance (fossil fuel 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 DHW-WWHP
8.33 = Specific heat of water; energy required (BTU), to heat one gallon of water by one degree Fahrenheit [BTU/(gal-F)]
365 = Days in one year
3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000,000 = Conversion factor, one MMBtu equals 1,000,000 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 NYC 0.86 for other cities	Fraction of desuperheater operation that occurs in the heating mode.
F_{EDHW}	1 for electric DHW	Factor indicating baseline DHW is electric.
F_{FFDHW}	1 for fossil fuel-fired DHW	Factor indicating baseline DHW is fossil fuel-fired.
GPD	17.2	Average daily hot water usage per person.[174]

[174] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016, pg. 5; 17.2 GPD equated from the report findings indicating an average 2.65 people per household and 45.5 GPD per household.

Variable	Value	Notes
PPH		From application. If unknown, use a value of 2.8 for single-family homes[175] and 2.0 for multifamily homes.[176]
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).[177]
$UEF_{baseline}$		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}, %)[178]
35	36%
45	30%
55	26%
65	22%

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

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.[179] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[180] (°F)	T_{main} (°F)
Albany	49.4	55.4
Binghamton	46.8	52.8
Buffalo	49.1	55.1
Massena	45.1	51.1
NYC	54.7	60.7

[175] Residential Statewide Baseline Study of New York State, July 2015. Volume 1: Single-Family Report, Table 9.
[176] Residential Statewide Baseline Study of New York State, July 2015. Volume 2: Multifamily Report, Table 8.
[177] 10 CFR 430 Appendix E to Subpart B of Part 430 Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Section 2. Test Conditions, 2.5 Set Point Temperature.
[178] 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 2020). 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.
[179] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.
[180] Average annual outdoor temperatures taken from NCEI 1991-2020 climate normals.

City	Annual average outdoor temperature[180] (°F)	T_{main} (°F)
Poughkeepsie	50.9	56.9
Syracuse	49.0	55.0

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 (v_t) 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.[181]

Residential Water Heaters[182]

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 (Storage Type Only)[183]

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

[182] 10 CFR 430.32(d).

[183] 10 CFR 429.17.

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

Example Calculation *(Not to be used as default)*

A desuperheater is installed with a GSHP system with a seasonal COP of 3.58 in a single-family home in Albany serving 4 residents. The existing gas DHW system has a 50-gallon storage capacity and High draw pattern. Annual Fossil Fuel Energy Savings are calculated as below.

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

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

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

$$\Delta MMBtu_{GSHP-DHW} = \frac{Q_{GSHP-DHW}}{1{,}000{,}000} \times \frac{F_{FFDHW}}{UEF_{baseline}}$$

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

COP_{desup} = 3.58, from application
$F_{desup,htg\ mode}$ = 0.86, from Summary of Variables and Data Sources table
F_{desup} = 0.22, from Desuperheater Annual Load Fraction table based on GPD (17.2, from Summary of Variables and Data Sources table) x PPH (4, from application) = 68.8
$\Delta T_{main} = T_{set} - T_{main}$ = 130 - 55.4 = 74.6 °F
T_{set} from Summary of Variables and Data Sources table
T_{main} from Cold Water Inlet Temperature lookup table based on location from application
F_{FFDHW} = 1, from Summary of Variables and Data Sources table
$UEF_{baseline}$ = 0.6920 - (0.0013 x V_t) = 0.6920 - (0.0013 x 50) = 0.6270
$UEF_{baseline}$ equation from Residential Water Heaters table based on product class and draw pattern from application
v_t from application
F_{EDHW} = 0, from Summary of Variables and Data Sources table

$$COP_{GSHP-DHW} = \frac{3.58}{0.86} = 4.16$$

$$F_{GSHP-DHW} = 0.22$$

$$Q_{GSHP-DHW} = 0.22 \times 17.2 \times 4 \times 365 \ \times 8.33 \times 74.6 = 3{,}433{,}111$$

$$\Delta MMBtu_{GSHP-DHW} = \frac{3{,}433{,}111}{1{,}000{,}000} \times \frac{1}{0.6270} = 5.48\ MMBtu$$

$$\Delta kWh_{GSHP-DHW} = \frac{3{,}433{,}111}{3{,}412} \times \left(\frac{0}{0.6270} - \frac{1}{4.16}\right) = -241.87\ kWh$$

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.
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 2020, Table C403.3.2(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/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC402

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.
8. Henderson, H.I., 2020. 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. Revised in June.
9. International Ground Source Heat Pump Association (IGSHPA). 2011. Ground Source Heat Pump Residential and Light Commercial Design and Installation Guide. Oklahoma State University. Stillwater.
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.
12. *Manual S Equipment Selection*, Arlington, VA. Air Conditioning Contractors Association
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.
15. 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.
16. *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.
17. Water Research Foundation: "Residential End Uses of Water, Version 2: Executive Report", April 2016.
 Available from: https://www.waterrf.org/research/projects/residential-end-uses-water-version-2
18. Residential Statewide Baseline Study of New York State, July 2015.
 Available from: https://www.nyserda.ny.gov/About/Publications/Evaluation-Reports/Building-Stock-and-Potential-Studies/Residential-Statewide-Baseline-Study-of-New-York-State
19. 10 CFR 430.32(e)(2)(iii)(A) Energy and water conservation standards and their compliance dates
 Available from: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32

Record of Revision

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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
7-20-22	7/31/2020
12-23-5	1/5/2024
6-24-24	7/8/2024

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HEAT PUMP – WATER-TO-AIR GROUND SOURCE (GSHPS) IN SYSTEMS WITH CENTRAL PUMPING

Measure Description

This measure covers the installation of multiple ENERGY STAR® certified Ground Source Heat Pump (GSHP) units combined into a system with a closed loop ground heat exchanger field and with central pumping. The GSHP units are water-to-air heat pumps with ducting to provide space heating and cooling to individual zones within a commercial building, including multifamily. The system can optionally include water-to-water heat pumps for domestic water heating. Methods for calculating annual DHW energy savings are presented separately below.

This measure applies to GSHPs in building applications with multiple heat pump units served by centralized ground loop pumping. The calculations only consider simple baseline conditions with separate zone-by-zone space heating and cooling equipment. They do not consider baseline conditions with centralized air handlers serving multiple zones, with terminal reheat, or with other forms of variable air volume terminals. Further, this measure only applies to single-owner facilities with closely-grouped buildings and does not consider multi-owner district, community, or shared loop systems with multiple levels of pumping and loop flow control.

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.
- GSHP units shall be sized in accordance with zone loads calculated with appropriate commercial load calculations, such as from the 2017 ASHRAE Fundamentals.[184]
- The ground loop heat exchanger is adequately sized and installed properly to allow the GSHP to meet the peak heating and peak cooling loads. The peak heating and cooling loads pertain to the total of zone loads established above.
- The design loop pumping power must be less than 60 Watts per nominal installed ton[185], or 7.5 HP per 100 tons, which corresponds to a grade of “B” according to the ASHRAE GSHP Design Guide (Kavanaugh and Rafferty 2015).
- 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.

This measure applies for the following types of GSHP central pumping options:

[184] 2017 ASHRAE Fundamentals Handbook, Chapter 18. Non-residential heating and cooling loads.

[185] The nominal tons are based on the rated cooling capacity at full load GLHP conditions as per ISO Standard 13256-1.

- Traditional variable speed control that varies pump speed to maintain differential pressure based on a sensor installed at a remotely located GSHP unit,
- Staged (two-speed) pumping control,
- "Sensorless" variable speed control where internal pump controls are used to approximately maintain constant pressure across the pump, or
- Hybrid options that combine central loop variable speed pumping with individual cartridge[186] circulators on each heat pump unit.

For the first 3 options, only the central pumping energy is calculated with no pumping adjustment to the heat pump efficiency ($F_{pump,full}$ & $F_{pump,part}$ should be set to 1.0). For the hybrid option, both central pumping energy as well as an adjustment to heat pump efficiency are required ($F_{pump,full}$ & $F_{pump,part}$ come from the table below).

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

<u>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 a Dedicated Water-to-Water Heat Pump* section of this measure for estimating DHW savings associated with these systems.</u>

Annual Electric Energy Savings

$$\Delta kWh = \left[\frac{BCL}{1{,}000} \times \left(\frac{F_{ElecCool}}{EER_{season,baseline}} - \frac{1}{EER_{season,ee}}\right) \times BEFLH_{cooling}\right] + \left[\frac{BHL}{3{,}412} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}}\right) \times BEFLH_{heating} - \left[F_{pump,avg} \times kW_{pump,design} \times 8760\right]\right]$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{BCL}{1{,}000} \times \left(\frac{F_{ElecCool}}{EER_{peak,baseline}} - \frac{1}{EER_{GSHP,full,,ee}}\right) \times CF - kW_{pump,design}$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \frac{BHL}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{AFUE_{baseline}} \times BEFLH_{heating}$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings

[186] Cartridge circulators are inline, self-contained pumps or circulators.

ΔMMBtu = Annual fossil fuel energy savings
AFUE = Annual fuel utilization efficiency, seasonal efficiency for fuel heat equipment
$_{baseline}$ = Characteristic of baseline condition
BCL = Building Cooling "Block" 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 "Block" 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.
$_{ee}$ = Characteristic of energy efficient condition
EER = Energy efficiency ratio (BTU/watt-hour)
$EER_{GSHP,full}$ = Full load energy efficiency ratio (BTU/watt-hours). Refers to GLHP-rated condition for closed loop GSHP systems.
EER_{season} = Energy efficiency ratio (BTU/watt-hour) at part-load seasonally-adjusted for fan and pump power, for baseline conditions or for energy efficient case, BTU/watt-hour
$F_{ElecCool}$ = Electric cooling factor; used to account for the presence or absence of an electric cooling system
$F_{ElecHeat}$ = Electric heating factor; used to account for the presence or absence of an electric heating system
$F_{FuelHeat}$ = Fossil fuel heating; used to account for the presence or absence of a fossil fuel heating system
$_{peak}$ = Peak rating condition
SEER = Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour, (used for average U.S. location/region)
$kW_{pump,\ design}$ = Pumping power at the design or full speed loop flowrate, kW
$F_{pump,\ avg}$ = Average pumping power percentage over the year, % or fraction
8760 = Number of hours in a year
3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000 = Conversion factor, one kW equals 1,000 Watts
1,000,000 = Conversion factor, (BTU/MMBtu), one MMBtu equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
BCL		Building cooling block load at design conditions determined by appropriate commercial load estimating method. Block load is the simultaneous or coincident peak load of all thermal zones (2017 ASHRAE Fundamentals, Chapter 18).
BHL		Building heating load at design conditions determined by appropriate commercial load estimating method. Block load is the simultaneous or coincident peak load of all zones (2017 ASHRAE Fundamentals, Chapter 18).
$F_{ElecCool}$		If an electric cooling system is present, set equal to 1. Otherwise, set equal to 0.

Variable	Value	Notes
$F_{ElecHeat}$		If an electric heating system is present, set equal to 1. Otherwise, set equal to 0.
$F_{FuelHeat}$		If a fossil fuel-fired heating system is present, set equal to 1. Otherwise, set equal to 0.
$EER_{season,baseline}$		Seasonal electric cooling energy efficiency rating of baseline equipment. See Baseline Efficiency section below for details.
$EER_{peak,baseline}$		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.
$EER_{GSHP,full}$		Full load energy efficiency ratio at AHRI rated conditions. Corresponds to GLHP-rated condition with fluid temperature of 77°F for closed loop systems.
$AFUE_{baseline}$		Annual fuel utilization efficiency, seasonal energy efficiency for fuel heating equipment. See Baseline Efficiency section below for details.
$COP_{season,baseline}$		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 heat pump unit) 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.
$kW_{pump,design}$		The power consumption of the pump motor (and variable speed drive) when the central loop pump provides the design or full speed flowrate, kW.
$F_{pump,avg}$		The average pumping power across the year, lookup based on diversity and bypass flow from table below.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69 in multifamily applications[187] and 0.8 in commercial and industrial applications.[188]

Baseline Efficiencies from which Energy Savings are Calculated

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[187] 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 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 RM Management Committee.

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

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.

For LMI applications, existing condition baseline shall be established based on nameplate or measured efficiency.

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.

Federal energy conservation standards[189] effective January 1, 2018 for small, large and very large package air conditioning and heating equipment are more stringent than NYS and NYC codes. These cases are denoted with footnotes in the table below.

Electric Cooling System Baseline Efficiencies

Unitary Air Conditioners				
Equipment Type	**Size Category (Cooling Capacity)**	**Heating Section Type**	**Subcategory or Rating Condition**	**Baseline Efficiency**
Air conditioners (air cooled)	< 65,000 BTU/h (single phase)	All	Split System	11.2 EER 13.0 SEER 11.4 EER2 13.4 SEER2
			Single Package	11.8 EER 14.0 SEER 11.4 EER2 13.4 SEER2
Through-the-wall (air cooled)	≤ 30,000 BTU/h (single phase)	All	Split System	10.6 EER 12.0 SEER
			Single Package	10.6 EER 12.0 SEER
Small-duct high-velocity (air cooled)	< 65,000 BTU/h (single phase)	All	Split System	9.9 EER 11.0 SEER

[189] 10 CFR 431.97 (Table 3).

Unitary Air Conditioners				
Equipment Type	**Size Category (Cooling Capacity)**	**Heating Section Type**	**Subcategory or Rating Condition**	**Baseline Efficiency**
Air conditioners (air cooled)	≥ 65,000 BTU/h and < 135,000 BTU/h[190]	Electric Resistance (or None)	Split System and Single Package	11.2 EER 12.9 IEER
		All Other	Split System and Single Package	11.0 EER 12.7 IEER
	≥ 135,000 BTU/h and < 240,000 BTU/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 12.4 IEER
		All Other	Split System and Single Package	10.8 EER 12.2 IEER
	≥ 240,000 BTU/h and < 760,000 BTU/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 11.6 IEER
		All Other	Split System and Single Package	9.8 EER 11.4 IEER
	≥ 760,000 BTU/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER 11.2 IEER
		All Other	Split System and Single Package	9.5 EER 11.0 IEER

Electric Cooling and Heating System Baseline Efficiencies for Package Terminal Equipment

Equipment Type	**Size Category (Input)**	**Subcategory or Rating Condition**	**Minimum Efficiency ECCCNYS[191]**
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[192]	All Capacities	95°F db Outdoor Air	EER = 10.9 - (0.213 × Cap/1,000)

[190] For equipment with ≥65,000 BTU/h and <135,000 BTU/h cooling capacity, IEER values are taken from 10 CFR 431.97 (Table 3).

[191] “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.”

[192] 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.

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency ECCCNYS[191]
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)

Fossil Fuel Fired Heating System Baseline Efficiencies: Systems Serving Single Units[193]

Equipment Type	Size Range	CFR Minimum Efficiency
Warm Air Furnace, Gas Fired	All Capacities	0.80 AFUE
Warm Air Furnace, Oil Fired	All Capacities	0.83 AFUE
Boiler, Hot Water, Gas Fired	All Capacities	0.84 AFUE
Boiler, Steam, Gas Fired	All Capacities	0.82 AFUE
Boiler, Hot Water, Oil Fired	All Capacities	0.86 AFUE
Boiler, Steam, Oil Fired	All Capacities	0.85 AFUE

Fossil Fuel Fired Heating System Baseline Efficiencies: 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	0.80 AFUE
	≥ 225 kBTU/h	0.80 Et
Warm Air Furnace, Oil Fired	< 225 kBTU/h	0.83 AFUE
	≥ 225 kBTU/h	0.81 Et
Warm Air Unit Heaters, Gas Fired	All Capacities	0.80 Ec
Warm Air Unit Heaters, Oil Fired	All Capacities	0.80 Ec

[193] 10 CFR 430.32(e)(2)(iii)(A) <last reviewed 6/21/2024>

Equipment Type	Size Range	ECCCNYS Minimum Efficiency for Climate Zones 4, 5 and 6
Boiler, Hot Water, Gas Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.80 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	0.80 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.77 Et
	> 2,500 kBTU/h	0.77 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.81 Et
	> 2,500 kBTU/h	0.81 Et

For scenarios where the baseline heating system is electric resistance heat, the baseline seasonal efficiency is assumed to be a COP of 1.0. For scenarios with PTHPs as the baseline heating system, we assume the rated heating efficiency is derated[194] to account for mix of electric resistance and PTHP operation:

$$COP_{season,baseline} = COP_{rated} \times F_{PTHP}$$

Where F_{PTHP} = 0.55 for NYC and 0.45 for upstate locations

For cooling, the seasonal average efficiency ($EER_{season,base}$), should be set to the values of SEER for residential equipment or IEER for commercial packaged equipment, as appropriate. For PTAC or PTHP systems use rated EER times a factor of 1.15.[195]

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.

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.

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[194] As per Tables 11 and 12 from NYSERDA report "High-Performance Packaged Terminal Heat Pump Market and Development Research", Report 18-27, October 2018 completed by Taitem Engineering. Effective annual COP with resistance heat backup are 1.76 in NYC and 1.32 in Syracuse with a change-over temperature of 35°F. This equates to derating factors of 0.55 for NYC and 0.45 for Upstate NY assuming a rated COP of 3.2 in NYC and 3.0 upstate.

[195] 1.15 is the typical ratio of SEER and EER (or IEER and EER) given in the tables above.

Central Loop Pumping Energy Use for GSHP Systems

In larger GSHP systems with centralized pumping, the loop flow is modulated in response to the building load (or the number of GSHP units operating). Each GSHP unit typically has a two-way (or ON/OFF) valve that restricts loop flow through the unit when it is off.[196] As a result, less loop flow is required at lightly-load conditions when fewer GSHP units are operating, so pumping power is significantly reduced.

The factor $F_{pump,avg}$ indicates the average fraction of the design or full power across the year. The design power is defined as the electric power required to provide the design or maximum loop flow rate ($kW_{pump,design}$). The table below provides values of $F_{pump,avg}$ based on climate cities as well as various design and operating factors. The operating factors include the type of pumping system, the amount of load diversity and the amount of bypass flow in the loop. This table was developed using a bin analysis as described in a White Paper.[197] These design and operating factors are discussed below:

- The type of loop flow modulation can include: 1) Traditional variable speed drive (VSD) driven pump controlled to maintain the differential pressure difference at a remote location in the system, 2) a staged pumping system, or 3) a sensorless VSD pump that maintains a constant pressure difference across the pump without using a pressure sensor (see the White Paper).
- Variable speed loops may require that some bypass flow be provided so that the loop pumps can continue to operate even when all the heat pumps are off. Bypass flow can be provided by leaving off two-way valves on some heat pump units or by providing fixed bypass plumbing from the supply to the return side of the loop. The % of bypass flow affects the minimum allowable flow (and therefore the minimum pumping power). The table includes bypass flows ranging from 30 to 60%.
- The load diversity in the system also affects the pumping energy use. Since each heat pump is sized to meet the local zone loads, it is unlikely that every heat pump unit will be operating at the same time, even at design conditions. The table considers the case with modest diversity (e.g., 80/90% of the maximum loop flow at cooling / heating design conditions) as well as the case with more diversity (e.g., 60/70% of the maximum loop flow at cooling / heating design conditions). The design loop flow can often be less than the theoretical maximum flow with every heat pump operating, which effects the diversity factor. We recommend that modest diversity (80/90%) be used when the design loop flow is less than the maximum theoretical flow. Otherwise use 60/70% diversity. The White Paper provides further guidance on situations where load diversity is likely to occur.

[196] If the GSHP unit is dual-stage or variable speed, then a modulating valve should be used to maintain a constant loop temperature difference across the unit.

[197] Henderson, H. 2020. White Paper Savings Calculations for Large Ground Source Heat Pumps with Central Pumping, For application in Multi-Family Buildings and Other Commercial Applications. Prepared for the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Public Service. November.

Tables for $F_{pump,avg}$ Based on Location and Other Factors

	Albany	Bing-hamton	Buffalo	Massena	New York City	Pough-keepsie	Syracuse
	Bypass Flow = 30% (10% min Power) & Diversity = 80%/90%						
Traditional VSD	18.1%	19.5%	19.5%	18.6%	19.2%	20.7%	19.1%
Two-Stage	42.6%	42.9%	43.1%	41.6%	40.9%	44.5%	43.0%
Sensorless VSD	19.0%	20.5%	20.5%	19.5%	20.1%	21.7%	20.0%
	Bypass Flow = 40% (13% min Power) & Diversity = 80%/90%						
Traditional VSD	19.7%	21.1%	21.1%	20.4%	20.7%	22.4%	20.6%
Two-Stage	42.6%	42.9%	43.1%	41.6%	40.9%	44.5%	43.0%
Sensorless VSD	20.7%	22.2%	22.1%	21.4%	21.8%	23.5%	21.7%
	Bypass Flow = 50% (22% min Power) & Diversity = 80%/90%						
Traditional VSD	25.6%	26.8%	26.7%	26.3%	26.2%	28.0%	26.2%
Two-Stage	42.6%	42.9%	43.1%	41.6%	40.9%	44.5%	43.0%
Sensorless VSD	26.8%	28.1%	28.0%	27.6%	27.5%	29.4%	27.5%
	Bypass Flow = 60% (33% min Power) & Diversity = 80%/90%						
Traditional VSD	34.3%	35.4%	35.2%	35.0%	34.7%	36.5%	34.8%
Two-Stage	42.6%	42.9%	43.1%	41.6%	40.9%	44.5%	43.0%
Sensorless VSD	36.1%	37.2%	37.0%	36.8%	36.4%	38.3%	36.5%
	Bypass Flow = 30% (10% min Power) & Diversity = 60%/70%						
Traditional VSD	13.0%	13.7%	13.7%	13.4%	13.4%	14.7%	13.4%
Two-Stage	34.0%	35.1%	35.1%	35.0%	34.2%	36.6%	33.8%
Sensorless VSD	13.7%	14.4%	14.4%	14.1%	14.1%	15.4%	14.1%
	Bypass Flow = 40% (13% min Power) & Diversity = 60%/70%						
Traditional VSD	15.2%	15.9%	15.8%	15.6%	15.5%	16.8%	15.5%
Two-Stage	34.0%	35.1%	35.1%	35.0%	34.2%	36.6%	33.8%
Sensorless VSD	16.0%	16.7%	16.6%	16.4%	16.2%	17.6%	16.3%
	Bypass Flow = 50% (22% min Power) & Diversity = 60%/70%						
Traditional VSD	22.4%	22.9%	22.8%	22.8%	22.6%	23.7%	22.6%
Two-Stage	34.0%	35.1%	35.1%	35.0%	34.2%	36.6%	33.8%
Sensorless VSD	23.5%	24.1%	23.9%	23.9%	23.7%	24.9%	23.7%
	Bypass Flow = 60% (33% min Power) & Diversity = 60%/70%						
Traditional VSD	32.6%	32.8%	32.7%	32.8%	32.7%	33.5%	32.7%
Two-Stage	34.0%	35.1%	35.1%	35.0%	34.2%	36.6%	33.8%
Sensorless VSD	34.3%	34.5%	34.3%	34.5%	34.4%	35.2%	34.3%

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 formulas adjust performance for closed loop systems to an average entering water temperature for both heating and for cooling. For small residential systems the average entering temperatures are approximately 40°F for heating and 77°F for cooling. For large GSHP systems, the user must specify the average entering water temperature for heating ($EWT_{avg,h}$) as well as for cooling ($EWT_{avg,c}$). Temperatures for large buildings are typically 5 to 15°F higher than the residential / small systems averages in heating and 10 to 20°F higher than the residential / small systems averages in cooling. Some loop sizing software can provide the average values. If only the design temperatures from the ground loop sizing calculations are known (EWT_{max} and EWT_{min}), then an approximate assumption would be:

$EWT_{avg,h} = EWT_{min} + 10°F$

$EWT_{avg,c} = EWT_{max} - 10°F$

The formulas determine the average seasonal cooling efficiency ($EER_{season,ee}$) and the average seasonal heating efficiency ($COP_{season,ee}$) for a GSHP system with a two-stage or variable speed compressor. For single-stage units the part load values are omitted and $F_{full} = 1$ & $F_{part} = 0$

$$\begin{aligned} EER_{season,ee} = \Big[&\left(F_{full} \times EER_{GLHP,full} \times \left(1 + 0.01 \times \left(77 - EWT_{avg,c}\right)\right) \times F_{pump,full}\right) \\ &+ \left(F_{part} \times EER_{GLHP,part} \times \left(1 + 0.01 \times \left(68 - EWT_{avg,c}\right)\right) \times F_{pump,part}\right)\Big] \\ &\times F_{dist,c} \end{aligned}$$

$$\begin{aligned} COP_{season,ee} = \Big[&\left(F_{full} \times COP_{GLHP,full} \times \left(1 + 0.01 \times \left(EWT_{avg,h} - 32\right)\right) \times F_{pump,full}\right) \\ &+ \left(F_{part} \times COP_{GLHP,part} \times \left(1 + 0.01 \times \left(EWT_{avg,h} - 41\right)\right) \times F_{pump,part}\right)\Big] \\ &\times F_{dist,h} \end{aligned}$$

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
$EWT_{avg,h}$ = The average entering loop temperature in the heating season
$EWT_{avg,c}$ = The average entering loop temperature in the cooling season
$F_{dist,c}$ = 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
0.01 = Correction for fractional change in EER or COP per each 1°F in entering loop temperature[198]

[198] Correction for % change in EER or COP as the entering fluid temperature changes by 1°F. Observed from published performance data as well as in the IGSHPA Design Manual.

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.
$EWT_{avg,h}$		The average entering loop temperature in the heating season, typically between 45 and 55°F for larger GSHP systems.
$EWT_{avg,c}$		The average entering loop temperature in the cooling season, typically between 60 and 80°F for larger GSHP systems.
EWT_{min}		The minimum expected entering loop temperature in the heating season, from the ground loop sizing calculations.
EWT_{max}		The maximum expected entering loop temperature in the cooling season, from the ground loop sizing calculations.
$F_{dist,c}$		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, for two-stage and variable speed GSHP units. Based in part on observed mix of low and high stage operation from field testing.[199] For single stage use 1.0.

[199] 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, for two-stage and variable speed GSHP units. Based in part on observed mix of low and high stage operation from field testing.[200] For single stage use 0.
$F_{pump,full}$		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 $F_{pump,part}$)

These correction factors are not required when centralized pumping is used with two-way valves on each heat pump. In that case set $F_{pump,full}$ and $F_{pump,part}$ to 1.0.

If the GSHP system includes central loop pumps AND also uses cartridge circulators on each GSHP unit (instead of two-way valves), then these correction factors must be applied. The discussion of pumping Watts below only applies to the cartridge circulator/pump and NOT to the central pumps.

A correction factor for cartridge 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 75 Watts/ton was performed to determine the impact of loop pumping power on efficiency. Results are shown in the Pumping Factors table below.

Pumping Power Adjustment Factors for Cartridge Pumps on each GSHP unit

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 with a staged or variable speed GSHP unit 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:

[200] Ibid.

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

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.

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). Single stage GSHP units only require the full load factor, while staged and variable speed GSHP units require both full and part load factors. The full load pumping factors are typically 0.86 to 0.94. Part load factors can range from 0.77 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	45 Watts/ton		60 Watts/ton		75 Watts/ton	
		Clg	Htg	Clg	Htg	Clg	Htg
Full load ($F_{pump,full}$)		0.94	0.94	0.93	0.92	0.91	0.90
Part load – constant flow pumping ($F_{pump,part}$)	0.75	0.89	0.91	0.86	0.89	0.83	0.86
Part load – constant flow pumping ($F_{pump,part}$)	0.40	0.81	0.85	0.77	0.81	0.72	0.77
Part load – staged pumping ($F_{pump,part}$)	0.75	0.92	0.94	0.89	0.91	0.87	0.89
Part load – staged pumping ($F_{pump,part}$)	0.40	0.92	0.94	0.89	0.91	0.87	0.89
Part load – variable pumping ($F_{pump,part}$)	0.40	0.94	0.95	0.92	0.93	0.90	0.92

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.[201]

[201] 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. 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 building equivalent full load operating hours for HVAC equipment based on the design heating and cooling loads (i.e., "Block Loads"). The table includes BEFLH values for small commercial buildings as well as low and high-rise multifamily buildings. These values were developed in a White Paper based on EnergyPlus simulation runs from a NYSERDA simulation project focused on commercial and multifamily buildings (Henderson 2021b). BEFLH values are given by climate zone and by building vintage for each building type. Large commercial buildings have been excluded from the table since baseline HVAC systems in those buildings (e.g., VAV systems) are not adequately considered in this measure. For facility types not listed, central-pumped GSHP measures shall be addressed via custom analysis.

Facility Type	**CZ***	**BEFLH Heating**			**BEFLH Cooling**		
		Pre-1980	**Post-1980**	**NC**	**Pre-1980**	**Post-1980**	**NC**
Office – Low-Rise (≤3 floors)	4A	351	537	285	1,000	1,186	984
	5A	545	793	505	634	778	786
	6A	599	790	521	495	641	672
Grocery	4A	1,029	1,055	1,269	609	622	656
	5A	1,206	1,204	1,447	358	343	506
	6A	1,130	1,130	1,344	277	263	355
Hotel – Small (≤4 floors)	4A	386	916	649	1,956	2,141	2,056
	5A	619	1,127	893	1,916	1,958	1,818
	6A	502	942	919	1,650	1,760	1,625

Facility Type	CZ*	BEFLH Heating			BEFLH Cooling		
		Pre-1980	Post-1980	NC	Pre-1980	Post-1980	NC
Restaurant	4A	1,153	1,236	778	767	788	1,141
	5A	1,481	1,508	1,183	545	547	808
	6A	1,413	1,386	1,142	381	417	663
Stand Alone Retail	4A	760	779	579	705	705	941
	5A	987	983	858	466	440	662
	6A	969	970	838	362	363	617
School	4A	550	558	178	552	632	1,160
	5A	688	729	394	362	394	885
	6A	690	709	275	327	323	818
Warehouse	4A	875	876	637	243	230	498
	5A	1,161	1,159	915	97	93	276
	6A	1,049	1,047	972	82	77	247
Multifamily (≤7 floors)	4A	1,332	1,324	1,100	900	935	987
	5A	1,713	1,668	1,320	631	666	497
	6A	1,449	1,393	1,450	453	470	542
Multifamily (>7 and ≤20 floors)	4A	1,242	1,216	1,144	965	1,007	1,192
	5A	1,625	1,563	1,391	693	738	638
	6A	1,375	1,301	1,406	494	523	697
Multifamily - Brick (>7 and ≤20 floors)	4A	1,431	1,317	1,198	1,141	1,074	1,212
	5A	1,793	1,668	1,430	752	777	639
	6A	1,606	1,382	1,478	573	572	699

* Climate Zones (CZ) shall be mapped to standard weather stations/cities as follows:

- 4A: NYC
- 5A: Albany, Buffalo, Poughkeepsie, Syracuse
- 6A: Binghamton, Massena

Example Calculation *(Not to be used as default)*

Several GSHP units are installed at a low-rise office building located near Albany (climate zone 5A) constructed in 1975. The units are combined into a system with a closed loop ground heat exchanger field with centralized pumping. The system is of hybrid design, combining traditional central loop variable speed pumping with individual cartridge circulators on each heat pump unit. Each heat pump has a full load EER of 19, part load EER of 25, full load COP of 3.5 and part load COP of 4.1. The GSHPs have 45 watts/ton system pumping power. The building has a total cooling load of 720 kBTUh and total heating load of 1,000 kBTUh. The baseline HVAC equipment comprise 20-ton packaged gas furnace/RTU AC units. The minimum expected temperature entering the loop in the heating season is 60ºF and the maximum expected temperature entering the loop in the cooling season is 60ºF. At full speed flowrate, the pump motor and variable speed drive draw 0.5 kW. The design loop flow is less than maximum theoretical flow, and when heat pumps are in off position, bypass flow is configured to 60% of design flowrate. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \left[\frac{BCL}{1{,}000} \times \left(\frac{F_{ElecCool}}{EER_{season,baseline}} - \frac{1}{EER_{season,ee}}\right) \times BEFLH_{cooling}\right] + \left[\frac{BHL}{3{,}412} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee}}\right) \times BEFLH_{heating} - \left[F_{pump,avg} \times kW_{pump,design} \times 8760\right]\right]$$

$$\Delta kW = \frac{BCL}{1{,}000} \times \left(\frac{F_{ElecCool}}{EER_{peak,baseline}} - \frac{1}{EER_{GSHP,full,,ee}}\right) \times CF - kW_{pump,design}$$

$$\Delta MMBtu = \frac{BHL}{1{,}000{,}000} \times \frac{F_{FuelHeat}}{AFUE_{baseline}} \times BEFLH_{heating}$$

BCL = 720,000, from application

$F_{ElecCool}$ = 1, from Summary of Variables and Data Sources table based on baseline HVAC from application

$EER_{season,baseline}$ = 11.4, from Baseline Efficiencies section based on equipment type and size from application

$EER_{season,ee}$ = ((F_{full} x $EER_{GLHP,full}$ x (1 + 0.01 x (77 – $EWT_{avg,c}$)) x $F_{pump,full}$) + (F_{part} x $EER_{GLHP,part}$ (1 + 0.01 x (68 – $EWT_{avg,c}$)) x $F_{pump,part}$)) x $F_{dist,c}$

= ((0.25 x 19 x (1 + 0.01 x (77 - 50)) x 0.93) + (0.75 x 25 x (1 + 0.01 x (68- 50) x 0.92)) x 0.95 = 24.67

$EER_{season,ee}$ equation from Compliance Efficiency section based on GSHP type

F_{full} from Compliance Efficiency section's Summary of Variables and Data Sources table

$EER_{GLHP,full}$ from application

$EWT_{avg,c}$ = EWT_{min} - 10°F = 60 - 10 = 50ºF

$EWT_{avg,c}$ equation from compliance efficiency section

EWT_{min} from application

$F_{pump,full}$ from Pumping Power Adjustment Factors table based on application

F_{part} from Compliance Efficiency section's Summary of Variables and Data Sources table

$EER_{GLHP,part}$ from application

$F_{pump,part}$ from Pumping Factors table based on application

$F_{dist,c}$ from Distribution Correction Factors based on application

$BEFLH_{cooling}$ = 634, from Operating Hours section based on location, Facility Type and construction year from application

BHL = 1,000,000, from application

$F_{ElecHeat}$ = 0, from Summary of Variables and Data Sources table based on existing HVAC from application

$COP_{seaseason,baseline}$ = N/A

$COP_{season,ee}$ = ((F_{full} x $COP_{GLHP,full}$ x (1 + 0.01 x ($EWT_{avg,h}$ – 32)) x $F_{pump,full}$) + (F_{part} x $COP_{GLHP,part}$ x (1 + 0.01 x ($EWT_{avg,h}$ – 41)) x $F_{pump,part}$)) x $F_{dist,h}$

= ((0.25 x 3.5 x (1 + 0.01 x (70- 32)) x 0.92) + (0.75 x 4.1 x (1 + 0.01 x (70 - 41)) x 0.93)) x 0.96 = 4.61

$COP_{season,ee}$ equation from Compliance Efficiency section based on GSHP type

$COP_{GLHP,full}$ from application

$EWT_{avg,h} = EWT_{min} + 10°F = 60 + 10 = 70°F$

$EWT_{avg,h}$ equation from compliance efficiency section

EWT_{min} from application

$F_{pump,full}$ from Pumping Power Adjustment Factors table based on application

$COP_{GLHP,part}$ from application

$F_{pump,part}$ from Pumping Power Adjustment Factors table based on application

$F_{dist,h}$ from Distribution Correction Factors based on application

$BEFLH_{heating}$ = 545, from Operating Hours section based on location, Facility Type and construction year from application

$F_{pump,avg}$ = 0.343, from Central Loop Pumping Energy Use for GSHP Systems section based on Bypass Flow, Diversity, type of loop flow modulation, and location from application

$kW_{pump,design}$ = 0.5, from application

$EER_{peak,baseline}$ = 9.8, from Baseline Efficiencies section based on equipment type and size from application

$EER_{GSHP,full,ee}$ = 19, from application

CF = 0.8, from Summary of Variables and Data Sources table based on application

$F_{FuelHeat}$ = 1, from Summary of Variables and Data Sources table based on existing HVAC from application

$AFUE_{baseline}$ = 0.8, from Baseline Efficiencies section based on equipment type and size from application

$$\Delta kWh = \left[\frac{720{,}000}{1{,}000} \times \left(\frac{1}{11.4} - \frac{1}{24.67}\right) \times 634\right] + \left[\frac{1{,}000{,}000}{3{,}412} \times \left(0 - \frac{1}{4.61}\right) \times 545 - [0.343 \times 0.5 \times 8760]\right] = -14{,}612.35\ kWh$$

$$\Delta kW = \frac{720{,}000}{1{,}000} \times \left(\frac{1}{9.8} - \frac{1}{19}\right) \times 0.8 - 0.5 = 27.96\ kW$$

$$\Delta MMBtu = \frac{1{,}000{,}000}{1{,}000{,}000} \times \frac{1}{0.8} \times 545 = 681.25\ MMBtu$$

Methods for Calculating Annual Domestic Hot Water Energy Savings from a Dedicated Water-to-Water Heat Pump

GSHP systems can meet DHW loads by installing a water-to-water heat pump (WWHP) dedicated to meeting the DHW load.

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

In this analysis the DHW-WWHP displaces nearly all the DHW load. Electric demand impacts are not considered at this time.

$$\Delta MMBtu_{DHW-WWHP} = \frac{Q_{DHW-WWHP}}{1{,}000{,}000} \times \frac{F_{FFDHW}}{UEF_{baseline}}$$

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

$$Q_{DHW-WWHP} = 1.1 \times GPD/unit \times 365 \times 8.33 \times \Delta T_{main}$$

$$COP_{DHW-WWHP} = COP_{AHRI,GLHP} \times 0.95$$

where:

$\Delta MMBtu_{DHW-WWHP}$ = Fossil fuel energy displaced by dedicated DHW-WWHP
$\Delta kWh_{DHW-WWHP}$ = Electricity savings from dedicated DHW-WWHP operation
$COP_{AHRI,GLHP}$ = Rated COP per ISO13256-2 at GLHP conditions (32°F source-side, 104°F load-side)
$COP_{DHW-WWHP}$ = Overall annual COP of dedicated DHW-WWHP
F_{EDHW} = Factor indicating that baseline DHW system is electric
F_{FFDHW} = Factor indicating that baseline DHW system is fossil fuel fired
GPD/unit = Gallons per day consumption, for DHW system per installed unit
$Q_{DHW-WWHP}$ = Annual DHW load served by dedicated DHW-WWHP, BTU
$UEF_{baseline}$ = Uniform energy factor of baseline DHW appliance (gas or electric). For commercial systems use AFUE or Et in place of UEF, as appropriate.
ΔT_{main} = Average temperature difference between delivered hot water temperature and the supply water temperature in water main (°F)
0.95 = Correction factor from AHRI rated conditions to 50-60°F source-side, 120-130°F load-side.
1.1 = Factor to increase DHW load served by DHW-WWHP to account for 10% tank losses (that are embedded in UEF).
8.33 = Specific heat of water; energy required (BTU), to heat one gallon of water by one degree Fahrenheit [BTU/(gal-F)]
365 = Days in one year
3,412 = Conversion factor, one kWh equals 3,412 BTU
1,000,000 = Conversion factor (BTU/MMBtu), one therm equals 1,000,000 BTU

Summary of Variables and Data Sources

Variable	Value	Notes
F_{EDHW}	1 for electric DHW	Factor indicating baseline DHW is electric

Variable	Value	Notes
F_{FFDHW}	1 for gas-fired DHW	Factor indicating baseline DHW is fossil fuel-fired
GPD/unit		From application, or lookup/calculate based on building type, square footage, and occupancy from GPD table below. If based on values per the table below, divide result by number of units installed.
T_{main}		Supply water temperature in water main (°F). Lookup in Cold Water Inlet Temperature table below based on nearest city.
T_{del}	125	Delivered hot water temperature (°F).[202]
$UEF_{baseline}$		Uniform Energy Factor of the baseline condition. See Baseline Efficiencies section for details regarding derivation of this input.
ΔT_{main}	T_{del} - T_{main}	Average temperature difference between delivered hot water temperature and the supply water temperature in water main (°F).
$COP_{AHRI,GLHP}$		From application.

Hot Water Consumption for Commercial and Multifamily Building Applications

Building Type	GPD	Rate	Notes/Assumptions	Source
Assembly	239	7.02 GPD per 1,000 SF	Assumes 10% hot water, 34,000 SF	EIA[203]: Public Assembly
Auto Repair	25	4.89 GPD per 1,000 SF	Assumes 10% hot water, 5,150 SF	EIA: Other
Big Box Retail	448	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,500 SF	EIA: Mercantile
Community College	1,520	1.9 GPD per person	Assumes 800 students	NREL[204]: School with Showers
Dormitory	8,600	17.2 GPD per resident	Assumes 500 residents	Water Research Foundation[205]
Elementary School	250	0.5 GPD per student	Assumes 500 students	NREL: School
Fast Food Restaurant	500	500 GPD per restaurant		FSTC[206]: Quick Service
Full-Service Restaurant	2,500	2,500 GPD per restaurant		FSTC: Full Service
Grocery	172	3.43 GPD per 1,000 SF	Assumes 10% hot water, 50,000 SF	EIA: Mercantile
High School	1,520	1.9 GPD per person	Assumes 800 students	NREL: School with Showers
Hospital	16,938	54.42 GPD per 1,000 SF	Assumes 40% hot water, 250,000 SF	EIA: Health Care, Inpatient
Hotel	9,104	45.52 GPD per 1,000 SF	Assumes 40% hot water, 200,000 SF	EIA: Lodging
Large Office	550	1.1 GPD per person	Assumes 500 people	NREL: Office
Large Retail	446	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,000 SF	EIA: Mercantile
Light Industrial	489	4.89 GPD per 1,000 SF	Assumes 10% hot water, 100,000 SF	EIA: Other
Motel	1,366	45.52 GPD per 1,000 SF	Assumes 40% hot water, 30,000 SF	EIA: Lodging
Multifamily High-Rise	3,440	34.4 GPD per unit	Assumes 100 units, 2 people per unit	Multifamily Baseline Study[207]
Multifamily Low-Rise	413	34.4 GPD per unit	Assumes 12 units, 2 people per unit	Multifamily Baseline Study
Refrigerated Warehouse	86	0.93 GPD per 1,000 SF	Assumes 10% hot water, 92,000 SF	EIA: Warehouse and Storage
Religious	77	7.02 GPD per 1,000 SF	Assumes 10% hot water, 11,000 SF	EIA: Public Assembly
Small Office	110	1.1 GPD per person	Assumes 100 people	NREL: Office
Small Retail	27	3.43 GPD per 1,000 SF	Assumes 10% hot water, 8,000 SF	EIA: Mercantile
University	1,000	0.5 GPD per student	Assumes 2,000 students	NREL: School
Warehouse	465	0.93 GPD per 1,000 SF	Assumes 10% hot water, 500,000 SF	EIA: Warehouse and Storage

[202] Aligned with residential measure set point temperature to normalize default GPD across sectors.
[203] U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings, Table WD1. Daily water consumption in large commercial buildings, 2012.
[204] National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use by Building Type, June 2011.
[205] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016.
[206] Improving Commercial Kitchen Hot Water System Performance, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010.
[207] Residential Statewide Baseline Study of New York State, July 2015. Volume 2: Multifamily Report, Table 8.

Building Type	GPD	Rate	Notes/Assumptions	Source
Other	Calculate	4.89 GPD per 1,000 SF	Assumes 10% hot water	EIA: Other

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.[208] Supply main temperatures based on the annual outdoor temperature are shown below.

City	Annual average outdoor temperature[209] (°F)	T_{main} (°F)
Albany	49.4	55.4
Binghamton	46.8	52.8
Buffalo	49.1	55.1
Massena	45.1	51.1
NYC	54.7	60.7
Poughkeepsie	50.9	56.9
Syracuse	49.0	55.0

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.[210]

Residential Water Heaters[211]

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)

[208] Burch, Jay and Christensen, Craig, “Towards Development of an Algorithm for Mains Water Temperature.” National Renewable Energy Laboratory.

[209] Average annual outdoor temperatures taken from NCEI 1991-2020 climate normals.

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

[211] 10 CFR 430.32(d).

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	Uniform Energy Factor
Oil-fired Storage Water Heater	≤50 gal	Very Small	0.2509 − (0.0012 × vt)
		Low	0.5330 − (0.0016 × vt)
		Medium	0.6078 − (0.0016 × vt)
		High	0.6815 − (0.0014 × vt)
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

Commercial Water Heaters for Central Systems

Commercial Equipment Type	Efficiency Level
Tank Type: All Sizes	0.80 Et
Gas-Fired Hot Water Boiler: < 300,000 BTU/h	0.82 AFUE
Oil-Fired Hot Water Boiler: < 300,000 BTU/h	0.84 AFUE
Gas-Fired Steam Boiler, All Except Natural Draft: < 300,000 BTU/h	0.80 AFUE
Gas-Fired Steam Boiler, Natural Draft: < 300,000 BTU/h	0.80 AFUE
Oil-Fired Steam Boiler: < 300,000 BTU/h	0.82 AFUE

First Hour Rating vs. Draw Pattern (Storage Type Only)[212]

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

Example Calculation *(Not to be used as default)*

A water-to-water heat pump is being installed with a GSHP with GLHP COP of 3.5 at a low-rise office building located near Albany (climate zone 5A). The existing DHW system is a gas-fired storage water heater that has a 50-gallon capacity and Medium draw pattern. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$COP_{DHW-WWHP} = COP_{AHRI,GLHP} \times 0.95$$

$$Q_{DHW-WWHP} = 1.1 \times GPD/unit \times 365 \times 8.33 \times \Delta T_{main}$$

212 10 CFR 429.17.

$$\Delta MMBtu_{DHW-WWHP} = \frac{Q_{DHW-WWHP}}{1{,}000{,}000} \times \frac{F_{FFDHW}}{UEF_{baseline}}$$

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

$COP_{AHRI,GLHP}$ = 3.5, from application
$COP_{DHW\text{-}WWHP}$ = 3.325
vt = 50, from application
F_{EDHW} = 0, from Summary of Variable and Data Sources table based on baseline DHW fuel source from application
F_{FFDHW} = 1, from Summary of Variable and Data Sources table based on baseline DHW fuel source from application
GPD/unit = 110, GPD/unit equation based on Hot Water Consumption for Commercial and Multifamily Building Applications table
ΔT_{main} = T_{del} - T_{main} = 125 - 55.4 = 69.6 °F
T_{del} from Summary of Variables and Data Sources table
T_{main} from Cold Water Inlet Temperature lookup table based on location from application
$UEF_{baseline}$ = 0.6483 - (0.0017 x v_t) = 0.6483 - (0.0017 x 50) = 0.5633
$UEF_{baseline}$ equation lookup from Baseline Efficiencies section based on Product Class from baseline application and Rated Storage Volume
v_t = 50, from application

$$COP_{DHW-WWHP} = 3.5 \times 0.95 = 3.325$$

$$Q_{DHW-WWHP} = 1.1 \times 110 \times 365 \times 8.33 \times 69.6 = 25{,}605{,}454$$

$$\Delta MMBtu_{DHW-WWHP} = \frac{25{,}605{,}454}{1{,}000{,}000} \times \frac{1}{0.5633} = 45.46\ MMBtu$$

$$\Delta kWh_{DHW-WWHP} = \frac{25{,}605{,}454}{3{,}412} \times \left(\frac{0}{0.5633} - \frac{1}{3.325}\right) = -2{,}257.00\ kWh$$

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
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. ECCCNYS, 2016, per IECC 2015; Section R403.7. Available from: https://codes.iccsafe.org/public/document/IECC2015NY-1/chapter-4-re-residential-energy-efficiency
5. *Guide to Geothermal Heat Pumps* (February 2011) U. S. Department of Energy, Energy Efficiency and Renewable Energy, DOE/EE-0385.
6. Henderson, H.I., 2020. 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. Revised in June.
7. Henderson, H.I., 2021a. Savings Calculations for Ground Source Heat Pumps with Central Pumping. For application in Multi-Family Buildings and Other Commercial Applications. Prepared for the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Public Service. Revised March 2021.
8. Henderson, H. 2021b. White Paper: Developing Building Equivalent Full Load Hour (BEFLH) Values for Commercial and Multi-Family Buildings in NYS. Prepared for the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Public Service. Revised in August.
9. International Ground Source Heat Pump Association (IGSHPA). 2011. Ground Source Heat Pump Residential and Light Commercial Design and Installation Guide. Oklahoma State University. Stillwater.
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.
12. *Manual S Equipment Selection*, Arlington, VA. Air Conditioning Contractors Association
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.
15. 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.
16. *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.
17. *Water Source Heat Pumps – Testing and Rating for Performance – Part 2: Water to Water Heat Pumps* (2012) Arlington, VA. ANSI/ASHRAE/ISO Standard 13256-2:1998 (RA 2012), AHRI, 2012.
18. Residential Statewide Baseline Study of New York State, July 2015. Available from: https://www.nyserda.ny.gov/About/Publications/Evaluation-Reports/Building-Stock-and-Potential-Studies/Residential-Statewide-Baseline-Study-of-New-York-State

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