Renewable Heating and Cooling Policy Framework:

Options to Advance Industry Growth and Markets in New York

February 7, 2017

NEW YORK STATE OF OPPORTUNITY. | NYSERDA

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EXECUTIVE SUMMARY

Thermal energy use for space heating, space cooling, domestic hot water, and process heat makes up a major part of New York State's energy system and is a substantial contributor to the State's greenhouse gas (GHG) emissions. Thermal energy in New York State's residential and commercial sector constitutes approximately 37% of statewide net energy consumption. It is also responsible for around 32% of New York State's energy-related, combustion-based GHG emissions.

In support of New York State's nation-leading GHG emissions reduction goals—targeting 40% reduction of GHG emissions by 2030, and 80% by 2050—the New York State Energy Research and Development Authority (NYSERDA) has begun a process of developing an integrated, long-term policy approach to addressing emissions from the heating and cooling sector.

Renewable heating and cooling (RH&C) technologies, such as cold-climate air source heat pumps (ccASHPs), ground source heat pumps (GSHPs, also known as geothermal heat pumps), and solar hot water (SHW), have the potential to contribute significantly to decarbonization of the heating and cooling sector. They can also offer a number of other benefits to those using RH&C technologies, including energy bill savings and increased comfort levels and health benefits compared to conventional heating and cooling technologies. Other benefits—in particular the value RH&C technologies can offer to the electricity grid—are not yet fully accessible to RH&C customers.

Today, RH&C technologies occupy a niche position in the State's heating and cooling market. Several barriers currently stand in the way of widespread market adoption. These include cost-effectiveness challenges, inadequate access to low-cost investment capital, limited customer awareness of and confidence in RH&C technologies, and a range of supply chain barriers to growth.

As a result, RH&C is often not competitive with conventional heating and cooling technologies in today's marketplace. At current installed costs and energy prices, only around 41 TBtu of heating and cooling load—around 4% of the State's residential/commercial heating, ventilation, and air conditioning (HVAC) load of approximately 1,000 TBtu—could cost effectively switch to using heat pumps ("cost effective" meaning that the returns from energy bill savings on the additional cost of the RH&C installation would meet a reasonable investor's payback requirement).

This analysis indicates that GSHPs are currently only cost effective from a customer's point of view in very limited circumstances. The current cost-effective resource potential for ccASHPs is more significant at almost 39 TBtu, identified as opportunities to replace electric resistance heating in single family sites in Upstate/ Western New York with either ducted or ductless systems, and electric heat replacements by ducted ccASHPs in commercial sites in New York City. The analysis has not identified any currently cost-effective resource in the SHW market.

The technical potential of RH&C resources (the maximum amount of heating and cooling that could be delivered by RH&C technologies based on technical and site suitability constraints) is much larger and provides a significant opportunity for realization of societal and customer benefits. Across all of the RH&C technologies assessed in this framework, the technical potential is approximately 700 TBtu, or around 70% of total statewide HVAC load—a figure likely to increase still further as installation practices develop.

To start unlocking this potential, this RH&C Policy Framework considers a set of policies that can support the growth of the RH&C market in New York State. The Policy Framework is structured around consideration of three major pillars: **(i) reducing technology costs and lowering barriers** such as supply chain, customer awareness and finance barriers; **(ii) RH&C mandates** that could drive demand for RH&C in new construction and major renovations; and **(iii) incentives** that improve project cost effectiveness.

Each of the three pillars is described in more detail below.

- **Reducing costs and lowering barriers.** RH&C technologies are characterized by high first costs relative to fossil fuel alternatives. In addition, there are several non-financial barriers that NYSERDA can help to reduce, such as supply chain barriers, consumer confidence and awareness barriers and limited availability of affordable finance. Options for policies and market-based strategies include:

  1. Implement community procurement programs (e.g., Solarize for Heat) to promote local clustering.
  2. Develop a customer targeting and engagement tool to enable contractors to identify local clusters of high-potential customers.
  3. Facilitate standardized equipment and design approaches by encouraging industry best practices and/or through requirements in incentive programs.
  4. Develop a unified, streamlined permitting process for RH&C technologies and encourage adoption across NYS municipalities.
  5. Provide technical and engineering assistance and project development support for larger projects in key market segments.
  6. Integrate RH&C into existing trade channels, such as the HVAC emergency replacement market or oil heat dealer sector to reach a broader customer base.
  7. Enable broader availability and development of cheaper finance options.
  8. Work with utilities and energy service companies (ESCOs) to pilot third-party ownership and other innovative models under Reforming the Energy Vision (REV).

  Altogether, this analysis estimates that in addition to their impact in terms of lowering non-financial adoption barriers, these options could reduce installed costs of RH&C technologies by 5% to 30% by 2021 at the project level depending on the technology and market segment. Further (indirect) cost reductions that could occur as increases in uptake lead to economies of scale have not been quantified at this stage.

  If the quantified cost reductions are implemented successfully (and coupled with expected changes in energy prices), this analysis estimates that by 2021 an additional 74 TBtu of resource would become cost effective. The resulting 116 TBtu of total cost-effective resource potential would represent around 12% of the statewide HVAC load.

- **Mandates.** New York State can also drive demand by creating RH&C mandates, which place an obligation on certain market actors to source a certain portion of their heating and cooling load from renewable resources. The nature of RH&C as an emerging market in New York State places constraints on the extent to which mandates are a viable policy option at this stage. However, there is an opportunity to integrate RH&C into building and energy mandates for public buildings, new construction, and renovation. Concepts presented for consideration include:

- Integrate RH&C into the Build Smart NY initiative.
- Integrate RH&C technologies into New York State's Stretch Code for new construction and existing building retrofits.
- Support a transition to a net-zero building requirement for new construction and renovation.

- **Incentives.** To achieve market growth, consumers or building owners interested in installing RH&C will need to realize a reasonable financial return on their investment. Given that RH&C technologies are, in most cases, not yet cost-competitive with conventional technologies, only a small level of uptake has been achieved in New York State to date (e.g., by early adopters). Cost reductions are a key path towards improving project returns. In addition, there are important value components that RH&C technologies can offer to society and ratepayers for which those who would make the investment into RH&C installations are currently not rewarded. Financial incentives could be provided as a proxy for some or all of these value streams to RH&C customers to help stimulate market growth.

  This Policy Framework provides the starting point for further consideration of the case for incentives. The three major venues for consideration of incentives in 2017 are:

  - A process to consider "Thermal Renewable Energy Certificates" (T-RECs) under the Clean Energy Standard (CES)
  - Ongoing REV-based proceedings including Value of Distributed Energy Resources (VDER) dealing with the design and reform of our electricity rate structures to enable rates to better compensate for value where it occurs
  - The Clean Energy Fund (CEF)

  Incentives could take several different forms:

  - Upfront rebates, or performance-based incentives (PBIs) which would be paid over a period of time
  - Direct payments, or tax credits
  - Fixed incentive levels (which may be set based on consideration of value), or market-based mechanisms such as reformed electricity tariffs or T-RECs

  We note that T-RECs and new tariff structures are under consideration in the CES and VDER proceedings. Without pre-empting any specific outcome from those proceedings, and recognizing the importance of starting to unlock RH&C potential now, we conclude as a matter of timeliness that incentive levels should initially be set at levels estimated to be both cost effective and market-accelerating. We also note that given current RH&C market circumstances, direct payments are more practical and effective than tax incentives (of equal monetary value), and that, while PBIs would ultimately be more effective and efficient than upfront incentives, in the short-term, rebates are more practical than PBIs.

  While the process to consider the case and design of incentives is underway, we propose to introduce a near-term upfront NYSERDA rebate for GSHPs to maintain market continuity. The program, with a budget of approximately $15 million, will plan to provide rebates of $1,500 per ton of installed capacity for residential/small-scale systems, and $1,200 per ton for commercial/large-scale systems. The program is expected to launch in the second quarter of 2017. Eligibility will include residential/small-scale systems pre-dating the launch if installed on or after January 1, 2017 (and subject to meeting the other requirements of the program). The program will be open for two years, or until the budget is exhausted. At that time, proceedings on T-RECs and electricity rate reform will have advanced sufficiently to allow determinations to be made whether there continues to be a policy case for direct incentives, and what the type and level of such incentives should be.

In summary:

- Only a small fraction (around 4%) of statewide HVAC load can be met by RH&C technology cost effectively today, despite a large technical potential.
- Cost-effective investment opportunities in RH&C would need to increase by an order of magnitude for RH&C to be able to move from its current niche position to a mainstream market. Projected energy price rises and the modest cost-reduction interventions summarized above are expected to increase the proportion of the market that RH&C could cost effectively serve to 12% over the next five years.
- A combination of cost reductions and value monetization is needed to increase the potential to a level where it creates the preconditions for mass market transformation. The analysis indicates that such an integrated approach of cost reductions and value monetization—reflecting the pillars described above—could increase the cost-effective RH&C potential to over a quarter of statewide HVAC load.
- To realize a transformative impact on the market, the policies and interventions must also be of adequate magnitude and duration and be designed with awareness of customer decision making, with the ultimate goal of creating a self-sustaining industry independent of incentives.

It is critical to start now, since transformation in the heating and cooling market is by its nature a gradual process. Some of the barriers referred to above—in particular behavioral and supply chain barriers—take time to overcome. In addition, HVAC equipment is typically only replaced towards the end of its useful life, so whenever a replacement with conventional heating and cooling occurs, the opportunity to switch to RH&C will only be available again well over a decade later.

For New York State (and the broader United States) to meet the clean energy and climate priorities that are needed to succeed in the 21st century, RH&C must be part of the solution. This Policy Framework lays the foundation for a step change in development of the RH&C market in New York State throughout the next decade, allowing RH&C to make a meaningful contribution toward the State's GHG goals in 2030 and beyond.

Next Steps

This Policy Framework constitutes the first step in a longer-term effort to stimulate the RH&C market in New York State. It sets out options for policies and market-based strategies for the next few years and concepts for longer-term action. Continued engagement with the industry, consumers, and other stakeholders will be necessary to successfully achieve desired outcomes, and NYSERDA invites comments and contributions from stakeholders, in particular on:

- The options set out in Chapter 4 on reducing costs and lowering barriers
- The concepts discussed in Chapter 5 in respect of potential mandates
- The concepts in Chapter 6 in respect of incentives

NYSERDA requests written feedback on this Policy Framework be sent by **5 PM on March 10, 2017** to:

renewableheatingandcooling@nyserda.ny.gov

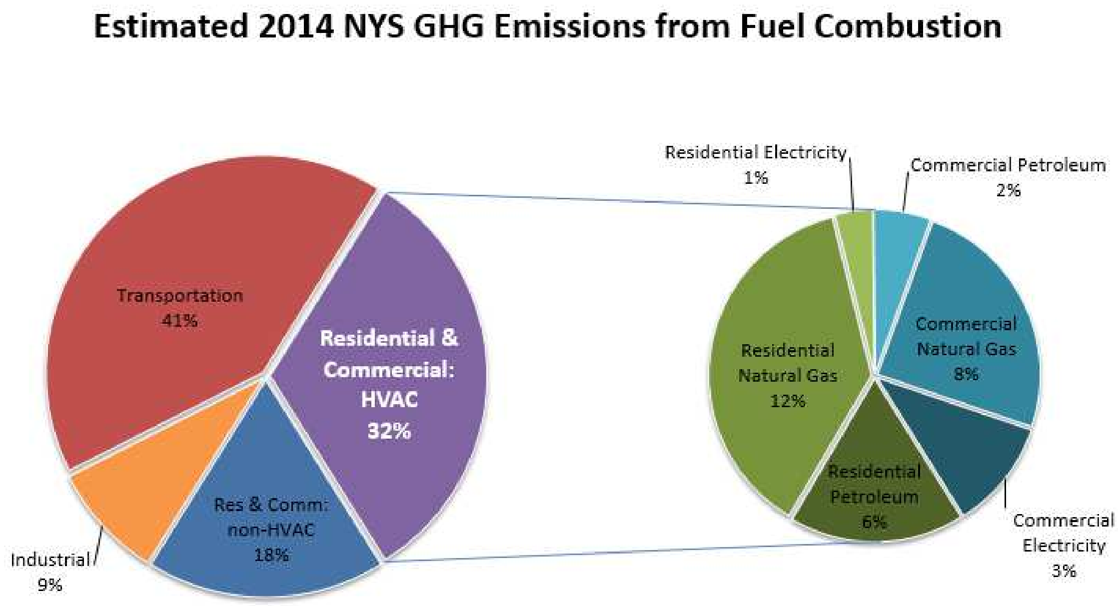
To facilitate stakeholder feedback, NYSERDA will schedule a webinar to discuss the Policy Framework during the comment period. Stakeholders interested in attending should send an expression of interest by email to the address above. NYSERDA will also be convening stakeholders to review the preliminary design of the proposed GSHP near-term incentive program.

CHAPTER 1 INTRODUCTION

SECTION 1.1 THE OPPORTUNITY

Thermal energy used for space heating and cooling, domestic hot water, and process heat is a primary component of the New York State energy system, and one of the largest contributors to the State's GHG emissions. Thermal energy usage in the residential and commercial sectors accounts for approximately 37% of net energy consumption and 32% of all combustion-based GHG emissions in the state. [1]

Figure 1.1 - NYS GHG Emissions



Total 2014 New York State GHG Emissions from Fuel Combustion: 181 MMtCO2e

[1] NYSERDA. (2015). *Patterns and Trends: New York State Energy Profiles: 1999-2013*. Retrieved from https://www.nyserda.ny.gov/-/media/Files/Publications/Energy-Analysis/1999-2013-Patterns-Trends.pdf; NYSERDA. (2015). *New York State Greenhouse Gas Inventory : 1990-2014* https://www.nyserda.ny.gov/-/media/Files/EDPPP/Energy-Prices/Energy-Statistics/greenhouse-gas-inventory.pdf

New York State leads the nation with its GHG emissions reduction goals, targeting a 40% reduction by 2030 below 1990 levels and 80% reduction by 2050. To achieve these goals, deep GHG emissions reductions must occur from all energy sectors, including heating and cooling. The State is well-positioned to build on its national leadership in advancing energy efficiency and renewable electricity generation by focusing new attention on reducing emissions associated with building heating and cooling. As such, this Policy Framework aims to articulate a broad, comprehensive strategy for New York State to begin to drive deep emissions reductions from thermal energy consumption.

RH&C technologies, such as ccASHPs, GSHPs, and SHW, are widely available, applicable across a majority of buildings in the State, and have the potential to achieve significant GHG emissions reduction. Such technologies can also offer a range of other important benefits including customer energy savings, broader energy system benefits, and improved resiliency and customer comfort (see Box 1.1).

While a comprehensive approach to growing the RH&C market has not yet been in place in New York State thus far, New York State has provided and continues to provide a range of policy interventions and support aimed at developing the nascent RH&C market, including foundational support through demonstration and pilot projects as well as incentives (see Box 1.2).

Nevertheless, RH&C technologies still occupy only a niche market.[2] Wider adoption of RH&C remains inhibited by a range of market barriers, including relatively high upfront costs and limited cost effectiveness, limited customer awareness, and constraints across different levels of the supply chain. Building on the State's past support for RH&C, a more structured and integrated approach will be needed to help the RH&C industry transform itself from its current niche role toward entering the mainstream and allow RH&C to make a meaningful contribution toward achieving our GHG reduction goals. This Policy Framework constitutes the first step in a longer-term effort to stimulate the RH&C market in New York State. It sets out options for policies and market-based strategies for the next few years and concepts for longer-term action. Continued engagement with the industry, consumers, and other stakeholders will be necessary to successfully achieve desired outcomes, and NYSERDA invites comments and contributions from stakeholders.

[2] See Chapter 2 for a discussion of available data on RH&C market penetration in New York to date.

Box 1.1 - Benefits of RH&C technologies

Broader deployment of RH&C technologies can yield a range of benefits for New York State, the State's ratepayers, and building owners. Such benefits may include:

- **Customer energy savings.** While RH&C technologies are more expensive upfront than conventional fossil fuel-based technologies, they offer significant energy cost savings to consumers in many applications. Since RH&C technologies are either fuel-free (SHW) or electric driven (GSHPs and ASHPs), they also have the potential to significantly reduce customer exposure to fossil fuel price volatility.
- **Customer comfort and health.** Heat pumps can provide a high-efficiency source of cooling to New Yorkers, 80% of whom use window units or lack air conditioning entirely.[3] The lack of air conditioning is an increasing health and safety risk for vulnerable populations, such as the elderly and low-to-moderate income (LMI) residents.
- **Site usability.** Adding cooling to facilities, such as schools and churches will allow for more services to the public. For example, schools that have been able to add air conditioning have been able to run community events, student enrichment, and adult education programming throughout the summer. Demand for cooling will grow as our climate continues to warm.
- **Building resiliency.** Climate change will also bring increased risk of extreme weather and associated disruptions to critical infrastructure. RH&C technologies can be critical components of resilient energy systems, with the potential to continue delivering thermal energy generated by distributed electricity resources during disruptions to critical infrastructure.
- **Energy system benefits.** Broader deployment of RH&C technologies will improve fuel diversity across the thermal energy mix, increase the choices available to customers, and reduce dependence on fossil fuel delivery infrastructure and direct consumer exposure to national and global fossil fuel price volatility. Additionally, heat pumps provide higher efficiency cooling than many conventional AC systems, contributing to peak load reductions and associated electricity cost savings passed on to ratepayers. The increased off-peak electricity sales from broader heat pump deployment will also enable fixed utility costs to be spread over a greater volume of sales, contributing to additional electricity cost savings for all ratepayers.
- **GHG emissions reduction.** On-site combustion of fossil fuels in residential and commercial buildings, over 80% of which is for space and water heating, amounted to nearly twice the GHG emissions from electricity generation (28% for onsite combustion versus 16% for electricity generation).[4] The RH&C technologies discussed throughout this framework significantly reduce or eliminate on-site fossil fuel combustion and related emissions and thus can offer significant potential for providing the necessary GHG emissions reductions to achieve New York State's emissions goals.

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[3] EIA RECS 2009 Survey for NY: https://www.eia.gov/consumption/residential/reports/2009/state_briefs/pdf/NY.pdf

[4] *New York State Greenhouse Gas Inventory : 1990-2014* https://www.nyserda.ny.gov/-/media/Files/EDPPP/Energy-Prices/Energy-Statistics/greenhouse-gas-inventory.pdf

Box 1.2 - Previous and ongoing RH&C market interventions and programs in New York State

Incentives

- NYSERDA previously offered a solar hot water incentive through 2016 that provided $20.3 million to support over 1,200 residential, commercial, and agricultural SHW installations.
- Over the past 15 years, NYSERDA has provided over $28 million in incentives to support over 560 GSHP and over 530 ASHP systems in new buildings or as part of major renovations through its commercial new construction program.
- Over the past 15 years, NYSERDA has supported over 400 residential GSHP projects through the Home Performance with Energy Star Program.
- Launched in 2014, the Renewable Heat NY program has committed approximately $10 million to support the growth of the high-efficiency, low-emissions biomass market in NY. Investments have included research and development, supply support, workforce development and a suite of residential and commercial incentive offerings for pellet boilers and stoves and advanced cord wood boilers. To date, the program has reduced annual particulate matter emissions by approximately 16 tons.[5]
- PSEG-LI offers rebates for ASHPs (up to $600 per system) and GSHPs (up to $2,000 per ton).[6]
- Several of New York's Investor Owned Utilities offer rebates for the purchase and installation of ASHPs including Con Edison (up to $500 per ton), NYSEG (commercial only up to $100 per ton) and Central Hudson (commercial only up to $125 per ton).[7]

Demonstration, measurement & verification, and pilot projects

- Through Governor Cuomo's Energy to Lead Competition, the NYSERDA REV Campus Challenge provided a $1 million award to SUNY Broome Community College for its "Geothermal Learning Laboratory" project that includes installing a closed loop geothermal system that uses the heat energy stored in the earth; real-time, public data-sharing about the system's operations; and development of hands-on, geothermal material for secondary schools.
- NYSERDA is conducting RH&C demonstrations, including heat pump installations in 90 homes. NYSERDA is also piloting commercial variable refrigerant flow (VRF) ASHP system retrofits in three buildings. M&V will be conducted by NYSERDA to establish and communicate system performance.
- NYSERDA is collecting and analyzing performance data on 40 existing residential GSHP installations across the State.
- National Grid, in the KEDLI (Long Island) service territory, has proposed to implement a pilot program to demonstrate geothermal heating and cooling as an alternative to either new or existing firm or interruptible gas customers. KEDLI is to work with local water utilities and LIPA/PSEG-LI in the program development. Funding for the program consists of $350,000 in rate year one and $50,000 in each of rate years two and three. The goal is to use geothermal technologies to potentially displace peak gas consumption versus adding pipeline capacity.[8]

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[5] . https://www.nyserda.ny.gov/All-Programs/Programs/Renewable-Heat-NY Renewable Heat New York (RHNY) is a long-term commitment to help the high-efficiency, low-emission biomass heating industry reach scale. RHNY encourages quicker development of the industry, raises consumer awareness, supports the development of New York-based advanced technology heating products, and develops local sustainable heating markets that use biomass as fuel. Renewable Heat NY also aims to reduce wood smoke, fine particles and carbon monoxide emissions.

[6] https://www.psegliny.com/page.cfm/Efficiency/Renewables/Geothermal

[7] https://www.conedhvacrebates.com/hvac, http://www.savingscentral.com/rebates/, http://www.nyseg.com/UsageAndSafety/usingenergywisely/eeps/cirp.html

[8] Case 16-G-0058 and Case 16-G-0059 Appendix page 109

SECTION 1.2 RH&C POLICY FRAMEWORK FOR NEW YORK STATE: CORE COMPONENTS

New York State aims to achieve its goal of unlocking the potential of RH&C by delivering three primary outcomes:

1. **Reduce costs and improve system economics** of RH&C technologies relative to fossil fuel incumbents.
2. **Build consumer awareness and confidence** in RH&C technologies, performance, and applications.
3. **Develop and strengthen the regional supply chain** both to help reduce costs and better enable a wider range of firms to deliver high-quality RH&C installations.

This Policy Framework details a diverse range of synergistic intervention options designed to pursue these outcomes. This framework comprises immediate action as well as consideration of follow-up initiatives across three core components:

- Initiatives aimed at facilitating significant **reductions in the installed costs of RH&C technologies** to help improve the returns and financial attractiveness of investments in these technologies over the next five years as well as **lowering barriers,** such as lack of consumer confidence and awareness and limited availability of affordable finance.
- Opportunities for introducing one or more **mandates** aimed at new construction and major renovation and/or the public sector.
- Consideration of the **value that RH&C technologies can offer and the case for incentives**, in parallel with introduction of a near-term incentive for GSHPs.

SECTION 1.3 CHAPTER STRUCTURE

Chapter 2 (Market Characterization) presents an assessment of the New York State RH&C market. It discusses available resource potential as well as the latest data on project economics and cost effectiveness. It also summarizes our analysis of RH&C value opportunities.

Chapter 3 (Barriers) analyzes the barriers that currently hold back the RH&C sector, each of which is addressed in the subsequent chapters.

Chapter 4 (Reducing Costs and Lowering Barriers) assesses the opportunities for lowering the non-financial barriers identified in Chapter 3, as well as for achieving reductions in the costs of RH&C technologies.

Chapter 5 (Mandates) discusses concepts to help drive development of the RH&C market through the use of mandates relevant to the heating and cooling sector. Mandates can achieve policy goals by obliging market participants to take certain actions or refrain from taking them.

Chapter 6 (Incentives) describes the proceedings by which the case for incentives going forward will be considered, as well as key incentive design choices. It proposes a near-term incentive for GSHPs to be implemented by the second quarter of 2017.

Chapter 7 (Next Steps) outlines a schedule for action and contains information on how to respond to this Policy Framework.

SECTION 1.4 SCOPE AND METHODOLOGY

This Policy Framework focuses on three primary renewable energy technologies used for space heating and cooling and domestic hot water: ASHPs,[9] GSHPs,[10] and SHW. Further details on the nature of these technologies and their potential contribution to our energy system are set out in Chapter 2.

Our assessment of the RH&C market and the intervention options discussed throughout this framework are supported by research and analysis as described in Appendix A. Our research has brought together the most comprehensive assessment of the economics, value, and resource potential of RH&C in New York State to date. An important contributor to the analysis was a Cost and Cost Reductions Advisory Committee (Advisory Committee) of industry stakeholders and experts convened by NYSERDA, which included over 30 industry experts.

A number of RH&C technologies and applications other than heat pumps and SHW are not addressed in the Policy Framework at this stage:

- NYSERDA already has a multi-year intervention program in place for biomass heating (Renewable Heat NY – see also Box 1.2). We will consider opportunities to integrate biomass heating into initiatives introduced as follow-up to this framework;
- Other technologies and applications not considered at this time include:
    - Heat pump water heaters
    - Combined heat and power
    - Process heating applications
    - Biofuels
    - Biogas injection into the gas grid
    - Solar air heating and cooling
    - Hybrid systems

  We may examine these technologies in more detail at a later stage.
- This framework focuses on increasing the market for mainstream, market-ready RH&C technologies. Opportunities for research and other innovative technology development, beyond the HVAC next generation technology challenge described in Section 4.3, are outside the scope of this framework and have been previously discussed in NYSERDA's Clean Energy Fund Investment Plan: Building Innovations Chapter.[11]

[9] Cold climate air source heat pumps only.
[10] In this Policy Framework and the underpinning analysis, GSHPs include: closed-loop horizontal, vertical and direct exchange systems, open loop systems, and groundwater or surface water systems..
[11] https://www.nyserda.ny.gov/-/media/Files/About/Clean-Energy-Fund/CEF-Building-Innovation.pdf

CHAPTER 2 MARKET CHARACTERIZATION

Heating and cooling is a significant part of New York State's overall energy use. We estimate that the net energy consumption for heating and cooling in New York State's residential and commercial[12] buildings is equivalent to approximately 1,000 trillion Btu (TBtu) per year, or 37% of total statewide net energy consumption.[13]

ccASHP, GSHP, and SHW technologies currently provide only a small fraction of New York State's thermal energy needs. Thermal energy for space heating, space cooling, and hot water is almost exclusively provided by fossil fuels, such as natural gas, fuel oil, or propane, as well as by direct electric heating. While a significant opportunity exists to grow RH&C markets and in turn contribute to achieving New York State's energy and climate goals, several barriers (described in more detail in Chapter 3) must be addressed to realize this technical potential. These include: strengthening the supply chain, reducing installation costs, and improving project economics.

The following sections introduce ccASHPs, GSHPs and SHW as technologies, discuss available data on market penetration to date in New York State, and provide an assessment of their resource potential and project economics between 2017 and 2021. The chapter concludes with an assessment of opportunities to significantly expand the size of the market that RH&C could cost effectively serve through a combination of cost reductions and value monetization.

SECTION 2.1 RH&C TECHNOLOGIES

As discussed in Section 1.4, this framework focuses on three main technologies: cold-climate air source heat pumps (ccASHPs), ground source heat pumps (GSHPs), and solar hot water (SHW). These are the three technologies (in addition to biomass heating, which is already the focus of multi-year NYSERDA support) that research and stakeholder input suggest to be the most relevant RH&C opportunities for NYS.

ccASHPs

ccASHPs provide space heating and cooling to residential and commercial buildings. They use a compressor, an expansion valve, refrigerant, and electric heat exchangers to transfer heat in and out

[12] As noted in Section 1.4, the scope of this framework excludes process heating. Accordingly, the analysis presented in this framework has assessed the residential and commercial, but not the industrial sector. Any figures presented here are similarly limited to the residential and commercial sectors. "Commercial," consistent with EIA definitions, includes institutional, government, and not-for-profit buildings and "Residential" includes both single family and multifamily buildings.

[13] Based on EIA data for 2014, RECS, and CBECS.

of a building.[14] Outdoor air serves as a reservoir for extracting heat (to provide space heating) or rejecting heat (to provide space cooling).

For this Policy Framework, only cold-climate ASHP (ccASHP) models (as defined by the Northeast Energy Efficiency Partnership) are considered in scope.[15] ccASHPs can operate down to temperatures of five degrees Fahrenheit while also maintaining an efficiency factor of 1.75 or greater.

Central ASHP systems distribute the heating and cooling output throughout a building, typically through an air duct distribution system.

Like standard (central) ASHPs, ductless mini-split ASHPs have two main components—an outdoor compressor/condenser and an indoor air-handling unit. Unlike central ASHPs, ductless mini-split ASHPs do not connect to a forced air distribution system. A conduit, which houses the power cable, refrigerant tubing, suction tubing, and a condensate drain, links the outdoor and indoor units. Ductless mini-split-system heat pumps (mini-splits) make good retrofit add-ons to houses with "non-ducted" heating systems, such as hydronic (hot water heat), radiant panels, and space heaters (wood, kerosene, and propane). They can also be a good choice for room additions where extending or installing distribution ductwork is not feasible and for very efficient new homes that require only a small space conditioning system.[16]

Within the residential sector, ASHPs have historically been used as a supplemental heating technology, providing a small portion of a home's heating load while also providing cooling in the summertime. For well-insulated homes, ASHPs can also provide a majority, or even 100%, of the space heating and cooling load, frequently with an integrated auxiliary heating source, such as an electric resistance coil or a gas intake line. ASHPs can also be used in multifamily buildings and commercial buildings, such as hotels, schools, or office buildings. ASHPs will typically provide 100% of the space heating and cooling needs for these commercial buildings, which often have a more pronounced cooling load.

GSHPs

GSHPs (also referred to as geothermal heat pumps) provide space heating, space cooling, and, in some cases, hot water for residential and commercial buildings. They use an indoor heat pump unit and a heat exchanging ground loop buried underground (or underwater) to transfer heat between the ground and the building. The variation in subsurface and/or groundwater temperatures remains constant across seasons—typically between 45°F and 75°F, depending on climate and latitude. As a result, GSHPs can extract heat with greater efficiency than ccASHPs in colder weather. Due to the drilling requirements and ground loop components, however, the installed cost of GSHPs tend to be significantly higher than ccASHPs on a like-for-like basis, particularly for smaller-scale installations.

GSHPs are typically sized to provide 100% of the heating and cooling load for a residential or commercial building. In some cases, though, GSHPs are sized below peak heating load—and installed with auxiliary electric resistance heat or cooling towers (depending whether the building is heating or cooling dominated)—to reduce installed costs.

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[14] Similar technologies are available for domestic hot water—typically referred to as heat pump water heaters. This framework focuses on the space heating/cooling applications of air source heat pumps.
[15] http://www.neep.org/initiatives/high-efficiency-products/emerging-technologies/ashp/cold-climate-air-source-heat-pump
[16] https://energy.gov/energysaver/ductless-mini-split-heat-pumps

There is significant variation in how the ground loop component is designed and installed, which affects project costs and efficiencies.

- **Closed-loop systems** use a ground loop (typically made of polyethylene or PVC) that circulates water or antifreeze to exchange heat with the ground or a groundwater source. For closed-loop residential and smaller commercial systems, horizontal “slinky” configurations are often used. Vertical configurations, which can have column wells of up to 400 feet deep, are often used for large commercial systems. Closed-loop systems can also be submerged in bodies of water.
- **Open-loop systems** circulate water for heat extraction and rejection directly from local groundwater sources. This can reduce the installed cost due to less piping and enhance system efficiency due to improved heat transfer.
- GSHPs can also be designed as **direct exchange systems**, which circulate a refrigerant through a copper pipe instead of a typical ground loop. Direct exchange systems are highly efficient at heat extraction and rejection; however, the high global warming potential of refrigerants means that a leak could compromise GHG emissions reductions gained from the system’s efficiency.

SHW

Solar thermal systems use thermal energy from sunlight to generate heat for hot water and space heating. When both hot water and space heating uses are deployed, the system is referred to as a solar combi-system. Many solar thermal installations in New York State and across the Northeast are designed and sized to serve hot water only, referred to as solar water heating or solar hot water (SHW). Like solar photovoltaic (PV) systems, the loss of solar insolation during the winter significantly affects production; thus, a secondary water heating source is necessary to provide hot water during the winter.

To capture solar energy, SHW systems use collectors, which may be designed as flat plates or evacuated tubes. In active SHW systems, a heat exchange liquid is circulated with a pump to capture heat from the collector when the collector temperature exceeds the temperature in the hot water storage tank. A heat exchanger is used to transfer heat from the heat exchange liquid to heat the hot water tank. In colder climates, such as New York State, freeze protection is required to prevent the risk of damage to the system. There are two main types of freeze protection: (i) an antifreeze mixture that is used in a pressurized, closed-loop system or (ii) a drainback design, which is used in an unpressurized system and allows water or antifreeze to automatically drain from the collector when pumping ceases (during cold temperatures). A pump is required to circulate the heat exchange fluid, which consumes a small amount of electricity over the course of the year.

SECTION 2.2 RH&C UPTAKE TO DATE IN NEW YORK STATE

Unlike the conventional (oil and gas) HVAC industry, the RH&C market is not currently being evaluated either in the U.S. or in New York State through detailed government or industry-maintained datasets which support market analyses. Consequently, a key challenge for New York State (and other states interested in scaling up RH&C markets) will be to establish robust datasets to track the RH&C supply chain and measure market development and growth over time.

ccASHPs

Data availability on historic annual and cumulative installation numbers of ASHPs is sparse. In addition, as noted in Section 1.4, the scope of this framework is limited to ccASHPs, and available data does not differentiate between cold-climate and regular systems.

- In July 2015, NYSERDA published the Residential Statewide Baseline Study[17] (RBS) that examined equipment and end-uses in one to four family homes in New York. The study included surveys, site visits, and data collection. Survey respondents indicated that as of 2014, ASHPs are installed in 0.5% of new homes (built after 2012) and 0.8% of existing homes (built before 2012).[18] This would equate to around 26,000 systems in total.
- Based on Heating, Air Conditioning and Refrigeration Distributors International (HARDI) sales data, which is collected from HVAC distributors, total ASHP sales in New York State for 2013, 2014, and 2015 were approximately 107,000, which would represent approximately 1.2% of single family homes, small commercial buildings, and multifamily units.

As noted, these numbers do not provide specific data on ccASHPs, but market data suggests that ccASHPs represent 10% to 15% of commercial ASHP sales and between 30% and 35% of residential ASHP sales in New York State.[19] Taken together, the available baseline data suggests that ccASHP has the highest market share of any of the RH&C technologies considered in this framework, but that nevertheless total penetration is at a level of low single-digit percentages at best.

GSHPs

As with ccASHPs, there is little data on historic annual and cumulative numbers of installations in New York State.

- NYSERDA's Residential Statewide Baseline Study (RBS)[20] reported GSHPs in 0.7% of existing homes (built prior to 2012), which would amount to around 36,000 installations in total. Taken together with estimates in the RBS on GSHPs in new construction homes, this data appears broadly consistent with anecdotal information from industry leaders estimating a rate of around 1,000 installations per year over recent years.
- NYSERDA's Publication "Patterns and Trends" indicates that, as of 2014, 1% of statewide residential load is met by solar and geothermal and 1.2% of commercial load is met by wood, waste, coal, and geothermal.[21]
- As shown in Box 1.2 in Chapter 1, NYSERDA has supported approximately 1,000 GSHP installations since 2000.

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[17] https://www.nyserda.ny.gov/About/Publications/Building-Stock-and-Potential-Studies/Residential-Statewide-Baseline-Study-of-New-York-State

[18] The *Residential Statewide Baseline Study* also looked at multifamily buildings, for multifamily tenants, 11.7% reported having an air source heat pump as their primary heating system. Due to the small sample size (95 out of 2,500,000 tenant spaces)—this data point has been disregarded.

[19] New York Sales data from a major air source heat pump manufacturer.

[20] https://www.nyserda.ny.gov/About/Publications/Building-Stock-and-Potential-Studies/Residential-Statewide-Baseline-Study-of-New-York-State

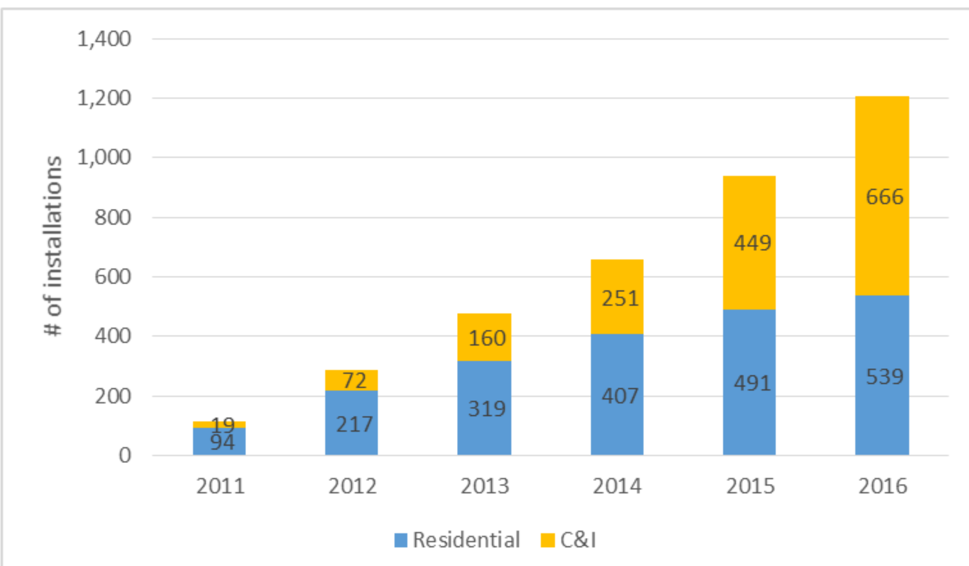
[21] https://www.nyserda.ny.gov/About/Publications/EA-Reports-and-Studies/Patterns-and-Trends

In all, the available data suggests that GSHPs currently account for less than 1% of statewide HVAC load.

SHW

There are no available independent statistics on SHW sales in New York State. Market baseline estimates were approximated using data from the NYSERDA's SHW rebate database. As illustrated in Figure 2.1, just over 1,200 SHW systems were installed between 2011 and 2016 in the residential, commercial and agricultural sectors based on NYSERDA program participation. Energy saved by hot water off-set by residential and commercial, SHW systems installed through NYSERDA's program is approximately 7,500 MWh per year, which represents approximately 0.2% of total residential and commercial hot water load. Over 400 of the 1,200 installations were at dairy farms, which represents a high-value niche market for SHW based on the large, consistent hot water load for equipment wash downs. It should be noted that, due to eligibility requirements (i.e., the counterfactual heating fuel was required to be electric for most installations), NYSERDA program data does not represent the entire market. However, based on anecdotal evidence, market activity outside NYSERDA's program has been limited.

Figure 2.1 - Cumulative SHW installations in New York State[22]



SECTION 2.3 RH&C RESOURCE POTENTIAL

We have carried out in-depth analysis of both the amount of the State's heating and cooling energy needs that could be served by RH&C technologies and the cost effectiveness or project economics of RH&C in the current market. See Appendix A for a description of the data and methodology used for this analysis, including the assumptions made to estimate resource availability (technical potential).

[22] Source: NYSERDA program database

Table 2.1 shows our estimate of technical potential by technology and type of heating and cooling end use. It contains the estimated amount of potential heating and cooling load that could be served by each RH&C technology, as well as the percentage of the total estimated statewide annual HVAC load[23] that each technology could serve, based on the current state of each technology and site suitability constraints.[24]

Table 2.1 - Technical potential of RH&C technologies by end use (TBtu)

RH&C Technology	Space Heating	Space Cooling	Water Heating	Total	% of State HVAC Load
ccASHP Central System	377	243	-	620	62%
ccASHP Mini-Split	133	43	-	177	18%
GSHP Horizontal Loop	124	24	-	148	15%
GSHP Vertical Loop	374	209	-	583	58%
SHW	-	-	47	47	5%
Total Potential[25]	407	243	47	697	70%

There is significant technical potential for RH&C technology to serve New York State's thermal energy needs. Technical potential varies across RH&C technologies, depending on the proportion of total number of sites and the proportion of each site's energy demand that each technology could serve. Central ccASHP systems and vertical-loop GSHP systems have the highest technical potential to serve New York State thermal load, with smaller potential loads served by mini-split ccASHPs (which are typically only installed on small sites and typically serve a limited amount of the site heating load) and horizontal GSHPs (which are only suitable where the site has sufficient surrounding land to accommodate the horizontal loop field). SHW has a potential to serve roughly a quarter of statewide water heating load (limited by site suitability and the fraction of total building water heat that may be provided through SHW), though this only corresponds to 5% of statewide HVAC load.

As there is overlap in the sites that may be served by ccASHP and GSHP technologies, the total RH&C technical potential is less than the sum of the individual technologies. Overall, RH&C

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[23] As stated in the introduction to this chapter, total current annual statewide HVAC load for the residential and commercial sector is estimated to be around 1,000 TBtu (this excludes the industrial sector). The RH&C resource potential analysis presented in this chapter includes an assessment of new construction over the period to 2030. Accordingly, figures in this chapter showing RH&C resource potential as a percentage of statewide HVAC load are slightly higher than what they would be if only the resource potential on existing sites was included.
Throughout this framework, figures and percentages relating to the amount of available heating and cooling resource are expressed as heating and cooling load, i.e., the amount of heating and cooling energy delivered at the site after (i) distribution losses, (ii) conversion losses (from combustion of fossil fuel in on-site heating devices), and (iii) conversion gains (in the case of air-conditioning and heat pumps). These figures are thus not directly comparable to the estimates of statewide heating and cooling net energy consumption as set out in Section 1.1, since such figures depict on-site energy use before accounting for on-site conversion and distribution gains/losses.
[24] See Appendix A for details on how technical resource potential was derived.
[25] The combined total does not equal the sum of the individual technology totals as there is overlap in the sites that may be served by the various technologies.

technologies could theoretically provide around 700 TBtus/yr of thermal load, or 70% of statewide HVAC load.

The figures in Table 2.1 reflect current installation practices—for instance, heat pumps are currently typically installed in sites with a forced-air distribution system. In the future, we expect heat pumps that can serve hydronic systems to become more prevalent, at which point heat pumps could serve a greater proportion of total statewide load.

With the exception of early adopters and environmentally motivated consumers, it will be important to customers that the RH&C investment makes financial sense compared to a conventional system. RH&C equipment typically has a higher upfront cost than conventional heating and cooling equipment, so customers will require a return on the additional cost through energy bill savings. Table 2.2 summarizes our analysis on project economics across the range of RH&C market segments. This is a starting point from which appropriate policies and interventions can be considered, along with the other benefits that RH&C systems provide.

Project economics are expressed in Table 2.2 as available amounts of technical potential at various levels of relative cost effectiveness. Cost effectiveness is expressed as the levelized cost of energy (LCOE) from the customer's (or investor's) perspective.[26] An LCOE of zero or less— marked in green in Table 2.2—means that the market segment in question would not require additional revenue to meet customers'/ investors' targeted hurdle rate of return and is thus considered to be cost effective. Market segments with positive LCOE values would require a payment per unit of heating or cooling load served equal to their LCOE to become cost effective. Cost effectiveness is shown excluding any currently available (federal and state) subsidies to provide a like-for-like comparison between technology costs.

Our analysis confirms that under current market conditions, only a very small portion of the RH&C market is cost effective (with an LCOE at or below zero). Note also that figures shown are for total available resource potential—on an annual basis we would only expect a small proportion of these sites to become available for installation of RH&C equipment, since heating and cooling equipment is typically only replaced at the end of, or when approaching the end of its life. The combination of relatively low cost-effective resource potential with slow turnover rates in the heating and cooling sector helps to explain current low levels of market penetration of RH&C.

[26] Defined as the annual amount of money (in nominal terms) per MMBtu of heating and cooling load served by an RH&C installation that would need to be made available to the RH&C installation over its lifetime for the project to achieve its hurdle rate requirement. See also Appendix A.

Table 2.2 - Cost-effective potential of RH&C technologies (TBtu) - 2017 - LCOE

LCOE in $/MMBtu		< $0	$0-$15	$15-$30	>$30	Total
LCOE per ¢/kWh (approx.)		< 0¢	0¢-5¢	5¢-10¢	>10¢	
ccASHP Central System	TBtu	35	404	148	34	620
	% of Tech. Potential	6%	65%	24%	5%	
	% of Statewide Load	3%	40%	15%	3%	62%
ccASHP Mini-Split	TBtu	11	34	131	2	177
	% of Tech. Potential	6%	19%	74%	1%	
	% of Statewide Load	1%	3%	13%	0%	18%
GSHP Horizontal Loop	TBtu	2	23	43	80	148
	% of Tech. Potential	1%	16%	29%	54%	
	% of Statewide Load	0%	2%	4%	8%	15%
GSHP Vertical Loop	TBtu	4	249	65	265	583
	% of Tech. Potential	1%	43%	11%	45%	
	% of Statewide Load	0%	25%	7%	26%	58%
Solar Hot Water	TBtu	0	0	0	47	47
	% of Tech. Potential	0%	0%	0%	100%	
	% of Statewide Load	0%	0%	0%	5%	5%
Combined Total[27]	TBtu	41	426	179	78	697
	% of Tech. Potential	6%	61%	26%	11%	
	% of Statewide Load	4%	43%	18%	8%	70%

Additionally, Table 2.3 displays cost effectiveness as levelized cost of carbon (LCOC), as opposed to LCOE.[28] The amount of cost-effective potential is the same in the case of both LCOE and LCOC, but there is a difference in the portion of near-cost-effective potential. Where in LCOE terms, central ccASHPs account for the majority of the near-cost-effective resource opportunity, mini-splits offer a greater share of the near-cost-effective opportunity when displayed in LCOC terms. The analysis also suggests that the majority of resource potential across the range of RH&C technologies investigated in this framework would need the equivalent of a carbon value greater than $300 per ton to become cost effective, underscoring again the need for deep cost reductions in addition to value monetization.

[27] The combined total does not equal the sum of the individual technology totals as there is overlap in the sites that may be served by the various technologies.
[28] Similar to LCOE, LCOC calculates the annual amount of "missing money"; in the case of LCOC expressed per ton of CO2e avoided by the RH&C installation rather than per MMBtu of thermal load served.

Table 2.3 - Cost-effective potential of RH&C technologies (TBtu) - 2017 - LCOC

LCOC per metric ton CO2e		< $0	$0-$25	$25-$50	$50-$100	$100-$300	>$300	Total
ccASHP Central System	TBtu	35	17	0	6	21	541	620
	% of Tech. Potential	6%	3%	0%	1%	3%	87%	
	% of Statewide Load	3%	2%	0%	1%	2%	54%	62%
ccASHP Mini-Split	TBtu	11	6	15	2	10	133	177
	% of Tech. Potential	6%	4%	8%	1%	6%	75%	
	% of Statewide Load	1%	1%	1%	0%	1%	13%	18%
GSHP Horizontal Loop	TBtu	2	1	1	2	33	110	148
	% of Tech. Potential	1%	0%	1%	1%	22%	74%	
	% of Statewide Load	0%	0%	0%	0%	3%	11%	15%
GSHP Vertical Loop	TBtu	4	0	3	3	70	503	583
	% of Tech. Potential	1%	0%	1%	1%	12%	86%	
	% of Statewide Load	0%	0%	0%	0%	7%	50%	58%
Solar Hot Water	TBtu	0	0	0	0	0	47	47
	% of Tech. Potential	0%	0%	0%	0%	0%	100%	
	% of Statewide Load	0%	0%	0%	0%	0%	5%	5%
Combined Total	TBtu	41	20	9	10	56	560	697
	% of Tech. Potential	6%	3%	1%	2%	8%	80%	
	% of Statewide Load	4%	2%	1%	1%	6%	56%	70%

By understanding which market segments are currently cost effective, or are likely to become cost effective over the next few years with various levels of improved LCOE/LCOC, we can focus policies and market-based strategies (see Chapter 4) with designs that enable them to make the most difference.

Almost all of the identified cost-effective **ccASHP** installations—for both central and minisplit ASHPs—are at sites replacing electric resistance heat, due to the relatively high operational cost of electric resistance heating and thus the higher energy bill savings that heat pumps can offer.

- For mini-splits, almost all of this resource (9 TBtu out of 11 TBtu of total cost-effective potential) is identified in single-family homes in Upstate/ Western New York, due to the relatively lower cost of installation there compared to Downstate.
- As regards central ccASHPs, the two largest cost-effective segments are identified as commercial VRF installations in New York City (9 TBtu) and single family sites in Upstate/Western New York (10 TBtu)—again, in all cases replacing electric resistance heating. Cost effectiveness for the NYC sites occurs through higher energy bills savings due to high electricity prices, which suffice to offset the relatively high installation costs in NYC. The remainder of the 35 TBtu of cost-effective central ccASHP resource is spread thinly across a number of sectors and across the State.

Current estimated cost-effective **GSHP** resource potential of around 6 TBtu[29] is very small when compared to the current statewide HVAC load of around 1,000 TBtu. The only cost-effective market segment of some significance appears to be for vertical GSHPs replacing electric resistance heating in commercial sites in New York City (around 3 TBtu). However, the analysis in Table 2.2 shows a significant amount of relatively near-cost effective resource—see the next section for our projections of the resource potential we would expect to become cost effective as a result of various cost reductions, including through options presented in this framework.

In our analysis, we were not able to identify any cost-effective **SHW** market segments. This remained the case even when accounting for the existing State and federal tax credits that SHW systems are eligible for. The summary of cost effectiveness analysis shown in Table 2.2 indicates that a significantly greater cost reduction would be needed than for ccASHPs or GSHPs for any SHW resource potential to become cost effective.

SECTION 2.4 IMPACT OF RH&C COST REDUCTIONS

Chapter 4 describes cost-reduction intervention options and estimates the amount of cost reductions that could be achieved by 2021 through these options. We have assessed the expected impact of such cost reductions on the amount of cost-effective resource by 2021, by projecting the levels of cost effectiveness in 2021 across the available RH&C resource both with and without such interventions.

In the scenario without the interventions described in Chapter 4, cost effectiveness of RH&C technologies can still be expected to improve by 2021, mainly as a result of expected increases in energy prices, which would increase the energy bill savings from RH&C. Our forecast for this scenario is set out Table 2.4.

Table 2.5 shows our projection once the additional impacts of both the expected global cost reductions and those from the New York State interventions discussed in Chapter 4 are taken into account.

[29] After discounting duplicative resource potential between horizontal and vertical GSHPs.

Table 2.4 - Cost-effective potential of RH&C technologies (TBtu) – 2021 without cost reduction interventions - LCOE

LCOE per $/MMBtu		< $0	$0-$15	$15-$30	>$30	Total
LCOE per ¢/kWh (approx.)		< 0¢	0¢-5¢	5¢-10¢	>10¢	
ccASHP Central System	TBtu	61	338	179	42	620
	% of Tech. Potential	10%	55%	29%	7%	
	% of Statewide Load	6%	34%	18%	4%	62%
ccASHP Mini-Split	TBtu	32	35	107	3	177
	% of Tech. Potential	18%	20%	61%	1%	
	% of Statewide Load	3%	3%	11%	0%	18%
GSHP Horizontal Loop	TBtu	4	22	44	78	148
	% of Tech. Potential	2%	15%	30%	53%	
	% of Statewide Load	0%	2%	4%	8%	15%
GSHP Vertical Loop	TBtu	9	246	63	264	583
	% of Tech. Potential	2%	42%	11%	45%	
	% of Statewide Load	1%	25%	6%	26%	58%
Solar Hot Water	TBtu	0	0	0	47	47
	% of Tech. Potential	0%	0%	0%	100%	
	% of Statewide Load	0%	0%	0%	5%	5%
Combined Total[30]	TBtu	79	346	217	54	697
	% of Tech. Potential	11%	50%	31%	8%	
	% of Statewide Load	8%	35%	22%	5%	70%

[30] The combined total does not equal the sum of the individual technology totals as there is overlap in the sites that may be served by the various technologies.

Table 2.5 - Cost-effective potential of RH&C technologies (TBtu) – 2021 with global and New York State cost reductions - LCOE

LCOE per $/MMBtu		< $0	$0-$15	$15-$30	>$30	Total
LCOE per ¢/kWh (approx.)		< 0¢	0¢-5¢	5¢-10¢	>10¢	
ccASHP Central System	TBtu	72	399	116	33	620
	% of Tech. Potential	12%	64%	19%	5%	
	% of Statewide Load	7%	40%	12%	3%	62%
ccASHP Mini-Split	TBtu	33	34	110	0	177
	% of Tech. Potential	19%	19%	62%	0%	
	% of Statewide Load	3%	3%	11%	0%	18%
GSHP Horizontal Loop	TBtu	24	24	83	17	148
	% of Tech. Potential	16%	16%	56%	12%	
	% of Statewide Load	2%	2%	8%	2%	15%
GSHP Vertical Loop	TBtu	35	270	90	188	583
	% of Tech. Potential	6%	46%	15%	32%	
	% of Statewide Load	4%	27%	9%	19%	58%
Solar Hot Water	TBtu	0	0	0	47	47
	% of Tech. Potential	0%	0%	0%	100%	
	% of Statewide Load	0%	0%	0%	5%	5%
Combined Total[31]	TBtu	116	403	136	42	697
	% of Tech. Potential	17%	58%	20%	6%	
	% of Statewide Load	12%	40%	14%	4%	70%

A number of observations emerge from this analysis:

- Energy prices make a substantial difference to the cost effectiveness of RH&C. At the current historically low levels of fossil fuel and electricity prices, only small parts of the RH&C market are cost effective, as seen in Section 2.3. If energy prices increase by 2021 in line with the forecast used in our analysis,[32] this would increase cost effective GSHP resource potential from roughly 6 TBtu currently to 13 TBtu (still only 1.3% of statewide HVAC load), and it would increase ccASHP resource potential from 39 TBtu (4% of statewide load) to 73 TBtu (7% of statewide load).
- The impact of expected global and New York State RH&C cost reductions is similar to that of expected energy price rises, but would have a more substantial impact on GSHP resource

[31] The combined total does not equal the sum of the individual technology totals as there is overlap in the sites that may be served by the various technologies.
[32] See Appendix A

than ccASHP resource. Potential cost reductions as discussed in Chapter 4, are expected to increase cost-effective GSHP resource to 58 TBtu (6% of statewide load) and cost-effective ccASHP resource to 84 TBtu (8% of statewide load) by 2021. However, it is important to note—as Section 4.2 explains—that we are currently unable to quantify the impact of additional cost reductions that could result from economies of scale and similar learning effects as uptake levels in New York State increase. Depending on our success in increasing uptake rates, these effects could lead to a meaningful acceleration of cost reductions. Accordingly, the options presented in Chapter 4 have a two-fold objective—to lead to direct cost reductions, but also to help increase uptake rates.

- While the increase in cost-effective resource potential by 2021 as shown in Tables 2.4 and 2.5 would be significant, we would still need to take additional action to improve cost effectiveness in the short term given the current low levels of cost-effective resource; furthermore, far-reaching transformation of the heating and cooling sector in the next decade would likely require a greater proportion of the technical potential for RH&C to be cost effective than that projected in Table 2.5. Such further improvements in cost effectiveness (beyond those coming from energy price rises and cost reductions) could be achieved by monetizing currently untapped RH&C value streams, in particular the value from RH&C to society in the form of carbon reductions, and the value to ratepayers in the form of electricity grid benefits. This is discussed further in Section 2.5.

SECTION 2.5 VALUE FROM RH&C

The main source of direct financial value currently available to those looking to invest in RH&C is energy bill savings. As discussed above, these currently do not suffice to make more than a niche section of the RH&C market cost effective. However, RH&C can provide a number of other value streams that currently do not directly translate into revenue to RH&C customers. We have undertaken analysis into the most important such value components of RH&C technologies. The methodology and data of this value analysis is described in Appendix A. The main value components investigated are the value of carbon as well as the value to electric ratepayers in the form of avoided grid and other utility costs.

- For the **carbon value**, the analysis estimates the amount of carbon saved by each type of installation in each market segment. Carbon value per installation is then determined based on an assumed carbon price.
- For the **electricity grid value**, heat pumps in particular have significant potential to reduce costs for ratepayers. Two examples of such value are:
    - A heat pump would reduce summer electricity consumption compared to air-conditioning. As a result, utility ratepayers can avoid some of the higher wholesale and distribution costs of electricity during peak demand periods in the summer. The average cost per unit of electricity to the utility would reduce, but the heat pump owner would still pay the same cost per unit of electricity and thus not benefit from this value.
    - Heat pumps also increase electricity use in the winter, which can increase utility revenue and—upon approval of rate changes—reduce the amount other ratepayers pay toward fixed electricity grid costs.

Our analysis estimates these and similar value components for the range of installations and market segments assessed in this framework. At the same time, the amount of such value will be highly dependent on site-specific factors, such as the hourly load profile of each site.

Tables 2.6 and 2.7 provide an indication of the annual grid value per ton of installed capacity by RH&C technology and, depending on the conventional heating technology being replaced, as a weighted average across the resource potential for each technology.

Table 2.6 – Weighted average annual grid value per ton of installed capacity, 2017 and 2021 installation vintages[33]

	Installation Year	Replacing electric resistance heating	Replacing fuel oil	Replacing natural gas
ASHPs	**2017**	-$482	$240	$218
	2021	-$548	$274	$249
GSHPs	**2017**	-$522	$189	$173
	2021	-$584	$214	$196

Table 2.7 – Weighted average annual grid value per MMBtu of heating and cooling load served (LCOE), 2017 and 2021 installation vintages [34]

	Installation Year	Replacing electric resistance heating	Replacing fuel oil	Replacing natural gas
ASHPs	**2017**	-$15.48	$7.70	$6.40
	2021	-$17.60	$8.80	$7.31
GSHPs	**2017**	-$17.16	$6.38	$5.15
	2021	-$19.19	$7.23	$5.85

Notes to Tables 2.6 and 2.7:

- We have not assessed the electricity grid value for SHW installations because their impact on the electricity grid is negligible.

[33] Grid value is calculated here for installations as the levelized annual lifetime value per ton of installed capacity (using a real discount rate of 5.5% for the levelization). This is then calculated as a weighted average across all reference installations in the market segment in question (technology and counterfactual fuel), weighted by the technical resource potential of each reference installation.

[34] Grid value is calculated here in the same manner as in Table 2.6, but expressed as an amount per MMBtu of heating and cooling load served rather than per ton of installed capacity.

- Value estimates are shown for installations occurring in 2017 and in 2021, with the slight increase in value forecast being reflective of expected energy price increases.
- Value is shown separately, depending whether RH&C installations replace heating using natural gas, heating oil, or conventional electric (resistance) heating. A negative amount indicates negative value: as discussed further above, one of the drivers of grid value is the change in total amount of electricity use, where an increase in electricity use when installing a heat pump would result in grid value since, under the current rate structure, the increase in electricity usage would result in additional payments from the RH&C user for fixed grid costs. Where heat pumps replace electric resistance heating, the opposite effect occurs—overall electricity consumption is reduced—and this contributes to a negative grid value estimate for installations replacing electric heating.

Value opportunities other than carbon and grid value may be assessed in future analysis, such as value from deferring investments into gas grid infrastructure upgrades or extensions.

Depending on the quantification of the estimated available value and the level to which it would be monetized for the benefit of RH&C investors, such value could significantly increase the amount of cost-effective RH&C resource potential above that identified in earlier sections. Table 2.8 shows the cost-effective resource that could be accessed if the grid value quantified in our analysis for each market segment as well as a carbon value set at the social cost of carbon (SCC)[35] was fully monetized for the benefit of RH&C investors.[36]

[35] Social cost of carbon as set out in the Environmental Protection Agency's Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866 (May 2013, Revised July 2015). The SCC is set out as an annually escalating amount. For RH&C installations installed in 2017, the levelized SCC per ton of CO_2e saved would be $41.40.

[36] This scenario assumes an idealized incentive program in which each RH&C installation is granted a unique annual incentive equal to the value of carbon and grid benefits generated. Carbon emission and savings associated with electricity are calculated based on a marginal grid carbon intensity factor after distribution losses of 1.16 lb of CO_2/ kWh.

Table 2.8 - Cost-effective potential of RH&C technologies (TBtu) – 2021 with global and New York State cost reductions and monetization of grid and carbon value - LCOE

LCOE per $/MMBtu		< $0	$0-$15	$15-$30	>$30	Total
LCOE per ¢/kWh (approx.)		< 0¢	0¢-5¢	5¢-10¢	>10¢	
ccASHP Central System	TBtu	190	390	29	10	620
	% of Tech. Potential	31%	63%	5%	2%	
	% of Statewide Load	19%	39%	3%	1%	62%
ccASHP Mini-Split	TBtu	65	82	30	0	177
	% of Tech. Potential	37%	46%	17%	0%	
	% of Statewide Load	6%	8%	3%	0%	18%
GSHP Horizontal Loop	TBtu	36	36	74	2	148
	% of Tech. Potential	24%	24%	50%	2%	
	% of Statewide Load	4%	4%	7%	0%	15%
GSHP Vertical Loop	TBtu	161	172	192	58	583
	% of Tech. Potential	28%	30%	33%	10%	
	% of Statewide Load	16%	17%	19%	6%	58%
Solar Hot Water	TBtu	0	0	0	47	47
	% of Tech. Potential	0%	0%	0%	100%	
	% of Statewide Load	0%	0%	0%	5%	5%
Combined Total[37]	TBtu	264	375	35	24	697
	% of Tech. Potential	38%	54%	5%	3%	
	% of Statewide Load	26%	37%	3%	2%	70%

Compared to the estimate of total cost-effective RH&C resource potential by 2021 of 116 TBtu (after cost reductions), the impact of such value monetization would be significant, increasing the amount of cost-effective resource potential to 264 TBtu in 2021, more than a quarter of statewide thermal load. Cost-effective potential would increase significantly for both ASHP and GSHP technology, with cost-effective ASHP potential reaching 214 TBtu, and GSHP potential reaching 174 TBtu. As shown in Table 2.9, this represents several multiples of the cost-effective potential available today or in 2021 with or without installed cost reductions. Also, where cost-effective potential today, as described in Section 2.3, is almost exclusively in RH&C installations replacing electric resistance heating, the increase in cost-effective resource from cost reductions and value monetization extends the reach of RH&C to current mainstream heating fuels, with the cost-effective resource of 264 TBtu split between installations replacing electric resistance heating (42 TBtu), fuel oil (122 TBtu) and natural gas (99 TBtu).

[37] The combined total does not equal the sum of the individual technology totals, as there is overlap in the sites that may be served by the various technologies.

Table 2.9 - Cost-effective resource by technology and scenario (TBtu)[38]

Technology	2017	2021		
		No Cost Reductions	With Cost Reduction Interventions	With Cost Reductions and Value Monetization
ASHP	39	73	84	214
GSHP	6	13	58	174
Total	**41**	**79**	**116**	**264**

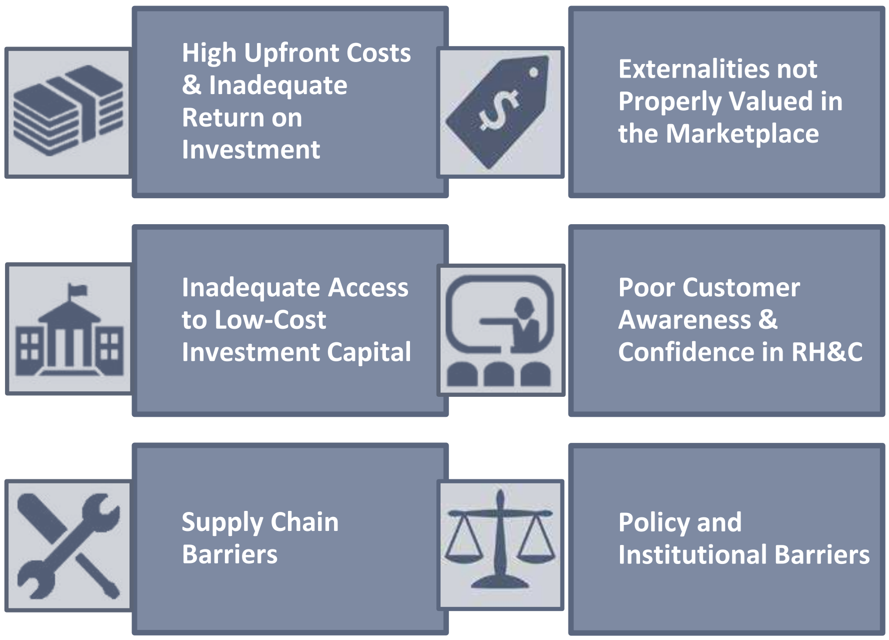
Cost-effective RH&C could currently only meet a small fraction (around 4%) of statewide HVAC load. For RH&C to be able to move from its current niche position to a mainstream market, it will be critical to expand cost-effective investment opportunities in RH&C by an order of magnitude. Projected energy price rises and cost reduction interventions are expected to increase the proportion of the market that RH&C could cost effectively serve to 12% over the next five years. However, the analysis presented in this chapter suggests that in order to increase the potential to over a quarter of statewide HVAC load and create the preconditions for mass market transformation, a combination of cost reductions and value monetization is needed. Chapter 4 sets out our approach to facilitating cost reductions. Chapter 6 discusses options for how incentives could be used to make unmonetized value available to RH&C customers.

[38] Non-duplicative resource. Total cost-effective resource does not equal the sum of ASHP and GSHP resource because these technologies overlap in the specific sites they are able to serve.

CHAPTER 3 BARRIERS

While RH&C technologies have a track record of providing reliable heating and cooling in many buildings, they have not seen widespread deployment in New York State. Figure 3.1 illustrates the major barriers that affect New York State's RH&C market. This chapter discusses each of these barriers in New York State.

Figure 3.1 - Summary of RH&C market barriers



SECTION 3.1 HIGH UPFRONT COSTS AND LOW RETURNS

RH&C systems have high upfront costs, which, when combined with low fossil fuel prices, results in RH&C systems that deliver inadequate returns on investment for many applications. In addition, because RH&C technologies are capital intensive, they are often considered out of reach by many residential customers who lack access to capital or financing.

In the commercial sector, many building owners require a quick payback, and RH&C technologies must compete for scarce internal investment dollars with other priorities, including priorities that are more central to the business or mission. Commercial decision-makers will often determine that the opportunity costs associated with focusing time, energy, or capital on evaluating the potential for RH&C heating systems is too great compared to potential returns.

Solutions that can address this include policies focused on cost reduction—across all elements of RH&C project cost—to improve economics. Policies can also include incentives that proximate future cost-reductions at levels that appropriately balance multiple policy considerations.

SECTION 3.2 EXTERNALITIES NOT PROPERLY VALUED IN THE MARKETPLACE

The typical benefits associated with RH&C projects—energy savings and comfort—are not the only benefits delivered by RH&C projects. RH&C systems also provide environmental and social benefits that are not properly valued in the marketplace. RH&C systems can reduce GHG emission reductions, provide electric grid benefits, and offer other social and environmental benefits; however, under current New York State policies, such value cannot be monetized by system owners.

Policy solutions that can address this include approaches to internalizing economic externalities by partially or fully monetizing (redistributing) value elements to project developers. Policies could also include incentives that proximate un-monetized externalities.

SECTION 3.3 INADEQUATE ACCESS TO LOW-COST INVESTMENT CAPITAL

Financiers have limited experience evaluating and financing RH&C systems. This is primarily because RH&C is a small niche market that currently does not generate a large volume of deals for investment. In addition, many installations—especially large commercial installs—are highly engineered to meet the unique needs of individual buildings, which makes it challenging to standardize and deploy at large-market scale. The industry has also not established standardized contracts, metering protocols, or other financing requirements, which make it time-consuming and expensive for investors to perform due diligence.

A lack of investor familiarity with RH&C deals combined with lack of standardization and performance data translates to a higher perception of risk among investors and thus a high cost of capital for RH&C projects. In other words, the risk-adjusted cost of capital for RH&C projects (i.e., capital that accounts for the risk-return profile) is too high and/or capital is not sufficiently available to provide ready liquidity for RH&C projects.

Policy solutions that may be able to mitigate these barriers include helping industry to develop new financing and business models, standardize installations, and standardize and aggregate RH&C contracts. As discussed in Chapter 4, these market interventions can help drive volume, reduce the cost of capital, and reduce RH&C costs. Public clean energy finance institutions, such as New York Green Bank can likely play a useful role in this regard.

SECTION 3.4 POOR CUSTOMER AWARENESS AND CONFIDENCE

New York State consumers typically lack awareness of RH&C technologies and/or confidence in their reliability and performance. This may be due to a historical focus by policymakers on incentivizing high-efficiency fossil fuel systems (i.e., via energy efficiency programs), low levels of education or training for RH&C technologies, lack of effective marketing by industry, and absence of government-led consumer education programs, among other factors.

The typical sales cycle for heating and cooling replacements also poses a challenge to RH&C. When a heating system unexpectedly breaks down, customers are less likely to shop around and find the best deal and instead will seek the fastest solution to get their heating or cooling system back online. Thus, they rely on contractors to provide a quick “emergency” service to replace their heating and cooling system. In such cases, a like-for-like replacement of their existing oil or gas heating system (or conventional A/C system) is often seen as the most expedient option, locking customers into another 15+ years of fossil fuel based heating or conventional cooling.

Customers may also perceive larger risks associated with RH&C than traditional systems, including concerns over quality and durability, warranties from the manufacturer, overall performance, and availability of maintenance services. In addition, larger commercial and industrial entities may be wary of investing in RH&C technologies that require new staff or additional training to maintain. Retrofit installations of RH&C systems also disrupt customer sites, in many cases significantly more than the fossil fuel based systems they are displacing.

Solutions include promoting innovative financing and ownership mechanisms, such as the provision of heat as a service to building users; New York State agencies could also intervene by creating educational, marketing, or other customer acquisition campaigns that raise awareness of the benefits of these technologies (see Section 4.3).

SECTION 3.5 SUPPLY CHAIN BARRIERS

In early-stage RH&C markets like New York State, a lack of capacity to manufacture, distribute, design, install, and service reliable, high-quality, and standardized RH&C systems is a significant barrier to market scale. Manufacturers and their distributors have limited resources to devote to building a base of potential customers for RH&C. This difficulty is amplified in sectors where sales staff face the dual challenges of selling their specific product and convincing customers about the RH&C opportunity more broadly.

RH&C technologies also require specialized training and skills to properly design, install, and service. Improperly installed and maintained systems can damage the industry’s reputation. This issue has been identified as one of the reasons for the collapse of the SHW market in the United States after several years of rapid growth in the late 1970s and early 1980s.[39]

[39] http://cesa.org/assets/Uploads/CESA-solar-hot-water-state-program-guide07.pdf

Within New York State, many traditional HVAC contractors have a limited understanding of how to sell, install, or price RH&C technologies. In recent interviews, ccASHP manufacturers report that contractors often use inappropriate pricing methodologies for mini-splits, which have higher equipment costs but can be installed with significantly less labor (compared to traditional oil or gas systems). The SHW and GSHP sectors also face challenges with conventional installers lacking the proper training to educate consumers on lifecycle product performance and long-term cost savings potential. Similar challenges are seen among traditional designers, architects, and engineers. As a result, during a bid process, designers and contractors may not offer RH&C as an option to commercial or residential customers. Professionals that set up bid structures also often over-emphasize initial costs and de-emphasize life-cycle costs.

These challenges are exacerbated by the additional business costs that HVAC professionals incur when working with non-conventional technologies like RH&C. Contractors report that they prefer selling conventional technologies because new technologies like RH&C require (i) new training and/or installation practices, and (ii) a different sales approach, both of which require investments in time and money for their staff. Moreover, contractors face higher risks of installing a poorly performing project when using new technologies, which can further increase their costs. For these reasons, conventional contractors will often mark up the cost of RH&C installations to cover these (real or perceived) business risks.

Solutions that can address these barriers include workforce and vendor training programs to help overcome these challenges. Workforce training programs should focus on standardizing installations to help contractors (i) learn best practices, and (ii) reduce risk of installing underperforming systems (see Chapter 4).

SECTION 3.6 POLICY AND INSTITUTIONAL BARRIERS

Frequently, RH&C technologies are overlooked as potential solutions by policy makers. As a result, policies that address building standards and electric and natural gas efficiency often fail to provide support for RH&C technologies, even when RH&C can advance the intended outcomes of those policies.

State and local building codes and environmental permitting requirements often do not address RH&C technologies, resulting in uncertainty for customers and installers regarding applicable permitting rules and procedures. This uncertainty creates burdens for installers attempting to operate at scale. Limited building inspector and permit reviewer familiarity with and confidence in the performance of RH&C systems further compounds this policy barrier and adds cost.

Some existing policies support important paths toward reduction of carbon in the HVAC sector, such as tax credits and ratepayer programs to encourage customers to install more efficient natural gas heating systems and/or help customers switch from oil heating to natural gas heating, and policies supporting the extension of the natural gas system. As we consider ways to achieve our GHG reduction goals, particularly the State's long-term 80% reduction by 2050, policies need to evolve to consider the impact of locking customers into a new fossil fuel system for 15-plus years. Similar to the use of demand reduction to defer the need for transmission and distribution (T&D) upgrades on the electric grid, there is a compelling opportunity to defer natural gas pipeline upgrades and extensions through use of renewable heating and cooling options, leading to a more cost-effective outcome.

Solutions include developing appropriate consideration of RH&C technologies in applicable State and local policies. Building on the work presented here, the State could convene a working group(s) of policy makers, stakeholders, and market participants to inventory and assess the impact of policy barriers and develop recommendations.

CHAPTER 4 LOWERING COSTS AND REDUCING BARRIERS

Chapter 3 describes a range of barriers, both financial and non-financial, that are preventing the RH&C sector from achieving its full potential. We have identified several areas where policies could contribute to removing both financial barriers—by helping to reduce technology installation costs—and non-financial barriers, including lack of customer awareness and confidence, and supply chain barriers:

- More effective customer targeting, and increased co-location and clustering of installations
- Standardization of equipment specification and design processes
- Standardization and simplification of permitting processes across State municipalities
- Better information on technical and economic viability
- Leveraging broader trade channels
- Finance and business model innovation

Section 4.3 describes options for policies and market-based strategies for each of these areas in turn.

Sections 4.1 and 4.2 contain further details on quantification of expected cost reductions: Section 4.1 discusses global cost reductions that are largely outside the reach of action at the State level but do still affect costs at the State level. Section 4.2 attempts to quantify cost reductions that can be expected to result directly from the New York State intervention options discussed in this chapter.

SECTION 4.1 GLOBAL COST REDUCTIONS

Some cost reductions occur outside New York State's sphere of influence. Equipment components ("hard" costs) tend to operate as a global, or at least regional, market, with cost reductions resulting from steady technology improvements, and generally showing a strong correlation with increases in global (or regional) levels of uptake. Action in New York State would not be expected to affect the level of cost reductions for hard costs; however, conversely, installed cost levels in New York State can be affected by changes in global hard equipment costs, and it is therefore useful to assess expected developments in this respect.

RH&C equipment is manufactured for a mostly global market:

- ASHPs are mainly manufactured in Asia and sold across Europe, Asia, and the U.S. ASHPs enjoy a 20% to 40% share of the HVAC market and are best suited to warm climates in the

U.S.[40] Cold climate ASHPs have extended ASHP technology geographic suitability to colder climates such as New York State, but these units are more expensive than standard ASHPs and are just entering the market.[41]

- Major SHW manufacturing facilities are located across the globe, with five of the 20 largest flat plate collector manufacturers located in Germany and three located in China.[42]
- GSHPs are manufactured in Europe, Asia, and the U.S. with major markets in Europe (Sweden, Germany, Austria), the U.S., and Asia (China).[43] U.S. market sales volumes are dominated by Climate Master (NIBE Group), Florida Heat Pump (a unit of Bosch), Waterfurnace International (NIBE Group), and Trane,[44] with somewhat limited competition.

A number of studies have examined developments in past equipment cost reductions and have expressed a correlation between increases in installed technology capacity and cost reductions through the concept of "**learning rates**," defined as an observed or expected percentage cost reduction for each doubling of cumulative installed capacity.[45] Relevant studies relating to learning rates are listed in Table 4.1. In each case, the studies appear to track learning rate as function of cumulative installed capacity in the geography in question rather than global volume; accordingly, especially learning rates from geographies outside the U.S. may not be immediately applicable if the pace of volume uptake differs between geographies.

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[40] Figure 1-1, "Ground-Source Heat Pumps: Overview of Market Status, Barriers to Adoption, and Options for Overcoming Barriers," Navigant Consulting, 2009.

[41] Jordann Brown, "Do Air Source Heat Pumps Work in Cold Climates?," Dec 9, 2015, Nordic Heat Pumps, http://www.nordicghp.com/2015/12/air-source-heats-pump-cold-climates/

[42] http://www.solarthermalworld.org/content/worldwide-largest-flat-plate-collector-manufacturers-2013

[43] "Ground-Source Heat Pumps: Overview of Market Status, Barriers to Adoption, and Options for Overcoming Barriers," Navigant Consulting, 2009.

[44] Xiaobing Liu, Shilei Lu, Zhe Cai, Jinjua Chen, "A Comparative Study on the Status of GSHP Applications in U.S. and China," U.S.-China Clean Energy Research Center for Building Energy Efficiency, 2012.

[45] Note that accordingly, learning rates do not represent an annual cost reduction rate.

Table 4.1 – HVAC learning rate studies

Geography and Market Sector	Est. Learning Rate	Source
U.S. residential central and heat pumps	10.7%	U.S. Department of Energy[46] (DOE)
U.S. unitary AC units	18%	DOE[47]
U.S. electric water heaters	17%	DOE[48]
Europe solar thermal	23% (collector only)	European Technology Platform[49]
Europe heat pumps	20%	European Heat Pump Association[50]
Sweden GSHPs	2.3%	Kiss, Neij, and Jakob[51]
Switzerland GSHPs	17%	Kiss, Neij, and Jakob[52]

We have used the above studies as well as feedback from the Advisory Committee to project the equipment cost reduction potential of the various technologies for the period to 2021.

- For ccASHPs and GSHPs, we used the 10.7% learning rate in the DOE study referenced above. While this is on the more conservative side of the range of learning rates shown above, we believe that this is justifiable because the DOE study was based on the U.S. market historical uptake specifically for heat pumps. We are assuming the same learning rate across ccASHPs and GSHPs (indoor equipment only) given that the technologies share substantially the same equipment manufacturing processes and the identity of primary components. Based

46 "2016-12 Final Rule Technical Support Document, Energy Efficiency Program for Consumer Products: Residential Central Air Conditioners and Heat Pumps," Section 8.2.1.5. The TSD for residential central AC and heat pumps calculated a 10.7% price reduction per market doubling.

47 https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/experience_curve_appliance_price_forecasting_3-16-11.pdf "Using the Experience Curve Approach for Appliance Price Forecasting," Feb 2011

48 *Ibid*.

49 http://www.rhc-platform.org/fileadmin/Publications/Solar_Thermal_SRP_single_page.pdf. Stryi-Hipp et al, "Strategic Research Priorities for Solar Thermal Technology," European Technology Platform on Renewable Heating and Cooling, Dec 2012. The European Technology Platform projects a learning rate of 23% for solar thermal technology. Their market has increased from 4 to 23 installed GWh from 1995 to 2010, which has corresponded to a cost reduction of nearly 50%.

50 Personal communication with the head of the European Heat Pump Association. A doubling of EU stock is projected by 2024, and a second doubling 8 to 10 years later, each of which is estimated to yield a 20% cost reduction.

51 Kiss, B., Neij, L. & M. Jakob (2012). Heat Pumps: A Comparative Assessment of Innovation and Diffusion Policies in Sweden and Switzerland. Historical Case Studies of Energy Technology Innovation in: Chapter 24, The Global Energy Assessment. Grubler A., Aguayo, F., Gallagher, K.S., Hekkert, M., Jiang, K., Mytelka, L., Neij, L., Nemet, G. & C. Wilson. Cambridge University Press: Cambridge, UK.

52 *Ibid*

on uptake projections for the heat pump and air-conditioning market, the aforementioned DOE study projects equipment cost to decline by 5% (real) by 2021. This projection is supported by previous cost reduction studies.[53]

- For SHW, we only have very limited data on past learning rates relating exclusively to solar collectors, in the form of the 23% estimate from the European Technology Platform study referred to above. However, in much of Europe and China, manufacturers have faced declining sales and overcapacity.[54] In addition, feedback from the Advisory Committee and recent studies indicate that prices for SHW equipment have increased recently at least with the rate of inflation. Accordingly, costs are projected to stay relatively flat (~0% rate of reduction in real terms) for the period to 2021.

Accordingly, the analysis underpinning this Policy Framework uses an assumption of 5% (real) reductions by 2021 in hard equipment costs for ccASHPs and GSHPs, and 0% for SHW.

SECTION 4.2 NEW YORK STATE COST REDUCTIONS

This section quantifies the level of cost reductions that we expect to realize between now and 2021 as a result of the intervention options described in Section 4.3.

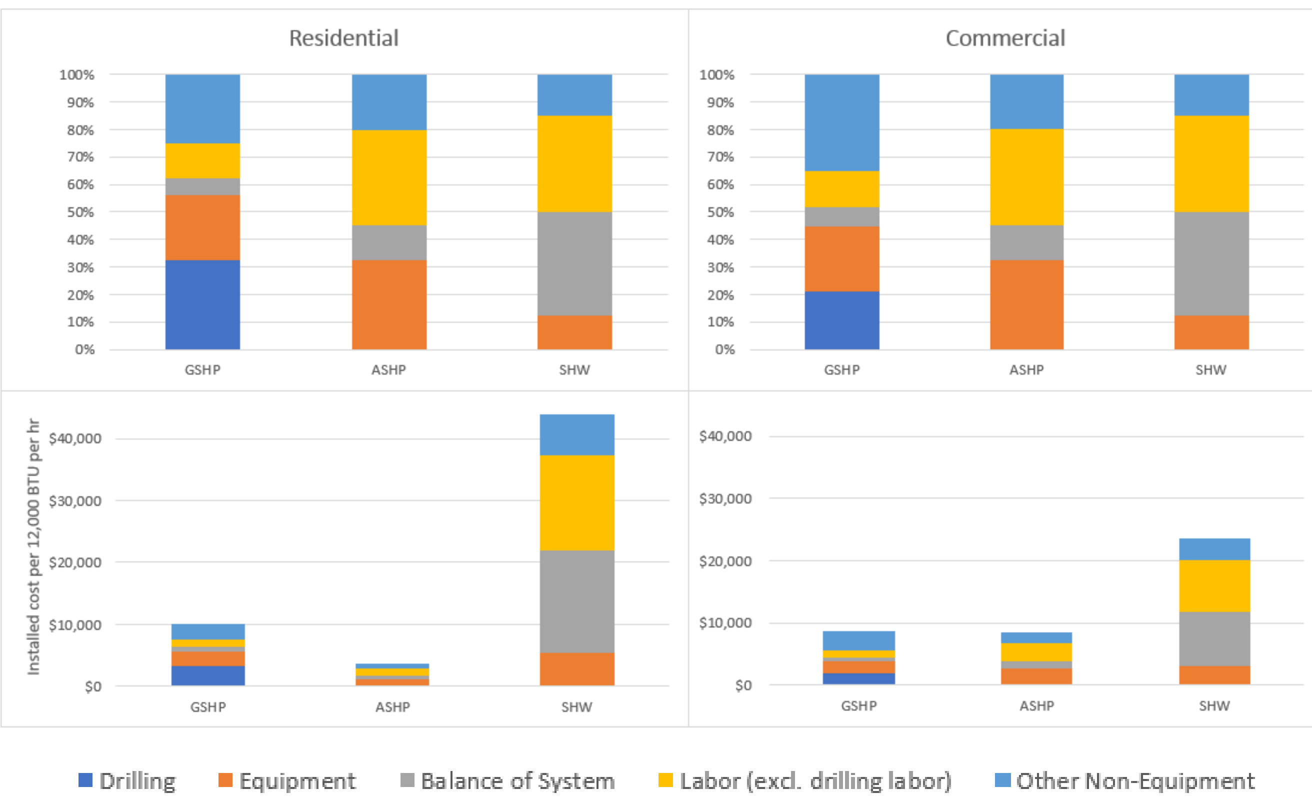
Total installed costs are made up of a number of major components, and the extent to which costs can likely be reduced will differ between components. Table 4.2 and Figure 4.1 provide an indication of the cost components and cost structure across the RH&C technologies. [55]

[53] UK Department of Energy and Climate Change, "Potential Cost Reductions for Ground Source Heat Pumps: The Scope for a Mass Market" (January 2016); see also Clean Energy Manufacturing Center, "Heat Pump Supply Chains and Manufacturing Competitiveness Considerations," 2016 Building Technologies Office Peer Review.
[54] Ren21, "Connecting the Dots: Convening Multi-Stakeholders on Renewable Energy," Annual Report 2016, Renewable Energy Policy Network.
[55] Cost component figures should be taken as order of magnitude indicators, since overall costs as well as the split between cost components can differ significantly for each installation.

Table 4.2 - RH&C cost components

Cost Component		GSHP	ccASHP	SHW
Drilling		Exterior house drilling, U-tubes, grout, manifolds, exterior labor and drilling contractor overhead	N/A	N/A
Equipment	**Heat Pump / Collector**	Heat pump and warranty		Collector panels
	Balance of System (BOS)	Internal piping, electrical wiring, condensate pump, auxiliary heater, internet monitoring, interior ductwork modifications	Internal ductwork modifications/ connection, condensate pump, electrical wiring, auxiliary heater	Collector mounting, pump stations, controller, piping, racking, misc.
Labor		Heat load/system design, old furnace removal, inside labor	System design, inside labor	
Other Non-Equipment		Sales tax, financing closing fees, R&D, sales and marketing, general and administrative, profit		Same, plus structural engineering

Figure 4.1 - RH&C cost structure



Our research—including input from the Advisory Committee—suggests that cost reduction opportunities across the RH&C technologies and their cost components can be characterized as follows:

- **GSHPs:** Non-equipment overhead costs account for over two-thirds of typical GSHP total installed costs, and GSHP systems are typically highly customized. Research and engagement with industry stakeholders have indicated that significant reductions in non-equipment costs (especially drilling and labor) could be achieved through greater scale. As such, the most significant cost reduction opportunities for GSHPs described in Section 4.3 focus on improving localized economies of scale through co-location and clustering of installations and greater standardization of equipment and installation processes—both of which can lead to significant reductions in drilling, labor, and equipment costs.
- **ccASHPs:** Labor costs account for a significant proportion of typical ccASHP installed costs. In general, ccASHP cost reduction opportunities are expected to be less significant than for GSHP due to having greater equipment standardization and higher existing market volume. However, it is expected that modest cost reductions could be achieved (particularly in labor costs) through improved geographic clustering of installations and greater standardization of installation processes.
- **SHW:** Plumbing labor and other non-equipment costs account for a significant proportion of typical SHW installed costs. Opportunities exist to reduce labor costs through improved clustering of installations and greater standardization and equipment integration. Additionally, industry stakeholders have noted that standardization of the widely varying permitting requirements and costs across New York State jurisdictions could result in significant installed cost reductions (see Section 4.3).

Tables 4.3-4.5 quantify our cost reduction estimates by cost component.

Table 4.3 – Estimated GSHP cost reductions by component (small installations)

GSHP Cost Components	Est. percentage of total cost for residential and small commercial/multifamily	Max. potential direct cost reduction
Drilling	32%	40%-50%
Equipment – heat pump	24%	15%-20%
Equipment – balance of system	6%	35%-40%
Labor (excl. drilling labor)	13%	35%-40%
Other non-equipment	25%	~10%
Total	**100%**	**~30%**

Table 4.4 – Estimated ccASHP cost reductions by component (small installations)

ccASHP Cost Components	Est. percentage of total cost for residential and small commercial/multifamily	Max. potential direct cost reduction
Drilling	N/A	N/A
Equipment – heat pump	33%	5%-10%
Equipment – balance of system	12%	10%-15%
Labor (excl. drilling labor)	35%	10%-15%
Other non-equipment	20%	5%-10%
Total	**100%**	**~10%**

Table 4.5 – Estimated SHW cost reductions by component (small installations)

SHW Cost Components	Est. percentage of total cost for residential and small commercial/multifamily	Max. potential direct cost reduction
Drilling	N/A	N/A
Equipment – collector	13%	10%-15%
Equipment – balance of system	37%	15%-20%
Labor (excl. drilling labor)	35%	25%-30%
Other non-equipment	15%	25%-30%
Total	**100%**	**~25%**

Some cost reduction opportunities, in particular co-location and standardization, also depend on the type or size of installation. The opportunities for and benefits from co-location reduce for larger installations, and, similarly, larger installations by their nature tend to require a more customized approach, reducing the scope for gains from standardization. It is expected that the cost reduction potential in medium commercial/multifamily and large commercial/multifamily sectors will be roughly two thirds and one half, respectively, of small residential/commercial/multifamily.

Based on these observations, Table 4.6 describes the estimated cost reduction potential by 2021, expressed as percentages of total installed costs, for each of the RH&C technologies across three broad market segments: (i) residential and small commercial/multifamily, (ii) medium commercial/multifamily, and (iii) large commercial/multifamily.

Table 4.6 - Estimated project-level direct reductions in total installed costs by 2021 from successful implementation of options set out in Section 4.3

Real % of total installed cost	**Small Residential/ Commercial/Multifamily**	**Medium Commercial/ Multifamily**	**Large Commercial/ Multifamily**
GSHP	30%	20%	15%
SHW	25%	15%	10%
ccASHP	10%	7%	5%

The potential cost reductions set out in Table 4.6 are estimated for projects that would successfully be targeted by the range of interventions set out in Section 4.3. For each project, such cost reductions are thus subject to the overall level of success of our interventions aimed at unlocking these cost reductions, and the proportion of the projects each year that we can reach with these interventions. For example, cost reductions as a result of clustering would only occur where we could successfully facilitate uptake in the form of clusters rather than isolated installations. In our analysis for this framework, we assumed that, on average, 50% of the cost reductions quantified in Table 4.6 could be realized by 2021.

The impact of the interventions discussed in this Chapter is expected to extend beyond the cost reductions quantified in Table 4.6. They are also expected to address many of the non-financial barriers identified in Chapter 3, and, by doing so, increase uptake rates in market segments where RH&C technologies are cost effective. In turn, it is expected that as uptake increases, industry will benefit from economies of scale and other learning effects and thus be able to bring down costs further. This would lead to a positive feedback loop between cost reductions and uptake rates—an effect similar to the one described in Section 4.1 for global reductions in hard costs. At the State level, increased uptake is expected to lead to reductions in soft costs. More specific impacts of these economy-of-scale and learning effects on cost components are discussed in Box 4.1.

Depending on the extent to which RH&C uptake rates can successfully be increased, we expect this cost reduction effect to be at least as meaningful as global and direct cost reductions. However, at this stage, we lack the data and research to allow us to determine a learning rate (similar to the learning rates discussed for global hard-cost reductions in Section 4.1) that would allow us to quantify such cost reductions in a meaningful way. For now, we have assumed that uptake-dependent reductions in soft costs in New York State will be at least at the same level as those identified in Section 4.1 for hard costs, and in our analysis we have thus applied the cost reduction forecast of 5% (real) for ccASHPs and GSHPs by 2021 to both hard and soft costs (i.e., to the entire installed cost). We expect to update our quantification of these volume-dependent cost reductions when more data and research are available.

Box 4.1 - Impact of greater market volume on cost components in the RH&C value chain

Greater RH&C uptake within New York State is generally expected to reduce costs across a range of cost components within RH&C value chains:

- **Installation costs.** Broader adoption of RH&C technologies by contractors and continued streamlining of installation procedures are expected to reduce labor costs due to improved economies of scale.
- **Drilling costs** (GSHP). Drilling costs are a significant component of a GSHP installation, and greater market volume will enable improved capacity utilization of drillers. Greater volume could also lead to other market innovations, such as the proliferation of drill rigs specially sized and equipped for GSHP loop field drilling, which could be cheaper than more general-use rigs but would require sufficient GSHP volume.
- **Overhead costs.** Market growth will enable longer-term consolidation in the market, ranging from the development of integrator (or "warranty wrap") companies to broader vertical integration.
- **Financing costs.** As market volume increases and greater data becomes available, perceived investor financial risk is expected to decrease and lower-cost capital will become available.
- **Warranty costs** (GSHP)**.** As the market scales up, installation quality improves, a greater range of performance data becomes available, greater standardization occurs within the market, and high warranty costs are expected to fall, particularly for residential GSHP where warranty costs are much higher than in commercial.
- **Equipment costs.** The scope for achieving reductions in equipment costs in correlation with New York State-specific RH&C uptake volume is limited, since equipment costs are dominated by global cost factors and global sales numbers. Nevertheless, increased local volume can drive some modest cost reductions, for instance by means of manufacturers setting aside whole manufacturing runs for a particular geography to meet demand**.**

SECTION 4.3 OPTIONS FOR POLICIES AND MARKET-BASED STRATEGIES

This section describes intervention options for the RH&C sector aimed at both unlocking cost reductions and removing non-financial market barriers. Possible market interventions in this area were identified by researching international best practices and consulting with members of the Cost and Cost Reductions Advisory Committee.[56] A high-level summary of the opportunities is provided in Box 4.2.

[56] See Section 1.4.

Box 4.2 - Summary of opportunities and intervention options to reduce costs and lower barriers

Opportunity	Options for policies and market-based strategies
More effective customer targeting, and increased co-location and clustering of installations	1. Implement community procurement programs (e.g., Solarize for Heat) to promote local clustering. 2. Develop a customer targeting and engagement tool to enable contractors to identify local clusters of high-potential customers.
Standardize equipment specification and design processes	3. Facilitate standardized equipment and design approaches by encouraging industry best practice and/or through requirements in incentive programs.
Standardize and simplify permitting processes across State municipalities	4. Develop a unified, streamlined permitting process for RH&C technologies and encourage adoption across NYS municipalities.
Better information on technical and economic viability	5. Provide technical and engineering assistance and project development support for larger projects in key market segments.
Leveraging broader trade channels	6. Integrate RH&C into existing trade channels, such as the HVAC emergency replacement market or oil heat dealer sector in order to reach a broader customer base.
Finance and business model innovations	7. Enable broader availability and development of cheaper finance options. 8. Work with utilities and energy service companies (ESCOs) to pilot third-party ownership and other innovative models under REV.

In addition to the opportunities listed in Box 4.2, NYSERDA plans to issue a $15 million technology challenge to the innovation/entrepreneur community to develop and demonstrate solutions for the next generation of HVAC equipment. These technology challenges will be focused on improving the performance and value proposition of existing and new heating and cooling technologies, including ccASHPs.

4.3.1 MORE EFFECTIVE CUSTOMER TARGETING, AND INCREASED CO-LOCATION AND CLUSTERING OF INSTALLATIONS

Barriers addressed:

- **Supply chain barriers and customer awareness barriers**. Given the niche nature of the RH&C market, contractors do not have the resources to invest significantly in customer acquisition, and typically therefore only reach a small part of the potential customer base. For their part, customers are often unaware of RH&C as an option. Community procurement programs and a customer targeting/engagement tool could help address these barriers.

Cost reduction opportunity:

- Due to the size of the RH&C market, contractors face a range of labor inefficiencies in the installation process. For example, the installation of a GSHP system typically requires two separate entities: one to install the interior system and one to conduct the drilling and connect exterior piping. In addition, recent industry research suggests that drilling teams and rigs are unutilized for up to 40% of time spent on-site. Increased labor costs resulting from this low utilization are passed on to the customer. Community procurement programs could be designed in a way that encourages co-location and clustering to reduce these inefficiencies. Identifying and targeting new construction projects could achieve the same benefit. Installers participating in community procurement campaigns may also be able to negotiate volume discounts for hardware, depending on the technology.

Option 1: Implement community procurement programs (e.g. Solarize for Heat) to promote local clustering
Such programs aim to aggregate customers within a community to purchase a renewable energy technology. With an aggregated pool of leads in a single neighborhood, contractors can develop an efficient installation process based on the geographic location of campaign participants. Programs can also be designed to take advantage of network effects—for example, providing additional discounts to homeowners that sign their neighbors up, thus enabling contractor to coordinate activities for clustered installations. Community-based outreach, education, and bulk procurement campaigns, such as Solarize, have been successful in reducing customer acquisition (and overall installation) costs, increasing consumer awareness of renewable technologies, and jump-starting solar PV markets in local jurisdictions.[57] Since 2015, NYSERDA has successfully run a Solarize program (Community Solar NY) in collaboration with local governments, school districts, and other community organizations across the state.[58] For RH&C, this approach has been piloted in Tompkins County (HeatSmart Tompkins)[59] and in Massachusetts[60] (with support from the Massachusetts Department of Energy Resources), with additional pilot campaigns planned across New England in 2017. Important elements include: • **Technical assistance and support.** In addition to providing grant funding to cover campaign expenses, NYSERDA could provide a similar level of technical assistance to community

[57] https://www.nyserda.ny.gov/all-programs/programs/ny-sun/communities/solarize The Solarize model uses a limited-time outreach and marketing campaign led by local governments or community groups to aggregate customers to purchase solar PV systems. Cost savings from customer acquisition and equipment costs are concentrated in a small number of participating installers and are passed on to customers, typically in the form of standard pricing with a tiered pricing structure or flat discount. The Solarize model has been deployed in over 200 campaigns across the United States with extensive campaigns in New York State and across the Northeast.
[58] Through Community Solar NY, NYSERDA provides participating communities with up to $5,000 in grant funding as well as technical assistance and standard marketing and educational materials to support campaign implementation.
[59] http://www.solartompkins.org/heatsmart-tompkins-program.html
[60] http://wepowr.com/massenergy

organizers, including but not limited to: installer selection support (e.g., model RFPs, selection guidelines, base pricing negotiation), standard marketing and educational materials, and on-call access to technical experts to support campaign design and implementation. Program designs should consider access and inclusion of LMI customers.

- **Start with previous Solarize communities.** Programs of this nature could initially engage communities that have already implemented campaigns through Community Solar NY, to leverage the previous experience of local campaign organizers and the community's familiarity with Solarize to strengthen the initial round of campaigns. Design should also consider strategies to increase access/involvement of communities with low/moderate income residents.
- **Contractor engagement.** All RH&C industry sectors could benefit from the program; however, success will depend on participation of local contractors who understand the benefits afforded by economies of scale and can offer pricing reflecting those benefits. Accordingly, a robust outreach and education process to engage industry leaders around the state and in targeted communities will also be necessary.

Impact:

All contractors are expected to benefit from reduced customer acquisition costs, local marketing support, volume discounts, and other economies of scale.

Solarize for RH&C campaigns are expected to be most effective in the residential and small commercial sectors, where customer acquisition costs are higher (as a proportion of installed costs) and system customization needs are lower. These sectors account for over 70% of all buildings in New York State.

Technology-specific considerations:

- Clustering. For **GSHPs**, geographic clustering of installations can achieve significant soft cost reductions through improved labor efficiencies for installers, greater capacity utilization of drillers, and efficiencies gained in transit and equipment set-up times. Research and interviews with industry stakeholders suggest that residential drilling costs could be reduced by over 40% if sufficient clustering occurs. The greatest opportunities for geographic clustering can come in new construction where contractors can work with developers to conduct clustered drilling early in the installation process. **ASHP** and **SHW** systems could also benefit from geographic clustering, as efficiencies could be gained in transit and equipment set-up times, though the potential cost reductions are expected to be lower than for GSHP (due in part to the higher drilling rig capital costs needed for GSHP).
- Volume. Increased volume and aggregation would also be expected to yield significant volume discounts for **GSHP** installers making bulk purchases of equipment from manufacturers. Opportunities for **ASHP** volume discounts are likely to be smaller due to relatively larger existing market size and established relationships between HVAC contractors and distributors. For SHW, volume discounts can be provided through purchasing equipment directly from manufacturers (as opposed to distributors). These volume discounts are largest at "container" shipment quantities (e.g., 100+ SHW collectors), since SHW equipment is often manufactured in Europe or Asia.

Option 2: Develop a customer targeting and engagement tool to enable contractors to identify local clusters of high-potential customers
Support the development of a robust, comprehensive customer-targeting tool for contractors, with resources that would also be available to customers. Such a tool can enable contractors to identify high-potential leads within a community (e.g., through a tool that includes building-by-building fuel usage, estimated heating appliance age, geological maps, insolation maps, etc.) and target outreach to geographic clusters. Such a tool could include: ◉ **A variety of technology, resource, and load maps** that would assist contractors, such as geological maps; building-by-building fuel usage and heating appliance age maps; utility load maps; existing RH&C installations; customer credit and home turnover maps, etc.—subject to data protection issues. This would enable contractors to market RH&C systems directly to highest-potential customers (e.g., geographically clustered, high-potential residential customers). As such, cost reductions can be driven by reducing customer acquisition costs and enabling clustering of installations. ◉ **Educational materials** and a lifecycle cost calculator, link to tools that can provide general guidance on a building's suitability for each of the RH&C technologies, and potentially provide a contractor identification service that enables customers to reach out to contractors and receive initial quotes.[61] Development of the RH&C database and tool would hinge on aggregating existing public data sources, accessing aggregate data from third-parties, and working with web developers to enable contractor and consumer accessibility. Primary steps would include: ◉ Collecting statewide building data, fuel usage data, existing system data (including age), insolation and sub-surface geology data, etc. from State and municipally owned data sources, utility energy usage rosters (where available), and other public data sources (such as soil and bedrock GIS layers, well-drilling reports, National Renewable Energy Laboratory (NREL) solar radiation maps, etc.) ◉ Aggregating these data into a queryable and user-friendly database that could give outputs in the forms of high-potential RH&C customer lists based on any of the above factors ◉ Developing the outward-facing portal and consumer education tools, such as lifecycle cost calculators for different building types
Impact: For each of the technologies being considered, customer acquisition costs will be reduced, particularly through improved timing and coordination enabled by HVAC age maps and consumer education materials.
Technology-specific considerations: ◉ A customer targeting tool could enable **GSHP** contractors to identify opportunities for clustered installations (e.g., in areas with no access to natural gas), which could allow contractors to be

[61] http://www.gridmarket.com/

- more efficient in completing grouped installations. Sub-surface geology maps could reduce the time spent on determining suitability of different sites, minimizing assessing costs.
- Segmenting the market by building size, type, occupation status (owner v. renter, organization v. individual) etc. would enable contractors to identify situations particularly suitable for **ASHP** mini-splits, which typically require short installation times.
- For **SHW**, insolation maps could help reduce site assessment costs, as could building type data if factors such as building ownership and roof orientation were included.

4.3.2 ENCOURAGE DEVELOPMENT OF STANDARDIZED EQUIPMENT SPECIFICATIONS AND DESIGN PROCESSES

Barriers addressed:

- **Supply chain barriers and customer awareness barriers**. Standardization can reduce the amount of training needed for on-site installations staff. Standardized specifications can also help encourage the involvement of third-party ownership structures (see also Option 8), which can help overcome consumer confidence barriers.

Cost reduction opportunity:

- There is a high degree of customization of RH&C systems in buildings, especially for GSHP and SHW installations. Customization of design increases installed costs of RH&C systems relative to more standardized conventional heating systems. While customization is necessary for most large, commercial-scale systems, there are opportunities to establish standardized design and installation approaches at the residential and small commercial level.

Option 3: Facilitate standardized equipment and design approaches by encouraging industry best practices and/or through requirements in incentive programs

Advisory Committee member input and analysis of design, site, and equipment variability suggest that it is possible to develop standardized design specifications and installations practices for RH&C technologies, which would be suitable for most residential and small commercial buildings. By creating a more standardized design specification, it is possible to enable greater scale at the manufacturing level and improving field labor utilization. This design class specification should be specific to the needs of the New York State market and achievable by most manufacturers. Standardized design can also be an important step to enable the development and proliferation of third-party financing models (see Option 8).

A standardized design specification could address a wide range of components throughout the value chain. Depending on the RH&C technology, the specification might include[62]:

[62] For GSHPs, the International Ground Source Heat Pump Association (IGSHPA) has developed some design and installation standards for each element of a GSHP, ranging from heat exchangers, to pipe placement, to indoor circulation systems, to permanent loop pipe decommissioning processes. These standards are periodically updated by a standards committee, which helps ensure standards keep pace with improvements to products and best practices. Such standards could be used as a starting point for developing a New York State

- **Pre-assembly of components off-site,** including, for example manufacturer pre-assembly of standard configurations (e.g., rubber-insulated interior piping components for GSHP, contractor off-site pre-assembly of certain pipe connections and fittings for GSHP and SHW)
- **Standard installation procedures,** including optimized (sequenced and/or integrated) outdoor and indoor installation work
- **Standardized design guides/software** that contractors can use to design and specify systems, satisfy the needs of most building conditions, and that minimize the need for skilled trade labor (e.g., eliminating need for hardwiring of SHW and GSHP). Additionally, GSHP loop fields are often oversized and other aspects of the installation are over-engineered, increasing capital expenditure and design costs. Standardized approaches and specifications to enable more accurate sizing of systems (and development of training and certification schemes to enforce them) developed by NYSERDA in collaboration with the industry can help to reduce unnecessary added costs
- **Standardized contracts and financing paperwork,** which should be developed and reviewed in conjunction with industry experts and stakeholders;
- **Standardized metering and monitoring systems,** which can provide metering accuracy within ± 95%, monitor long-term reliability, and provide a check against poor installations
- **Standardized approaches to quality control schemes**, including standardized and efficient training and accreditation schemes for installers and designers, as well as system inspection processes.

It will be critical to engage State and regional industry groups—as well as other relevant agencies—to support the creation of the design specification and endorse adoption of the specification across the industry. For example, a series of competitions could be implemented (for manufacturers and installers) to encourage development of various components, system designs and installation techniques that have broad applicability across the market. In addition, incentive adders for use of the standardized design specification and/or as a pre-condition to streamlined permitting may be effective tools for encouraging adoption of the specification.

Impact:

This opportunity is expected to have the greatest impact for residential and small commercial projects. Installations in residential new construction are expected to have the greatest potential for standardization, as current New York State energy code dictates the heat load and the design for new houses to a significant level of uniformity. Residential retrofits would see more modest cost reductions as heat load and insulation quality are less consistent across a more diverse building stock, though greater use of variable speed compressors and other new technologies may help address these uncertainties.

Technology-specific considerations:

- **GSHP** systems are currently highly customized and thus offer the greatest opportunity for cost reductions from standardization, particularly from more efficient integration of interior and exterior components and labor utilization (with associated reduced labor costs).

standard. For more information, see: http://www.igshpa.okstate.edu/pdf_files/publications/IGSHPA_2014_Standards_free_copy.pdf

- It is expected that there will be fewer opportunities for cost reduction from on-site standardization for **ASHPs** because a relatively greater proportion of equipment already comes pre-assembled/ packaged.
- It is expected that cost reductions would be modest for **SHW** (compared to GSHP) since there are fewer opportunities for equipment integration.

4.3.3 STANDARDIZE AND SIMPLIFY PERMITTING PROCESSES

Barrier addressed:

- **Policy barrier**. State and local building codes and environmental permitting requirements often do not address RH&C technologies, resulting in uncertainty for customers and installers regarding applicable permitting rules and procedures. This uncertainty creates burdens for installers attempting to operate at scale. Limited building inspector and permit reviewer familiarity with and confidence in the performance of RH&C systems further compounds this policy barrier and add cost.

Cost reduction opportunity:

- Where permits are required, the process of obtaining permits can substantially increase the time and cost of an installation. Moreover, processes, requirements, and costs for installation permits can vary significantly between jurisdictions, presenting informational, logistical, and financial challenges for contractors. For example, SHW contractors noted that permitting costs can greatly increase total installed costs (e.g. causing non-equipment costs to balloon from approximately 15% of an installation to 25% in some jurisdictions) and that significant engagement with local inspectors and code officials is often necessary. Slow or cumbersome review processes can also greatly lengthen the time it takes to obtain a permit, inhibiting market development, and placing avoidable cost burdens on installers and potential customers.

Option 4: Develop a unified, streamlined permitting process for RH&C technologies and encourage adoption across NYS municipalities
Create streamlined and standardized permitting processes across NYS localities for RH&C projects. This would entail the creation and dissemination of model codes for various RH&C technologies. There are several examples in New York State where model codes have been developed regionally and at the State level for various renewable energy technologies: • **Long Island Unified Solar Permit Initiative** (LIUSPI).[63] In 2009, the Suffolk and Nassau County Planning Commissions and the Long Island Power Authority launched a collaborative effort to develop a model solar permitting code for residential solar photovoltaic (PV) and SHW systems for municipalities across Long Island. The model process included a standard fast track permit application, waived or minimized application fees, and guaranteed response within 14 days of submission. As of April 2016, 22 municipalities in Long Island had adopted the model permitting code.

[63] http://www.suffolkcountyny.gov/Portals/0/planning/Publications/SCPCLIPAEnergyr.pdf; https://nysolarmap.com/media/1182/longislandunifiedsolarpermitform.pdf

- **NYS Unified Solar Permit.**[64] Building off the LIUSPI initiative, NYSERDA, New York Power Authority (NYPA), and the City University of New York engaged municipalities across the State to develop a unified solar permit for solar PV systems of under 12 kW capacity. NYSERDA established an opportunity through the Cleaner, Greener Communities program to provide incentives of $2,500 to $5,000 (depending on population) to municipalities to cover the administrative costs of adoption. As of April 2016, 100 municipalities across the State had adopted the permit.
- **Suffolk County Model Geothermal Code.** In 2014, the Suffolk County Planning Commission (SCPC) and Long Island Geothermal Energy Organization (LI-GEO) developed a model geothermal code based on a simplified code previously developed by the Town of Brookhaven. PSEG Long Island provided an incentive of $5,000 or $10,000 to villages and townships in Suffolk and Nassau County that adopted the code by March 31, 2015.

Once model permitting codes are developed, building inspectors and permit reviewers will also need to be trained on RH&C technologies, performance history, and installation best practices. In addition, it will be important for New York State to establish an incentive for municipalities that adopt the model codes.

Impact:

Adoption of model codes could reduce permitting costs for both local governments and contractors, increase installation quality, and greatly shorten the turn-around time from project inception to completion.

Technology-specific considerations:

- Open-loop **GSHP** systems in particular are subject to significant regulatory requirements owing to their direct interaction with a groundwater aquifer. Model codes or streamlined permitting processes could have meaningful impacts on installed costs.
- **ASHPs**, which are similar to traditional air conditioning units, tend to be less affected by regulatory issues, and are likely to experience only minimal cost reductions from implementation of this option.
- Rooftop **SHW** systems, which are subject to plumbing and/or mechanical permits, can see significant cost reductions resulting from streamlined permitting.

4.3.4 BETTER INFORMATION ON TECHNICAL AND ECONOMIC VIABILITY

Barrier addressed:

- **Customer confidence barrier**. Pre-development costs, such as initial site assessments, feasibility studies, and project design can be difficult for customers and contractors to justify based on perceived risk and project development timelines. Since customers are generally unfamiliar with RH&C project design and uncertain about RH&C project performance, they have greater difficulty justifying them and are, therefore, more likely to choose a more familiar HVAC technology. RH&C contractors are typically smaller than their mainstream HVAC counterparts

[64] http://www.cuny.edu/about/resources/sustainability/nyssolar/NYSolarSmartPermitWorkshops.html

and, therefore, have difficulty carrying pre-development costs, especially for large projects with long lead times.

Option 5: Provide technical and engineering assistance and project development support for larger projects in key market segments.

NYSERDA could provide cost-shared financial support for strategic market segments to reduce the risk of pre-development costs.
• **Segments** could include colleges and universities, State and municipal buildings, new construction developments, affordable housing and low-rise multifamily sites, and large commercial sites.
• **Support** would likely include:
  ○ Initial assessments, including site suitability assessments
  ○ Feasibility studies to establish lifecycle costs for RH&C and counterfactual systems
  ○ Design support to ensure the RH&C systems are designed by seasoned RH&C professionals
  ○ Measurement and verification to increase the confidence in outcomes and replicability of success

Impact: It is expected that large projects with the most promising potential would be the most likely to proceed to installation; their relatively high profile could allow positive experiences as well as lessons learned to be leveraged to encourage subsequent projects to go ahead.

4.3.5 ENCOURAGE INTEGRATION INTO EXISTING TRADE CHANNELS

Barriers addressed:

- **Supply chain barriers and customer awareness barriers**. The RH&C supply chain in New York State is under-developed with few contractors focusing primarily on installing RH&C technologies. Though some traditional HVAC contractors provide customers access to RH&C technologies as an ancillary service, they tend to focus more heavily on fossil fuel technologies. This provides an additional barrier to adoption because replacement of space and water heating systems at the residential and small commercial level often occurs upon failure, meaning that customers have an immediate need for replacement and are not likely to "shop around" to explore new technologies. Thus, customers are less aware of the opportunities and benefits offered by RH&C technologies, and HVAC contractors are unlikely to suggest alternatives.

Option 6: Integrate RH&C into existing trade channels such as the HVAC emergency replacement market or oil heat dealer sector in order to reach a broader customer base
There is an opportunity to engage contractors and promote greater integration of RH&C into existing trade channels. This could include developing outreach programs targeted to existing heating and hot water contractors, oil heat dealers, plumbers, or other trades to educate them on the benefits of incorporating RH&C technologies into their product offerings (or establishing

relationships with RH&C-specialized contractors to be able to provide customer referrals). By promoting RH&C technologies in established trade channels, it may be possible to increase market awareness and deployment of RH&C. NYSERDA is well-positioned to act as a convener and to support outreach to trade organizations and contractors. Design engineer and contractor training programs can be developed to improve design and installation quality of RH&C technologies, including International Ground Source Heat Pump Association (IGSHPA) training programs for design, installation, and inspection of GSHP systems. This could include development of a qualified designer and installer list, which would be populated by contractors who have gone through the training, and had three or more of their designs or installations certified by a highly-qualified inspector (who could potentially be identified and certified by NYSERDA).
Impact: Two key opportunities for success exist in this area—in the commercial sector, where clients proactively seek advice from system designers for installation of a new or replacement system, a sales opportunity for RH&C only exists if such design firms have the expertise and motivation to propose RH&C options to their clients. In the residential sector, where replacements often take place as emergency replacements upon end-of-life failure of the existing system, the opportunity to switch to RH&C would depend on traditional HVAC installers (who would typically be the first point of contact upon failure of the existing system) both offering RH&C as well as solutions needed in an emergency replacement situation (e.g., temporary heating systems). Success in either of these sales channels would enable RH&C technologies to significantly broaden the available market opportunity.
Technology-specific considerations: ⦿ Stakeholders have suggested that it is possible for **GSHP** to serve the emergency replacement market with adjustments to the installation process. ⦿ While **ASHP** are already broadly integrated into existing HVAC trade channels, there is potential for ASHP to be more broadly offered by oil heat dealers, which occupy a unique position in the market with regular direct customer engagement. ⦿ HVAC contractors or solar PV installers who are accustomed to sizing systems and going on roofs, and who have relevant skills and insurance, could potentially expand product lines to include **SHW**.

4.3.6 FINANCE AND BUSINESS MODEL INNOVATION

Barriers addressed:

- **Inadequate access to low-cost investment capital and customer confidence barriers.** The high upfront costs of RH&C systems is one of the biggest barriers to customer adoption, deterring customers even when the lifetime economics of the energy savings are favorable. In addition, many customers are not prepared to assume the performance risk of an RH&C system and may be unable to monetize the value of any available tax incentives. Where projects are cost effective, finance can overcome these barriers; however, RH&C projects have limited access to low-cost financing in New York State. Because RH&C installations are often structured as customized deals, there has not been (to date) a ready supply of bankable RH&C assets that can attract large-scale investment from institutional investors or other low-cost capital providers. Instead, most RH&C deals are financed through cash, consumer loans (e.g., credit cards), or on a company's balance sheet. These finance sources are either expensive or sub-optimal for other reasons (e.g., compete with on-balance sheet financing needed by businesses for their core business operations).

Cost reduction opportunity:

- Finance or third-party ownership is unlikely to be a solution where projects are uneconomic (i.e. where investors' hurdle rates are not met). However, policy interventions, together with increased volume as the RH&C market grows, can help reduce the hurdle rate requirements of funders over time, by reducing risk perception and due diligence, and other overhead costs. As lower-cost finance solutions enter the market, more projects are able to meet hurdle rates and become cost effective. Accordingly, facilitating the development and availability of lower-cost finance presents an important cost reduction opportunity.

Option 7: Enable broader availability and development of cheaper finance options

Many funders are unfamiliar with the range of RH&C technologies, their benefits and potential for lifetime cost savings. This lack of familiarity increases the cost of financing and reduces its availability, reducing the pool of potentially profitable projects that can be offered to consumers. There is a general opportunity to expand existing and emerging financing options for RH&C, including home equity lines of credit for residential sales, on-bill financing options, Property Assessed Clean Energy (PACE) financing, and third-party ownership (TPO).

NYSERDA can provide support to lenders aimed at improving investor knowledge of and confidence in these technologies, e.g., through:

- Development of informational materials
- Sharing project performance data sets
- Workshops and other direct engagement with financiers

Closely related, a number of concrete facilitating interventions could help to increase funders' levels of confidence in RH&C technologies, as well as reduce funders' due diligence and other overhead costs:

- **Establish clear guidelines for thermal energy metering.** Standardized measurement and verification of performance will be critical to increasing investor confidence and reducing RH&C performance risk. This would be particularly important to support the development of third-party ownership structures that base their revenue model on payments from customers for metered heating and cooling, as well as in relation to any performance-based incentive programs (PBI, see Chapter 6).
- **Standardize contracts, performance metrics, and production guarantees.** Standardizing transaction terms is expected to be important to reduce financing costs and increase the scale of available capital. Standardized contracts create common industry terms for RH&C assets or contracts, addressing key terms and features across the variety of contractual relationships necessary to finance RH&C projects. In doing so, standardized contracts increase understanding, precedent and predictability and reduce due diligence costs for investors. Notably, the process of standardizing contracts has long been used in the finance industry, from

futures contracts to mortgage loans. It has recently been applied to renewable energy markets in the U.S., such as solar. Standardization would also enable future aggregation of projects into a pool of finance assets that could be financed or refinanced at a lower cost of finance than individual projects.

- **Explore options with New York Green Bank to offer loan guarantees, support for aggregation/ warehousing and other credit enhancement instruments for RH&C.** Loan guarantees and other credit enhancement products provided by New York Green Bank could significantly lower the interest rate charged by financiers. First, having the enhanced credit of New York State standing behind an RH&C customer would improve the credit profile of a customer. Second, the “endorsement” of an RH&C project by New York State as evidenced by Green Bank’s participation would reduce the perceived technical risk of the project to financiers.

NYSERDA, Yale University, and the Connecticut Green Bank have convened the Renewable Thermal Alliance, a consortium of market actors in the Northeast that aims to tackle some of these issues by sharing best practices, harmonizing standards, exploring RH&C asset quality, providing analytical tools, and developing scalable financing models.

Impact:

This intervention option would reduce the perceived technology risk of RH&C technologies by investors. The reduction in perceived risk should translate into lower due diligence costs and risk premiums embedded in the cost of capital that investors apply to RH&C projects. Standardization and aggregation of RH&C contracts are anticipated to increase the supply of RH&C deals for investment, which will be necessary to achieve deal volumes large enough to attract low-cost capital providers, such as institutional investors.

Option 8: Work with utilities and energy service companies (ESCOs) to pilot third-party ownership and other innovative models under REV

TPO structures—in which a customer leases or purchases a service derived from equipment owned by a third-party—re a financing option that can mitigate high upfront cost barriers. Similar to how a consumer might lease a car, TPO models have become popular, established financing solutions in the solar PV markets. In the solar PV market, a company finances, installs, and maintains a solar PV system on a customer’s property then leases the system or sells the electricity generated by the system to the customer over a fixed period (e.g., 15 years). Such arrangements often have no or low down payments and are priced at levels that enable a customer to immediately realize lifetime energy savings that might otherwise take several years to achieve.

Notably, TPO models like PPAs and leases have been successful in helping scale up the solar PV market—accounting for over three-quarters of residential PV installations in major markets like New York State and California.[65] These financing models reduce the burden of high upfront costs for consumers and unlock access to greater sources of lower-cost capital. Additionally, in some cases, TPO models might not be classified as debt for accounting purposes, depending on the structure of

[65] Kann, S., Shiao, M. J., Honeyman, C., Litvak, N., Jones, J., Cooper, L., et al. (2014). U.S. solar market insight report: 2013 year in review. Washington, D.C.: Solar Energy Industries Association.

the agreement, making them particularly suitable for commercial projects where clients may wish to preserve their balance sheet equity to support finance needed for their core businesses. There is a significant opportunity for TPO models to be applied to the RH&C market, with RH&C systems either leased to consumers or the heat generated being sold via a PPA. Several companies and utilities across North America have piloted such models (see below), though they have not yet seen broader adoption across the market. As a prerequisite, TPO business models will only be successful in market segments where RH&C installations are cost effective compared to conventional (fossil-based) technologies (i.e., meet the hurdle rate requirements of the investors and developers of the TPO structure). Where this is the case, New York State has an opportunity to enable TPO-based pilots. New York State's utilities and ESCOs are in a unique position to own all or part of RH&C systems. For example, a gas utility could offer access to a geothermal loop field in geographic areas where natural gas isn't available to provide customers access to otherwise unavailable low-cost heating. Through REV and other demonstrations, New York State, investor owned utilities, and ESCOs have the opportunity to prove that TPO models for RH&C can work and develop and test tools like metering approaches, standardized contracts, and technical requirements (see also Option 7) that could be made available broadly to reduce the cost of entering the space to other third-party owners.
Impact: It is worth noting that TPO can increase the cost of RH&C investment (e.g., because system must be financed and some sources of TPO capital can be higher cost compared to a consumer loan). However, broader adoption of TPO are anticipated to decrease costs over time by enabling larger numbers of customers to install systems and improving total economies of scale.
Technology-specific considerations: ◉ **GSHPs**. To date there have been a handful of third-party ownership models that have been deployed in the U.S. and Canada for GSHPs; Increase in the number of companies that can serve as systems integrators to coordinate the value chain and provide accountability for all aspects of the installation may be necessary to enable the broader proliferation of third-party ownership models. Some companies within the GSHP industry have assumed an integrator role (e.g. Marmott Énergies), but this role has not yet seen broader adoption across the industry. ◉ **ASHPs.** Some utilities have been exploring the potential to implement third-party ownership models for ccASHPs, including for example Green Mountain Power's ASHP leasing program implemented in 2014.[66] However, the model has not yet seen broader adoption across the U.S. ◉ **Solar thermal.** Several third-party ownership models have already been piloted for solar thermal in the U.S. (e.g. by Lakeland Electric Co./Posigen[67] and Nextility[68]). The U.S. Environmental Protection Agency (EPA) has also worked with several industry stakeholders to identify best practices for third party financed contracts. However, a comprehensive initiative to standardize contracts and access low-cost capital has not been in place.

[66] http://products.greenmountainpower.com/product/ductless-heat-pump/
[67] http://www.lakelandelectric.com/customers/programs-services/solar-water-heater
[68] http://www.nextility.com/wp-content/uploads/2014/11/4600%20Connecticut%20SWH%20Case%20Study%20from%20Nextility.pdf

CHAPTER 5 MANDATES

This chapter describes the potential for RH&C mandates in New York State. Mandates are regulatory policies that place a legal obligation on market actors, such as utilities or building owners. While there are no current mandates for RH&C in New York State, several U.S. states and international jurisdictions have used them to scale up the RH&C market. This chapter describes potential approaches New York State could take to develop and implement RH&C mandates and a brief overview of mandates in the U.S. and internationally.

There are two primary types of mandates that could be used in New York State to increase the adoption of RH&C technology: utility mandates and building mandates.

Utility mandates can place a legal obligation on load serving entities (LSEs) to procure a certain amount of their annual load from RH&C sources. Within the U.S., utility mandates have historically been implemented through a Renewable Portfolio Standard and have focused on renewable electric technologies, such as solar PV or wind. In recent years, U.S. states, such as New Hampshire and Massachusetts, have also established RH&C obligations for the state RPS and Alternative Portfolio Standards (APS), respectively. In order to comply, utilities buy enough thermal renewable energy credits (T-RECs) from RH&C generators to meet their obligation under the portfolio standard. The concept of T-RECs is discussed in Chapter 6.

Building and energy mandates place obligations on building owners, and, in some cases, building developers. Such obligations could either be a direct or indirect mandate. A direct mandate would require building owners to source a certain portion of the building's heating and cooling load from RH&C technologies. An indirect mandate would require certain building performance standards, which in practice necessitate incorporating RH&C into the building. Building and energy mandates can occur through multiple pathways, including the building code, energy code, new legislation, or an executive order.

Past building and energy mandates in the U.S., including in New York State, have focused primarily on energy efficiency and renewable electric technologies. Model building codes, including Energy Conservation Codes used in New York State, are developed by a national board (the International Code Council) and adopted at the State and local level.

Internationally, there are several examples in European Union (EU) and Middle Eastern countries where RH&C building mandates have been used for new construction or building renovations. Direct renewable thermal building mandates are usually expressed as a percentage of the total energy demand of the building (e.g., 10% of space and water heating must come from renewable sources). For example, Germany passed the "Renewable Heating Act" that specifies a national target of 14% renewable heating by 2020 and imposes an RH&C obligation on all new construction of building greater than 50 square meters.[69] The Renewable Heating Act also introduces technology quotas for new buildings based on investment and fuel costs. Solar-thermal technologies have to provide at least

[69] Sticks and Carrots: Germany's Approach to Renewable Heating http://arnejungjohann.de/wp-content/uploads/Sticks-and-Carrots_FINAL.pdf

15% of the heat demand. Biomass or geothermal appliances have to cover 50% of the required heat in the building. In addition,several of jurisdictions, such as Baden Württemberg, Germany and Kenya[70] have established RH&C mandates for existing buildings. By implementing and enforcing RH&C mandates during new construction or renovation of buildings, policymakers can provide building owners with the regulatory driver to stimulate the RH&C market. This has been the experience, for example, in Carugate, Italy where a local solar thermal mandate in residential and commercial buildings resulted in a per capita solar energy use nearly 30 times the national average.[71]

The RH&C market is an emerging market, subject to high first costs and an early-stage supply chain, which would make it challenging to establish fully binding RH&C mandates across all building sectors at this time. It would be especially difficult and costly to enforce mandates in existing buildings. Moreover, New York State codes include a cost-effectiveness assessment, in which technologies must provide a simple 10-year payback, which many RH&C technologies would not be able to meet. However, there is an opportunity to establish RH&C building mandates for public buildings (e.g., “leading by example” requirements), and in new construction and major renovation projects through near-term changes to Stretch Code and long-term adoption of Zero Net Energy codes. Costs of compliance are expected to be lower in new construction and major retrofits, and it is anticipated that this approach would provide a range of benefits to building owners, tenants, and broader society[72].

By establishing such building and energy mandates, New York State could help create awareness of and demand for RH&C technologies, support the development of robust supply chains, enable building owners to prepare for a low-carbon energy sector, and start to address landlord-tenant challenges.

The establishment of building mandates can drive market actors to make individual decisions that benefit society as a whole over the long term. This is especially important for new construction and major renovations of buildings that will be operating for the next 30 to 50 years. Benefits can be even greater if policymakers create outreach, education, and training programs that provide building owners and developers with technical assistance to comply with the RH&C mandate.

The following sections outline policy concepts for RH&C mandates. The concepts set out here address public buildings, new construction, and major retrofits.

[70] Since 2008, Baden Württemberg (Germany) has required all new residential buildings to cover 20% of yearly heat demand with renewable heat sources. Additionally, existing buildings undergoing modernization of central heating system must cover 10% of heat demand with renewable. Another example is Kenya, which in 2012 issued national legislation that mandated all new buildings using over 100 liters of hot water per day must use solar heating to meet at least 60% of their demand. In 2017, this requirement will extend to all existing buildings. IEA-RETD (2015) Waking the Sleeping Giant- *Next Generation Policy Instruments for Renewable Heating and Cooling in Commercial Buildings*

[71] http://www.estif.org/policies/solar_ordinances

[72] http://iea-retd.org/wp-content/uploads/2015/02/RES-H-NEXT.pdf

SECTION 5.1 LEADING BY EXAMPLE: RH&C MANDATES FOR PUBLIC BUILDINGS

Concepts: New York State's existing lead by example program (Build Smart NY) [73] represents a model of how mandates could support RH&C technologies, thereby increasing awareness–and driving demand—for RH&C. Build Smart NY was issued by Governor Cuomo in 2012 through Executive Order 88 and mandates a 20% energy efficiency improvement by 2020 in all State-owned buildings. It requires buildings that have an area larger than 20,000 square feet to annually benchmark their energy consumption. Buildings that receive lower scores on their benchmark are required to go through additional audits and implement recommended improvements in energy efficiency, including retro-commissioning. Under the current standard, on-site renewable energy generation is encouraged when "feasible and reasonable".

Options could include:

- A future executive order that builds on Build Smart NY and requires deeper energy improvements by 2030 (e.g., 40% or more) and/or require replacement of fossil fuel heating and cooling technologies with RH&C technologies
- Encouraging RH&C for high-performing public buildings that have already reached their efficiency targets and want to increase their renewable energy efforts

A key focus of the policy could be development of a planned replacement cycle. As existing heating and cooling systems age and need to be replaced, the state could require that RH&C technology systems are installed in their place when cost effective on a life cycle basis, including the social cost of carbon. In 2015, the New York City Council passed a geothermal energy bill that requires the City to identify and implement geothermal heat pumps in all new construction and retrofits for city-owned buildings when shown to be cost effective. The bill, Int. 0609-A-2015, requires that a site-specific analysis comparing the life cycle costs of conventional heating and cooling and GSHP be performed before an HVAC system choice is made. The analysis must consider greenhouse gas emissions, impacts on air pollution, power and fuel costs, and potential revenue generation from peak demand reduction. There is potential to leverage lessons learned from this existing program and apply them to public buildings across the State.

Impact:

- State-owned property impacted by Build Smart NY comprise a large building footprint of over 200 million square feet. This includes the State Universities of New York (SUNYs), the Metropolitan Transportation Authority (MTA), hospitals, prisons, and a number of other state agency office buildings. State-owned buildings consume approximately 2.5% of the energy consumed by residential and commercial buildings in the State (approximately 3,000 GWh annually).[74] Thus, addressing heating and cooling in State-owned buildings could have a significant impact on energy use and emissions, as well as leveraging the State's procurement power.

[73] http://www.buildsmart.ny.gov/about/
[74] http://www.buildsmart.ny.gov/about/

- “Lead by example” programs can set the stage and be a testing ground for a broader RH&C mandate in all buildings, illustrating how RH&C solutions are possible and can be replicated across building sectors.

SECTION 5.2 RH&C IN NEW CONSTRUCTION & MAJOR RENOVATIONS

Concepts: By mandating RH&C in new construction and major retrofits of a certain size, building owners and developers would gain experience with the technology. The increased uptake of RH&C will also help the State meet long-term energy and climate goals.

There are two primary options for addressing new construction and major renovations via the building code. The first option, which could be accomplished in the near-term, is to amend the Stretch Code to include an RH&C optional package. The second, longer-term option is to integrate RH&C into the Net Zero Codes currently being considered by NYSERDA for 2025. Each are described below

- **Stretch Code:** The New York State Stretch Code is a voluntary model code that goes above the minimum, mandatory base code and provides more energy efficient alternatives to the base energy code.[75] The Stretch Code must be adopted at the local level and when implemented is applicable to new construction and existing building retrofits in commercial and residential sectors. New York State is currently in the process of updating the Stretch Code, which will increase energy savings by approximately 10% beyond the base code for residential, commercial, and multifamily buildings. Current draft amendments to the 2016 Stretch Code include SHW and GSHPs in the residential provisions, and SHW in commercial provisions.[76] The Stretch Code requires that developers choose one out of six “optional packages,” which allow developers flexibility in how they meet the Stretch Code requirements across various building systems (building envelope, HVAC, energy production/use, etc.). Stretch Code amendments could include more provisions for renewable technologies that service buildings’ heating, cooling, and hot water loads. Doing so would increase awareness of RH&C by presenting it as an option without making it an explicit requirement. This would also signal to building owners and developers potential changes to base code in the future.
- **Net Zero:** In addition to the Stretch Code, a longer-term opportunity is to adopt Zero Net Energy or Zero Net Carbon codes, which can serve as a de-facto requirement for the integration of ASHP,

[75] New York State base code is the Energy Conservation Construction Code of New York State (ECCCNYS) which applies to all government, commercial, and residential buildings. New York State adopted the 2015 International Energy Conservation Code (IECC) for new construction and major renovations (i.e,. which involve replacing building systems). The IECC recently finished the model code for 2018, which will most likely be adopted by New York State in the coming years. However, State legislation restricts amendments to those that can meet a 10-year payback to the building owner.

[76] Proposed Stretch Code amendments in the residential sector include increased efficiency in HVAC performance which can be accomplished by a closed-loop GSHP. Residential provisions also call for high-efficiency water heating or solar thermal hot water heater. Commercial provisions include a 60% to -100% load fraction for hot water requirements that include a solar water-heating systems option.

GSHP, SHW, or other RH&C technologies.[77] Currently, NYSERDA is working on a Zero Net Energy Road Map with a goal to promulgate a Zero Net Energy Code by 2025, which is intended for new construction and major renovations. The Zero Net Energy approach will require a fundamental shift in how buildings are designed and constructed as building experts figure out how to heat, cool, and power every new construction without any net GHG emissions.

Notably, there are several ways to define Net Zero codes. Some cities and states have taken the approach of Zero Net Carbon—or Zero Net Emissions—which has more of a focus on GHG emissions and also allows off-site generation to meet energy needs. Such carbon-based codes, like the one adopted by Vancouver, have been used to transform building practices, including HVAC systems. In addition, there is a growing interest in making building codes less prescriptive and instead based on outcomes. As New York State moves toward buildings with higher performance requirements, it is anticipated that this will provide a boost to RH&C over time.

Impact: Targeting RH&C in commercial and residential buildings over a certain size is more cost effective when implemented during initial construction, rather than doing expensive retrofits.

- From 2015 to 2018, the annual new construction and substantial renovation market is projected to be approximately 60 million feet of commercial space and 20,000 dwelling units.[78]
- Stretch codes are often one cycle ahead of the baseline code and allow the State to vet potential new base energy codes. They can help prepare the construction market for coming changes to the code by allowing municipalities and developers to experiment without making them a requirement.

[77] For example, the EU Energy Performance of Buildings Directive (2002/91/EC, EPBD), which requires all new buildings to be nearly zero energy by 2020, drives integration of RH&C for new construction projects. To meet low energy building performance standards, many builders are using ASHPs, solar water heating, and other RH&C technologies.

[78] NYSERDA, Clean Energy Fund Information Supplement (2015).

CHAPTER 6 INCENTIVES

As discussed in Chapter 2 (Market Characterization), past uptake rates for RH&C technologies have been modest. We expect that the loss of federal tax credits for GSHPs as of December 31, 2016, will further reduce the rate of GSHP installations.

Chapter 4 sets out a range of intervention options. Through these options, if confirmed, we would expect to be able to help the market unlock cost reductions of 5% to 30% at the project level by around 2021. Ongoing global cost reductions in the equipment costs of heat pumps and SHW panels would also provide a further boost to the market. In addition, interventions aimed at reducing non-financial barriers and encouraging uptake can be expected to accelerate growth in the industry.

However, the analysis presented in this framework suggests that in order to increase the potential to levels needed for mass market transformation, improvements of resource cost effectiveness beyond those expected from cost reductions are needed.

This chapter discusses examples of incentives used elsewhere, describes options for RH&C incentive programs in New York State, and proposes a near-term incentive for GSHPs, to be implemented in parallel with ongoing proceedings and further analysis.

SECTION 6.1 RH&C INCENTIVES OUTSIDE NEW YORK STATE

Federal tax credits

At the federal level, renewable thermal policy has been limited to investment tax credits (ITCs) for SHW and GSHPs. Solar thermal and residential GSHPs have been eligible for a 30% ITC, with a 10% ITC applicable to non-residential GSHPs. The GSHP tax credits expired on December 31, 2016.

State Renewable Portfolio Standards (RPS)

RPSs typically operate by obligating utilities or load-serving entities to procure a certain annual target (typically increasing year-by-year) of renewable or clean energy, with varying eligibility criteria as to which technologies count toward the targets. Target compliance is accounted by means of Renewable Energy Certificates (RECs) awarded to generators of eligible technologies for each unit of energy (typically per MWh). Obligated entities are required to procure a number of RECs equivalent to their target (although many RPS policies allow alternative compliance payments instead, in order to contain costs). The trade in RECs between generators and obligated entities results in payments—effectively an incentive—being made available to generators.

State RPS programs have historically focused on electricity generation produced by renewable resources. However, some states have started to incorporate renewable thermal energy into their RPS as a way of supporting the development and market growth of solar thermal, biomass thermal, geothermal, and other renewable thermal technologies.

States have classified RH&C technologies into their RPS in a variety of ways. Many RPS structures use tiers to group eligible technologies, with each tier being subject to separate targets or budgets. In several states, RH&C technologies are included in tiers that focus on non-electric technologies:

- For instance, in Pennsylvania, SHW and GSHPs are classified as Tier II demand-side management resources, and they earn Tier II energy efficiency credits.[79]
- In Arizona, SHW and GSHPs are classified as customer-sited resources.[80]
- In Texas, these technologies are classified as generation-offset technologies.[81]
- Wisconsin has an RPS tier for non-electric resources which displace electricity (e.g., electric resistance heating or conventional cooling), which includes RH&C technologies.[82]
- In Nevada, GSHPs count toward the RPS as an energy efficiency measure.[83] Also, solar thermal technologies count toward the RPS as "renewable resources."
- Massachusetts is in the process of including RH&C technologies in its Alternative Portfolio Standard (APS).[84]

Many RPS policies set a separate tier or carve-out for solar PV electricity. The effect of such a carve-out is typically to provide a higher level of subsidy and guaranteed market size compared to what would be expected to result otherwise in the RPS. In some states (e.g., Maryland, Nevada, and North Carolina), SHW is included as being eligible for such a solar carve-out.[85] In other states (e.g., Pennsylvania, Colorado, and Delaware), the objective of making a higher level of incentive available to solar PV is pursued through REC multipliers (awarding multiple RECs per unit of solar electricity) instead of carve-outs. Again, in some cases, solar thermal technologies are included.

In other states, RH&C technologies are directly eligible for the Main Tier of electricity-generating renewable technologies. In the District of Columbia's RPS, for example, solar thermal is included as a Tier I technology along with solar electric and other renewable electricity technologies.[86] Solar thermal is also classified as Tier I resources in Maryland.[87] In these cases, the thermal output of such

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[79] See 73 P.S. § 1648.2 for detailed definitions of eligible alternative-energy sources. See also http://programs.dsireusa.org/system/program/detail/262.
[80] See Arizona Administrative Code, Article 18: Renewable Energy Standard and Tariff, Pages 162-168 http://apps.azsos.gov/public_services/Title_14/14-02.pdf
[81] See http://www.puc.texas.gov/agency/rulesnlaws/subrules/electric/25.173/25.173.pdf
[82] See http://docs.legis.wisconsin.gov/statutes/statutes/196/378
[83] See http://puc.nv.gov/Renewable_Energy/Portfolio_Standard/; http://puc.nv.gov/Renewable_Energy/RPS/PEC_Trading_Program ; Nevada Revised Statutes (NRS) 704.7801-704.7828, Portfolio Standard http://www.leg.state.nv.us/NRS/NRS-704.html#NRS704Sec7802; Nevada Administrative Code (NAC) 704.8831-704.8937, Portfolio Standard http://nvrules.elaws.us/nac/chapter704_27_4
[84] The Massachusetts Department of Energy Resources (DOER) has filed draft regulations to include renewable thermal in the Massachusetts APS pursuant to Chapter 251 of the Acts of 2014. See http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/renewable-thermal/renewable-heating-and-cooling-alternative-portfolio-std.html
[85] See http://www.ncleg.net/EnactedLegislation/Statutes/HTML/BySection/Chapter_62/GS_62-133.8.html.
[86] See http://programs.dsireusa.org/system/program/detail/303.
[87] Biomass Thermal regulations http://mlis.state.md.us/2012rs/bills/sb/sb1004f.pdf; Geothermal regulations http://mlis.state.md.us/2012rs/bills/sb/sb0652e.pdf; Solar thermal regulations http://mgaleg.maryland.gov/2011rs/chapters_noln/Ch_407_sb0717E.pdf; Report of the Thermal Renewable Energy Credit Task Force, Maryland Energy Administration, January 2014 http://msa.maryland.gov/megafile/msa/speccol/sc5300/sc5339/000113/018000/018939/unrestricted/20140015e.pdf

systems (in Btu) is typically converted into units of kWh or MWh for the purpose of determining the number of RECs to be awarded.

New Hampshire is the only state to date that has created a specific carve-out for RH&C technologies, using "Thermal RECs" (T-RECs) as the means of accounting for eligible RH&C energy.[88] New Hampshire utilities are now required to purchase "Class I" T-RECs relating to RH&C technologies (including solar thermal, GSHPs, and thermal biomass) equivalent to a percentage of their energy. In 2017, the target for Class I T-RECs is 1.40% of the electricity generated in New Hampshire.

Rebates and other grant-type incentives

As summarized in Tables 6.1 and 6.2, a number of states in the Northeast have developed technology-specific rebate programs to encourage RH&C technologies. Three states offer incentives for residential GSHPs including Maine, Massachusetts and Connecticut. In addition, Rhode Island has a tax credit for residential GSHPs. All states in the Northeast also have incentives for residential ASHPs, generally covering both central ASHP systems and mini-splits. Massachusetts also has non-residential rebates for both GSHP and ASHP.

Table 6.1 - GSHP incentives in the Northeast

State	Base Incentive/ Rebate/ Tax Credit	Sector	Units	Entity offering
Connecticut[89]	$500 up to $1,500	Residential	Per cooling ton of installed capacity	State/utility
Maine[90]	33% up to $5,000	Residential	Per Installation	State
Massachusetts[91]	$1,500 up to $12,500	Residential	Per ton of installed capacity	State
Massachusetts[92]	$1,200/$800 up to $250,000	Non-Residential	Per heating ton of installed capacity	
Rhode Island[93]	$25% up to 7,000		Per installation	State

[88] Clean Energy State Alliance, "Renewable Thermal in State Renewable Portfolio Standards," April 2015. http://www.cesa.org/assets/Uploads/Renewable-Thermal-in-State-RPS-April-2015.pdf

[89] http://www.energizect.com/your-home/solutions-list/geothermal-heat-pump-rebates

[90] http://www.efficiencymaine.com/docs/HESP-Completion-Form-Universal.pdf

[91] http://files.masscec.com/get-clean-energy/govt-np/clean-heating-cooling/GSHPProgramManualResidentalSmallScale.pdf

[92] http://files.masscec.com/get-clean-energy/govt-np/clean-heating-cooling/GSHPProgramManualResidentalSmallScale.pdf

[93] http://programs.dsireusa.org/system/program/detail/2807

Table 6.2 - ASHP incentives in the Northeast

State	Base Incentive/ Rebate/ Tax Credit	Sector	Units	Entity offering
Connecticut[94]	$300 up to $500	Residential	Per Home	State/utility
Maine[95]	$500 up to $750	Residential	Per dwelling unit	State
Massachusetts[96]	$625 up to $6,000	Residential	Per heat pump	State/utility
Massachusetts[97]	$625 up to $225,000	Non-residential	Per heat pump	State/utility
Rhode Island[98]	$500		Per heat pump	utility
New Hampshire[99]	$250 up $2,500		Per ton of installed capacity	utility
Vermont[100]	$600 up $800		Per installation	State

Publicly available data from rebate programs in neighboring states generally suggests that RH&C market penetration is at a similarly low level as in New York.[101] Due to the relatively new nature of the programs summarized above, it is too early to draw conclusions as to their relative success in increasing RH&C uptake.

California established a $280.2 million SHW incentive program[102] in 2010 to support installations displacing natural gas and electric water heating. The program targets residential as well as multifamily/commercial systems. Incentives vary by sector and by utility and are paid on a per-therm basis. Among other goals, policymakers expect to reduce installation costs of SHW systems in California by 16% by 2018[103] through increased market efficiency and innovation as well as increasing consumer confidence and understanding of SHW technology. California has traditionally been a leader in the U.S. SHW market, and as a result of this program, many experts expect to see California significantly expand the size of its SHW market.

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94 http://www.energizect.com/your-home/solutions-list/ductless-split-heat-pump-rebates
95 http://www.efficiencymaine.com/docs/HESP-Completion-Form-Universal.pdf
96 http://www.masscec.com/get-clean-energy/business/air-source-heat-pumps Includes income adders. Base rebate cap is $2,500 per installation.
97 http://files.masscec.com/get-clean-energy/business/clean-heating-cooling/ASHPProgramManualCommercialScale.pdf
98 https://www.nationalgridus.com/media/pdfs/resi-ways-to-save/ri_electric_heating-cooling_form_2016_fillable.pdf
99 https://www.nhsaves.com/wp-content/uploads/2017/01/2017-Liberty-Residential-HeatingCooling-Water-Heating-Rebate-12-12-16.pdf
100 https://www.efficiencyvermont.com/rebates/list/heat-pump-heating-cooling-system
101 Efficiency Maine annual reports, MassCEC Residential Program Rebate Data, Connecticut CEEF: Energy Efficiency Board Programs and Operations Reports
102 https://www.csithermal.com
103 http://www.gosolarcalifornia.ca.gov/documents/CSIThermal_SingleFamily_Handbook.pdf
http://www.pge.com/includes/docs/pdfs/shared/solar/solareducation/csi_thermal_workshop.pdf

The United Kingdom Renewable Heat Incentive

The United Kingdom operates the Renewable Heat Incentive (RHI) policy, described as the first comprehensive, long-term support scheme specifically aimed at renewable heating in the world. As such, it serves as a useful benchmark for comparison. A number of features can be highlighted:

- The program covers GSHPs, ASHPs, SHW, biomass and biomethane grid injection. It opened in 2011 for non-residential installations and provided a commitment to remain open for new installations until 2020 in order to increase long-term market certainty. A residential RHI program was started in 2014. The RHI is currently being reformed, with changes to support levels and other aspects expected to be implemented in Spring 2017.[104] As reformed, the RHI is projected to deliver an increase in renewable heat in the UK of 22 TWh (75 TBtu) by 2020, roughly 4% of UK annual thermal load;
- Support is provided as a performance-based incentive (PBI), paid to accredited installations over a period of up to 20 years. In the commercial sector, the incentive is paid per metered unit of renewable heat; in the residential sector, it is paid as an annual payment calculated on the basis of the estimated heating load of the home.
- Under the reformed RHI, subsidy spend is budgeted at £596 million in 2016/17 (~$750 million), rising to £1.1 billion per year (nominal) (~$1.4 billion) in 2020/2021, with subsequent further annual payments until accredited installations reach the end of the period of entitlement to annual payments.[105]
- Program subsidy levels differentiate by technology and system size; in addition, the tariffs for biomass installations contain a two-tier structure (with an initial tier paid at a higher amount and subsequent generation each year paid at the lower tier amount) aimed at disincentivizing over-generation of heat. The program assumes that technology costs reduce over time in line with increasing uptake levels, and accordingly, reductions in subsidy levels are triggered automatically for new installations as certain uptake targets are achieved (degression).[106]
- Since its start in 2011, the non-residential incentive has brought forward around 16,000 non-residential installations with a total of around 3 GW (~10,000 MMBtu/h) of heat generation capacity, mostly from biomass heat. The residential incentive has achieved over 50,000 installations to date, almost half of which are in the form of ASHPs, over 20% biomass systems, and 15% each solar thermal and GSHP systems. During 2016, RHI installations generated around 6 to 7 TWh (20 to 24 TBtu) of renewable heat.[107]

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[104] See the RHI Impact Assessment at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/577026/RHI_Reform_Govt_Response_Impact_Assessment_FINAL.pdf and the RHI government policy document at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/577024/RHI_Reform_Government_response_FINAL.pdf

[105] See the aforementioned impact assessment.

[106] See https://www.ofgem.gov.uk/environmental-programmes/non-domestic-rhi/contacts-guidance-and-resources/tariffs-and-payments-non-domestic-rhi for further details on the non-domestic RHI and https://www.ofgem.gov.uk/environmental-programmes/domestic-rhi/contacts-guidance-and-resources/tariffs-and-payments-domestic-rhi/current-future-tariffs for the domestic RHI. Various reforms to the scheme are currently being introduced, see https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/577024/RHI_Reform_Government_response_FINAL.pdf

[107] See https://www.gov.uk/government/collections/renewable-heat-incentive-statistics#monthly-deployment-data

SECTION 6.2 RH&C INCENTIVES IN NEW YORK STATE

A Policy Framework aimed at unlocking the potential of RH&C as a substantial contributor toward our GHG emissions reduction goals requires an integrated approach to incentives and other interventions that considers:

- Relative strategic importance of each technology in achieving our goals
- Extent to which technology costs exceed those of conventional technologies
- Extent to which incentives can contribute to unlocking future cost reductions
- Extent to which non-financial barriers can be resolved
- Value that the technology can bring to society or ratepayers
- Whether or not other types of interventions, such as mandates, can and should be employed in tandem

Furthermore, the approach must be of adequate duration and magnitude, with transparent market signals, to effectuate significant market uptake, scalability, and market transformation to a robust, subsidy-free, and self-sustaining industry. A “stop and go” approach that disrupts market development should be avoided.

New York State has support in place for residential SHW in the form of a 25% tax credit. This tax credit is in addition to a federal tax credit of 30% for this technology. Biomass heating benefits from support under the Renewable Heat NY program, which provides financial incentives for a range of applications (see Box 1.2). Available utility rebates, in particular for ASHPs, are noted in Chapter 1 (Box 1.2). Other incentives have been available from time to time. With the expiration of the GSHP federal tax credit on December 31, 2016, GSHPs are the only RH&C technology that is not eligible for statewide incentives (federal, state or utility) to address or compensate for the non-monetized value that these technologies provide.

There are three major venues in New York State where financial incentives are being considered for RH&C technologies.

- As part of **Reforming the Energy Vision** (REV) and the **Clean Energy Standard** (CES), the Department of Public Service (DPS) Staff will conduct a process for parties to consider the complexities of T-RECs and to explore the practical administrative mechanisms that might be employed to accommodate geothermal heat pumps as an eligible technology in the CES.[108] T-RECs are discussed further in Section 6.3. This Policy Framework and the studies underpinning it will provide analytical support to the CES T-REC process. DPS has announced that the CES T-REC process referred to above will commence with a stakeholder conference to be held on February 8, 2017.[109]

[108] Order Adopting a Clean Energy Standard, CASE 15-E-0302, p105. See http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?Mattercaseno=15-E-0302
[109] See http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={189D2904-E768-4436-9AFB-A9EA6A58D080}

- Ongoing REV-based Public Service Commission proceedings including Value of Distributed Energy Resources (VDER)[110] deal with the **design and reform of our electricity rate structures** to enable rates to better compensate for value where it occurs. Section 2.5 discusses our analysis on value from RH&C technologies to electricity ratepayers and society and concludes that there is value to electricity ratepayers and society from RH&C that is not yet monetized and reflected in the market. Reformed rate design could take the place of any incentives aimed at monetizing such value for investors in RH&C technologies.
- The **Clean Energy Fund (CEF**), approved in February of 2016, specifically identified the development of RH&C technologies and markets as a priority, and proposed consideration of incentives along with a range of cost reduction interventions and activities to remove non-cost barriers.[111]

In addition, the **New York State Legislature** has considered a GSHP tax credit bill in several recent sessions that would provide a 25% tax credit for GSHP, much like SHW.[112]

The REV-related RH&C deliberations above have the potential to transform the RH&C market given the magnitude of the CES, the grid/carbon-based value identified in Section 2.5, and the significant effect that electricity rate design can have on clean energy markets. These decisions could have an impact on the RH&C market far greater than what could be achieved with a tax credit or an incentive/rebate program. It would not be prudent to advance long-term financial incentives prior to those significant REV/CES decisions.

At the same time, we recognize that these processes take time. It is important to support market continuity and make progress ahead of the conclusion of these proceedings. Accordingly, we propose to use the CEF to provide a near-term incentive for GSHPs, described in more detail in Section 6.4. This GSHP incentive will be introduced in early 2017, run for two years and be available alongside the federal tax credits for SHW and utility incentives for ASHPs. These incentives, combined with initiatives to address non-financial barriers and opportunities for cost reduction across the suite of RH&C technologies will begin to grow and position the RH&C market to meaningfully contribute to the thermal load in NYS. The need for any other longer-term incentives for RH&C technologies will be assessed as conclusions emerge from near-term rate design and CES deliberations.

More details on next steps on incentives and other interventions are set out in Chapter 7.

SECTION 6.3 INCENTIVE DESIGN FEATURES

This section discusses key incentive design issues that would need to be addressed when implementing an RH&C incentive.

Incentive designs that are transparent and predictable to market participants are generally more effective in building a market and mobilizing capital. Mechanisms such as those used for NY-Sun with a transparent long-term step-down in incentive levels have proved to be effective clean energy market

[110] CASE 14-M-0101 (Reforming the Energy Vision), CASE 15-E-0751 (In the Matter of the Value of Distributed Energy Resources)
[111] https://www.nyserda.ny.gov/About/Clean-Energy-Fund
[112] A.9925/S.6249

growth strategies. Such incentive designs typically require several years of market data on performance and realized cost reductions to be designed properly. Given the very early stage of the RH&C markets in the State, this type of pre-determined step-down may not yet be appropriate for RH&C.

Incentives could be provided either in the form of one-off payments at or around the time of initial installation of the project in question, or in the form of recurring payments typically over a period of several years.

In the latter case, payments would typically be linked to the amount of energy generated. Such incentives are often referred to as performance-based incentives (PBIs). This type of incentive is common in the renewable electricity sector, where support spread out over a number of years occurs, for instance, in the form of RECs under portfolio standards, as discussed in Section 6.1 above, or through feed-in tariffs. These structures are less common in the RH&C sector, although Section 6.1 describes examples where this type of incentive has been introduced or is being introduced for RH&C.

Table 6.3 summarizes pros and cons of upfront and ongoing incentives.

Table 6.3 - Comparison between upfront and ongoing incentives

	Upfront incentive	Ongoing incentive (including PBI)
Finance and third-party ownership	An upfront incentive may not overcome any finance hurdles—finance would still be needed for the balance of the capital cost. However, it could provide a "first loss" hedge from a funder's perspective. (This may not be the case for tax credits, where at least initially the customer would still need 100% finance.)	An annual incentive payment is bankable from the perspective of a funder or third-party ownership (lease/PPA) structure—more so than uncertain annual energy bill savings. Since the project still requires 100% upfront finance, total deal size is greater (from a funder's perspective) than in the case of upfront rebates. This can make the project more attractive to finance.
Impact on public purse	Annual incentive spending would happen more quickly than in the case of ongoing payments since the entire incentive payment is paid in one year.	Ongoing incentive payments reduce the early-year cash-flow pressure on the public purse or ratepayers (depending how the incentive is funded) but because project developers discount future cash flow, a higher total amount of incentive would have to be provided than would be the case in an upfront incentive.
Persistent fuel switching	In the case of an upfront subsidy, there is no assurance built into the subsidy design as to system usage (e.g., when fossil fuel prices are favorable, a "backup" fossil fuel system might be brought back into action).	Annual payments provide an incentive to continue using the RH&C installation.
Risk of project breakdown	In the case of upfront incentives, the entire subsidy investment is at risk if an installation breaks down prematurely.	Ongoing incentives are only paid while the installation continues to operate, so this encourages high-quality installations as well as necessary maintenance and repairs.
Design complexity	Design and implementation of an upfront incentive program is generally simple.	Performance-based incentives for renewable heating and cooling can be more complex and take longer to design, to address issues such as metering of heating and cooling.
Administrative complexity	Upfront incentives can be administratively simpler than ongoing payments, especially if the ongoing payments are based on measured performance.	Ongoing payments would add burdens on the customer and the administrating authority in terms of regular meter readings, other periodic reports, and payments.
Cost reductions	There is a potential for installers to inflate prices, with an upfront incentive, or tax credit based on total system cost.	Both ongoing and upfront incentives could help drive cost reductions by reducing the incentive levels for new installations over time.
Customer engagement and access to data	While there could be a requirement for the customer to provide data and feedback to NYSERDA on an ongoing basis, this may not be an effective obligation since the customer has already received the full subsidy.	There is a platform for ongoing engagement with the customer, including obtaining performance data.

Both upfront and performance-based incentives could be structured in several ways, depending on who would provide the incentive and how it would be funded.

Upfront payments could be provided:

- In the form of a direct rebate provided by a government organization such as NYSERDA, or by utilities
- Alternatively, a state tax credit could be made available, which would have the effect of reducing the upfront capital cost (though with some possible delay beyond the installation date, depending on when tax refunds are issued).

An ongoing incentive could be provided:

- Directly by a state organization, such as NYSERDA, or by utilities
- Alternatively, a performance-based incentive could be structured through a portfolio standard, such as those described in Section 6.1 in other states. As noted above, the CES will consider RH&C support through T-RECs. Such T-RECs could provide an annual value stream—a performance-based incentive—to RH&C installations.
- Subsidized loans could be another form of an ongoing incentive
- The option of allowing utilities to rate-base investments in RH&C systems under a TPO model could also be regarded as a performance-based incentive. In this approach, the return that ratepayers would be paying utilities would, to the extent such return would exceed the commercial returns from the RH&C installations, constitute an incentive.

On balance, we believe that performance-based incentives—where payments are made based on metered generation—would ultimately be a more efficient and effective way of bringing forward RH&C technologies than upfront incentives. However, these types of schemes are generally more complex than upfront incentives. Delivery of an incentive scheme in the short term—in particular the near-term GSHP incentive set out in Section 6.4—is thus more practical as an upfront incentive, in order to minimize the delay associated with designing and implementing the policy. Ultimately, metered PBIs are likely suitable only for larger installations, since heat metering and reporting would likely constitute an impractical burden for small residential customers. However, in these cases, some of the benefits of metered PBIs could also be obtained by designing an incentive with annual payments or milestone payments based on estimated rather than metered performance.

As regards the available **types of upfront incentives**, when comparing tax credits to direct rebates from NYSERDA or utilities, we believe that rebates are a preferable instrument for the following reasons:

- Tax credits may be worth less than a comparable rebate because customers would have to wait to do their tax return and subsequently receive their tax refund, whereas the rebate process is often completed at or shortly after installation. Equally, rebate applications are often handled to a large extent by the installation contractor, reducing the administrative burden for the customer.
- Tax credits are less suitable in the case where businesses or individuals, especially LMI individuals, are not paying enough tax to be able to monetize the tax credit. In these cases, it is possible, particularly for commercial structures, for third parties to provide the “tax equity” that would allow the tax credit to be utilized, but this comes at a cost and increases project complexity.

- Tax credits typically do not result in any involvement from an energy authority such as NYSERDA. As a result, the benefit of access to uptake and performance data, as well as a platform for ongoing interaction with the customer or business on energy-related issues would be lost.

However, in the case of rebates funded by the Clean Energy Fund, we would need to determine whether availability of rebates should be limited to customers who have contributed to such funds, which would exclude Long Island, South-eastern New York (SENY) customers, and municipal electric customers.

As regards possible **performance-based incentives**, from the investor's perspective, certainty about the amount of incentive payment over the payment period of the incentive (which could be installation lifetime or a shorter period of time) would be important. This could influence incentive design in a number of ways:

- It is critically important that once an installation is complete, the incentive arrangement applicable to the installation would not subsequently be changed.
- Nevertheless, the subsidy amount could still fluctuate over the lifetime of an installation as a result of the policy design. T-RECs issued under portfolio standards would be traded, and the level of available T-RECs in a given period, compared to the target that load-serving entities (LSEs) would need to comply with, would determine the price of RECs and T-RECs from time to time. Exposing investors to this volatility would create additional risk and thus additional cost. However, structures could be designed to mitigate these risks and costs—for instance the portfolio standard currently being designed in Massachusetts (see Section 6.1) is expected to contain the option of paying customers the T-REC value in the form of a fixed rebate. The New York CES itself provides a further example of a similar concept: Tier 1 of the CES (which covers new renewable electricity installations) envisions that installations would be able to access the incentive in the form of long-term contracts provided by NYSERDA under annual auctions, where such long-term contracts provide a guaranteed performance-based payment to the generator in return for NYSERDA receiving the RECs. Where such parallel incentive programs are used, (T-)RECs effectively become a funding mechanism.

If and when performance-based incentives are introduced, a number of other design questions would need to be addressed, including whether such incentives would be paid on the basis of units of energy generated or another indicator reflecting performance; and whether performance would be metered or estimated (see Section 4.3 regarding metering standards and guidelines).

A general principle that will guide consideration of any future incentives as well as transition from one type of incentive to another (such as from upfront to performance-based incentives) is the importance of avoiding excessive incentive payments by allowing projects to access several incentives where this would constitute unnecessary additional support.

SECTION 6.4 MARKET CONTINUITY: GSHP NEAR-TERM INCENTIVE

While the CES/REV follow-up processes referred to above are taking place over the next one to two years, we will invest in market continuity where there is a significant potential for impact.

Accordingly, we propose to introduce a near-term NYSERDA incentive for GSHPs. This incentive is planned to have the following key features:

- Noting our assessment in Section 6.3 that, for the short term, the practical advantages of upfront incentives outweigh the ultimate benefits of performance-based incentives, the incentive will take the form of upfront rebates.
- The level of the incentive will be $1,500 per ton of installed capacity for residential/small-scale systems (≤10 tons of heating capacity) and $1,200 per ton of installed capacity for all other installations.
- The program will include a maximum incentive payment per site for large projects.
- The incentive would be provided to the designer or installer, similar to NY-Sun, and must be reflected in the price to the customer. Criteria for eligible designers and installers include IGSHPA certification, Certified Geothermal Designer certification and/or a PE license with experience in designing and installing GSHP systems.
- The incentive will be available for GSHP installations including: closed-loop horizontal, vertical and direct exchange systems, open loop systems, and groundwater or surface water systems.
- All market sectors, including the residential, multifamily, commercial, public, and voluntary sectors, will be eligible so long as they contribute to the Clean Energy Fund.
- The incentive will be available both for systems installed in new properties or as retrofits on existing sites.
- The program will be a companion incentive to the PSEG GSHP rebate on Long Island and will accordingly be available in other parts of the State.
- The program will remain open for two years or exhaustion of available funds.
- NYSERDA will allocate a budget of approximately $15 million to this GSHP program.
- Eligibility will include systems pre-dating the launch if installed on or after January 1, 2017 (and subject to meeting the other requirements of the program).

Further features, such as more detailed eligibility issues and application process, will be announced as soon as possible.

This program responds to the specific and unique situation faced by GSHPs as a result of the expiration of federal tax credits at the end of 2016. Possible incentives for other RH&C technologies will be considered as described in Section 6.2.

CHAPTER 7 NEXT STEPS

This Policy Framework constitutes the first step in a longer-term effort to stimulate the RH&C market in New York State. It sets out options for policies and market-based strategies for the next few years and concepts for longer-term action. Continued engagement with the industry, consumers, and other stakeholders will be necessary to successfully achieve desired outcomes, and NYSERDA invites comments and contributions from stakeholders, in particular on:

- The options set out in Chapter 4 on reducing costs and lowering barriers (see Box 7.1)
- The concepts discussed in Chapter 5 in respect of potential mandates
- The concepts in Chapter 6 in respect of incentives

NYSERDA requests written feedback on this Policy Framework be sent by **5 PM on March 10, 2017** to:

renewableheatingandcooling@nyserda.ny.gov

To facilitate stakeholder feedback, NYSERDA will schedule a webinar to discuss the Policy Framework during the comment period. Stakeholders interested in attending should send an expression of interest by email to the address above.

Box 7.1 - Options for policies and market-based strategies

1. **Implement community procurement programs (e.g., Solarize for Heat) to promote local clustering** (page 46).
2. **Develop a customer targeting and engagement tool to enable contractors to identify local clusters of high-potential customers** (page 48).
3. **Facilitate standardized equipment and design approaches by encouraging industry best practices and/or through requirements in incentive programs** (page 49).
4. **Develop a unified, streamlined permitting process for RH&C technologies and encourage adoption across State municipalities** (page 51).
5. **Provide technical and engineering assistance and project development support for larger projects in key market segments** (page 53).
6. **Integrate RH&C into existing trade channels such as the HVAC emergency replacement market or oil heat dealer sector in order to reach a broader customer base** (page 53).
7. **Enable broader availability and development of cheaper finance options** (page 55).
8. **Work with utilities and energy service companies (ESCOs) to pilot third-party ownership and other innovative models under Reforming the Energy Vision (REV)** (page 56).

Other next steps are as follows:

- New York State will consider and develop, as appropriate, the intervention options set out throughout this framework, taking into account stakeholder feedback. Decisions will be announced in due course throughout 2017, with subsequent investment plans and market implementation.
- Decisions on the following options and proposals can be expected in early 2017, with implementation soon thereafter:
    - Piloting community-based campaigns for RH&C
    - Technical/financing assistance support for strategic market segments
- In February 2017, NYSERDA will convene members of the Advisory Committee to discuss and review preliminary design of the GSHP near-term incentive program. The program will be available no later than the second quarter of 2017.
- DPS has announced that the CES T-REC process referred to above will commence with a stakeholder conference to be held on February 8, 2017. NYSERDA will provide analytical support to this process.
- We intend to publish an update to this Policy Framework, reflecting stakeholder input and decisions taken as per the above process and market progress, in 2018.

APPENDIX A – METHODOLOGY OF SUPPORTING ANALYSIS

Supporting analysis was carried out to underpin the assessment of RH&C economics, cost reduction potential, value, and resource potential as referenced throughout this framework. The analysis was led by NYSERDA. NYSERDA acknowledges the contributions of Meister Consulting Group, Inc. (as well as its subcontractors PW Grosser and Synapse Energy Economics) and Energy and Environmental Economics for their primary analytical role in the development of this analysis.

The objective of the analysis was to obtain and evaluate best available data describing costs, value, and resource potential for the RH&C technologies examined in this framework. As the primary tool to facilitate assessment of the data, a supply curve model was built. Inputs and functionality of the supply curve analysis are summarized below.

A.1 SUPPLY CURVE ANALYSIS

The analysis was carried out by describing the New York State RH&C market by means of a number of reference sites, each depicting a segment of the market with shared characteristics, referred to as "differentiating factors". The market was segmented by seven key differentiating factors:

- Installed technology, which includes central ccASHPs and mini-split ccASHPs, GSHPs with horizontal or vertical loop fields (in each case with or without desuperheaters), and SHW.[113]
- Counterfactual fuel, including electric resistance heating, fuel oil, or natural gas.
- Building sector, including single family residential, multifamily residential (small, medium, and large), and commercial (small, medium, and large) buildings.
- Building subsector, differentiated by owned and rented single family buildings, public and private commercial buildings, and market-rate or publicly-owned multifamily buildings.
- Geography including the Hudson Valley, Long Island, NYC, Upstate/Western New York.
- Age, including existing buildings and new construction.

[113] In addition, initial analysis on heat pump water heaters was carried out but not deemed sufficiently mature for inclusion in this framework. As regards assessment of GSHPs with or without desuperheaters, the analysis suggested only small differences in their relative cost-effectiveness, so for simplicity the analysis reflected in this framework was limited to GSHPs without desuperheaters. The analysis of GSHPs was assessed to be representative also of direct exchange and open loop GSHP systems, as well as groundwater or surface water systems, without separate analysis of these technologies.

After accounting for inapplicable combinations of differentiating factors, the supply curve assessed around 1,000 reference installations. For each, the model evaluates the estimated amount of technical resource potential, and the economics (costs and benefits) over time.

Some of the key output indicators are as follows:

- **Technical resource potential**, expressed as the amount of annual heating and cooling load that could be served by each RH&C technology at each reference site (taking into account the number of available sites of each type, the amount of thermal load at each site, the suitability of each RH&C for each site and the amount of the site's thermal load that each RH&C technology could serve – all as described in more detail in Section A.2).
- **Simple payback**, expressed as the net capex (RH&C capex minus applicable upfront incentives and savings on avoiding capital costs of a new conventional system) divided by net revenue (the net cash flow of energy bill savings, operations and maintenance (O&M) and any ongoing subsidy payments).
- **Project internal rate of return (nominal, pre-tax)**, which is the discount rate at which the annual net cash flow of a reference installation over its lifetime can be discounted to yield a net present value of zero compared to the net upfront capital cost.
- **Levelized cost of energy (LCOE)**: the amount, expressed as a constant nominal amount over the installation's lifetime that would be required as an additional annual revenue stream for the installation to achieve its hurdle rate of return, divided by its annual output of heating and cooling energy. In other words, the LCOE for an installation, multiplied by its annual heating and cooling load, would yield the annual (nominal) subsidy amount that an installation would require each year over its lifetime to meet the assumed investor return requirement. An LCOE of zero, or a negative LCOE, indicates that the installation does not require a subsidy and is thus cost effective.
- **Levelized cost of carbon (LCOC)**: this indicator is similar to the LCOE indicator, with the exception that the annual revenue requirement is divided by net tons of CO2e saved; it thus shows the subsidy need per ton of carbon saved. As with LCOE, a negative or zero amount indicates that the installation is cost effective.

The supply curve tool can be used to show available resource potential, or it can provide a forecast of expected adoption in a particular year or over a particular period of time, based on the economics of reference installations with or without any incentive inputs. Uptake is forecast by assuming that out of total available resource potential, adoption in any year only occurs at sites where the current conventional heating and cooling equipment is deemed to reach the end of its useful life. In each segment, the RH&C technology (or technologies) with the most favorable payback is identified, and if this technology or these technologies deliver the minimum required hurdle rate of return for the market segment in question, adoption of such RH&C technology or technologies is forecast to occur at a set uptake percentage of the amount of end-of-life resource potential as described above. If no RH&C technology meets the hurdle rate, a low level of (uneconomic) uptake is forecast to occur (only in residential market segments).

Based on an adoption forecast as described above, the model can calculate program costs, ratepayer value, and cumulative carbon saved.

A.2 SUPPLY CURVE INPUTS

The supply curve model as described above uses a range or data inputs, loosely organized into four categories, each of which is discussed in more depth further below:

- Site inputs, which describe the number of statewide sites of each type, the amount of thermal load consumed at each reference site, as well as other factors considered at the site level.
- RH&C inputs, which consider the cost, performance, and other attributes of renewable heating and cooling equipment to be installed at each site.
- Counterfactual inputs, which consider these same attributes for the conventional heating equipment that would otherwise be installed at a given reference site.
- Retail energy prices for electricity, natural gas and fuel oil.

Inputs were derived from a number of sources, as shown below. Preliminary data inputs were confirmed and revised based on input from the Advisory Committee of industry stakeholders, convened by NYSERDA, which met twice to provide input on measure parameters and data sources, and one-on-one interviews with industry stakeholders.

The period covered by the analysis ranges from 2017 to 2030, with any installations installed during this period being evaluated throughout their lifetime (e.g. up to 2054 for an installation installed in 2030 with a 25-year lifetime).

A.2.1 SITE INPUTS

The site-level inputs included in the supply curve model include:

- Site count, or the projected number of sites in New York pertaining to each possible installation site types.
- Site suitability, or the number/proportion of sites that are technically feasible for each RH&C technology.
- Site thermal load, the typical space heating, space cooling, and water heating load of each reference site.
- Miscellaneous site inputs, such as expected customer hurdle rates and heating equipment turnover rates.

Site Count

As a first step in establishing total available resource by reference installation the total number of residential and commercial buildings were allocated across the 336 combinations of counterfactual heating fuel, building sector and subsector, geographic region, and building age.

Data from the US Census Bureau's American Community Survey (ACS) (5 year estimates, 2010-2014) was used to allocate roughly 4.5 million residential buildings into single family and multifamily categories, and to separately identify rented and owned single family buildings. Multifamily buildings were separated into small, medium, and large thermal consumption buckets based on the distribution of thermal load seen in the Energy Information Administration's (EIA) Residential Energy Consumption Survey (RECS), and were separated into privately- and publicly-owned buildings based on data from the US Department of Housing and Urban Development Picture of Subsidized Housing database.

Figures from the EIA Commercial Buildings Energy Consumption Survey (CBECS) and US Census 2014 County Business Patterns database were used to estimate a total of roughly 250,000 total commercial buildings in New York. CBECS data was used to estimate the share of educational or public sector buildings, and to allocate buildings into small, medium, and large commercial categories based on the distribution of building-level thermal energy consumption.

Additionally, average annual building construction rates over the last fifteen years were established for residential (from ACS data) and commercial (from CBECS) buildings, and allocated across reference sites. Roughly 28,000 buildings are projected to be constructed in New York each year. Over the 14-year (2017-2030) study period, this equates to nearly 400,000 new buildings.

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). As granular geographic data on commercial buildings is not available, the geographic distribution for each multifamily building size was applied to the respective commercial building category as well (e.g. large commercial buildings were allocated across the four geographic regions based on the known geographic distribution of large multifamily buildings). To capture differences between new and existing buildings, new construction sites were also allocated by geography using ACS data, but using only the subset of data from buildings constructed in the last fifteen years.

Finally, installation sites were allocated across counterfactual fuel categories, i.e. 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 RH&C. 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. A Mid-Atlantic regional distribution of commercial counterfactual fuels is available from CBECS data, and this regional distribution was adjusted to account for the relative prevalence of different fuels among residential buildings in each geographic region. A small number of buildings (roughly 4.7%) in New York have a primary heating (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 no new buildings would use electricity as a counterfactual fuel, that the share of oil heat in new buildings would be half of the share in existing buildings, and that all new construction in New York City would have natural gas as a counterfactual fuel.

In all, just under 5 million buildings are included in the model. A summary by building sector is provided in Table A.1.

Table A.1 - Number of buildings statewide by building sector.

Building Sector	Sites
Residential	3,944,929
Small Multifamily	550,588
Medium Multifamily	140,936
Large Multifamily	58,256
Small Commercial	154,433
Medium Commercial	55,223
Large Commercial	61,338

Site Suitability

As not every building is a suitable site for a particular RH&C technology, a series of percentage reductions were applied to the raw site count totals to arrive at numbers of suitable sites for each RH&C option. Specific reductions include:

- A building control haircut of 75% for the single family rental market and for the market-rate multifamily market, reflecting that renters and multifamily residents often do not have decision-making authority over whole-building heating systems, and that split incentive barriers are substantial detriments to the growth of RH&C in these market segments.
- A geographic incompatibility haircut, reflecting that some technologies (primarily horizontal-loop GSHPs and solar hot water systems) require certain site characteristics, limiting their potential in some geographic regions.
    - Constraints for horizontal heat pumps based on limited land availability to accommodate the horizontal ground loop field were based on a qualitative assessment, with input from members of the Advisory Committee. See Table A.2. (Additionally, a 20% haircut was applied to vertical GSHPs located in New York City):
    - Based on similar input, a 20% reduction was applied for Solar Hot Water applications in existing buildings statewide, assuming that some existing buildings not be viable sites due to shading, roof quality, or roof alignment issues, but that new buildings could be constructed with SHW in mind to avoid these issues. An additional 30% haircut was applied for both new and existing buildings in NYC, where shading issues are expected to be more dramatic.
- A sector incompatibility reduction of 100% for mini-split ccASHPs in medium and large commercial and multifamily settings, reflecting feedback from the Advisory Committee that ductless mini-splits are not a preferred ASHP technology for large buildings for technical and aesthetic reasons, and that the ASHP technology applied in these building sectors is a centralized system using variable refrigerant flow (VRF).
- A thermal distribution haircut, which assumed that residential potential for central ccASHPs and GSHPs would be restricted to homes with existing forced-air ductwork. A resource haircut of 40% was applied, based on EIA RECS data. It is noted that heat pumps suitable for use with hydronic distribution systems are expected to become more prevalent, at which point this reduction assumption could be revised or removed.
- A vacant building haircut, which applies a haircut of between 9% and 14% to residential buildings based on geography and flat haircut of 4% to commercial buildings to account for buildings that are not currently occupied year-round for a variety of reasons (including vacancy, seasonal homes, etc.). Residential data is from ACS, commercial data is from CBECS.

Table A.2 - Horizontal GSHP resource reductions applied by building sector and geographic region.

Geography	Residential	Small Multifamily	Small Commercial	Medium/Large Comm/MF
Long Island	80%	90%	90%	95%
NYC	85%	95%	95%	99%
Hudson Valley	20%	80%	65%	95%
Upstate/Western New York	20%	80%	65%	95%

Site Thermal Load

Estimates of site-specific space heating, space cooling, and water heating thermal load were compiled from EIA RECS and CBECS databases. These estimates were then revised based on data provided by project team and Advisory Committee members. Table A.3 shows the assumed annual space heating (SH), space cooling (SC), and water heating (WH) thermal load (in MMBtu) of sites across various buildings segments and geographies.

Table A.3 - Annual thermal load (MMBtu) assumed by building sector, region, and thermal end use

Geography	Long Island			NYC			Hudson Valley			Upstate/Western New York		
End Use	SH	SC	WH	SH	SC	WH	SH	SC	WH	SH	SC	WH
Residential	74	26	20	74	26	20	87	19	18	109	11	18
Small Multifamily	108	52	23	108	52	23	126	39	21	157	22	21
Medium Multifamily	289	140	110	289	140	110	340	104	102	423	60	102
Large Multifamily	1,969	955	632	1,969	955	632	2,312	707	585	2,879	411	585
Small Commercial	121	163	23	121	163	23	125	154	21	131	154	21
Medium Commercial	326	438	110	326	438	110	336	414	102	353	414	102
Large Commercial	2,220	2,342	632	2,220	2,342	632	2,288	2,213	585	2,402	2,217	585

Miscellaneous Site Inputs

Additional reference site attributes include:

- Assumed hurdle rates, or the return on investment that must be achieved for an RH&C investment to be deemed attractive to a given customer: a hurdle rate of 16% (nominal pre-tax project internal rate of return) was assumed for most building segments. For publicly-owned buildings (both public-sector non-residential buildings and publicly-owned multifamily housing) a lower hurdle rate of 10% was assumed, in recognition of the lower costs of capital accessible to public sector entities and their potential willingness to accept lower rates of return.

- The assumed thermal system replacement cycle, or the expected lifetime of typical equipment: based on RECS data, and adjusted based on project team feedback, it was assumed that building space heating equipment is replaced every twenty years, and water heating equipment is replaced every twelve years. These values were used to determine the number of existing buildings across New York that are expected to replace space or water heating equipment in each year (and that therefore could be targeted for RH&C system installation).

A.2.2 RH&C INPUTS

Various data points collected for each RH&C reference installation include:

- RH&C System Size.
- RH&C System Efficiency.
- RH&C Installation Costs.
- RH&C Operations and Maintenance Costs.
- RH&C Expected Useful Lifetime.

Each category of data is described in more detail below.

RH&C System Size

ccASHP and GSHP system sizes were considered in terms of rated tonnage (tons of installation size), and solar hot water system sizes were considered in terms of the number of collectors. System sizes for single-family buildings were developed through conversations with Advisory Committee members about the typical system size installed to serve residential buildings, and (where relevant) the appropriate percentage of building thermal load served. System sizes for multifamily and commercial buildings (for which there is a much greater degree of variation in installation sizes and types) were scaled from these single-family values based on building thermal load values.

Assumed system sizes, and the corresponding percentage of space or water heating load served by the RH&C equipment, are shown in the Table A.4. Based on conversations with Advisory Committee members, the assumed system size of single family and small multifamily Central ccASHPs varies depending on whether the equipment is installed in an existing building (in which case it is assumed the ccASHP would provide roughly 80% of a building's heating load and utilize the existing heating system as backup) or as part of a new building (in which case the ccASHP would be oversized to allow it to serve as the building's sole heating source, with an integrated electric resistance backup). Reflecting the current state of the ccASHP market, it was assumed that mini-split ccASHP installations would serve only a small portion of a home's heating needs (mini-splits are capable of serving a much larger share of a home's heating needs, but based on available regional ccASHP rebate data, the majority of customers today install smaller systems that are one or two tons in size).

Table A.4 - RH&C system size and percent load served assumptions

Building Sector	Central ccASHP		Mini-Split ccASHP		GSHP		SHW	
	Tonnage	% of Space Heat Served	Tonnage	% of Space Heat Served	Tonnage	% of Space Heat Served	Collectors	% of Water Heat Served
Residential	3-5	80-100%	1.5	40%	4	100%	2	52-56%
Small Multifamily	5-8	80-100%	3	40%	6	100%	3	52-56%
Medium Multifamily	16	100%	N/A	N/A	16	100%	12	52-56%
Large Multifamily	107	100%	N/A	N/A	107	100%	65	52-56%
Small Commercial	9	100%	5	40%	8	100%	3	52-56%
Medium Commercial	20	100%	N/A	N/A	20	100%	12	52-56%
Large Commercial	106	100%	N/A	N/A	106	100%	65	52-56%

RH&C Efficiency

Preliminary RH&C equipment efficiencies were sourced from available rebate database in New York and neighboring states. These efficiency values were reviewed with Advisory Committee working groups, and revised based on their feedback. The resulting input values are shown in Table A.5.

For the most part, ccASHP efficiencies of 3.0 COP and 16 SEER are used. The exception is small-scale central ccASHPs installed in new construction settings, for which a lower COP of 2.5 is assumed to reflect the reduced efficiencies and use of a backup electric resistance system (discussed above) in very cold weather. GSHPs heating efficiencies are assumed to be lower for larger systems than for smaller systems, based on Advisory Committee feedback.

Solar Hot Water efficiencies are considered not as a ratio of input energy to output energy, but in terms of the usable system output per collector per day. Input energy for SHW systems is not tracked in the model (which ignores any negligible kWh consumption from the pumping system).

Table A.5 - RH&C equipment efficiency assumptions

Technology	Building Sector	Space Heating		Space Cooling	
		Efficiency Unit	Efficiency Rating	Efficiency Unit	Efficiency Rating
Central ccASHP	Residential & Small MF/Comm; Existing Buildings	Seasonal COP	3.0	SEER	16
	Residential & Small MF/Comm; New Construction	Seasonal COP	2.5	SEER	16
	Medium/Large MF/Comm (Variable Refrigerant Flow)	Seasonal COP	3.0	SEER	16
Mini-Split ccASHP		Seasonal COP	3.0	SEER	16
GSHP	Residential & Small MF/Comm	Seasonal COP	4.15	EER	23
GSHP	Medium/Large MF/Comm	Seasonal COP	3.45	EER	23

Solar Hot Water SRCC rating (kBTU/collector/day)	14

RH&C Installation Costs

RH&C installation cost vary by building sector, geographic region and building age, and each reference installation input into the supply curve model has a unique installed cost per ton based on the differentiating factors in place for that site. The range of installed costs put into the model (on a $/ton of installed capacity basis for ccASHPs and GSHPs and a $/collector basis for SHW) are displayed below.

To arrive at these inputs, preliminary costs were compiled based on regional rebate databases and a review of prior reports, and these were vetted and adjusted through conversations with the Advisory Committee. Specific inputs were developed for unique reference installations, and these were adjusted by differentiating factor for all other sites. Most notably, prices were adjusted for geographic region using cost factors available through the RSMeans construction cost data service.

Table A.6 - RH&C installation costs per ton (ccASHP/GSHP) or collector (SHW), by technology and building size

Technology	Building Size	Installation Cost per Ton/Collector	
		Min	Max
Central ccASHP	Single Family	$3,135	$4,857
	Small MF/Comm	$2,665	$4,128
	Medium/Large MF/Comm	$5,602	$11,065
Mini-Split ccASHP	Single Family	$3,279	$4,317
	Small MF/Comm	$2,787	$3,669
Horizontal GSHP	Single Family	$6,956	$10,776
	Small MF/Comm	$5,913	$9,160
	Medium/Large MF/Comm	$5,913	$9,160
Vertical GSHP	Single Family	$8,606	$13,331
	Small MF/Comm	$7,315	$11,331
	Medium/Large MF/Comm	$7,315	$11,331
Solar Hot Water	Single Family	$4,383	$7,214
	Small MF/Comm	$3,892	$6,405
	Medium/Large MF/Comm	$2,354	$3,955

Notes:

- The cost per ton of installed capacity for medium/large central ccASHPs is higher than that for small systems because of the shift in technology to VRF systems in larger installations, which have a higher $/ton installation cost.
- Vertical-loop GSHPs have a higher installed cost per ton than horizontal-loop GSHPs due to the increased drilling cost associated with that installation approach.

RH&C Operation & Maintenance (O&M)

Conversations with Advisory Committee members yielded a range of estimates of typical O&M costs for RH&C technologies. Much of the uncertainty related to variation in how much of the maintenance cost is paid by the customer on an ongoing basis versus paid by the installer as part of a warranty (which would therefore be included as part of the upfront cost).

To avoid favoring one technology over the other, standard O&M cost inputs across technologies of roughly $100/year were applied for single family installations and roughly $100/ton/year for larger installations, scaled based on geography and system size.

RH&C Equipment Lifetimes

Based on conversations with Advisory Committee members and a review of the existing literature (such as the New York Technical Reference Manual, ASHRAE equipment standards, and reports from DOE National Laboratories), the following equipment lifetimes were used in this study.

Table A.7 - RH&C equipment lifetime by technology

Technology	Lifetime (Years)
ccASHP	15
GSHP	25
SHW	20

Notably, the project team received feedback from the GSHP Advisory Committee working group that 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.

A.2.3 COUNTERFACTUAL INPUTS

Avoided costs associated with a conventional heating or cooling system that would have been installed and used in the absence of RH&C are counted as a value stream when calculating the RH&C project economics. This regards avoided fuel costs, and capital/ O&M costs (where the RH&C replaces the relevant site load requirements entirely). Counterfactual equipment costs and performance efficiencies were collected from both Advisory Committee data as well as a broader literature review (primarily DOE Technical Reference documents).

The type of counterfactual space heating and cooling equipment varied based on counterfactual heating fuel and building sector. In residential and small multifamily buildings, the assumed counterfactual equipment is either a gas or oil furnace or electric resistance heat, combined with central residential air-conditioning.[114] In small and medium commercial buildings and medium multifamily buildings, the counterfactual heating and cooling equipment is a packaged rooftop unit, operational with any of the three fuels. Similarly, the counterfactual heating and cooling equipment for a large commercial or multifamily building is a combined chiller-boiler, operational on either oil or gas (it is assumed that no large commercial or multifamily buildings use electric heat).

[114] Since the analysis assumes end-of-life system replacements, the avoided capital cost of a conventional system is counted as a benefit towards the RH&C project economics except where the RH&C installation does not replace all of the relevant load. However, in reference installations replacing electric resistance heat (only relevant for existing buildings, as it is assumed that no new buildings will use electric resistance heat), it is assumed that the counterfactual setting would be to continue to use the existing heating system, and so no avoided installed capital cost is counted.

Table A.8 - Counterfactual equipment efficiency and installed cost by thermal end use, building sector, system type, and counterfactual fuel

End Use	Building Sector	System Type	Counter-factual Fuel	Efficiency		Total Installed Cost	
				Unit Type	Rating	Min	Max
Space Heat	Small Residential	Residential Furnace	Natural Gas	AFUE/ COP	76%	$3,227	$7,499
		Residential Furnace	Fuel Oil	AFUE/ COP	66%	$4,841	$11,248
		Electric Resistance	Electricity	AFUE/ COP	100%	Not Applicable	
	Medium Comm/MF	Packaged Rooftop Unit	Natural Gas	AFUE/ COP	80%	$7,239	$39,737
			Fuel Oil	AFUE/ COP	80%	$7,239	$39,737
			Electricity	AFUE/ COP	80%	$7,239	$39,737
	Large Comm/MF	Chiller/Boiler Combination	Natural Gas	AFUE/ COP	80%	$564,137	$882,147
			Fuel Oil	AFUE/ COP	80%	$564,137	$882,147
Space Cool	Small Residential	Central AC	Electricity	SEER	13	$2,438	$6,924
	Medium Comm/MF	Packaged Rooftop Unit		SEER	10	Included in Space Heat	
	Large Comm/MF	Chiller/Boiler Combination		kW/ton	1.1	Included in Space Heat	
Water Heat	Small Residential		Natural Gas	Energy Factor	75%	Not Applicable	
			Fuel Oil	Energy Factor	75%	Not Applicable	
			Electricity	Energy Factor	90%	Not Applicable	
	Medium Comm/MF		Natural Gas	Energy Factor	75%	Not Applicable	
			Fuel Oil	Energy Factor	75%	Not Applicable	
			Electricity	Energy Factor	90%	Not Applicable	
	Large Comm/MF		Natural Gas	Energy Factor	75%	Not Applicable	
			Fuel Oil	Energy Factor	75%	Not Applicable	
			Electricity	Energy Factor	90%	Not Applicable	

As SHW systems only account for a portion of a building's hot water needs, they do not avoid the need for an existing or new building to purchase a conventional water heater. Therefore, no water heat installed costs are listed in Table A.8 or included in this study.

A.2.4 RETAIL ENERGY PRICES

For each reference installation, the projected energy consumption of both RH&C and counterfactual equipment was calculated based on thermal load values and equipment efficiency inputs, and the costs of this consumption were valued according to price data on electricity, natural gas, and fuel oil.

Electricity bills both with and without the RH&C system were calculating taking into account a range of utility retail rates in place for residential and commercial customers (including both volumetric and demand rate components), as well as assumed hourly load profiles for each reference installation. See Section A.3 for details.

As electricity impacts are calculated on an hourly basis separately for each reference installation, there is not a single flat $/kWh retail price to use to represent these costs. However, Table A.9 shows the average $/kWh of electricity consumption (post-RH&C installation, weighted by electricity consumption and number of sites) by region and sector. These illustrative figures were derived by dividing total annual retail electricity bills by total annual kWh consumption, and therefore include demand and fixed charges and are not equivalent to a true volumetric $/kWh charge.

Escalation of electricity retail prices over the period examined in the analysis was implemented by means of separate approaches to escalation of the supply charge and distribution charge portions of overall energy bills. The supply charge was escalated proportionally to the NY CARIS energy price forecast and the NYISO base case capacity price forecast; energy was assumed to comprise 75% of the MSC and capacity was assumed to comprise 25%. The distribution charge portion of energy bills was escalated using standard EIA retail rate escalators which varied by utility and customer class.

Table A.9 - 2016 electricity prices, $/kWh

Sector	Long Island	NYC	Hudson Valley	Upstate/Western New York
Residential	$0.183	$0.166	$0.126	$0.093
Commercial	$0.133	$0.125	$0.097	$0.065

Natural gas and fuel oil prices were input on an annual basis, separately for each region and for residential and commercial sites.

Natural gas prices were determined using 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 gas utilities. Fixed-price revenue was estimated for each combination of customer class and utility, and non-fixed revenue was divided by natural gas sales to derive a per-unit variable price for use in this study.

Residential fuel oil prices were calculated from monthly home heating oil data collected at the regional level by NYSERDA, with annual values derived by weighting monthly prices by monthly statewide fuel oil sales available from EIA. These prices were adjusted for the commercial sector by comparing annual residential and commercial heating oil prices collected by NYSERDA.

The base annual natural gas and fuel oil prices (for 2015) used in this analysis are shown in Table A.10. Fuel prices are escalated according to EIA Mid-Atlantic price forecasts.

Table A.10 - 2015 annual natural gas and fuel oil prices

Sector	Region	Physical Units		Per MMBtu	
		Natural Gas ($/Mcf)	Fuel Oil ($/gallon)	Natural Gas	Fuel Oil
Residential	Long Island	$9.96	$3.02	$9.70	$26.25
	NYC	$8.82	$3.02	$8.59	$26.23
	Hudson Valley	$9.23	$2.86	$8.99	$24.84
	Upstate/Western New York	$6.33	$2.84	$6.16	$24.72
Commercial	Long Island	$9.08	$2.71	$8.84	$23.59
	NYC	$6.11	$2.71	$5.95	$23.57
	Hudson Valley	$7.94	$2.57	$7.73	$22.33
	Upstate/Western New York	$6.43	$2.55	$6.26	$22.21

A.3 ELECTRICITY BILL SAVINGS CALCULATION

The analysis calculated value:

- currently available to RH&C installations in the form of energy bill savings and potential
- currently unmonetized value streams:
    - the value of the carbon avoided by RH&C installations
    - any value to the electricity system (or "grid value") which under current rate structures do not flow back to RH&C customers.

To calculate potential dollar bill savings for customers that adopt specific types of RH&C technologies, the electric retail rate tariffs were compiled for the following utilities:

Table A.11 – Utility retail rate tariffs used by geography

Geography Used in Reference Installations	New York Utility
Long Island	PSE&G Long Island
NYC	Consolidated Edison
Hudson Valley	Central Hudson
Upstate/Western	National Grid

Specifically, within each utility, a utility tariff was selected that was representative for each sector.

Table A.12 – Rate class used by sector

Sector Used in Reference Installations	Rate Class for Utility Tariff
Residential	Residential
Small Multifamily	Residential
Medium Multifamily	Residential
Large Multifamily	Residential
Small Commercial	Commercial (No Demand Charge)
Medium Commercial	Small/Medium Commercial (With Demand Charge)
Large Commercial	Large Commercial (With Demand Charge)

For each electric retail rate tariff, the $/kWh energy charges were analyzed, including all system benefit charges. In some cases, these charges varied on a time-of-use basis. $/kW-month demand charges were also analyzed, which also varied by time-of-use in some cases. To calculate the bill savings to the customer, the total electricity bill for the counterfactual customer was calculated, i.e. before the RH&C technology and the total electricity bill with the RH&C technology. The difference between these two bills is the dollar savings (or incremental cost) to the customer.

The following tariffs were assumed to be representative of the rate classes modeled:

Table A.13 – Tariffs modeled by rate class

Utility	Rate Class	Tariff	Seasonal energy charges	TOU energy charges	Seasonal demand charges	TOU demand charges
Central Hudson	Residential	SC-1 (Residential)	No	No	N/A	N/A
Consolidated Edison	Residential	SC-1 (Residential)	No	No	N/A	N/A
National Grid	Residential	SC-1 (Residential)	No	No	N/A	N/A
PSE&G Long Island	Residential	SC-1 (Residential)	No	No	N/A	N/A

Utility	Rate Class	Tariff	Seasonal energy charges	TOU energy charges	Seasonal demand charges	TOU demand charges
Central Hudson	Commercial (Without Demand Charges)	SC-2 (Non-demand)	No	No	N/A	N/A
Consolidated Edison	Commercial (Without Demand Charges)	SC-2 (General small time of day)	Yes	Yes	N/A	N/A
National Grid	Commercial (Without Demand Charges)	SC-2 (Non-demand)	No	No	N/A	N/A
PSE&G Long Island	Commercial (Without Demand Charges)	Rate 280	Yes	No	N/A	N/A
Central Hudson	Small/Medium Commercial (With Demand Charges)	SC-2 (Secondary with demand)	No	No	No	No
Consolidated Edison	Small/Medium Commercial (With Demand Charges)	SC-9 (General large rate 1)	No	No	No	Yes
National Grid	Small/Medium Commercial (With Demand Charges)	SC-2 (With demand)	No	No	No	No
PSE&G Long Island	Small/Medium Commercial (With Demand Charges)	Rate 281	Yes	No	Yes	No
Central Hudson	Large Commercial (With Demand Charges)	SC-3 (Large power primary)	No	No	No	No

Utility	Rate Class	Tariff	Seasonal energy charges	TOU energy charges	Seasonal demand charges	TOU demand charges
Consolidated Edison	Large Commercial (With Demand Charges)	SC-9 (General large rate II TOU primary)	No	No	Yes	Yes
National Grid	Large Commercial (With Demand Charges)	SC-3 (Secondary)	No	No	No	No
PSE&G Long Island	Large Commercial (With Demand Charges)	Rate 285	No	Yes	No	Yes

A.4 GRID VALUE CALCULATION

The analysis quantified any difference between the change in a customer's energy bill upon adoption of RH&C and any change in the utility's costs resulting from the same RH&C installations. Where the difference between the two constitutes a positive amount, this indicates a value amount resulting from the installation of RH&C that is not passed through to the RH&C customer under the current rate structure, and would thus be available as a value to ratepayers as a whole.

Calculating the dollar savings and costs of RH&C technologies from a grid value perspective requires calculating the change in hourly electricity load relative to a counterfactual hourly electricity load. For example, an efficient heat pump being used in cooling mode to replace an inefficient air conditioner would reduce hourly electric loads while a heat pump being used in heating mode to replace a natural gas furnace would increase hourly electric loads. A decrease in electric load results in reduced costs to the electric utility but also a loss in collections. The opposite is true for an increase in electric loads

To calculate the change in hourly electric load, New York State specific data was used available from the OpenEI[115] database from the EIA. This database contains hourly end-use specific load profiles for residential and commercial buildings as simulated using different weather locations throughout the U.S. The New York JFK weather station was chosen to represent all buildings downstate (Long Island and NYC reference installations) and the New York Albany weather station to represent all buildings upstate (Hudson Valley and Upstate/Western reference installations). Within this database, the following hourly end-use profiles were extracted:

[115] http://en.openei.org/datasets/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states/resource/b341f6c6-ab5a-4976-bd07-adc68a2239c4

- Hourly natural gas profiles
  - Space Heating
  - Water Heating
- Hourly electricity profiles
  - Space Cooling
  - Non-Thermal

Given the mismatch between building types available in the OpenEI database and the sectors used in the supply curve analysis building types were mapped to sectors as follows.

Table A.14 – Building type used by sector

Sector Used in Reference Installations	Building Type from OpenEI Database
Residential	Residential
Small Multifamily	Residential
Medium Multifamily	Midrise Apartment
Large Multifamily	Midrise Apartment
Small Commercial	Small Office
Medium Commercial	Small Office
Large Commercial	Large Office

These profiles were then scaled to match the annual electricity kWh and natural gas Btu input amounts used in the supply curve analysis. Using both the counterfactual and renewable heating and cooling annual usage values used for the reference installations in the supply curve analysis, two separate hourly electricity load profiles were calculated (before and after installation of RH&C), from which the change in hourly electricity load was derived.

To calculate the dollar savings (or incremental dollar costs) to the utility ratepayer resulting from the changes in hourly electric loads, an hourly set of marginal utility avoidable costs was created using all costs incurred by the utility for serving marginally less or more electric load. These marginal avoidable utility costs were then compared to the total electricity bill savings of a customer that adopts a particular RH&C technology to determine the potential dollar savings (or incremental cost) for all utility ratepayers. The following table lists the marginal cost components considered and a description of the calculation methodology and data source.

Table A.15 – Methodology by cost component

Component	General Description	Input Assumption
Energy	Reduction or increase in costs due to change in production from the marginal conventional wholesale generating resource associated with RH&C technologies	The value of energy for each utility is derived from a forecast based on production simulation modeling per the NYISO's Congestion Assessment and Resource Integration Study (CARIS). This includes generation energy losses and compliance costs for criteria pollutants but does not include any financial CO_2 emission costs.
Energy Losses	Reduction or increase in electricity losses from the points of generation to the points of delivery associated with RH&C technologies	Utility transmission and distribution loss factors, i.e. expansion factors, as reported in their respective approved Tariffs. Generation losses are already accounted for in the energy costs.
Capacity	Reduction or increase in the fixed costs of building and maintaining new conventional generation resources associated with RH&C technologies	The most recent DPS installed capacity (ICAP) model was used to forecast future ICAP prices appropriate under a load modification approach applicable to each utility. These capacity costs are also adjusted for the appropriate energy T&D losses as well as adjusted by the expected system peak load reduction value.
Ancillary Services	Reduction or increase in the costs of services like operating reserves, voltage control, reactive power, and frequency regulation needed for grid stability associated with RH&C technologies	A proxy value of 1% assigned. The New York Independent System Operator (NYISO) procures ancillary services on a fixed rather than load following basis based on a largest single contingency measure, which means the amount of ancillary services procured would not likely decrease in any appreciable way due to the adoption of RH&C measures.
Transmission Capacity	Reduction or increase in costs associated with expanding/replacing/upgrading transmission capacity associated with RH&C technologies	The value of transmission capacity is captured in the NYISO CARIS zonal production simulation modeling results and is represented as congestion, i.e., energy price differentials, between the NYISO modeled zones. It is also likely captured to some extent in the various zonal NYISO capacity prices, i.e., more transmission and generation constrained capacity zones would likely have a higher zonal capacity price all else being equal.
Sub-Transmission Capacity	Reduction or increase in costs associated with expanding/replacing/upgrading sub-transmission capacity such as substations, lines, transformers, etc. with RH&C technologies	Costs based on existing estimates for marginal sub-transmission capacity costs as provided by each utility in their Marginal Cost of Service Studies as updated in the Value of Distributed Energy Resources (DER) proceeding (Case 15-E-0751). These costs are adjusted by the expected sub-transmission system peak load reduction value realized by each type of RH&C technology based on NYISO zonal load data.
Distribution Capacity	Reduction or increase in costs associated with expanding/replacing/upgrading distribution capacity such as lines, transformers, etc. with RH&C technologies	Costs based on existing estimates for marginal distribution capacity costs as provided by each utility in their Marginal Cost of Service Studies as updated in the Value of DER proceeding (Case 15-E-0751). These costs are adjusted by the expected distribution system peak load reduction value realized by each type of RH&C technology based on utility sample substation load data.

Component	General Description	Input Assumption
Criteria Pollutants	Reduction or increase in SO_2, ad NO_x emissions of the electricity sector only due to reduction/increase in production from the marginal wholesale generating resources associated with RH&C technologies	The compliance costs associated with these criteria pollutants is included in the zonal energy cost NYISO CARIS forecasts.
Financial CO_2 Emissions Cost	Reduction or increase of CO_2 emissions of the electricity sector only due to reduction/increase in production from the marginal wholesale generating resources associated with RH&C technologies	The financial value of carbon as determined by the NYISO in its CARIS forecast.

APPENDIX B – ABBREVIATIONS

Abbreviation	Description	Notes
A/C	Air conditioning	
Advisory Committee	Cost and Cost Reductions Advisory Committee	A group of RH&C stakeholders and experts convened by NYSERDA (see Chapter 1)
AEO	Annual Energy Outlook	
APS	Alternative Portfolio Standard	
(cc)ASHP	(Cold climate) air source heat pump	
BOS	Balance of system	
CARIS	Congestion Assessment and Resource Integration Study	
CBECS	Commercial Building Energy Consumption Survey	
CES	Clean Energy Standard	CASE 15-E-0302
C&I	Commercial and industrial	
CO_2	Carbon dioxide	
CO_2e	Carbon dioxide equivalent	
COP	Coefficient of performance	The ratio of useful heating or cooling output to input energy
DER	Distributed energy resource	
DHW	Domestic hot water	
DOE	U.S. Department of Energy	
DOER	Massachusetts Department of Energy Resources	
DPS	New York State Department of Public Service	

Abbreviation	Description	Notes
ECCCNYS	Energy Conservation Construction Code of New York State	
EIA	U.S. Energy Information Administration	
EPA	U.S. Environmental Protection Agency	
ESCO	Energy services company	
GHG	Greenhouse gas	
GSHP	Ground source heat pump	
GWh	Gigawatt-hour	
HARDI	Heating, Air Conditioning, and Refrigerator Distributors International	
HVAC	Heating, ventilation, and air conditioning	
ICAP	Installed capacity	
IECC	International Energy Conservation Code	
IGSHPA	International Ground Source Heating Pump Association	
ITC	Investment tax credit	
kWh	Kilowatt-hour	
LI-GEO	Long Island Geothermal Energy Organization	
LIUSPI	Long Island Unified Solar Permit Initiative	
LCOC	Levelized cost of carbon	See Section 2.3
LCOE	Levelized cost of energy	See Section 2.3
LMI	Low-to-moderate income	
LSE	Load-serving entity	
Mcf	Thousand cubic feet	
MMBtu	Million British thermal units	
MTA	Metropolitan Transportation Authority	
MWh	Megawatt-hour	
NOx	Nitrogen oxide	

Abbreviation	Description	Notes
NEPOOL GIS	New England Power Pool Generation Information System	
NREL	National Renewable Energy Laboratory	
NYISO	New York Independent System Operator	
NYPA	New York Power Authority	
NYS	New York State	
NYSERDA	New York State Energy Research and Development Authority	
O&M	Operations and Maintenance	
PBI	Performance-based incentive	
PPA	Power purchase agreement	
PVC	Polyvinyl chloride	
PV	Photovoltaic	
REC	Renewable Energy Certificate	
RECS	Residential Energy Consumption Study	
REV	Reforming the Energy Vision	CASE 14-M-0101
RH&C	Renewable heating and cooling	
RHNY	Renewable Heat New York	
RPS	Renewable Portfolio Standard	
SCPC	Suffolk County Planning Commission	
SENY Customers	Southeastern New York Customers	Customers, typically in the public sector, of NYPA in Westchester and NYC that typically that do not pay the system benefits charge.
SHW	Solar hot water	
SO_2	Sulfur dioxide	
SUNY	State University of New York	
TBtu	Trillion British thermal units	
T&D	Transmission and distribution	

Abbreviation	Description	Notes
Ton (of installed capacity)	12,000 BTU per hour	
TPO	Third party ownership	
T-REC	Thermal renewable energy credit	
VDER	Value of Distributed Energy Resources	CASE 15-E-0751
VRF	Variable refrigerant flow	