New Efficiency: New York

Analysis of Residential Heat Pump Potential and Economics

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Analysis of Residential Heat Pump Potential and Economics

Final Report

Prepared by:

New York State Energy Research and Development Authority

Albany, NY

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Notice

Abstract

This Report describes NYSERDA's analysis of the costs, benefits, and adoption opportunities for small-scale residential heat pumps in New York State over the period to 2025. The Report concludes that, based on a conservative application of constraint assumptions, heat pumps could serve approximately half of the thermal energy load in the small residential sector, with potential to increase this estimate as barriers such as landlord-tenant constraints or availability of hydronic heat pump systems are overcome. Achievable adoption potential for small-scale residential heat pumps is assessed to be around 7.5 TBtu of incremental site energy savings from oil and resistance heating replacements by 2025.

Keywords

Heat pump; air source; ground source; ductless minisplit; energy efficiency; heating; cooling; thermal energy; technical potential; economic potential; achievable potential; adoption; cost benefit analysis; residential sector; single-family residential; small multifamily residential

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Acronyms and Abbreviations

ACS	U.S. Census Bureau's American Community Survey
ASHP	Cold climate central air source heat pump
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BCA	benefit/cost analysis
Btu	British thermal unit
Capex	capital cost
CARIS	Congestion Assessment and Resource Integration Study
CBECS	Commercial Buildings Energy Consumption Survey
CF	counterfactual
Cf	cubic feet (of gas)
CO_2e	carbon dioxide equivalent
ConEdison	Consolidated Edison
COP	coefficient of performance
DOE	U.S. Department of Energy
DPS	Department of Public Service
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
ETIP	Energy Efficiency Transition Implementation Plan
Framework	Renewable Heating and Cooling Policy Framework: Options to Advance Industry Growth and Markets in New York, *NYSERDA, February 7, 2017*
GSHP	central vertical ground source heat pump
HUD	U.S. Department of Housing and Urban Development
HV	Hudson Valley

HVAC	heating, ventilation and air conditioning
IRR	pre-tax pre-finance nominal project internal rate of return
ITC	investment tax credit
kW	kilowatt
kWh	kilowatt-hour
LHV	Lower Hudson Valley
LI	Long Island
LIPA	Long Island Power Authority
Minisplit	cold climate ductless minisplit
MMBtu	Million British thermal units
Nat Grid	National Grid
NPV	net present value
NYISO	New York Independent System Operator
NYSEG	New York State Electric and Gas utility
Order	Order Adopting Accelerated Energy Efficiency Targets, *Public Service Commission, December 13, 2018,* Case 18-M-0084
O&M	operation and maintenance
ORU	Orange and Rockland Utilities
PSC	Public Service Commission
PSEG	Public Service Electric and Gas Company, Long Island
RECS	EIA Residential Energy Consumption Survey
RG&E	Rochester Gas & Electric
RGGI	Regional Greenhouse Gas Initiative
ROS	rest of state
SCT	Societal Cost Test
SEER	seasonal energy efficiency ratio
T&D	transmission and distribution
TBtu	Trillion British thermal units
TMY	typical meteorological year
VDER	Value of Distributed Energy Resources
White Paper	New Efficiency: New York, NYSERDA and Department of Public Service, April 2018

Summary

This Report describes NYSERDA's analysis of the costs, benefits, and adoption opportunities for small-scale residential heat pumps in New York State over a span of six years, from 2019 to 2025. This analysis was used to underpin the heat pump scenario included in the New Efficiency: New York White Paper published in April 2018, which considered the opportunity for adoption of over 100,000 residential heat pump installations by 2025, delivering 8 trillion British thermal units (TBtu) of site energy savings as a contribution towards New York State's energy efficiency target of realizing 185 TBtu of site energy savings by 2025 (relative to forecasted energy consumption). Key findings from this analysis were presented by NYSERDA staff at a public forum discussion organized as part of the New Efficiency: New York proceeding on October 3, 2018.

Following on the New Efficiency: New York White Paper, the Public Service Commission issued its Order Adopting Accelerated Energy Efficiency Targets on December 13, 2018, setting out a minimum target of 5 TBtu of site energy savings from heat pumps for New York State's jurisdictional utilities as part of the overall 2025 energy efficiency goal. This Report is intended to support development of program proposals (and implementation thereof) to deliver this level of heat pump deployment.

While early adoption of heat pumps is expected to focus on the small-scale residential sector, a significant part of thermal energy use in buildings occurs across larger buildings, in the multifamily, commercial, and public sectors. The analysis in this Report covers single-family and small multifamily installations. NYSERDA's analysis of heat pump potential and barriers in the larger-scale multifamily and nonresidential sectors is under ongoing development.

The analysis examines a wide range of market segments, reflective of different heat pump technology options as well as site characteristics. The heat pump technologies covered in this Report are cold climate central air source heat pumps, ductless minisplits, and ground source heat pumps. Installation opportunities for these technologies are assessed for single-family and small multifamily sites across the various geographies within New York State, with further consideration given to differences arising from other factors, such as the conventional heating fuel being replaced by heat pumps. Key outputs include quantification of the technical, economic, and achievable potential.

The technical potential—expressed as the portion of New York State's space heating and cooling energy load that could be served by heat pumps—is determined by quantifying the number of sites in each of the market segments, multiplied by the thermal load per site that could be served by each heat pump option. The technical potential is expressed as the adoption that could occur; it does not consider either cost or speed of adoption. However, it does apply a range of site suitability constraints, with adjustments for vacant sites, technological limitations (such as insufficient space for ground source heat pump drilling) and adoption barriers related to landlord-tenant situations. Some of these barriers may be addressable within the period under consideration in this Report. For instance, the current analysis assumes that heat pumps will not be installed in homes with hydronic distribution systems (radiators), but heat pump systems serving such sites may become widely available in the near term.

Based on a conservative application of constraints in this analysis, it is estimated that heat pumps at small residential sites could serve approximately half of statewide load within the small residential sector, which equates to almost a quarter of all statewide space heating and cooling load.

Table S-1. Potential Statewide Thermal Load Served by Small-Scale Residential Heat Pumps (Existing and New Buildings to 2025)

Technology	Statewide Space Heating & Cooling Load (TBtu)		Space Heating & Cooling Load Addressable by Heat Pumps		Technical Potential as % of Statewide Load	
	Small Residential	All Sectors	Thermal Load (TBtu)	Non-Duplicative Total (TBtu)	Small Residential	All Sectors
ASHP	382	833	184	190	50%	23%
Minisplit			118			
GSHP			185			

Economic aspects are first considered in the form of an all-fuels Societal Cost Test (SCT), which provides an indicator of the relative attractiveness to pursue heat pump adoption in each relevant market sector from the perspective of society as a whole. On the basis of this test, the analysis concludes that heat pumps present the most attractive proposition in heating oil and electric resistance heating replacement situations. Residential gas heating replacement situations do not at present succeed under this test.

Second, cost effectiveness is calculated as the return on investment that an individual customer perceives when purchasing a heat pump solution. Where such adoption—in the absence of State support policies—is assessed to be uneconomic from the customer's point of view, the analysis provides a "missing money" output indicator that quantifies the estimated additional payment that would need to be made available in order to deliver an adequate return to a heat pump customer.

The analysis also assesses opportunities where the cost of incentive payments to customers would be outweighed by the value or benefit society and ratepayers would derive from heat pump adoption. It concludes that heat pumps can deliver significant value in the form of reductions to the systemwide summer-peak electricity demand as well the value of avoided carbon emissions. The analysis also identifies an inverse cost shift effect where heat pump customers could significantly overpay on their electricity bills under prevailing residential electric rate structures.

Table 2 summarizes both the missing money estimates and quantification of value and cost shift for illustrative single-family, residential heat pump installations. Continued declines in heat pump costs throughout the period assessed in this Report are expected to further improve the balance between missing money needed to make heat pumps economic and the amount of value and benefit they deliver. Table 2 illustrates these developments by presenting both the initial estimates for 2019 and the projection of average figures through 2025.

Table S-2. Upfront Missing Money, Carbon and Peak Reduction Value, and Inverse Cost Shift

Single-family retrofit, Hudson Valley, heating oil replacements — 2019 projection and average 2019–2025.

Technology	Projection	Missing Money	Carbon Value	Peak Value	Inverse Cost Shift	Total Value and Inverse Cost Shift
ASHP	2019	**$3,901**	$2,644	$202	$7,696	**$10,541**
	2019-2025	**$2,268**	$2,873	$240	$8,382	**$11,495**
Minisplit	2019	**$1,838**	$1,041	$117	$2,948	**$4,106**
	2019-2025	**$1,154**	$1,131	$139	$3,211	**$4,481**
GSHP	2019	**$5,514**	$4,358	$692	$7,260	**$12,310**
	2019-2025	**$4,324**	$4,641	$799	$7,866	**$13,306**

The analysis presents an achievable adoption projection indicating that by 2025 more than 100,000 new small-scale residential heat pump installations could be installed, contributing around 7.5 TBtu of incremental site energy savings to the statewide 2025 energy efficiency goal—if the missing money hurdles identified in this analysis as well as non-financial barriers are addressed. When expressed for the jurisdictional utilities in New York State (excluding Long Island), the projected figure is 5 TBtu of net site energy savings, matching the target stipulated by the Public Service Commission's December 13 Order.

1 Introduction

Around one-third of New York State's greenhouse gas (GHG) emissions originates from space and water heating and cooling. Reducing these emissions will be central to achieving the State's GHG reduction targets of 40% by 2030 and 80% by 2050.

In April 2018, the New Efficiency: New York White Paper[1] launched a process to significantly accelerate the State's efforts in this area, by setting out a new energy efficiency target of 185 TBtu of site energy savings to be achieved by 2025 relative to forecasted energy consumption. The White Paper identified heat pumps as having the potential to make an important contribution to the energy efficiency target, and, in turn, aid in the decarbonization of thermal energy use in buildings. It considered a scenario whereby residential heat pumps alone could provide nearly 8 TBtu of onsite energy savings in over 100,000 households by 2025. Although a range of NYSERDA and utility programs aimed at heat pumps are currently in place,[2] they are not set up with a time horizon consistent with the White Paper's 2025 energy efficiency goal.

Following on the White Paper, the Public Service Commission (PSC) issued its Order, Adopting Accelerated Energy Efficiency Targets on December 13, 2018,[3] setting out a minimum target of 5 TBtu of site energy savings from heat pumps for New York State's jurisdictional electric utility portfolios, as part of the overall energy efficiency target.

This Report provides an assessment of the resource potential, economics, and potential adoption levels of heat pumps from 2019 to 2025. In doing so, it provides analytical detail underpinning the heat pump scenario that was presented in the White Paper. The analysis can also serve to support development of heat pump program proposals (and implementation thereof) as instructed in the Order.

An earlier version of a similar heat pump analysis was published in NYSERDA's 2017 Renewable Heating and Cooling Policy Framework (2017 Framework).[4] Key findings from the analysis in its current state were furthermore presented by NYSERDA staff at a public forum discussion organized as part of the New Efficiency: New York proceeding on October 3, 2018.

The analysis in this Report focuses on small-scale residential heat pump installations. It is noted that the heat pump scenario presented in the White Paper also included (larger) multifamily heat pump installations. Potential for heat pump adoption in the nonresidential sector is significant, yet subject to ongoing NYSERDA analyses and, therefore, not addressed in this Report.

NYSERDA acknowledges the contributions of The Cadmus Group, LLC and Energy and Environmental Economics, Inc for their primary analytical role in the development of the analysis.

2 Overview and Scope

The analysis described in this Report aims to assess small-scale residential heat pumps in New York State regarding their available resource potential, cost effectiveness (both from a societal and customer's perspective) and potential adoption from 2019 to 2025. The analysis consists of the following main components, discussed in more detail in the subsequent sections of the Report:

- **Section 3: Segmentation**. The market is segmented into a number of "reference sites" that differ from each other in one or more relevant aspects (e.g., capital cost, energy bill savings).
- **Section 4: Technical potential.** For each market segment, an estimate is produced as to the number of sites and thermal energy that could be served by heat pumps.
- **Section 5: Installation costs and cost reductions** and **Section 6: Energy bill and operational savings**. An assessment of the economics of heat pumps depends primarily on the payback from energy bill savings on the upfront investment. These components of the analysis are discussed in Sections 5 and 6.
- **Section 7: Economic potential**. This section describes how a Societal Cost Test (SCT) is applied in order to help identify the market segments where heat pumps can be considered sufficiently cost effective to warrant policy action.
- **Section 8: Customer cost effectiveness**. Even heat pump potential that meets the SCT in many cases does not meet customers' payback requirements. Section 8 quantifies the additional payments that would be needed to make installation of heat pumps cost effective for residential customers.
- **Section 9: Value and cost shift opportunities.** A number of value components including carbon reduction value and peak reduction value can justify policy action to address the payment gaps identified in the preceding section. In addition, so-called "cost shift" effects offer an opportunity to improve the payback for heat pump installations without creating additional burdens to ratepayers.
- **Section 10: Achievable potential**. This section projects the amount of residential heat pump adoption that could occur from 2019 to 2025 if market segments that qualify under the SCT receive sufficient policy support to satisfy customers' payback requirements.

The analysis presented in this Report covers single-family and small multifamily (two-four units) residential installations. Heat pump opportunities in large multifamily and commercial/nonresidential sites are subject to ongoing further analysis.

The heat pump technologies covered in this Report are ducted cold climate air source heat pumps (ASHP), ductless cold climate minisplits (minisplit) and vertical ground source heat pumps (GSHP). See also Section 3.

This analysis covers space heating and cooling, not hot water heating, which is a market warranting separate consideration. Adoption projections are presented for the period 2019 to 2025, matching the White Paper target period.

3 Market Segmentation

Key outputs of the analysis—in particular, cost effectiveness and other outputs based on cost effectiveness such as adoption projections—differ between market segments. The analysis attempts to reflect these differences by assessing a range of market segments. Market segmentation is applied by means of a number of "differentiating factors," listed below. The analysis assesses each of the permutations of these differentiating factors.

Table 3-1. Segmentation

Differentiating factor	Permutations
Heat pump technology	Cold climate central air source heat pumps (ASHP), cold climate ducted minisplit air source heat pumps (minisplit); vertical ground source heat pumps (GSHP).
Counterfactual heating fuel[5]	Electric resistance heating; fuel oil; natural gas.
Building sector	Single-family residential; small multifamily residential.
Building subsector	Single-family residential: owned or rented; small multifamily: market rate or publicly-owned housing.
Geography	Long Island, New York City, Hudson Valley and Upstate/Western New York. Parts of the analysis are applied by utility territory instead.
Vintage	Existing buildings (retrofit replacements of fossil heating systems by heat pumps); new construction.

More than 500 market segments result from the combination of these factors. The analysis treats each one as a reference site for which outputs are generated. Components of the analysis focusing on electricity costs are calculated by individual utility rather than geography. Other parts of the analysis assume a representative utility for each of the four geographies considered, as shown in Table 3.2.

Table 3-2. Representative Utilities by Geography

Geography	Representative Utility
Long Island	PSEG
New York City	ConEdison
Hudson Valley	Central Hudson
Upstate/ Western New York	National Grid

4 Technical Potential

The analysis assesses the resource potential for heat pumps as follows:

- A quantification of sites suitable for heat pump installation is derived from estimates of the number of sites in each market segment and assumptions on relevant constraints.
- The thermal load per site (energy needed to serve site space heating and cooling demand) is estimated for each type of site.
- The estimate for statewide thermal load that can be served by heat pumps depends on the proportion of site heating and cooling needs each type of heat pump is expected to serve.

4.1 Suitable Sites

As a first step in establishing total available resource potential by reference site, the total number of statewide residential buildings was allocated across all potential combinations of counterfactual heating fuel, building sector and subsector, geographic region, and building age.

Data from the U.S. Census Bureau's American Community Survey (ACS) (five-year estimates, 2010–2014) were used to identify a total statewide number of roughly 4.3 million single-family and small (two to four unit) multifamily buildings as well as to separately identify rented and owned single-family buildings. Multifamily buildings were differentiated between publicly-owned and privately-owned housing using statistics available from the U.S. Department of Housing and Urban Development (HUD) Picture of Subsidized Households database, which indicates that roughly 5% of statewide multifamily units are publicly owned.

Additionally, average annual construction rates over the last fifteen years were established for residential buildings (from ACS data) and allocated across reference installations. Roughly 24,000 single-family and small multifamily buildings are projected to be constructed in New York State each year. Over the seven-year (2019–2025) study period, this equates to nearly 170,000 new residential buildings within scope of this Report.

Residential installation sites were allocated across the four geographic regions based on ACS data, which is available at a geographically granular level, and separately by building size category. To capture differences between new and existing buildings, new construction sites were also allocated by geography using ACS data, but only the subset of data was applied from buildings constructed in the last fifteen years.

Finally, sites were allocated across counterfactual fuel categories—either the main heating fuel currently in use or the heating fuel that would be expected to be used in new construction in the absence of heat pumps. ACS data was used to allocate residential buildings across the three counterfactual fuel categories (heating oil, natural gas, and electricity), separately for each building sector and region. Data relating to mid-Atlantic regional distribution of commercial counterfactual fuels is available from the Commercial Buildings Energy Consumption Survey (CBECS), and this regional distribution was adjusted to account for the relative prevalence of different fuels among residential buildings in each geographic region.

Counterfactual propane use sites were merged into the counterfactual heating oil resource. This combined resource is referred to as having counterfactual fuel oil throughout this analysis, although an estimated 13% of these households are served by propane. A small number of buildings (roughly 4.7%) in New York State have a primary heating fuel (such as wood) that is not included in the model, and these buildings were not included in the study.

The counterfactual fuel mix for new construction was based on that of existing buildings, but it was assumed that (1) no new buildings would use electricity as a counterfactual fuel, (2) the share of oil heat in new buildings would be half that of existing buildings, and (3) all new construction in New York City would have natural gas as the counterfactual fuel.

In all, about 4.3 million buildings are included in this analysis. An overview by building sector, counterfactual fuel, geographic region, and vintage (current building or new construction) is provided in Tables 4.1 and 4.2.

Table 4-1. Number of Buildings, Single-Family

Counterfactual Heating Fuel	Geography	Subsector	2018 Buildings	2019-2025 New Build	Total by 2025
Natural Gas	Long Island	Owned	328,121	15,725	343,846
		Rented	43,254	2,073	45,327
	NYC	Owned	391,922	13,659	405,581
		Rented	51,665	1,801	53,466
	Hudson Valley	Owned	222,107	18,281	240,388
		Rented	29,279	2,410	31,689
	Upstate/Western New York	Owned	1,096,784	65,086	1,161,870
		Rented	144,583	8,580	153,163
Fuel Oil	Long Island	Owned	388,673	5,489	394,161
		Rented	51,237	724	51,960
	NYC	Owned	67,732	0	67,732
		Rented	8,929	0	8,929
	Hudson Valley	Owned	213,592	5,187	218,778
		Rented	28,157	684	28,840
	Upstate/Western New York	Owned	333,510	7,268	340,778
		Rented	43,965	958	44,923
Electricity	Long Island	Owned	26,282	0	26,282
		Rented	3,465	0	3,465
	NYC	Owned	18,877	0	18,877
		Rented	2,488	0	2,488
	Hudson Valley	Owned	31,329	0	31,329
		Rented	4,130	0	4,130
	Upstate/Western New York	Owned	102,203	0	102,203
		Rented	13,473	0	13,473
Total			**3,645,757**	**147,922**	**3,793,679**

Table 4-2. Number of Buildings, Small Multifamily

Counterfactual Heating Fuel	Geography	Subsector	2018 Buildings	2019-2025 New Build	Total by 2025
Natural Gas	Long Island	Market rate	15,801	1,045	16,846
		Publicly owned	817	54	871
	NYC	Market rate	221,962	13,480	235,442
		Publicly owned	11,471	697	12,167
	Hudson Valley	Market rate	23,276	1,503	24,779
		Publicly owned	1,203	78	1,281
	Upstate/Western New York	Market rate	117,500	2,953	120,453
		Publicly owned	6,072	153	6,225
Fuel Oil	Long Island	Market rate	7,959	177	8,136
		Publicly owned	411	9	420
	NYC	Market rate	36,625	0	36,625
		Publicly owned	1,893	0	1,893
	Hudson Valley	Market rate	13,596	272	13,868
		Publicly owned	703	14	717
	Upstate/Western New York	Market rate	11,009	108	11,117
		Publicly owned	569	6	574
Electricity	Long Island	Market rate	3,496	0	3,496
		Publicly owned	181	0	181
	NYC	Market rate	15,004	0	15,004
		Publicly owned	775	0	775
	Hudson Valley	Market rate	7,027	0	7,027
		Publicly owned	363	0	363
	Upstate/Western New York	Market rate	26,000	0	26,000
		Publicly owned	1,344	0	1,344
Total			**525,056**	**20,546**	**545,601**

For the purpose of the potential forecast in this analysis, an adjustment to the number of sites was applied. The annual heating and cooling load per site as determined in this analysis reflects stakeholder input on reasonable "typical" installation sizes (e.g., a 4-ton, single-family GSHP installation), but may not match the average statewide load per site. In order to correct for this, the analysis adjusts the site count, such that the total statewide space heating and cooling load implied by the analysis (namely the modeled load per site, as discussed in Section 4.2, multiplied by the adjusted site count) equals NYSERDA's estimate of the statewide space heating and cooling load from other data sources (see Table 4.3). This resulted in an adjustment factor of around +24% on the site count, indicating that the installation sizes modeled in this analysis tend to be smaller than average.

Table 4-3. 2018 Statewide Residential and Commercial Thermal Load (Space Heating and Cooling)

End Use	Statewide Residential & Commercial Load (TBtu)
Space Heating	557
Space Cooling	221
Total	778

Note: Based on an estimate of the portion of building primary energy use associated with thermal end uses (derived from RECS and CBECS), applied to an estimate of primary energy consumption for residential and commercial buildings available from NYSERDA's *Patterns and Trends* report (2014 data). Excludes hot water heating and process heating. Excludes new build after 2018.

Not every building is a suitable site for some or all of the heat pump technologies examined in this analysis. The analysis captures this by applying a series of percentage reductions to the raw site count totals to arrive at numbers of suitable sites for each heat pump option. Specific reductions include:

- A vacant building constraint, which applies a reduction of between 9% and 14% to residential buildings (based on geography) using data from ACS to account for buildings that are not occupied year-round for a variety of reasons (including vacancy, seasonal homes, etc.).
- A technology incompatibility constraint, reflecting that some technologies require certain site characteristics, which limits their potential in geographic regions with more limited land availability. Specifically, a 20% reduction was applied to GSHP potential in New York City.
- A building control constraint, reducing the single-family rental market and market-rate multifamily resource by 75%, reflecting market conditions where renters and multifamily residents often do not have decision-making authority over whole-building heating systems, and that for the foreseeable future (over the period to 2025), so-called split incentives can be expected to present continued substantial barriers to the growth of heat pumps in these market segments.
- A thermal distribution system constraint, which assumes that in single-family and small multifamily homes the potential for central (ducted) ASHPs and GSHPs would be restricted to homes with existing forced-air ductwork. Currently available heat pump technology focuses on such distribution systems, and it was assumed that the cost of a distribution system conversion would be prohibitive. A resulting resource reduction of 40% was applied to single-family and small multifamily sites to reflect homes with hydronic distribution systems, based on EIA Residential Energy Consumption Survey (RECS) data.

Not all of these constraints to the technical potential are absolute. For instance, heat pumps suitable for use with hydronic distribution systems are expected to become more prevalent, at which point the reduction assumption in this respect could be revised or removed. Equally, ongoing efforts, including through NYSERDA policies, are being directed at issues around "split incentives" and similar barriers constraining investment decisions in landlord-tenant situations. As such barriers are reduced over time, the technical potential for heat pumps would be expected to increase further above the levels estimated in this analysis.

The adoption analysis presented in this Report applies the assumption that the opportunity to install a heat pump retrofit in an existing building only arises when the current heating system reaches (or approaches) the end of its life. Based on RECS data, as adjusted based on stakeholder feedback, it was assumed that building space heating equipment is replaced every 20 years. This value was used to determine the number of existing buildings across New York State that are expected to replace space heating equipment in each year (and that therefore could be targeted for heat pump system installation).

Table 4.4 shows the resulting numbers of suitable sites, in total (including the existing building stock as of 2018 and new build over the period to 2025) as well as the number of sites that become available for replacement based on the 20-year lifecycle assumption. These numbers are presented prior to the 24% site count adjustment described previously.

Table 4-4. Heat Pump Suitable Sites (Existing and New Buildings by 2025)

Sector	Technology	Sites before constraints	Site Suitability	Adjusted Sites	Annual End-of-Life or New Build Sites
Single-Family	ASHP	3,941,601	52%	2,033,097	107,441
	Minisplit		81%	3,207,237	166,148
	GSHP		50%	1,973,544	104,342
Small Multifamily	ASHP	566,147	16%	92,446	4,875
	Minisplit		26%	146,161	7,561
	GSHP		14%	81,818	4,309

4.2 Thermal Load of Suitable Sites and Site Reference Size

Section 4.1 identifies heat pump technical potential expressed as the number of suitable sites in each relevant market segment. In order to determine the contribution heat pumps can provide in terms of the amount of thermal energy or energy savings, the thermal load per site needs to be determined.

In this analysis, "thermal load" refers to the amount of space heating or cooling energy demand of a site, as opposed to the input energy, which is the energy content of the fuel (e.g., gas for a gas furnace or electricity for a heat pump) used to deliver such load. The thermal load per site is derived from the assumed size of the site and hourly heating and cooling load shapes describing heating and cooling usage for the site in question throughout the year.

Site size is expressed as the assumed size of a GSHP that serves full-site space heating and cooling needs without oversizing. This site reference size is set at 4 tons (48,000 btu/h) of thermal capacity for single-family residential sites and 6 tons (72,000 btu/h) for small multifamily. Although these tonnages are used as an indication of the size of a particular site, system size assumptions for some technologies (mostly ASHP and minisplit) are assumed to differ from the site reference size in some situations depending on the characteristics of such technologies and the extent to which they are assumed to serve full heating and cooling load. For instance, minisplits are not assumed to serve full heating and cooling load and are thus assumed to be sized smaller than the reference tonnage of a particular site. Assumed system sizes for each of the technology options are discussed in Section 4.3.

The analysis calculates the annual site thermal load using available hourly load profile data. Hourly load data is taken from the OpenEI[6] dataset from the U.S. Department of Energy (DOE) which contains 8760 hourly residential electric and natural gas load profiles for all TMY3[7] weather locations in the United States. The OpenEI dataset contains simulated energy usage for a residential dwelling using TMY3 weather data and a set of building characteristics including square footage, insulation efficiency, window efficiency, occupancy, HVAC efficiency, and more. Hourly energy usage is reported by end-use category, which has been aggregated into the following categories in this analysis:

- Non-thermal electricity usage
- Space heating
- Space cooling

The dataset contains energy usage for each residential dwelling simulated under low, base, and high conditions. High-energy usage represents larger, less efficient, higher occupancy homes and vice versa for low-energy usage. For the current analysis, load profiles for the four model geographies were selected as shown in Table 4.5. This table also provides an indication concerning the relative annual heating and cooling usage in the form of load factors. Heating load factor is defined as the average hourly thermal heating demand across the year divided by thermal heating demand during the peak hour. Cooling load factor is defined equivalently for cooling loads.

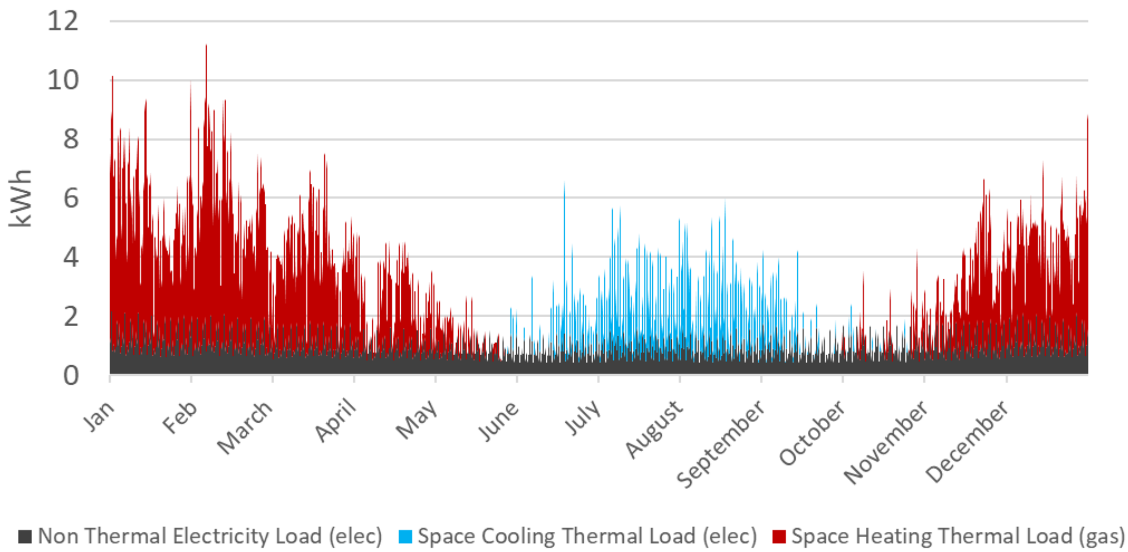
Table 4-5. Heating and Cooling Load Profile Sources and Load Factors

NYSERDA segmentation		OpenEI			
Sector	Geography	Building Type	TMY3[7] Location	Space Cooling Load Factor	Space Heating Load Factor
Single-Family and Small Multifamily	NYC/Long Island/ Hudson Valley	Residential Base	JFK	6%	16%
	Upstate/Western	Residential High	Albany	4%	21%

The OpenEI hourly load profiles contain electricity and natural gas consumption as measured at the customer meter. To determine the underlying thermal heating and cooling site load of the residential dwelling, these hourly electricity and natural gas consumption values were multiplied by the corresponding heating and cooling device efficiencies embedded in the EIA data.

The following graph displays the 8,760 hourly site energy loads for one illustrative reference installation, showing non-thermal electric load, space heating load, and space cooling load.

Figure 4-1. Illustrative Hourly Site Energy Load: Single-Family Homes in NYC



The resulting site heating and cooling hourly demand profiles (after adjustment for device efficiency) were then scaled as necessary so they matched the reference site size assumption. This was done by comparing the site reference system size (expressed as its output capacity) to the maximum hourly heating or cooling load of the OpenEI hourly load profile. Any difference between the two resulted in a scaling factor that was applied to scale up or down all 8760 hourly loads of the three end-use hourly profile categories (non-thermal, space heating, and cooling). For example, if the maximum hourly thermal load in the EIA profile was 5 tons (or the kW equivalent), comparison with the site size of a 4-ton single family system in the analysis would yield a scaling factor of 1.25, and all hourly loads in the EIA profile would be divided by this factor. The resulting scaled 8,760 hourly loads added together yield the annual site load.

Table 4.6 shows the resulting site space heating and cooling thermal load after scaling for each sector and geography. The figures shown are used as both new construction and existing building assumptions.

Table 4-6. Scaled Annual Site Thermal Load

		Non-Thermal Electricity (kWh)	Space Heating Thermal Load (kWh)	Space Heating Thermal Load (MMBtu)	Space Cooling Thermal Load (kWh)	Space Cooling Thermal Load (MMBtu)
Single-Family	NYC/ LI/HV	11,282	20,058	68	4,095	14
	Upstate	7,875	25,505	87	2,339	8
Small Multifamily	NYC/ LI/HV	16,923	30,087	103	6,142	21
	Upstate	11,812	38,257	130	3,508	12

4.3 Thermal Site Load Served by Heat Pumps and Heat Pump System Size

A number of adjustments were made to the annual site thermal load to derive the amount of site load that could be served by each of the heat pump measures under investigation. This was done to reflect assumptions that not all types of heat pumps serve the full site heating and cooling load in all circumstances.

- ASHPs were assumed to be sized to serve full cooling demand in both retrofit and new construction situations; however, for existing buildings it was assumed that the conventional heating system (oil, gas, or electric resistance heating) would remain in place to serve peak heating loads in the winter that would exceed the capacity of the heat pump. Accordingly, such ASHP systems were assumed to be installed at a somewhat smaller system capacity of 3 tons for single-family and 5 tons for small multifamily (compared to the reference site size of 4 tons and 6 tons, respectively) to reflect their sizing to meet summer cooling load rather than the higher winter peak load. By contrast, ASHP installations in single-family and small multifamily new construction settings were assumed to be sized somewhat bigger than the reference size (at 5 tons for single family and 8 tons for small multifamily) to enable such ASHP systems to meet the peak heating demand despite their expected lower performance levels during the coldest hours of the years.
- It was assumed that minisplits would be installed to serve a proportion of the building, with the remainder continuing to be served by the conventional heating system. These systems were assumed to be sized at 1.5 tons (single-family) and 3 tons (small multifamily) and the load served by these systems is quantified as the proportion of the minisplit size relative to the site reference size discussed in Section 4.2 (e.g., 1.5 divided by 4 for single-family).
- GSHPs were assumed to serve full space heating and cooling site load, thus their system size was assumed to match the site reference size. The analysis assumes that GSHP units would use vertical, rather than horizontal, loop fields, and that installations would not include a desuperheater that provides supplemental water heat.

Table 4.7 compares full-site loads to the loads served by each heat pump option and provides the load factors expressing the resulting annual usage levels (as explained in Section 4.2).

Table 4-7. Site and System Tonnage: Thermal Load Served

Sector	Technology	Vintage	Geo-graphy	Site Reference Size (Tons)	Heat Pump Size (Tons)	Full Site Load (MMBtu)		Load Served (MMBtu)		Load Factor	
						Heat	Cool	Heat	Cool	Heat	Cool
Single Family	ASHP	Existing Building	NYC/LI/HV	4	3	68	14	66	14	21%	4%
			Upstate/Western	4	3	87	8	82	8	26%	3%
	ASHP	New Constr.	NYC/LI/HV	4	5	68	14	68	14	13%	3%
			Upstate/Western	4	5	87	8	87	8	17%	2%
	Minisplit	Existing Building & New Constr.	NYC/LI/HV	4	1.5	68	14	26	5	16%	3%
			Upstate/Western	4	1.5	87	8	33	3	21%	2%
	GSHP	Existing Building & New Constr.	NYC/LI/HV	4	4	68	14	68	14	16%	3%
			Upstate/Western	4	4	87	8	87	8	21%	2%
Small Multifamily	ASHP	Existing Building	NYC/LI/HV	6	5	103	21	101	21	19%	4%
			Upstate/Western	6	5	131	12	128	12	24%	2%
	ASHP	New Constr.	NYC/LI/HV	6	8	103	21	103	21	12%	2%
			Upstate/Western	6	8	131	12	131	12	16%	1%
	Minisplit	Existing Building & New Constr.	NYC/LI/HV	6	3	103	21	51	10	16%	3%
			Upstate/Western	6	3	131	12	65	6	21%	2%
	GSHP	Existing Building & New Constr.	NYC/LI HV	6	6	103	21	103	21	16%	3%
			Upstate / Western	6	6	131	12	131	12	21%	2%

4.4 Technical Potential

Based on the suitable site count discussed in Section 4.1 and the thermal load served by heat pumps per site discussed in Section 4.3, Table 4.8 below summarizes the space heating and cooling load that could be served by heat pumps across current sites and new construction added over the period 2019–2025. Technical potential is also expressed as a percentage of total space heating and cooling load, both compared to the statewide heating and cooling load of the small residential sector and the statewide all-sectors load (including load of large multifamily and commercial buildings outside the scope of this analysis).

Table 4-8. Potential Thermal Load Served by Small-Scale Residential Heat Pumps, Existing and New Building to 2025, Summary

Geography	Technology	Total Market Segment Space Heating & Cooling Load (TBtu)		Space Heating & Cooling Load Addressable by Heat Pumps		Technical Potential as % of Statewide Load	
		Small Residential	All Sectors	Thermal Load (TBtu)	Non-Duplicative Total (TBtu)	Small Residential	All Sectors
Long Island	ASHP	69	87	36	37	54%	43%
	Minisplit			23			
	GSHP			37			
NYC	ASHP	76	423	29	29	38%	7%
	Minisplit			19			
	GSHP			24			
Hudson Valley	ASHP	51	83	26	27	52%	32%
	Minisplit			16			
	GSHP			27			
Upstate/ Western New York	ASHP	186	240	92	97	52%	40%
	Minisplit			59			
	GSHP			97			
Total	ASHP	382	833	184	190	50%	23%
	Minisplit			118			
	GSHP			185			

Note: most of the heat pump technologies could serve most of the same sites. Their potential is largely duplicative, and as a result, the total potential shown across all heat pump technologies does not significantly exceed the potential of any single technology. Results for individual market segments are shown in Table 4.9.

Table 4-9. Potential Annual Thermal Load Served by Small-Scale Residential Heat Pumps, Existing and New Buildings to 2025, Detail (TBtu)

Counter-factual Fuel	Geography	Sector	ASHP		Minisplit		GSHP	
			Existing Building	New Constr.	Existing Building	New Constr.	Existing Building	New Constr.
Natural Gas	Long Island	Single Family	14.5	1.3	9.3	0.5	15.0	1.3
		Small MF	0.5	0.0	0.3	0.0	0.5	0.0
	NYC	Single Family	17.4	1.1	11.2	0.4	14.4	0.9
		Small MF	0.6	0.0	0.4	0.0	0.5	0.0
	Hudson Valley	Single Family	10.6	1.7	6.8	0.6	10.9	1.7
		Small MF	0.3	0.1	0.2	0.0	0.4	0.1
	Upstate/ Western	Single Family	56.0	6.8	36.9	2.5	59.0	6.8
		Small MF	1.8	0.2	1.2	0.1	1.9	0.2
Fuel Oil	Long Island	Single Family	17.2	0.5	11.1	0.2	17.7	0.5
		Small MF	0.6	0.0	0.4	0.0	0.6	0.0
	NYC	Single Family	3.0	N/A	1.9	N/A	2.5	N/A
		Small MF	0.1	N/A	0.1	N/A	0.1	N/A
	Hudson Valley	Single Family	10.1	0.5	6.5	0.2	10.5	0.5
		Small MF	0.3	0.0	0.2	0.0	0.3	0.0
	Upstate/ Western	Single Family	17.0	0.8	11.2	0.3	17.9	0.8
		Small MF	0.6	0.0	0.4	0.0	0.6	0.0
Electricity	Long Island	Single Family	1.2	N/A	0.7	N/A	1.2	N/A
		Small MF	0.0	N/A	0.0	N/A	0.0	N/A
	NYC	Single Family	0.8	N/A	0.5	N/A	0.7	N/A
		Small MF	0.0	N/A	0.0	N/A	0.0	N/A
	Hudson Valley	Single Family	1.5	N/A	1.0	N/A	1.5	N/A
		Small MF	0.0	N/A	0.0	N/A	0.1	N/A
	Upstate/ Western	Single Family	5.2	N/A	3.4	N/A	5.5	N/A
		Small MF	0.2	N/A	0.1	N/A	0.2	N/A

5 Installation Costs and Cost Reductions

In order to advance from technical potential to an assessment of the economics and the economic potential of heat pumps, the analysis needs to consider the equipment installation costs (discussed in this section) and energy bill savings (discussed in Section 6).

Equipment installation costs vary by building sector, geographic region, and building age. The range of installed cost assumptions is displayed in Tables 5.1 and 5.2. The analysis takes into account both the cost of the heat pump measure under consideration as well as any avoided cost of the conventional heating and cooling measures that would have been installed.

To arrive at these inputs, preliminary cost data was originally compiled for the 2017 Framework analysis based on regional rebate databases and a review of prior reports, as vetted and adjusted through stakeholder conversations. Inputs were developed for the Hudson Valley and Upstate/ Western NY regions; these were translated to cost figures applicable to NYC and Long Island using cost adjustment factors available through the RSMeans construction cost data service.[8] Since the 2017 Framework publication, capital cost assumptions were updated regularly based on ongoing stakeholder conversations and data from NYSERDA's heat pump rebate programs; the data shown thus reflects 2018 figures.

Based on industry feedback about increased public-sector contracting costs, both heat pump and counterfactual capex figures for publicly-owned multifamily buildings were assumed at 40% above the following figures listed.

Table 5-1. Heat Pump Capital Cost per Installation, 2018

Sector	Geography	Age	ASHP		Minisplit		GSHP	
			Tonnage	Capex	Tonnage	Capex	Tonnage	Capex
Single-Family	Long Island	Existing	3	$12,784	2	$5,682	4	$35,660
		New	5	$18,111	2	$5,682	4	$35,660
	NYC	Existing	3	$13,740	2	$6,107	4	$38,327
		New	5	$19,465	2	$6,107	4	$38,327
	Hudson Valley/ Upstate/Western	Existing	3	$12,368	2	$5,497	4	$34,500
		New	5	$17,522	2	$5,497	4	$34,500
Small MF	Long Island	Existing	5	$21,307	3	$11,364	6	$53,489
		New	8	$28,977	3	$11,364	6	$53,489
	NYC	Existing	5	$22,900	3	$12,214	6	$57,490
		New	8	$31,144	3	$12,214	6	$57,490
	Hudson Valley/ Upstate/Western	Existing	5	$20,614	3	$10,994	6	$51,750
		New	8	$28,035	3	$10,994	6	$51,750

Table 5-2. Counterfactual Capital Cost per Installation, 2018

Sector	Geography	Natural Gas Heating	Fuel Oil Heating	Central A/C	Window A/C
Single Family	Long Island	$4,651	$6,977	$3,514	$615
	NYC	$4,999	$7,499	$3,777	$661
	HV/Upstate/Western	$4,500	$6,750	$3,400	$595
Small MF	Long Island	$5,582	$8,372	$4,685	$1,230
	NYC	$5,999	$8,998	$5,036	$1,322
	HV/Upstate/Western	$5,400	$8,100	$4,533	$1,190

Concerning the avoided counterfactual equipment cost, the following assumptions were made:

- In single-family and small multifamily buildings, the assumed counterfactual heating equipment is either a gas or oil furnace or electric resistance heat, with forced air distribution. It is assumed that no distribution system upgrade costs are incurred.
- In the case of GSHP and ASHP installations, the counterfactual cooling equipment is assumed to be central air conditioning; in the case of minisplit installations, the analysis assumes that the counterfactual air conditioning unit would be a window air conditioner (A/C), with a lower coefficient of performance (COP) than central A/C.
- The cost of counterfactual cooling equipment is counted as an avoided cost in new construction buildings. Regarding retrofits in existing buildings, from the point of view of the customer, no correlation between the timing of the heat pump installation and the remaining useful life of the existing cooling system is assumed, and thus no air conditioning capital cost is accounted as an avoided cost. However, for the purpose of the SCT (explained in Section 7), these costs are counted as an avoided cost since the need for a counterfactual new cooling system is assumed to occur at some point during the heat pump lifetime if not at the time the heat pump investment decision is made.
- Counterfactual heating equipment is accounted as follows:
  - GSHPs are assumed to be installed at the end of the life of the current heating system and serve full space heating needs, so the cost of a counterfactual new heating system is counted as an avoided cost (i.e., effectively reduces the cost of the heat pump system).
  - ASHPs, like GSHPs, are assumed to be installed at the end of the life of the current heating system. In new construction buildings, ASHP are assumed to serve full space heating needs, so the counterfactual heating equipment cost is counted as an avoided cost as in the case of GSHP. Regarding retrofit heat pumps in existing buildings, it is assumed that a new conventional heating system will still be needed to provide heating during peak winter hours. Accordingly, no avoided heating capital cost is counted for ASHP retrofit installations.
  - Minisplits are assumed to only deliver part of the heating needs, so no avoided heating system capex is accounted for.
  - In reference installations with electric resistance heat systems (only relevant for existing buildings, as it is assumed that no new buildings will use electric resistance heat), the counterfactual setting would be continued use of the existing heating system, and so no avoided heating system cost is counted.

The cost in particular of residential GSHPs has come down considerably in New York State over the past two years, confirming the expectation as stated in the 2017 Framework that significant cost reductions can be expected as the market scales and as a State policy framework provides the enabling foundation for such scaling. This analysis assumes that with a continued supportive policy environment and market growth in line with projections described in this Report, further year-on-year cost reductions as summarized in Table 5.3 should be possible.

Table 5-3. Assumed Nominal Cumulative Change in Capex by Year (as % of 2018 Values)

Year	ASHP	Minisplit	GSHP	Counter-factual HVAC
2019	-1%	-1%	-5%	2%
2020	-2%	-2%	-11%	4%
2021	-3%	-3%	-16%	6%
2022	-4%	-4%	-20%	9%
2023	-5%	-5%	-22%	11%
2024	-6%	-6%	-23%	13%
2025	-7%	-7%	-25%	16%

A number of factors are expected to contribute to such cost reductions, described in greater detail in the 2017 Framework, including (1) device cost reductions ("hard" equipment costs), (2) installation economies of scale and other soft cost efficiencies and learning effects, and (3) improvements over time in heat pump efficiency factors. At the same time, it must be recognized that there is limited data to underpin any forecast of future heat pump hard or soft cost reductions. Accordingly, the cost reduction assumptions set out in the following paragraphs should also be seen as a guideline to the heat pump market, indicating the level of cost reduction that NYSERDA would expect the market to deliver over time within the context of a supportive policy framework.

Assumed cost reductions for GSHPs over the period to 2022 were linked to the phase-out of federal investment tax credits (ITC) for GSHPs during this period. In order to enable a sustainable GSHP market after the expiry of the tax credits, it was assumed that the GSHP market would be able to deliver cost efficiencies at least equal to the value of such tax credits. The ITC is available on a declining basis by installation year, separately for residential and nonresidential systems. As residential systems are defined for the purposes of the ITC as those installed in owner-occupied housing, the nonresidential tax credit is applied both for single-family residential rental units and for all small multifamily systems. Table 5.4 reflects the value of these tax credit (as a percentage of GSHP capex).

The analysis assumes no cost reductions in counterfactual HVAC devices, keeping their costs constant in real terms (i.e., costs are escalated to account for inflation).

Table 5-4. GSHP Federal Tax Credit Percentage

Customer Segment	2019	2020	2021	2022	2023	2024	2025
Residential Single-Family Owner-Occupied	30%	26%	22%	0%	0%	0%	0%
Residential Single-Family Rental; Small Multifamily	10%	10%	10%	0%	0%	0%	0%

6 Energy Bill and Operational Savings

In order to calculate a customer's energy bill savings from a heat pump installation, the thermal load served in each installation (as discussed in Section 4.3) is converted to the amount of input fuel (oil, gas and/or electricity) consumed both in the counterfactual situation and in the case of each type of heat pump installation. Using inputs on retail prices for each fuel type, the customer's bills are calculated for these amounts of fuel consumption, which allows net bill savings to be derived.

6.1 System Efficiency and Fuel Consumption

Space heating and cooling fuel use of each type (gas or oil regarding counterfactual conventional heating, electricity for counterfactual resistance heating, air conditioning, as well as the various heat pump measures) was determined by multiplying the thermal load served by the efficiency factor of each device type. Table 6.1 shows the efficiency factors, and Tables 6.2 to 6.3 indicate the resulting annual fuel consumption.

Heat pump system efficiency assumptions were sourced from available rebate databases in New York and neighboring states, revised based on stakeholder feedback. Efficiency factors reflect annual average system efficiencies (e.g., including distribution losses).

Counterfactual performance efficiencies were collected from a literature review (primarily DOE Technical Reference documents) with stakeholder feedback. The type of counterfactual space heating and cooling equipment varied based on counterfactual heating fuel and building sector.

Table 6-1. Equipment Efficiency

Technology	Vintage	Heat Pump Efficiency			Counterfactual Efficiency				
		Heat COP	Cool COP	Cooling SEER	Nat Gas Heat COP	Fuel Oil Heat COP	Electric Heat COP	Cooling COP	Cooling SEER
ASHP	Existing Building	300%	469%	16	76%	66%	100%	381%	13
ASHP	New Constr.	250%	469%	16	76%	66%	100%	381%	13
Minisplit	Existing Building & New Constr.	300%	469%	16	76%	66%	100%	381%	13
GSHP	Existing Building & New Constr.	415%	674%	23	76%	66%	100%	381%	13

This analysis does not explicitly model potential efficiency factor improvements over time, though such performance improvements are indirectly reflected as part of the assumed cost reductions over time set out in Section 5.

Applying these efficiency factors to the hourly heating and cooling demand of each residential dwelling type yields the counterfactual and heat pump fuel usage. Table 6.2 shows thermal electricity use.

- For minisplit installations, both the counterfactual and heat pump case show only electricity for heating or cooling use associated with the portion of site load served by the minisplit.
- Note that non-thermal electric use is discussed further in Table 4.6.

Table 6-2. Thermal Electricity Usage per Installation

			Annual kWh	CF Elec. Resistance Heating[9]	Counter-factual Cooling	Heat Pump Heating[10]	Heat Pump Cooling	kWh Change (CF Oil or Gas)	kWh Change (CF Elec. Resistance)
Single-Family	ASHP	New Construction	NYC/LI/HV	20,058	1,075	8,023	873	7,822	-12,236
Single-Family	ASHP	New Construction	Upstate	25,505	614	10,202	499	10,087	-15,418
Single-Family	ASHP	Existing Building	NYC/LI/HV	20,058	1,075	6,429	873	6,228	-13,830
Single-Family	ASHP	Existing Building	Upstate	25,505	614	8,033	499	7,918	-17,587
Single-Family	Minisp.	Existing Build. & New Constr.	NYC/LI/HV	7,522	444	2,507	327	2,391	-5,131
Single-Family	Minisp.	Existing Build. & New Constr.	Upstate	9,564	254	3,188	187	3,122	-6,443
Single-Family	GSHP	Existing Build. & New Constr.	NYC/LI/HV	20,058	1,075	4,833	607	4,366	-15,692
Single-Family	GSHP	Existing Build. & New Constr.	Upstate	25,505	614	6,146	347	5,879	-19,626
Small Multifamily	ASHP	New Construction	NYC/LI/HV	30,087	1,612	12,035	1,310	11,733	-18,354
Small Multifamily	ASHP	New Construction	Upstate	38,257	921	15,303	748	15,130	-23,127
Small Multifamily	ASHP	Existing Building	NYC/LI/HV	30,087	1,612	9,894	1,310	9,592	-20,495
Small Multifamily	ASHP	Existing Building	Upstate	38,257	921	12,536	748	12,363	-25,894
Small Multifamily	Minisp.	Existing Build. & New Constr.	NYC/LI/HV	15,043	888	5,014	655	4,781	-10,262
Small Multifamily	Minisp.	Existing Build. & New Constr.	Upstate	19,129	507	6,376	374	6,243	-12,886
Small Multifamily	GSHP	Existing Build. & New Constr.	NYC/LI/HV	30,087	1,612	7,250	911	6,549	-23,538
Small Multifamily	GSHP	Existing Build. & New Constr.	Upstate	38,257	921	9,219	520	8,818	-29,439

Based on a similar calculation of site thermal load divided by device efficiency factor, annual counterfactual oil and gas usage for space heating is as shown in Table 6.3. Only fuel use associated with site load to be served by the heat pump option is shown, that is, in the case of a minisplit this regards the oil or gas usage displaced in the part of the building served by the minisplit. In the case of an ASHP in an existing building this excludes the small amount of oil or gas usage still assumed to be used by the backup conventional heating system during peak winter heating hours.

Table 6-3. Counterfactual Oil and Gas Space Heating Usage per Installation

Sector	Technology	Vintage	Geography	Natural Gas		Fuel Oil	
				Cubic feet	MMBtu	Gallons	MMBtu
Single Family	ASHP	Existing Building	NYC/LI/HV	84,232	87	725	100
			Upstate	105,248	108	906	125
		New Construction	NYC/LI/HV	87,597	90	754	104
			Upstate	111,385	115	959	132
	Minisplit	Existing Build. & New Constr.	NYC/LI/HV	32,849	34	283	39
			Upstate	41,769	43	360	49
	GSHP	Existing Build. & New Constr.	NYC/LI/HV	87,597	90	754	104
			Upstate	111,385	115	959	132
Small Multifamily	ASHP	Existing Building	NYC/LI/HV	129,628	133	1,116	153
			Upstate	164,236	169	1,414	194
		New Construction	NYC/LI/HV	131,395	135	1,131	156
			Upstate	167,077	172	1,438	198
	Minisplit	Existing Build. & New Constr.	NYC/LI/HV	65,698	68	566	78
			Upstate	83,538	86	719	99
	GSHP	Existing Build. & New Constr.	NYC/LI/HV	131,395	135	1,131	156
			Upstate	167,077	172	1,438	198

6.2 Site Energy Savings

Heat pumps will reduce overall energy consumption. However, heat pumps used for heating and cooling will typically not save electricity on an annual basis, and although they reduce summer electricity use for cooling compared to conventional air conditioning, the additional electricity consumed for winter heating tends to outweigh these savings. This is only different where a heat pump replaces electric resistance heating, in which case the heat pump will save very significant amounts of electricity due to the much higher heating efficiency factor.

In terms of replacing oil or gas heating, heat pumps save substantial amounts of energy overall when the net balance of the electricity consumption and the displacement of oil and gas usage is considered. Consistent with the White Paper, this approach is the basis for quantification of heat pump energy savings in this analysis. As part of this quantification, electricity is accounted as the kilowatt-hour (kWh) of electricity consumed on site (as opposed to the energy consumed during electricity generation). The resulting approach is referred to as "net all-fuels site energy savings." Site energy savings are generally reported as Btu.

Based on the change in electricity usage and reduction in oil or gas usage as identified in Section 6.1, Table 6.4 summarizes the resulting annual site energy savings per installation.

Table 6-4. Annual Net All-Fuels Site Energy Savings per Installation (MMBtu)

Sector	Technology	Vintage	Geography	CF Gas Heat	CF Oil Heat	CF Electric Heat
Single-Family	ASHP	Existing Building	NYC/LI/HV	65	78	45
			Upstate	81	98	55
		New Construction	NYC/LI/HV	63	77	42
			Upstate	80	97	53
	Minisplit	Existing Build. & New Constr.	NYC/LI/HV	26	31	18
			Upstate	32	39	22
	GSHP	Existing Build. & New Constr.	NYC/LI/HV	75	89	54
			Upstate	94	112	67
Small Multifamily	ASHP	Existing Building	NYC/LI/HV	101	121	69
			Upstate	127	152	86
		New Construction	NYC/LI/HV	95	116	63
			Upstate	120	146	79
	Minisplit	Existing Build. & New Constr.	NYC/LI/HV	51	61	35
			Upstate	65	78	44
	GSHP	Existing Build. & New Constr.	NYC/LI/HV	113	133	80
			Upstate	142	168	100

6.3 Electricity Bills

To calculate customer electricity bills before and after the installation of a heat pump device, actual rate schedules for each New York State utility were used. The analysis includes volumetric charges, fixed charges, and, where applicable, demand charges. Where appropriate, these charges are further segmented by season or time of day. All single-family residential and small multifamily bills were calculated using Service Class 1 (SC-1) default residential rate. Long Island bills were calculated using the residential Rate 180. The rate schedules assessed in this analysis are shown in Table 6.5.

Table 6-5. Utility Electric Rates

			Energy		Fixed
			$/kWh		$/mo
Geography	Utility	Rate	Summer (Jun-Sep)	Winter (Oct-May)	All
Long Island	PSEG LI	Rate 180	$ 0.183	$ 0.183	$ 4.320
Hudson Valley	Central Hudson	SC -1	$ 0.128	$ 0.128	$ 24.000
Upstate/Western New York	National Grid	SC1	$ 0.094	$ 0.094	$ 17.000
NYC	Consolidated Edison	SC1 - Rate I	$ 0.235	$ 0.221	$ 15.760
Hudson Valley	Orange & Rockland	SC -1	$ 0.180	$ 0.166	$ 20.000
Upstate/Western New York	NYSEG	1 Residential Regular	$ 0.140	$ 0.140	$ 15.110
Upstate/Western New York	Rochester Gas and Electric	SC1 - Residential	$ 0.098	$ 0.098	$ 21.380

The rates were researched in late 2016.

The analysis employs separate approaches to escalation of the supply charge and distribution charge portions of overall energy bills for the relevant time period.

- The supply charge is escalated proportionally to the NY CARIS[11] energy price forecast and the New York Independent System Operator (NYISO) base case capacity price forecast;[12] energy is assumed to comprise 75% of the market supply charge (MSC) and capacity is assumed to comprise 25%. See Section 7 for more information on energy and capacity price forecasts.
- The distribution charge portion of energy bills is escalated using standard EIA retail rate escalators which vary by utility and customer class. [13]

Applying these rates, as escalated, to the hourly electricity profiles for both the counterfactual and heat pump cases electricity usage yields the projected site electric bills as shown in Tables 6.6 and 6.7 for the year 2019—the first year considered in the analysis.

The bill amounts include all electricity usage (thermal and non-thermal), with the exception of minisplit cases, in which any electricity associated with heating or cooling the part of the building not served by the minisplit is ignored (in both the counterfactual and heat pump case electricity bills).

Table 6-6. Annual Electricity Bills and Savings per Installation (2019)—Single Family

	Annual Bill ($2019)	Base Case Electric Bill: Fuel Oil/ Natural Gas Customers	Base Case Electric Bill: Electric Heating Customers	Heat Pump Case Electric Bill: Replacing Fuel Oil/ Natural Gas	Heat Pump Case Electric Bill: Replacing Electric Heating	Change in Electric Bill: Fuel Oil/ Natural Gas Customers	Change in Electric Bill: Electric Heating Customers
ASHP (New Construction)	PSEG LI	$2,522	N/A	$4,031	$4,031	$1,510	N/A
	ConEdison	$3,207	N/A	$5,061	$5,061	$1,855	N/A
	Central Hudson	$1,921	N/A	$2,950	$2,950	$1,029	N/A
	Nat Grid	$1,081	N/A	$2,103	$2,103	$1,023	N/A
	RG&E	$1,163	N/A	$2,219	$2,219	$1,056	N/A
	NYSEG	$1,478	N/A	$3,003	$3,003	$1,524	N/A
	ORU	$2,428	N/A	$3,763	$3,763	$1,335	N/A
ASHP (Existing Building)	PSEG LI	$2,522	$6,393	$3,724	$3,873	$1,202	($2,521)
	ConEdison	$3,207	$7,970	$4,683	$4,866	$1,476	($3,105)
	Central Hudson	$1,921	$4,559	$2,740	$2,841	$819	($1,717)
	Nat Grid	$1,081	$3,666	$1,883	$2,026	$803	($1,640)
	RG&E	$1,163	$3,833	$1,992	$2,219	$829	($1,614)
	NYSEG	$1,478	$5,332	$2,675	$2,887	$1,196	($2,445)
	ORU	$2,428	$5,860	$3,491	$3,763	$1,062	($2,096)
Minisplit	PSEG LI	$2,400	$3,852	$2,861	$2,861	$461	($990)
	ConEdison	$3,047	$4,834	$3,613	$3,613	$566	($1,220)
	Central Hudson	$1,838	$2,827	$2,152	$2,152	$314	($675)
	Nat Grid	$1,044	$2,014	$1,361	$1,361	$316	($653)
	RG&E	$1,125	$2,126	$1,452	$1,452	$327	($675)
	NYSEG	$1,424	$2,869	$1,896	$1,896	$472	($974)
	ORU	$2,311	$3,598	$2,718	$2,718	$407	($879)
GSHP	PSEG LI	$2,522	$6,393	$3,364	$3,364	$843	($3,029)
	ConEdison	$3,207	$7,970	$4,237	$4,237	$1,030	($3,734)
	Central Hudson	$1,921	$4,559	$2,495	$2,495	$574	($2,064)
	Nat Grid	$1,081	$3,666	$1,677	$1,677	$596	($1,990)
	RG&E	$1,163	$3,833	$1,778	$1,778	$616	($2,055)
	NYSEG	$1,478	$5,332	$2,367	$2,367	$888	($2,966)
	ORU	$2,428	$5,860	$3,168	$3,168	$740	($2,691)

Table 6-7. Annual Electricity Bills and Savings per Installation (2019)—Small Multifamily

	Annual Bill ($2019)	Base Case Electric Bill		Heat Pump Case Electric Bill		Change in Electric Bill	
		Fuel Oil/ Natural Gas Customers	Electric Heating Cus-tomers	Replacing Fuel Oil/ Natural Gas	Replacing Electric Heating	Fuel Oil/ Natural Gas Customers	Electric Heating Customers
ASHP (New Construc-tion)	PSEG LI	$3,714	N/A	$5,979	$5,979	$2,265	N/A
	ConEdison	$4,708	N/A	$7,490	$7,490	$2,782	N/A
	Central Hudson	$2,733	N/A	$4,276	$4,276	$1,543	N/A
	Nat Grid	$1,511	N/A	$3,045	$3,045	$1,534	N/A
	RG&E	$1,607	N/A	$3,191	$3,191	$1,584	N/A
	NYSEG	$2,120	N/A	$4,406	$4,406	$2,286	N/A
	ORU	$3,518	N/A	$5,521	$5,521	$2,003	N/A
ASHP (Existing Building)	PSEG LI	$3,714	$9,522	$5,566	$5,644	$1,851	($3,878)
	ConEdison	$4,708	$11,854	$6,982	$7,078	$2,273	($4,776)
	Central Hudson	$2,733	$6,690	$3,995	$4,048	$1,261	($2,642)
	Nat Grid	$1,511	$5,389	$2,764	$2,830	$1,253	($2,559)
	RG&E	$1,607	$5,613	$2,902	$3,191	$1,294	($2,421)
	NYSEG	$2,120	$7,900	$3,988	$4,086	$1,868	($3,814)
	ORU	$3,518	$8,665	$5,155	$5,521	$1,636	($3,144)
Minisplit	PSEG LI	$3,574	$6,478	$4,497	$4,497	$923	($1,981)
	ConEdison	$4,525	$8,098	$5,657	$5,657	$1,132	($2,441)
	Central Hudson	$2,638	$4,616	$3,267	$3,267	$629	($1,349)
	Nat Grid	$1,469	$3,408	$2,102	$2,102	$633	($1,306)
	RG&E	$1,564	$3,567	$2,218	$2,218	$654	($1,349)
	NYSEG	$2,057	$4,948	$3,001	$3,001	$943	($1,947)
	ORU	$3,384	$5,957	$4,198	$4,198	$815	($1,759)
GSHP	PSEG LI	$3,714	$9,522	$4,978	$4,978	$1,264	($4,543)
	ConEdison	$4,708	$11,854	$6,253	$6,253	$1,545	($5,601)
	Central Hudson	$2,733	$6,690	$3,595	$3,595	$861	($3,095)
	Nat Grid	$1,511	$5,389	$2,405	$2,405	$894	($2,984)
	RG&E	$1,607	$5,613	$2,530	$2,530	$923	($3,082)
	NYSEG	$2,120	$7,900	$3,452	$3,452	$1,332	($4,448)
	ORU	$3,518	$8,665	$4,628	$4,628	$1,110	($4,037)

6.4 Natural Gas and Fuel Oil Bills

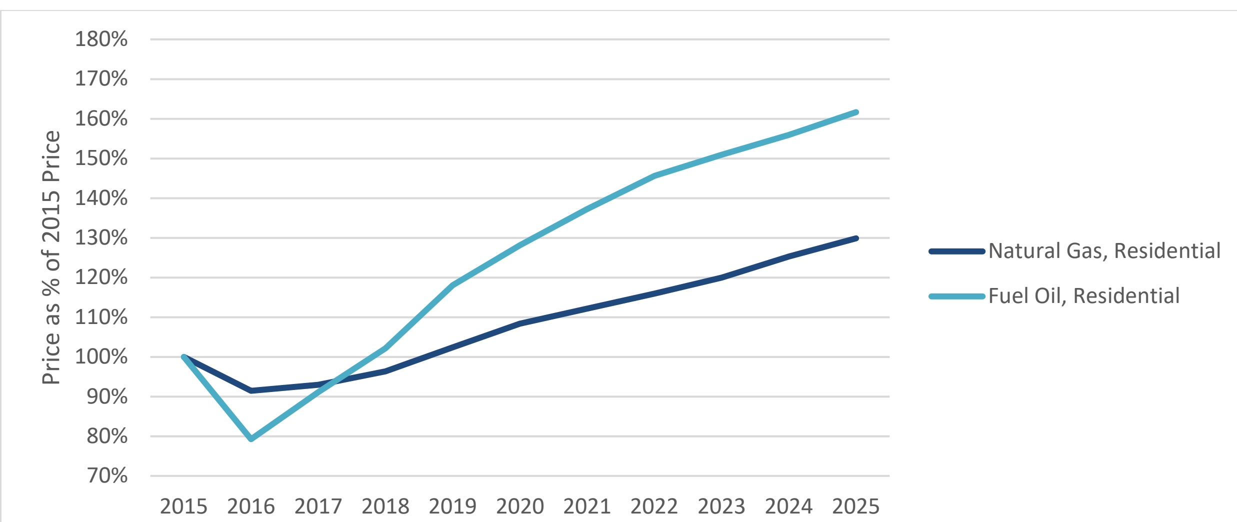
Residential natural gas and fuel oil retail prices were input on an annual basis, separately for each region. Natural gas prices derive from 2015 EIA data on natural gas utility revenues, sales, and customer counts, and the current level of fixed charge bill components levied by New York State gas utilities. Fixed-price revenue was estimated for each utility, and nonfixed-price revenue was divided by natural gas sales to derive a per-unit variable price for use in this study. Residential fuel oil prices derive from monthly home heating oil data were collected at the regional level by NYSERDA, with annual values derived by weighting monthly prices by the monthly statewide fuel oil sales reported by EIA. The base annual natural gas and fuel oil prices (for 2015) used in this analysis are shown in Table 6.8.

Table 6-8. Residential Natural Gas and Fuel Oil Retail Prices (2015)

Sector	Region	Physical Units		Per MMBtu	
		Natural Gas ($/Mcf)	Fuel Oil ($/gallon)	Natural Gas	Fuel Oil
Single Family and Small Multifamily	Long Island	$14.04	$2.86	$13.66	$20.79
	NYC	$12.44	$2.86	$12.10	$20.77
	Hudson Valley	$13.02	$2.71	$12.67	$19.67
	Upstate/Western New York	$8.93	$2.69	$8.68	$19.57

Fuel prices are escalated according to the EIA mid-Atlantic price forecasts, illustrated in Figure 6.1.

Figure 6-1. Natural Gas and Fuel Oil Retail Price Projection, Nominal Percentage Change



Avoided customer annual energy bills are derived by multiplying the prices by the amount of natural gas or fuel oil consumption necessary to serve the heating loads that would be displaced by an installed heat pump system, as shown in Section 6.1. Where reference installations are assumed to still use some portion of conventional heating after installation of the heat pump option (i.e., minisplits and ASHP in existing buildings), the analysis only accounts for the avoided quantity of oil or gas. Resulting avoided gas and oil customer heating bills for 2019 are shown in Table 6.9.

Table 6-9. Annual Avoided Natural Gas and Fuel Oil Bills per Installation (2019)

Counter-factual Fuel	Sector	Region	ASHP Central System		Minisplit	GSHP
			Existing Building	New Construction		
Natural Gas	Single-Family	Long Island	$1,211	$1,259	$472	$1,259
		NYC	$1,073	$1,116	$419	$1,116
		Hudson Valley	$1,123	$1,168	$438	$1,168
		Upstate/Western NY	$962	$1,018	$382	$1,018
	Small Multifamily	Long Island	$1,864	$1,889	$945	$1,889
		NYC	$1,652	$1,674	$837	$1,674
		Hudson Valley	$1,728	$1,752	$876	$1,752
		Upstate/Western NY	$1,501	$1,527	$764	$1,527
Fuel Oil	Single-Family	Long Island	$2,447	$2,545	$954	$2,545
		NYC	$2,445	$2,543	$954	$2,543
		Hudson Valley	$2,316	$2,409	$903	$2,409
		Upstate/Western NY	$2,879	$3,047	$1,143	$3,047
	Small Multifamily	Long Island	$3,766	$3,818	$1,909	$3,818
		NYC	$3,763	$3,814	$1,907	$3,814
		Hudson Valley	$3,565	$3,613	$1,807	$3,613
		Upstate/Western NY	$4,493	$4,571	$2,285	$4,571

6.5 Net Energy Bill Savings

Net customer bill savings are calculated in each year as the total of the customer's electric bill and (where applicable) oil or gas bill in the counterfactual situation (where no heat pump would have been installed), minus the customer's electric bill in the heat pump situation. As noted previously, in both cases bill calculation excludes any load that is not or would not be served by the heat pump.[14]

Table 6-10. Heat Pump Annual Net Energy Bill Savings per Installation (2019)

Sector	Technology	Vintage	Geography	CF Natural Gas	CF Fuel Oil	CF Electric Resistance
Single-Family	ASHP	Existing Building	Long Island	$9	$1,245	$2,521
			NYC	($403)	$969	$3,105
			Hudson Valley	$304	$1,497	$1,717
			Upstate/Western New York	$159	$2,077	$1,640
		New Construction	Long Island	($250)	$1,035	$2,362
			NYC	($738)	$688	$2,909
			Hudson Valley	$139	$1,380	$1,609
			Upstate/Western New York	($4)	$2,025	$1,563
	Minisplit	Existing Build. & New Constr.	Long Island	$11	$493	$990
			NYC	($147)	$388	$1,220
			Hudson Valley	$124	$589	$675
			Upstate/Western New York	$65	$826	$653
	GSHP	Existing Build. & New Constr.	Long Island	$417	$1,702	$3,029
			NYC	$86	$1,513	$3,734
			Hudson Valley	$594	$1,835	$2,064
			Upstate/Western New York	$422	$2,451	$1,990
Small Multi-family	ASHP	Existing Building	Long Island	$12	$1,915	$3,878
			NYC	($622)	$1,489	$4,776
			Hudson Valley	$467	$2,303	$2,642
			Upstate/Western New York	$248	$3,240	$2,559
		New Construction	Long Island	($376)	$1,553	$3,543
			NYC	($1,108)	$1,032	$4,364
			Hudson Valley	$209	$2,070	$2,414
			Upstate/Western New York	($7)	$3,037	$2,345
	Minisplit	Existing Build. & New Constr.	Long Island	$22	$986	$1,981
			NYC	($295)	$775	$2,441
			Hudson Valley	$247	$1,178	$1,349
			Upstate/Western New York	$131	$1,653	$1,306
	GSHP	Existing Build. & New Constr.	Long Island	$625	$2,553	$4,543
			NYC	$129	$2,269	$5,601
			Hudson Valley	$891	$2,752	$3,095
			Upstate/Western New York	$633	$3,677	$2,984

Note: Electricity bills reflected based on representative utilities as noted in Section 3.

For the purpose of calculating the customer's payback or return, the customer's calculated energy bill savings are held flat at the level of the year in which a heat pump installation is installed. In other words, although escalation of electric, oil, and gas bills (as discussed in Sections 6.3 and 6.4) is applied to each consecutive vintage of new installations, the analysis assumes that customers do no attach any value to any potential increase in their future energy bill savings over the lifetime of the installation. By contrast, for the purpose of the Societal Cost Test (explained in Section 7) energy bill escalation factors are also applied throughout the lifetime of each vintage, reflecting the different perspective of this test.

6.6 Operation and Maintenance Costs

The analysis incorporates modest annual operation and maintenance (O&M) cost assumptions for single-family residential installations, depending on the technology as follows:

- $0 for window air conditioning
- $50 for a minisplit
- $100 for ASHP, GSHP, or central air conditioning
- $143 for gas or oil heating

These amounts are scaled by system size for small multifamily units. Amounts (shown for 2018) are escalated over time with inflation. The total O&M cost for each use case also depends on the assumptions regarding avoided equipment, as discussed in Section 5. For example, a single-family GSHP unit which fully replaces both a central A/C and a gas heating unit would benefit from annual O&M savings of $150 for gas heating plus $100 for air conditioning, minus $100 for the heat pump, or a net savings of $150 per year. On the other hand, an ASHP which replaces central air conditioning but only partially displaces conventional heating would see no net impact on O&M costs.

7 Economic Potential

Section 10 discusses the residential heat pump uptake projections provided by this analysis. Such adoption projections depend on an assessment of heat pump economics from the customer's perspective. If payback (or rate of return) from the customer's perspective is insufficient, policies and programs would likely be needed to ensure that sufficient levels of compensation are made available to customers to enable adoption to occur. This analysis applies a Societal Cost Test (SCT) as an indicator to identify the likely market sectors where heat pump installations merit the introduction of such policies and programs to provide additional compensation because of the societal benefits that such installations would provide. Heat pump market segments that qualify under such SCT are regarded as constituting the economic heat pump potential.

The analysis uses an amended version of the SCT prescribed by the New York Public Service Commission's (PSC) Benefit Cost Analysis Framework (BCA) for projects and investments considered in course of the Reforming the Energy Vision proceeding and related proceedings.[15] The BCA specifies a set of factors to be treated as costs and benefits and indicates appropriate approaches to valuing those factors, including applicable discount rates. The BCA factors include various costs—potentially incurred or avoided—to the grid (and thus ratepayers), such as generation capacity, transmission and distribution capacity, line losses, and others. They also include quantifiable "external benefits," such as avoided carbon emissions. Considering these factors from the perspective of society as a whole provides the PSC, utilities, and stakeholders with an important point of reference.

In order to recognize the full benefits of heat pumps, the SCT applied in this analysis accounts for both the costs and carbon savings of all fuels (oil, gas, and electricity).

The SCT is defined for this analysis as the total net present value of the following components:

- Net reduction or increase in bulk electricity, capacity, and distribution cost
- Value of avoided costs of natural gas or heating oil
- Value of net carbon savings from all fuels, using the Social Cost of Carbon
- The value or cost of a net reduction or increase of on-site O&M
- Net cost of installation capital expenses (calculated as the cost of the heat pump minus avoided counterfactual capital expenses and, where applicable, federal tax credits for GSHP)

A 7% nominal discount rate is used, consistent with the BCA.[16]

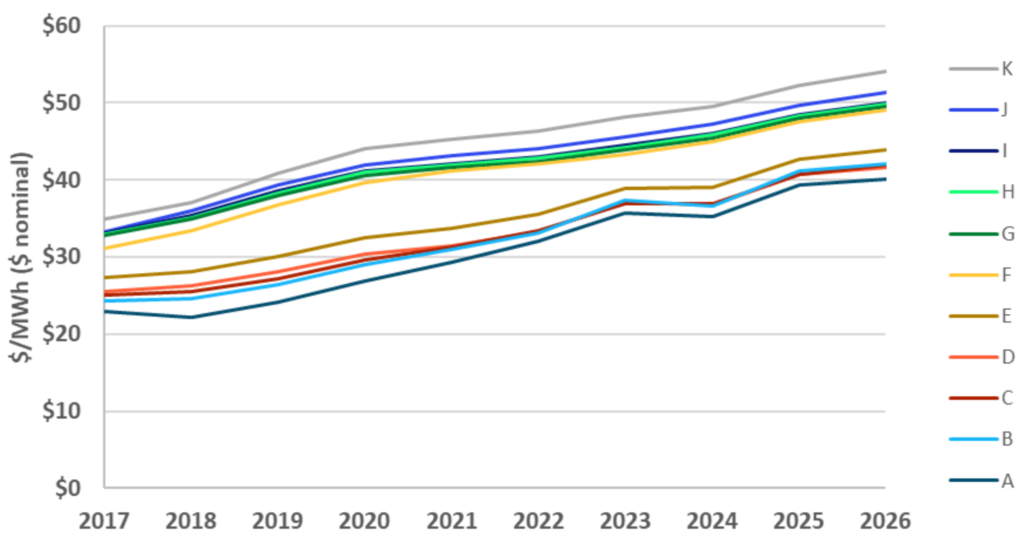
Full detail on the capital expenses and operation and maintenance expenses assumed in this analysis is provided in Sections 5 and 6.6. The other components of the calculation are discussed in more detail in the following sections. Section 7.5 concludes this section by summarizing the economic potential based on the Societal Cost Test calculation.

7.1 Bulk Electricity Cost

Customers who install a heat pump technology to replace conventional oil or gas combustion heating and air conditioning increase electricity usage during the winter heating season and decrease electricity usage during the summer cooling season. This change in usage pattern results in corresponding additional or reduced expenditure by the utility to procure this energy on the wholesale market.

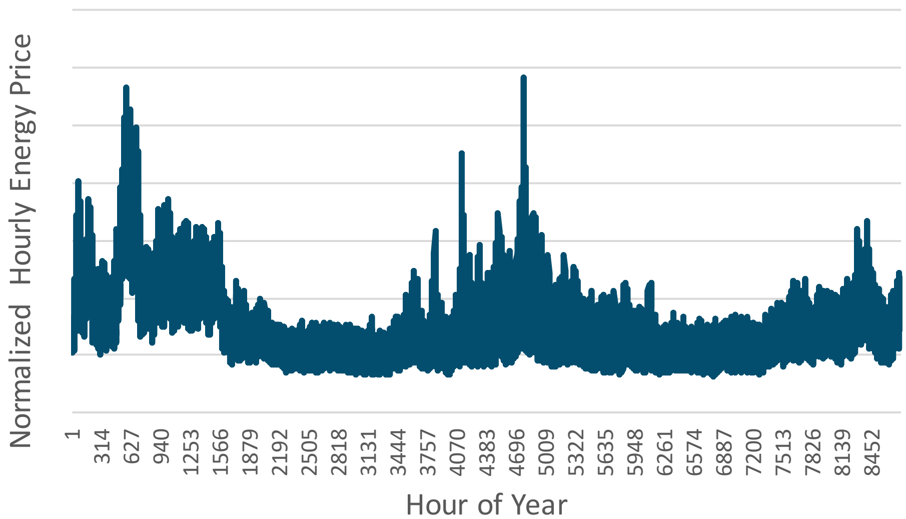
Projections of annual wholesale energy prices by NYISO load zone were taken from the 2017 CARIS[17] forecast (which extends to 2026, see Figure 7.1) and escalated at 2% inflation from 2027. The value of transmission congestion between different NYISO zones is reflected through the different zonal price forecasts.

Figure 7-1. CARIS Energy Price Forecast by Load Zone



These annual $/MWh price forecasts were shaped into an 8760 hourly profile using zonal NYISO wholesale day-ahead hourly energy prices on a load-weighted basis for each utility from a representative year. For illustration, the normalized hourly energy price profile for ConEdison is shown in Figure 7-2.

Figure 7-2. Illustrative Hourly Wholesale Energy Prices (ConEdison)



Each kWh saved at the customer meter translates to additional savings to the utility at the wholesale level due to the avoided transmission and distribution losses associated with not having to deliver that kWh. Conversely, each additional kWh consumed requires additional generation equal to the loss factor. The following transmission and distribution loss factors were applied to each utility in the analysis.

Table 7-1. Utility Loss Factors

Utility	Loss Factor
Central Hudson	6.73%
Con Edison	6.46%
National Grid	7.67%
NYSEG	7.28%
Orange & Rockland	4.64%
RG&E	6.93%
PSEG LI	6.84%

The CARIS wholesale price forecast includes the value of monetized carbon emissions resulting from the Regional Greenhouse Gas Initiative (RGGI).[18]

The resulting change in bulk electricity costs incurred by utilities is as shown in Tables 7.2 and 7.3 for each reference installation. Each of the components—bulk electricity cost, losses, and the carbon value component of CARIS wholesale prices—is shown separately. The table indicates that the utility's cost of procuring electricity increases where a heat pump replaces oil or gas heating (reflecting the overall increase in annual electricity consumption primarily associated with the heat pump electricity usage for heating) and conversely reduces where a heat pump replaces electric resistance heating (reflecting the substantially lower amount of electricity needed by a heat pump to deliver the same amount of heating).

Tables 7.2 to 7.3 and other output tables throughout Section 7 show figures for existing building retrofits and thus ignore the small additional heat pump electricity use in the case of ASHP installation in new construction (reflecting the assumption that for ASHP in existing buildings a conventional heating system serves winter peak hours).

Table 7-2. Change in Wholesale Electricity Cost, per Installation—Single-Family Retrofit (2019)

		Fuel Oil/Natural Gas Counterfactual			Electric Resistance Counterfactual		
	$2019	**Energy**	**Losses**	**Carbon**	**Energy**	**Losses**	**Carbon**
ASHP	PSEG LI	$261	$19	$16	($553)	($41)	($34)
	ConEdison	$255	$18	$16	($537)	($37)	($34)
	Central Hudson	$248	$18	$16	($521)	($38)	($34)
	Nat Grid	$229	$19	$21	($470)	($39)	($42)
	RG&E	$198	$15	$21	($406)	($30)	($42)
	NYSEG	$219	$17	$21	($449)	($35)	($42)
	ORU	$248	$12	$16	($521)	($25)	($34)
Mini-split	PSEG LI	$101	$7	$6	($219)	($16)	($13)
	ConEdison	$99	$7	$6	($212)	($15)	($13)
	Central Hudson	$96	$7	$6	($206)	($15)	($13)
	Nat Grid	$91	$8	$8	($188)	($16)	($17)
	RG&E	$78	$6	$8	($162)	($12)	($17)
	NYSEG	$87	$7	$8	($179)	($14)	($17)
	ORU	$96	$5	$6	($206)	($10)	($13)
GSHP	PSEG LI	$181	$13	$11	($671)	($49)	($41)
	ConEdison	$179	$12	$11	($649)	($45)	($41)
	Central Hudson	$175	$13	$11	($629)	($45)	($41)
	Nat Grid	$170	$14	$15	($572)	($48)	($51)
	RG&E	$147	$11	$15	($494)	($37)	($51)
	NYSEG	$162	$13	$15	($547)	($43)	($51)
	ORU	$175	$9	$11	($630)	($31)	($41)

Table 7-3. Change in Wholesale Electricity Cost per Installation—Small Multifamily Retrofit (2019)

	$2019	Fuel Oil/Natural Gas Counterfactual			Electric Resistance Counterfactual		
		Energy	Losses	Carbon	Energy	Losses	Carbon
ASHP	PSEG LI	$404	$30	$25	($855)	($63)	($52)
	ConEdison	$395	$27	$25	($830)	($57)	($52)
	Central Hudson	$384	$28	$25	($805)	($58)	($52)
	Nat Grid	$359	$30	$32	($734)	($61)	($66)
	RG&E	$310	$23	$32	($634)	($47)	($66)
	NYSEG	$343	$27	$32	($702)	($55)	($66)
	ORU	$385	$19	$25	($806)	($39)	($52)
Mini-split	PSEG LI	$201	$15	$12	($438)	($32)	($27)
	ConEdison	$197	$14	$12	($424)	($29)	($27)
	Central Hudson	$192	$14	$12	($412)	($30)	($27)
	Nat Grid	$181	$15	$16	($375)	($31)	($33)
	RG&E	$156	$12	$16	($324)	($24)	($33)
	NYSEG	$173	$14	$16	($359)	($28)	($33)
	ORU	$192	$9	$12	($412)	($20)	($27)
GSHP	PSEG LI	$272	$20	$17	($1,006)	($74)	($61)
	ConEdison	$269	$19	$17	($973)	($67)	($61)
	Central Hudson	$262	$19	$17	($944)	($68)	($61)
	Nat Grid	$255	$21	$23	($858)	($71)	($76)
	RG&E	$220	$16	$23	($741)	($55)	($76)
	NYSEG	$244	$19	$23	($820)	($64)	($76)
	ORU	$262	$13	$17	($946)	($46)	($61)

7.2 Capacity and Distribution Value

To the extent that heat pump technologies reduce electricity consumption during peak grid hours, utilities can avoid or defer investments necessary to meet peak loads and maintain reliable service. This value is counted in the Societal Cost Test.

The analysis quantifies this value by first establishing the value per kilowatt of system peak reduction. In order to reduce the system peak and realize the value thereof, a heat pump would have to be operational during the system peak hour, reducing the amount of electricity used compared to the counterfactual equipment. It is recognized that there will necessarily be uncertainty as to (1) when during the year the system peak hour will occur, and (2) the level of coincidence of a typical heat pump's operation with this peak hour. In order to manage the uncertainty, the analysis examines the profile of historic systemwide demand across the year and establishes a weighting system that reflects the top hours.

The analysis considers the value separately at three levels:

- Generation capacity
- Sub-transmission capacity
- Distribution capacity

As noted earlier, transmission capacity cost is addressed through the bulk electricity price forecast.

Each of these systems is sized to serve its respective peak load.

7.2.1 Generation Capacity

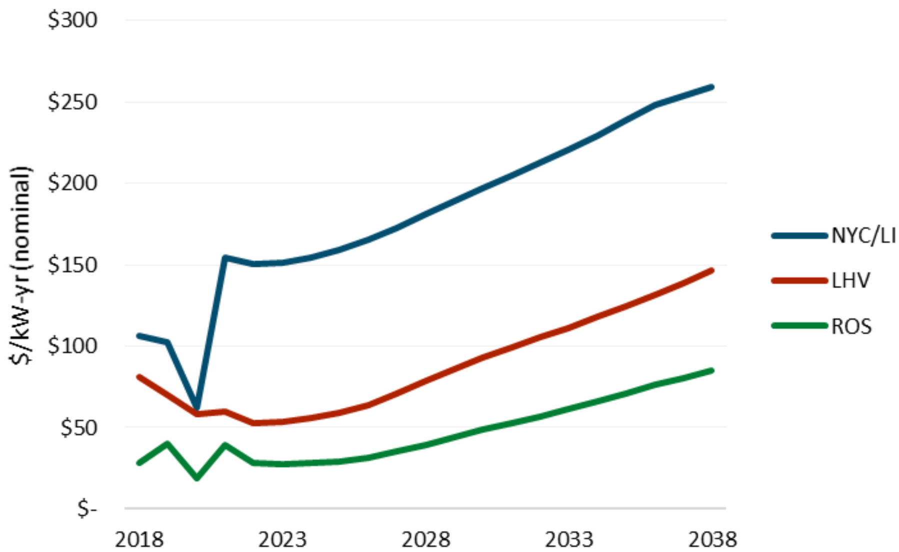
The value of avoiding generation capacity is derived from Department of Public Service (DPS) 2017 projections[19] for each of the four NYISO generation capacity zones. The following table shows the annual value of generating capacity per kW in 2017. These values are grossed up to reflect transmission and distribution losses.

Table 7-4. Generation Capacity Values

Zone	$/kW-yr ($2017)
New York City (NYC)	$104.60
Long Island (LI)	$104.60
Lower Hudson Valley (LHV)	$79.24
Rest of State (ROS)	$27.64

The projection of these values is shown in Figure 7.3; escalation is assumed at 2% nominal per year beyond 2038.

Figure 7-3. ICAP Price Forecast (Nominal)



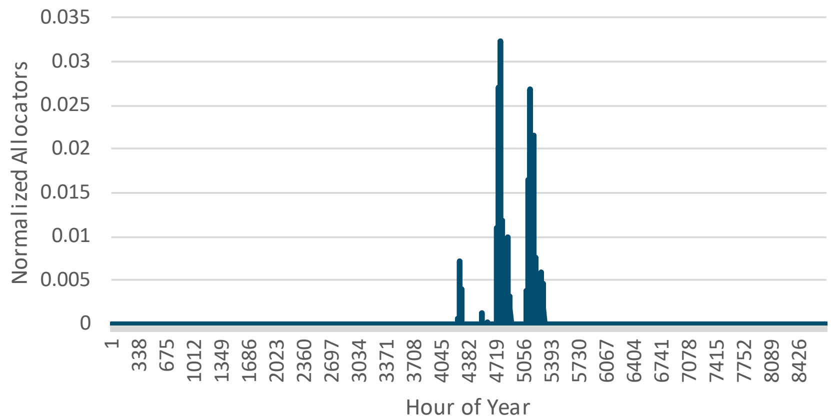
These four generation capacity zones were mapped to each utility as shown in the Table 7.5.

Table 7-5. Mapping Utility to Generation Capacity Zone

Utility	Generation Capacity Zone
Central Hudson	LHV
Con Edison	87% NYC/13% LHV
National Grid	ROS
NYSEG	ROS
Orange & Rockland	LHV
RG&E	ROS
PSEG LI	LI

The value shown in Table 7.4 constitutes the value of reducing the system peak. As mentioned, a weighting approach is used to establish coincidence between the system peak and heat pump operation. First, the $/kW-yr values were allocated to the statewide top 100 NYISO-system load hours of 2014 as a representative year. These "allocators" (which in aggregate sum to one) were determined by assigning a fraction to each of the 100 hours based on the load in that hour minus the load in the 100th largest hour. The generation capacity allocators are shown in the chart below. The generation capacity peak reduction value of a given heat pump technology was then determined by taking the product of these allocators and the heat pump kW reduction in each of the top 100 hours (according to its hourly load profile as described in Section 4.2), and then summing across all hours of the year.

Figure 7-4. Generation Capacity Allocators in Top 100 Load Hours of Year



7.2.2 Sub-transmission and Distribution Capacity

Sub-transmission and distribution values are derived from the 2017 ETIP filings.[20] These values are shown in Table 7.6.

Table 7-6. Sub-transmission and Distribution Capacity Values (2017)

$/kW-yr ($2017)	Distribution	Sub-transmission
Central Hudson	$0	$0
Con Edison	$216.49	$10.29
National Grid	$72.08	$23.00
NYSEG	$31.46	$4.26
Orange & Rockland	$48.78	$20.82
RG&E	$32.21	$3.32
PSEG LI	$86.29	$61.67

The sub-transmission and distribution capacity values used in this analysis are system average values. In practice, the value of reducing peak load at any particular location within a particular utility service territory may be higher or lower but would be expected to equal the values used in this analysis on average across the utility territory. The forecast values for both distribution and sub-transmission are shown in the Figures 7-5 and 7-6. Escalation beyond the available forecast period is applied at 2% nominal per year.

Figure 7-5. Distribution Capacity Value Forecasts (Nominal)

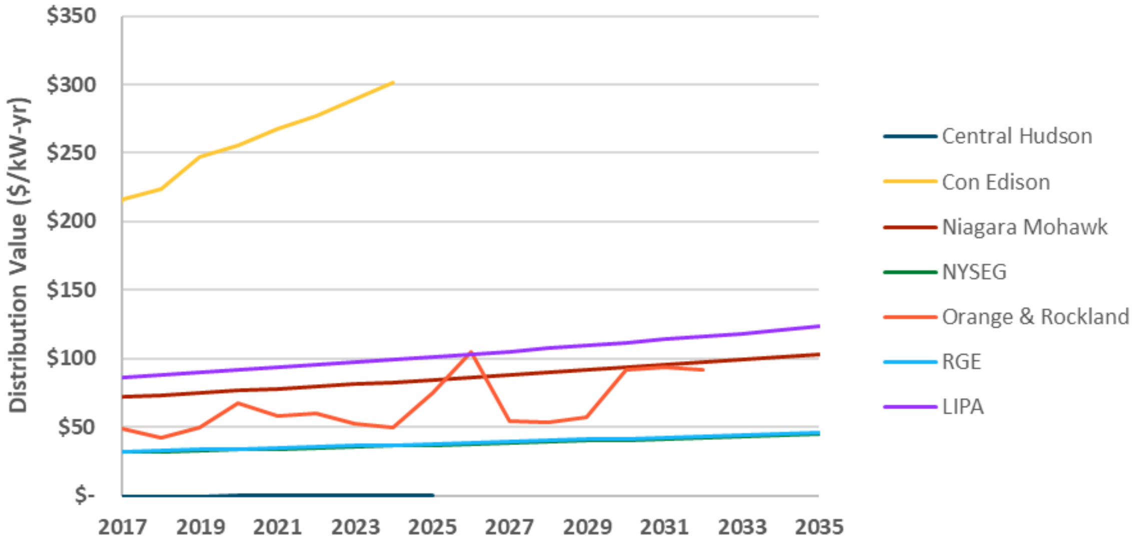
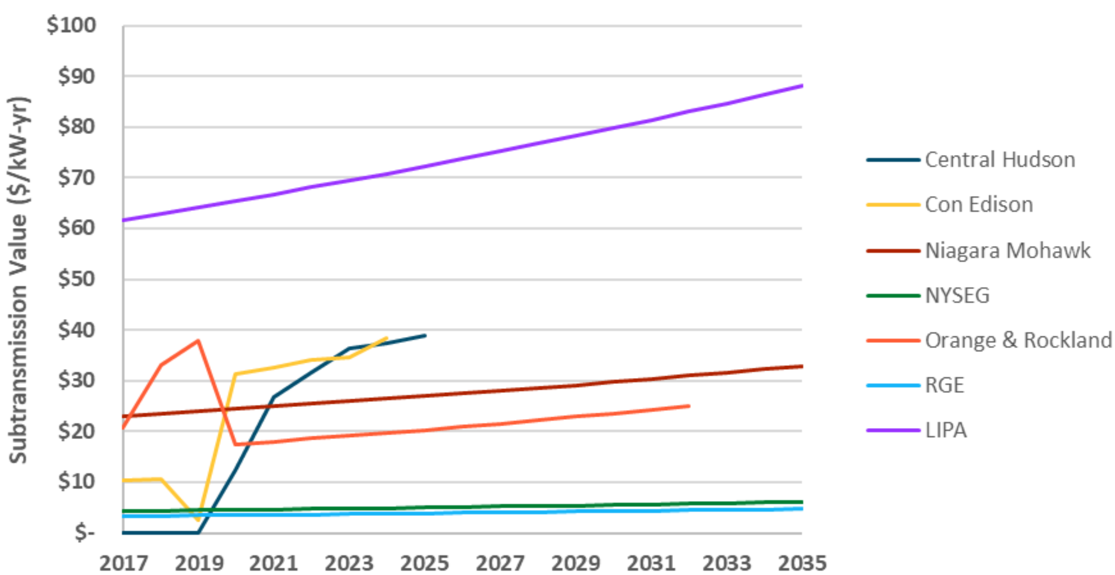


Figure 7-6. Sub-transmission Capacity Value Forecasts (Nominal)



A similar weighting approach as described previously for generation capacity was followed to establish coincident peak reduction value. Instead of the top 100 hours, the top 10 load hours were used as provided by each utility for the VDER proceeding—see Table 7.7—for the distribution and sub-transmission allocators.[21]

Table 7-7. Distribution/Sub-transmission Allocators Top 10 Load Hours of the Year

		Top 10 Distribution & Sub-Transmission Hours									
		1	2	3	4	5	6	7	8	9	10
Central Hudson	Hour Weight	10.2%	10.2%	10.0%	10.0%	10.0%	10.0%	9.9%	9.9%	9.9%	9.9%
	Day	20-Jul	20-Jul	13-Jun	19-Jul	19-Jul	20-Jul	20-Jul	21-Jul	19-Jul	21-Jul
	Hour	4:00 PM	3:00 PM	4:00 PM	5:00 PM	4:00 PM	5:00 PM	2:00 PM	4:00 PM	6:00 PM	5:00 PM
National Grid	Hour Weight	10.2%	10.2%	10.0%	10.0%	10.0%	10.0%	9.9%	9.9%	9.9%	9.9%
	Day	25-Sep	25-Sep	25-Sep	26-Sep	26-Sep	26-Sep	25-Sep	3-Aug	25-Sep	25-Sep
	Hour	4:00 PM	5:00 PM	3:00 PM	4:00 PM	3:00 PM	5:00 PM	2:00 PM	4:00 PM	6:00 PM	7:00 PM
NYSEG	Hour Weight	10.1%	10.1%	10.1%	10.0%	10.0%	10.0%	10.0%	9.9%	9.9%	9.9%
	Day	13-Dec	13-Dec	13-Dec	19-Jul	21-Jul	21-Jul	19-Jul	19-Jul	21-Jul	22-Aug
	Hour	6:00 PM	7:00 PM	5:00 PM	5:00 PM	3:00 PM	4:00 PM	4:00 PM	6:00 PM	2:00 PM	2:00 PM
RGE	Hour Weight	10.1%	10.1%	10.1%	10.0%	10.0%	10.0%	9.9%	9.9%	9.9%	9.9%
	Day	25-Sep	25-Sep	12-Jun	12-Jun	26-Sep	27-Sep	26-Sep	25-Sep	19-Jul	2-Aug
	Hour	4:00 PM	3:00 PM	4:00 PM	3:00 PM	4:00 PM	2:00 PM	3:00 PM	2:00 PM	4:00 PM	4:00 PM
PSEG Long Island	Hour Weight	20.0%	13.9%	11.5%	11.2%	10.1%	10.1%	8.2%	6.2%	5.2%	3.5%
	Day	11-Aug	10-Aug	11-Aug	11-Aug	10-Aug	10-Aug	11-Aug	12-Aug	12-Aug	12-Aug
	Hour	5:00 PM	5:00 PM	6:00 PM	4:00 PM	4:00 PM	6:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM
Orange & Rockland	Hour Weight	10.3%	10.2%	10.1%	10.1%	10.1%	9.9%	9.8%	9.8%	9.8%	9.8%
	Day	13-Jun	13-Jun	20-Jul	13-Jun	20-Jul	13-Jun	20-Jul	17-Jun	19-Jul	17-Jun
	Hour	4:00 PM	4:00 PM	4:00 PM	3:00 PM	3:00 PM	6:00 PM	5:00 PM	2:00 PM	5:00 PM	5:00 PM
Con Edison	Hour Weight	10.1%	10.1%	10.1%	10.1%	10.0%	10.0%	9.9%	9.9%	9.9%	9.9%
	Day	13-Jun	20-Jul	13-Jun	20-Jul	13-Jun	20-Jul	20-Jul	13-Jul	13-Jun	13-Jul
	Hour	4:00 PM	4:00 PM	5:00 PM	3:00 PM	3:00 PM	2:00 PM	1:00 PM	2:00 PM	2:00 PM	1:00 PM

7.2.3 Coincident Generation, Distribution, and Sub-transmission Peak Reduction

Tables 7.8 and 7.9 set out the resulting estimate of coincident peak load reduction for each heat pump reference installation. To contextualize these kW capacity reductions, they are also presented in terms of coincidence percentage, where the percentage represents the coincident kW capacity reductions divided by the maximum kW reduction (counterfactual kW minus heat pump kW) in any hour of the year.

The tables include specific figures for counterfactual resistance heat replacements in NYSEG territory. As indicated in Table 7.7, NYSEG has a winter peak component in its top 10 hours for sub-transmission and distribution. For this utility, results are thus different depending whether the heat pump replaces oil/gas or electric heating. For all other utilities the results apply regardless of the counterfactual winter heating fuel.

Table 7-8. Coincident Peak Reduction per Installation, Single-Family Retrofit

			Generation Capacity		Sub-transmission Capacity		Distribution Capacity	
		Heat Pump System Size (tons)	Coincident kW Reduction	% Coincidence	Coincident kW Reduction	% Coincidence	Coincident kW Reduction	% Coincidence
ASHP	PSEG LI	3	0.19	49%	0.21	54%	0.21	54%
	ConEdison	3	0.19	49%	0.16	41%	0.16	41%
	Central Hudson	3	0.19	49%	0.21	54%	0.21	54%
	Nat Grid	3	0.14	49%	0.03	12%	0.03	12%
	RG&E	3	0.14	49%	0.02	6%	0.02	6%
	NYSEG CF Oil/Gas	3	0.14	49%	(0.44)	N/A	(0.44)	N/A
	NYSEG CF Electric	3	0.14	2%	1.28	18%	1.28	18%
	ORU	3	0.19	49%	0.13	33%	0.13	33%
Minisplit	PSEG LI	1.5	0.11	49%	0.12	54%	0.12	54%
	ConEdison	1.5	0.11	49%	0.09	41%	0.09	41%
	Central Hudson	1.5	0.11	49%	0.12	54%	0.12	54%
	Nat Grid	1.5	0.08	49%	0.02	12%	0.02	12%
	RG&E	1.5	0.08	49%	0.02	11%	0.02	11%
	NYSEG CF Oil/Gas	1.5	0.08	49%	(0.14)	N/A	(0.14)	N/A
	NYSEG CF Electric	1.5	0.08	2%	0.51	14%	0.51	14%
	ORU	1.5	0.11	49%	0.07	33%	0.07	33%
GSHP	PSEG LI	4	0.45	49%	0.49	54%	0.49	54%
	ConEdison	4	0.45	49%	0.37	41%	0.37	41%
	Central Hudson	4	0.45	49%	0.49	54%	0.49	54%
	Nat Grid	4	0.34	49%	0.08	12%	0.08	12%
	RG&E	4	0.45	49%	0.30	33%	0.30	33%
	NYSEG CF Oil/Gas	4	0.34	49%	(0.10)	N/A	(0.10)	N/A
	NYSEG CF Electric	4	0.34	3%	1.61	15%	1.61	15%
	ORU	4	0.45	49%	0.30	33%	0.30	33%

Table 7-9. Coincident Peak Reduction per Installation, Small Multifamily Retrofit

			Generation Capacity		Sub-transmission Capacity		Distribution Capacity	
		Heat Pump System Size (tons)	Coincident kW Reduction	% Coincidence	Coincident kW Reduction	% Coincidence	Coincident kW Reduction	% Coincidence
ASHP	PSEG LI	5	0.29	49%	0.32	54%	0.32	54%
	ConEdison	5	0.29	49%	0.24	41%	0.24	41%
	Central Hudson	5	0.29	49%	0.32	54%	0.32	54%
	Nat Grid	5	0.22	49%	0.05	12%	0.05	12%
	RG&E	5	0.22	49%	0.03	6%	0.03	6%
	NYSEG CF Oil/Gas	5	0.22	49%	(0.65)	N/A	(0.65)	N/A
	NYSEG CF Electric	5	0.22	2%	1.91	16%	1.91	16%
	ORU	5	0.29	49%	0.19	33%	0.19	33%
Minisplit	PSEG LI	3	0.22	49%	0.24	54%	0.24	54%
	ConEdison	3	0.22	49%	0.18	41%	0.18	41%
	Central Hudson	3	0.22	49%	0.25	54%	0.25	54%
	Nat Grid	3	0.17	49%	0.04	12%	0.04	12%
	RG&E	3	0.17	49%	0.04	11%	0.04	11%
	NYSEG CF Oil/Gas	3	0.17	49%	(0.27)	N/A	(0.27)	N/A
	NYSEG CF Electric	3	0.17	2%	1.01	14%	1.01	14%
	ORU	3	0.22	49%	0.15	33%	0.15	33%
GSHP	PSEG LI	6	0.67	49%	0.73	54%	0.73	54%
	ConEdison	6	0.67	49%	0.55	41%	0.55	41%
	Central Hudson	6	0.67	49%	0.74	54%	0.74	54%
	Nat Grid	6	0.50	49%	0.12	12%	0.12	12%
	RG&E	6	0.50	49%	0.17	16%	0.17	16%
	NYSEG CF Oil/Gas	6	0.50	49%	(0.15)	N/A	(0.15)	N/A
	NYSEG CF Electric	6	0.50	3%	2.42	15%	2.42	15%
	ORU	6	0.67	49%	0.45	33%	0.45	33%

Multiplying the value of deferred/avoided capacity per kW times the quantity of coincident kW peak reduction (grossed up for losses) yields the following value totals by category.

Table 7-10. Coincident Peak Reduction Value per Installation per Year, Single-Family Retrofit (2019)

	$2019	Generation	Sub-transmission	Distribution	Total
ASHP	PSEG LI	$21	$15	$20	$56
	ConEdison	$20	$0	$41	$62
	Central Hudson	$15	$0	$0	$15
	Nat Grid	$6	$1	$3	$10
	RG&E	$6	$0	$1	$7
	NYSEG CF Oil/Gas	$6	($2)	($15)	($11)
	NYSEG CF Electric	$6	$6	$45	$57
	ORU	$14	$5	$7	$26
Minisplit	PSEG LI	$12	$8	$12	$32
	ConEdison	$12	$0	$24	$36
	Central Hudson	$8	$0	$0	$8
	Nat Grid	$4	$1	$2	$6
	RG&E	$4	$0	$1	$4
	NYSEG CF Oil/Gas	$4	($1)	($5)	($2)
	NYSEG CF Electric	$4	$2	$18	$24
	ORU	$8	$3	$4	$15
GSHP	PSEG LI	$49	$34	$47	$130
	ConEdison	$47	$1	$95	$143
	Central Hudson	$34	$0	$0	$34
	Nat Grid	$15	$2	$6	$23
	RG&E	$15	$0	$4	$19
	NYSEG CF Oil/Gas	$15	($0)	($3)	$11
	NYSEG CF Electric	$15	$8	$57	$79
	ORU	$33	$12	$15	$60

Table 7-11. Coincident Peak Reduction Value per Installation per Year, Small Multifamily Retrofit (2019)

	$2019	Generation	Sub-transmission	Distribution	Total
ASHP	PSEG LI	$32	$22	$30	$84
	ConEdison	$30	$1	$62	$93
	Central Hudson	$22	$0	$0	$22
	Nat Grid	$10	$1	$4	$15
	RG&E	$9	$0	$1	$11
	NYSEG CF Oil/Gas	$9	($3)	($23)	($17)
	NYSEG CF Electric	$9	$9	$68	$86
	ORU	$21	$8	$10	$39
Minisplit	PSEG LI	$24	$17	$23	$65
	ConEdison	$23	$0	$47	$71
	Central Hudson	$17	$0	$0	$17
	Nat Grid	$7	$1	$3	$12
	RG&E	$7	$0	$1	$9
	NYSEG CF Oil/Gas	$7	($1)	($10)	($4)
	NYSEG CF Electric	$7	$5	$36	$48
	ORU	$16	$6	$8	$30
GSHP	PSEG LI	$74	$51	$70	$194
	ConEdison	$70	$1	$143	$215
	Central Hudson	$51	$0	$0	$51
	Nat Grid	$22	$3	$9	$35
	RG&E	$22	$1	$6	$29
	NYSEG CF Oil/Gas	$22	($1)	($5)	$16
	NYSEG CF Electric	$22	$12	$85	$119
	ORU	$50	$18	$23	$90

7.3 Avoided Cost of Natural Gas or Heating Oil

For the purpose of the SCT calculation, natural gas impacts were valued at the utility avoided cost level based on CARIS data available from NYISO. NYISO gas avoided costs are calculated by developing an index of regional utility avoided natural gas costs and applying these to a national forecast of delivered retail prices available from the EIA's Annual Energy Outlook.

This methodology yielded the following price inputs in 2018 (with values escalating according to the forecasts for future years).

Table 7-12. Natural Gas Avoided Costs by Region (2018)

NYISO Load Zones	Associated Regions in Analysis	2018 $/MCf	2018 $/MMBtu
A-E	Upstate/Western NY	$2.98	$2.89
F-I	Hudson Valley	$4.16	$4.04
J-K	NYC & Long Island	$3.72	$3.62

Fuel oil impacts were valued at the full-retail level, with values used as described in Section 6.4.

7.4 Carbon Savings

To calculate the value of avoided carbon dioxide equivalent (CO_2e) emissions, for each reference installation the analysis takes the amount of energy consumed of each fuel both in the heat pump and counterfactual case. The net reduction or increase in each fuel use (see Section 6.1) is multiplied by standard coefficients for the carbon intensity of natural gas, fuel oil, and grid electricity (see Table 7.13). Electricity carbon intensity accounts for electric grid line losses and is based on marginal grid emissions. Carbon intensity factors are maintained unchanged throughout the assessment period, reflecting a conservative approach in respect of expected ongoing carbon intensity reductions in the electricity mix.

Table 7-13. Carbon Intensity by Fuel Type

Fuel	Physical Units	lbs/ Physical Unit	lbs/ MMBtu
Electricity	kWh	1.16	340
Fuel Oil	gallon	22.5	164
Natural Gas	cubic feet	0.12	117

Table 7.14 shows the resulting average annual carbon savings (measured in metric tons), as differentiated by installation type and the counterfactual heating type. As noted, carbon savings per year are calculated as the net savings from the change in electric use (which is an increase in the case of heat pumps replacing oil or gas) and the reduction in oil or gas usage (where applicable).

Lifetime carbon savings per installation can be derived by multiplying these figures with the assumed installation lifetime of 15 years for ASHP/minisplit or 25 years for GSHP. As the table shows, installation emissions reductions are lowest for installations replacing counterfactual gas heat, and greatest for installations replacing counterfactual electric heat.

Table 7-14. Annual Net Carbon Savings per Installation (Metric Tons CO_2e)

Sector	Technology	Geography	Vintage	CF Natural Gas Heat	CF Fuel Oil Heat	CF Electric Heat
Single-Family	ASHP	NYC/LI/HV	Existing Building	1.3	4.1	6.9
			New Construction	0.7	3.6	6.4
		Upstate	Existing Building	1.6	5.1	8.5
			New Construction	0.8	4.5	8.1
	Minisplit	NYC/LI/HV	Both	0.5	1.6	2.7
		Upstate	Both	0.6	2.0	3.4
	GSHP	NYC/LI/HV	Both	2.5	5.4	8.3
		Upstate	Both	3.0	6.7	10.3
Small Multifamily	ASHP	NYC/LI/HV	Existing Building	2.0	6.3	10.6
			New Construction	1.0	5.4	9.7
		Upstate	Existing Building	2.5	7.9	13.3
			New Construction	1.2	6.7	12.2
	Minisplit	NYC/LI/HV	Both	1.1	3.3	5.4
		Upstate	Both	1.3	4.1	6.8
	GSHP	NYC/LI/HV	Both	3.7	8.1	12.4
		Upstate	Both	4.5	10.0	15.5

The quantity of annual carbon savings of each reference installation, in metric tons of CO_2e, is multiplied by the "Social Cost of Carbon," as published by the Environmental Protection Agency (EPA) to derive the monetary value of avoided carbon. Figure 7.7 shows the social cost of carbon used in this analysis.[22] This social cost of carbon forecast is consistent with the PSC's January 21, 2016 Order, "Order Establishing the Benefit Cost Analysis Framework," Note, however, that the specific values used reflect a slight modification due to a revision from the EPA. As regards carbon savings from electricity, the cost of carbon is limited to the value in excess of the carbon value already included in the wholesale electricity price through RGGI, since the RGGI carbon value is already counted as part of bulk electricity (see Section 7.1).

Figure 7-7. Social Cost of Carbon Value per Metric Ton of CO_2e (Nominal)

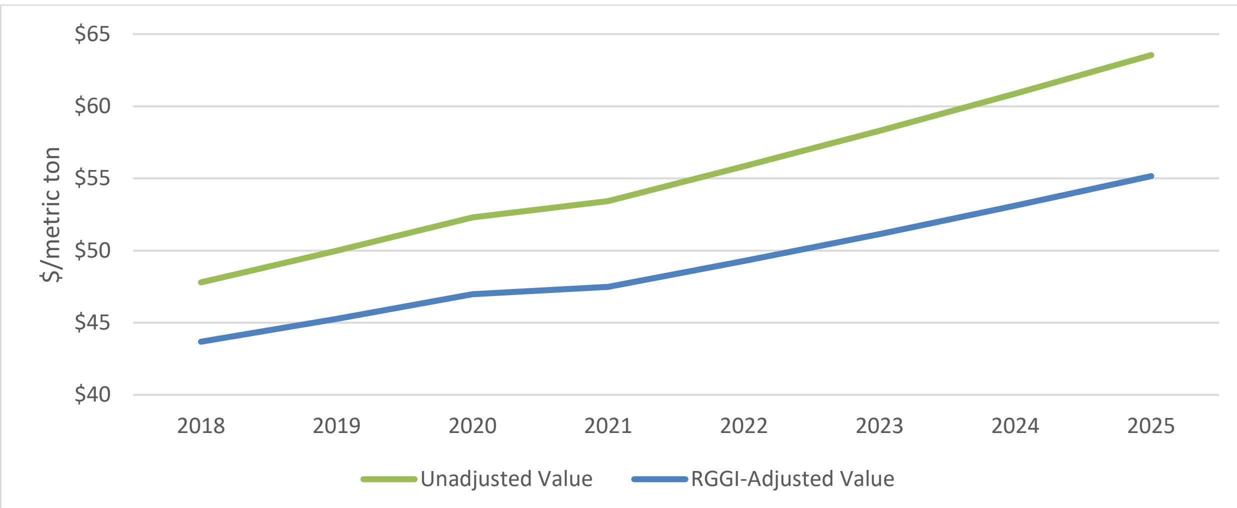


Table 7.15 provides the resulting annual value of carbon delivered by each reference installation, reflecting the product of the tons of carbon savings and the value per ton.

Table 7-15. Annual Carbon Value per Installation, 2019

Sector	Technology	Geography	Vintage	CF Natural Gas Heat	CF Fuel Oil Heat	CF Electric Heat
Single Family	ASHP	NYC, LI, HV	Existing Building	$82	$222	$311
Single Family	ASHP	NYC, LI, HV	New Construction	$53	$198	$291
Single Family	ASHP	Upstate	Existing Building	$99	$274	$385
Single Family	ASHP	Upstate	New Construction	$64	$249	$367
Single Family	Minisplit	NYC, LI, HV	Both	$33	$87	$122
Single Family	Minisplit	Upstate	Both	$40	$109	$153
Single Family	GSHP	NYC, LI, HV	Both	$135	$281	$374
Single Family	GSHP	Upstate	Both	$164	$349	$467
Small Multifamily	ASHP	NYC, LI, HV	Existing Building	$125	$341	$478
Small Multifamily	ASHP	NYC, LI, HV	New Construction	$79	$298	$437
Small Multifamily	ASHP	Upstate	Existing Building	$154	$427	$601
Small Multifamily	ASHP	Upstate	New Construction	$96	$374	$551
Small Multifamily	Minisplit	NYC, LI, HV	Both	$66	$175	$244
Small Multifamily	Minisplit	Upstate	Both	$79	$218	$307
Small Multifamily	GSHP	NYC, LI, HV	Both	$203	$421	$561
Small Multifamily	GSHP	Upstate	Both	$246	$524	$701

7.5 Economic Potential: Societal Cost Test Results

The annual impacts of the SCT benefit and cost components as described previously are discounted to a single net present value. Tables 7.16 and 7.17 provide summary results, reported as the amount of technical potential with a positive or negative resulting net present value under the SCT.

As the various cost and benefit components escalate over the years, the results of the SCT test change. To illustrate this, results are shown for the year 2019 as well as the average of the years 2019–2025.

Table 7-16. Summary Societal Cost Test Results, Small Residential, 2019

	Counter-factual Fuel	Technical Potential Passing SCT in 2019 [23]			Technical Potential Failing SCT in 2019		
		ASHP	Minisplit	GSHP	ASHP	Minisplit	GSHP
TBtu	Natural Gas	0.0	0.0	0.0	121.6	77.6	121.3
	Fuel Oil	52.1	33.6	53.3	0.0	0.0	0.0
	Electricity	9.9	0.0	6.7	0.2	6.8	3.6
Percentage	Natural Gas	0%	0%	0%	100%	100%	100%
	Fuel Oil	100%	100%	100%	0%	0%	0%
	Electricity	98%	0%	65%	2%	100%	35%

Table 7-17. Summary Societal Cost Test Results, Small Residential, 2019–2025 Average

	Counter-factual Fuel	Technical Potential Passing SCT in 2019-2025 (avg)			Technical Potential Failing SCT in 2019-2025 (avg)		
		ASHP	Minisplit	GSHP	ASHP	Minisplit	GSHP
TBtu	Natural Gas	0.0	0.0	0.0	121.6	77.6	121.3
	Fuel Oil	52.1	33.6	53.3	0.0	0.0	0.0
	Electricity	10.0	3.3	8.4	0.1	3.5	1.9
Percentage	Natural Gas	0%	0%	0%	100%	100%	100%
	Fuel Oil	100%	100%	100%	0%	0%	0%
	Electricity	99%	49%	82%	1%	51%	18%

The most significant differentiating factor impacting the SCT in this analysis is the counterfactual fuel. All installations replacing oil heating qualify under the SCT, but gas heating replacement installations are not assessed as meeting the SCT test over the analysis period. For installations replacing electric resistance heating, it can be observed that in 2019 most but not all reference installations pass the SCT. As a result of the cost reduction and other assumptions detailed throughout this Report, when measured as an average over the period 2019–2025, almost all electric replacements meet the SCT.

For the purpose of the uptake projection ("achievable potential") presented further in this Report, it is assumed that heat pump policy interventions aimed at encouraging customer adoption over the period to 2025 will focus on oil replacement and resistance heating replacement installations.

8 Customer Cost Effectiveness

The analysis assumes that for a typical customer a critical factor that determines whether a heat pump would be chosen instead of another heating/cooling solution is whether a heat pump is cost effective. Cost effectiveness is modeled as delivering at least a return on investment to the customer of 16% (nominal pre-finance pre-tax project internal rate of return), except for publicly owned multifamily housing for which a 10% hurdle rate is applied.[24] The return is calculated as the return from energy bill and operational savings (Section 6.5) on the incremental net capital cost of the heat pump (the installation cost minus value of avoided counterfactual capex and any tax credits, as discussed in Section 5), over the assumed useful life.

Heat pump equipment lifetimes are assumed as 15 years for ASHP and minisplit, and 25 years for GSHP, based on conversations with stakeholders and a review of the existing literature (such as the New York Technical Reference Manual, ASHRAE equipment standards, and reports from DOE National Laboratories).[25] Table 8.1 shows the IRR as calculated by the analysis as of 2019 across the range of reference installations, without subsidies (other than the federal tax credits for GSHP).

Outputs are not reported separately for single-family rented accommodation (outputs reflect owner occupied) and small multifamily publicly owned buildings (outputs reflect market-rate buildings) due to the small amount of resource potential of those segment in the current analysis, see Section 4.

Generally, installations replacing natural gas have negative IRRs (indicating that customers do not experience any payback during the life of the installed equipment). This is in line with the findings in Section 7, which concluded that gas replacement installations were as yet not cost-effective under an SCT. Accordingly, gas replacement installations are not considered in the remainder of the analysis presented in this Report.

Installations replacing fuel oil and electric heating generally experience positive IRRs, with the customer proposition for replacing electric resistance heat offering the greatest value proposition. However, and in spite of cost reductions that have occurred since the publication of the 2017 Framework, Table 8.1 indicates that in most cases these market segments do not yet deliver a sufficient rate of return to customers.

Table 8-1. Internal Rate of Return, Small Residential (2019)

Counter-factual Fuel	Geography	Sector	ASHP Existing Building	ASHP New Constr.	Minisplit Existing Building	Minisplit New Constr.	GSHP Existing Building	GSHP New Constr.
Natural Gas	Long Island	Single fam.	-34%	None	None	None	-2%	-1%
		Small MF	None	None	None	None	-5%	-4%
	NYC	Single fam.	None	None	None	None	-8%	-7%
		Small MF	None	None	None	None	-10%	-10%
	Hudson Valley	Single fam.	-10%	-10%	-15%	-15%	0%	1%
		Small MF	-12%	-13%	-15%	-15%	-3%	-2%
	Upstate/Western	Single fam.	-16%	-17%	-23%	-23%	-2%	-1%
		Small MF	-17%	-21%	-23%	-23%	-5%	-4%
Fuel Oil	Long Island	Single fam.	5%	10%	4%	4%	10%	12%
		Small MF	4%	5%	4%	4%	5%	6%
	NYC	Single fam.	1%	N/A	-1%	N/A	8%	N/A
		Small MF	0%	N/A	-1%	N/A	4%	N/A
	Hudson Valley	Single fam.	9%	16%	7%	7%	12%	14%
		Small MF	7%	10%	7%	7%	6%	7%
	Upstate/Western	Single fam.	15%	24%	14%	14%	16%	18%
		Small MF	13%	17%	14%	14%	10%	11%
Electricity	Long Island	Single fam.	18%	N/A	17%	N/A	12%	N/A
		Small MF	16%	N/A	17%	N/A	9%	N/A
	NYC	Single fam.	22%	N/A	20%	N/A	14%	N/A
		Small MF	19%	N/A	20%	N/A	10%	N/A
	Hudson Valley	Single fam.	11%	N/A	10%	N/A	8%	N/A
		Small MF	10%	N/A	10%	N/A	5%	N/A
	Upstate/Western	Single fam.	10%	N/A	9%	N/A	7%	N/A
		Small MF	9%	N/A	9%	N/A	5%	N/A

Note "N/A" refers to reference installations with zero resource. "None" indicates cases where no return can be calculated (for example, cases where annual energy bill savings are negative).

Table 8.2 shows the corresponding amount of upfront payment that would need to be provided to customers in each market segment to allow the rate of return to reach the assumed hurdle rate of 16% in 2019 – also referred to as "missing money."[26]

Note that this analysis assumes upfront payments. If payments were provided to customers over time, customers would likely discount such future payments significantly, in which case higher payment amounts would need to be provided to still overcome the missing money hurdle.

The amount of missing money roughly corresponds to the IRR values—for instance, the necessary amount is less for reference installations that are already close to the 16% investor threshold.

Table 8-2. Missing Money per Installation, Small Residential (2019)

Counter-factual Fuel	Geography	Sub Sector	ASHP		Minisplit		GSHP	
			Existing Building	New Constr.	Existing Building	New Constr.	Existing Building	New Constr.
Fuel Oil	Long Island	Single Fam.	$5,718	$2,218	$2,545	$2,545	$7,390	$4,559
		Small MF	$10,583	$7,855	$5,090	$5,090	$22,657	$19,564
	NYC	Single Fam.	$8,205	N/A	$3,529	N/A	$10,701	N/A
		Small MF	$14,545	N/A	$7,057	N/A	$27,570	N/A
	Hudson Valley	Single Fam.	$3,901	$35	$1,838	$1,838	$5,514	$2,776
		Small MF	$7,725	$4,433	$3,675	$3,675	$20,013	$17,020
	Upstate/Western	Single Fam.	$671	$0	$565	$565	$342	$0
		Small MF	$2,479	$0	$1,129	$1,129	$13,914	$10,921
Electricity	Long Island	Single Fam.	$0	N/A	$0	N/A	$7,325	N/A
		Small MF	$0	N/A	$0	N/A	$19,901	N/A
	NYC	Single Fam.	$0	N/A	$0	N/A	$3,707	N/A
		Small MF	$0	N/A	$0	N/A	$16,529	N/A
	Hudson Valley	Single Fam.	$2,674	N/A	$1,359	N/A	$14,638	N/A
		Small MF	$5,837	N/A	$2,718	N/A	$28,063	N/A
	Upstate/Western	Single Fam.	$3,103	N/A	$1,530	N/A	$15,281	N/A
		Small MF	$6,275	N/A	$3,060	N/A	$28,796	N/A

The IRR and missing money figures shown are projected for heat pump installations in 2019. Both indicators will change for reference installations that would be installed in subsequent years, as a function of the various factors described earlier in this study, in particular projected changes in capital cost and energy bill savings. Generally, IRR is projected to increase over time and missing money is projected to reduce, as energy prices (and thus net energy bill savings) increase and incremental heat pump capital costs reduce.

9 Value and Cost Shift Opportunities

Cost effectiveness as assessed in this analysis from the perspective of the customer reflects the balance of on the one hand (typically) increased upfront costs for a heat pump compared to conventional HVAC installations and on the other hand the value of energy bill savings. As discussed in Section 8, this value often does not deliver a sufficient payback or return to the customer. However, installing a heat pump can deliver a number of other "value" streams. These may not currently translate into a monetary payment to the customer but may constitute real benefits either for ratepayers or society as a whole. In addition, the analysis identifies instances where typical residential electric rate structures may not result in a fair level of net bill savings for heat pump customers. A comprehensive analysis should attempt to quantify these values and effects in order to allow options to be considered to deliver appropriate greater levels of monetization to customers and help overcome "missing money" hurdles.

While this analysis is not exhaustive in quantifying all potential value and benefit opportunities, it has assessed three such factors:

- The societal value of reducing greenhouse gas emissions ("carbon value")
- The value to ratepayers of reducing systemwide peak electric load
- The so-called "inverse cost shift" effect, which can result in heat pump customers paying for more than their fair share of fixed electric grid costs, reducing burdens on other ratepayers

The analysis on carbon value and peak reduction value has already been discussed in Section 7.

The "inverse cost shift" refers to the following effect. Customers who install heat pump technology to replace conventional oil or gas combustion heating and air conditioning increase electricity usage during the winter and decrease electricity usage during the summer. For many customers, the result is a net increase in annual electricity usage that results in a net annual bill increase and increased revenues for the utility. Because the system is generally less constrained in the winter heating season, the increase in cost for the utility to provide the additional electricity in the winter is often less than the increase in revenue for the utility. This phenomenon most typically occurs for installations in the residential sector and is largely due to the structure of volumetrically based retail rates in the residential sector, which are designed to recover both variable costs as well as a portion of fixed-system infrastructure costs through a variable rate.

For regulated utilities that earn a specified return on invested capital, an increase in utility revenues that exceeds the cost to serve additional load cannot be retained as profit but must be returned to utility ratepayers. As a result of these dynamics, the installation of a heat pump may lead the customer to start paying for a relatively larger fraction of the total systemwide grid infrastructure costs, which in turn, translates to a rate decrease for ratepayers as a whole; an "inverse cost shift" from non-heat pump ratepayers to the heat pump customer occurs. Rectifying this cost shift could improve the payback for customers.

To quantify the inverse cost shift, this analysis compares the change in customer electricity bills between the heat pump and counterfactual case to the change in utility costs of providing the additional electricity; to the extent, upon installation of the heat pump, the customer's electricity bill is calculated to increase by more than the underpinning utility cost of procuring the bulk electricity, this is counted as the inverse cost shift.

Both components of this calculation have been discussed; see Section 6.3 for the calculation of the customer's electricity bill and Section 7.1 for the calculation of bulk electricity costs. Combining the utility revenue increases (customer bill changes) and utility cost increases yields the total inverse cost-shift benefit to non-heat pump customers as shown in Tables 9.1 and 9.2.

Note that the inverse cost shift analysis is based on standard electric rates available to residential customers. The analysis does not consider utility programs or initiatives outside standard electric rates that may already monetize part of the cost shift calculation for the benefit of either residential customers with high overall winter usage, or more specifically, heat pump customers. For instance, PSEG Long Island offers customers with electric heating (including heat pump users) an opt-in rebate of $0.03 per kWh during the winter months, which addresses part of the inverse cost shift for Long Island.

Table 9-1. Inverse Cost Shift per Installation per Year, Single-Family, Fuel Oil Replacement Retrofit (2019)

	2019 Annual	Bill Change	Utility Cost Change	Inverse Cost Shift
ASHP	PSEG LI	$1,202	$296	$906
	ConEdison	$1,476	$289	$1,187
	Central Hudson	$819	$282	$537
	Nat Grid	$803	$269	$534
	RG&E	$829	$233	$596
	NYSEG	$1,196	$257	$940
	ORU	$1,062	$277	$786
Minisplit	PSEG LI	$461	$114	$347
	ConEdison	$566	$112	$454
	Central Hudson	$314	$109	$205
	Nat Grid	$316	$106	$210
	RG&E	$327	$92	$235
	NYSEG	$472	$101	$370
	ORU	$407	$107	$300
GSHP	PSEG LI	$843	$206	$637
	ConEdison	$1,030	$203	$827
	Central Hudson	$574	$199	$375
	Nat Grid	$596	$200	$396
	RG&E	$616	$173	$443
	NYSEG	$888	$190	$698
	ORU	$740	$195	$545

Table 9-2. Inverse Cost Shift per Installation per Year, Small Multifamily, Fuel Oil Replacement Retrofit (2019)

	2019 Annual	Bill Change	Utility Cost Change	Inverse Cost Shift
ASHP	PSEG LI	$1,851	$459	$1,392
	ConEdison	$2,273	$448	$1,826
	Central Hudson	$1,261	$437	$825
	Nat Grid	$1,253	$421	$833
	RG&E	$1,294	$365	$930
	NYSEG	$1,868	$402	$1,466
	ORU	$1,636	$428	$1,208
Minisplit	PSEG LI	$923	$228	$695
	ConEdison	$1,132	$223	$909
	Central Hudson	$629	$218	$411
	Nat Grid	$633	$213	$420
	RG&E	$654	$184	$470
	NYSEG	$943	$203	$740
	ORU	$815	$214	$601
GSHP	PSEG LI	$1,264	$309	$955
	ConEdison	$1,545	$305	$1,240
	Central Hudson	$861	$298	$563
	Nat Grid	$894	$300	$594
	RG&E	$923	$259	$664
	NYSEG	$1,332	$286	$1,047
	ORU	$1,110	$292	$818

Inverse cost shift projections for years beyond 2019 will rise as a function of escalation of the components of the cost shift calculation, i.e., customer electricity bill and avoided bulk electricity generation and distribution costs, as discussed in Sections 6 and 7.

The inverse cost shift is quantified in this analysis for heat pumps replacing fuel oil only. Current resistance heating users are likely to be subject to an inverse cost shift burden greater than heat pump users given the very high winter electricity usage resulting from electric resistance heating. When switching to a heat pump, the inverse cost shift for such customers would reduce to the levels projected in this analysis. In other words, heat pumps replacing resistance heating are unlikely to create a new inverse cost shift effect as oil (or gas) replacements do but are likely to reduce an existing inverse cost shift.

10 Achievable Potential

In this analysis, achievable potential describes the projection of customer heat pump adoption that is projected to occur depending on the extent to which heat pumps are cost effective from the customer's point of view. Section 8 describes the missing money hurdle that would need to be overcome to achieve such cost effectiveness. Section 9 summarizes the value and cost shift opportunities that, if monetized for customers, could help to overcome such missing money hurdles without constituting a net burden for ratepayers and society.

Tables 10.1 and 10.2 provide a comparison between the missing money and value/benefit quantification for the key reference installations examined in this analysis. Missing money has been quantified as upfront amounts (i.e., the portion of installation capex that would need to be provided to customers to overcome the missing money hurdle). The tables also provide the carbon value, peak value, and inverse cost shift effects expressed as upfront amounts to enable a like-for-like comparison. These upfront amounts are calculated as the value/benefit stream over the lifetime of the installation (reflecting escalation of each component as discussed throughout this Report), discounted to a net present value amount at the societal discount rate of 5.5% (real).

Table 10-1. Missing Money and NPV Lifetime Value/Inverse Cost Shift per Installation, Single-Family Retrofit, 2019

Technology	CF Fuel	Geography	Missing Money	Carbon Value	Peak Value	Inverse Cost Shift
ASHP	Fuel Oil	Long Island	$5,718	$2,644	$661	$10,007
		NYC	$8,205	$2,644	$793	$13,962
		Hudson Valley	$3,901	$2,644	$202	$7,696
		Upstate/Western	$671	$3,266	$91	$6,941
	Electricity	Long Island	$0	$3,527	$661	N/A[27]
		NYC	$0	$3,527	$793	N/A
		Hudson Valley	$2,674	$3,527	$202	N/A
		Upstate/Western	$3,103	$4,370	$91	N/A
Minisplit	Fuel Oil	Long Island	$2,545	$1,041	$382	$3,838
		NYC	$3,529	$1,041	$459	$5,347
		Hudson Valley	$1,838	$1,041	$117	$2,948
		Upstate/Western	$565	$1,302	$53	$2,733
	Electricity	Long Island	$0	$1,386	$382	N/A
		NYC	$0	$1,386	$459	N/A
		Hudson Valley	$1,359	$1,386	$117	N/A
		Upstate/Western	$1,530	$1,740	$53	N/A
GSHP	Fuel Oil	Long Island	$7,390	$4,358	$2,106	$9,645
		NYC	$10,701	$4,358	$2,526	$13,187
		Hudson Valley	$5,514	$4,358	$692	$7,260
		Upstate/Western	$342	$5,425	$310	$7,068
	Electricity	Long Island	$7,325	$5,552	$2,106	N/A
		NYC	$3,707	$5,552	$2,526	N/A
		Hudson Valley	$14,638	$5,552	$692	N/A
		Upstate/Western	$15,281	$6,944	$310	N/A

Table 10-2. Missing Money and NPV Lifetime Value/Inverse Cost Shift per Installation, Single-Family Retrofit, 2019–2025 Average

Technology	CF Fuel	Geography	Missing Money	Carbon Value	Peak Value	Inverse Cost Shift
ASHP	Fuel Oil	Long Island	$3,529	$2,873	$732	$10,973
		NYC	$6,442	$2,873	$881	$15,172
		Hudson Valley	$2,268	$2,873	$240	$8,382
		Upstate/Western	$335	$3,550	$105	$7,680
	Electricity	Long Island	$0	$3,803	$732	N/A[28]
		NYC	$0	$3,803	$881	N/A
		Hudson Valley	$1,337	$3,803	$240	N/A
		Upstate/Western	$1,551	$4,712	$105	N/A
Minisplit	Fuel Oil	Long Island	$1,645	$1,131	$423	$4,209
		NYC	$2,789	$1,131	$510	$5,811
		Hudson Valley	$1,154	$1,131	$139	$3,211
		Upstate/Western	$282	$1,415	$61	$3,024
	Electricity	Long Island	$0	$1,494	$423	N/A
		NYC	$0	$1,494	$510	N/A
		Hudson Valley	$680	$1,494	$139	N/A
		Upstate/Western	$765	$1,876	$61	N/A
GSHP	Fuel Oil	Long Island	$5,582	$4,641	$2,307	$10,522
		NYC	$9,499	$4,641	$2,776	$14,294
		Hudson Valley	$4,324	$4,641	$799	$7,866
		Upstate/Western	$171	$5,778	$350	$7,751
	Electricity	Long Island	$6,918	$5,884	$2,307	N/A
		NYC	$1,853	$5,884	$2,776	N/A
		Hudson Valley	$12,543	$5,884	$799	N/A
		Upstate/Western	$13,729	$7,360	$350	N/A

The comparison in Tables 10.1 and 10.2 indicates there is substantial potential to address the inverse cost shift and peak reduction value to the point where oil heating replacement heat pumps could be considered cost effective, while still delivering net monetary benefits to ratepayers. The carbon value of increased heat pump adoption provides an important further societal benefit resulting from increased heat pump adoption. In the case of electric resistance heat replacements where the same inverse cost shift does not occur, the combination of carbon value and peak reduction value exceeds the missing money in most cases.

Based on the SCT results discussed in Section 7, the analysis considers a policy scenario where action is taken throughout the period of 2019–2025 to overcome adoption hurdles at least for heat pumps replacing oil and resistance heating; based on the comparison between missing money levels and value/benefits as shown in Tables 10.1 and 10.2, the analysis assumes that across the full range of single-family and small multifamily oil and resistance heating replacements, such policy action would include sufficient monetization of value or cost shift to enable heat pumps to become cost effective from the customer’s perspective. No assumption is made in this analysis as to the type of program or other intervention used to deliver such monetization. Designs to optimize cost effectiveness of such programs would need to be considered, recognizing that it would likely not be feasible to design programs that deliver tailored missing money monetization by individual market segment as modeled in this analysis.

On this basis, the analysis assumes that within each of the oil and electric replacement heat pump market segments, uptake occurs in line with an adoption trajectory as set out in Table 10.3. This trajectory is expressed as the percentage of end-of-life replacement retrofits and new-build customers who adopt a heat pump solution as their new or replacement technology. The amount of such end-of-life resource potential for each market segment as well as the end-of-life replacement cycle are discussed in Section 4. It is assumed that—over the period under assessment—each heat pump technology can be considered as a separate market, with its own adoption trajectory.

Table 10-3. Heat Pump Adoption Trajectory, Percentage of End-of-Life Replacements/New Construction

Year	All Technologies
2019	5.0%
2020	7.5%
2021	10.0%
2022	12.5%
2023	15.0%
2024	17.5%
2025	20.0%

Given the nascent nature of the (cold climate) heat pump market in New York, data availability to support adoption trajectory assumptions is limited. As set in the analysis, the adoption trajectory is considered aggressive but achievable, assuming a comprehensive supporting policy environment as outlined in the 2017 Framework publication, including both “missing money” monetization and flanking initiatives aimed at overcoming nonfinancial barriers.

A number of aspects relevant to achievable heat pump penetration levels are outside the scope of the current analysis (see also the scoping notes in Section 2). These can be considered to increase the confidence level in the projected overall adoption trajectories:

- Heat pump water heaters replacing conventional hot water heating have not been assessed but could be included in a long-term heat pump policy framework.
- Modeling assumptions of zero uptake in the gas replacement sector and no heat pump adoption ahead of the end of life of the old heating equipment are likely conservative.
- Some of the current technology and site suitability constraints—in particular, the availability of heat pump systems suitable for hydronic distribution systems and barriers in landlord-tenant situations—will likely be overcome at least to some extent over the period to 2025.
- The analysis does not make an explicit assessment of adoption—potentially at higher levels than assumed in this analysis—that may occur where specific locational value exists; for example, value of avoided gas grid infrastructure investments.

The resulting adoption projection is shown in Tables 10.4 through 10.8. A summary table with year-by-year results for 2019–2025 is followed by detailed cumulative results by reference installation, showing:

- The number of installations projected to be adopted by 2025
- Space heating and cooling load served by such installations in 2025
- The net site energy savings delivered by such installation in 2025
- The lifetime carbon savings delivered by such installations in 2025

Table 10-4. Achievable Potential—Small Residential Summary by Year

Year		2019	2020	2021	2022	2023	2024	2025	Total
Installations (1000s)	ASHP	1.9	2.9	3.8	4.8	5.8	6.7	7.7	**33.7**
	Minisplit	2.9	4.4	6.0	7.8	9.3	10.9	12.4	**53.7**
	GSHP	1.8	2.8	3.8	4.4	5.6	6.5	7.6	**32.5**
	Total	**6.7**	**10.1**	**13.6**	**17.0**	**20.7**	**24.1**	**27.7**	**119.9**
Annual TBtu Load Served (New Installs)	ASHP	0.2	0.2	0.3	0.4	0.5	0.6	0.7	**2.9**
	Minisplit	0.1	0.1	0.2	0.3	0.3	0.4	0.4	**1.8**
	GSHP	0.2	0.2	0.3	0.4	0.5	0.6	0.7	**2.9**
	Total	**0.4**	**0.6**	**0.9**	**1.1**	**1.3**	**1.5**	**1.7**	**7.5**
Annual TBtu Site Energy Savings (New Installs)	ASHP	0.2	0.2	0.3	0.4	0.5	0.5	0.6	**2.7**
	Minisplit	0.1	0.1	0.2	0.2	0.3	0.3	0.4	**1.7**
	GSHP	0.2	0.3	0.3	0.4	0.5	0.6	0.7	**3.0**
	Total	**0.4**	**0.6**	**0.9**	**1.1**	**1.3**	**1.5**	**1.7**	**7.5**
Lifetime Metric Tons CO_2e Avoided (New Installs) (1000s)	ASHP	144	215	287	359	432	503	575	**2,514**
	Minisplit	85	128	174	236	283	330	378	**1,614**
	GSHP	295	453	603	680	891	1,040	1,222	**5,183**
	Total	**524**	**796**	**1,065**	**1,274**	**1,606**	**1,873**	**2,174**	**9,312**

Table 10-5. Achievable Potential—Small Residential Cumulative Installations in 2025

Counter-factual Fuel	Geography	Sub-sector	ASHP		Minisplit		GSHP		Total
			Existing	New	Existing	New	Existing	New	
Fuel Oil	Long Island	Single Fam.	9,719	723	16,191	723	9,719	723	**37,798**
		Small MF	57	5	93	5	57	5	**222**
	NYC	Single Fam.	1,699	N/A	2,834	N/A	1,363	N/A	**5,896**
		Small MF	260	N/A	433	N/A	207	N/A	**900**
	Hudson Valley	Single Fam.	5,750	738	9,575	738	5,750	738	**23,289**
		Small MF	105	10	172	10	105	10	**412**
	Upstate/ Western	Single Fam.	8,532	1,034	14,220	1,034	8,532	1,034	**34,386**
		Small MF	80	4	133	4	80	4	**305**
Electricity	Long Island	Single Fam.	657	N/A	1,095	N/A	608	N/A	**2,360**
		Small MF	25	N/A	42	N/A	16	N/A	**83**
	NYC	Single Fam.	474	N/A	790	N/A	272	N/A	**1,536**
		Small MF	108	N/A	178	N/A	53	N/A	**339**
	Hudson Valley	Single Fam.	844	N/A	1,303	N/A	600	N/A	**2,747**
		Small MF	53	N/A	81	N/A	32	N/A	**166**
	Upstate/ Western	Single Fam.	2,616	N/A	3,799	N/A	2,418	N/A	**8,833**
		Small MF	181	N/A	258	N/A	141	N/A	**580**

Note “N/A” indicates reference installations with zero resource potential

Table 10-6. Achievable Potential—Small Residential Cumulative Thermal Load Served, Billion British Thermal Units (GBtu) in 2025

Counter-factual Fuel	Geography	Sub- sector	ASHP		Minisplit		GSHP		Total
			Existing	New	Existing	New	Existing	New	
Fuel Oil	Long Island	Single Fam.	775	60	500	22	801	60	**2,218**
		Small MF	7	1	6	0	7	1	**21**
	NYC	Single Fam.	136	N/A	88	N/A	112	N/A	**335**
		Small MF	32	N/A	27	N/A	26	N/A	**84**
	Hudson Valley	Single Fam.	459	61	296	23	474	61	**1,373**
		Small MF	13	1	11	1	13	1	**40**
	Upstate/ Western	Single Fam.	770	98	507	37	811	98	**2,320**
		Small MF	11	1	9	0	11	1	**34**
Electricity	Long Island	Single Fam.	52	N/A	34	N/A	50	N/A	**136**
		Small MF	3	N/A	3	N/A	2	N/A	**8**
	NYC	Single Fam.	38	N/A	24	N/A	22	N/A	**85**
		Small MF	13	N/A	11	N/A	7	N/A	**31**
	Hudson Valley	Single Fam.	67	N/A	40	N/A	49	N/A	**157**
		Small MF	6	N/A	5	N/A	4	N/A	**15**
	Upstate/ Western	Single Fam.	236	N/A	135	N/A	230	N/A	**601**
		Small MF	25	N/A	18	N/A	20	N/A	**64**

Table 10-7. Achievable Potential—Small Residential Cumulative Net Site Energy Savings, Billion British Thermal Units (GBtu) 2019–2025

Counter-factual Fuel	Geography	Sub-sector	ASHP		Minisplit		GSHP		Total
			Existing	New	Existing	New	Existing	New	
Fuel Oil	Long Island	Single Fam.	763	56	498	22	863	64	**2,265**
		Small MF	7	1	6	0	8	1	**22**
	NYC	Single Fam.	133	N/A	87	N/A	121	N/A	**341**
		Small MF	31	N/A	27	N/A	28	N/A	**86**
	Hudson Valley	Single Fam.	451	57	294	23	511	66	**1,401**
		Small MF	13	1	11	1	14	1	**40**
	Upstate/ Western	Single Fam.	832	101	552	40	954	116	**2,594**
		Small MF	12	1	10	0	13	1	**37**
Electricity	Long Island	Single Fam.	29	N/A	19	N/A	33	N/A	**81**
		Small MF	2	N/A	1	N/A	1	N/A	**4**
	NYC	Single Fam.	21	N/A	14	N/A	15	N/A	**50**
		Small MF	7	N/A	6	N/A	4	N/A	**18**
	Hudson Valley	Single Fam.	38	N/A	23	N/A	32	N/A	**93**
		Small MF	4	N/A	3	N/A	3	N/A	**9**
	Upstate/ Western	Single Fam.	144	N/A	84	N/A	162	N/A	**390**
		Small MF	16	N/A	11	N/A	14	N/A	**41**

Table 10-8. Achievable Potential—Small Residential, Cumulative Lifetime Metric Tons of Carbon Equivalent Avoided 2019–2025 (1,000s)

Counter-factual Fuel	Geography	Sub Sector	ASHP		Minisplit		GSHP		Total
			Existing	New	Existing	New	Existing	New	
Fuel Oil	Long Island	Single Fam.	601	39	395	18	1,312	98	**2,462**
		Small MF	5	0	5	0	12	1	**23**
	NYC	Single Fam.	105	N/A	69	N/A	184	N/A	**358**
		Small MF	25	N/A	21	N/A	42	N/A	**88**
	Hudson Valley	Single Fam.	356	40	234	18	776	100	**1,523**
		Small MF	10	1	8	0	21	2	**43**
	Upstate/ Western	Single Fam.	650	69	432	31	1,428	173	**2,784**
		Small MF	10	0	8	0	20	1	**39**
Electricity	Long Island	Single Fam.	68	N/A	44	N/A	125	N/A	**237**
		Small MF	4	N/A	3	N/A	5	N/A	**12**
	NYC	Single Fam.	49	N/A	32	N/A	56	N/A	**137**
		Small MF	17	N/A	14	N/A	16	N/A	**48**
	Hudson Valley	Single Fam.	87	N/A	53	N/A	124	N/A	**263**
		Small MF	8	N/A	7	N/A	10	N/A	**25**
	Upstate/ Western	Single Fam.	334	N/A	193	N/A	624	N/A	**1,151**
		Small MF	36	N/A	26	N/A	55	N/A	**117**

The projection of around 7.5 TBtu of net all-fuels site energy savings by 2025 (incremental compared to 2018) reflects the majority of the heat pump scenario of 8 TBtu considered in the White Paper. The main difference reflects limited inclusion of large multifamily buildings in the White Paper scenario. The current Report covers the single-family and small multifamily residential sectors; further NYSERDA analysis of large multifamily and commercial installations is ongoing.

The projection of net site energy savings for New York's jurisdictional utilities (excluding Long Island) included in Table 10.7 is slightly more than 5 TBtu, consistent with the 5 TBtu target set out by the Public Service Commission's Order of December 13, 2018.

The projections are subject to a range of uncertainties around each of the input assumptions described throughout this Report. In addition, this Report does not assess differences between policy and program options that could be used to deliver heat pump adoption—as noted previously, the analysis projects adoption on the basis of each reference installation receiving the "missing money" calculated for such installation. Adoption projections would be expected to deviate depending on the design of implementation policies. For example, as part of a New Efficiency: New York public forum held on October 3, NYSERDA presented an illustrative heat pump policy scenario based on the analysis presented in this Report, but assuming a program option of statewide rebates; this option was projected to deliver around 6 TBtu of Statewide site energy savings from small residential heat pumps.

Both the methodological framework as well as the data presented in this Report are made available to support the process of designing and implementing heat pump program proposals as called for in the PSC's Order.

Endnotes

1 http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=18-m-0084&submit=Search ; see also https://www.nyserda.ny.gov/About/Publications/New-Efficiency

2 See https://www.nyserda.ny.gov/All-Programs/Programs/Ground-Source-Heat-Pump-Rebate and https://www.nyserda.ny.gov/All-Programs/Programs/Air-Source-Heat-Pump-Program for NYSERDA's current heat pump rebate programs. Heat pump incentive programs are also offered by a number of New York's utilities.

3 http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={B330F932-3BB9-46FA-9223-0E8A408C1928}.

4 https://www.nyserda.ny.gov/Researchers-and-Policymakers/Clean-Heating-and-Cooling

5 "Counterfactual" describes the situation that would occur where sites do not install a heat pump solution. The counterfactual heating fuel is thus the heating fuel that would be used in the absence of heating by means of a heat pump.

6 https://openei.org/doe-opendata/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states

7 TMY (typical meteorological year) is a set of hourly weather data including temperature, humidity, insolation, and others for a specific location. This data represents the weather in a typical year while still maintaining the variability of weather on a day-to-day basis. TMY3 is the third iteration of the TMY which is released by the National Renewable Energy Laboratory (NREL). For more information, see https://www.nrel.gov/docs/fy08osti/43156.pdf.

8 www.rsmeans.com

9 This only applies for sites using electric resistance heating as the counterfactual heating fuel.

10 Excludes small amount of electricity for resistance heating operation during peak heating hours that is assumed to additionally be used in the case of an ASHP displacing resistance heating in an existing building. Such additional electric use is however accounted for in the electricity bill calculations in Section 6.3.

11 www.nyiso.com/public/webdocs/markets_operations/committees/bic_espwg/meeting_materials/2018-03-01/03_2017_Report_CARIS2017_final_draft_030118_ESPWG_REDLINE.pdf

12 http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7BFB2EBAEA-7DF0-48B9-A479-B2F742B74D02%7D

13 ConEd, O&R = 2.53%; Central Hudson, National Grid, NYSEG, RG&E = 2.27%; PSEG LI = 2.43%

14 With the exception of the small amount of peak winter resistance heating that is still assumed to take place where ASHP displaces electric resistance heating in existing buildings; this is included in both the counterfactual and heat pump case electric bill calculation.

15 Order Establishing the Benefit Cost Analysis Framework, Case No. 14-M-0101 (Jan. 21, 2016).

16 *Ibid.* at 26–27.

17 www.nyiso.com/public/webdocs/markets_operations/committees/bic_espwg/meeting_materials/2018-03-01/03_2017_Report_CARIS2017_final_draft_030118_ESPWG_REDLINE.pdf

18 http://www.nyiso.com/public/webdocs/markets_operations/committees/bic_espwg/meeting_materials/2018-02-22/2017_Report_CARIS2017_Appendix.pdf

19 http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7BFB2EBAEA-7DF0-48B9-A479-B2F742B74D02%7D

20 Documents are publicly available on NY PSC website: Matter Number 15-00990, Case Number 15-M-0252. PSEG Long Island data estimated from 2015 NYSERDA NEM analysis.

21 https://www.nyserda.ny.gov/All-Programs/Programs/NY-Sun/Contractors/Value-of-Distributed-Energy-Resources/Solar-Value-Stack-Calculator

22 EPA's Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866 (May 2013, Revised July 2015).

23 Technical resource as calculated in Section 4 (see Table 4.8), reflecting current resource and new build over the period 2019-2025.

24 Defined as the rate at which the net cash flows of a reference installation heat pump over its useful life must be discounted to yield a net present value equal to the net upfront investment.

[25] Many of the below-ground components of a GSHP system could be expected to have a substantially longer equipment lifetime than the 25-year lifetime of the above-ground components. Consistent with prior studies of GSHP cost effectiveness, the decision was made to calculate project economics based on the lifetime of the system as a whole, and thus treat GSHP expected lifetime based on the above-ground components.

[26] In the case of GSHP installations an assumed upfront missing money payment would likely result in a reduction of available federal tax credits – where the customer receives a state-level upfront subsidy payment, such amount generally reduces the equipment capital cost that is accounted for the purpose of calculating the value of the federal tax credit (which is expressed as a percentage of capital cost, see Section 5). Accordingly, the GSHP missing money amounts shown reflect grossed-up amounts that would compensate for this loss of tax credit.

[27] Not assessed for resistance heat replacements, see Section 9.

[28] Not assessed for resistance heat replacements, see Section 9.

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New York State
Energy Research and
Development Authority

17 Columbia Circle
Albany, NY 12203-6399

toll free: 866-NYSERDA
local: 518-862-1090
fax: 518-862-1091

info@nyserda.ny.gov
nyserda.ny.gov

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