Table of Revisions/Changes

Revision Number	Addition/ Revision	Issue Date	Effective Date	Measure	Description of Change	Location/Page in TRM
3-25-2	R	5/14/2025	1/1/2026	R/MF Heat Pump - Air Source (ccASHP)	Algorithms updated to reflect SEER2, EER2, and HSPF2 equipment ratings; set cooling load factor equal to 1.0 for all applications; updated baseline provisions to accommodate SEER2, EER2, and HSPF2 ratings and conversion for baselines rated in SEER, EER, and HSPF; refreshed whole building and displacement scenario table to eliminate non-applicable scenarios; updated seasonal efficiency coefficients and heating load factors to reflect results of updated NEEP ccASHP analysis using SEER2, EER2, and HSPF2 ratings; modified control factors to align with refreshed scenarios; adjusted heating EFLH to align with NCEI 30-year climate normals; updated example calculation to reflect applied revisions	Pg. 278
3-25-4	R	5/14/2025	1/1/2026	R/MF Heat Pump – Water-to-Air Ground Source (GSHP)	Updated baseline provisions to accommodate SEER2, EER2, and HSPF2 ratings and conversion for baselines rated in SEER, EER, and HSPF; adjusted heating EFLH to align with NCEI 30-year climate normals; updated example calculation to reflect applied revisions	Pg. 308
3-25-7	R	5/14/2025	1/1/2026	C/I Interior Lighting Control	Added provisions for treatment of LLLC separate from other networked lighting controls; updated measure description, compliance requirements, and example calculation for LLLC	Pg. 963

Note: Revisions, Additions, Corrections and Removals to the measures listed above were undertaken by the Joint Utilities Technical Resource Manual (TRM) Management Committee between January 24, 2025 – May 14, 2025.

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[1] comprising units with rated cooling capacity less than 65,000 BTU/h that provide heating and cooling in residential applications.[2] 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.[3,4]

- 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 full load or whole-house application is limited to an ASHP system that is sized and installed to provide between 100% and 120% of the design heating load.[5] 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 Northeast Energy

[1] NEEP Cold Climate Air Source Heat Pump (ccASHP) Specification (Version 4.0) effective January 1, 2023
[2] "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, per 2021 International Residential Code (IRC) Section R101.2 Scope.
[3] ECCCNYS 2020, Section R403.7.
[4] ECCCNYS 2020 requires that systems serving multiple dwelling units follow Sections C403 and C404.
[5] Code reference above. The 100% 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.

Efficiency Partnerships (NEEP) *Guide to Sizing & Selecting Air-Source Heat Pumps in Cold Climates*[6].

The ASHP efficiency must meet the NEEP 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

$$\Delta kWh = \left(\left(\frac{BCL}{1{,}000} \times \left(\frac{1}{SEER2_{baseline}} - \frac{1}{EER_{season,ee}}\right) \times BEFLH_{cooling} \times F_{load,cooling}\right) + \left(\frac{BHL}{1{,}000} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee} \times F_{derate,ER}}\right) \times \frac{1}{3.412} \times BEFLH_{heating} \times F_{load,heating} \times F_{ctrl}\right)\right)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \frac{BCL}{1{,}000} \times \left(\frac{1}{EER2_{baseline}} - \frac{1}{EER2_{ee}}\right) \times F_{load,cooling} \times CF$$

Annual Fossil Fuel Energy Savings

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

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
$F_{FuelHeat}$	= 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
SEER2	= Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour, used for average U.S. location/region
EER2	= Full load energy efficiency ratio (BTU/watt-hour)
EER_{season}	= Seasonally adjusted average energy efficiency (BTU/watt-hour)

[6] NEEP Guide to Sizing & Selecting Air Source Heat Pumps in Cold Climates, December 2018

COP = Coefficient of performance for heating, ratio of output energy/input energy
COP_{season} = Seasonally adjusted average coefficient of performance
$F_{derate,ER}$ = Efficiency derate factor to account for a new heat pump's reliance on supplemental electric resistance heat to meet full heating load
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[7] cooling load met by the heat pump
$F_{load,heating}$ = Adjustment factor to account for the portion of the seasonal[8] 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.
$F_{FuelHeat}$		If the baseline heating system is a fossil fuel system, set equal to 1. Otherwise, set equal to 0.
$SEER2_{baseline}$		Electric cooling seasonal energy efficiency rating of baseline equipment. See Baseline Efficiencies section below for details.
$EER2_{baseline}$		Electric cooling full load energy efficiency rating of baseline equipment. See Baseline Efficiencies section below for details.
$EER2_{ee}$		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.
$COP_{season,baseline}$		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[9], use the baseline calculations below.

[7] Fraction of annual (vs. design) cooling load served by the equipment as shown in the Cooling Load Factor table.
[8] Fraction of annual (vs. design) heating load served by the equipment as shown in the Heating Load Factor table.
[9] 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.

Variable	Value	Notes
$COP_{season,ee}$		Seasonally adjusted Coefficient of Performance of the efficient equipment. See Compliance Efficiency section below for details.
$F_{derate,ER}$		For ducted systems installed with integrated supplemental electric resistance heat, use a value of 0.84. Otherwise, use a value of 1.0.[10]
$AFUE_{baseline}$		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.
$F_{load,cooling}$	1.0	Equal to 1.0 for all climates and scenarios.
$F_{load,heating}$		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		See Coincidence Factor (CF) section below.

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.69 for ducted systems[11] and 0.30 for ductless mini-split systems.[12]

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

[10] Technical Study of New York State Heat Pump Performance, Prepared for NYS DPS by DNV, July 25, 2024, pg. 40

[11] 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.

[12] Technical Study of New York State Heat Pump Performance, Prepared for NYS DPS by DNV July 25, 2024, pg. 39

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.

Electric Cooling and Heating System Baseline Efficiencies

Product Class	Seasonal Energy Efficiency Ratio 2 (SEER2)[13]	Energy Efficiency Ratio 2 (EER2)[14]	Heating Seasonal Performance Factor 2 (HSPF)[15]
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

Where existing equipment efficiency is used as baseline and is rated in SEER, EER, and HSPF, efficiency ratings shall be converted to SEER2, EER2, and HSPF2 as follows:

$$SEER2 = SEER \times F_{SEER2}$$

$$EER2 = EER \times F_{EER2}$$

$$HSPF2 = HSPF \times F_{HSPF2}$$

[13] 10 CFR 430.32(c)(5)
[14] Calculated via the relationship EER2 = (1.12 x SEER2) – (0.02 x SEER2^2) from DOE, Building America House Simulation Protocols, October 2010
[15] 10 CFR 430.32(c)(5)

Where F_{SEER2}, F_{EER2}, and F_{HSPF2} are established based on equipment type per the table below:[16]

Equipment Type	F_{SEER2}	F_{EER2}	F_{HSPF2}
Ductless System	1.00	1.00	0.90
Centrally Ducted Split System	0.95	0.95	0.85
Centrally Ducted Single Packaged System	0.95	0.95	0.84

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[17]

Equipment Type	Size Range	Baseline 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[18] 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	Baseline Efficiency
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	0.84 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	0.86 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.82 Et
	> 2,500 kBTU/h	0.84 Ec

[16] Conversion factors developed by AHRI and adopted by RESNET, as published in Draft PDS-02 MINHERS® Addendum 71f, SEER/HSPF2 Conversions, RESNET, January 2023
[17] 10 CFR 430.32(e)(2)(iii)(A); last reviewed 10/1/2024
[18] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5).

Equipment Type	Size Range	Baseline Efficiency
Boiler, Steam, Gas Fired, All Except Natural Draft	< 300 kBTU/h	0.82 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	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.85 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 HSPF2 and the typical operating conditions in New York State, as shown below.

The HSPF2 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:

$$COP_{season,baseline} = \frac{HSPF2_{baseline} \times Adj_{HSPF2}}{3.412}$$

where:
$HSPF2_{baseline}$ = Heating seasonal performance factor of the baseline system
Adj_{HSPF2} = HSPF2 Climate Adjustment Factor, from table below
3.412 = Conversion factor, one watt-hour equals 3.412 BTU

HSPF2 Climate Adjustment Factor (Adj_{HSPF2}) for Conventional ASHP Used as a Baseline

City	HSPF2 < 8.5	HSPF2 ≥ 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 SEER2 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 NEEP 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:

$$COP_{season,ee} = a + b \times HSPF2 \times \frac{1}{3.412}$$

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

$$EER_{season,ee} = c + d \times SEER2$$

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)
HSPF2 = Rated Heating Season Performance Factor from AHRI or derived based on guidance in Efficiency Conversion section below
SEER2 = 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.[19]

Summary of Variables and Data Sources

[19] See *Henderson, H.I., 2020. White Paper: Savings Calculations for Residential Ground Air Source Heat Pumps: The Basis for Equivalent Full Load Hours (EFLH) and Seasonal Efficiency Factors* for detailed assumptions and descriptions of conducted analysis.

Variable	Value	Source
a & b		Coefficients to represent offset and slope from the table below to determine seasonal heating efficiency ($COP_{season,ee}$) from HSPF2. 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 SEER2. Depends on city and scenario.
HSPF2		Rated heating season performance factor from AHRI or derived based on guidance in Efficiency Conversion section below
SEER2		Rated seasonal energy efficiency ratio from AHRI or derived based on guidance in Efficiency Conversion section below

Whole Building and Displacement Scenarios

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[20]. 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 supplemental heating system are on separate thermostats and there is no effort to lock out the heat pump at cold temperatures when the supplemental system is running.
- **Integrated:** The ASHP and supplemental heating system are on the same thermostat. The supplemental 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 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 system pairs a single indoor unit to a single outdoor unit. There may be multiple single-zone systems to achieve the HP sizing shown. When multiple HPs are used, the capacity-weighted rated efficiencies (HSPF2 and SEER2) 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 HSPF2 and SEER2.

Scenario	Description	ASHP Type	Application	Controls	HP Sizing Parameter Range
1d	Central ASHP	Central, Ducted	Whole or Full Load	(see F_{ctrl} table)	1.0+

[20] 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 Range
2b	Single-zone Ductless (Wall, Ceiling, Floor)	Single-Zone Ductless	Displace or Part Load	Separate	0 to 0.699
2c					0.7 to 0.999
2h			Whole or Full Load	(see F_{ctrl} table)	1.0+
3a	Ductless Multi-Split sized to 0-99% and 100%	Multi-Zone Ductless	Displace or Part Load	Separate	0 to 0.999
3c			Whole or Full Load	(see F_{ctrl} table)	1.0+
4a	Compact Ducted Mini-Split sized at 0-69%, 70-99% and 100%	Single-Zone Compact Ducted	Displace or Part Load	Separate	0 to 0.699
4b					0.7 to 0.999
4d			Whole or Full Load	(see F_{ctrl} table)	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. See Appendix T: Zip Code / City Lookup for appropriate weather city based on project zip code. BHL is the design heating load for the home:

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

where:
$QH_{17,max}$ or $QH_{5,max}$ = Maximum system heating capacity at 17°F or 5°F, depending on project location
BHL = Building Heating Load at design conditions (BTU/h)

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.

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 must be determined to comply with code and satisfy any requirements established for full load sizing.

Actual HP Sizing = QH @ T_{des} / BHL ≠ HP Sizing Parameter

Coefficients for Seasonal Heating Efficiency: $COP_{season,ee} = a + b \times HSPF2/3.412$														
Scenario	Albany		Binghamton		Buffalo		Massena		NYC		Poughkeepsie		Syracuse	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b
1d	0.531	0.757	0.578	0.723	0.599	0.746	0.429	0.682	1.158	0.651	0.609	0.758	0.542	0.749
2b	2.604	0.115	2.551	0.118	2.672	0.106	2.238	0.137	3.011	0.085	2.791	0.075	2.581	0.119
2c	2.550	0.141	2.517	0.136	2.634	0.123	2.146	0.180	2.983	0.104	2.632	0.134	2.537	0.142
2h	2.226	0.183	2.198	0.179	2.290	0.172	1.839	0.225	2.573	0.165	2.320	0.175	2.217	0.183
3a	1.559	0.568	1.546	0.551	1.619	0.555	1.462	0.494	1.464	0.747	1.532	0.605	1.555	0.565
3c	1.768	0.407	1.850	0.360	1.832	0.399	1.509	0.384	1.765	0.547	1.820	0.420	1.776	0.401
4a	2.451	0.130	2.393	0.136	2.478	0.130	2.157	0.152	2.889	0.071	2.584	0.102	2.440	0.130
4b	2.506	0.100	2.467	0.099	2.570	0.087	2.140	0.152	2.956	0.038	2.567	0.097	2.482	0.105

Coefficients for Seasonal Heating Efficiency: $COP_{season,ee} = a + b \times HSPF2/3.412$														
Scenario	**Albany**		**Binghamton**		**Buffalo**		**Massena**		**NYC**		**Poughkeepsie**		**Syracuse**	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b
4d	2.293	0.120	2.258	0.122	2.392	0.096	1.866	0.193	2.844	0.018	2.437	0.092	2.287	0.120

Coefficients for Seasonal Cooling Efficiency: $EER_{season,ee} = c + d \times SEER2$														
Scenario	**Albany**		**Binghamton**		**Buffalo**		**Massena**		**NYC**		**Poughkeepsie**		**Syracuse**	
	c	d	c	d	c	d	c	d	c	d	c	d	c	d
1d	-6.85	1.274	-5.02	1.188	-5.14	1.180	-6.95	1.266	-6.06	1.244	-6.82	1.267	-6.86	1.274
2b	7.89	0.466	7.23	0.510	7.41	0.508	6.30	0.563	7.33	0.486	6.65	0.477	7.86	0.466
2c	7.83	0.493	5.23	0.62	5.10	0.627	4.55	0.627	7.36	0.513	7.00	0.503	7.78	0.495
2h	6.49	0.542	4.85	0.639	4.61	0.642	6.14	0.541	6.20	0.560	6.95	0.508	7.58	0.496
3a	12.20	0.085	12.32	0.087	12.32	0.088	12.14	0.082	12.25	0.078	12.03	0.085	12.25	0.083
3c	11.98	0.081	12.39	0.076	12.23	0.077	12.04	0.057	11.96	0.087	12.25	0.073	11.97	0.082
4a	-1.84	0.904	-2.01	0.923	-2.17	0.937	2.01	0.673	-1.99	0.911	-1.22	0.848	-1.84	0.903
4b	-1.05	0.860	2.04	0.681	2.26	0.662	-0.58	0.816	-1.26	0.874	-1.31	0.867	-1.05	0.859
4d	-0.66	0.819	-0.80	0.857	-0.71	0.841	-0.27	0.768	-0.76	0.831	-0.96	0.838	-0.69	0.821

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**	**NYC**	**Poughkeepsie**	**Syracuse**
1d	0.99	1.00	1.00	0.98	1.00	1.00	0.99
2b	0.15	0.15	0.15	0.15	0.15	0.15	0.15
2c	0.65	0.62	0.63	0.63	0.61	0.65	0.65
2h	0.97	0.98	0.98	0.95	0.97	0.98	0.97
3a	0.72	0.69	0.72	0.69	0.69	0.73	0.72
3c	0.96	0.96	0.96	0.94	0.96	0.96	0.96
4a	0.43	0.41	0.42	0.41	0.42	0.43	0.42
4b	0.65	0.62	0.64	0.62	0.62	0.65	0.65
4d	0.98	0.98	0.98	0.95	0.98	0.98	0.98

Heating Load Fractions for Scenario 2b fixed at 0.15 per NYSERDA HP Tech Study.[21]

Cooling Load Factor ($F_{load,cooling}$)

$F_{load,cooling}$ factor values shall be set equal to 1.0 for all climates and scenarios.[22] The cooling sizing is determined using assumptions about the relative size of cooling loads (BCL) and heating loads (BHL) in NY based on climate.

Optional Control Features

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 supplemental heating source but still allows the heat pump to operate with the supplemental heat. This

[21] Technical Study of New York State Heat Pump Performance, Prepared for NYS DPS by DNV , July 25, 2024, pg. 41.

[22] This approach replaces the tabulated values by climate zone, control, and displacement scenario presented in previous versions of this measure.

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 supplemental 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 23°F in NYC and 9°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.

Control Factors (Fctrl) for Optional Control Features (Fctrl = 1.0 for default controls)

Scenarios	Application	Integrated Control	Changeover DT+5°F
Centrally Ducted (Scenario 1)	Full	1.01	0.92
Ductless Mini-Spilt (Scenario 2)	Full	1.02	0.95
Ductless Multi-Splits (Scenario 3)	Full	1.04	0.94
Compact Ducted (Scenario 4)	Full	1.02	0.94

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 the building design load. The heating BEFLH is based on 30-year NCEI climate normal data from 1991 to 2020 that consider the 1% heating design temperature, the bin temperature data, and the design heating load. For heating, bin 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. The cooling values from Appendix G were then further adjusted to reflect 30-year NCEI climate normal from 1991 – 2020.

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

City	Prior to 1979	From 1979 Through 2006	From 2007 Through Present
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	Prior to 1979	From 1979 Through 2006	From 2007 Through Present
Albany	1,975	1,851	1,723
Binghamton	2,143	2,021	1,896
Buffalo	2,079	1,952	1,820
Massena	2,005	1,898	1,788
NYC	1,859	1,698	1,535
Poughkeepsie	1,950	1,821	1,689
Syracuse	2,001	1,879	1,753

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 SEER2, 13 EER2, and 12 HSPF2 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.

$$\Delta kWh = \left(\left(\frac{BCL}{1{,}000} \times \left(\frac{1}{SEER2_{baseline}} - \frac{1}{EER_{season,ee}}\right) \times BEFLH_{cooling} \times F_{load,cooling}\right) + \left(\frac{BHL}{1{,}000} \times \left(\frac{F_{ElecHeat}}{COP_{season,baseline}} - \frac{1}{COP_{season,ee} \times F_{derate,ER}}\right) \times \frac{1}{3.412} \times BEFLH_{heating} \times F_{load,heating} \times F_{ctrl}\right)\right)$$

$$\Delta kW = \frac{BCL}{1{,}000} \times \left(\frac{1}{EER2_{baseline}} - \frac{1}{EER2_{ee}}\right) \times F_{load,cooling} \times CF$$

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

BCL = 36,000, from application
$SEER2_{baseline}$ = 13.4, from Electric Cooling and Heating System Baseline Efficiencies table based on equipment type from application

$EER_{season,ee}$ = c + d x SEER2 = -6.85 + 1.274 x 20 = 18.63
- $EER_{season,ee}$ 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
- SEER2 from application

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

$F_{load,cooling}$ = 1.0, from Summary of Variables and Data Sources table

BHL = 58,000, from application

$F_{ElecHeat}$ = 0, from application

$COP_{season,baseline}$ = N/A, from application

$COP_{season,ee}$ = a + b x HSPF2 x 1/3.412 = 0.531 + 0.757 x 12 x 1/3.412 = 3.19
- $COP_{season,ee}$ equation from Compliance Efficiency section
- a and b from Coefficients for Seasonal Heating Efficiency table based on scenario and location from application
- HSPF2 from application

$F_{derate,ER}$ = 0.84, from Summary of Variables and Data Sources table

$BEFLH_{heating}$ = 1,975, from Operating Hours section tables based on housing type, city, and vintage from application

$F_{load,heating}$ = 0.99, from Heating Load Factor table based on scenario from application

F_{ctrl} = 1.0 from application for default controls

$EER2_{baseline}$ = 11.4, from Electric Cooling and Heating System Baseline Efficiencies table based on equipment type from application

$EER2_{ee}$ = 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

$$\Delta kWh = \left(\left(\frac{36{,}000}{1{,}000} \times \left(\frac{1}{13.4} - \frac{1}{18.63}\right) \times 465 \times 1\right) + \left(\frac{58{,}000}{1{,}000} \times \left(0 - \frac{1}{3.19 \times 0.84}\right) \times \frac{1}{3.412} \times 1{,}975 \times 0.99 \times 1.0\right)\right) = -12{,}053.0\ kWh$$

$$\Delta kW = \frac{36{,}000}{1{,}000} \times \left(\frac{1}{11.4} - \frac{1}{13}\right) \times 1 \times 0.69 = 0.27\ kW$$

$$\Delta MMBtu = \frac{58{,}000}{1{,}000{,}000} \times \frac{1}{0.80} \times 1{,}975 \times 0.99 \times 1.0 = 141.8\ MMBtu$$

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.

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Record of Revision

Record of Revision Number	Issue Date
1	10/15/2010
12-17-8	12/31/2017
9-18-4	9/28/2018
2-20-2	2/28/2020
7-20-21	7/31/2020
3-23-9	3/31/2023
3-25-2	5/14/2025

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HEATING, VENTILATION AND AIR CONDITIONING (HVAC)

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

Measure Description

This measure covers the installation of an ENERGY STAR® certified Ground Source Heat Pump (GSHP) system with a closed loop heat exchanger field or an open loop ground water system as permissible by local environmental review.[23] 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.[24] 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. See the Residential Heat Pump – GSHP Water-to-Water Heat Pump or Desuperheater measure in this TRM for details.

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.[25,26]

- 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.

[23] 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.
[24] "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.
[25] ECCCNYS 2020, Section R403.7.
[26] ECCNYS 2020 requires that systems serving multiple dwelling units follow Sections C403 and C404.

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

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

The algorithms below address energy impacts associated with space conditioning load only. See the Residential Heat Pump – GSHP Water-to-Water Heat Pump or Desuperheater measure in this TRM 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 (EER or SEER2). See Baseline Efficiency section below for details.
$EER_{peak,baseline}$		Electric cooling energy efficiency rating of baseline equipment (EER or EER2). See 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 Efficiencies section below for details. The assumed COP of an electric resistance/electric furnace system is 1.0. If the baseline is a conventional ASHP[27], use the baseline calculations below.
$COP_{season,ee}$		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.

[27] 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.

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.[28]

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 central air conditioning system and 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.

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

[28] 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.

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

Product Class	Seasonal Energy Efficiency Ratio 2 (SEER2)[29]	Energy Efficiency Ratio 2 (EER2)[30]	Heating Seasonal Performance Factor 2 (HSPF2)[31]
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

Where existing equipment efficiency is used as baseline and is rated in SEER, EER, and HSPF, efficiency ratings shall be converted to SEER2, EER2, and HSPF2 as follows:

$$SEER2 = SEER \times F_{SEER2}$$

$$EER2 = EER \times F_{EER2}$$

$$HSPF2 = HSPF \times F_{HSPF2}$$

Where F_{SEER2}, F_{EER2}, and F_{HSPF2} are established based on equipment type per the table below:[32]

Equipment Type	F_{SEER2}	F_{EER2}	F_{HSPF2}
Ductless System	1.00	1.00	0.90
Centrally Ducted Split System	0.95	0.95	0.85
Centrally Ducted Single Packaged System	0.95	0.95	0.84

[29] 10 CFR 430.32(c)(5).
[30] Calculated via the relationship EER2 = (1.12 x SEER2) – (0.02 x $SEER2^2$) from DOE, Building America House Simulation Protocols, October 2010
[31] 10 CFR 430.32(c)(5).
[32] Conversion factors developed by AHRI and adopted by RESNET, as published in Draft PDS-02 MINHERS® Addendum 71f, SEER/HSPF2 Conversions, RESNET, January 2023

GSHP System Baseline Efficiencies

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[33]

Equipment Type	Size Range	Baseline 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[34] 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	Baseline Efficiency
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	0.84 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.80 Et
	> 2,500 kBTU/h	0.82 Ec

[33] 10 CFR 430.32(e)(2)(iii)(A); last reviewed 10/1/2024
[34] ECCCNYS 2020, Table C403.3.2(4) & Table C403.3.2(5).

Equipment Type	Size Range	Baseline Efficiency
Boiler, Hot Water, Oil Fired	< 300 kBTU/h	0.86 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	0.82 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	0.82 AFUE
	≥ 300 kBTU/h and ≤ 2,500 kBTU/h	0.79 Et
	> 2,500 kBTU/h	0.79 Et
Boiler, Steam, Oil Fired	< 300 kBTU/h	0.85 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 HSPF2 and the typical operating conditions in New York State, as shown below:

The HSPF2 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:

$$COP_{season,baseline} = \frac{HSPF2 \times Adj_{HSPF2}}{3.412}$$

where:
HSPF2 = Heating seasonal performance factor of the baseline system
Adj_{HSPF2} = HSPF2 Climate Adjustment Factor, from table below
3.412 = Conversion factor, one watt-hour equals 3.412 BTU

HSPF2 Climate Adjustment Factor (Adj_{HSPF2}) for Conventional ASHP Used as a Baseline

City	HSPF2 < 8.5	HSPF2 ≥ 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 SEER2 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 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[35].

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):

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

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

where:

$COP_{GLHP,full}$ = Rated COP of the unit at GLHP full load heating conditions

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

$COP_{GLHP,part}$ = 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[36]
1.08 = Correction for change in COP[37]

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.
$COP_{GWHP,full}$		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.

[36] 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.
[37] 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
$COP_{GWHP,part}$		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.[38]
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.[39]
$F_{pump,full}$		Factor to adjust the full load efficiency to account for additional pumping power used by the system. Choose the appropriate factor from Pumping Power Adjustment Factor table below.
$F_{pump,part}$		Factor to adjust the part load efficiency to account for additional pumping power used by the system. Choose the appropriate factor from Pumping Power Adjustment Factor table below.

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

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

[38] 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.

[39] Ibid.

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.[40]

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 pumping control strategy, the capacity ratio of the heat pump, and the pumping power. The factor closest to the actual situation should be used. Factors labeled "Clg" shall be applied to seasonal cooling efficiency (i.e., $EER_{season,ee}$) and factors labeled "Htg" shall be applied to seasonal heating efficiency (i.e., $COP_{season,ee}$).

[40] 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 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 pump-ing ($F_{pump,part}$)	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 pump-ing ($F_{pump,part}$)	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.[41]

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 are 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

[41] Ibid.

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 the building design load. The heating BEFLH is based on 30-year NCEI climate normal data from 1991 to 2020 that consider the 1% heating design temperature, the bin temperature data, and the design heating load. For heating, bin 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. The cooling values from Appendix G were then further adjusted to reflect 30-year NCEI climate normal from 1991 – 2020.[42]

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

City	Prior to 1979	From 1979 Through 2006	From 2007 Through Present
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	Prior to 1979	From 1979 Through 2006	From 2007 Through Present
Albany	1,975	1,851	1,723
Binghamton	2,143	2,021	1,896
Buffalo	2,079	1,952	1,820
Massena	2,005	1,898	1,788
NYC	1,859	1,698	1,535
Poughkeepsie	1,950	1,821	1,689
Syracuse	2,001	1,879	1,753

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

[42] NOAA National Centers for Environmental Information – NCEI 1991-2020 Climate Normals.

City	Pre-war uninsulated brick	Prior to 1979	From 1979 Through 2006	From 2007 Through present
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 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

$EER_{season,baseline}$ = 13.4, 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
$BEFLH_{heating}$ = 1,851, from Operating Hours section tables based on housing type, city, and vintage from application
$EER_{peak,baseline}$ = 11.4, 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

$$\Delta kWh = \left[\frac{36{,}000}{1{,}000} \times \left(\frac{1}{13.4} - \frac{1}{20.96}\right) \times 448\right] + \left[\frac{58{,}000}{3{,}412} \times \left(0 - \frac{1}{3.58}\right) \times 1{,}851\right] = -8{,}355.54\ kWh$$

$$\Delta kW = \frac{36{,}000}{1{,}000} \times \left(\frac{1}{11.4} - \frac{1}{19}\right) \times 0.69 = 0.872\ kW$$

$$\Delta MMBtu = \frac{58{,}000}{1{,}000{,}000} \times \frac{1}{0.8} \times 1{,}851 = 134.20\ MMBtu$$

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

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

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Record of Revision

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1	10/15/2010
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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
3-25-4	5/14/2025

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LIGHTING – CONTROL

INTERIOR LIGHTING CONTROL

Measure Description

This measure covers the installation of lighting control systems on lighting in interior spaces. Interior spaces are defined as any covered area not adequately lit during daylight hours by sunlight, thus requiring daytime operation of lighting. Lighting control systems covered under this measure include occupancy sensors, stepped and dimming daylighting controls, institutional tuning, and networked lighting control systems, including luminaire-level lighting controls (LLLC). Lighting control systems save energy and peak demand by shutting off power to lighting fixtures when the space is unoccupied, or illumination is not required. They also save energy and demand by reducing power to lighting systems to correct for over-illumination due to excessive lamp output or the presence of daylight.

LLLC systems have a networked occupancy sensor and ambient light sensor installed for each luminaire or kit which are directly integrated or embedded into the form factor either during the manufacturing process or during field installation. LLLC's have a one-to-one relationship between sensors and luminaires. Where non-LLLC networked lighting control systems will have a one-to-many relationship between sensors and luminaires.

This measure is not applicable in spaces for which occupancy or daylight-responsive controls are required by federal, state, local or municipal codes or standards. Refer to chapter C405.2 Lighting Controls (Mandatory) of the Energy Conservation Construction Code of New York State[43] (ECCCNYS) for details. This measure is also not applicable if the equipment is installed or controlled as part of a utility demand response program. Bi-level lighting controls installed in stairwells, corridors, parking garages and parking lots shall use the Commercial Bi-Level Lighting measure detailed in this TRM document.

Method for Calculating Annual Energy and Summer Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \left(\frac{W_{ctrl}}{1{,}000}\right) \times hrs_{baseline} \times ESF \times (1 + HVAC_c)$$

Summer Peak Coincident Demand Savings

$$\Delta kW = \left(\frac{W_{ctrl}}{1{,}000}\right) \times ESF \times (1 + HVAC_d) \times CF$$

[43] ECCCNYS 2020; C405.2: Lighting Controls (Mandatory)

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = \left(\frac{W_{ctrl}}{1{,}000}\right) \times hrs_{baseline} \times ESF \times HVAC_{ff}$$

where:

ΔkWh = Annual electricity energy savings
ΔkW = Peak coincident demand electric savings
ΔMMBtu = Annual fossil fuel energy savings
W_{ctrl} = Total wattage of controlled lighting (Watts)
hrs = Lighting operating hours
$_{baseline}$ = Characteristic of baseline condition
$HVAC_c$ = HVAC interaction factor for annual electric energy consumption
$HVAC_d$ = HVAC interaction factor at utility summer peak hour
$HVAC_{ff}$ = HVAC interaction factor for annual fossil fuel consumption (MMBtu/kWh)
ESF = Energy savings factor
CF = Coincidence factor
1,000 = Conversion factor, one kW equals 1,000 Watts

Summary of Variables and Data Sources

Variable	Value	Notes
W_{ctrl}		Connected load of controlled lighting fixtures (in Watts), from application.
$hrs_{baseline}$		Lighting operating hours. From application or see Operating Hours section below.
$HVAC_c$		HVAC interaction factor for annual electric energy consumption (dimensionless). Vintage and HVAC type weighted average by city. See Appendix D. For lighting in unconditioned space, use a value of 0.
$HVAC_d$		HVAC interaction factor for peak demand at utility summer peak hour (dimensionless). Vintage and HVAC type weighted average by city. See Appendix D. For lighting in unconditioned space, use a value of 0.
$HVAC_{ff}$		HVAC interaction factor for annual fossil fuel energy consumption (MMBtu/kWh). Vintage and HVAC type weighted average by city. See Appendix D. For lighting in unconditioned space, use a value of 0.
ESF		See Energy Savings Factors table below.
CF		Lookup CF from the CF column of the table in the "Operating Hours" section of the Commercial and Industrial Interior and Exterior Lighting measure based on Facility Type.

Energy Savings Factor[44]

The ***energy savings factor*** (ESF) is the average annual reduction in electric consumption achieved by a particular control measure type. Energy savings factors for various automated lighting control types are specified in the table below.

Control Type	ESF
Occupant Sensing Controls in large open plan offices: one sensor controlling an area no larger than 125 square feet[45]	0.40
Occupant Sensing Controls in large open plan offices: one sensor controlling an area between 126 to 250 square feet[46]	0.30
Occupant Sensing Controls in large open plan offices: one sensor controlling an area between 251 to 500 square feet[47]	0.20
Occupant Sensing Controls: applicable to all space types other than large open plan offices with one sensor controlling an area less than 500 square feet	0.20
Institutional Tuning in non-daylit areas[48]	0.10
Institutional Tuning in daylit areas[49]	0.05
Daylight Dimming Control – On/Off Control: Luminaries in skylit daylit zone or primary sidelit daylit zone[50]	0.10
Daylight Dimming Control – multiple step dimming[51]	0.20
Daylight Dimming Control – continuous dimming[52]	0.30
Occupant Sensing with Daylight Dimming Controls – On/Off controls[53]	0.35
Occupant Sensing with Daylight Dimming Controls – multiple step dimming[54]	0.35
Non-LLLC Networked Lighting Controls[55]	0.35
LLLC Networked Lighting Controls[56]	0.63

- ***Occupancy Sensor*** – Reduces lighting operating hours by switching off lighting in unoccupied spaces.

[44] The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures; Chapter 3: Commercial and Industrial Lighting Controls Evaluation Protocol, National Renewable Energy Laboratory, September 2017, pg. 15.
[45] 2019 CA Title 24, Part 6, Table 140.6-A: Lighting Power Adjustment Factors (PAF).
[46] Ibid.
[47] Ibid.
[48] Ibid.
[49] Ibid.
[50] Ibid.
[51] NREL, The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures, Chapter 3: Commercial and Industrial Lighting Controls Evaluation Protocol, Table 4: Lighting Control Savings Factors by Control Type.
[52] Ibid.
[53] Ibid.
[54] Ibid.
[55] Energy Savings from Networked Lighting Control (NLC) Systems with and without LLLC, DesignLights Consortium®, September 24, 2020, Table 2. Summary of estimated control factors by LLLC and control strategies.
[56] Ibid.

- ***Institutional Tuning*** – Also referred to as "task tuning" or "high-end trim", this control strategy allows luminaries in layouts designed with the consideration of a light loss factor to be dimmed to the recommended light level and restored to full output when lumen output has degraded. Maximum light level adjustments are available only to authorized personnel.[57]
- ***Daylight Dimming Control*** – Reduces lighting output to a set level in response to natural daylighting using continuous or stepped dimming capability.
- ***Networked Lighting Control*** – A networked lighting control system consists of an intelligent network of individually addressable luminaires and control devices, allowing for application of multiple control strategies, programmability, building- or enterprise-level control, zoning and rezoning using software, and measuring and monitoring, compliant with DesignLights Consortium V5.0 requirements.[58]

Coincidence Factor (CF)

Refer to the CF column of the table in the "Operating Hours" section of the Commercial and Industrial Interior and Exterior Lighting measure for prescribed coincidence factor for commercial indoor lighting measures based on Facility Type.

Baseline Efficiencies from which Energy Savings are Calculated

The baseline case for this measure is a lighting system with manual or time-switch controls.

Compliance Efficiency from which Incentives are Calculated

The compliance case is a lighting system with institutional tuning, occupancy sensing, daylighting, or networked lighting controls designed and installed in accordance with manufacturers' and/or designer recommendations. Note that networked lighting controls require high-end trim, occupancy sensing, and daylight sensing capability to qualify and achieve prescribed savings factors, per DLC.[59, 60]

Operating Hours

The baseline lighting operating hours are the average operating hours for all fixtures subject to lighting control measures before the lighting controls are installed. This information shall be taken from the application. If unavailable, refer to the "Operating Hours" section of the Commercial and Industrial Interior and Exterior Lighting measure for default hours of operation.

[57] 2019 CA Title 24, Part 6, pg. 64
[58] Networked Lighting Controls V5.0 Requirements, DesignLights Consortium.®
[59] DesignLights Consortium®, "Energy Savings from Networked Lighting Control (NLC) Systems with and without LLLC", September 2020
[60] DesignLights Consortium®, "Clarifications to the 2020 Report: 'Energy Savings from Networked Lighting Control (NLC) Systems With and Without LLLC'", January 2025

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

Occupancy sensors are installed in 8 offices of 150 square feet each in a small office building near Albany. Each office contains six 24-watt fixtures for a total controlled wattage of 1,152 W. Prior to installation of controls, the fixtures were illuminated for 2,800 hours per year. The building has central air conditioning and gas heat. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \left(\frac{W_{ctrl}}{1{,}000}\right) \times hrs_{baseline} \times ESF \times (1 + HVAC_c)$$

$$\Delta kW = \left(\frac{W_{ctrl}}{1{,}000}\right) \times ESF \times (1 + HVAC_d) \times CF$$

$$\Delta MMBtu = \left(\frac{W_{ctrl}}{1{,}000}\right) \times hrs_{baseline} \times ESF \times HVAC_{ff}$$

W_{ctrl} = 1,152, from application
$hrs_{baseline}$= 2,800 hours/year, from application.
$HVAC_c$= 0.0552, from Appendix D based on Building Type, City and HVAC type
$HVAC_d$= 0.1478, from Appendix D based on Building Type, City and HVAC type
$HVAC_{ff}$= -0.0011, from Appendix D based on Building Type, City and HVAC type
ESF= 0.30, from Energy Savings Factors table
CF = 0.92, from "Operating Hours" section of the Commercial and Industrial Interior and Exterior Lighting based on facility type

$$\Delta kWh = \left(\frac{1{,}152}{1{,}000}\right) \times 2{,}800 \times 0.30 \times (1 + 0.0552) = 1{,}021.10\ kWh$$

$$\Delta kW = \left(\frac{1{,}152}{1{,}000}\right) \times 0.30 \times (1 + 0.1478) \times 0.92 = 0.365\ kW$$

$$\Delta MMBtu = \left(\frac{1{,}152}{1{,}000}\right) \times 2{,}800 \times 0.30 \times -0.0011 = -1.06\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

Reduction in lighting power increases space heating requirements in conditioned spaces. Interactive HVAC impacts are addressed in the prescribed energy savings calculation methodology. Interactive savings associated with Networked Lighting Controls integrated with a building management system are not considered.

Ancillary Electric Savings Impacts

Reduction in lighting power decreases cooling requirements in conditioned spaces. Interactive HVAC impacts are addressed in the prescribed energy savings calculation methodology.

References

1. ECCCNYS 2020 Chapter C405.2: Lighting Controls (Mandatory).
   Available from: https://codes.iccsafe.org/content/NYSECC2020P1/chapter-4-[ce]-commercial-energy-efficiency#NYSECC2020P1_CE_Ch04_SecC405.2
2. The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures; Chapter 3: Commercial and Industrial Lighting Controls Evaluation. Protocol, National Renewable Energy Laboratory, September 2017.
   Available from: https://www.nrel.gov/docs/fy17osti/68559.pdf
3. CA Title 24: part 6; 2019 Building Energy Efficiency Standards for Residential and Non-residential Buildings, California Energy Commission.
   Available from: https://codes.iccsafe.org/content/CAEC2019
4. DLC/NEEA 2020 study "Energy Savings from Networked Lighting Control (NLC) Systems with and without LLLC"
   Available from: https://designlights.org/resources/reports/report-energy-savings-from-networked-lighting-control-nlc-systems-with-and-without-lllc/
5. Networked Lighting Controls V5.0 Requirements, DesignLights Consortium.®
   Available from: https://www.designlights.org/our-work/networked-lighting-controls/technical-requirements/nlc5/
6. DesignLights Consortium®, "Energy Savings from Networked Lighting Control (NLC) Systems with and without LLLC", September 2020
   Available from: https://designlights.org/resources/reports/report-energy-savings-from-networked-lighting-control-nlc-systems-with-and-without-lllc/
7. DesignLights Consortium®, "Clarifications to the 2020 Report: 'Energy Savings from Networked Lighting Control (NLC) Systems With and Without LLLC'", January 2025
   Available from: https://designlights.org/resources/reports/memo-2020-report-on-energy-savings/

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