New Jersey Ground Source Heat Pump Baseline Report

December 2023

New Jersey Department of Environmental Protection

Bureau of Climate Change & Clean Energy

Primary Authors and Data Analysts:

Ryan Gergely

Anthony Bevacqua, Ph.D.

R. Christopher Barry, Ph.D., P.E.

Additional Collaborators:

Stephen Myers

Helaine Barr, BCCCE Chief

Jessica August

Kristen Brennan

Acknowledgements:

This work was advanced by the contributions of staff in the NJDEP Bureau of Climate Change & Clean Energy (BCCCE), NJDEP Bureau of Water Allocation and Well Permitting, NJDEP Geological and Water Survey, members of the State Well Drillers & Pump Installers Examining & Advisory Board, State Geologist, and the NJDEP Bureau of GIS. Additional thanks to former BCCCE staff, Sheryl Tembe & Lauren Drumm.

Cover Image: Monmouth Battlefield State Park Visitor's Center – LEED Certified building with Ground Source Heat Pump system installed in 2001. *Photo Credit: Ryan Gergely, NJDEP*

Executive Summary

The New Jersey Department of Environmental Protection's (NJDEP) Ground Source Heat Pump Baseline Report was developed with the objective of establishing foundational information to inform future policies supporting use of ground source heat pumps (GSHP) in New Jersey. This report leverages historic NJDEP GSHP well records, Geographic Information Systems (GIS), stakeholder surveys, informational interviews, and emissions reduction estimates to investigate deployment, climate mitigation benefits, and the barriers to adoption of GSHP technology. In doing so, this report illustrates trends in GSHP installations over time, identifies locations of systems and the building sectors they serve, quantifies emissions reduction benefits, and integrates input from GSHP developers to put forward strategic policy recommendations.

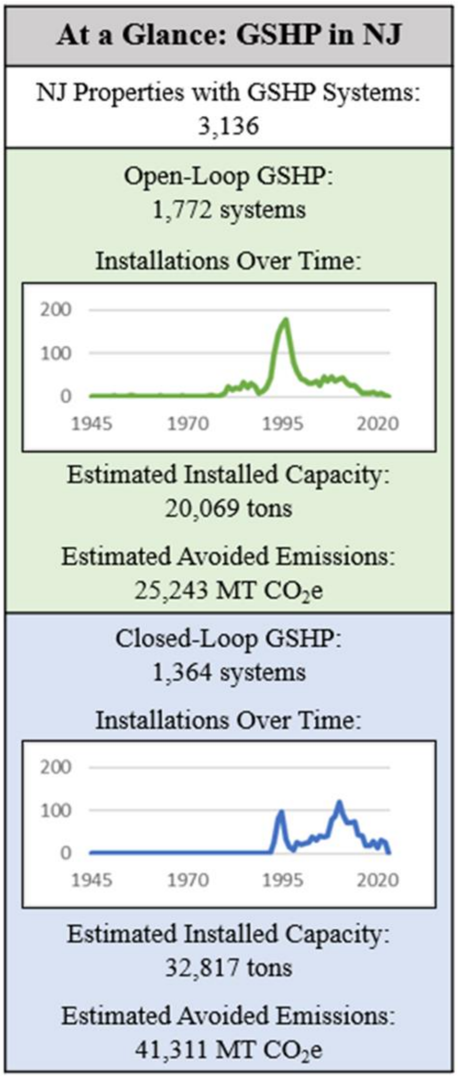
Building electrification remains a core tenet of the State's broader approach to achieving its greenhouse gas (GHG) reduction goals, as proposed in the 2019 Energy Master Plan[1] and the 2020 Global Warming Response Act 80x50 Recommendations Report[2]. By 2050, 90% of the State's building sector will need to convert to electric heating and hot water systems. To advance this, Governor Murphy recently signed Executive Order 316[3], which set a goal of electrifying 400,000 residential properties and 20,000 commercial spaces by 2030. This Baseline Report highlights the opportunity for growth in adoption and meaningful GHG reductions the State could realize across building sectors through use of GSHP. The report identifies how heat pump technology complements economy-wide electrification, thus making it ideal for holistic strategies in climate change mitigation.

This report uses a multipronged approach to establish a baseline inventory of known GSHP systems in New Jersey. Through this approach, more than 3,000 well-based (vertical) GSHP systems were identified and geolocated across the State. Based on an evaluation of vertical, closed-loop systems, regional grid emissions, and comparisons to conventional, fossil-fuel based home heating technologies, it was found that GSHP installations in NJ avoid approximately 66,000 MT CO_2e per year (Figure ES1). Additionally, emissions are also avoided by horizontal closed-loop installations, although quantification of this type of system was not included in this report due to data limitations. Furthermore, this report identifies historic trends in adoption of GSHP technology, correlates system adoption rates with parcel property classification type, and projects future emissions reductions under a conservative adoption scenario. Under this "Business as Usual" scenario, installed capacity of GSHP systems would grow by more than 44,000 tons by 2050. This new installed capacity, paired with the existing capacity of installed systems, would avoid more than 100,000 MT CO_2e annually in 2050, with cumulative emissions avoided from this technology reaching more than 4 MMT CO_2e. To put this into perspective, New Jersey's building sector emitted 23.1 MMT CO_2e in 2020[4].

---

[1] 2019 New Jersey Energy Master Plan: Pathway to 2050 - https://www.nj.gov/emp/docs/pdf/2020_NJBPU_EMP.pdf
[2] New Jersey's Global Warming Response Act 80x50 Report - https://dep.nj.gov/wp-content/uploads/climatechange/nj-gwra-80x50-report-2020.pdf
[3] Executive Order No. 316 - https://nj.gov/infobank/eo/056murphy/pdf/EO-316.pdf
[4] New Jersey Greenhouse Gas Inventory: 2022 Mid-Cycle Update Report - https://dep.nj.gov/wp-content/uploads/ghg/2022-ghg-inventory-mcu_final.pdf

__Figure ES1:__ GSHP Overview/Summary



To further understand market conditions impacting GSHP rates of adoption in the State, an online stakeholder survey was performed by the Department in 2017 targeting architects, HVAC contractors, and other industry professionals operating in the New Jersey GSHP market. Responses to the contractor survey highlighted the lackluster history of policy incentives in the State, limited consumer awareness, and financial barriers as principal contributors to the slow market growth of GSHP in New Jersey. Consistent and readily accessible incentives, improved consumer marketing and education, practical site feasibility tools, and professional training all ranked as key factors for growth among survey respondents.

The NJDEP GSHP Baseline Report concludes that policy-based actions can increase adoption of GSHP technology and thereby reduce fossil fuel consumption while improving energy efficiency across building sectors in the State. Critical recommendations to spur future adoption include significantly increasing consumer awareness, introducing financial incentives that supplement existing State and Federal incentives and target sectors with larger buildings for greater emissions reductions benefits per system, supporting the development of GSHP siting and planning tools, and expanding access to the technology across different socio-demographic communities via large scale pilot projects.

Consideration of the recommendations presented in this report and resulting policy action is likely to result in a significant uptick in GSHP adoption statewide. This increase in adoption will result in meaningful greenhouse gas reductions from the building sector, far greater than the estimates presented under the “Business as Usual” scenario.

Report Contents

Section 1: Introduction

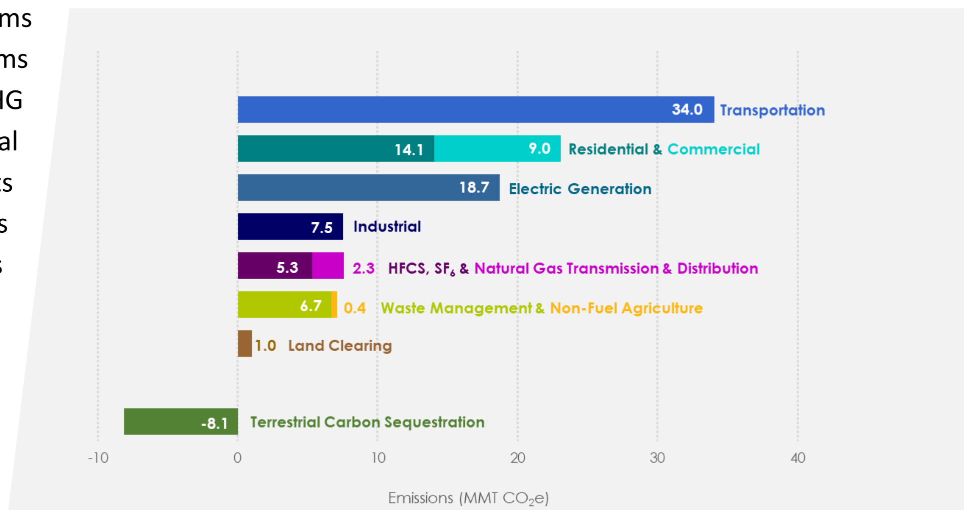
The NJDEP Ground Source Heat Pump Baseline Report identifies the universe and evaluates the benefits of ground source heat pumps (GSHP) in New Jersey, with the objective of putting forth novel insights that can inform climate mitigation policy. New Jersey's climate action is guided by the Global Warming Response Act (GWRA)[5] (P.L. 2007 c.112; P.L. 2019 c.197), which established a goal of reducing the State's 2006 greenhouse gas emissions 80% by 2050, and Executive Order 274[6], which set an interim target of 50% reduction by 2030.

To achieve these ambitious targets, New Jersey needs to rapidly adopt key strategies, including replacement of internal combustion vehicles with electric vehicles, conversion of space and water heating in residential and commercial buildings to electrified heating, and replacement of fossil fuels in the electric generation sector with renewable energy sources. In particular, decarbonizing the building sector will be technically challenging, as, according to the 2019 Energy Master Plan, under the least cost scenario, 90% of New Jersey's buildings must be converted to 100% clean energy systems by 2050 in order to achieve the necessary emissions reduction goals.

In New Jersey, a significant portion of energy is used for space heating and cooling by both residential and commercial buildings. Per the New Jersey Greenhouse Gas Inventory: 2022 Mid-Cycle Update Report[7], the energy used in these applications in 2020 resulted in greenhouse gas emissions of 14.1 MMT CO_2e for the residential sector and 9.0 MMT CO_2e for the commercial sector (15.5% and 9.9% of the total net greenhouse gas emissions, respectively – Figure 1). Collectively, the residential and commercial sectors represent the largest stationary sources of greenhouse gas emissions in the state.

To drive down emissions from these sectors, the Garden State will need to adopt a range of clean heating technologies, with GSHP systems potentially playing a critical role. These systems have the ability to significantly reduce GHG emissions, while simultaneously improving local air quality and providing financial benefits associated with increased building efficiency. As an interim step to achieving full-sector emissions reductions, Governor Murphy signed Executive Order 316 on February 15, 2023, setting a goal of electrifying a minimum of 400,000 additional residential dwelling units and 20,000 additional commercial spaces/public facilities by December 31, 2030.

Figure 1: *Projected Greenhouse Gas Emissions for 2020 in millions of metric tons of CO_2e (MMT).*

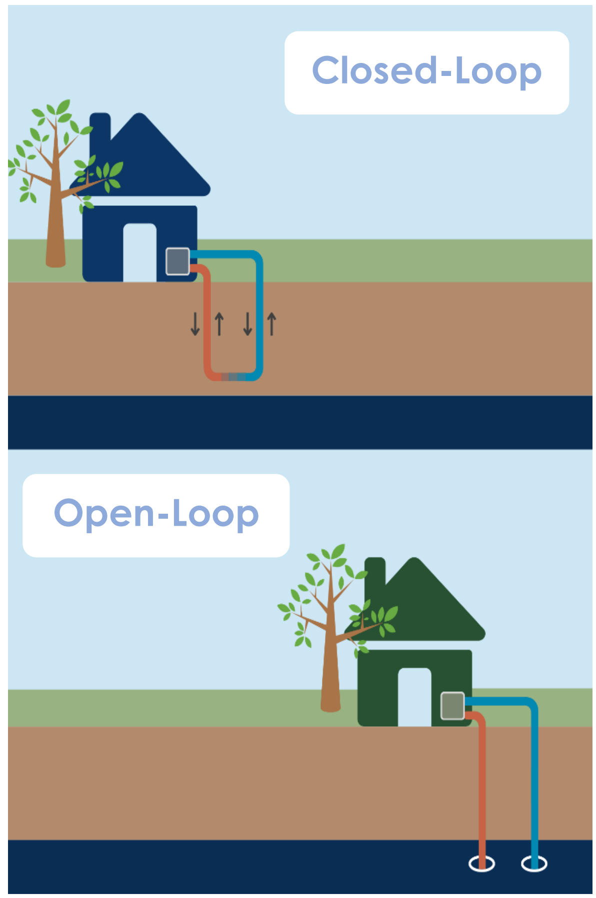


[5] New Jersey Global Warming Response Act (GWRA) - https://pub.njleg.gov/bills/2006/PL07/340_.PDF ; https://pub.njleg.gov/bills/2018/PL19/197_.HTM
[6] Executive Order No. 274 - https://www.nj.gov/infobank/eo/056murphy/pdf/EO-274.pdf
[7] New Jersey Greenhouse Gas Inventory: 2022 Mid-Cycle Update Report - https://dep.nj.gov/wp-content/uploads/ghg/2022-ghg-inventory-mcu_final.pdf

Section 2: GSHP Technology Overview

Ground source heat pump (GSHP) systems were first developed in the late 1940's. Differing from direct source geothermal energy production, which is oriented around steam-based electricity generation, GSHP systems leverage the relative constant underground temperature (~54°F) to transfer heat between the earth and a building through ground loops. GSHP systems provide energy efficient space heating and cooling in both residential and commercial applications, often reaching efficiencies several times greater than conventional heating, ventilation, and air conditioning (HVAC) systems.

__Figure 2:__ Diagrams of Closed-Loop GSHP System (top) and Open-Loop GSHP System (bottom).



GSHP systems have three major components, which include the ground heat exchanger, the heat pump, and the building distribution system. The ground heat exchanger, which is filled with water or a water and antifreeze solution, can be configured in several loop configurations, as shown in Figure 2. Open-loop systems employ a single-pass design where water, typically from a well, is used for heat exchange in the heat pump and is then returned to the environment, most frequently to the same aquifer through a second diffusion well located downstream. While open-loop systems are historically less expensive to install, they are more sensitive to local geology, lithology, water chemistry and environmental quality conditions that may hinder successful use of these types of systems under sub-optimal circumstances. This in turn may increase operating costs and challenge equipment reliability for the system owner.

In contrast, closed-loop systems recirculate fluid through tubing in the earth, rather than using a single-pass approach. Closed-loop systems in New Jersey typically use 1 to 1.5-inch diameter high-density polyethylene tubing and a heat transfer fluid that circulates within the loops. Propylene glycol and ethanol are typically used within the loops to prevent freezing and are fully biodegradable in the event of a leak. In vertical closed-loop systems, the tubing is inserted into narrow boreholes and the wells are backfilled with thermally conductive grout. The heat pump itself is an indoor mechanical component that replaces the conventional heating and air conditioning unit in the building and connects to the building distribution system, which can take a variety of forms such as ductwork for forced-air systems or radiant floor heating. A second category of closed-loop system uses tubing that is laid horizontally in the soil below the frost line. Where large plots of land are available, this approach may be less expensive than drilling vertical wells, especially if earth-moving construction equipment is already on site and can be used to dig trenches to lay the tubing. However, the technical analysis in this report focuses on vertical, well-based installations since available well data can be used to infer approximate system sizes and therefore emissions reductions. Both vertical and horizontal closed-loop installations result in comparable emissions reductions for a given size of heat pump.

There are several advantages to GSHP systems over their conventional counterparts that make them appealing in modern building designs. Along with potential human health benefits from improved local air quality associated with emissions reductions, both residential and commercial or industrial GSHP adopters stand to realize financial returns over the medium to long-term considering favorable payback conditions and system longevity. GSHP systems are one of the most efficient heating and cooling systems available and typically operate with heating efficiencies 70% greater than other space-heating systems and 40% greater than conventional air conditioning systems[8]; these in turn yield direct energy cost savings to the system owner.

Additionally, closed-loop ground heat exchangers can last over 50 years, and above-ground GSHP hardware is typically located indoors where it is away from the elements and secure from vandalism. Overall, these features work to extend the life of GSHP installations, maintain low operating costs, and provide long-term emissions and energy savings benefits (see Section 5 below).

[8] Per the International Ground Source Heat Pump association - https://igshpa.org/frequently-asked-questions/

Section 3: Ground Source Heat Pumps Regulatory and Incentive Landscape

GSHP Regulations

New Jersey State law[9] requires all installers of vertical GSHP systems to be licensed (N.J.A.C. 7:9D-1.7) and to obtain a well permit (N.J.A.C. 7:9D-1.11) before installing a system and to submit a well record after system installation. The NJDEP's Bureau of Water Allocation & Well Permitting oversees this regulatory program and has compiled a robust inventory of GSHP borehole and well records dating back to 1948. The well records mandated by this regulatory program can be leveraged to assist in the identification and analysis of the universe of GSHP systems installed to-date.

Well drillers and pump installers are required to obtain a license and are classified into seven categories, (N.J.A.C. 7:9D-1.7), as noted in Table 1 below. License category codes MD, JD and JB can drill open-loop and closed-loop system wells whereas category CL can only drill closed-loop system wells (331 total licensees – shown in yellow in Table 1 below).

Table 1: Currently Licensed New Jersey Well Drillers and Pump Installers

License Code	License Type	# of Active Licensees
MD	Master Well Driller License	111
JD	Journeyman Well Driller License	202
JB	Journeyman Class B Well Driller License	8
EG	Env Resource Geotec Well Driller License	272
DW	Dewatering Well Driller License	14
CL	VRT Closed Loop Geo Well Driller License	10
PI	Pump Installer License	209
	Total	**826**

GSHP Incentives

In New Jersey, several financial incentives currently exist to improve the energy efficiency of buildings – including for the purchase and installation of ground source heat pump systems. The New Jersey Board of Public Utilities (BPU) Clean Energy Program (NJCEP) administers energy efficiency incentive programs and co-administers the New Jersey Comfort Partners program with the State's utility service providers. The seven utility service providers for gas and electric services in New Jersey also administer energy efficiency incentive programs for existing buildings and efficient products, such as the Home Performance with ENERGY STAR program.

The SmartStart Buildings Program[10] for new commercial and industrial (C&I) buildings is administered by the BPU and offers fixed dollar amounts for installation of efficiency technologies with well-established savings. All electric utilities offer custom incentives for technology that performs beyond code and result in energy savings in existing C&I buildings.

[9] New Jersey Administrative Code: Title 7 – Environmental Protection, Chapter 9D – Well Construction and Maintenance; Sealing of Abandoned Wells, Subchapter 1 – General Requirements for Permitting of Wells, and for Licensing of Well Drillers and Pump Installer, Procedures and Practices of the State Well Drillers and Pump Installers Examining and Advisory Board - https://regulations.justia.com/states/new-jersey/title-7/chapter-9d/subchapter-1/

[10] New Jersey Board of Public Utilities SmartStart Buildings Program - https://www.njcleanenergy.com/commercial-industrial/programs/nj-smartstart-buildings/nj-smartstart-buildings

Certain ground source heat pump systems that meet the eligibility requirements are included under this program – both open-loop and closed-loop systems – and can be eligible to earn up to $500/ton of system capacity (Table 2).

Table 2: *Clean Energy Program and Utility-based GSHP Incentives for New and Existing Commercial & Industrial Buildings.*

	Ground Source Heat Pumps		Ground Water Source Heat Pumps	
	Specifications	**Incentive**	**Specifications**	**Incentive**
NJ Clean Energy Program SmartStart Buildings (New C&I Buildings)	<135,000 Btu/h - 18.4 EER - 3.7 COP	$80/ton	<135,000 Btu/h - 14.4 EER - 3.2 COP	$80/ton
	<135,000 Btu/h - 22.0 EER - 3.9 COP	$96/ton	<135,000 Btu/h - 18.0 EER - 3.6 COP	$100/ton
Atlantic City Electric (Existing C&I)	<11.25 tons - Tier 1 - 5% Above Baseline	$80/ton	<11.25 tons - Tier 1 - 5% Above Baseline	$80/ton
	<11.25 tons - Tier 2 - 12% Above Baseline	$100/ton	<11.25 tons - Tier 2 - 12% Above Baseline	$100/ton
Jersey Central Power & Light (Existing C&I)	<11.25 tons - Tier 1 - 5% Above Baseline	$80/ton	<11.25 tons - Tier 1 - 5% Above Baseline	$80/ton
	<11.25 tons - Tier 2 - 12% Above Baseline	$100/ton	<11.25 tons - Tier 2 - 12% Above Baseline	$100/ton
Public Service Electric & Gas (Existing C&I)	<11.25 tons - Tier 1 - 5% Above Baseline	$100/ton	<11.25 tons - Tier 1 - 5% Above Baseline	$100/ton
	<11.25 tons - Tier 2 - 12% Above Baseline	$500/ton	<11.25 tons - Tier 2 - 12% Above Baseline	$500/ton
Orange & Rockland (Existing C&I)	<11.25 tons - Tier 1 - 5% Above Baseline	$80/ton	<11.25 tons - Tier 1 - 5% Above Baseline	$80/ton
	<11.25 tons - Tier 2 - 12% Above Baseline	$100/ton	<11.25 tons - Tier 2 - 12% Above Baseline	$100/ton

Prior to the start of fiscal year 2022, the BPU maintained other programs that provided incentives for residential GSHP systems, but since then incentives have transitioned to the electric utility service providers for disbursement. At the time of the publication of this report, only Jersey Central Power & Light[11] offered incentives for ground source heat pump systems in their high efficiency HVAC rebates for existing residential buildings, with rebates of either $500 or $1,500 for the installation of a GSHP system, dependent on the type of system being replaced.

The Inflation Reduction Act of 2022[12] (IRA) was signed into law on August 16, 2022. Among its provisions, the IRA includes changes to existing federal tax incentives for residential renewable energy products, including ground source heat pumps. These changes became active in 2023 and provide tax credits of up to 30% for ground source heat pump systems placed in service between December 31, 2021 and January 1, 2033. Additionally, and perhaps more importantly, as it supports leading by example and implementing GSHP at larger buildings, the IRA allows certain entities that have no tax liability to receive direct payment from the U.S. Treasury for GSHP projects, equal to the amount allowed under the applicable rate. Direct pay[13] is available under Section 48 of the IRA for State and local governments as well as other tax-exempt entities.

[11] Jersey Central Power & Light HVAC Equipment Rebates - https://residential.energysavenj.com/jersey-central/hvac/
[12] US Internal Revenue Service: Inflation Reduction Act of 2022 - https://www.irs.gov/inflation-reduction-act-of-2022
[13] Direct Pay through the Inflation Reduction Act - https://www.whitehouse.gov/cleanenergy/directpay/

Section 4: Report Methodology

State well-drilling records identify those wells used for closed-loop and open-loop vertical GSHP systems, and include descriptive data such as year installed, well depth, and geographic location. Further, for closed-loop systems the total depth of wells used in the system is closely correlated with system heating and cooling capacity. It was therefore possible to use this data to characterize how and where GSHP technology is being used, system capacities, and greenhouse gas emissions avoided compared with conventional systems. Data was also cross-evaluated against related geographic and property databases to understand opportunities for optimal use of GSHP. The main components of this methodology include:

1. Inventorying GSHP well records;
2. Geoprocessing and spatial analysis of GSHP well record locations;
3. Analysis of closed-loop GSHP well record data to estimate greenhouse gas emission avoidance;
4. Projection of future avoided emissions under potential "Business As Usual" GSHP adoption scenario;
5. Stakeholder survey of GSHP contractors; and
6. Informational interviews.

Inventorying GSHP Well Records

Ground source heat pump data was collected by querying the GSHP borehole permit records from NJDEP's New Jersey Environmental Management System (NJEMS) database. As mentioned previously, all GSHP wells drilled in the State require permits, and thus records for drilled wells are collected and stored within this database. This query provided insightful information for each well record from the beginning of 1948 to the end of 2022, including the classification of the GSHP system, the year installed, the number of boreholes drilled, the total system drilled depth, and locational information for the installation.

As part of the data collection process, system information was manually spot checked against historic scanned PDF documents of well permit applications and well record documents to ensure the accuracy of the data contained within NJEMS. Aggregation was also completed, by system type at unique locations – providing a universe of properties with GSHP systems. Certain systems were drilled over more than one year, for example where a permit and record existed for a test bore in one year followed by installation of a larger system at the same property the next. These situations were identified and consolidated during the aggregation process.

Geoprocessing and Spatial Analysis

A foundational step of the subsequent analysis of systems included a place-based geocoding procedure which translated location information yielded from the GSHP well records into a Geographic Information System (GIS) environment. Using a combination of methods, including geocoding via street address, latitude and longitude coordinates, and cross-referencing parcel block and lot information – all stored within the well records database – point locations for each system were identified and mapped. A spatial overlay was conducted, joining the attributes from the GSHP well records with the New Jersey Parcel & MOD-IV[14] GIS dataset, effectively appending insightful property information to each well record, such as the property classification / building sector. Additional analyses were conducted over specific geographies, such as the Overburdened Communities under the New Jersey Environmental Justice Law[15], in order to investigate the spatial distribution of systems alongside socio-economic and other built environment conditions. Furthermore, supplementary

[14] New Jersey Parcels & MOD-IV Composite GIS Dataset; combines parcel boundaries with NJ tax assessor data related to property ownership and tax information - https://gisdata-njdep.opendata.arcgis.com/documents/newjersey::parcels-composite-of-nj-download/about

[15] Overburdened Communities under the New Jersey Environmental Justice Law (2021) GIS Dataset - https://gisdata-njdep.opendata.arcgis.com/datasets/njdep::overburdened-communities-under-the-new-jersey-environmental-justice-law-2021/explore

spatial aggregations were conducted to better understand the spatial distribution across specific geographies (i.e., municipalities, Census Tracts, Census Block Groups, Electric and Gas Distribution Company Territories, etc.).

Greenhouse Gas Avoidance Estimates

Quantitative evaluation of the GHG mitigation benefits of vertical closed-loop GSHP systems began with the individual system information present in the well records. The total linear feet of well depth across all closed-loop system boreholes was combined with published relationships between borehole length and system capacities to infer individual system sizes. Implied energy consumption was then calculated using standard design principles incorporating equivalent full load hours for heating and cooling (EFLHh & EFLHc), heating and cooling degree days (HDD and CDD), and typical coefficient of performance (COP) factors for a sample of GSHP units currently on the market. Comparisons of emissions and energy costs with conventional electric cooling (air conditioning) and natural gas heating relied on data from the United States Energy Information Administration (USEIA) State Energy Data System[16] (SEDS) and the United States Environmental Protection Agency (USEPA) GHG Emissions Factors Hub[17]. Emissions from electric power consumption were based on emissions rates from the USEPA eGRID program[18] for the RFC East region for 2020. A list of emissions assumptions and variables can be found in Appendix I.

"Business As Usual" GSHP Projections

Understanding the current universe and past trends in adoption are important aspects of this report, but generating forward-looking projections are also critical to examine through the lens of emissions reductions and how adoption of this technology may help achieve the State's emissions reduction goals. In order to generate a "Business as Usual" (BAU) projection of an increase in installed GSHP capacity and associated emissions reductions from the growth in GSHP adoption, a conservative growth rate was established. The last 20 years of GSHP records were examined, and the average annual increase in installed capacity over that period was calculated and applied as the projected growth rate under the BAU scenario. Further calculations were conducted to determine the percent share of the growth rate that each sector would be allocated under the BAU scenario, based on the percent of installed capacity that each sector accounted for over the last 20 years. The projected emissions avoided, both annually and cumulatively from the projected increase in installed capacity under the BAU scenario were also calculated and plotted through 2050.

Stakeholder Survey

To further understand market conditions constraining GSHP adoption in the state, an online stakeholder survey was performed in 2017 by the Department targeting architects, HVAC contractors, and other industry professionals operating in the New Jersey GSHP market. In the previously unpublished results, over 300 survey participants responded to questions regarding their technical background, company history, and GSHP related business activities. Market survey questions were further used to determine each contractor's experience with incentives, perception of market gaps, and opinions about where additional State involvement would be most beneficial. Most survey recipients were identified from the New Jersey Department of Community Affairs' (DCA) list of licensed professionals. Development of the questions was collaborative, with feedback solicited from the Bureau of Water Allocation & Well Permitting, the Geological & Water Survey, and the State Well Drillers and Pump Installers Examining and Advisory Board. Additional information on the survey, including overviews of the respondents and responses can be found in Appendix II.

Targeted informational discussions with key industry stakeholders were conducted in early 2023 to supplement and verify the conceptual findings of the stakeholder survey and better inform the authors' understanding of the current state of

[16] United States Energy Information Administration State Energy Data System (SEDS) - https://www.eia.gov/state/seds/
[17] United States Environmental Protection Agency GHG Emissions Factors Hub - https://www.epa.gov/climateleadership/ghg-emission-factors-hub
[18] United States Environmental Protection Agency eGRID Program - https://www.epa.gov/egrid

the GSHP market in New Jersey. These discussions provided valuable information regarding modern challenges and opportunities from the perspective of both residential and commercial GSHP developers, geothermal trade organizations, technology advocates, and Federal research laboratories[19]. These dialogues illuminated recent advances in GSHP technology, limitations in system siting and installation barriers, workforce outlook, and insights on perceptions of newly developed Federal incentive programs.

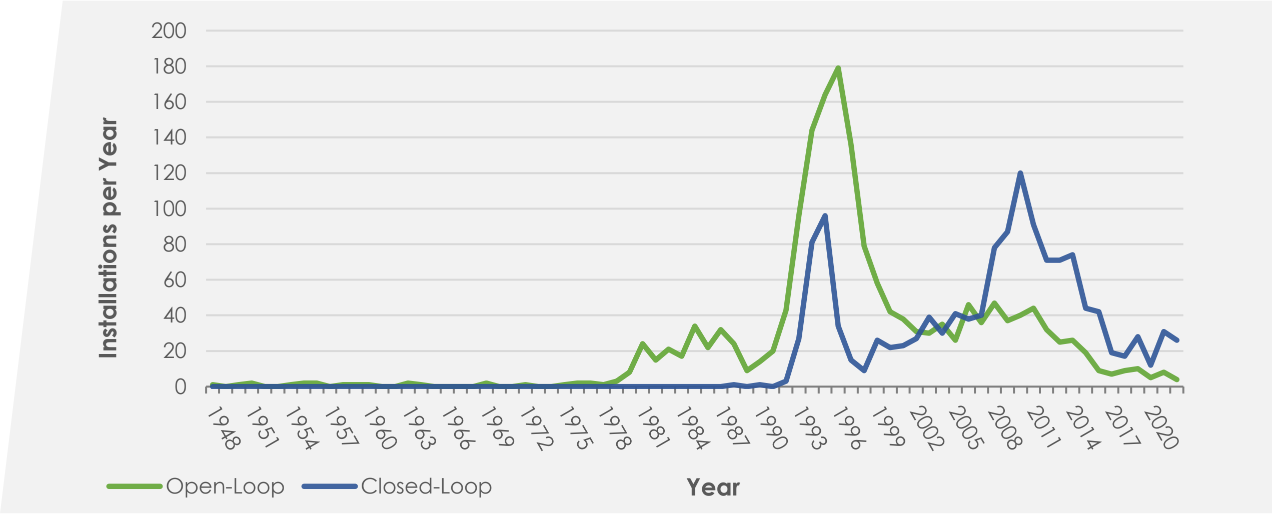
[19] Discussion participants included representatives of the International Ground Source Heat Pump Association, the Geothermal Exchange Organization, Dandelion Energy, Inc., Salas O'Brien, Inc., and the U.S. Department of Energy Geothermal Technologies Office.

Section 5: Study Results

Universe of GSHP Systems

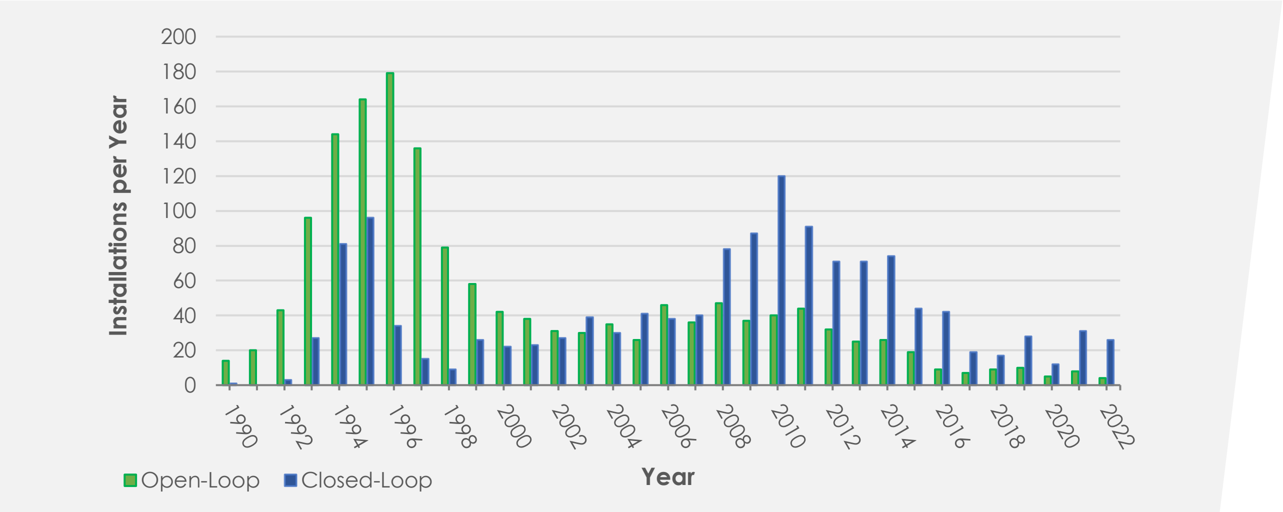
The first ground source heat pump was installed in New Jersey in 1948, making it one of the very first in the world[20]. Growing very slowly at first, GSHP adoption accelerated significantly during the early 1990s, before dipping back in the mid-2000's until a second peak in 2010 (Figure 3). A total of 3,136 vertical systems have been installed at properties in New Jersey through the end of 2022. Of these systems, there are a total of 1,772 open-loop systems, with the remaining 1,364 being classified as closed-loop systems.

***Figure 3:** Open-Loop and Closed-Loop GSHP Installations in New Jersey per Year.*



The initial wave of installations during the 1990s relied primarily on open-loop technology, reaching a peak installation rate in 1996. Around that time, closed-loop systems came on the market and eventually became more dominant, overtaking open-loop systems before peaking in 2010. Since that time, installations of both types of systems have sseen their installation rates decline (Figure 4).

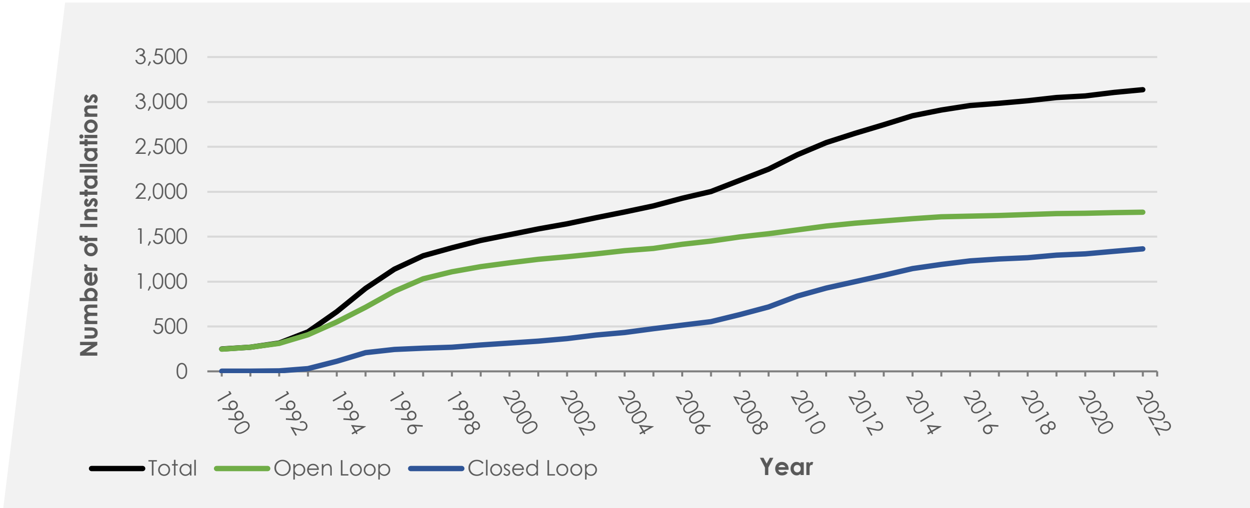
***Figure 4:** Annual Open-Loop and Closed-Loop GSHP Installations in New Jersey, Truncated, Beginning in 1990.*



[20] R. Gordon Bloomquist, Ph. D. 2000. Geothermal Heat Pumps Five Plus Decades of Experience in the United States. Olympia, WA. - https://www.geothermal-energy.org/pdf/IGAstandard/WGC/2000/R0875.PDF

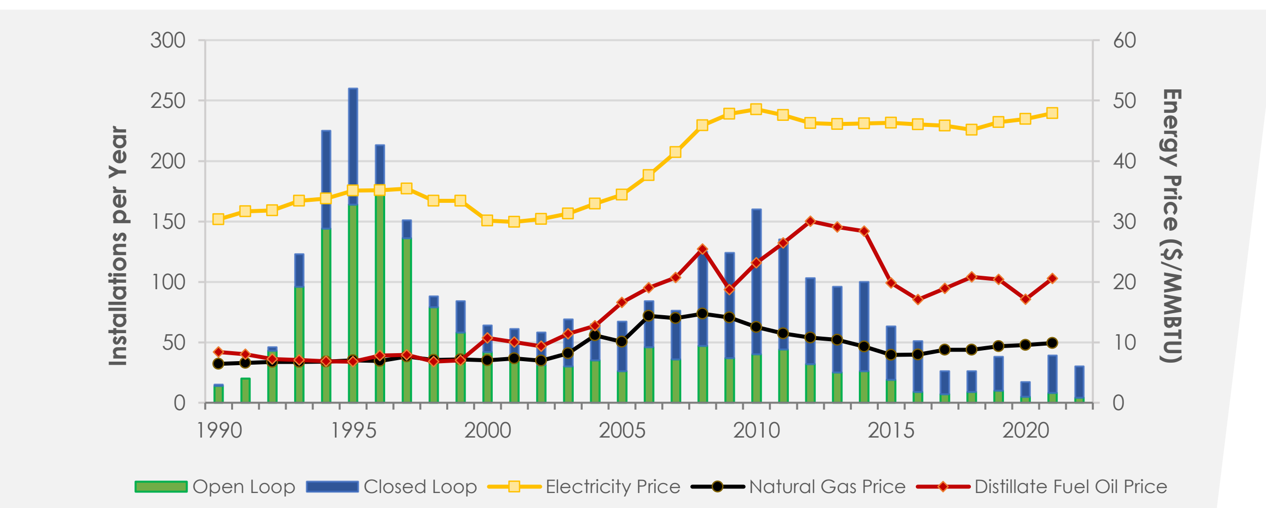
As illustrated in Figure 5, the cumulative number of open-loop systems remains slightly greater than those of closed-loop, although closed-loop systems have shown higher rates of installation in recent years. This point is encouraging, as closed-loop systems exhibit long operational life, and pose less risk for premature failure due to soil conditions than open-loop technology. The changes in rates of installation may be due to several factors, including shifts in the dynamics in incentive programs over the past three decades.

Figure 5: *Cumulative Open-Loop and Closed-Loop GSHP Installations in New Jersey per Year Beginning in 1990.*



Any given property owner's motivation for installing GSHP is an open question, but adoption of GSHP has correlated well with rising social concern for the environment. Installations of GSHP surged following the 1992 Rio Earth Summit—the United Nations conference that first brought climate change to the world's attention. A second peak in adoption correlated with renewed public awareness through efforts such as former Vice President Al Gore's 2006 movie "An Inconvenient Truth." An added factor for many purchasers was likely the cost of energy during these times, particularly during the second surge (Figure 6), as natural gas and fuel oil costs rose substantially between 2000 and 2010, only waning after the introduction of less expensive natural gas from Pennsylvania fracking at the end of this period.

Figure 6: *Annual Open-Loop and Closed-Loop GSHP Installations in New Jersey vs Energy Prices Since 1990.*

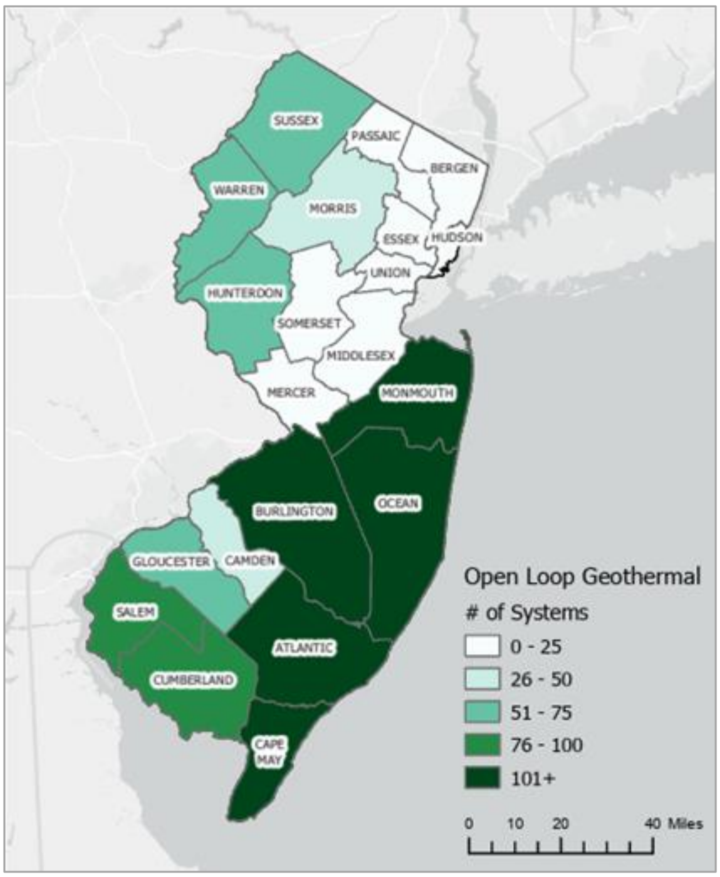


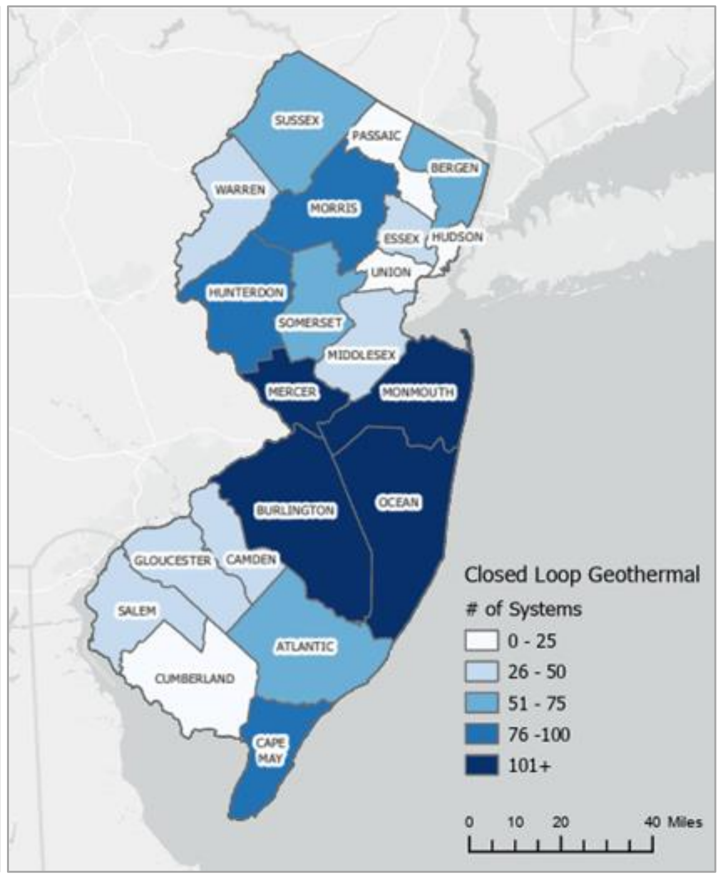
The availability of subsidies also almost certainly encouraged potential adopters to consider GSHP technology. Looking forward, the interplay between these forces hinges on public perceptions, economics, and the availability of competing technologies such that subsidies can most effectively increase adoption when paired with outreach and complementary support.

Geographic Distribution of Installed GSHP Systems

To-date, GSHP systems have been installed in all 21 counties of the State – (Figure 7). Through spatial aggregation (i.e., clustering or summarizing within a defined geographic extent), it is apparent that both open-loop and closed-loop installations appear in the greatest clusters in the central and Atlantic-coastal regions of the State. Unlike closed-loop installations, which have a relatively even distribution across other portions of the State, open-loop installations are less common along the I95 corridor and in the northeast counties of the State.

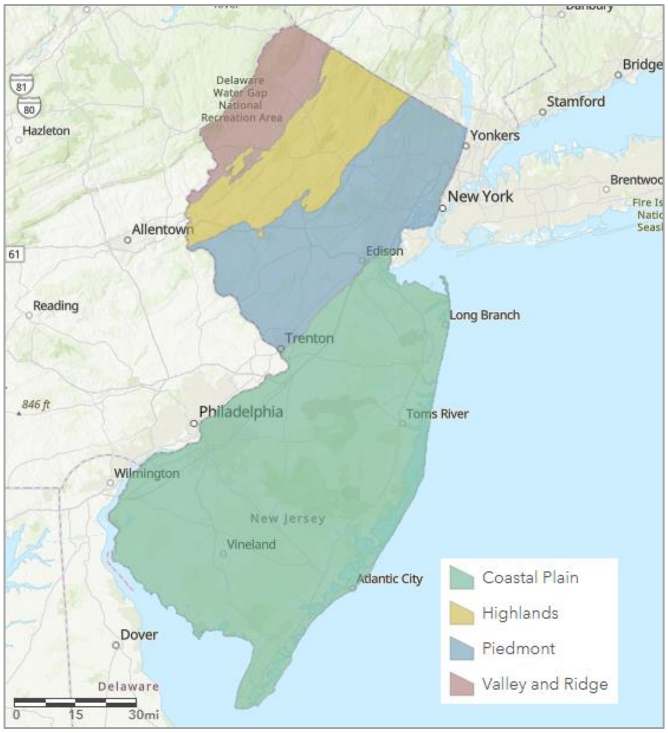
Figure 7: *Spatial Distribution of Vertical Open-Loop and Closed-Loop GSHP Systems (Aggregated by County).*





Because of its pass-through design, the applicability of open-loop technology is influenced by regional hydrology. In New Jersey, wells in the Coastal Plain Province draw from shallower aquifers, lending to the ease of installations and lower associated costs. By contrast, the Piedmont, Highlands and Valley and Ridge Provinces would typically require deeper wells to tap into fractured rock aquifers, thus increasing the difficulty and potential costs associated with pursuing open-loop systems in these regions (Figure 8). Closed-loop systems can be installed in a variety of rock formations, making them versatile in design for the Central and Northern portions of New Jersey, as is reflected in the spatial distribution of known systems.

Figure 8: Physiographic Provinces of New Jersey.



Figures 9 and 10, display open-loop and closed-loop GSHP systems aggregated by municipality, census tract, and census block group to demonstrate the spatial distribution and clustering for each GSHP system type. Across all three spatial scales, central and southern New Jersey, and particularly along the coast, show higher numbers of installations. This is likely a function of regional geology and lithology, but dispensable income for energy efficiency improvements is also likely a factor. Within these varying geographies, additional analyses can be conducted, including looking at well distribution as a function of residential population (for residential systems), or even leveraging other demographic information to determine correlations related to current levels of adoption.

Figure 9: Open-Loop GSHP Installations Aggregated by Municipality, Census Tract, and Census Block Group.

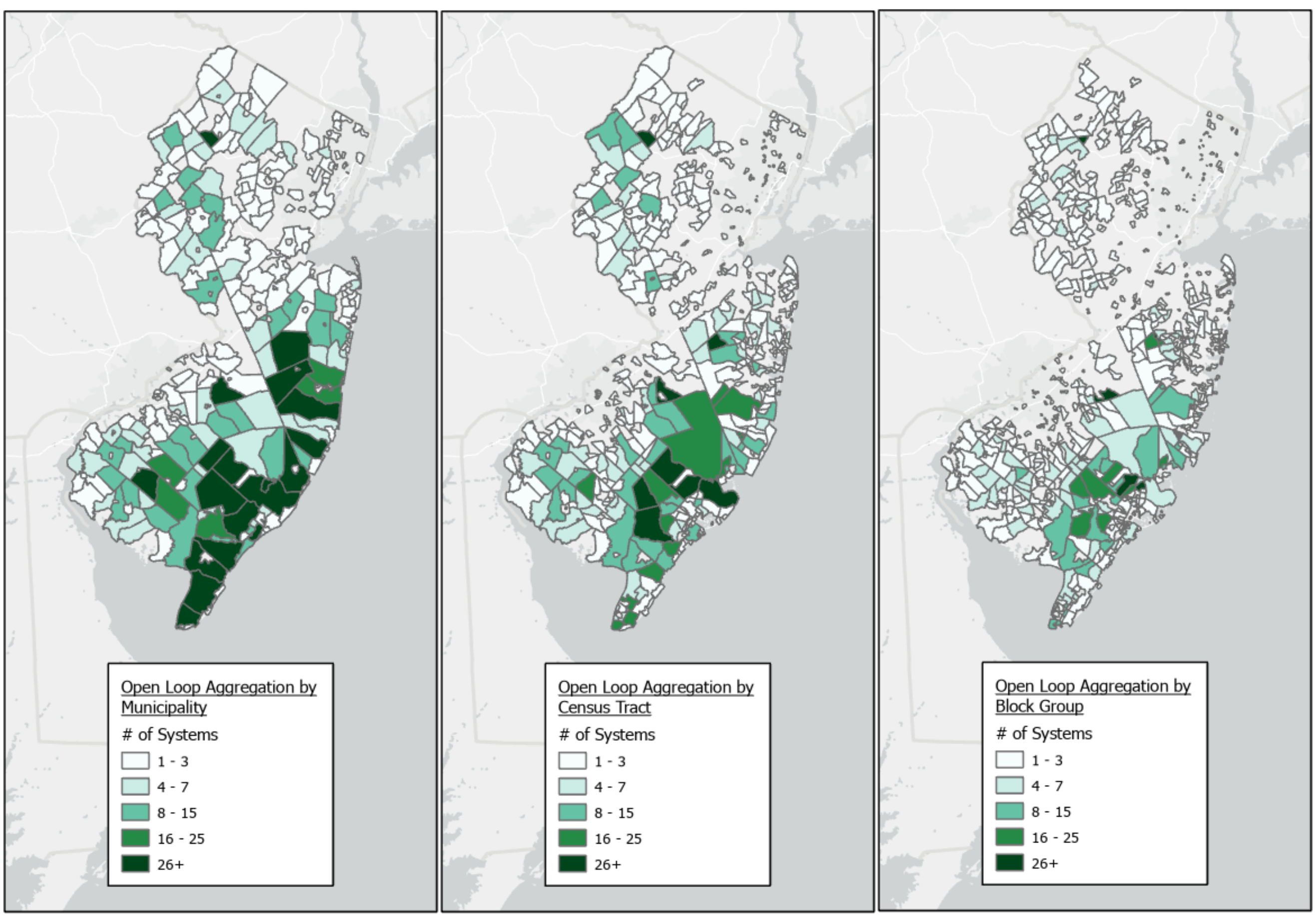
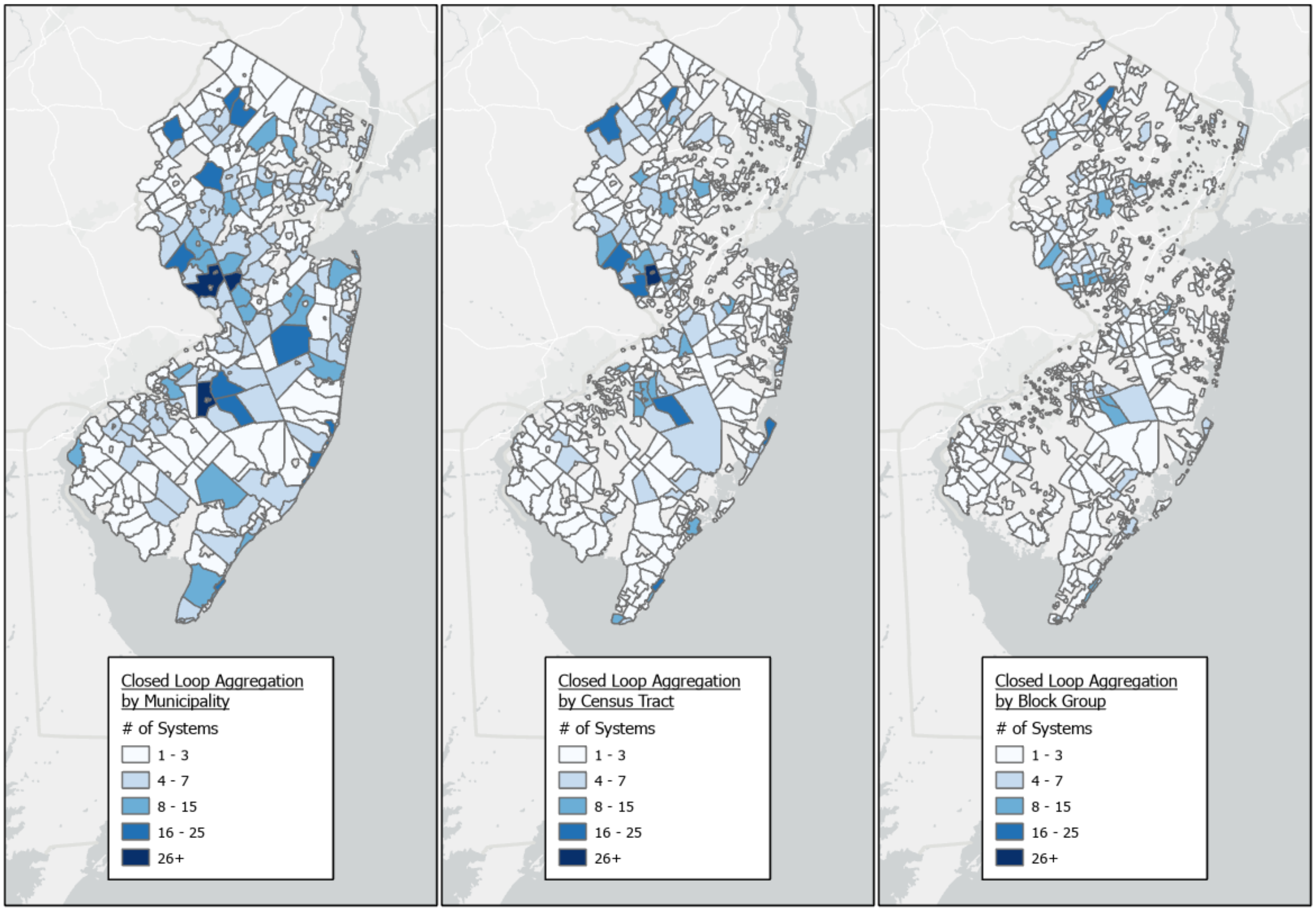


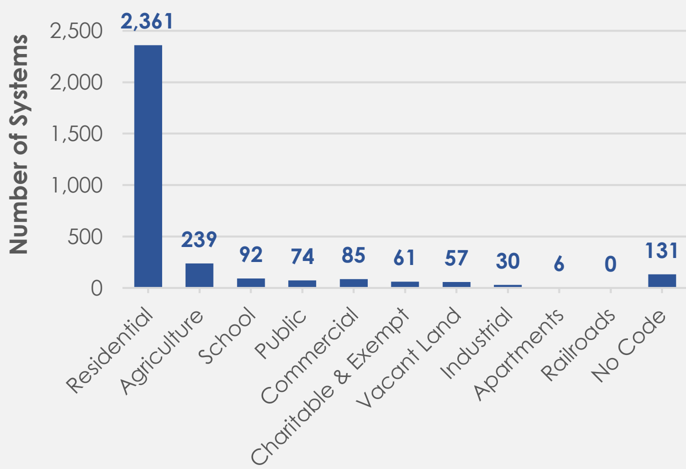
Figure 10: Closed-Loop GSHP Installations Aggregated by Municipality, Census Tract, and Census Block Group.



GSHP Property Analysis

An additional benefit of the location-based nature of the GSHP well records is that it enables summaries and analyses to be conducted to determine the distribution of GSHP installations across multiple building sectors using Parcel MOD-IV data, as shown in Figure 13 and Table 3.

Figure 11/Table 3: GSHP Installation Breakdown by Property Classification (all systems).



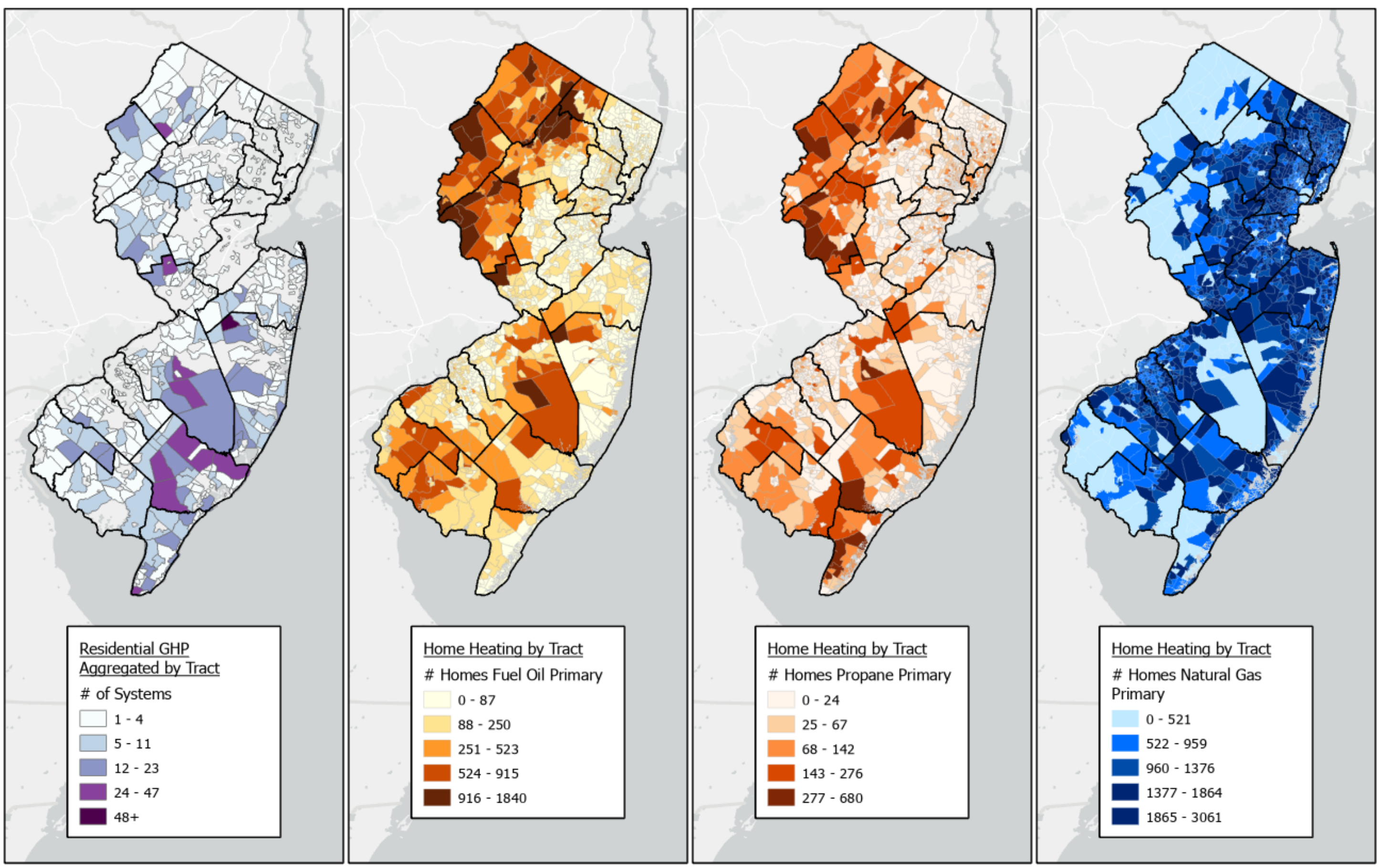
Parcel MOD-IV Prop Class	Property Description	Number of Systems
2	Residential	2,361
3A, 3B, QFARM	Agriculture	239
15A, 15B	School	92
15C	Public	74
4A	Commercial	85
15D, 15E, 15F	Charitable & Exempt	61
1	Vacant Land	57
4B, 6B	Industrial	30
4C	Apartments	6
5A, 5B	Railroads	0
No Code	No Code	131

Residential systems currently dominate the universe of installed GSHP systems, accounting for 75% of all installations in the State (2,361 total). While this is significant, commercial, industrial, school, and agricultural[21] applications are all represented and demonstrate the flexibility of this technology to serve varying building types and sectors (Table 3). It is also worth noting that non-residential applications can have much larger scales, for example at an entire office park or a school campus, and this benefit of scale is not captured in the simple installation counts shown in these figures.

Home Heating Juxtaposition

Regions that are heavily dependent on propane and fuel oil for heating represent some of the greatest opportunities to reduce GHG emissions because these fuels are both highly emitting and costly. Using GSHP technology to displace fossil heating fuels in these circumstances can therefore reduce GHG emissions at the source while also offering higher efficiencies for cooling compared to conventional air conditioning. Towards that end, spatial data published by the US Census Bureau American Community Survey[22] for residential household heating fuels was used to create visual comparisons identifying the portions of the State most dependent on propane, fuel oil, and natural gas for home heating. This data was then placed side-by-side with a map showing the current known prevalence of residential GSHP systems in the State (map series Figure 12 below).

Figure 12: *Map series displaying primary home heating fuel at the Census Tract level for Fuel Oil, Propane, and Natural Gas (number of surveyed homes reporting that fuel type as the primary heating source). GSHP well aggregation by tract for residential properties also shown for contrast in spatial distribution.*



[21] These designations were determined based on the Parcel & MOD-IV Property Classification field. While there are instances of agricultural applications, in some cases, lands classified as agriculture may not be actively farmed and may contain buildings and structures that the GSHP systems are serving.

[22] United States Census American Community Survey: Home Heating Fuel - https://www.census.gov/acs/www/about/why-we-ask-each-question/heating/

One insight from this analysis is that tracts in northwestern New Jersey seem to rely more heavily on propane and fuel oil, as shown in both the number of homes relying on these fuels for their primary fuel source as well as the percentage of homes within each tract utilizing these fuels (not shown), likely due to limitations in the natural gas distribution network in these areas. Despite this, the current universe of known GSHP systems is relatively limited within these regions. This in turn suggests this area could be a prime target for investment and growth of GSHP and other heat pump technologies. The attractiveness of GSHP in this region is even greater given the cold winter climate and the efficiency advantages of GSHP under very cold conditions when compared to current-generation air source heat pumps (ASHP). In effect, GSHP will result in lower GHG emissions than ASHP when temperatures drop below the optimal efficiency range of the ASHP because GSHP uses the subsurface as its heat source and is therefore unaffected by low ambient air temperature. Also, in the future it is anticipated that essentially all buildings will be heated with electricity, and as a result, peak electricity demand is projected to occur during the coldest winter months rather than during summers as is currently the case. Since GSHP efficiency is unaffected by cold air temperature, strategic deployment of this technology will reduce peak wintertime demand in the future and therefore reduce the need for costly peak-response infrastructure investments.

This analysis also implies the availability of natural gas in a region does not detract from the appeal of GSHP, as regions with a high number of GSHP installations also show relatively high levels of natural gas availability and adoption. Therefore, one can infer that under favorable market conditions and with increased customer awareness, GSHP technology can potentially be competitive against fossil fuels even if those fuels are nominally less expensive and in areas where the distribution network is already built out.

As this analysis shows, understanding where the greatest benefits can be had is the first step in crafting effective emissions reductions strategies. Looking ahead, mapping can be applied to document the displacement of older fossil-powered systems with new, non-emitting technologies as a means to evaluate policy effectiveness. Combined with data on the transfer of other energy demands from fossil fuels to clean, renewable electricity, strategies can be refined to target emerging challenges and achieve the greatest benefits.

Utility Territory Breakdown

An investigation into levels of adoption in each Electric Distribution Company and Gas Distribution Company Territory was also conducted and can be seen below in Figure 13 and Table 4. Analyzing the breakdown of installed systems in each of these territories will prove to be insightful moving forward, especially if utility-based incentives are bolstered in the coming years.

__Figure 13:__ Spatial Breakdown of GSHP Projects by Electric Distribution Company Territory and Gas Distribution Company Territory.

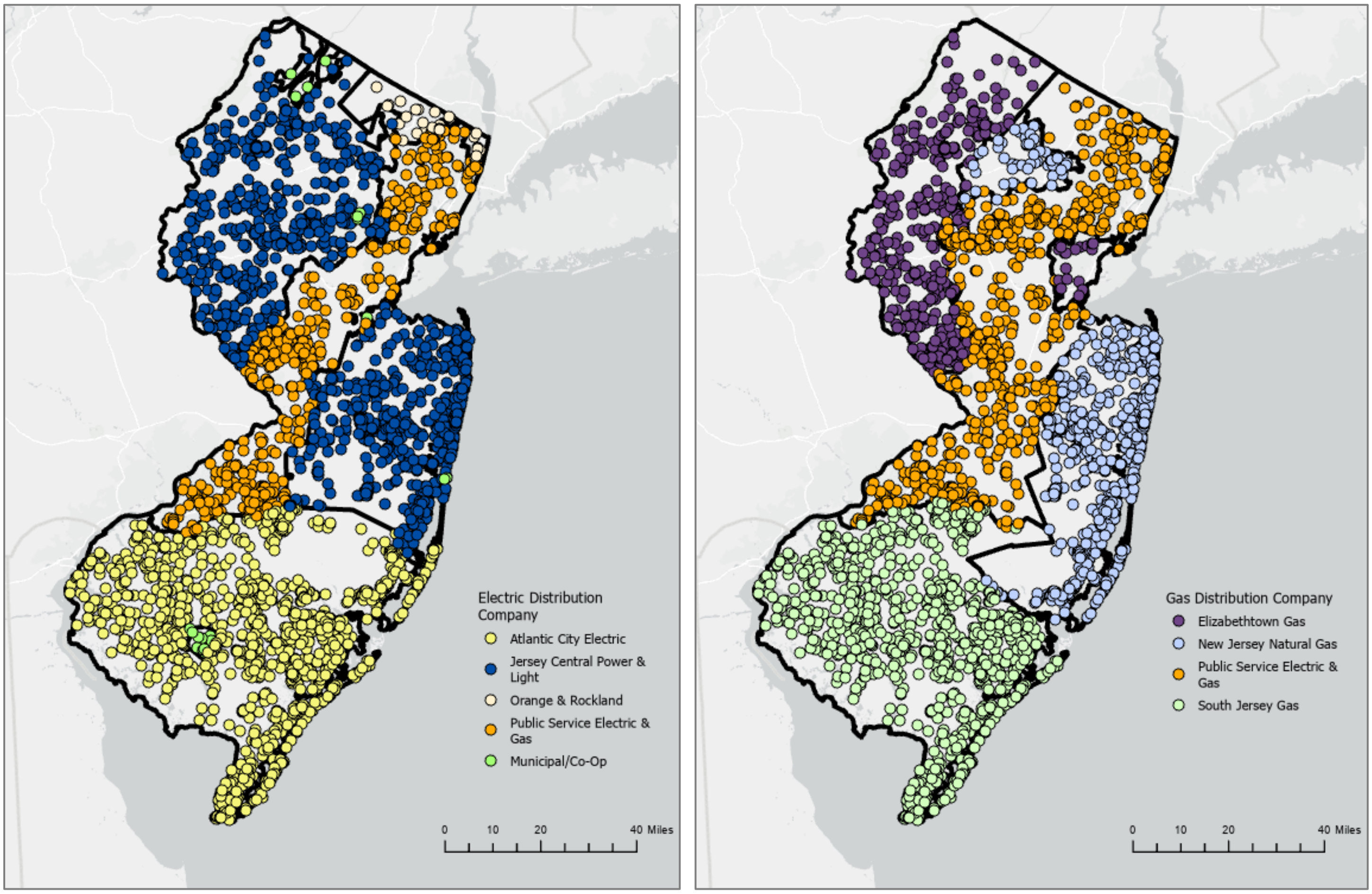


__Table 4:__ Number of GSHP Projects in each Electric Distribution Company and Gas Distribution Company Territory, by Property Classification.

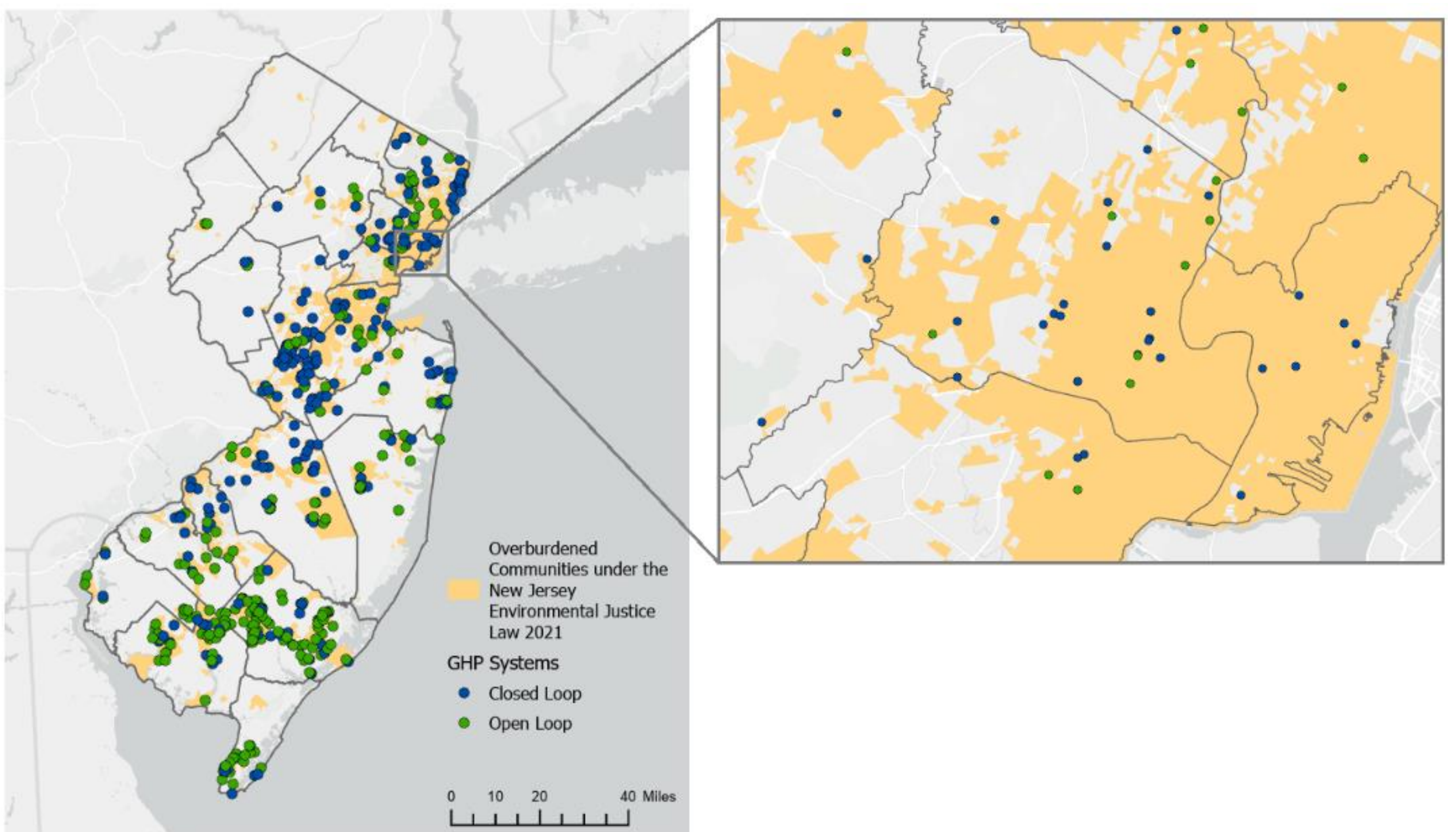
	Electric Distribution Company					Gas Distribution Company			
Property Classification	**ACE**	**JCPL**	**PSEG**	**ORU**	**MUN**	**ETG**	**NJNG**	**PSEG**	**SJG**
(1) Vacant Land	33	6	16	1	1	2	7	9	29
(2) Residential	1,029	982	310	23	17	328	690	450	893
(3A, 3B) Agriculture	79	112	29	2	1	73	12	60	78
(4A) Commercial	37	26	18	1	3	11	20	20	34
(4B) Industrial	1	12	15	2		6	3	20	1
(4C) Apartments	2	2	2					4	2
(15A, 15B) School	25	33	31		3	5	22	35	30
(15C) Public	26	29	15	2	2	11	21	21	21
(15D, 15E, 15F) Charitable & Exempt	25	21	14		1	3	13	22	23
(Blank)	69	51	27			11	38	32	66
Grand Total	**1,326**	**1,274**	**477**	**31**	**28**	**450**	**826**	**683**	**1,177**

The majority of installed systems are clustered within Atlantic City Electric and Jersey Central Power & Light's territories, with significantly less penetration in Public Service Electric & Gas and Orange & Rockland territories. A similar trend is apparent when looking at the natural gas utilities, with South Jersey Gas and New Jersey Natural Gas accounting for the highest number of customers with GSHP systems, followed by Public Service Electric & Gas and Elizabethtown Gas. Having this baseline understanding of the breakdown of existing systems by utility territory will enable tracking of future adoption rates across these territories as utility electrification efforts and utility-driven incentives develop and expand in the coming years.

Overburdened Communities Analysis

An additional spatial overlay analysis was performed to identify the distribution of systems within New Jersey's Overburdened Communities (OBCs) – shown below in Figure 14. The criteria for an overburdened community, per the New Jersey Environmental Justice Law[23], include any census block group in which: (1) at least 35% of the households qualify as low-income households; (2) at least 40% of the residents identify as a minority or as members of a State recognized tribal community; or (3) at least 40% of the households have limited English proficiency. In total, 503 GSHP systems have been installed within the boundaries of an OBC, representing 16 % of total installations. Creative strategies such as shared access to heat exchangers installed in public rights-of-way could increase access for those who otherwise would be unable to adopt GSHP technology within these communities.

Figure 14: *GSHP Installations and Distribution within NJ Overburdened Communities.*



[23] New Jersey Environmental Justice Law - https://dep.nj.gov/wp-content/uploads/ej/docs/ej-law.pdf

A deeper dive into the universe of GSHP projects within Overburdened Communities reveals that most of these projects are within block groups that may not be as heavily burdened from an income perspective than others, as is evident in Table 5. Less than 10 GSHP projects are within block groups with greater than 70 percent low-income residents, and only 51 projects fall within block groups with greater than 50 percent low-income residents. This further speaks to the potential financial barriers of this technology within the current landscape and the need for enhanced incentives that may better serve those with economic hardships.

***Table 5:** GSHP Projects in OBCs Based on Percentage of Low-Income Residents within OBC Block Groups.*

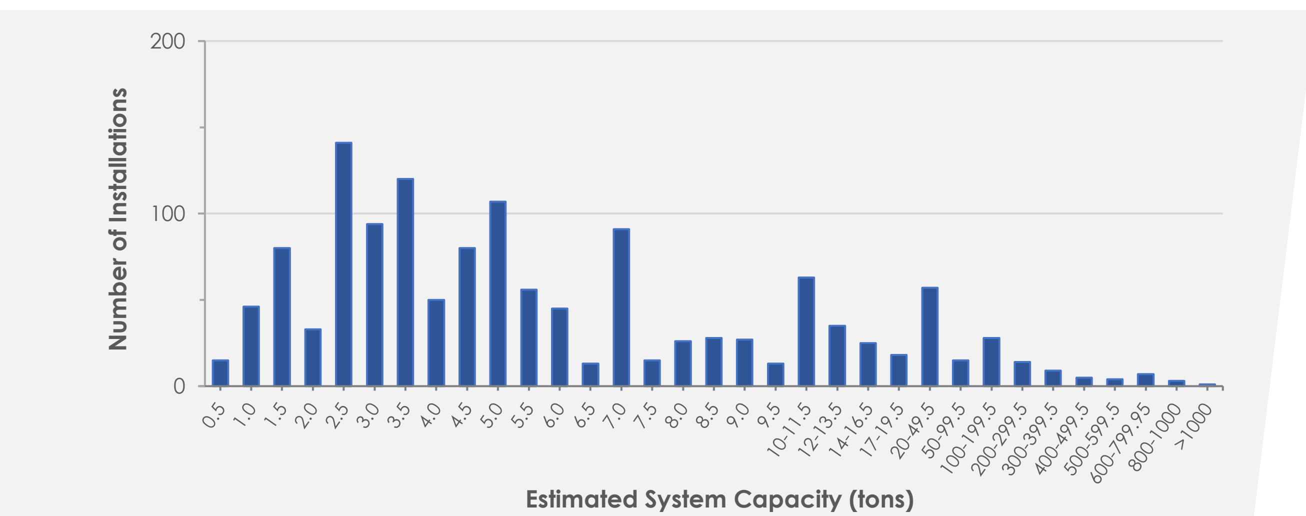
Low Income Percent	Number of Block Groups	Number of GSHP Projects
Greater than 80	2	2
70 to 79.9	5	7
60 to 69.9	9	12
50 to 59.9	25	30
40 to 49.9	29	53
30 to 39.9	48	104
20 to 29.9	40	114
10 to 19.9	52	76
Less than 10	70	105
Total	**280**	**503**

Emissions Avoided by Ground Source Heat Pumps

Closed-Loop Installations

Closed-loop GSHP system capacities are based on the heating and cooling demands within buildings, and emissions reductions compared to conventional fossil-powered technologies are in turn proportional to system capacities. For vertical closed-loop GSHP installations, wells serve as the heat exchangers, and the amount of heat exchange capacity is directly proportional to the total length of the boreholes, that is, the sum of each of the well depths. From historical records of vertical closed-loop GSHP systems, the total combined length of all wells presents at a given site is typically in the range of 150 to 200 feet for each ton of heating or cooling capacity[24], or about 1 ton of capacity per 175 feet of well depth. Well drilling records for the known universe of vertical closed-loop systems include well depths, to which applying the rate of 1 ton per 175 feet of length to the drilling log data yields an approximate distribution of system capacities (Figure 15). The greatest number of installations are found to be between 2.5 to 5.0 tons, which is consistent with the dominance of residential applications described earlier.

***Figure 15:** Capacity Size Distribution for Vertical Closed-Loop GSHP Systems.*



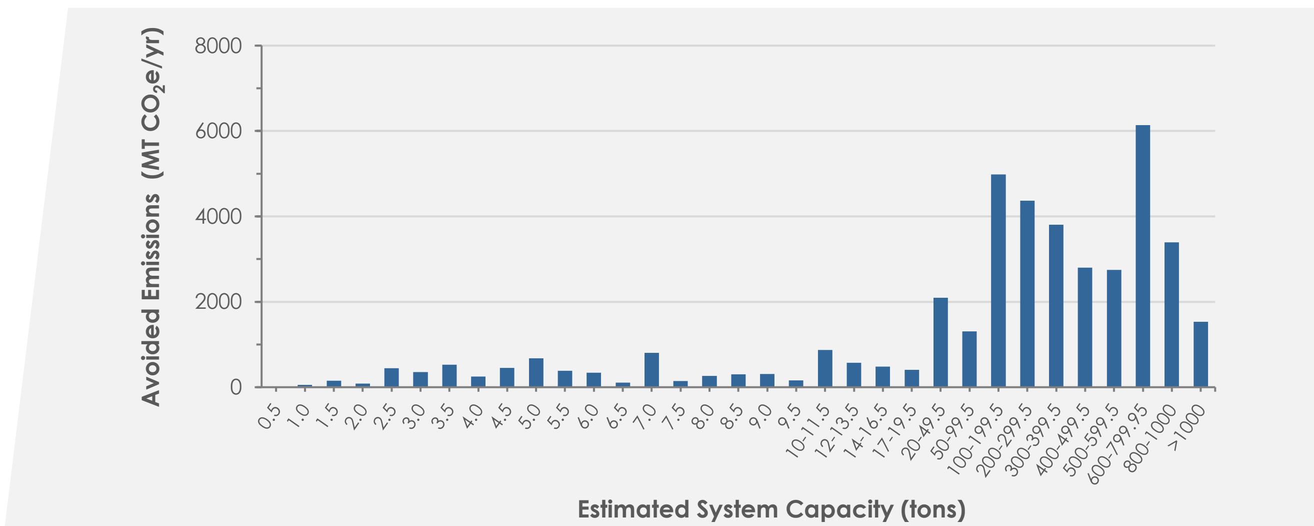
[24] Geothermal Heat Pump Consortium. 2007. Understanding and Evaluating Geothermal Heat Pump Systems - https://northeastgeo.com/wp-content/uploads/2017/10/NYSERDA_Evaluating_GHP_Applications.pdf

Leveraging key assumptions and variables (Appendix I), it was found that, across all 1,364 vertical closed-loop installations, a total of 41,311 MT CO_2e are being avoided annually when compared to conventional natural gas furnaces. A breakdown of the annual emissions avoided by system capacity can be found in Figure 16 below, and Table 6 to the right.

***Table 6:** Estimated Annual Emissions Avoided by Existing Closed-Loop GSHP Installations Compared to Conventional Systems, Grouped by System Capacity.*

Size Range (tons)	Number of Systems	Avoided Emissions/yr. MT CO_2e
0.5-3.5	529	1,630
4-6.5	351	2,213
7-9.5	200	1,967
10-99.5	213	5,726
100-1000	70	28,245
>1000	1	1,530
Total	**1,364**	**41,311**

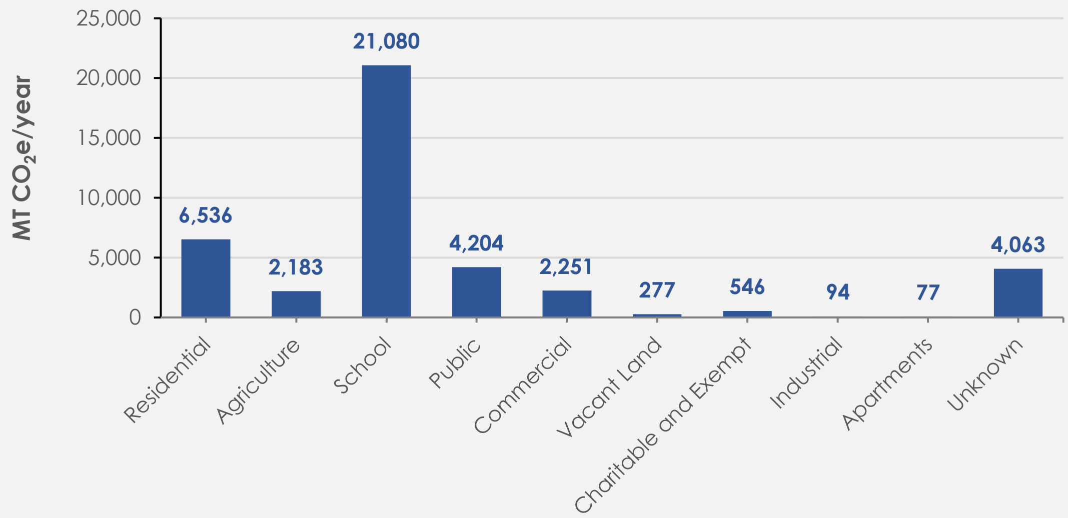
***Figure 16:** Estimated Annual Emissions Avoided by Existing Closed-Loop GSHP Installations Compared to Conventional Systems, Grouped by System Capacity.*



Despite only having a total of 71 projects with associated system capacities greater than 100 tons, these systems make up more than 72% of the total annual avoided emissions – due to their larger size and greater potential to offset emissions. By comparison, the remaining 1,293 closed loop GSHP systems in the State, all totaling less than 100 tons in capacity, account for the remaining 28% of avoided emissions, with the majority of those installations being smaller than 10 tons in size, again confirming the high number of smaller systems serving the residential sector.

A further breakdown and analysis of the emissions avoided by property classification can be found in Figure 17 and Table 7 on the following page.

Figure 17: Annual Emissions Avoided by Existing Closed-Loop GSHP Installations Compared to Conventional Systems, Grouped by Property Classification.



Through the data collection process, it was noted that many colleges, universities, and secondary school institutions have adopted GSHP systems as a means to reduce their carbon footprint while also improving the efficiency of their heating and cooling systems. These school facilities often have upwards of hundreds of rooms and spaces that require being climate controlled. From this data, it is evident that the School sector is the current leader with regards to annual avoided emissions, accounting for 51% of all reductions despite only having 83 operating closed-loop GSHP systems. On average, these systems are avoiding approximately 254 MT CO_2e per year (21,080 MT CO_2e per year for the whole sector), with more than half of the systems in this category being sized at more than 100 tons.

Table 7: Annual Emissions Avoided by Existing Closed-Loop GSHP Installations Compared to Conventional Systems, Grouped by Property Classification.

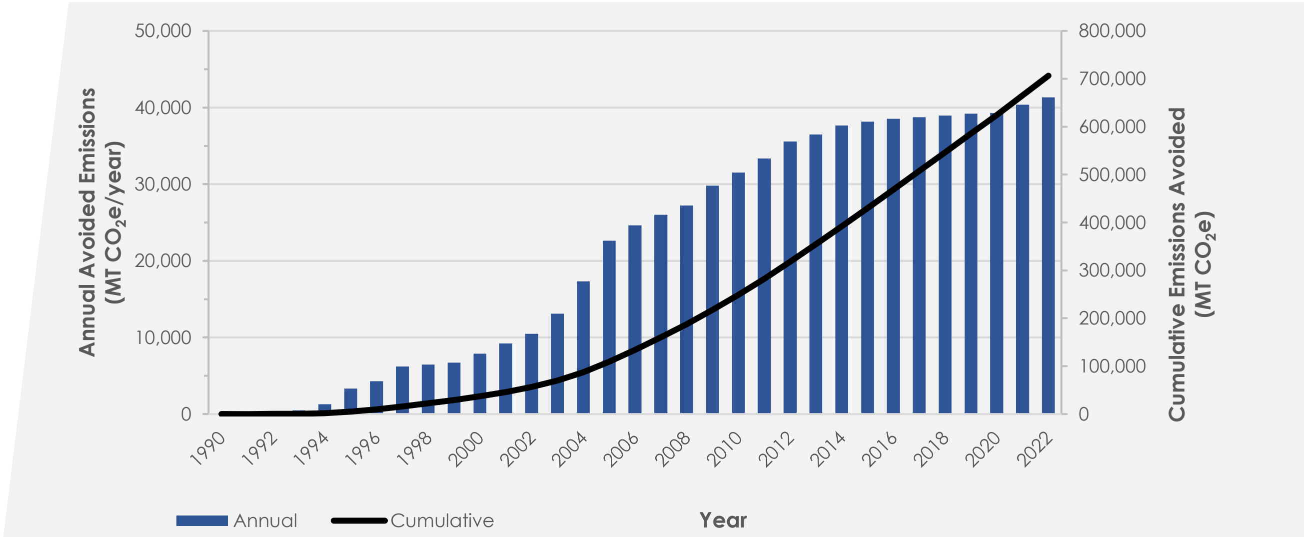
Parcel MOD-IV Prop Class	Property Type	Number of Installations	Emissions Avoided (MT CO2e/yr.)
2	Residential	948	6,536
3A, 3B	Agriculture	122	2,183
15A, 15B	School	83	21,080
15C	Public	46	4,204
4A	Commercial	34	2,251
1	Vacant Land	28	277
15D, 15E, 15F	Charitable & Exempt	24	546
4B, 6B	Industrial	8	94
4C	Apartments	2	77
-	Unknown	69	4,063
Total		**1,364**	**41,311**

*On average, closed- loop GSHP projects serving the **School sector** are avoiding **254 metric tons of CO_2e** annually, while the average **residential** project avoids approximately **7 metric tons of CO_2e** annually.*

By contrast, the residential sector (property classification types 2 and 4C) accounted for the highest number of closed-loop installations in the State by a large margin, totaling 950 systems, and on average reduced emissions by only 6.96 MT CO_2e per year per site.

In total, an estimated 41,311 MT CO_2e were being avoided annually by 2022, while total cumulative emissions avoided by all vertical closed-loop GSHP systems from 1990 to 2022 reached 706,505 MT CO_2e (Figure 18). As can be seen, emissions avoidance has increased more quickly during periods of greater GSHP adoption.

Figure 18: Annual and Cumulative Emissions Avoided by Closed-Loop GSHP Systems, Beginning in 1990.



While these numbers seem small compared to the State's total GHG emissions of approximately 100 million MT CO_2e/year, they are surprisingly large in light of the fact that they represent less than 1,400 sites out of the hundreds of thousands of residential and commercial structures where this technology could potentially be applied. Further, these estimates do not include reductions from horizontal trench GSHP or sites using open-loop technology.

Open-Loop Installations

Heat exchange in an open-loop GSHP system depends on the temperature and flow rate of water coming from a well, rather than the depth of the well. Because temperature and flow rate data are not available in the State's well records, open-loop system capacities cannot be directly inferred from the available information. That said, if it is reasonable to assume that the heating needs of buildings using open-loop technology are similar to those of buildings using closed-loop technology, data from the closed-loop analysis can provide insight into the benefits of open-loop systems. For example, in the case of single family, duplex and row housing, the average closed-loop installation reduced annual greenhouse gas emissions by 6.89 MT CO_2e per year. Applying that same rate to the 1,413 open-loop installations in this sector would yield about 9,735 MT CO_2e of avoided emissions annually as a result. Table 8 to the right shows similar calculations and estimates for open-loop GSHP systems across the other sectors, using the average values for annual avoided emissions from the closed-loop universe in each corresponding sector. These are approximations that show the general scale of reductions (25,243 MT CO_2e/year)

***Table 8:** Open-Loop GSHP System Breakdown by Sector, with Estimated Emissions Avoided Based on Assumptions from Closed-Loop GSHP Calculations.*

Parcel MOD-IV Prop Class	Property Type	Number of Installations	Assumed avoided MT CO_2e/yr. per unit (Sector Avg from Closed Loop)	Approx. Avoided Emissions (MT CO_2e/yr.)
2	Residential	1,413	6.89	9,735
3A, 3B	Agriculture	117	17.89	2,093
4A	Commercial	51	66.21	3,377
15D, 15E, 15F	Charitable & Exempt	37	22.75	842
15C	Public	28	91.39	2,559
1	Vacant Land	29	9.90	287
4B, 6B	Industrial	22	11.73	258
15A, 15B	School	9	253.98	2,286
4C	Apartments	4	38.73	155
5A, 5B	Railroads	0	-	-
-	Unknown	62	58.88	3,651
Total		**1,772**	**-**	**25,243**

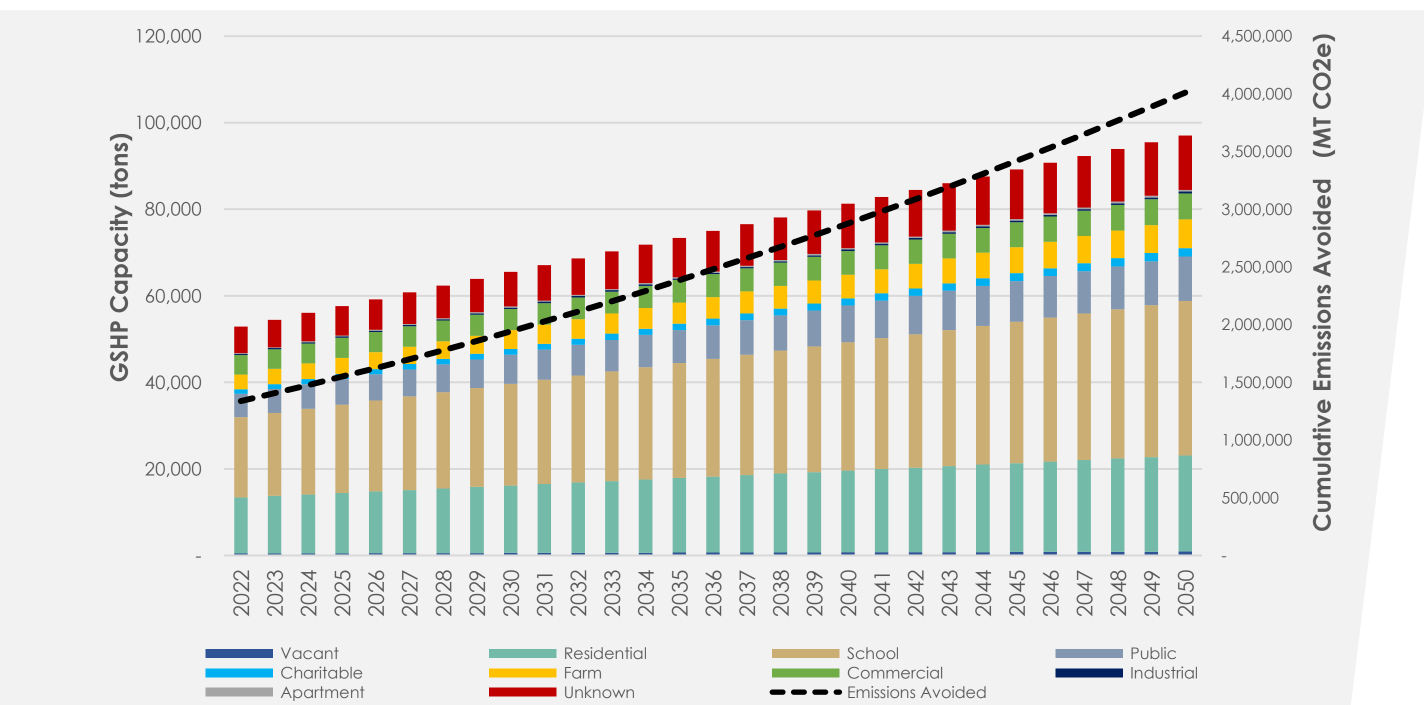
that may be occurring from existing open-loop systems in the State. These estimates for open-loop systems, in combination with closed-loop systems, provide an estimated annual reductions of more than 66,000 MT CO_2e from GSHP.

Adoption Scenarios and Projected Emissions Reductions

With the universe of installed GSHP systems in the State quantified and defined, along with estimations of each system's capacity (tonnage) and associated emissions avoided, forward looking projections and assumptions can be made about the growth of GSHP in the State. In order to determine a "Business as Usual" (BAU) scenario, information pertaining to installed GSHP systems was examined looking back over the last 20 years (2003-2022). For this period, the number of installations (both closed-loop and open-loop) and the total well depth were summarized, looking first by the sector the wells were serving. For the closed-loop systems, an estimate of the total installed capacity (tonnage) for each sector was determined, using the conversion of 1 ton of capacity per 175 feet of well depth. To determine an estimate of the installed capacity for the open-loop systems over the same 20-year period, the closed-loop system average capacity for each sector was multiplied by the number of open-loop projects within that sector (i.e., for the residential sector, the closed-loop average capacity over the last 20 years was 6.31 tons per system – this value was multiplied by the 371 open-loop systems serving the residential sector, to generate a coarse estimate of the total installed capacity from those open-loop systems). Once the estimates for closed-loop and open-loop systems were generated, they were combined to determine the total installed capacity over the last 20 years. This value was then divided by 20, to determine the average annual increase in capacity from all installed systems, which was found to be 1,577.72 tons/year, and would serve as the projected annual increase under the BAU scenario.

Figure 19 below shows the projected increase in installed GSHP capacity under the BAU scenario. This figure includes a breakdown of how each sector would grow independently, as the average annual increase of 1,577.72 tons was allocated based on the percentage of installed capacity per sector over the past 20 years (i.e., the School sector was found to account for 39% of total installed capacity over the past 20 years, and as such, under this BAU scenario, the School sector would account for 39% of the projected annual growth, or 614.13 tons annually).

Figure 19: *Business As Usual (BAU) GSHP Projection Showing Annual Increase in Capacity and Cumulative Emissions Avoided Through 2050.*



Under this scenario, by 2050, installed GSHP capacity would grow by more than 44,000 tons, with the sector-based projection based on their percent allocation shown in Table 9 to the right, with the largest sector-based increases being associated with systems serving the School, Residential, and Public sectors.

Table 9: Projected Increases in Capacity by 2050 Under the BAU Scenario (by Sector).

BAU New Capacity by 2050 (tons)	
Vacant	425.11
Residential	9,245.64
School	17,195.74
Public	4,892.56
Charitable	835.14
Farm	3,206.30
Commercial	1,580.78
Industrial	107.15
Apartment	216.00
Unknown	6,471.87
Grand Total	**44,176.28**

The projected increase in installed GSHP capacity under the BAU scenario can be linked to an increase in projected emissions avoided over the same period. The calculations and estimates conducted for this baseline report conclude that all GSHP systems installed to date in New Jersey have avoided an estimated cumulative 1.3 million metric tons of CO_2e. Using this value as the starting point and incorporating the estimates of added annual capacity under the BAU scenario, the estimated cumulative emissions avoided would more than triple by 2050, to more than 4 million metric tons of CO_2e (Figure 19).

The BAU scenario displays a conservative growth of GSHP systems in the State over the next three decades, with assumptions that financial incentives and current programs to promote GSHP systems remain at the levels that they are today. However, this report identifies that enhanced policies and an increase in financial incentives and customer awareness will be needed to spur growth of this technology to achieve our statewide emissions reduction goals. As State and Federal policies evolve, additional projections can be conducted, utilizing varying rates of annual growth, and even specific rates for each sector, to capture how sector-specific policies and incentives may spur increased rates of adoption over time.

Stakeholder Survey

In 2017, NJDEP conducted a survey campaign of HVACR contractors with the goal of collecting information regarding the state of the GSHP industry in New Jersey and identifying challenges and opportunities from the perspective of individuals operating in this sector. This section summarizes the results of the stakeholder survey at a high level. More detailed information is provided in Appendix II.

Participants in the survey included licensed HVACR contractors, well drillers, architects and planners, and general contractors. Overall, more than 300 people surveyed submitted robust responses. Business owners made up the majority of survey respondents, at 74%, while employees represented an additional 21% of survey participants. Survey questions were designed to illustrate contractor profiles, experience with incentives, perception of market gaps, and to elicit opinions on how State involvement could be most beneficial for the sector and the future growth of the technology. The survey consisted of a combination of multiple choice and open-ended response prompts.

Evaluating apparent roadblocks and barriers to GSHP technology growth in New Jersey from the perspective of the participating stakeholders through the open-ended response format proved to be very insightful. The average company age for respondents in the HVAC, well drilling, architecture and planning, and general contracting or other related professions was 33 years, with some being in existence for more than 100 years, thus showing the wealth of institutional knowledge and experience in the HVACR installation, planning, and siting sector. Their feedback reinforced and confirmed perceived concepts in addition to providing new insights.

When prompted to discuss their experience with GSHP systems in New Jersey, participants often described limitations in customer awareness and willingness to invest in a technology with such significant upfront costs. Additionally, common responses included a call for large demonstration projects and increased customer outreach materials, including detailing the environmental and climate benefits of the technology, the energy and cost savings, and the available financial incentive programs.

> *"Customers lack awareness of the benefits, but the cost of implementation can make GSHP systems beyond budgets of residential customers. GSHP systems make most sense for public and institutional clients."*
>
> ***– Survey Participant***

Section 6: Discussion and Recommendations

The results of this study highlight the substantial emission reduction potential for GSHP systems coupled with the need for additional market mechanisms. GSHP technology could significantly decarbonize New Jersey's buildings sector if a considerable uptick in adoption occurred. The spatial and building sector analysis found that installation of GSHP technology peaked in the late 1990's and mid 2000's but has not been able to gain a strong foothold in recent years. The residential sector currently dominates the number of installed systems in the State, while the greatest emissions reduction benefits can be seen attributed to the school sector. Due to the large footprint of school buildings, these systems have provided sizeable emission reductions, indicating that large buildings, campuses and institutional properties are a key segment for future adoption. Further, the information gained from stakeholder engagement confirms known barriers, which center around limited financial incentives and lack of customer awareness. To support the growth in GSHP systems across the state, NJDEP identified five key recommendations.

1. Increase Customer Awareness

Partner with other State and federal agencies, research institutions, and industry leaders to develop customer educational materials, promote workforce development and training certifications, and support project demonstrations and case studies.

Lack of knowledge and awareness among customers concerning the benefits of GSHP systems, potential return on investment (ROI), and availability of incentive mechanisms was common throughout participant feedback. By developing educational and marketing materials, the proven technology and available workforces can be leveraged to drive further utilization of GSHP systems. Furthermore, engaging with and providing resources for individuals within the GSHP tangent industries can move the market towards a more efficient HVAC landscape.

2. Expand and Prioritize Financial Incentives Towards Larger Buildings to Maximize Emissions Reductions

Investigate opportunities for new financial incentive programs targeting specific segments of the building sector to overcome cost barriers, reduce fossil fuel use, and improve energy equity in New Jersey.

The analysis in this report concludes that emissions reductions benefits are directly correlated to GSHP system size. While incentivizing GSHP technology overall will lead to emissions reductions, tailored incentive programs geared towards certain sectors (i.e. schools, public facilities, commercial buildings, etc.) where larger GSHP systems would likely be installed, will lead to greater emissions reductions on a per-installation basis. To date, less than 100 GSHP projects are sited at schools/colleges and universities – yet they are currently offsetting the greatest share of emissions on a sector-basis. According to the NJ Department of Education[25], there are more than 3,000 school institutions in the State – illustrating the significant opportunity to further reduce emissions through GSHP adoption in this sector, if properly promoted and incentivized. Additionally, geographic-based incentives could prove effective if designed to target specific regions of the State that are reliant on costly and highly-polluting fuel types, specifically fuel oil and propane, and additional priority for incentives could be given to Overburdened Communities where GSHP can provide access to electrification at larger scales, and with lower costs and greater reliability than piecemeal alternatives.

[25] New Jersey School Directory. New Jersey Department of Education - https://homeroom5.doe.state.nj.us/directory/

3. Support the Development of Siting & Planning Tools for New GSHP Systems

Support the development of web-based planning tools and other resources to assist with identification of potential GSHP sites.

As with most clean energy technologies, system design for GSHP requires advanced project-specific siting and technical analyses in the design process. Although there are engineering-specific analyses required by system developers, less technical engineering-based web tools could be developed to inform stakeholders interested in adoption of the technology. These tools could readily make connections between location-specific incentives and rebates with environmental conditions that relate to system feasibility. Additional studies on the technical and economic feasibility of the technology in New Jersey can also help identify target areas for outreach and additional investment in GSHP technology.

4. Develop Pilot Programs to Increase Access

While many mature projects already exist in the State, additional pilot projects can prove useful in displaying both the environmental and energy efficiency benefits of GSHP technology.

The State should evaluate available funding opportunities to develop GSHP market models to expand market potential and improve energy efficiency access in various building sectors or geographies of the State (i.e., Community or District Geothermal). Additional emphasis should be on pilot programs that seek to integrate a full suite of complementary clean energy and energy efficiency strategies to promote co-location and maximization of emissions reduction benefits.

5. Determine Improved Method of GSHP Tracking

Tracking the growth of GSHP systems in the future will be integral towards tracking emissions reduction goals.

This report, and all efforts to better understand the landscape and universe of installed GSHP systems in the State have been reliant on the NJDEP's well-permitting and well records database. While this database serves as an effective means to quantify and understand vertically-drilled GSHP wells, it does not capture horizontally-drilled GSHP systems, and also does not contain any information pertaining to the actual GSHP system installed (i.e. capacity/tonnage). As a result, this report relied on assumptions about the installed capacity and how that relates to the emissions avoided.

As GSHP systems are an electrification-based technology, installed systems could be quantified by the electric utilities, but it may require the development of uniform electric customer classification codes. Doing so would enable the utilities to classify a customer as a "residential ground source heat pump" or "non-residential ground source heat pump" customer, for example, and the number of customers that meet these, and other, classifications could be provided annually to assist with tracking the growth of this technology over time.

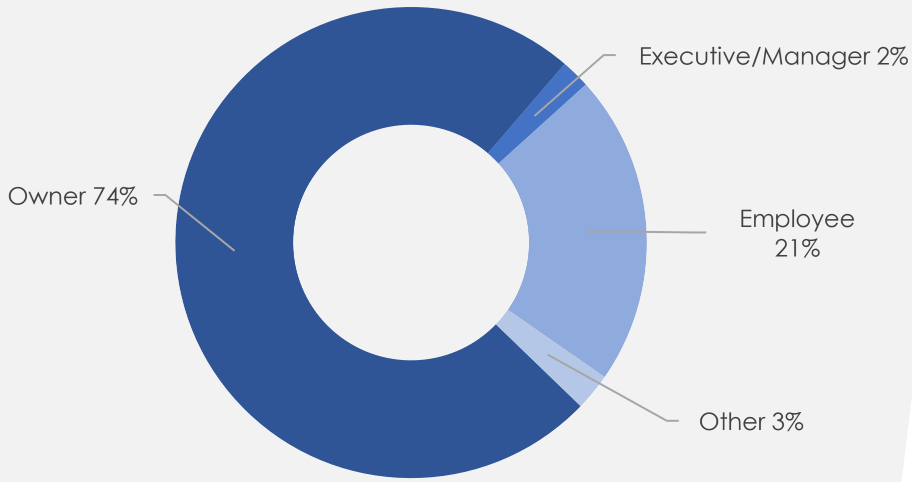
Appendix I: Key Emissions Assumptions and Variables

Assumption Category	Value	Reference
GSHP COP – Heating	4.0	Typical value based on review of several recent models.
GSHP COP - Cooling	5.9	Typical value based on review of several recent models.
Heating Degree Days	5885	USEPA Energy Star program; Mercer County, NJ; maximum value 2010 - 2021
Cooling Degree Days	1205	USEPA Energy Star program; Mercer County, NJ; maximum value 2010 – 2021
EFLH – heating	2769 hours	Based on HDD, 65F reference
EFLH – cooling	1157 hours	Based on CDD, 65F reference
Heating design temperature	14 F	USEPA Energy Star Certified Homes Design Temperature Limit Reference Guide; value is for Mercer County NJ, 99th percentile
Cooling design temperature	90 F	USEPA Energy Star Certified Homes Design Temperature Limit Reference Guide; value is for Mercer County NJ, 1st percentile
Feet of well length per ton of closed-loop GSHP thermal capacity	Low 150 ft/ton; Average 175 feet/ton; High 200 ft/ton	NYSERDA, "Understanding and evaluating GHP systems, information for evaluating geoexchange applications, Feb. 2004, rev. Jul 2007. Average of high and low estimates used in calculations.
Electricity GHG Emissions Rate	655.374 lbs/MWh	USEPA eGrid data for 2020, RFC East region
Conventional gas furnace AFUE	95%	USEPA Energy Star program compliant; NJ utility rebate eligible
Conventional central air conditioning	12.5 EER/3.66 COP	USEPA Energy Star program compliant; NJ utility rebate eligible
Natural gas emissions factor	53.1 kg CO_2e /MMBTU Natural Gas	USEPA, adjusted for CH_4 and N_2O, 100-year global warming potential
Electricity cost	0.15849 $/kWh	USEIA State Energy Data System, NJ residential price, 2019
Natural gas cost	9.35 $/million BTU	USEIA State Energy Data System, NJ residential price, 2019
System Replacement		On retirement, existing GSHP units are assumed to be replaced with new GSHP

Appendix II: Stakeholder Survey Results

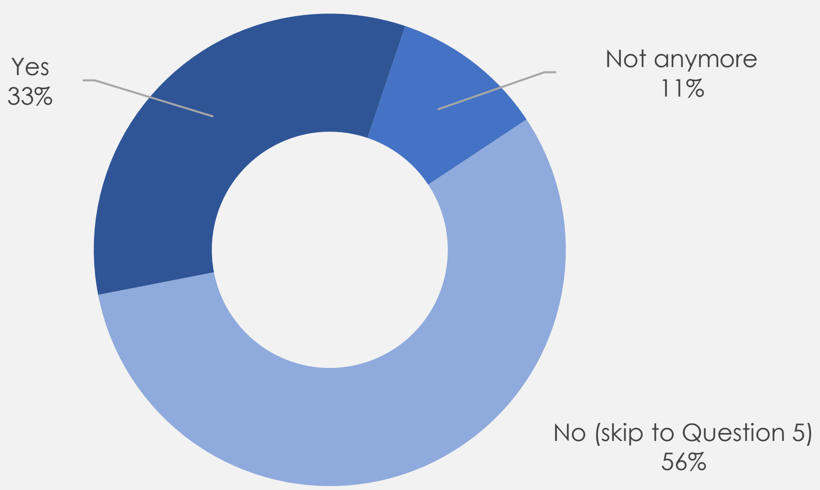
This appendix contains summaries of the responses to the stakeholder survey conducted in 2017.

Question 1: Please identify your position in the company.



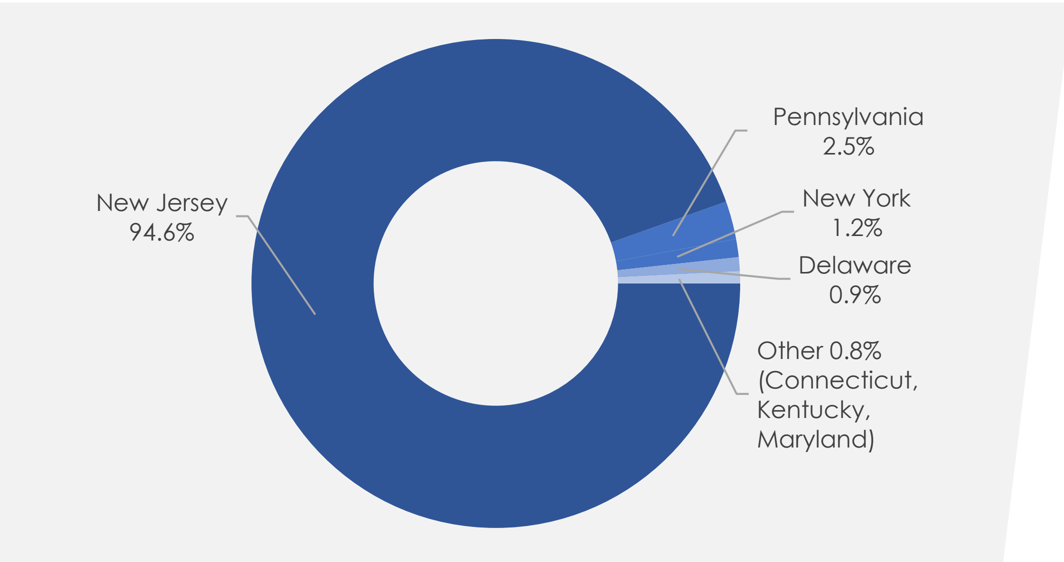
Owner	260
Executive/Manager	7
Employee	75
Other	9
TOTAL	**351**

Question 2: Does your company currently work on ground-source/geothermal heat pump systems?



Yes	117
Not anymore	37
No (skip to Question 5)	198
TOTAL	**352**

Question 3: In which counties and States does your company conduct the majority of its GSHP system business? This includes construction, bids, consultation, repair and replacement.



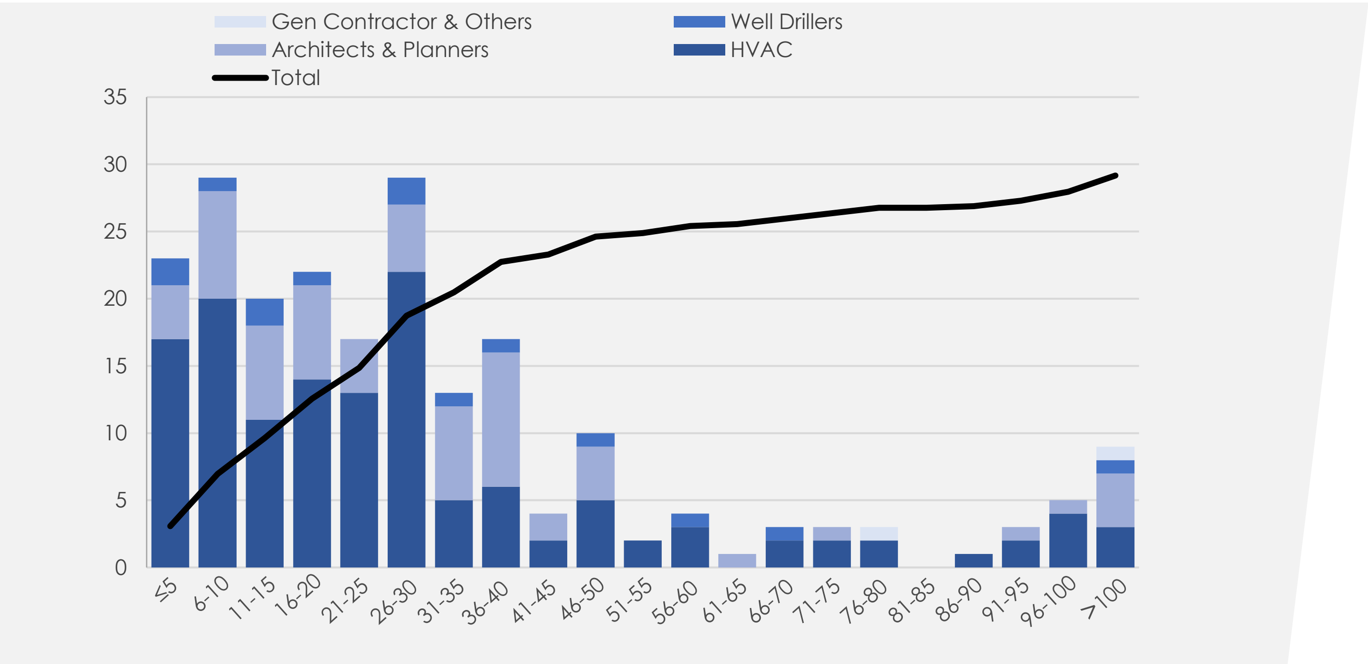
Question 4: Approximately what percentage of your sales is generated from each of the following loop types?

The majority of responses to this question were for vertical-closed loop systems, followed by supply and return wells for open loop systems. A smaller minority of responses were for horizontal-closed loop systems, or other directionally drilled installations.

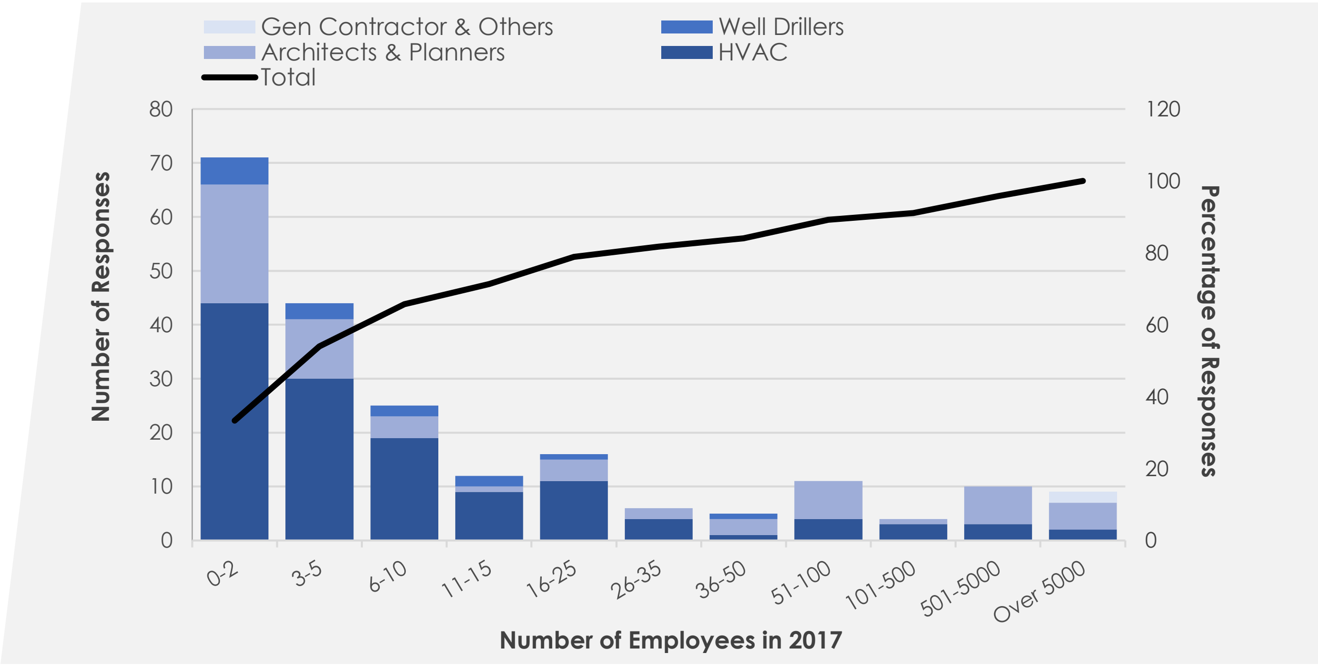
Question 5: Approximately what percentage of your GSHP sales are generated from the following segments?

The majority of responses to this question indicated a high percentage of sales serving the single family/multi-family up to 4 units sectors, followed by schools/institutional/municipal buildings. To a lesser extent, multifamily building with more than 5 units, as well as commercial/industrial sectors were also identified.

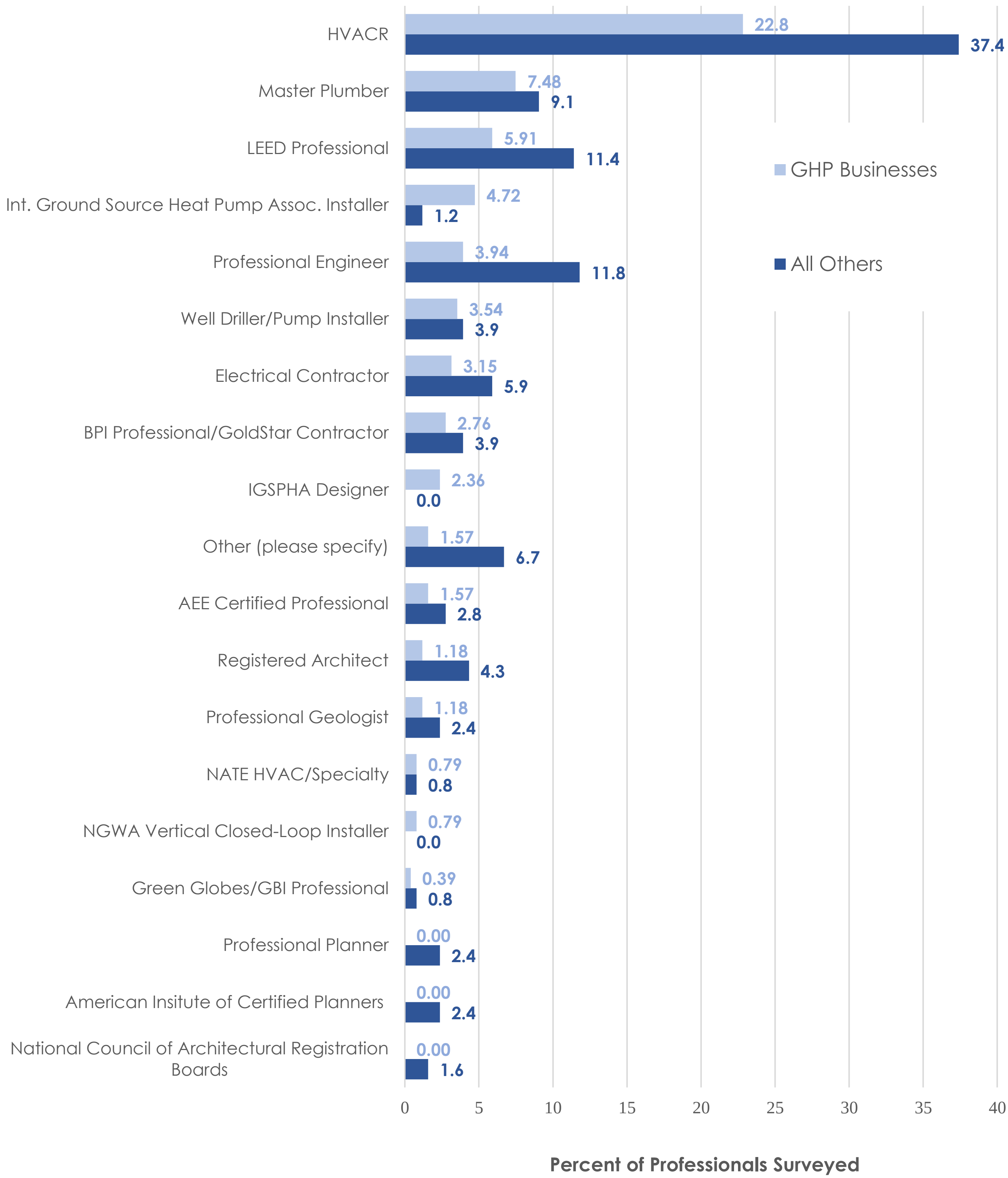
Question 6: How long has your company been in business?



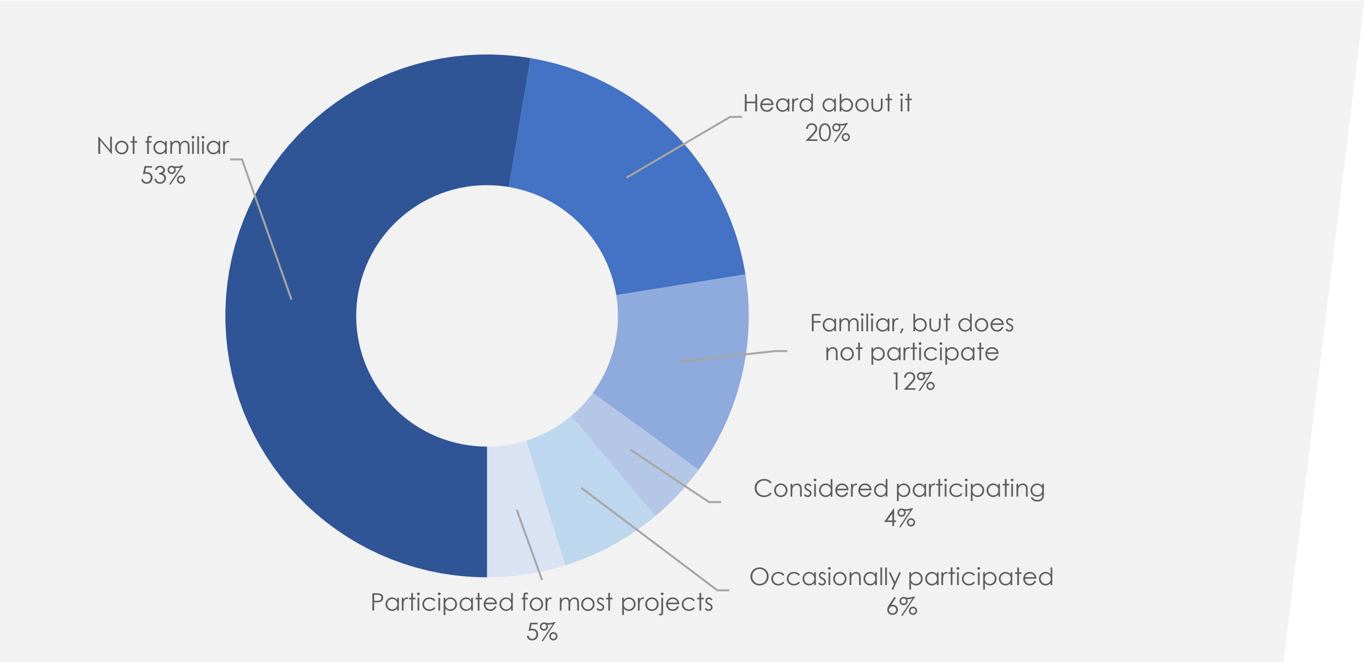
Question 7: On average, how many employees worked for the company in 2017?



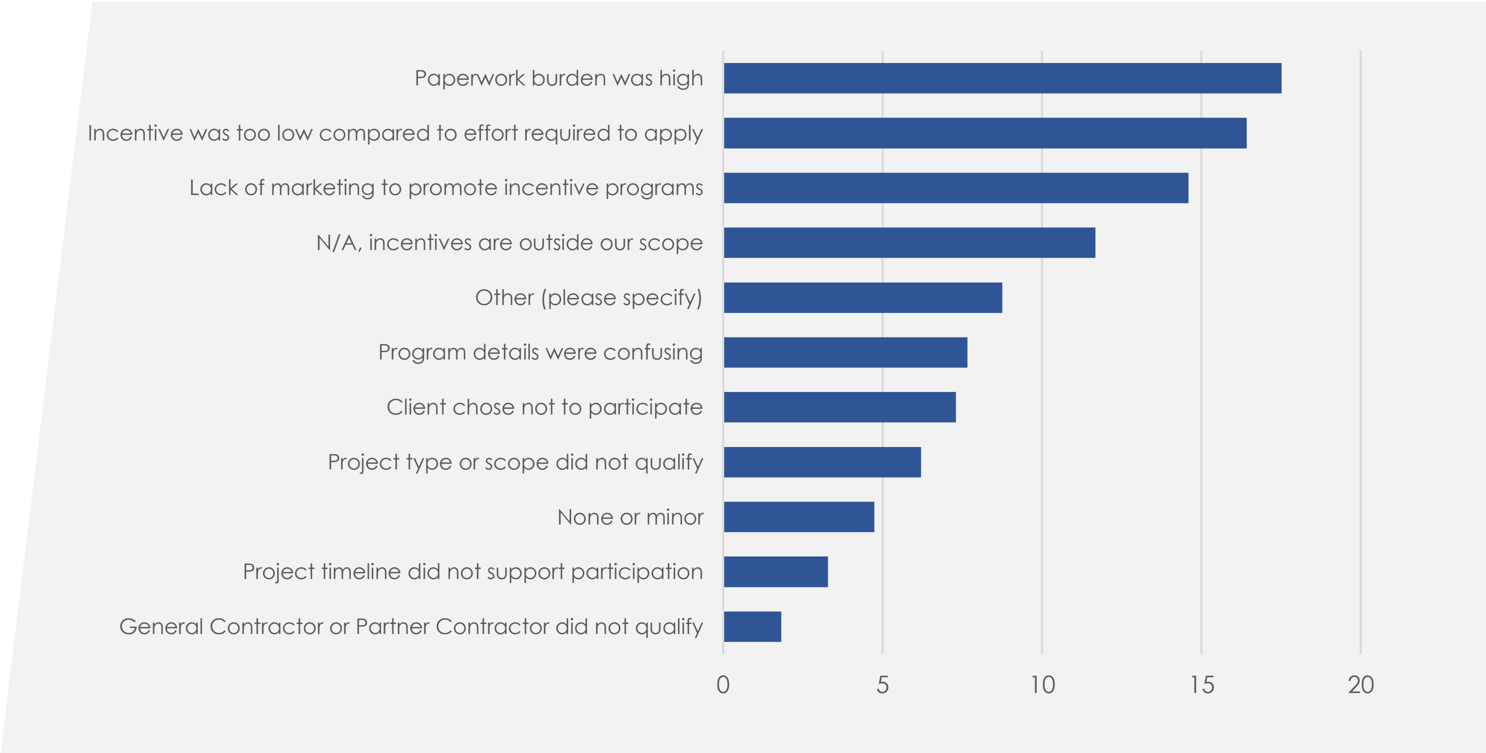
Question 8: What certifications or licenses do you or your employee(s) hold?



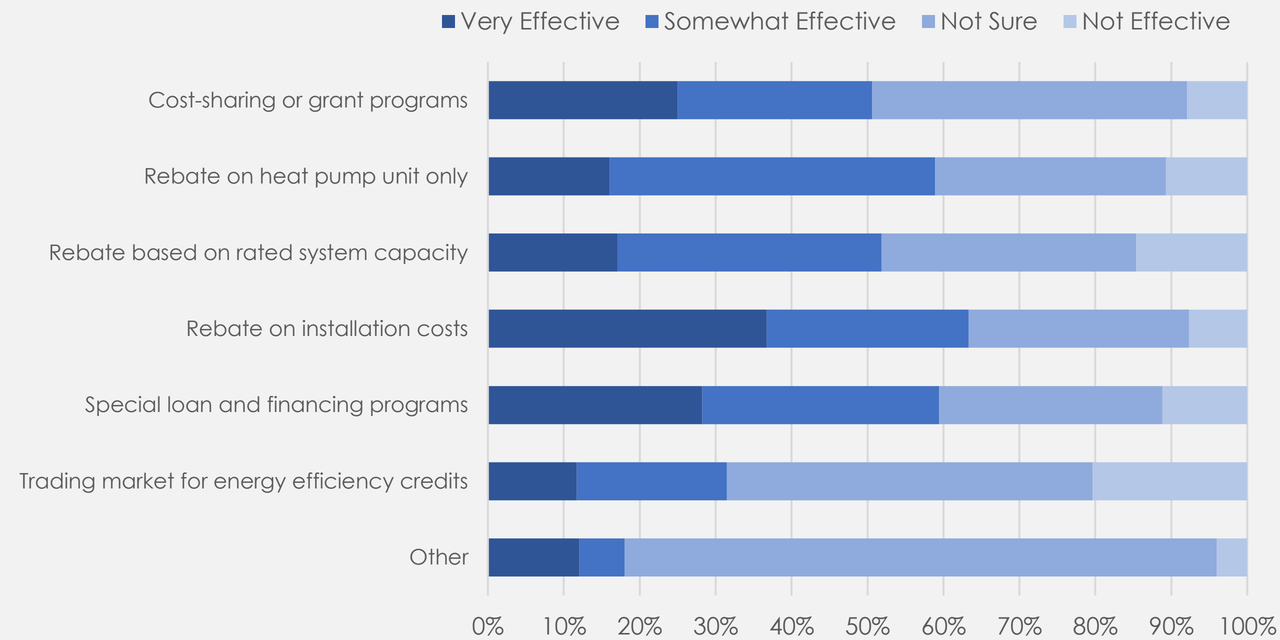
Question 9: How familiar is your company or your customers with New Jersey's incentive programs offered for GSHP systems?



Question 10: Please identify any challenges in participating in New Jersey's incentive programs?



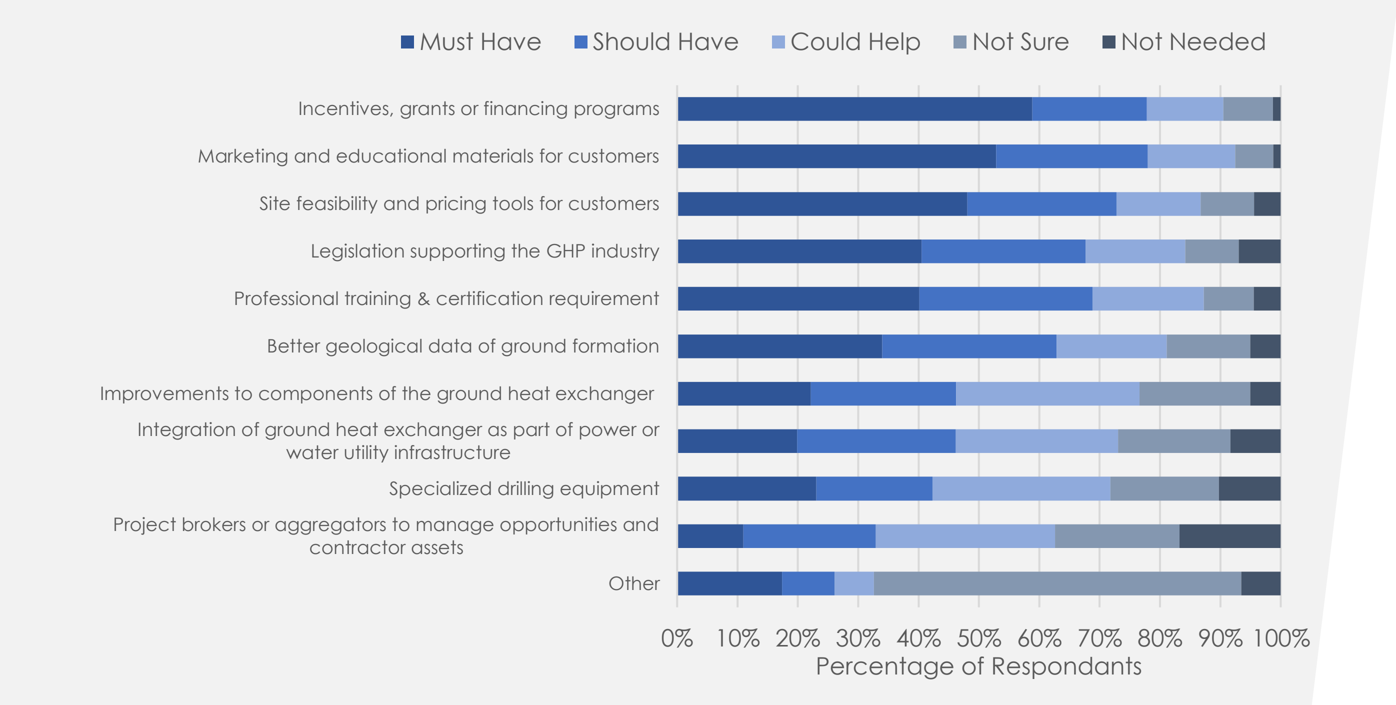
Question 11: Based on your experience, please rate the overall effectiveness of possible incentives models for GSHP systems in the residential and non-residential sectors.



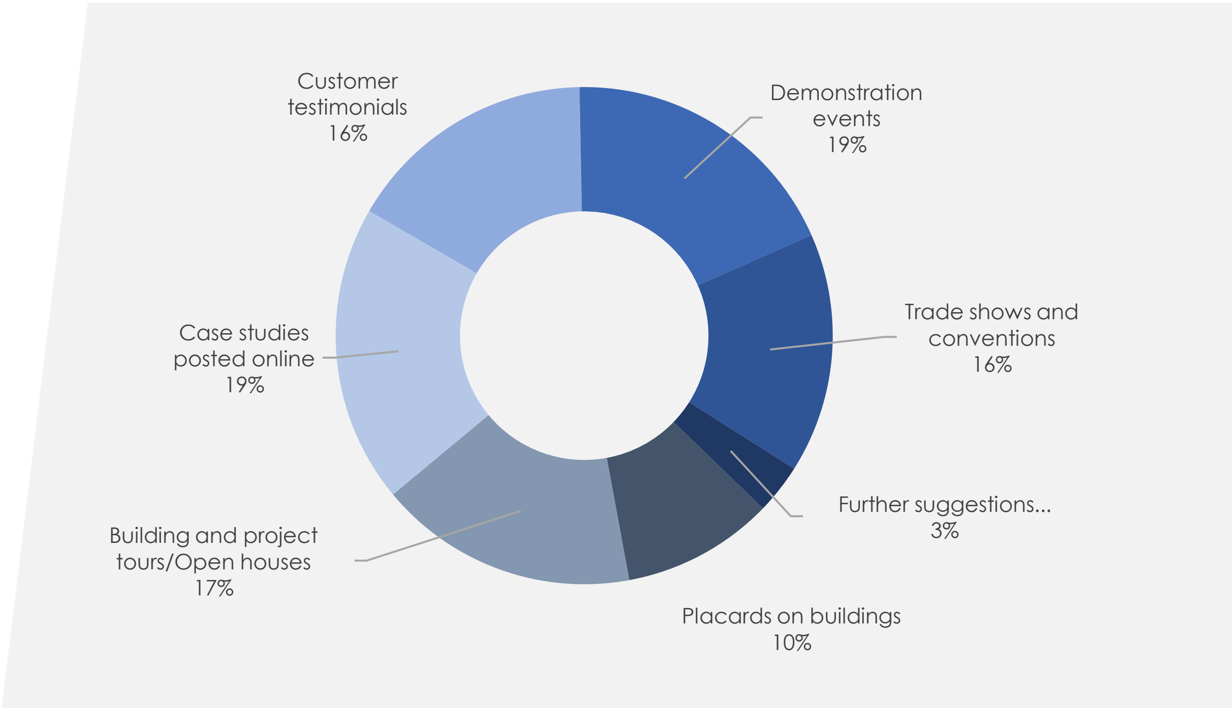
Question 12: With regard to customer adoption of GSHP systems, from your perspective, what barriers prevent wider adoption?

This open-ended question yielded many responses around cost being the biggest barrier to widespread adoption, followed by lack of awareness about the technology, the benefits, and the incentives available. Other responses alluded to difficulty around siting systems (both geographic and available space constraints), as well as the relatively low price of natural gas compared to electricity costs in the Northeast.

Question 13: With respect to increasing market penetration, which of the following is needed or could help?



Question 14: Product awareness and trial evaluation are important steps in building customer confidence. How can this be accomplished for GSHP systems?



Question 15: In which segment would your business like to see the most growth?