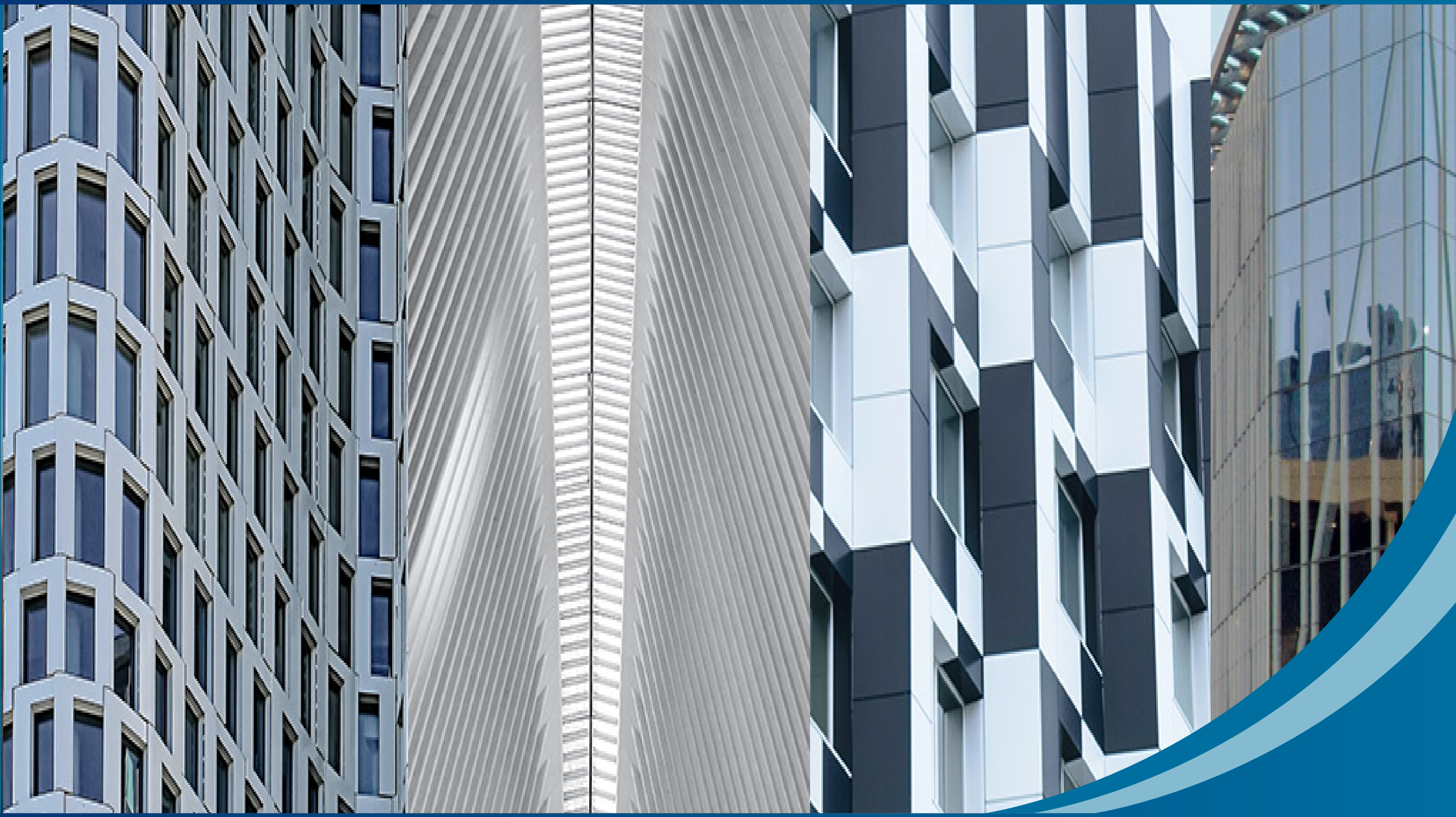
Innovation Queens: Geothermal Scoping Study in Astoria



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NEW YORK STATE | NYSERDA

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Advance clean energy innovation and investments to combat climate change, improving the health, resiliency, and prosperity of New Yorkers and delivering benefits equitably to all.

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Innovation Queens:
Geothermal Scoping Study in Astoria

Final Report

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Notice

Abstract

District thermal systems can offer greater efficiency and lower emissions than conventional heating, ventilation, and air conditioning (HVAC) systems. Developing and constructing district thermal systems face challenges from initial capital costs for design and installation and uncertain regulatory pathways. Endurant Energy explored the feasibility of a thermal district system at the Innovation QNS development (New York, NY) to determine technical, regulatory, and lifecycle cost viability as compared to a business-as-usual approach. Endurant explored both geothermal and sewer heat exchange district thermal designs and compared life cycle costs to the business-as-usual case. Results indicate that a geothermal district system offers significant savings around operational cost and emissions. After accounting for incentives, project payback occurs as quickly as one year. Thirty-year life cycle costs were lower for both the sewer heat exchange and geothermal configurations as compared to a business-as-usual configuration.

Keywords

District geothermal system, sewer heat exchange, campus district thermal system, life-cycle cost analysis

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Summary

Innovation QNS is a proposed mixed-use development of 3 million square feet (sq. ft.) that spans five city blocks in Astoria Queens, between 35th and 36th avenues, and 43rd and 37th streets. Innovation QNS will feature over 3,000 apartments, including 725 affordable housing apartments, two acres of open space, 250,000 sq. ft. of commercial space for small businesses, start-ups, and nonprofits, as well as an arts and culture hub, and health and wellness facilities. The development is a joint venture (JV) between Kaufman Astoria Studios, Silverstein Properties, and Bedrock Real Estate Partners, and will create a unique venue for community, culture, and living.

Figure S-1. Innovation QNS Rendering Developed by ODA New York

The site offers a compelling opportunity to include a geothermal district thermal system as part of the development. Endurant Energy has led the feasibility study for Innovation QNS and submitted periodic milestone reports to NYSERDA. This report includes a compilation of the feasibility assessment and results for both geothermal and sewer heat exchange (SHX) district systems for Innovation QNS.

S.1 Approach

Endurant deployed the following approach to provide the JV with a comprehensive view to the costs and benefits of a district energy solution.

1. Develop the business-as-usual (BAU) scenario
   - Model thermal loads
   - Develop capital cost estimates
   - Model utility costs and maintenance costs
   - Establish 30-year life cycle cost
2. Discuss technologies considered and identify use-cases.
3. Develop district thermal conceptual design:
   - Estimate capital and operating cost
   - Quantify carbon savings against BAU
   - Identify and quantify potential incentives
   - Regulatory review of proposed conceptual design
   - Establish 30-year life-cycle cost
4. Identify commercial approaches to project development.
5. Make recommendations based on key findings.

S.2 Business-as-Usual

Endurant developed an energy model using IES VE software to estimate thermal loads based on proposed schematic architectural design from ODA. This exercise produced an 8760 hourly thermal profile for all 13 buildings in the district. The team used hourly profiles to determine peak capacity requirements and estimate capital and operating costs. The baseline HVAC equipment configuration assumes variable refrigerant flow (VRF) for space heating and cooling and gas fired boilers for domestic hot water (DHW) production.

S.3 Technologies Considered

Endurant assessed multiple technologies to meet thermal demands, electric generation, and energy storage. After performing a technical viability screening, we developed a conceptual design that included the following technologies.

1. **Ground Source Heat Pump** (GSHP) paired with the following ground loop heat exchangers (GLHEs):
   - **Bore holes** are purpose drilled wells, 6-8” in diameter to depths of 500’

   - **Enerdrape panels** are a heat exchange technology that can be fixed to the walls of unconditioned parking areas. The intent of deploying this technology is to reduce the number of bore holes, which are more capital intensive

2. **Air Source Heat Pump** (ASHP) uses ambient air as a source or sink to generate heating or cooling
3. **Sewage Heat Exchange** (SHX) is a heat pump-based solution that uses sewer mains as a heat source or sink
4. **Battery Energy Storage** (BESS) can provide revenue opportunities or support demand management

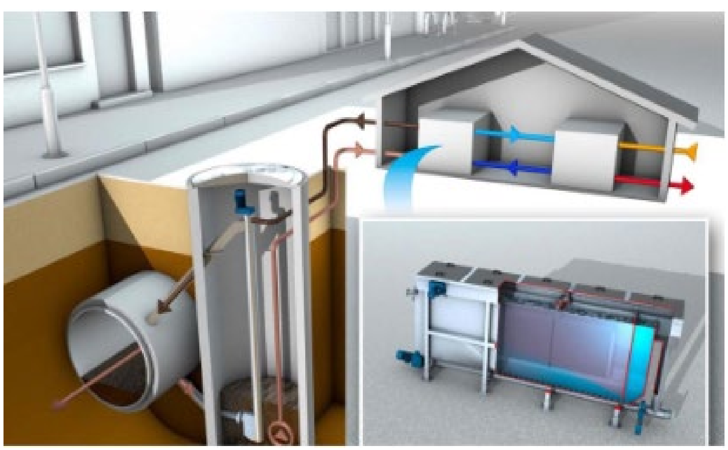
S.4 Proposed Thermal Energy Solutions

Endurant identified and assessed two district system configurations: a geothermal hybrid solution and a sewer heat exchange design.

S.4.1 Geothermal Hybrid Solution

The proposed geothermal hybrid system includes GSHP and ASHP along with conventional equipment for peak heating and cooling periods. This results in a 868-ton GSHP solution that meets the majority of the annual heating and cooling loads, with the remaining loads being served by simultaneous heat pumps, ASHPs, electric boilers, and dry air coolers. This solution will require at least 406 bores drilled 500’ deep and spaced 20’ on center. The borefield would require an estimated 162,400 sq. ft. across all five blocks. Due to the scarce availability of green space, our team proposes siting vertical bores underneath each building.

Figure S-2. Sewer Heat Exchange Conceptual Illustrations



S.4.2 Sewer Heat Exchange Solution

Wastewater that is normally discarded into sewer lines can be diverted, separated (into liquids and solids), and passed through a heat exchanger to extract thermal energy. The average temperature of wastewater is 70ºF, which provides an excellent opportunity for thermal extraction. Innovation QNS sits adjacent to a sewer line on Northern Boulevard with approximately 12,680 gallons per minute (GPM) of flow. At this flowrate, a SHX solution that deploys heat exchangers in-series can serve 100% of Innovation QNS's thermal loads (including heating, cooling, and domestic hot water). The installation of this system is relatively simple compared to geothermal, and can be installed when sewer interconnection is scheduled to occur. The primary hurdle for SHX is receiving approvals from Authorities Having Jurisdiction (AHJs) to make the interconnection.

S.4.3 Heat Pump Configurations

Given the size of the district, our team assessed the viability of both a centralized and decentralized heat pump arrangement and the benefits of each.

1. **Centralized:** a central energy plant (CEP) would house all mechanical equipment in a central location. The CEP would generate heat hot water and chilled water and distribute each to buildings across the district. The CEP results in the lowest operating costs.
2. **Decentralized**: water-to-air or water-to-water heat pumps would be located in residential and commercial units linked to an ambient district loop. This solution has a lower capital cost but is more maintenance intensive and requires more dedicated mechanical space within each residential unit.

Both heat pump configurations are compatible with SHX and the geothermal hybrid solution.

S.5 Economic Analysis

Endurant estimated capital cost, utility cost, maintenance cost, incentive values, and life cycle costs for the business-as-usual (BAU), SHX (centralized *and* decentralized heat pumps), and geothermal hybrid (centralized *and* decentralized heat pumps).

The budgetary cost estimates range between as little as a 1% premium to as high as a 27% premium against the BAU before incentives. Federal, state, and utility incentives are available to GSHP and SHX projects in this location. Incentive estimates sit at $40 million assuming full monetization. After accounting for incentives, project payback occurs as quickly as year 1. All solutions showed impressive operational savings between 34% and 55%, which in turn demonstrated a life cycle cost benefit as well. All projects showed life cycle cost savings against the baseline with the best-case scenario showing $124 million in savings over 30-years. Furthermore, the efficiencies of the proposed solutions yield a 31% and 37% carbon emissions reduction and eliminate on-site emissions making the project carbon-neutral ready.

S.6 Recommended Approach

This report finds that a district thermal system will produce multiple benefits to the project JV. The economic analysis shows significant savings opportunities and numerous avenues to buy down capital costs with incentives. From a technical perspective, natural gas can be eliminated from the project which would reduce interconnection costs and futureproof buildings against costly retrofits. The local community will benefit from the elimination of on-site emissions and substantial carbon savings. The project produces value for all stakeholders, and Endurant recommends pursuing a district thermal system.

The next step is to down-select to a single technical solution and preferred configuration. A SHX system has the potential to supply 100% of the site's heating, cooling, and domestic hot water loads with very high efficiencies. Based on these benefits Endurant recommends engaging city agencies to illustrate the concept and quantify the benefits to key AHJs. Endurant expects the conversations with AHJs will be a key determinant in whether this solution is able to proceed at the scale outlined in this report.

The GSHP hybrid solution would be the preferred alternative if SHX is ruled out as an option. This solution uses 500' geothermal boreholes as part of a hybrid system with 868-tons of capacity sitting on the GSHP system and the remaining capacity placed on supplemental equipment including ASHPs, electric boilers, and dry air coolers. By deploying a hybrid solution, the capital costs are greatly reduced while maintaining environmental and operational value. Lastly, if there is adequate space for batery storage (5,000-10,000 sq. ft.) the site could host a battery in exchange for a revenue stream or use the asset to support demand management and yield additional operational savings.

1 Innovation QNS—Baseline Scenario

1.1 Thermal Energy Profile

Understanding a project's thermal load profile is imperative for identifying on-site distributed energy resource (DER) opportunities to meet space heating and cooling loads. This is particularly important while designing ground sourced heat pump (GSHP) systems as they require annual balancing to prevent overheating or overcooling of the ground loop heat exchanger (GLHE).

A building's thermal profile is driven by the type of space use; therefore, the first step is to create an 8760 hourly energy model that reflects the thermal energy consumption patterns of various space-uses intended for the building. Innovation QNS has a mix of residential, commercial, and retail uses. The unique consumption patterns of each use were modeled at a building-level to arrive at the site's overall annual thermal energy usage.

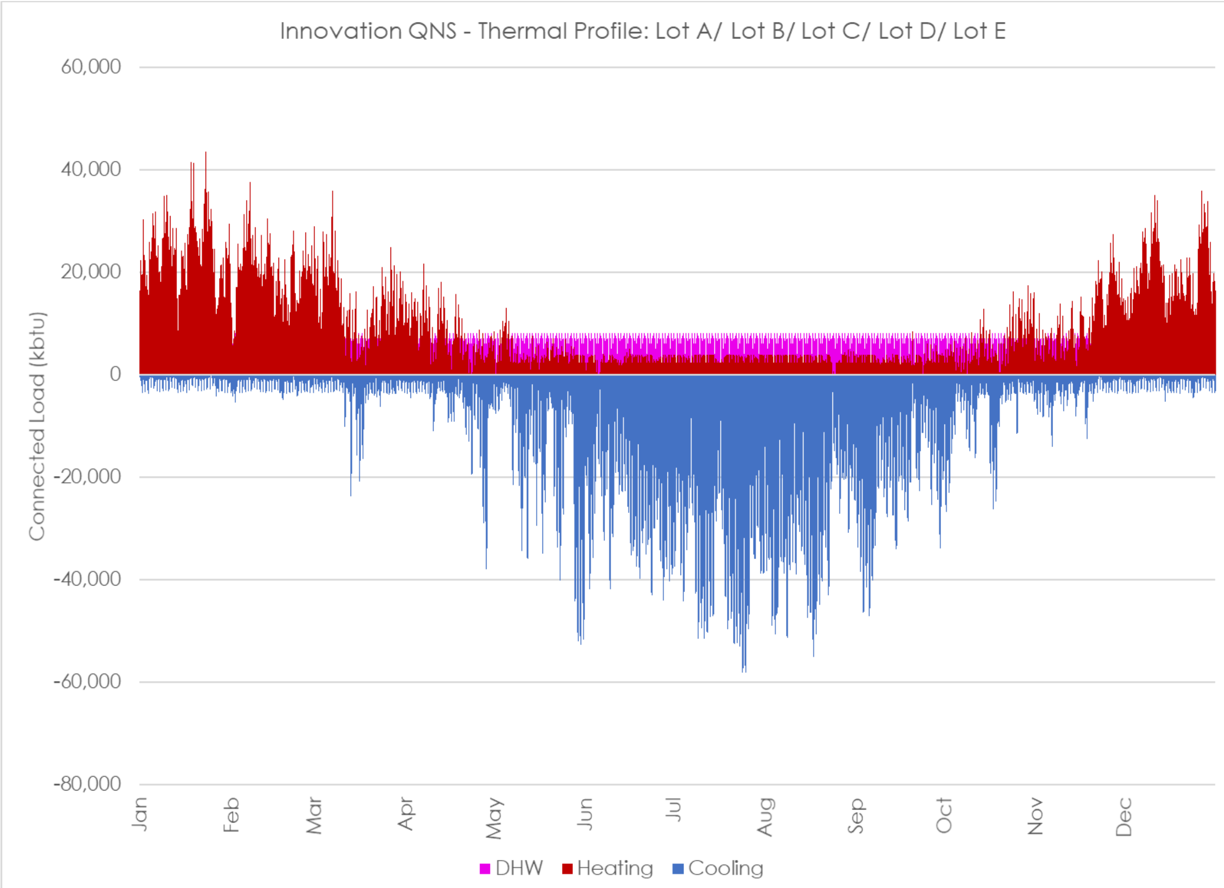
All buildings were modelled using IES VE 2019 energy modelling software based on the proposed schematic architectural design. All assumptions for envelope thermal properties, all internal loads and schedules were modelled per ASHRAE 90.1. Garages and garage ramps were assumed to be unconditioned spaces. Modelling assumptions are further detailed in the Appendix.

Hourly thermal load profiles were developed for each building and broken down by use-type: residential, office, retail, and back-of-house spaces. By modelling unique use-types we can more accurately project utility costs as time-of-use is an important variable in electricity consumption.

Table 1. Aggregated Thermal Profile for Innovation QNS (Blocks A, B, C, D, and E Combined)

Peak Heating (kBtu/hr)	43,600
Peak Cooling (kBtu/hr)	58,192
Peak Domestic Hot Water (kBtu/hr)	8,118
Annual Heating Load (kBtu)	71,414,571
Annual Cooling Load (kBtu)	87,266,365
Annual Domestic Hot Water Load (kBtu)	37,150,779

Figure 1. Annual Thermal Profile for Innovation QNS (Buildings A, B, C, D, and E Combined)



The lot-level summary of Innovation QNS forms the baseline against which the proposed heat pump systems will be compared. A more detailed breakdown of building level thermal profiles and operating costs is available in the appendix.

Table 2. Block Level Thermal Profiles

Lot	A	B	C	D	E
Modelled Area (sq. ft.)	667,971	682,764	434,590	704,327	572,457
Peak Heating (kBtu/hr)	8,818	8,266	6,769	11,428	8,318
Peak Cooling (kBtu/hr)	12,258	11,512	8,846	14,628	11,269
Peak Domestic Hot Water (kBtu/hr)	1,620	2,117	1,095	1,917	1,369
Annual Heating Load (kBtu)	14,051,234	14,977,622	10,776,269	18,486,722	13,122,684
Annual Cooling Load (kBtu)	18,902,075	19,324,199	12,514,432	20,729,925	15,795,734
Annual DHW Load (kBtu)	7,451	9,656,701	4,995,582	8,748,162	6,298,879

1.2 Baseline Capital and Operating Costs

In addition to estimating annual thermal loads, the building energy model also quantifies the input energy (electricity or natural gas) required to run equipment to provide the thermal loads. This is useful to estimate baseline utility costs associated with providing the projected space heating and cooling energy across the development. The baseline configuration assumes variable refrigerant flow (VRF) driven heating, cooling, and gas fired domestic hot water (DHW) for all blocks. The 8760 profiles were run through Endurant Energy's proprietary tariff engines, which simulate delivery and supply costs by mirroring how Con Edison would meter and bill for electricity and/or gas delivery. The tariff calculator is based on current, published tariff leaves and includes all applicable surcharges, riders and taxes that are typically applied to Con Edison bills. For this analysis, we assumed fully bundled Con Edison service (i.e., Con Edison rates for delivery and supply).

The rate class modeled for each solution depends on the metering configuration (e.g., a single master meter for the entire development versus distributed, building or unit-level meters), as well as the peak kilowatt (kW) demand for the solution. The total input electrical energy for the baseline VRF systems was divided by the number of residential apartment units to estimate electricity for a direct-meter setup. Each apartment is assumed to be on Con Edison's SC1 Rate 1 (Residential and Religious). Each commercial/retail space is assumed to be on Con Edison's SC9 Rate 1 (General-Large with peak kW demand less than 1,500 kW).

In addition to utility costs, operations and maintenance costs associated with VRF systems were also estimated and included in the overall operating cost estimates. The annual operating costs for each block are summarized in Table 3.

Table 3. Annual Operating Costs and Associated Emissions Based on Electricity and Gas Consumption

Block	A	B	C	D	E	Total
Annual Business as Usual Utility Costs	$1,243,490	$1,295,556	$805,253	$1,373,280	$929,454	$5,647,033
Annual Maintenance Costs	$100,422	$92,947	$60,588	$97,398	$81,845	$433,200
Annual CO_2 Emissions (tons)[1]	1390	1391	840	1475	994	6090

Endurant Energy's engineering, procurement and construction (EPC) team worked with several reputed equipment manufacturers and local contractors to develop budgetary estimates for baseline equipment. Multiple price quotes were used to ensure budgetary estimates are in-line with market pricing for the specified equipment. The estimated capital costs for the baseline VRF-driven system are summarized in Table 4.

Table 4. Capital Cost Estimates for Variable Refrigerant Flow Heating/Cooling and Gas Fired Domestic Hot Water

Block	A	B	C	D	E	Total
Capital Cost	$22,136,000	$20,488,000	$13,355,000	$21,469,000	$18,041,000	$95,489,000

Table 5. Capital Cost Components for the Business-as-Usual Scenario

Building	• 1.5-ton air-cooled VRF condenser • Refrigerant distribution • DHW storage • DHW distribution
Soft Costs	• Contingency • Design • Permitting • Project Management

1.3 Baseline Life-Cycle Cost Analysis

Endurant conducted a 30-year life cycle cost analysis (LCCA) for the aggregated district as outlined in Table 6. The LCCA summarizes the operational and capital costs to construct a business-as-usual scenario. The LCCA considers capital costs, annual utility and maintenance costs, a 2.5% inflation rate, a 3.0% escalation on utility costs, and a 4.0% discount rate. Major equipment replacement is scheduled in year 15 and year 30 for the heating and cooling equipment.

Table 6. Business-as-Usual Life-Cycle Cost Analysis

Total conditioned area (sq. ft.)	3,094,290
VRF system installed cost (including in building distribution)	$95,489,000
Major equipment replacement costs (Year 15)	$19,972,000
Annual maintenance costs	$433,000
Annual utility cost	$5,647,000
30-year Life-Cycle Cost	**$281,277,651**

2 District Thermal Energy and On-Site Energy Assets

The baseline analysis and building energy models set the business-as-usual (BAU) case against which various on-site distributed energy resource (DER) solutions are assessed. Endurant Energy followed a comprehensive process to evaluate multiple technologies and design configurations that provide a sustainable and cost-effective alternative to Innovation QNS's baseline VRF-driven system.

2.1 Technologies Assessed

Endurant Energy assessed a variety of technologies that can optimally dispatch against the modeled thermal loads while achieving greater efficiencies and life-cycle value. We explored GSHP, air source heat pumps (ASHP), and wastewater heat recovery to meet the thermal demands. Additionally, we assessed the potential for solar photovolatic (PV) and battery energy storage systems (BESS). This section will provide a brief description of each technology, its applicability at Innovation QNS, and the intended benefits.

2.1.1 Ground Source Heat Pumps

GSHPs are one of the most efficient heating and cooling technologies commercially available. The technology relies on a water sourced heat pump (WSHP) containing a refrigeration loop that drives thermal exchange between a GLHE and a working fluid (glycol- water solution) contained within the GLHE. Ground temperatures remain more stable than air temperatures throughout the year. This dynamic allows the GSHP to treat the ground as a heat source in the winter and a heat sink in the summer.

A unique benefit to developing a GSHP solution is the ability to exploit simultaneous loads. For example, a simultaneous load would be when a building is cooling and producing domestic hot water at the same time. A water-based heat pump can reject the waste heat from the cooling process into the DHW circuit. Simultaneous loads at Innovation QNS are shown in Figure 1.

Table 7. Ground Source Heat Pumps—Key Considerations

Pros	Cons
• - Most efficient heating and cooling technology (Full Load Co-efficient of Performance (COP) of 5-6)	• Higher capital costs • Impact on construction schedule
• Lowest operating cost compared to conventional equipment and other technologies assessed	
• Lower maintenance costs than conventional equipment	
• Ability to supply heating and cooling simultaneously	
• Low- to zero-carbon solution	
• Quieter operations than rooftop condensers	

Innovation QNS's annual load is well balanced, with the annual space cooling load higher than the space heating load. This suggests a cooling-dominant load profile which is preferred for a GSHP solution that uses the earth as a heat source and sink. GSHP systems require annual balancing, so that the system does not overheat or freeze. When factoring in the heat of compression[1] generated by the pumps, the profile is relatively balanced. This makes the site an excellent candidate for a geothermal system.

In this study we considered multiple GLHEs. The primary reason for considering different GLHEs is cost optimization. However, fundamentally they all operate on the same thermal principles. On this project we evaluated the impact of the following GLHEs:

- Closed-loop bores
- Energy piles
- Enerdrape panels

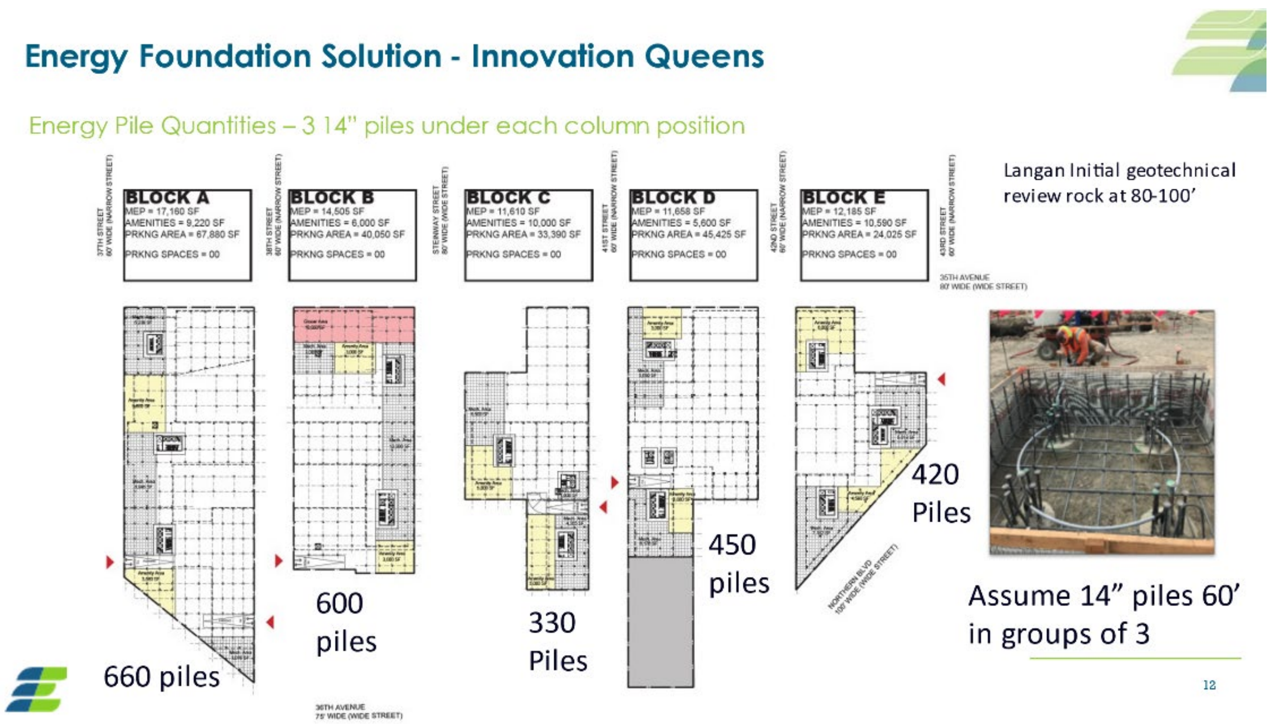
2.1.2 Closed-Loop Bores

Closed-loop bores are one of the most common geothermal GLHEs. They are typically drilled to depths between 350 feet and 1000 feet. Closed-loop bores are an excellent solution for tight building footprints and large building areas. Due to regulations in New York State, Endurant typically proposes drilling to 500 feet depths and will assume 500 feet depths for the remainder of this study. The primary drawbacks to this solution are cost and schedule impact.

2.1.3 Energy Piles

Instead of drilling 500 foot boreholes deep underneath the building, geo-loops can be placed within the foundation piles that are used as structural support for the building thereby creating an energy pile. The proposed energy pile solution at Innovation Queens would consist of a closed source water loop similar to a vertical geothermal heat exchanger, but instead, loops are placed the full depth of the foundation as part of the foundation works carried out by the piling contractor. We estimated pile lengths for this project at 60 feet. Both technology mixes were investigated for performance and financial implications.

Figure 2. Energy Piles for Innovation QNS



The table below summarizes the energy pile count and corresponding GSHP capacity for each building block. Based on capacity estimates, Endurant recommends against energy piles on this project. If during a later design stage pile lengths are significantly increased beyond 60 feet, it may be worth revisiting the concept.

Table 8. Energy Piles Summary for Innovation QNS

Building Lot	Energy pile count	Calculated geo capacity (tons)
A	660	111
B	600	105
C	330	56
D	450	75
E	420	73

2.1.4 Enerdrape Panels

Enerdrape panels are a product that acts a heat source or sink by circulating source water through panels that are fixed to unconditioned parking area walls. This could potentially alleviate the required geothermal system capacity by using the unconditioned parking garages as a means to dissipate/absorb heat.

Table 9. Enerdrape Panels Impact on Borefield

Building Lot	Parking Garage Perimeter	Estimated Flr-flr height	Total Enerdrape panel SF	Estimated annual contribution	Geo Capacity (tons)	Vertical bores (500' deep)	Vertical bores (after enerdrape panels)
A	1,389	13	18,057	22%	200	98	77
B	920	13	11,960	14%	200	105	97
C	1,218	13	15,834	28%	125	64	45
D	1,482	13	19,266	20%	200	102	80
E	622	13	8,086	12%	143	95	63

2.1.5 Sewage Heat Exchange (SHX)

Wastewater that is normally discarded into sewer lines can be diverted, separated (into liquids and solids) and passed through a heat exchanger to extract thermal energy. The average temperature of wastewater is 70ºF, which provides an excellent opportunity for thermal extraction if adequate flow rates are available.

Table 10. Wastewater Heat Recovery—Key Considerations

Pros	Cons
• Electrically powered • Can work in parallel with GLHE • Highly efficient • Performance not directly dictated by ambient conditions • Low- to zero-carbon solution	• Dependent on location and flow through mains • Variable rates of heat production depending on flow • Available thermal energy may not cover load • Local municipality considerations if connecting into publicly owned sewer infrastructure

This technology therefore ranks high in the priority list of solutions to consider for Innovation QNS. The significant hurdle likely to be faced will be from municipal authorities, as the sewer mains are publicly owned, and access to them for thermal exchange would need to be approved.

2.1.6 Air Source Heat Pumps

Air source heat pumps provide a flexible solution for backup heating and cooling capacity. In lieu of a GLHE, ASHPs rely on ambient air as a source or sink for thermal energy. A refrigeration loop drives thermal exchange between the ambient air and working fluid. This solution performs best at moderate ambient conditions (i.e., fall and spring), while performance during summer and winter dwindles significantly.

Table 11. Air Source Heat Pumps—Key Considerations

Pros	Cons
• Electrically powered • Good performance at moderate temperature (COP of 3-3.5 at 50°F) • Low- to zero-carbon solution	• Requires roof space • Reduced efficiency at extreme temperatures (<10°F). (COP of < 2.3 at 10°F) •

Innovation QNS is a relatively dense urban development with space limitations to locate mechanical systems and GLHE. ASHPs are used as a complementary technology to a GSHP system to handle unbalanced loads and peaks that exceed the GSHP capacity. Since they do not require GLHE, they are an ideal complement to a GSHP system.

2.1.7 Solar PV and Battery Energy Storage Systems

Rooftop solar PV produces electricity from solar energy. It has been widely adopted across all building types due to its technical familiarity, relatively low costs, and ease of modular installation. In addition, utility programs allow for communities to access the value of solar PV via programs administered via their utility bill.

The benefits of solar PV are limited in two ways. First, it requires area to place panels, either on rooftops, parking structures, or unused land. This requirement can be a significant limitation in urban areas where space (including rooftops) is at a premium. Second, solar PV is an intermittent resource that only generates electricity as solar energy is available. The system will not generate energy during nighttime hours and is limited when clouds obstruct sunlight. Because solar PV's energy production is intermittent, a PV system by itself cannot adequately serve an individual building's electric needs—it would need to be paired with utility grid power or a BESS. Furthermore, the dense built-environment and planned amenity spaces severely limits the amount of solar PV that can be deployed at Innovation QNS.

Table 12. Solar PV—Key Considerations

Pros	Cons
• Low capital cost	• Intermittent productions
• Able to deploy on otherwise unusable space (Rooftops, parking canopies, etc.)	• Large space requirements
• Low maintenance	

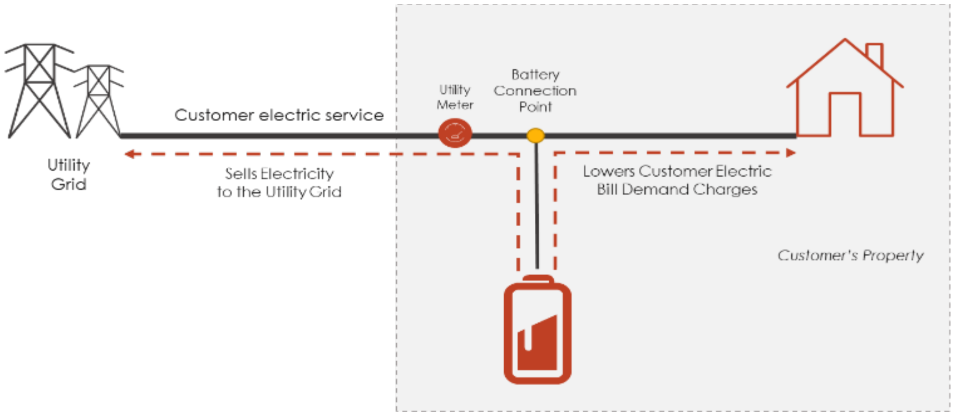
While solar PV may not be a possibility at Innovation QNS, there may be an opportunity to explore standalone BESS at the site. BESS is a versatile technology that is capable of charging and discharging electrical energy on demand. BESS technologies vary across their chemistry, though lithium-ion is currently the most commercially viable chemistry being deployed across the globe.

Table 13. Battery Energy Storage Systems—Key Considerations

Pros	Cons
• Demand response capabilities • Ability to shift production to more valuable hours in the day • Value stacking revenue streams Low capital cost	• Cost is high and often requires incentives to make projects viable

There are two main use cases for batteries in New York State. The first is a "front-of-the-meter" (FTM) application where the battery would not connect to Innovation QNS's facilities but would connect to Consolidated Edison's distribution network directly and sell energy services to the grid. In this instance, Innovation QNS would receive a simple lease payment on a monthly or annual basis as compensation for letting the battery sit on the land.

Figure 3. Illustration of Energy Storage Configuration



In the second use case, the “behind-the-meter” (BTM) model, the battery connects to Innovation QNS’s facilities. During the facility’s peak demand hours, the Innovation QNS’s buildings would draw power off the battery instead of the grid, minimizing each building’s demand on the grid for that hour (possibly even making it “zero” from the grid’s perspective) and therefore minimizing the facility’s electric bill demand charges. In some behind-the-meter applications, the battery can also back-feed into the grid to supply electricity and services to grid operators (seen in Figure 3.)

From a technical perspective, Innovation QNS’s legacy infrastructure and planned development make the site an excellent prospect for battery storage.

To start, the mixed-use plan for the property makes for a diverse, complementary load profile. This mix gives the BESS’s energy value in different ways at different times of the day or year. With 3,000 apartments, plus an additional 725 affordable housing apartments, paired with 250,000 sq. ft. of business/commercial space all planned, the commercial and residential mix rounds the energy demand curves for the development. Further, the location’s energy in the early morning hours will likely be lower, making it a more opportune time to charge at night and discharge during the day, as is typical for these systems.

If used in a behind-the-meter application, the complementarity of the loads comes into play. The time-of-use demand from daytime commercial loads to evening residential loads (peaking from 4:00 pm–8:00 pm) would make the battery valuable across different times of day.

This applies seasonally, too (winter and summer peaks versus shoulder seasons). For example, the BESS drive or curtail heat pumps during the winter and HVAC loads during the summer. Lastly, the battery could be used to provide several (~4) hours of resilient backup power during grid outages, year-round.

From a zoning perspective, Innovation Queens's lots are predominantly zoned as M-1 manufacturing or C-4 commercial zoning. This will make meeting NYC zoning requirements easier for batteries, even if the development plans to re-zone parts of the property. The map below shows the historic zoning map for the development site:

Figure 4: Historic Zoning Map

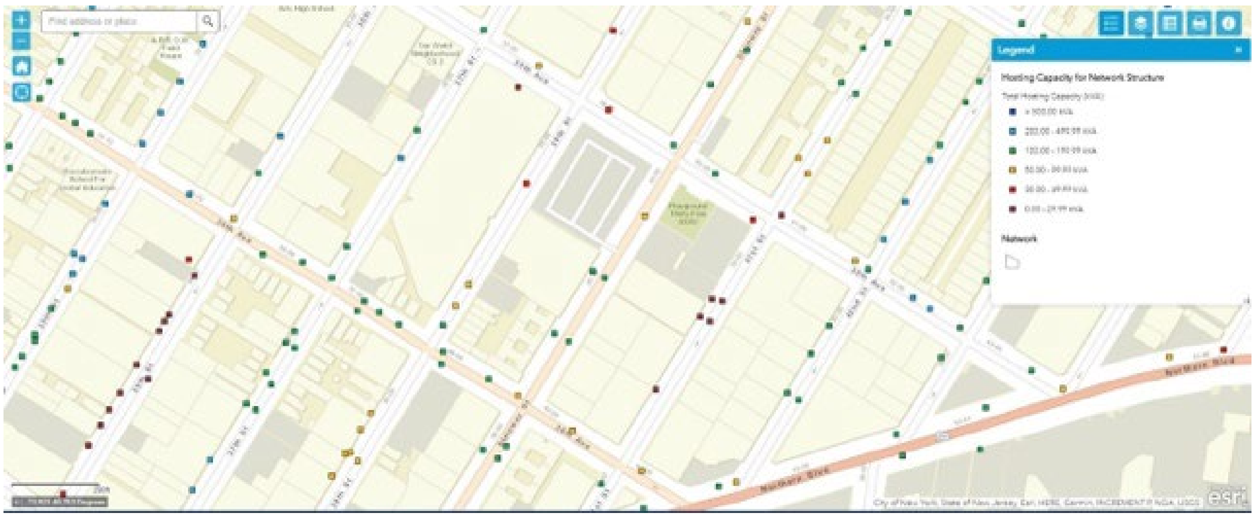
The same can be said for the floodplain analysis. Some sites closer to the water face challenges where flooding is a concern, especially during storm events. However, Innovation QNS's inland, high-elevation location keeps it outside of Federal Emergency Management Agency (FEMA) flood zone maps and within a safe area to build a battery system. The map below shows the floodplain analysis of the site. The lack of "blue" and "orange" highlights indicates that the site is outside of the flood zone area:

Figure 5. Flood Zone Map

Endurant reviewed Con Edison's existing distribution infrastructure at the site to determine the grid's ability to accommodate new energy storage on the network. Innovation QNS is within the Long Island City Networked grid area. This part of the network has ~221kVa of hosting capacity, which often limits the amount of distributed generation (or energy storage) that would be able to connect to the system without a significant and costly substation upgrade.

However, because there are several possible interconnection points across the development boundary, and the new development will certainly require distribution system upgrades at the far end of Con Edison's system, the new infrastructure could benefit greatly from having a local peaking capacity resource at that node of the grid. Additionally, Con Edison's new infrastructure could be structured to accommodate new distributed energy resources like energy storage, solar, etc. As such, given the several-block boundary of the development and the new service potential, it would be worth understanding Con Edison's distribution system upgrade plans for the development and evaluate how that would impact the grid's ability to accommodate the new storage system. The map below shows Con Edison's existing distribution infrastructure at the site:

Figure 6. Con Edison Hosting Capacity Map



With a hosting capacity limitation this low, a behind-the-meter use case that manages Innovation QNS's peak demand charges and time-of-use energy charges may be most applicable. Further, a BTM BESS used for demand management may make the most sense if there are little-to-no utility service upgrades. However, if new service is installed, and/or the cost of an interconnection upgrade is low, then a FTM system would likely be a simpler, better use case for Innovation QNS.

From an economic perspective, energy storage is highly valuable in Queens for several reasons. First, the State's most lucrative energy storage markets are under the new "Value of Distributed Energy Resources" (VDER) tariff. These markets pay batteries (and solar + storage systems) for the locational marginal value of flexibility and demand relief that they provide to the electric utility.

The "Demand Relief Value" (DRV) market, for instance, incentivizes assets that provide additional demand relief where it's needed the most, in the most densely populated networks (like New York City's). The "Locational System Relief Value" (LSRV) market, in another example, pays batteries (and solar + storage) for the demand relief it provides for that specific node on the grid. Nodes that are more congested receive "LSRV Zone" status, making them eligible for payments in that special program. Endurant Energy analyzed the local market prices and VDER rates which can be shown below:

Table 14. Innovation Queens Value of Distributed Energy Resources Value Stack Rates

Market	Rate Price
Capacity (Alternative 3)	$4.22 ($/kW)
Environmental Component	$0.03103 ($/kWh)
Demand Reduction Value (DRV)	$0.85360 ($/kWh)
LSRV	Does not Qualify

Notably, electricity and capacity prices are relatively high in Queens compared to other areas of the State (especially vs. energy costs upstate), meaning that the economics are typically strong for DER systems in NYC. NYC's (Zone J) VDER market rates are lucrative enough to make energy storage projects viable in the city without additional incentives. However, new NYSERDA grant incentives would make the project more lucrative or make "almost-viable" projects economically viable.

Endurant also evaluated the value of energy storage assets if they were paired with solar PV. Pairing the BESS with solar energy does improve project economics under ideal conditions by making them federal Investment Tax Credit (ITC) eligible and able to harvest the Environmental and Community Credit components of the Value Stack (VDER) markets. However, the economics at Innovation QNS are still not lucrative enough to justify the investment in enough solar PV to meet the 70% charging threshold needed to secure the ITC benefits. Further, to install enough PV capacity to charge the battery would require a substantial amount of land, which is a key restriction at the site and in NYC.

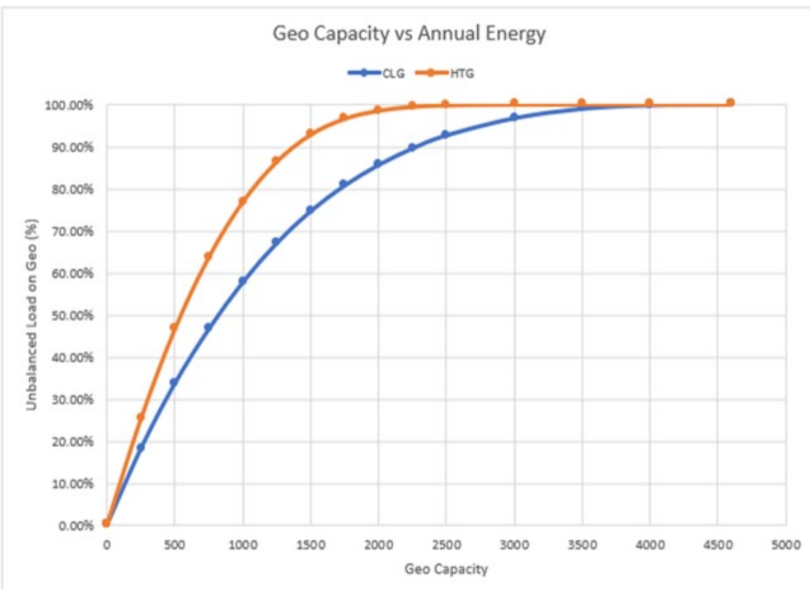
It is notable that the "Reconciliation" legislation under consideration in the US Congress is expected to include making the ITC applicable for stand-alone energy storage systems, but if and how that materializes is to be determined. In sum, even without a new ITC or solar PV, the markets for energy storage are strong enough in Queens to make a battery project lucrative.

Innovation Queens is a strong candidate for a battery storage project. With lucrative VDER tariff incentives in Queens, new utility service that will likely be able to accommodate several MW of new storage, and the balanced load profile of the planned development, energy storage has great promise at the site. Zoning and floodplain risks are very low here and are highly unlikely to be a barrier for adding batteries at the site. Storage can provide valuable lease payments to developers, while occupying a relatively small area (5,000—10,000 sq. ft.). A key hurdle for BESS development at the site would be to identify suitable areas of approximately ~5,000—10,000 sq. ft. across the development that are in close proximity to interconnection points.

2.2 District Heat Pump Concepts and Optimization

The thermal profile for Innovation QNS indicates a significant simultaneous load throughout the year, particularly during the summer months due to concurrent space cooling and DHW needs. To appropriately size the GSHP solution, the balanced simultaneous loads are excluded; the sizing is done based on the annual unbalanced load, in accordance with the principle of diminishing returns. This is illustrated in Figure 7.

Figure 7. Percent Unbalanced Load Covered (Y) versus Ground Source Heat Pump System Capacity in Tons (X)



An 868-ton system can cover 50% of the unbalanced annual cooling load and ~65% of the unbalanced annual heating load. Doubling the system size to 1,600 tons does not double the amount of unbalanced annual load covered. This principle of diminishing returns, in addition to other considerations such as the impact on ground temperature over time and overall capital expense of the system are considered when sizing the GSHP system.

Several GLHE configurations were simulated for each building to determine the level of unbalanced load covered at different system sizes. This is summarized in Table 15.

Table 15. System-Size Simulations

		Annual		Peak		
Building Loads	Geo Size (tons)	CLG	HTG	CLG	HTG	Bore count at 500' depth
A	100	53.88%	64.88%	9.05%	13.26%	52
	200	68.31%	82.24%	18.09%	26.52%	98
	300	78.50%	92.53%	27.14%	39.78%	147
B	100	58.08%	68.22%	11.77%	16.86%	52
	200	73.96%	86.82%	23.53%	33.72%	105
	300	85.23%	96.47%	35.30%	50.58%	153
C	75	52.33%	64.32%	11.29%	15.97%	39
	125	64.40%	79.65%	18.81%	26.62%	64
	200	78.33%	93.39%	30.10%	42.59%	100
D	100	49.28%	55.78%	9.00%	12.25%	52
	200	64.39%	75.36%	18.00%	24.50%	105
	300	76.09%	88.56%	27.00%	36.75%	159
E	100	55.06%	66.27%	11.47%	16.79%	52
	200	72.41%	86.77%	22.95%	33.58%	102
	300	84.15%	96.58%	34.42%	50.37%	148
Combined	500	54.68%	64.90%	10.90%	15.49%	272
	1000	71.10%	84.74%	21.79%	30.97%	529
	1500	82.66%	95.26%	32.69%	46.46%	780

Endurant focused on a closed loop solution for this project to circumvent any regulatory concerns that are typically associated with open loop systems (such as aquifer contamination). The team explored vertically drilled boreholes to a depth of 500 feet which is appropriate for both state drilling regulations and the geological factors present at the site. GLHE sized for annually unbalanced thermal loads run the risk of evaporator temperatures falling below operationally permissible limits during the peak heating season. This is particularly prevalent in northern climates where undisturbed ground temperatures are low (~50ºF) and seasonal heating demands are high. In these cases, extracting heat from the ground to provide space heating could result in the ground temperature falling below 40ºF which will cause the water flowing through the evaporator to freeze. To avoid this, a larger GLHE would be needed to increase the surface area for heat exchange to meet the peak heating loads. In sites where space is constrained and/or drilling costs are high, this can often be prohibitive.

This issue is alleviated by adding propylene glycol to the solution. The glycol-water GHLE solution has a lower freezing point, which allows for much lower evaporator temperatures. As a result, the same sized GHLE can now serve a larger peak heating load since more heat can be extracted from the ground without causing the evaporator fluid to freeze. Glycol therefore serves to lower the overall size of GLHE needed to serve peak heating loads and is a preferred approach in northern climates and projects where space is scarce and drilling costs are high. Our analysis suggests that a ~20% propylene glycol solution can reduce the GLHE size by up to, and in some cases more than, 50%.

Conversely, the addition of glycol results in a decrease in the specific heat of the GLHE solution. This means that for the same amount of heat transfer to/from the fluid, flow must increase (added pumping energy). Additionally, since the glycol solution's temperature can fall lower than pure water, the system must work to supply the same condenser temperature to satisfy heating loads by extracting heat from a GLHE with a cooler working fluid temperature. The compressor must work harder to accomplish this. The addition of glycol therefore negatively impacts the overall operational performance of the system.

The ultimate benefit of adding glycol is dependent on the interplay between lower capital costs and increased inefficiencies in operating performance. Our team tested each sizing run assuming a ~18% glycol GLHE solution. However, since the efficacy of adding glycol to the evaporator solution is highly dependent on project site conditions and location, our team recommends testing the runs without glycol as well to determine the overall benefits (or additional costs) imposed by the addition of glycol.

The process of determining the appropriate size for a GSHP system is iterative and involves studying the impact of several variables such as system cost, percentage of unbalanced load coverage, operational efficiencies, and the project's overall goals and objective related to energy and sustainability.

Based on the geo-optimization exercise presented in Table 10 and the visualization in Figure 7, a 4,000-ton system will supply the full site's unbalanced annual and peak heating and cooling loads. However, constructing a GLHE to support 4,000-tons of unbalanced load would be the costliest configuration. We determined that a more optimized capacity would be between 800 and 900 tons of capacity.

Our proposed hybrid system includes GSHP and ASHP along with conventional equipment for peak heating periods. This results in an 868-ton GSHP solution that meets the majority of the annual heating and cooling loads, with the remaining loads being served by simultaneous heat pumps, ASHPs, electric boilers, and dry air coolers. This solution will require at least 406 bores drilled 500 feet deep and spaced 20' on center. The borefield would require an estimated 162,400 sq. ft. across all five blocks.

Due to the scarce availability of green space, our team proposes siting vertical bores underneath each building. This approach is beneficial for the following reasons:

1. Reduces risk of damage to loops during excavation for horizontal pipe work.
2. Reduces excavation and material to be removed from site.
3. Easier to control water and arisings, in other words, cleaner operations.
4. Less impact on overall project schedule.

Figure 8. Drilling Vertical Bores Under a Building Foundation

This approach does require consideration and coordination of structural, utility, and other subgrade infrastructure. Table 16 indicates the space requirements for the proposed GSHP solution.

Table 16. Available Space for Vertical Bores

Building Lot	Building Footprint	% of building footprint allocated for vertical drilling	Vertical Bores (500' deep)	Geo Capacity (tons)
A	90,800	61%	98	200
B	74,865	77%	105	200
C	59,777	56%	64	125
D	87,800	68%	102	200
E	53,400	75%	95	143

In addition to the GSHP system, ASHP and conventional equipment will be deployed to meet the buildings annual and peak loads. The intent of developing a hybrid solution is to reduce overall project cost by targeting the annual load served rather than the peak. We have encountered many projects where the GSHP system can meet upwards of 90% of the annual load yet would require more than double the capacity to meet the annual peak. Capacity requires additional boreholes, which is the most expensive component of a geothermal system. By developing a hybrid solution, we aim to find the ideal capacity before we encounter diminishing returns. The table below outlines a cost optimized approach to managing baseload and peak thermal demands.

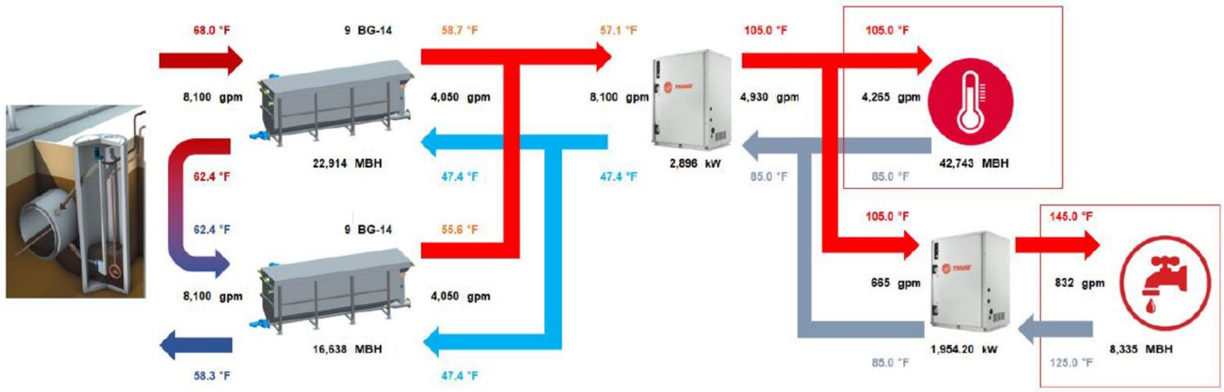
Table 17. Equipment Capacities and Annual Load Served

		CLG	HTG	CLG	HTG	CLG	HTG	CLG	HTG
		Simultaneous		**Geothermal**		**ASHP**		**Cooling Only Air-chiller**	**Electric Boiler**
A	Capacity	167 Tons		200 Tons		513 Tons	4,041 MBH	392 Tons	4,646 MBH
	Annual load (kbtu)	6,905,009	8,976,511	7,159,774	10,218,161	6,533,609	3,880,327	502,412	243,457
	% Annual load	33%	38%	34%	44%	31%	17%	2.4%	1.0%
B	Capacity	167 Tons		200 Tons		378 Tons	2,978 MBH	272 Tons	3,132 MBH
	Annual load (kbtu)	7,095,414	9,224,039	7,146,644	10,852,809	4,740,486	2,880,570	281,383	150,651
	% Annual load	37%	40%	37%	47%	25%	12%	1.5%	0.7%
C	Capacity	100 Tons		125 Tons		378 Tons	2,978 MBH	161 Tons	2,376 MBH
	Annual load (kbtu)	3,455,196	4,491,755	4,413,289	7,037,088	4,235,153	2,874,016	110,563	66,615
	% Annual load	28%	31%	36%	49%	35%	20%	0.9%	0.5%
D	Capacity	167 Tons		200 Tons		648 Tons	5,105 MBH	263 Tons	4,613 MBH
	Annual load (kbtu)	6,042,449	7,855,184	7,173,335	11,921,220	7,148,917	6,216,105	158,040	225,643
	% Annual load	29%	30%	35%	45%	35%	24%	0.8%	0.9%
E	Capacity	125 Tons		143 Tons		513 Tons	4,041 MBH	215 Tons	3,060 MBH
	Annual load (kbtu)	4,635,943	6,026,726	5,209,352	8,173,951	5,619,270	4,234,785	101,900	100,171
	% Annual load	30%	33%	33%	44%	36%	23%	0.7%	0.5%

2.2.1 Sewer Heat Exchange District Concept and Design Optimization

As an alternative to the GSHP concept, a SHX solution avoids the need for drilling boreholes across the development. Furthermore, SHX carries thermal energy downstream of the point of interconnection, therefore the system does not require annual thermal balancing. This solution presents a cost effective and highly efficient option for the site.

Figure 9. Configuration for Heating Operations from a Sewer Heat Exchange Solution



Innovation QNS sits adjacent to a 54-inch sewer line. The 54-inch sewer line is projected to have a flowrate of approximately 1,100 GPM, which is insufficient to satisfy the thermal loads at Innovation QNS. However, if the SHX system is connected to the interceptor (a major sewer line that receives wastewater flows from collector sewers), significantly larger volumes of wastewater are available for heat transfer, approximately 12,680 gallons per minute (GPM). To satisfy the overall thermal load across the development, a peak flowrate of 13,950 GPM is required. Under a conventional SHX design that deploys heat exchangers in parallel, approximately 97% of the total thermal demand can be satisfied, which would necessitate the need for conventional HVAC equipment to provide supplemental thermal energy. However, design alternatives, such as an in-series configuration that deploys heat exchangers in series, can serve to extract more thermal energy from the same sewer flow. These strategies can be explored to configure a SHX solution that can meet 100% of Innovation QNS's thermal loads.

2.3 Plant Configurations

The layout of Innovation QNS was evaluated for several configurations that could serve the heating and cooling loads across the five blocks. For each scenario, we evaluated both the GSHP configuration and the SHX configuration.

2.3.1 Central Plant

One design option for a district thermal system is to locate the major equipment in a central mechanical space (central plant). A thermal distribution system connects the buildings to the central plant, which supplies the heating hot water and chilled water to the connected buildings. This design requires space to construct the central plant but will reduce mechanical space otherwise required within the buildings.

With Metropolitan Transit Authority (MTA) subway bifurcating the site at Steinway Street we developed three central plant concepts:

1. A singular district system that traverses Steinway Street. This solution would be more cost effective than the two-district solution and would introduce more load diversity to the district.
2. Two independent central plants one serving Blocks A and B, and another serving Blocks C, D, and E. This approach would mitigate permitting requirements from the MTA.
3. Block level central energy plants delivering hot or chilled water to the block. This option will reduce the requirement for easements over public right-of-ways, but reduce load diversity.

Figure 10. Single Central Plant Serving Two Districts

Figure 11. Two Central Plants Serving Two Independent Districts

Figure 12. Decentralized Heat Pump Configuration

The central plant option assumes a four-pipe distribution (hot water and chilled water supplies and returns) configuration will connect each building to the central plant. This requires a greater investment in trenching and lateral piping than a decentralized plant concept and presents an increased chance for thermal loss/gain in the distribution network. Thermal losses/gains can be minimized with insulation. The pros and cons of the central plant configurtion are summarized below.

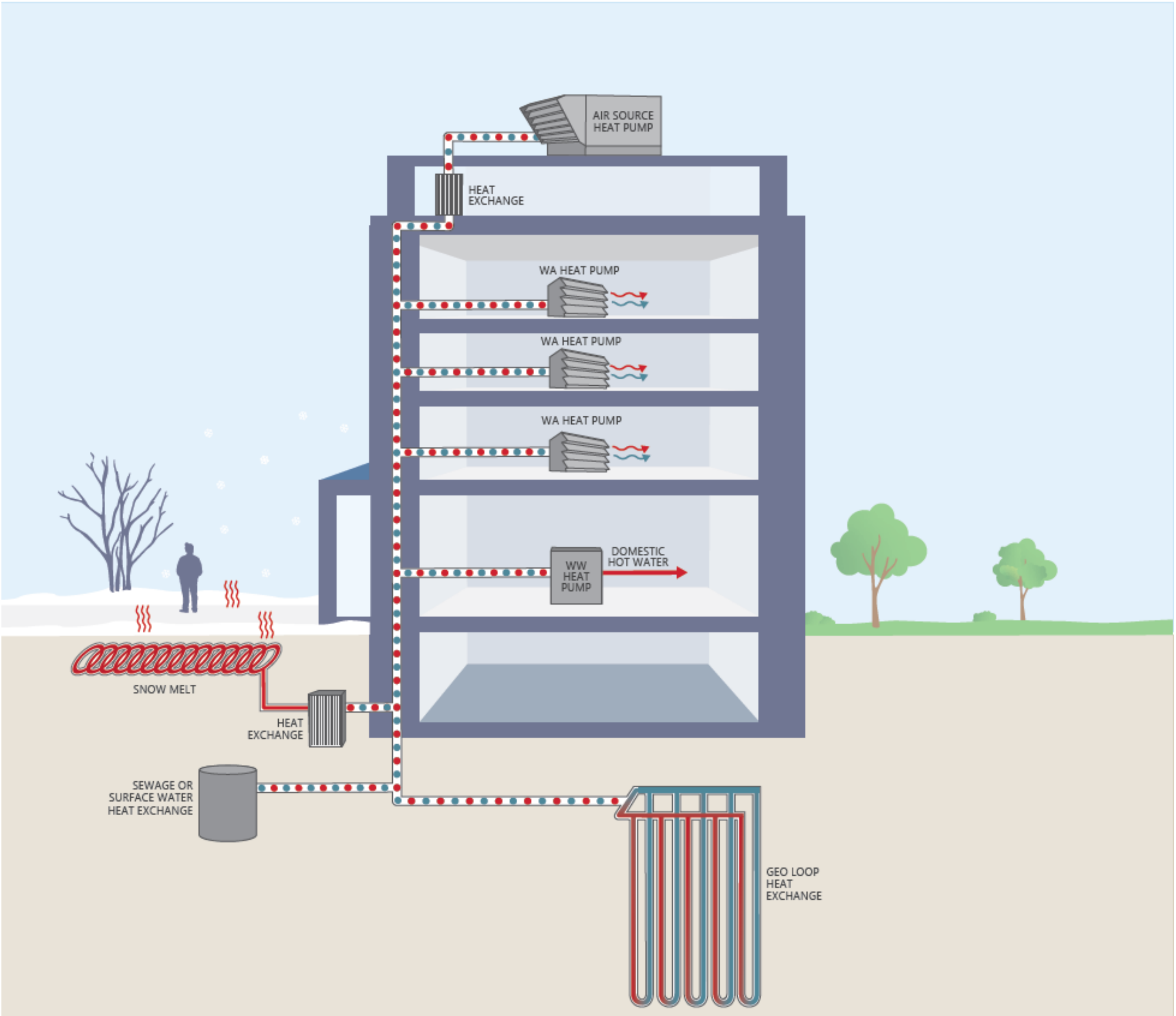
Table 18. Pros and Cons of the Central Plant Configurtion

Pros	Cons
• Economies of scale on plant equipment	• Requires greater existing space allocation or new building
• More efficient dispatch of plant assets	• 4-pipe distribution: ○ Increased investment cost for site trenching and lateral piping ○ Increased investment cost at building level
• Reduced maintenance (fewer compressors to service)	• Increased opportunity for thermal losses in distribution
• Greatest opportunity for simultaneous load	

2.3.2 Decentralized Configuration

The other design option for a district thermal system is to locate heat pump equipment in each apartment. GSHPs would supply thermal loads to the building and would be connected to the GLHE (and/or wastewater heat exchangers) via a source loop.

Figure 13. In-Unit Heat Pumps in a Decentralized Configuration



The GLHE will ideally be located as close to the source/energy loop as possible. A two-pipe distribution system will thermally connect the buildings and GLHE. The two-pipe supply/return design will reduce investment in lateral piping and trenching as compared to the four-pipe central plant design. The moderate temperature of the loop will minimize the potential for thermal losses and will not require additional insulation.

The pros and cons of a decentralized solution are summarized below.

Table 19. Pros and Cons of a Decentralized Solution

Pros	Cons

• 2-pipe distribution:
  ○ Reduced investment cost for site trenching and lateral piping
  ○ Reduced investment cost at building level
• Flexibility at building level:
  ○ Utilize 2-pipe and/or 4-pipe distribution to spaces
  ○ Supplemental assets can be localized (ASHP)
	• Less opportunity for “true” simultaneous load
	• Larger investment in equipment:
	  ○ Less opportunity for economies of scale
	  ○ Redundancy/resiliency requirements localized
	• Increased potential for maintenance (more compressors)

2.4 Resiliency

Resiliency requires consideration at every stage of development from energy modelling to operations and maintenance. During the modelling process it is important to consider the impacts of climate change on the thermal profiles of buildings. To account for this and maintain serviceability Endurant recommends the N+1 redundancy principle is followed where technically feasible. This allows for 1 unit to be serviced without negatively impacting the system’s ability to deliver peak loads, improving serviceability and resilience. The GLHE manifold design will allow each ground loop to be isolated, thereby preventing a single point of failure for the system.

Figure 14. GLHE Manifold

2.5 Capital Costs for Design Alternatives

Capital costs for each system design are estimated in Table 20 and Table 21 by building and phase.

Table 20. Capital Cost Summary—Centralized Design

	Block A	Block B	Block C	Block D	Block E	Total
BAU HVAC	$22,136,000	$20,488,000	$13,355,000	$21,469,000	$18,041,000	**$95,489,000**
SHX Design	$30,507,000	$28,236,000	$18,406,000	$29,588,000	$24,864,000	**$131,601,000**
GSHP Design	$28,663,000	$26,531,000	$17,294,000	$27,801,000	$23,362,000	**$123,651,000**

Table 21. Capital Cost Summary—Decentralized Design

	Block A	Block B	Block C	Block D	Block E	Total
BAU HVAC	$22,136,000	$20,488,000	$13,355,000	$21,469,000	$18,041,000	**$95,489,000**
SHX Design	$22,478,000	$20,805,000	$13,562,000	$21,802,000	$18,321,000	**$96,968,000**
GSHP Design	$23,503,000	$21,754,000	$14,181,000	$22,796,000	$19,156,000	**$101,390,000**

Table 22. Supply and Install Cost Components Included in Capital-Cost Budgets

	BAU HVAC	SHX Design	GSHP Design
Building	• Air-cooled VRF condenser • Refrigerant distribution • DHW storage • DHW distribution	• Water source heat pumps • Hydronic distribution for heating, cooling, & DHW[2]	• Water source heat pumps • ASHP • Electric Boiler • Dry air chiller • Hydronic distribution for heating, cooling, & DHW[3]
District Distribution	• N/A	• District loop • Sewer interconnection and heat exchangers	• District loop • Geothermal bore field
Soft Costs	• Contingency • Design • Permitting • Project Management	• Contingency • Design • Permitting • Project Management	• Contingency • Design • Permitting • Project Management

2.6 Operating Costs

Each configuration was modeled to generate an 8760 electric-energy profile of the input energy required to drive the thermal system. The 8760 profiles are run through Endurant Energy's tariff engines, which simulate electric delivery and supply costs by mirroring how Con Edison would meter and bill for electricity and/or gas delivery. The tariff calculator is based on current, published tariff leaves and includes all applicable surcharges, riders, and taxes that are typically applied to Con Edison bills. For this analysis, we assumed fully bundled Con Edison service (i.e., Con Edison rates for delivery and supply).

The rate class modeled for each solution depends on the metering configuration (e.g., a single master meter for the heat pumps versus distributed, building or unit-level meters), as well as the peak kilowatt (kW) demand for the solution. The baseline configuration assumes variable refrigerant flow (VRF) driven heating, cooling, and gas fired DHW for all blocks. Each building within the various blocks has different space uses. For each building, the following assumptions on metering configuration were made for the total input energy for the baseline VRF systems and gas fired boilers.

- Each apartment is assumed to be on Con Edison's SC1 Rate 1 (Residential and Religious) for electric service and SC1 for gas service.
- Each commercial/retail/office space is assumed to be on Con Edison's SC9 Rate 1 (General-Large with peak kW demand less than 1,500 kW) for electric service and SC2 Rate 1 or 2 for gas service.

In addition to utility costs, equipment maintenance costs are also included in the total operating costs for each configuration.

2.6.1 Centralized Plant Operating Costs

The operating costs for the centralized solutions are summarized in Table 23 below. Under a centralized configuration, all mechanical equipment associated with the technical solution is assumed to be on a single, commercial electric account. Based on the peak demand (kW) needed to drive the system(s), both SHX and GSHP hybrid will qualify for Con Edison's SC9 Rate 2 (General-Large with peak demand greater than 1,500 kW).

Table 23. Operating Cost Summary—Centralized Design

	BAU	SHX	GSHP Hybrid
Electricity use (kWh)	12,469,757	11,604,610	12,711,420
Gas (therms)	423,772	-	-
Annual gas utility costs	$1,722,885	-	-
Annual electric utility costs	$3,924,160	$2,547,664	$3,212,897
Annual maintenance costs	$433,000	$159,000	$185,657
Total operating cost	$6,080,045	$2,706,424	$3,398,554
Operational savings (Year 1)	**-**	**$3,373,621**	**$2,681,491**

A centralized plant's inherent advantage is that it will be billed as one large commercial account, as opposed to unit-level or block-level billing. Unit-level or block-level billing will result in the accumulation of each meter's fixed charges such as customer charge, taxes, and demand charges, which will result in a higher annual utility cost estimate. This is avoided when all usage is aggregated and billed under one account.

2.6.2 Decentralized Pant Operating Costs

The operating costs for the decentralized solutions are summarized in Table 17. Under a decentralized configuration, each block will be treated as its own "district" with dedicated mechanical equipment serving loads within that block.

The decentralized configuration will involve block-level billing. Depending on the peak kW demand modeled, each block is assumed to be either on Con Edison's SC9 Rate 1 (General-large with peak kW demand under 1,500 kW) service or SC9 Rate 2 (General-large with peak kW demand greater than 1,500 kW).

Table 24. Operating Cost Summary—Decentralized Design

	BAU	SHX	GSHP Hybrid
Electricity use (kWh)	12,469,757	11,604,610	15,277,159
Gas (Therms)	423,772	-	-
Annual gas utility costs	$1,722,885	-	-
Annual electric utility costs	$3,924,160	$2,694,201	$3,403,000
Annual maintenance costs	$433,000	$159,000	$ 185,657
Total operating cost	$5,647,044	$2,852,961	$3,588,657
Operational savings (Year 1)	**-**	**$2,794,083**	**$2,058,842**

While both the centralized and decentralized GSHP and SHX configurations offer significant operational cost savings compared to the base case, the centralized configuration offers the greater savings of the two.

2.7 Carbon Savings

The baseline HVAC system for Innovation QNS is a VRF for space heating and cooling with gas-fired boilers for DHW. As such, the carbon emissions associated with HVAC operations are dependent on the fuel-mix of the local electric grid and the carbon dioxide (CO_2) content of natural gas. Both the SHX and GSHP hybrid solutions require less electricity to supply the district's thermal demands. To estimate carbon emissions, we assumed the same carbon intensity factor used in Local Law 97 (0.2890 kg/kWh of CO_2).

Table 18 below summarizes the reduction in tons of CO_2 per year for the SHX and GSHP hybrid solutions when compared to the baseline VRF + gas boiler system.

Table 25. Summary of Annual Carbon Dioxide Reductions

	BAU	SHX	GSHP Hybrid
Electricity use (kWh)	12,469,757	11,604,610	12,711,420
Gas usage (therms)	423,772	0	0
Annual CO_2 emissions (tons)	5,350	3,353	3,673
Annual CO_2 reduction (tons)	**-**	**1,997**	**1,677**

2.8 Potential Incentives

While geothermal heating and cooling technologies offer a compelling on-site solution that offers operating cost savings and sustainable on-site energy, a significant hurdle in their deployment is high upfront capital expenses. These projects benefit from incentives that serve to lower the upfront costs. There are four incentive programs applicable to the proposed SHX or GSHP hybrid solution at Innovation QNS.

Potential incentives may vary depending on a variety of factors. Each incentive program outlined in this section does require certain qualifying criteria that may apply to either the applicant or project. Once qualifying criteria are met, most incentive programs require a technical third-party review to verify the methodology and assumptions behind an incentive application. Additionally, incentive funds can be exhausted or sunset.

2.8.1 New York State Clean Heat Incentive

The NYSCHI[4] is a statewide incentive program administered through the New York State Joint Utilities[5]. The program has a variety of incentive categories that encompass small to large scale energy projects and numerous heat pump-based technologies. This is a performance-based incentive that compensates the project based on energy savings generated against a standard New York State code compliant energy baseline. The incentive value is calculated by taking the difference in annual heating and cooling energy between the BAU and geothermal HVAC systems and multiply it by the prescribed incentive value.

Innovation QNS will qualify for Category 4: Custom Incentives. This category pays $200 per MMBtu of energy savings generated. Within Category 4, the Category 4A– Heat Pump + Envelope allows for additional incentives if the dominant load is reduced by 5% by implementing eligible measures including:

- Window Replacements
- Window Film
- Wall Insulation
- Continuous Insulation
- Window Walls
- Curtain Walls
- Exterior Façade
- Air Leakage Sealing
- Air Barrier Continuity
- Roof Insulation

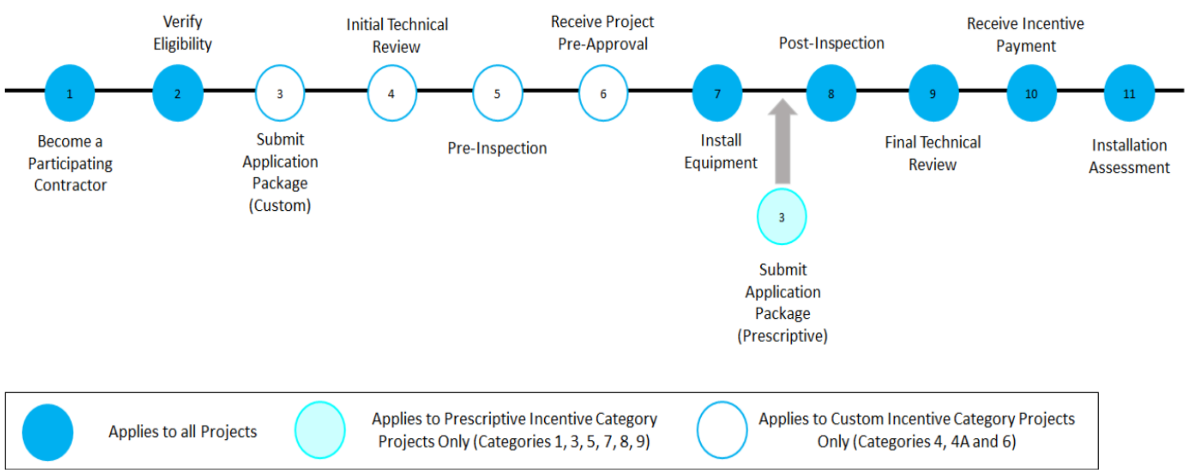
The applicability of any additional incentives from Category 4A to Innovation QNS will depend on the eventual envelope design parameters.

The application for these incentives, followed by Con Edison's review and incentive approval, must be completed prior to the installation. The application requires the following elements:

- Completed Program Application
- Cutsheets for Proposed Equipment
- Cost Estimate for Proposed Work
- Load Calculations
- Detailed Scope of Work
    - Description of baseline
    - Description of the extent of the work
    - Specify type of heat pump technology
    - Provide design capacity

- Specify what percentage of the design heating/ cooling load heat pumps will meet
    - Specify whether supplemental heating is required
        - Describe why electrification is non-feasible
        - Document a controls strategy that prioritizes heat pump dispatch
- Approved Department of Buildings Permit Submission
- Savings Analysis

Figure 15. Application and Approvals Timeline for New York State Clean Heat Incentive



2.8.2 NYSERDA New Construction Housing Program

NYSERDA's New Construction Housing Program under Program Opportunity Notice (PON) 4337 provides support for highly efficient new construction multifamily buildings. Innovation QNS would qualify for this program based on the reduction in input energy needed for the SHX and GSHP hybrid solutions compared to a code compliant baseline.

Under PON 4337 there are two incentive tiers and two categories: Market Rate and Low-moderate income (LMI). Incentive values increase based on performance tiers, and LMI category projects receive higher payments than Market Rate. Our analysis indicates Innovation QNS would qualify under the 30% Performance Threshold at Market Rate.

PON 4337 also contains an additional incentive for commercial space paid out at a rate up to $2/SF, with a cap of $250,000 per project. This incentive can be layered on top of residential incentives. Incentives are paid out in three milestones as defined in Table 27.

Table 26. Incentive Rate Schedule under PON 4337

Market Rate			Performance	LMI		
Residential Space Type 1 (per Dwelling Unit)	Residential Space Type 2 (per Square Foot)	Cap on per Project Incentives, exclusive of the commercial space incentive		Residential Space Type 1 (per Dwelling Unit)	Residential Space Type 2 (per Square Foot)	Cap on per Project Incentives, exclusive of the commercial space incentive
$1,000	$1.00	$300,000	20% Threshold	$2,000	$2.00	$400,000
$2,500	$2.00	$500,000	30% Threshold	$4,000	$4.00	$600,000

Table 27. PON 4337 Incentive Milestone Payment Schedule

Milestone 1 Proposed Design	Milestone 2 Open Wall	Milestone 3 As Built
40%	**30%**	**30%**
• Proposed design meeting eligibility thresholds • Deliverable: Contracts between engineer and project, LMI Qualifications, Energy Models, Design Documents, Workbooks	• 30% completion of various measures: exterior insulation, insulated concrete form, exterior insulation and finishing systems, interior insulation only, exterior insulation with interior insulation, prefabricated exterior wall assembly and modular construction • Deliverable: Multifamily Workbook, checklists, multifamily high-rise measurement & verifications, photo documentation	• Project Completion • Deliverables: Multifamily workbook or equivalent, photo documentation as required, as-built energy modeling files, ASHRAE path calculator or approved equivalent, proof of review by Multifamily Review Organization, HVAC functional testing checklist, testing and verification worksheets

2.8.3 NYSERDA Community Heat Pump Systems

PON 4614 is a competitive solicitation designed to support the development of district scale heat pump systems. A qualifying district contains at least 2 buildings with a total area of greater than 40,000 sq. ft. or at least 10 buildings of any size. The program contains four categories that support different stages of the heat pump design and development.

- Category A—offers up to a $100,000 contribution to study a district heat pump system with no cost share required.
- Category B—offers up to a $500,000 contribution to the design of a district scale heat pump system with a 50% cost share required.
- Category C—offers up to a $4 million contribution towards the construction of a district scale heat pump system.
- Category D—offers up to $250,000 to support the development of best practices guidebooks for district scale heat pump projects.

2.8.4 Federal Accelerated Depreciation Schedules

Geothermal assets are eligible for accelerated methods of depreciation such as Bonus Depreciation and Modified Accelerated Cost-Recovery System (MACRS). Under the federal MACRS program, companies may recover investments in qualified property (including geothermal ground source heat pumps) via depreciation deductions on an accelerated schedule. When MACRS is elected, one of the two types of systems apply: the General Depreciation System (GDS) or the Alternative Depreciation Systems (ADS) which determine the depreciation method and recovery periods used. GDS is generally used unless ADS is required by law. Under GDS, property is depreciated over 3, 5, 7, 10, 15, 20, 25, 27.5, and 39 years depending on the property class as defined by the IRS. Bonus depreciation of 100% in the first year is available for qualified property placed in service between September 27, 2017 and January 1, 2023.[6]

2.8.5 Federal Business Energy Investment Tax Credit

The Federal Business Energy Investment Tax Credit (ITC) is a tax credit that may be claimed for qualifying investments in renewable technologies. The ITC has been extended on numerous occasions. Currently, the ITC rate for qualifying geothermal heat pumps is set at 10%.[7] It is due to expire at the end of 2023.

The value of the ITC may be monetized via a reduction in federal taxes owed by the project owner. Real estate developers or project owners that have an effective tax rate of 0% or near 0% will not be able to monetize this benefit. Alternatively, there are tax equity investors who may be able monetize this tax credit via an equity partnership role in the project. Under Endurant's EaaS we can partner with tax equity investors to monetize the ITC benefit on behalf of the project.

This incentive applies only to GSHP equipment and downstream distribution equipment receiving at least 75% of the annual thermal energy from the GHSP system. For example, a fan coil unit delivering heat that is at least 75% derived from the GSHP on an annual basis would be eligible for the ITC. The ITC must be monetized within one year of initial operations and cannot be monetized before the equipment becomes operational.

It should be noted that any federal tax incentives monetized through a tax equity partner are complex to structure, are not guaranteed, and require transaction costs that erode the net value of the ITC and/or accelerate depreciation.

2.8.6 Summary of Incentive Values for Innovation QNS

The total estimated incentive value applicable to Innovation QNS from each of the programs identified above is summarized in Table 28 and Table 29.

Table 28. Summary of Incentives for Ground Source Heat Pumps

Program	Block A	Block B	Block C	Block D	Block E	All Blocks
NYSCHI	$4,712,000	$5,650,000	$3,555,000	$6,016,000	$4,352,000	**$24,285,000**
PON 4337	$1,313,300	$1,095,480	$1,021,060	$1,630,840	$1,072,800	**$6,133,480**
ITC[8]	$2,350,300	$2,175,400	$1,418,100	$1,448,000	$2,747,200	**$10,139,000**
Total	**$8,375,600**	**$8,920,880**	**$5,994,160**	**$9,094,840**	**$8,172,000**	**$40,557,480**

Table 29. Summary of Incentives for Sewer Heat Exchange

Program	Block A	Block B	Block C	Block D	Block E	All Blocks
NYSCHI	$4,852,800	$5,739,200	$3,676,200	$6,264,600	$4,507,200	**$25,040,000**
PON 4337	$1,313,300	$1,095,480	$1,021,060	$1,630,840	$1,072,800	**$6,133,480**
ITC[9]	$2,148,800	$1,988,900	$1,296,400	$2,084,100	$1,751,300	**$9,269,500**
Total	**$8,314,900**	**$8,823,580**	**$5,993,660**	**$9,979,540**	**$7,331,300**	**$40,442,980**

The impact of each incentive value is considered on total project costs and life-cycle cost analyses in the following section.

2.9 Life-Cycle Cost Analysis

Endurant conducted a 30-year life cycle cost analysis (LCCA)for each design alternative as outlined in the tables below. The LCCA summarizes the initial capital expense and annual operational expense associated with each scenario. The LCCA considers capital costs, annual utility costs, and maintenance costs for the solution as well as 2.5% inflation rate, 3.0% escalation on utility costs, and 4.0% discount rate. Major equipment replacement is scheduled for the heating and cooling equipment. Finally, the benefit of upfront incentives is considered while calculating the life-cycle cost of each solution.

For the purposes of this analysis, we have excluded ITC in the incentive stack. The ability of SHX to qualify for ITC remains an open item. In addition, the construction schedule for these buildings is not likely to align with the requirement to have the systems at mechanical completion by the end of 2023 when the current ITC for geothermal expires. It may be extended, as it has historically, but any extensions are not available as of this report.

Table 30. Life-Cycle Cost Analysis—Centralized Sewer Heat Exchange

Total conditioned area (Sq. Ft.)	3,094,290
SHX installed cost	$131,601,000
Estimated incentive value (without ITC)	$31,173,480
SHX installed cost net incentives	$100,427,520
Major equipment replacement costs (Year 20)	$9,149,000
Annual maintenance costs	$159,000
Annual utility cost	$2,548,000
30-year Life-Cycle Cost	**$177,147,000**

Table 31. Life-Cycle Cost Analysis—Centralized Hybrid Ground Source Heat Pump

Total conditioned area (Sq. Ft.)	3,094,290
GSHP hybrid installed cost	$124,540,000
Estimated incentive value (without ITC)	$30,418,480
GSHP hybrid installed cost after applying incentives	$94,121,520
Major equipment replacement costs (Year 20)	$15,060,000
Annual maintenance costs	$155,000
Annual utility cost	$3,213,000
30-year Life-Cycle Cost	**$192,400,000**

Table 32. Life-Cycle Cost Analysis—Decentralized Sewer Heat Exchange

Total conditioned area (Sq. Ft.)	3,094,290
SHX installed cost	$96,968,000
Estimated incentive value (without ITC)	$31,173,480
SHX installed cost after applying incentives	$65,794,520
Major equipment replacement costs (Year 20)	$21,781,000
Annual maintenance costs	$217,000
Annual utility cost	$2,694,000
30-year Life-Cycle Cost	**$157,145,000**

Table 33. Life-Cycle Cost Analysis—Decentralized Hybrid Ground Source Heat Pump

Total conditioned area (Sq. Ft.)	3,094,290
GSHP hybrid Installed cost	$101,390,000
Estimated incentive value (without ITC)	$30,418,080
GSHP hybrid installed cost after applying incentives	$70,971,920
Major equipment replacement costs (Year 20)	$33,263,000
Annual maintenance costs	$217,000
Annual utility cost	$3,403,000
30-year Life-Cycle Cost	**$189,284,455**

3 Regulatory Review

A district scale geothermal heating and cooling project is a relatively new concept; as such, there is a lack of precedent in New York City to follow in terms of rules, regulations, and requirements of various stakeholders. Endurant Energy worked with a team of internal experts and external consultants to conduct a comprehensive review of the regulatory landscape for district-scale thermal solutions. The regulatory review identified approximately 30 different agencies, stakeholders, and Authorities Having Jurisdiction (AHJs) from whom various permits, approvals and general support need to be sought.

The SHX solution will require adherence to City requirements around system design and connections to the sewer mains, maintaining sewer temperatures and right of way restrictions. Further, any interaction with the sewer system will require coordination and approval from City Officials.

Other pertinent regulatory considerations relate to tenant sub-metering, maintaining standards of heat delivered to tenants and monetizing tax benefits efficiently. These regulatory hurdles can be overcome through effective contractual arrangements.

Recommended contractual arrangement include:

1. **Third-Party Energy Services.** An energy services agreement with Endurant as the geothermal system operator will be required if Endurant owns and operates the geothermal system. Any arrangements with a third-party energy services provider should require performance and compliance consistent with developer obligations to tenants and requirements that may be imposed by the New York Public Service Commission or other government agencies in relation to provision of heat to tenants.
2. **Submetering and Tenant Leases.** If the project plans to submeter heating services so that individual tenants control their usage and pay for their heat services on an individual basis, submetering arrangements should be approved by the Public Service Commission prior to entering leases with any tenants. Leases should then be drafted with language clearly allocating financial responsibility for billed to the tenant.
3. **Submeter Billing.** The developer or a third-party energy service provider operating the system will be required to use an approved form of bill and maintain billing service and dispute mechanisms as required by New YorkState's submetering regulations. The developer or third-party energy service provider may desire to contract with a third-party billing provider to comply with these requirements. Such arrangements must provide compliance with any applicable landlord-tenant laws.

4. **Tax Optimization**. The geothermal system is a depreciable asset that provides opportunities for tax-advantaged financing. The form of ownership for those assets can be separated from the project and its phases to exploit tax advantages. A separate geothermal financing structure potentially improves the financial return of the overall project; however, this must be weighed against the additional complexity and legal risk in the event of a failure to meet obligations for any reasons or a legal dispute.

A detailed report of the regulatory analysis conducted for district geothermal system feasibility in New York City is provided in the appendix.

4 Commercial Alternatives

There are two commercial options available for the proposed SHX or GSHP hybrid solution. The first is an Energy-as-a-Service (EaaS) model. Under this offering, Endurant would design, build, own, operate, and maintain all heat pump equipment and the GLHE serving the building's heating, cooling, and DHW loads. The second is a more traditional engineering, procurement, and construction (EPC) service to develop the project. Silverstein Properties would own the equipment and subcontract the various project components, as they would in the baseline scenario with conventional HVAC equipment. These two business models are explored in greater detail below.

4.1 Energy-as-a-Service

EaaS is a comprehensive solution that Endurant offers clients for the development, construction, ownership, and maintenance of bespoke energy solutions for specific sites, delivered through an energy services agreement. It may include a wide array of services and products and is tailored to meet the specific needs of each project.

Developing distributed, on-site energy systems enhances reliability and energy flexibility, and will position the development to better adapt to future changes in the energy landscape. Localized generation can produce revenue streams, electrified heating and cooling systems can be used in demand response programs, and energy storage can support resiliency. As Silverstein Properties' EaaS partner, Endurant will develop a solution that will serve as a platform for long term value creation.

4.1.1 Endurant's EaaS offering

Endurant's EaaS offering includes DBOOOM (Design, Build, Own, Optimize, Operate, Maintain) services across the following technologies:

- Ground Source and Air Source Heat Pumps
- Solar PV/Solar Thermal
- Battery Energy Storage Systems (BESS)
- EV Charging
- Fuel Cells
- Combined Heat and Power (CHP)
- Demand Management
- Energy supply contracts
- Efficiency upgrades

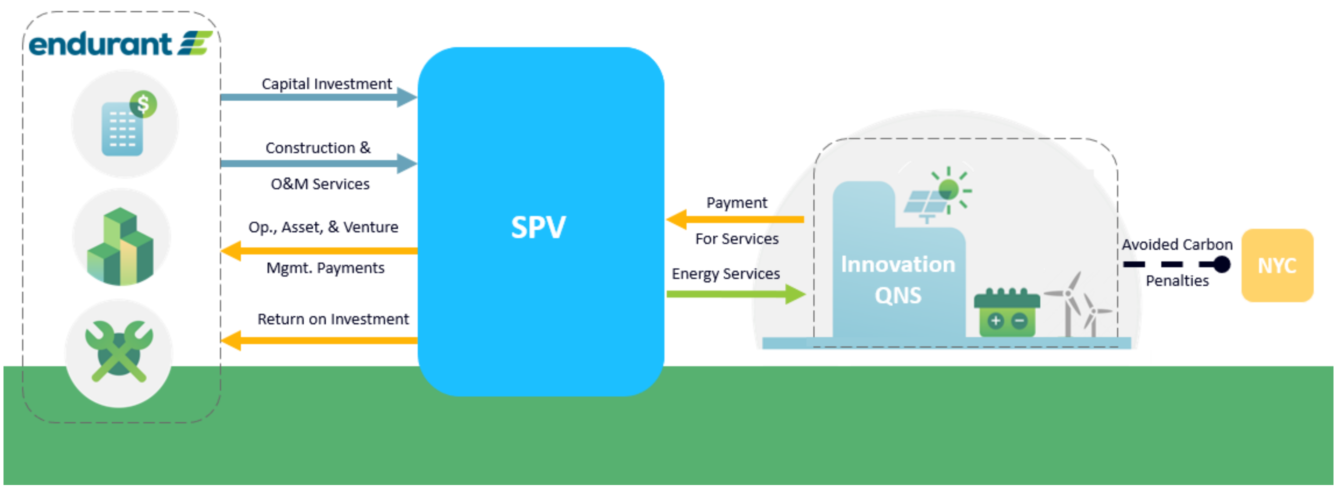
For the proposed thermal solution (either SHX or GSHP hybrid), Endurant's EaaS will encompass the following services:

- Detailed Design
- Installation
- Commissioning
- Operations/ optimization and Maintenance
- Decommissioning
- Project financing

All phases are presently owned by the same entity but will be subdivided into separate tax lots within separate special purpose vehicles upon commissioning.

Figure 17. Below illustrates the overarching relationships and responsibilities in the EaaS business model

Figure 16. Energy-as-a-Service Business Model



Endurant will set up a Special Purpose Vehicle (SPV) that will develop, finance, build, own, optimize and operate the proposed SHX or GSHP hybrid system. A core component of the EaaS model is to simplify counter-party relationships. In our proposed structure, the SPV will contract directly with the building owner/operator for Energy Services, namely heating and cooling energy from the system. From the building owner's perspective, this relationship would be like their relationship with Con Edison in the BAU case, i.e., a payment in exchange for the heating energy (either gas or electricity).

The annual capacity fee includes a "turnkey" service to the building, including provision of energy as well as timely maintenance. There are unique advantages to the EaaS business model proposed here:

1. The building owner receives the benefit of installing GSHP without the risk of financing and owning the asset.
2. Endurant can wrap several value-added benefits into the EaaS, such as:
   - Hedged electric supply pricing, if determined to be necessary for the project.
   - Monetization of tax-based benefits such as the ITC and depreciation, which serves to improve project economics for all stakeholders involved.
   - Electric supply can be sourced from fully renewable sources, which will help position the project as 100% green and renewable.

The EaaS business model's fundamental tenet is to maximize value to all stakeholders, as summarized in Table 34.

Table 34. Energy-as-a-Service Benefits Summary

Stakeholder	Benefits of EaaS Business Model
Developer	• Lower utility/operational costs incurred to provide heating and cooling to tenants • Low risk since the developer is not responsible for financing and owning a complex DER project on their balance sheet • Improves the brand value and marketability of future development projects
Tenants	• Lower utility costs
Endurant	• Directly in-line with our mandate to deploy capital and own DER projects • Builds on our expertise in GSHP design, construction, and financing
Community	• More efficient thermal energy means more carbon emission reductions • Eliminate on-site emissions completely • Serves as a proof-of-concept for the scalability of this model to other parts of the community

4.2 Engineering, Procurement, and Construction (EPC)

The EPC model represents the "business-as-usual" approach. Under this model, Silverstein Properties would design, build, own, operate, and maintain the proposed solution and equipment through multiple subcontracts. Value for tenants is realized via operational savings produced by the efficiencies of the proposed system. However, Silverstein Properties would be exposed to more project risk than when compared to the EaaS model. Three key risks are:

- Execution Risk–throughout the development process, schedules, quality, and delivery must be carefully managed to avoid costly delays
- Economic Risk–Silverstein Properties must secure financing and service debt, or equity associated with the equipment capital costs

- Operational Risk–energy assets require on-going preventative maintenance and occasional repairs

Risks are common in the development process, and none pose an insurmountable hurdle to the project. One common misstep we have encountered in GSHP risk management is the subcontracting of various project components to multiple vendors, including the energy modelling, ground loop design, mechanical design, controls strategy, and installation. Each one of these project components interacts with one other to create an optimal GSHP system and it is therefore critical that each iteration in the design process is closely coordinated. Under the EPC approach, Endurant would strongly recommend that Silverstein Properties pursue an EPC contract that places all the GSHP design elements under one subcontractor. This approach is more likely to produce a reliable outcome while placing accountability with one subcontractor.

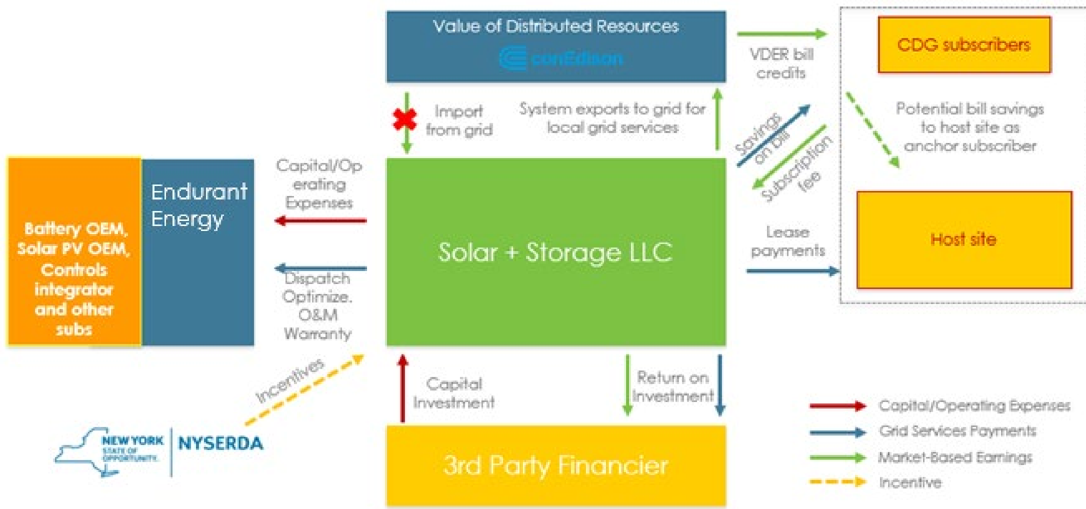
4.3 Front-of-the-Meter Community Storage

The dense built-environment and planned amenity spaces severely limits the amount of solar PV that can be deployed at Innovation QNS. Due to this, solar PV has been ruled out for Innovation QNS. However, the site was also assessed for a standalone Battery Energy Storage System (BESS) project.

New York State has an established program called Value of Distributed Energy Resources (VDER) that allows BESS systems to connect directly to the distribution grid in front of the customer meter (FTM). An asset enrolled in the VDER program generates a monetary credit for each kilowatt-hour (kWh) of electricity injected into the grid. The VDER program has several sub-options that dictate how that monetary credit can be applied to a variety of customer bills.

Community Distributed Generation (CDG) is one such version of the VDER program, which allows commercial and residential customers to "subscribe" to the output of an FTM VDER asset and see a portion of those monetary credits as savings on their bill. FTM assets deployed under the CDG VDER program offer landowners the opportunity to generate stable lease payments for use of their land (or rooftops) by third party asset developers, as well as the opportunity for Con Edison customers to subscribe to the renewable energy generated by the asset. As per the rules of the CDG VDER program, up to 40% of the total monetary credit may be allocated to a large commercial account, with the remaining 60% reserved for mass-market (residential and small business) customers. Figure 18 below summarizes the third party funded business model for the FTM CDG VDER asset.

Figure 17. Third-Party Funded FTM CDG VDER Commercial Structure



Under this business model, all credits appear as savings (or bill reductions) on each allocated subscribers' bill. The project then recovers 90%-95% of this credit as a fee (this is the primary revenue to the BESS asset owner), leaving the remainder as savings on the subscribers' bills.

Silverstein Properties would receive a lease payment from the third-party asset owner for use of their ground space. Furthermore, the proposed SHX or GSHP hybrid solution's primary Con Edison account can be designated as a subscriber to the solar PV + BESS project, thereby seeing approximately 5%-10% reduction in electricity bills. FTM VDER projects offer the following advantages:

- They are technically independent of the proposed thermal solution and can therefore be pursued in parallel; however, they create *virtual* financial benefits and enhance overall value to Silverstein Properties in the following ways:
  - Offers stable and predictable cash flows in the form of lease payments which can serve to further reduce the operating expenses associated with the thermal solution.
  - Provide savings to the Innovation QNS community without any out-of-pocket costs.
  - Enhance renewable energy attributes and overall marketability of the Innovation QNS development.
- Excess or unused credits may be shared with the wider Queens community outside of Innovation QNS.

The total VDER credits generated is driven by the New York Independent System Operator (NYISO) energy and capacity prices. Based on historical NYISO Zone J energy and capacity pricing as well as the published VDER rates for other time and location specific values (e.g., local demand reduction during peak hours in the summer), we estimate that the total savings generated for all subscribers will be in the range of $100,000–$150,000 per year.[10]

5 Recommended Approach

Key findings in the report suggest that a district thermal system would produce multiple benefits to the project joint venture (JV). The economic analysis shows significant savings opportunities and numerous avenues to buy down capital costs with incentives. From a technical perspective gas can be eliminated from the project, which would reduce interconnection costs and futureproof buildings against costly retrofits. The local community would benefit by experiencing no onsite emissions and substantial carbon savings. The project produces value for all stakeholders, and Endurant recommends pursuing a district thermal system.

The next step will be to down-select to a single technical solution and preferred configuration. A SHX system has the potential to supply 100% of the site's heating, cooling, and DHW loads with very high efficiencies. Based on these benefits Endurant recommends engaging city agencies to illustrate the concept and quantify the benefits to key AHJs. Endurant expects the conversations with AHJs will be a key determinant in whether this solution is able to proceed at the scale outlined in this report.

The GSHP hybrid solution would be the preferred alternative if SHX is ruled out as an option. This solution uses 500 feet geothermal boreholes as part of a hybrid system with 868-tons of capacity sitting on the GSHP system and the remaining capacity placed on supplemental equipment including ASHPs, electric boilers, and dry air coolers. By deploying a hybrid solution, the capital costs are greatly reduced while maintaining environmental and operational value.

Our team also recommends that Innovation QNS should consider deploying BESS at the development. Under the VDER program, each tax lot can host up to 5 MW of BESS capacity. The BESS project will follow a parallel development process and as such, would be technically independent of any onsite thermal solution project. However, the projects have the following "virtual" synergies:

- The BESS project will generate lease payments which can serve to subsidize any payments needed for the onsite thermal energy solution.
- The VDER program is akin to a "community subscription" model; as such, the electric accounts associated with the heat pumps (for either SHX or GSHP/ASHP) can subscribe to the output from the BESS and see bill savings.
- Residences across Innovation QNS or the surrounding communities in Astoria can also subscribe to the output of the BESS to see bill savings.
- Cumulatively, subscribers to VDER projects typically save 5%–10% off their baseline electric spend with no out-of-pocket costs.

The recommendation to pursue a BESS project is based on expected project economics and macro site conditions (e.g., floodplain, zoning, and local distributed generation (DG) hosting capacity on the distribution grid). However, a key hurdle is finding appropriate parcels of land (~5,000–10,000 sq. ft.) across the dense built environment of Innovation QNS that can host the proposed BESS project. Additionally, the location for the BESS needs to consider the types of buildings and space-use that are in close proximity to it.

5.1 Lessons Learned

After completing the analysis for this report, the team has two major lessons to report. First, the regulatory review and approval process for district thermal systems that interface with public, city infrastructure is novel and detailed. We would suggest early engagement with all AHJs to allow adequate time for the city to review and approve any submissions near city water tunnel infrastructure. The goal of early engagement is often to identify appropriate stakeholders and decisionmakers within the AHJ. The process of identifying the correct individuals is often not accounted for in "permitting/AHJ approval" process maps. However, it is our experience that significant time is required to connect with appropriate individuals and educate them on the proposed project.

Second, the team recognizes that district systems benefit from thermal load diversity and operate more efficiently. From a load diversity perspective, it would be better to operate a single district system that supplied thermal energy to all five blocks. However, due to existing infrastructure (such as MTA subway lines), it may be easier and more cost effective to consider two smaller (or even five) independent districts rather than a single district serving all blocks. This approach reduces exposure to regulatory and implementation risks associated with intersecting subway infrastructure and public rights of way.

Appendix A. Energy Model Assumptions

A.1 Energy Model Assumptions A1

Envelope	• Roof assembly U-0.032
	• External Wall Steel-framed assembly U- 0.064
	• External Wall below ground assembly C=1.14
	• Window assembly U-0.420; SHGC= 0.400
	• Opaque Door U-0.500
	• Ground floor unheated U=F(0.52)
	• Window to wall area assumptions
	    o Residential 30%
	    o Office 40%
	    o Retail and Lobby 50%
	    o School 40%
	• Overall window to wall area ratio: 42%

Occupancy	Occupancy per ASHRAE 90.1 space-by-space method
Interior Lighting Power Density	• Lighting power density per ASHRAE 90.1 space-by-space method • All buildings Residential Area 0.7 W/SF • Overall LPD 0.90 W/SF
Exterior Lighting	• Estimated exterior lighting 0.02 W/SF of buildings excluding garage 2,946 Watts
Miscellaneous Loads	• Receptacles plug load per ASHRAE 90.1 space by space method • Residential area 0.5 W/SF • Overall building 1.19 W/SF • 3 Elevators 20kW each

HVAC Systems	• Residential Spaces
	    o Residential Area
	        – VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
	    o Residential Area DOAS Unit
	        – VRF cooling [COP 3.5] and heating [COP 3.2]
	        – ERV 50% sensible, 50% latent effectiveness, 0.54 kW motor
	• Office/Retail/Common/School
	    o VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
	• Back of house spaces heating only with Electric Resistance [100% Eff.]
	• Unconditioned interior parking garage.

A.2 Energy Model Assumptions Block A2

Envelope	• Roof assembly U-0.032External Wall Steel-framed assembly U- 0.064
	• External Wall below ground assembly C=1.14
	• Window assembly U-0.420; SHGC= 0.400
	• Opaque Door U-0.500
	• Ground floor unheated U=F(0.52)
	• Window to wall area assumptions
	  o Residential 30%
	  o Office 40%
	  o Retail and Lobby 50%
	  o School 40%
	• Overall window to wall area ratio: 33%

Occupancy	Occupancy per ASHRAE 90.1 space-by-space method
Interior Lighting Power Density	• Lighting power density per ASHRAE 90.1 space-by-space method • All buildings Residential Area 0.7 W/SF • Overall LPD 0.69 W/SF
Exterior Lighting	• Estimated exterior lighting 0.02 W/SF of buildings excluding garage 4,727 Watts
Miscellaneous Loads	• Receptacles plug load per ASHRAE 90.1 space by space method • Residential area 0.5 W/SF • Overall building 0.47 W/SF • 4 Elevators 20kW each

HVAC Systems	• Residential Spaces
	  o Residential Area
	    – VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
	  o Residential Area DOAS Unit
	    – VRF cooling [COP 3.5] and heating [COP 3.2]
	    – ERV 50% sensible, 50% latent effectiveness, 0.54 kW motor
	• Office/Retail/Common/School
	  o VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
	• Back of house spaces heating only with Electric Resistance [100% Eff.]
	• Unconditioned interior parking garage.

A.3 Energy Model Assumptions Block A3

Envelope	• Roof assembly U-0.032
	• External Wall Steel-framed assembly U- 0.064
	• External Wall below ground assembly C=1.14
	• Window assembly U-0.420; SHGC= 0.400
	• Opaque Door U-0.500
	• Ground floor unheated U=F(0.52)
	• Window to wall area assumptions
	  ○ Residential 30%
	  ○ Office 40%
	  ○ Retail and Lobby 50%
	  ○ School 40%
	• Overall window to wall area ratio: 32%

Occupancy	Occupancy per ASHRAE 90.1 space-by-space method
Interior Lighting Power Density	• Lighting power density per ASHRAE 90.1 space-by-space method • All buildings Residential Area 0.7 W/SF • Overall LPD 0.71 W/SF
Exterior Lighting	• Estimated exterior lighting 0.02 W/SF of buildings excluding garage 5,323 Watts
Miscellaneous Loads	• Receptacles plug load per ASHRAE 90.1 space by space method • Residential area 0.5 W/SF • Overall building 0.47 W/SF • 4 Elevators 20kW each

HVAC Systems	• Residential Spaces
	  ○ Residential Area
	    – VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
	  ○ Residential Area DOAS Unit
	    – VRF cooling [COP 3.5] and heating [COP 3.2]
	    – ERV 50% sensible, 50% latent effectiveness, 0.54 kW motor
	• Office/Retail/Common/School
	  ○ VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
	• Back of house spaces heating only with Electric Resistance [100% Eff.]
	• Unconditioned interior parking garage.

A.4 Energy Model Assumptions Block A4

Envelope	• Roof assembly U-0.032
	• External Wall Steel-framed assembly U- 0.064
	• External Wall below ground assembly C=1.14
	• Window assembly U-0.420; SHGC= 0.400
	• Opaque Door U-0.500
	• Ground floor unheated U=F(0.52)
	• Window to wall area assumptions
	  ○ Residential 30%
	  ○ Office 40%
	  ○ Retail and Lobby 50%
	  ○ School 40%
	• Overall window to wall area ratio: 40%

Occupancy	Occupancy per ASHRAE 90.1 space-by-space method
Interior Lighting Power Density	• Lighting power density per ASHRAE 90.1 space-by-space method • All buildings Residential Area 0.7 W/SF • Overall LPD 0.87 W/SF
Exterior Lighting	• Estimated exterior lighting 0.02 W/SF of buildings excluding garage 1,600 Watts
Miscellaneous Loads	• Receptacles plug load per ASHRAE 90.1 space by space method • Residential area 0.5 W/SF • Overall building 0.50 W/SF

HVAC Systems	• Residential Spaces
	  ○ Residential Area
	    − VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
	  ○ Residential Area DOAS Unit
	    − VRF cooling [COP 3.5] and heating [COP 3.2]
	    − ERV 50% sensible, 50% latent effectiveness, 0.54 kW motor
	• Office/Retail/Common/School
	  ○ VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
	• Back of house spaces heating only with Electric Resistance [100% Eff.]
	• Unconditioned interior parking garage.

A.5 Energy Model Assumptions Block B1

<table>
<tr><td>Envelope</td><td>

Roof assembly U-0.032
External Wall Steel-framed assembly U- 0.064
External Wall below ground assembly C=1.14
Window assembly U-0.420; SHGC= 0.400
Opaque Door U-0.500
Ground floor unheated U=F(0.52)
Window to wall area assumptions

Residential 30%
Office 40%
Retail and Lobby 50%
School 40%

Overall window to wall area ratio: 32%
</td></tr>
<tr><td>Occupancy</td><td>Occupancy per ASHRAE 90.1 space-by-space method</td></tr>
<tr><td>Interior Lighting Power Density</td><td>

Lighting power density per ASHRAE 90.1 space-by-space method
All buildings Residential Area 0.7 W/SF
Overall LPD 0.73 W/SF
</td></tr>
<tr><td>Exterior Lighting</td><td>

Estimated exterior lighting 0.02 W/SF of buildings excluding garage 6,389 Watts
</td></tr>
<tr><td>Miscellaneous Loads</td><td>

Receptacles plug load per ASHRAE 90.1 space by space method
Residential area 0.5 W/SF
Overall building 0.49 W/SF
4 Elevators 20kW each
</td></tr>
<tr><td>HVAC Systems</td><td>

Residential Spaces

Residential Area
VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
Residential Area DOAS Unit
VRF cooling [COP 3.5] and heating [COP 3.2]
ERV 50% sensible, 50% latent effectiveness, 0.54 kW motor

Office/Retail/Common/School
VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
Back of house spaces heating only with Electric Resistance [100% Eff.]
Unconditioned interior parking garage.
</td></tr>
</table>

A.6 Energy Model Assumptions Block B2

Envelope	• Roof assembly U-0.032
	• External Wall Steel-framed assembly U- 0.064
	• External Wall below ground assembly C=1.14
	• Window assembly U-0.420; SHGC= 0.400
	• Opaque Door U-0.500
	• Ground floor unheated U=F(0.52)
	• Window to wall area assumptions
	  ○ Residential 30%
	  ○ Office 40%
	  ○ Retail and Lobby 50%
	  ○ School 40%
	• Overall window to wall area ratio: 32%

Occupancy	Occupancy per ASHRAE 90.1 space-by-space method
Interior Lighting Power Density	• Lighting power density per ASHRAE 90.1 space-by-space method • All buildings Residential Area 0.7 W/SF • Overall LPD 0.73 W/SF
Exterior Lighting	• Estimated exterior lighting 0.02 W/SF of buildings excluding garage 7,216 Watts
Miscellaneous Loads	• Receptacles plug load per ASHRAE 90.1 space by space method • Residential area 0.5 W/SF • Overall building 0.46 W/SF • 6 Elevators 20kW each

HVAC Systems	• Residential Spaces
	  ○ Residential Area
	    – VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
	  ○ Residential Area DOAS Unit
	    – VRF cooling [COP 3.5] and heating [COP 3.2]
	    – ERV 50% sensible, 50% latent effectiveness, 0.54 kW motor
	• Office/Retail/Common/School
	  ○ VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
	• Back of house spaces heating only with Electric Resistance [100% Eff.]
	• Unconditioned interior parking garage.

A.7 Energy Model Assumptions Block C1

Envelope	• Roof assembly U-0.032
	• External Wall Steel-framed assembly U- 0.064
	• External Wall below ground assembly C=1.14
	• Window assembly U-0.420; SHGC= 0.400
	• Opaque Door U-0.500
	• Ground floor unheated U=F(0.52)
	• Window to wall area assumptions
	  ○ Residential 30%
	  ○ Office 40%
	  ○ Retail and Lobby 50%
	  ○ School 40%
	• Overall window to wall area ratio: 36%

Occupancy	Occupancy per ASHRAE 90.1 space-by-space method
Interior Lighting Power Density	• Lighting power density per ASHRAE 90.1 space-by-space method • All buildings Residential Area 0.7 W/SF • Overall LPD 0.79 W/SF
Exterior Lighting	• Estimated exterior lighting 0.02 W/SF of buildings excluding garage 6,099
Miscellaneous Loads	• Receptacles plug load per ASHRAE 90.1 space by space method • Residential area 0.5 W/SF • Overall building 0.47 W/SF • 6 Elevators 20kW each

HVAC Systems	• Residential Spaces
	  ○ Residential Area
	    – VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
	  ○ Residential Area DOAS Unit
	    – VRF cooling [COP 3.5] and heating [COP 3.2]
	    – ERV 50% sensible, 50% latent effectiveness, 0.54 kW motor
	• Office/Retail/Common/School
	  ○ VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
	• Back of house spaces heating only with Electric Resistance [100% Eff.]
	• Unconditioned interior parking garage.

A.8 Energy Model Assumptions Block C2

<table>
<tr><td>Envelope</td><td>Roof assembly U-0.032
External Wall Steel-framed assembly U- 0.064
External Wall below ground assembly C=1.14
Window assembly U-0.420; SHGC= 0.400
Opaque Door U-0.500
Ground floor unheated U=F(0.52)
Window to wall area assumptions
Residential 30%
Office 40%
Retail and Lobby 50%
School 40%
Overall window to wall area ratio: 30%</td></tr>
<tr><td>Occupancy</td><td>Occupancy per ASHRAE 90.1 space-by-space method</td></tr>
<tr><td>Interior Lighting Power Density</td><td>Lighting power density per ASHRAE 90.1 space-by-space method
All buildings Residential Area 0.7 W/SF
Overall LPD 0.65 W/SF</td></tr>
<tr><td>Exterior Lighting</td><td>Estimated exterior lighting 0.02 W/SF of buildings excluding garage 2,553</td></tr>
<tr><td>Miscellaneous Loads</td><td>Receptacles plug load per ASHRAE 90.1 space by space method
Residential area 0.5 W/SF
Overall building 0.48 W/SF
4 Elevators 20kW each</td></tr>
<tr><td>HVAC Systems</td><td>Residential Spaces
Residential Area
VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
Residential Area DOAS Unit
VRF cooling [COP 3.5] and heating [COP 3.2]
ERV 50% sensible, 50% latent effectiveness, 0.54 kW motor
Office/Retail/Common/School
VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
Back of house spaces heating only with Electric Resistance [100% Eff.]
Unconditioned interior parking garage.</td></tr>
</table>

A.9 Energy Model Assumptions Block D1

Envelope	• Roof assembly U-0.032
	• External Wall Steel-framed assembly U- 0.064
	• External Wall below ground assembly C=1.14
	• Window assembly U-0.420; SHGC= 0.400
	• Opaque Door U-0.500
	• Ground floor unheated U=F(0.52)
	• Window to wall area assumptions
	  ○ Residential 30%
	  ○ Office 40%
	  ○ Retail and Lobby 50%
	  ○ School 40%
	• Overall window to wall area ratio: 34%

Occupancy	Occupancy per ASHRAE 90.1 space-by-space method
Interior Lighting Power Density	• Lighting power density per ASHRAE 90.1 space-by-space method • All buildings Residential Area 0.7 W/SF • Overall LPD 0.68 W/SF
Exterior Lighting	• Estimated exterior lighting 0.02 W/SF of buildings excluding garage 3,097 Watts
Miscellaneous Loads	• Receptacles plug load per ASHRAE 90.1 space by space method • Residential area 0.5 W/SF • Overall building 0.46 W/SF • 4 Elevators 20kW each

HVAC Systems	• Residential Spaces
	  ○ Residential Area
	    – VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
	  ○ Residential Area DOAS Unit
	    – VRF cooling [COP 3.5] and heating [COP 3.2]
	    – ERV 50% sensible, 50% latent effectiveness, 0.54 kW motor
	• Office/Retail/Common/School
	  ○ VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
	• Back of house spaces heating only with Electric Resistance [100% Eff.]
	• Unconditioned interior parking garage.

A.10 Energy Model Assumptions Block D2

Envelope	• Roof assembly U-0.032
	• External Wall Steel-framed assembly U- 0.064
	• External Wall below ground assembly C=1.14
	• Window assembly U-0.420; SHGC= 0.400
	• Opaque Door U-0.500
	• Ground floor unheated U=F(0.52)
	• Window to wall area assumptions
	  ○ Residential 30%
	  ○ Office 40%
	  ○ Retail and Lobby 50%
	  ○ School 40%
	• Overall window to wall area ratio: 36%

Occupancy	Occupancy per ASHRAE 90.1 space-by-space method
Interior Lighting Power Density	• Lighting power density per ASHRAE 90.1 space-by-space method • All buildings Residential Area 0.7 W/SF • Overall LPD 0.84 W/SF
Exterior Lighting	• Estimated exterior lighting 0.02 W/SF of buildings excluding garage 5.274 Watts
Miscellaneous Loads	• Receptacles plug load per ASHRAE 90.1 space by space method • Residential area 0.5 W/SF • Overall building 0.47 W/SF • 4 Elevators 20kW each

HVAC Systems	• Residential Spaces
	  ○ Residential Area
	    – VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
	  ○ Residential Area DOAS Unit
	    – VRF cooling [COP 3.5] and heating [COP 3.2]
	    – ERV 50% sensible, 50% latent effectiveness, 0.54 kW motor
	• Office/Retail/Common/School
	  ○ VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
	• Back of house spaces heating only with Electric Resistance [100% Eff.]
	• Unconditioned interior parking garage.

A.11 Energy Model Assumptions Block D3

<table>
<tr><td>Envelope</td><td>Roof assembly U-0.032
External Wall Steel-framed assembly U- 0.064
External Wall below ground assembly C=1.14
Window assembly U-0.420; SHGC= 0.400
Opaque Door U-0.500
Ground floor unheated U=F(0.52)
Window to wall area assumptions
Residential 30%
Office 40%
Retail and Lobby 50%
School 40%
Overall window to wall area ratio: 32%</td></tr>
<tr><td>Occupancy</td><td>Occupancy per ASHRAE 90.1 space-by-space method</td></tr>
<tr><td>Interior Lighting Power Density</td><td>Lighting power density per ASHRAE 90.1 space-by-space method
All buildings Residential Area 0.7 W/SF
Overall LPD 0.69 W/SF</td></tr>
<tr><td>Exterior Lighting</td><td>Estimated exterior lighting 0.02 W/SF of buildings excluding garage 5,716</td></tr>
<tr><td>Miscellaneous Loads</td><td>Receptacles plug load per ASHRAE 90.1 space by space method
Residential area 0.5 W/SF
Overall building 0.48 W/SF
4 Elevators 20kW each</td></tr>
<tr><td>HVAC Systems</td><td>Residential Spaces
Residential Area
VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
Residential Area DOAS Unit
VRF cooling [COP 3.5] and heating [COP 3.2]
ERV 50% sensible, 50% latent effectiveness, 0.54 kW motor
Office/Retail/Common/School
VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
Back of house spaces heating only with Electric Resistance [100% Eff.]
Unconditioned interior parking garage.</td></tr>
</table>

A.12 Energy Model Assumptions Block E1

Envelope	• Roof assembly U-0.032
	• External Wall Steel-framed assembly U- 0.064
	• External Wall below ground assembly C=1.14
	• Window assembly U-0.420; SHGC= 0.400
	• Opaque Door U-0.500
	• Ground floor unheated U=F(0.52)
	• Window to wall area assumptions
	  ○ Residential 30%
	  ○ Office 40%
	  ○ Retail and Lobby 50%
	  ○ School 40%
	• Overall window to wall area ratio: 34%

Occupancy	Occupancy per ASHRAE 90.1 space-by-space method
Interior Lighting Power Density	• Lighting power density per ASHRAE 90.1 space-by-space method • All buildings Residential Area 0.7 W/SF • Overall LPD 0.70 W/SF
Exterior Lighting	• Estimated exterior lighting 0.02 W/SF of buildings excluding garage 2,039
Miscellaneous Loads	• Receptacles plug load per ASHRAE 90.1 space by space method • Residential area 0.5 W/SF • Overall building 0.46 W/SF • 3 Elevators 20kW each

HVAC Systems	• Residential Spaces
	  ○ Residential Area
	    – VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
	  ○ Residential Area DOAS Unit
	    – VRF cooling [COP 3.5] and heating [COP 3.2]
	    – ERV 50% sensible, 50% latent effectiveness, 0.54 kW motor
	• Office/Retail/Common/School
	  ○ VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
	• Back of house spaces heating only with Electric Resistance [100% Eff.]
	• Unconditioned interior parking garage.

A.13 Energy Model Assumptions Block E2

Envelope	• Roof assembly U-0.032
	• External Wall Steel-framed assembly U- 0.064
	• External Wall below ground assembly C=1.14
	• Window assembly U-0.420; SHGC= 0.400
	• Opaque Door U-0.500
	• Ground floor unheated U=F(0.52)
	• Window to wall area assumptions
	  ○ Residential 30%
	  ○ Office 40%
	  ○ Retail and Lobby 50%
	  ○ School 40%
	• Overall window to wall area ratio: 34 %

Occupancy	Occupancy per ASHRAE 90.1 space-by-space method
Interior Lighting Power Density	• Lighting power density per ASHRAE 90.1 space-by-space method • All buildings Residential Area 0.7 W/SF • Overall LPD 0.78 W/SF
Exterior Lighting	• Estimated exterior lighting 0.02 W/SF of buildings excluding garage 9,410
Miscellaneous Loads	• Receptacles plug load per ASHRAE 90.1 space by space method • Residential area 0.5 W/SF • Overall building 0.70 W/SF • 9 Elevators 20kW each

HVAC Systems	• Residential Spaces
	  ○ Residential Area
	    – VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
	  ○ Residential Area DOAS Unit
	    – VRF cooling [COP 3.5] and heating [COP 3.2]
	    – ERV 50% sensible, 50% latent effectiveness, 0.54 kW motor
	• Office/Retail/Common/School
	  ○ VRF cooling [COP 3.5] and heating [COP 3.2] with heat recovery
	• Back of house spaces heating only with Electric Resistance [100% Eff.]
	• Unconditioned interior parking garage.

Appendix B. Building Level Thermal Profiles and Operating Costs

B.1 Building level summaries

Building	A1	A2	A3	A4
Modelled Area (sq. ft.)	147,281	236,366	266,164	80,000
Peak Heating (kBtu/hr)	2,697	2,755	2,673	2,175
Peak Cooling (kBtu/hr)	4,048	3,876	3,912	2,660
Peak Domestic Hot Water (kBtu/hr)	68	705	804	288
Annual Heating Load (kBtu)	2,977,445	4,582,624	4,694,368	2,591,874
Annual Cooling Load (kBtu)	4,165,478	6,586,853	7,472,731	2,373,330
Annual DHW Load (kBtu)	274,569	3,216,354	3,667,729	1,313,474
Annual CO_2 Emissions (tons)[1]	196	470	521	203
Annual Business as Usual Utility Costs	$171,078	$434,248	$501,125	$137,040

Building	B1	B2
Modelled Area (sq. ft.)	319,461	363,304
Peak Heating (kBtu/hr)	3,535	3,932
Peak Cooling (kBtu/hr)	5,333	6,037
Peak Domestic Hot Water (kBtu/hr)	977	1,140
Annual Heating Load (kBtu)	6,348,167	7,103,205
Annual Cooling Load (kBtu)	9,113,960	10,149,967
Annual DHW Load (kBtu)	4,455,814	5,200,882
Annual CO_2 Emissions (tons)[1]	651	740
Annual Business as Usual Utility Costs	$595,329	$700,228

Building	C1	C2
Modelled Area (sq. ft.)	304,956	127,661
Peak Heating (kBtu/hr)	4,553	1,687
Peak Cooling (kBtu/hr)	6,456	2,207
Peak Domestic Hot Water (kBtu/hr)	710	378
Annual Heating Load (kBtu)	6,545,801	2,960,101
Annual Cooling Load (kBtu)	8,910,067	3,310,118
Annual DHW Load (kBtu)	3,240,11	1,723,459
Annual CO_2 Emissions (tons)[1]	580	260
Annual Business as Usual Utility Costs	$556,698	$248,556

Building	D1	D2	D3
Modelled Area (sq. ft.)	154,837	263,698	285,792
Peak Heating (kBtu/hr)	2,109	5,143	3,565
Peak Cooling (kBtu/hr)	2,863	6,836	4,959
Peak Domestic Hot Water (kBtu/hr)	437	596	884
Annual Heating Load (kBtu)	3,497,360	7,836,966	6,135,659
Annual Cooling Load (kBtu)	4,276,958	8,420,213	7,825,570
Annual DHW Load (kBtu)	1,994,642	2,718,170	4,035,355
Annual CO_2 Emissions (tons)[1]	314	571	590
Annual Business as Usual Utility Costs	$293,240	$530,466	$549,574

Building	E1	E2
Modelled Area (sq. ft.)	101,956	470,501
Peak Heating (kBtu/hr)	1,480	6,442
Peak Cooling (kBtu/hr)	1,800	9,485
Peak Domestic Hot Water (kBtu/hr)	290	1,079
Annual Heating Load (kBtu)	2,516,712	9,720,044
Annual Cooling Load (kBtu)	2,658,835	12,907,630
Annual DHW Load (kBtu)	1,324,836	4,974,041
Annual CO_2 Emissions (tons)[1]	209	785
Annual Business as Usual Utility Costs	$196,819	$732,635

Appendix C. Regulatory Roadmap

C.1 Background

The proposed heat pump solution contemplates linking 12 planned buildings with a district ground loop heat exchange system, enabling lower carbon heating and cooling to reduce costs and comply with New York Local Law 97 requiring carbon emissions reductions. In addition to thermal energy, the developer will consider solar PV, battery energy storage, and electric vehicle charging.

To implement a district system over five New York City blocks, certain regulatory hurdles associated with crossing public rights of way, coordinating rights and responsibility among multiple building owners, and obtaining the approval of various City authorities to install a geothermal system that will be in proximity to or potentially integrate with city infrastructure presents unique regulatory challenges.

The parties are exploring heating as a service through this project, and the ownership of the district geothermal system may be structured based on economic and tax considerations. Endurant is exploring two build out approaches on this project, firstly an Engineer Procure Construct (EPC) and secondly a develop-build-own-operate-maintain (DBOOM) approach to this project, which could simplify maintenance and administration of the system, and presents its own legal and tax considerations. Under this configuration Endurant would be responsible for funding, installing, operating, and maintaining all on-site energy assets including thermal production, distribution, electrical generation, and storage. This allows Endurant to simplify the energy approach for the project and deliver efficient clean energy to the tenants. Alternatively, the project could operate the system, with engineering, procurement and construction performed by Endurant.

One variation of importance is exploiting sewage pipes as a thermal source using a return loop for sewage that could slightly lower the temperature of sewage entering the New York City sewer system. Flow rates and upper/lower temperature ranges of sewage entering pipes, and potential lower temperatures of sewage, may pose regulatory concerns for City authorities. Another variation under consideration is the use of New York Metropolitan Transit Authority subway infrastructure as a thermal heat source/sink.

Working with sewer, transit, and other underground infrastructure, including any water tunnels that may exist in the proximity of the project, can cause delay and cost due to additional approvals required.

C.2 Description of Regulatory Approach to Individual Ground Source Heat Pump Systems (Alternative 3)

An alternative configuration of several smaller individual systems could simplify the common management of a shared loop system among separately owned buildings following development. Individual systems would obviate the need for shared operation and maintenance of a common system. However, separate development, operation, and maintenance will necessarily involve duplication of effort and likely lower technology and institutional efficiencies, and thus higher costs.

Because common development, albeit separate ownership, requires a common development-wide governance agreement to be adopted, common management can be achieved cost effectively. Under these circumstances, the next-best alternative to a district system is likely sub-optimal.

C.3 State Clean Water Requirements

The federal Clean Water Act establishes a permitting scheme that regulates the discharge of pollutants into the waters of the United States, known as the National Pollution Discharge Elimination System (NPDES) permit program.[11] NPDES requires all facilities that discharge pollutants, including heat, into surface water from a point source obtain a permit before discharging.[12] NPDES permits incorporate both water quality standards and technology-based effluent limitations to protect water quality.

The Clean Water Act authorizes EPA to delegate enforcement authority to the states and allows states to administer their own State Pollution Discharge Elimination System (SPDES) Programs upon approval from the EPA. New York's SPDES program has been approved by the EPA for the control of surface wastewater and stormwater discharges in accordance with the Clean Water Act. Notably, New York State law is also broader in scope and stricter than the federal NPDES program and requires a SPDES Permit for point source discharges of pollutants into all waters of the State including both surface waters and ground waters. In other words, in New York State, a SPDES permit may be required for discharges to both surface waters and groundwaters.

The Clean Water Act also directs states to adopt water quality standards to protect, maintain and improve the quality of the nation’s surface waters.[13] State water quality standards define the maximum allowable levels of chemical pollutants and are used as the regulatory targets for permitting, compliance, enforcement, and monitoring and assessing the quality of the state's waters. Pursuant to the CWA, "water quality standard(s) shall consist of designated uses of the navigable waters involved and the water quality criteria for such waters based on such uses."[14] New York State has adopted water quality standards for all surface waters and groundwaters in the state. Additionally, EPA regulations require states to include in their water quality standards an antidegradation policy.[15]

Accordingly, effluent standards set in NPDES/SPDES permits must ensure that state water quality standards will be achieved for the receiving waters.[16] These effluent limitations are based either on technology-based standards prescribed by the EPA,[17] or on water-quality-based standards in instances when applicable technology standards would still cause an exceedance of state water quality standards for the receiving waterbody.[18] SPDES permits may also impose additional conditions such as temperature monitoring and reporting, as well as limitations on how much heat may be discharged from the system depending on the receiving waterbody's classification.

C.4 State Discharge and General Water Quality Standards Application to Geothermal

The NPDES/SPDES discharge requirements and the New York State water quality standards both potentially regulate geothermal systems. These regimes, which both flow from the Clean Water Act, can be applied separately, and potentially together, depending on the circumstances of the geothermal design and regulatory decisions by NYSDEC.

Under the SPDES program, a discharge includes thermal discharges.[19] Separately, under New York State's general water quality standards, thermal discharges are defined as "a discharge that results or would result in a temperature change of the receiving water."[20] Pursuant to NYSDEC's criteria governing thermal discharges, "[a]ll thermal discharges to the waters of the State shall assure the protection and propagation of a balanced, indigenous populations of shellfish, fish, and wildlife in and on the body of water."[21]

While open loop systems clearly are regulated under both regimes through issuance of a SPDES permit that authorizes the effluent discharge in accordance with general water quality requirements, for closed loop systems NYSDEC would apply general water quality standards, but it is unclear whether they would require a SPDES permit as part of its regulatory approach.

More specifically, geothermal systems that discharge heat, cooling or water treatment chemicals into waters of the state must obtain a SPDES permit. While this is typically more applicable to open-loop systems, all systems are subject to New York State's water quality standards and best use criterion set forth
at 6 NYCRR Parts 649-758, including criteria for thermal discharges.[22] Accordingly, even if closed-loop systems do not trigger SPDES permitting requirements, closed-loop systems must adhere to applicable water quality standards.

Under all approaches that NYSDEC might adopt, NYSDEC can require meeting technological standards for the geothermal activity in order to mitigate thermal impacts on the receiving water body, which could include criteria for mixing zones.

C.5 State Pollution Discharge Elimination System for Geothermal Systems

The specific requirements of a SPDES permit will depend on whether the geothermal system discharges to groundwater or surface water, the classification of the receiving water body and whether the system discharges heat or some type of water or heat treatment chemicals.[23] Generally, geothermal systems that discharge heat, cooling or water treatment chemicals into waters of the state must obtain a SPDES permit. Open loop residential systems with a design flow greater than 1,000 gallons per day or that use water treatment chemicals, as well as all commercial open loop systems, require a SPDES permit. Additionally, depending on the circumstances, NYSDEC may require a SPDES permit for closed-loop systems if the system "discharges" heat, or otherwise changes the temperature, of a receiving waterbody including groundwater.

C.6 State Pollution Discharge Elimination System Permits for Construction and Stormwater Pollution

A SPDES permit might also be required for construction-related activities. Section 402 of the CWA requires permits for stormwater discharges from construction activities, which would include geothermal drilling operations, that disturb one or more acres of land. In New York State, a SPDES General Permit for Stormwater Discharges from Construction activity is required for construction activities involving soil disturbances of one or more acres based on a common plan, and soil disturbances of less than one acre that could potentially contribute to a violation of a water quality standard or pollutants to surface waters. To qualify for the permit, permit applicants are required to develop a Stormwater Pollution Prevention Plan (SWPPP) in accordance with the requirements in the General Permit to prevent discharges of construction-related pollutants to surface waters.

C.7 State Water Quality Standards of General Application

Beyond the requirements under the SPDES program, New York State water quality standards always apply to geothermal and other activities even if operations are not subject to the SPDES permitting requirements, such that geothermal or other activities must not cause or contribute to any violation of water quality standards.[24] Review by NYSDEC is required to determine whether the system would violate state water quality standards or whether a SPDES permit is required.

New York's water quality standards establish classifications and designated uses for all waters in the State including groundwater.[25] Best usage of the classes of waters include fish, shellfish and wildlife propagation and survival, fishing, drinking water supply and primary and secondary contact recreation.[26] NYSDEC regulations also contain general conditions applying to all water classifications including criteria governing thermal discharges.[27] Pursuant NYSDEC regulations, thermal discharges are defined as "a discharge that results or would result in a temperature change of the receiving water."[28] NYSDEC's thermal discharge criteria include general and waterbody-specific standards for thermal discharges, mixing zone criteria, and additional limitations on thermal discharges that may ultimately impact system design.

There are presently no surface waters on site. However, pursuant NYSDEC regulations, there is a presumption that discharges to the ground will result in discharges to groundwater.[29] Additionally, as previously explained, NYSDEC has promulgated water quality standards for all waters in the state including groundwater. Accordingly, review by NYSDEC is required to ensure that the system will not violate applicable state water quality standards for groundwater and NYSDEC's thermal discharge criteria.

At the time of review, NYSDEC may also impose additional conditions appropriate to the system, which may require the applicant to provide biological information on the water body and an analysis of available technology or operational measures that can be employed to minimize any adverse impacts caused by the thermal discharge.

C.8 Drilling Permits

New York State imposes different requirements for geothermal wells drilled less than 500 feet and wells over 500 feet, based on permitting regimes that were designed for non-geothermal systems, but adapted for these purposes.

Wells that are less than 500 feet deep are regulated by the NYSDEC Division of Water. The Division of Water requires the submission of driller and pump installer registration and certification, and preliminary notice and well completion reports for open loop or standing column systems.[30] Completion reports are waived for closed loop geothermal systems with boreholes drilled up to 500 feet deep.[31]

The NYSDEC Division of Mineral Resources regulates the drilling, construction, operation, and plugging of geothermal wells deeper than 500 feet.[32] Wells deeper than 500 feet impose additional requirements, which are set out in the table below. Among these requirements, detailed information regarding well locations, depth, use, casing material, cementing procedures, drilling fluid, and cutting disposal methods, as well as completion of an Environmental Assessment Form, which will be used by the NYSDEC to evaluate the environmental impacts of the well, and to decide whether any "special permit conditions, a Supplemental Environmental Impact State, or any additional NYSDEC permits are required."[33] NYSDEC also imposes reporting requirements throughout the permitting and drilling process, and a separate permit must be obtained before a well may be permanently plugged and abandoned by the well owner.[34]

Importantly, prior to obtaining a well drilling permit for a well that may produce brine, saltwater, or other polluting fluids in sufficient quantities to harm the surrounding environment, the well owner must obtain a permit for the safe and proper disposal of such produced fluids.[35] Depending on the applicable method of disposal, NYSDEC may require the well owner to obtain additional permits for discharge and/or disposal.

NYSDEC also mandates minimum standards for all wells pursuant to the division's Casing and Cementing Practices to protect groundwater by preventing the migration of fluids.[36] However, NYSDEC imposes stricter permitting conditions for wells that will be drilled through primary and principal aquifers, as well as for wells where subsurface conditions are unknown or where high pressures are expected.[37][38]

The Division of Mineral Resources will also consult with the New York State Historic Preservation Office (SHPO) within the New York State Office of Parks, Recreation and Historic Preservation to determine whether the proposed location of a well is within a State-listed historic area, which would require additional permissions.[39] If applicable, SHPO will review the project and ensure the well will not negatively impact cultural resources.[40] The permit application process takes approximately six to eight weeks, but may take longer depending on the project. Additionally, filing fees for the application materials vary depending on the depth of the well.[41] Drilling permit requirements and restrictions under both regimes are summarized in the table below.

C.9 Requirements for Closed Ground Source Loops

Source: Well Owner and Applicants Information Center, NYSDEC, available at https://www.dec.ny.gov/energy/1522.html (accessed March 6, 2021); Well Operator Responsibility, NYSDEC, available at https://www.dec.ny.gov/energy/1639.html (accessed March 6, 2021); Ground Source Heat Pump Drilling Regulations Discussion, Presentation by NY-GEO (November 12, 2020).

Under 500 Feet	500+ Feet
Driller and pump installer certification and registration	
Municipalities may impose additional requirements	
	Organizational Report (Form 85-15-12)
	Application for permit to drill well (Form 85-12-5)
	Environmental Assessment (Form 85-16-5)
	Financial Security Worksheet (Form 85-11-2) and deposit of required financial security starting at $2,500 per well over 500 feet
	Certified site plan
	Casing and cementing plan
	Drilling progress reports
	Periodic drilling drift correction
	Well drilling and completion report (Form 85-15-7)
	Annual reports of status and use of well
	Incident reports of leakage or condition posing risk to environment or the health, safety, welfare, or property of any person
	Permit to plug and abandon

C.10 State Environmental Quality Review Act

The New York State Environmental Quality Review Act (SEQRA) requires state and local agencies to consider environmental factors in the planning, review, and decision-making processes regarding permits, zoning changes, or government funding. SEQRA review is triggered by projects that require some form of discretionary State or local government approval.

The SEQRA review process requires agencies to determine whether actions they directly undertake, fund, or approve may have a “significant impact” on the environment (“a determination of significance”), and if so, to prepare, or require to be prepared, an Environmental Impact Statement (EIS) that assesses the potential impacts of the proposed actions, as well as ways to avoid or mitigate those impacts. The lead agency responsible for authorizing the project issues a “negative declaration” if it determines that the proposed action will not result in a significant environmental impact. This ends the SEQRA review process and can result in subsequent litigation brought by project opponents. A positive declaration triggers the procedural mandates that lead to the preparation of a Final Environmental Impact Statement (EIS), which will be the basis of the final decision to fund or approve the project.

An action is subject to review under SEQRA if any State or local agency has authority to issue a discretionary permit, license, or other type of approval for that action, as well as if an agency funds or directly undertakes a project. Consequently, any State or local approvals such as issuing a permit, will trigger the provisions of SEQRA. Additionally, any funding by NYSERDA for subsequent phases of the project would likely constitute an agency action subject to SEQRA.

Once there is an “agency action” the agency must determine whether the action is subject to SEQRA. Type II actions, which are action for which it has been determined not to have a significant effect on the environment, are not subject to the SEQRA review process. However, if the action does not fall within one of these exclusionary categories, then it is subject to SEQRA and the agency will need to determine whether it is a Type I action or an unlisted action, which will trigger different procedural requirements.

To reach a determination of significance, the agency must prepare an Environmental Assessment Form (EAF) (either a short EAF or full EAF, depending on the action).

The short form EAF, which is used for unlisted actions deemed to have a significant effect, requires the lead agency to consider whether the proposed action would cause “an increase in the use of energy” and whether it “fails to incorporate reasonably available energy conservation or renewable energy opportunities.” The Full EAF also requires applicants for commercial and industrial projects to provide information about the proposed action’s new or additional demand for energy, including information about the anticipated sources of energy.

If the agency issues a positive declaration, the preparation of an EIS is required, which involves the preparation of a Draft Environmental Impact Statement (DEIS) that is then circulated for public review and comment. In addition to "analyzing the significant adverse impacts and evaluating all reasonable alternatives," the DEIS should include an "assessment of impacts only where relevant and significant" including "impacts of the proposed action on the use and conservation of energy" and "measures to avoid or reduce both an action's impacts on climate change and associated impacts due to the effects of climate change…"

C.11 New York State Historic Preservation Act

The New York State Historic Preservation Office (SHPO) within the New York State Office of Parks, Recreation and Historic Preservation helps communities identify, evaluate, preserve, and revitalize their historic, archeological, and cultural resources. SHPO administers programs authorized by both the National Historic Preservation Act of 1966 and the New York State Historic Preservation Act of 1980. These programs, including the Statewide Historic Resources Survey, the New York State and National Registers of Historic Places, the federal historic rehabilitation tax credit, the Certified Local Government program, the state historic preservation grants program, state and federal environmental review, and a wide range of technical assistance, are provided through a network of teams assigned to territories across the State.

In carrying out these responsibilities, SHPO conducts project review, specifies conditions for modification of sites subject to their jurisdiction, and approves or assists other agencies in approving plans for modifications to historic sites. Project sponsors are required, to the fullest extent practicable consistent with other provisions of the law, avoid or mitigate adverse impacts to such properties, to fully explore all feasible and prudent alternatives, and give due consideration to feasible and prudent plans that will avoid or mitigate adverse impacts.[42] Accordingly, geothermal elements be designed and constructed, including drilling, to avoid impacting historic features.

There are no listed historic resources present on site. However, the Paramount Studios Complex which is listed on the State and National Registry is located in the vicinity of the project development complex. While it is unlikely that the geothermal system would adversely impact the Paramount Studios Complex, review by SHPO may be required as part of the SEQRA review process.

C.12 Uniform Heat Standards for Multi-Unit Residential Buildings

New York State establishes statewide standards for the provision of heat in multi-unit buildings. Heating facilities must be capable of maintaining a temperature of 68 degrees F.

Heat must be supplied from October 1 through May 31 to tenants in multiple dwellings. If the outdoor temperature falls below 55°F between the hours of 6 am to 10 pm, each apartment must be heated to a temperature of at least 68°F. If the outdoor temperature falls below 40°F between the hours of 6 am to 10 pm, each apartment must be heated to a temperature of at least 55°F.[43]

C.13 Utilities Regulation

The New York Public Service Law governs utilities and delegates the regulation of utilities to the New York Public Service Commission. The scope of the Public Service Law covers electricity, natural gas, water and telecommunications, but does not cover geothermal or the provision of heat generally.[44] As a result, utilities are presently not permitted to own or operate geothermal assets. Also, because geothermal falls outside the scope of the law, private providers of heat services are not presently regulated under the Public Service Law.

Beyond the omission of geothermal from the Public Service Law, common law principles suggest that geothermal heat services provided on a competitive basis by a company that does not possess a monopoly or otherwise exert market power would not be deemed a utility or regulated as a utility. The historical genesis of utility regulation is rooted in concerns over market power during the early 1900s as a variant of anti-trust legislation. The modern approach to defining a utility for purposes of determining whether an energy provider is deemed and regulated as a utility has been refined by the courts deciding whether third party power providers entering into power purchase agreements with energy users, a situation analogous to the provision of geothermal services. Multiple factors are considered in determining whether the activity constitutes provision of utility services:

- The nature of the transaction and relationship between the parties, in particular whether it is an arm’s length transaction between willing buyer and willing seller.
- Whether the services are for the public or private use, determined in part by whether the provision of energy is in front or behind the meter.
- Whether the service provided is an indispensable service that generally requires public regulation; if the service is structured so that the end user has alternative grid-supplied options in addition to the service, it may be deemed non-essential or not requiring regulation.
- The presence of market power or monopoly.
- Ability to serve all members of the public.

- Ability to discriminate against members of the public.
- Actual or potential competition with other entities that are regulated in the public interest.[45]

Although no single factor is determinative, if a geothermal provider contracts on a one-to-one basis with a building or commercial user, and the building retains backup utility service for heating as an alternative option, it is unlikely that such an arrangement would be deemed as requiring regulation as a utility under common law principles.

C.14 Home Energy Fair Practices Act and Submetering Regulations for Electric Heat

Notwithstanding providing geothermal services may not be regulated as a utility, a building or service provider that provides electricity and/or electric heat to residents on a submeter basis must comply with the Home Energy Fair Practices Act (HEFPA) part of the Public Service Law §§30-53, and the Department of Public Service Residential Electrical Submetering regulations,[46] pursuant to the New York Public Service Law.[47] Importantly, for purposes of submetering, electric heat services include heat services provided by electric heat pumps.[48]

HEFPA and its regulations subject covered parties to the same standards as utilities for consumer initiation and termination of service, billing and deposits, disputes over service and charges, and standards for quality of service. The submetering regulations further require that buildings apply to the New York Public Service Commission for permission to submeter, which approval may be conditioned upon requirements set by the Commission. These conditions include rate caps, and violation of Commission conditions or failure to adhere to regulations can result in reductions in rate caps,[49] sanctions and termination of authority to submeter. [50]

For existing buildings that seek to convert from a master meter to a submeter, in order to approve the application, the Commission must make a positive determination that the proposed submetering is in the public interest and consistent with the provision of safe and adequate electric service to residents.[51] This requirement applies to rental buildings, condominiums and cooperative buildings.

For conversion of rental buildings, the application requires notice to all residents, publication for public comment, and the Commission may consider all supplemental information submitted, including public comments.[52] Conversion of an existing building is therefore a far more cumbersome process involving actual tenants with pre-existing contractual and statutory rights that must be adjusted if submetering is to be permitted.

For buildings that are mixed rental and condominium, such as where sponsors retain ownership of certain units that are rentals, the regulations do not specify which regime is followed. The answer should follow whether the sponsor remains obligated to pay the submeter bill under the lease, or whether that can be passed to tenants. Contract, landlord-tenant, rent control and other laws would be relevant to what would be permissible.

Applications for submetering must include a plan for complying with HEFPA, demonstration that submetering will comply with equipment, energy efficiency, income-based housing assistance, rate cap, and other requirements.[53]

The process is complex, requires months to complete, and the public interest finding is a relatively high standard to meet. However, submetering that supports meeting State and local climate targets by enabling geothermal technologies could be deemed to be in the public interest, provided all other requirements are also satisfied.

C.15 Non-Electric Heat and Cooling

While HEFPA regulates electric heat submeters, non-electric heat and cooling fall outside of HEFPA and the submetering regulations. The absence of a specific regulatory regime means other non-energy regimes at the State and local level may set default rules without providing a clear path toward submetering residential units for these services. As described in the following section, these include municipal landlord-tenant laws.

Non-electric heating is allocated as a responsibility of the landlord in State and municipal law and leases, whereas cooling generally is omitted from both. This may enable bifurcated business models that more easily support cooling as a service to be offered, the provision of electric heat under HEFPA, but non-electric heat facing barriers under local law.

Proposals to submeter geothermal will likely require the submetering regulations for electricity and electric heat be adapted to incorporate geothermal or new regulations developed for geothermal.

C.16 Other Consumer/Tenant Protection Laws

Regardless of whether heat services are billed as electric heat or therms, contract law, consumer protection laws, tort laws, and other laws and regulation governing the marketing of heat services would apply.

In the context of building contracting geothermal heat services and on-selling them to tenants, local landlord-tenant laws would apply to protect tenant-consumers, which would necessarily expand the range of regulatory stakeholders to include municipal regulatory authorities regulating buildings and protecting tenants. Thus, the New York State Division of Homes and Community Renewal, as well as municipal tenant advocates could become actively involved, including the NYC Department of Housing Preservation and Development and NYCHA. Other non-government tenancy advocacy groups will also likely become active to influence government decision making processes.

The New York State construction code requires buildings to provide a means to heat residential units, but does not allocate in the specific responsibility for the cost of operation of those units or fuel:

> §27-740 Heating requirements. All habitable or occupiable rooms or spaces, and all other rooms or spaces … shall be provided with means of heating in accordance with the requirements of this subchapter and reference standard RS 12-1….[54]

As noted in the prior section, in the absence of a regulatory regime like HEFPA for non-electric heating, municipal landlord tenant laws may allocate the responsibility for heating to landlords. Similarly, for existing buildings, incumbent leases will allocate the responsibility to landlords.

Assuming a building provider is permitted to separately provide and bill for heat, failure to provide adequate heat according to standards set in municipal regulations protecting tenants could result in violations and penalties under these laws. In turn, this could trigger contractual violations between the building owner and a third-party heat provider.

C.17 Affordable Housing

If a multi-unit residential building is deemed affordable housing, New York State and local municipal regulations set maximum amounts that can be charged to residential tenants. In determining housing affordability, all housing costs must be included in the calculation. In rental units, housing costs include rent and any tenant paid utilities. In ownership units, costs include the mortgage payment (principal and interest), property taxes and homeowner insurance, and any common charges or homeowner's association fees for condominiums or cooperatives.

The U.S. Department of Housing and Urban Development (HUD) sets income limits annually for a variety of housing programs known as the Area Median Income (AMI) for each Metropolitan Statistical Area (MSA). MSAs are typically large cities or counties. NYC Department of Housing Preservation and Development and NYCHA, which finance housing and administer their own affordability programs, uses the AMI standard to set eligibility requirements for its funding programs for both rental and ownership housing. Affordability is broadly defined as a household paying no more than 30% of their monthly gross income towards their housing costs. The number of persons in the household determines the specific amount that may be charged for housing costs to stay within the affordability thresholds.

In addition, HUD annually publishes HOME Program Rent Limits for each MSA based on affordability for households with incomes at or below 50% AMI or up to 60% AMI.

For rental units, because both rent and utilities are included in the calculation, an arrangement between a building owner and third-party heat providers must be governed by contractual arrangements to ensure that affordability compliance thresholds are met.

C.18 Local

New York City has not developed permitting guidelines for geothermal systems; however, various local laws and regulations could apply to the geothermal aspects of the project.

C.19 Building Code and Permitting

The building permitting process reviews mechanical and construction approvals. Although no specific requirements for geothermal systems are provided by regulation, the geothermal elements will be reviewed for mechanical, structural and other standard requirements.

C.20 City Environmental Quality Review

As authorized by the New York State SEQRA, New York City formulated a separate "City Environmental Quality Review" (CEQR) process by which city agencies may disclose and review the potential environmental effects of discretionary actions which impact the urban environment in particular.[55] CEQR adapts the SEQRA review process to the urban setting and is required when a proposed discretionary action will be approved, funded, or undertaken by a city agency and will take place in New York City.[56] Similarly to SEQRA, CEQR requires agencies to study the environmental consequences of their actions and to take all feasible measures to avoid, minimize, and mitigate damage to the environment.[57] Some of the primary practical differences between CEQR and SEQRA are that CEQR provides guidance on selection of a lead agency, adds public scoping requirements, uses City-created forms for assessments, and promotes the use of the City's detailed CEQR Technical Manual in conducting environmental reviews.[58]

C.21 Drilling and Excavation Permit

No person may drill or excavate in a corridor within the City of New York, to a depth greater than 50 feet below ground surface in the borough of the Bronx or on or north of 135th Street in the borough of Manhattan; or greater than 100 feet in the borough of Brooklyn, Queens or Staten Island or south of 135th Street in the borough of Manhattan or to any depth within 200 feet horizontal distance of a water tunnel shaft, without obtaining a permit from the department.[59]

Drilling beyond these depths require submission of a pre-application for proposed drilling and/or excavation to NYC Department of Environmental Protection's Bureau of Water and Sewer Operations.[60] Within 10 days from receipt of a pre-application assessment submission, the department will notify the applicant as to whether the proposed drilling and/or excavation requires a permit or is located in a No Drilling/ Excavation Zone.[61] If the proposed drilling and/or excavation is located in a corridor, defined as "a block that has any part of its boundary falling within five hundred feet horizontal distance from any centreline of any water tunnel or shaft as measure at or near the surface," a permit from the NYC Department of Environmental Protection's Bureau of Water and Sewer Operations permitting office is required.[62]

For drilling/excavation located in a corridor, NYC Department of Environmental Protection will issue a permit within thirty days from receipt of an application and processing fee if it determines that the drilling and/or excavation will not impair the stability of a water tunnel or shaft and complies with all other applicable standards and requirements.[63] NYC Department of Environmental Protection will not issue a permit for drilling/excavation in a No Drilling and/or Excavation zone. A No Drilling and/or Excavation zone means a boundary area defined as 200 feet on either side of the centreline of a water tunnel and vertical distances of 150 feet above the crown of a water tunnel and 150 feet below the invert of a water tunnel; or, except as otherwise indicated, 200 feet on either side of the centreline of a water tunnel shaft.[64]

C.22 New York City Department of Environmental Protection—Proximity to Water: Tunnels

Prior to drilling geothermal boreholes, NYC Department of Environmental Protection requires a letter addressed to the Bureau of Water and Sewer Operations stating their depth and use, and a map showing their locations. NYC Department of Environmental Protection will issue a letter stating if boreholes are located within 500 feet of a City water tunnel or associated structure and, if drift monitoring and reporting are required.

The locations of subsurface water infrastructure should be checked for all boroughs with the Bureau of Water and Sewer Operations.[65]

While this process should ordinarily require approximately four weeks to complete in most cases, according to Langan, for this particular site, the subsurface investigation and approval process may take about three to four weeks and the review process for excavation may take up to six to eight months.

C.23 Landmark Preservation Commission

The New York City Landmarks Law establishes Landmark Preservation Commission (LPC) and grants it the authority to designate City Landmarks, Interior Landmarks, Scenic Landmarks, and Historic Districts and to regulate any construction, reconstruction, alteration, or demolition of such landmarks and districts.[66] In addition, LPC maintains records of known archaeological sites and areas that are considered likely to contain archaeological resources. Under the Landmarks Law, no new construction, alteration, reconstruction, or demolition can take place on Landmarks, Landmark sites, or within designated New York City Historic Districts until the LPC has issued a Certificate of No Effect on protected architectural features, Certificate of Appropriateness, or Permit of Minor work.[67]

As part of the CEQR review process for the project, which is currently underway, LPC was consulted for a preliminary determination regarding the archaeological sensitivity of the site.[68] In a letter dated March 25, 2021, LPC determined that the site had no potential archaeological significance. Additionally, there are no known architectural resources present on site.[69] However, in the vicinity of the site is the Paramount Studios Complex which is listed on the State/National Register of Historic Places and is designated as a New York City Landmark, and spans portions of several blocks west of 37th Street.[70] While it is unlikely that the geothermal system would adversely impact the Paramount Studios Complex, review by LPC may be required as part of the CEQR process.

C.24 New York City Department of Transportation—Streets/Sidewalks

If any part of the geothermal system is installed under a City street or sidewalk, the building owner must enter into a revocable consent agreement with the New York City Department of Transportation Bureau of Franchises.[71] A revocable consent is the grant of right to an individual or organization to construct and maintain certain structures on, over, or under the inalienable property (streets and sidewalks) of the City.[72] Generally revocable consents are granted for a term of ten years, but may be renewed. However, the City retains the right to revoke consent at any time.[73]

Obtaining a revocable consent agreement can take up to 6 months,[74] and can cost $100–$750 in filing fees and additional costs as high as $1,200 for NYCDOT to publish notice of public hearing as part of the consideration process.[75]

To apply for a revocable consent agreement, submit the following information to the NYCDOT:

- Initial Submission
  - Draft petition form
  - Non-refundable filing fee of $100–$750, which are reduced for landmark buildings and districts[76]
  - Copy of deed
  - Copy of corporate papers, articles of organization or condominium declaration

- Current IRS 147-C Letter or current IRS SS-4 Letter
- Signed/sealed drawings with surveyed well locations and sections through sidewalks and roads with elevations, using an RC-10 form and conforming to City template requirements

- Final Submission
  - City of New York substitute W-9 taxpayer form
  - Affirmation form
  - Certification of insurance (ACORD form)
  - Broker's certification
  - Security deposit (amount to be determined)
- Prior to Issuance
  - Fee for issuance, which may be a one-time or annual fee, depending on duration of work

NYCDOT will circulate the application to other departments. The Department of City Planning may determine through their review that a proposed revocable consent requires land use review pursuant to the Uniform Land Use Review Procedure (ULURP). If ULURP is needed, the petitioner will be required to complete any of the additional paperwork and submit the petition for ULURP review, which in most cases takes approximately six months.

Most above-ground structures require the approval of the New York City Public Design Commission. Structures proposed within a designated New York City Historic District or adjacent to a designated New York City Landmark require the approval of the New York City Landmarks Preservation Commission. NYCDOT will require obtaining these approvals when necessary. NYCDOT will also check if the applicant has any outstanding warrants, liens or unpaid taxes, and will confirm the applicant is registered with the New York Secretary of State and licensed to do business within the State of New York.

Following multi-agency document review, NYCDOT will schedule a public hearing. Applicants are not required to attend; however, it is advisable to attend in case any issues are raised. NYCDOT will publish a notice of the hearing, at the expense of the petitioner, in one daily newspaper and one local area newspaper. The combined cost of these advertisements varies may be as high as $1,200. If no issues arise at the hearing or during the subsequent 10-day comment period, NYCDOT will prepare the revocable consent agreement for applicant's signature, countersign the agreement, and then submit to the mayor for approval and registration with the New York City Comptroller.[77]

Additionally, if construction of the geothermal system requires use of adjoining sidewalks or streets as a work area for equipment and material storage, a permit may be required from the NYCDOT Office of Construction Mitigation and Coordination.[78] Three categories of construction-related permits for work on a sidewalk/street may be potentially relevant:

- Street opening permits: applies to openings/excavations or other work in a street that may cause damage to the street surface.[79]
- Building operations/construction activity permits: applies to construction related activity that takes place within and adjacent to the street, such as placement of materials, equipment and temporary structures on the street or sidewalk, or movement of construction equipment across roadways and sidewalks.[80]
- Sidewalk construction permit: applies to any repairs, replacements or new sidewalk installations.[81]

There is one permit application form for all three permits. Permit applications can be submitted through the NYC Streets Permit Management System and require about four weeks.[82]

All permits that are required by other state and federal agencies must be in place before the NYCDOT issues a permit.[83]

C.25 New York City Office of Parks and Recreation

New York City Department of Parks and Recreation (NYC Parks) requires a permit for any construction work that affects assets under the jurisdiction or control of NYC parks, which may include natural areas, adjacent sidewalks and roadways, monuments, and concessions.[84] Project proponents must first submit the scope and design of the project for approval, and a subsequent construction permit upon approval from NYC Parks.[85]

The permit can only be issued for a limited amount of time (usually for the duration of construction), which in most cases cannot exceed two years, and the area must be restored to NYC Parks' satisfaction at the conclusion of the construction period.[86] Additionally, if construction may affect any tree under NYC Parks jurisdiction, a tree work permit must be obtained by NYC Parks before issuing a construction permit.[87]

The block between Steinway Street and 41st Street contains Playground 35, a recently renovated City Park.[88] As such, any construction or installation of the geothermal system within the playground area would require a permit. Generally, it takes NYC Parks up to six weeks upon receipt of a complete permit application to review a permit.[89]

C.26 Metropolitan Transportation Authority Approvals

The Metropolitan Transportation Authority (MTA), which includes the New York City Transit Authority, the Long Island Rail Road and Metro North, and the Port Authority of New York and New Jersey, must be informed of planned drilling/excavation located within 200 feet from their transportation structures, including tunnels, substations, ventilation buildings and stations.[90] If approval is required, the owner and drilling firm may also have to procure additional insurance coverage and vibration monitoring may be required depending on the proximity to the site.[91]

The project is adjacent to New York City Transit Authority infrastructure in Steinway Street and Northern Boulevard. Specifically, M and R subway lines run along Steinway Street, and E and F subway lines run along Northern Boulevard. Additionally, the nearest New York City Transit Authority Station is located one block north at 34th and Steinway Street.

We understand that the project contemplates thermal exchange pipes cross MTA-controlled rights of way, crossing over MTA subway tunnels. Approval by MTA will be required, which we expect will involve negotiations concerning how such work would be performed.

Applications are submitted to MTA, and require:

- Site plan showing the proposed drilling locations in relation to transportation structures.
- Review to verify the transportation structures' location.

Plan review and approval, or finding of no impact, is conducted through the MTA's External Partner Program. The program will coordinate with developers and engineers if necessary to modify design to protect MTA infrastructure.[92]

C.27 New York City Noise Code—Construction Noise Mitigation Plan

NYC Department of Environmental Protection regulates construction noise that may be triggered by drilling activities that create noise, vibrations, or dust. A construction noise mitigation plan may be required as part of the application to the NYC Department of Buildings for a construction permit. Operation outside the hours of 7 am to 6 pm requires a variance. Copies of the plans must also be available on site for inspection. [93]

C.28 Groundwater Discharge Permits

The NYC Department of Environmental Protection issues permits for the temporary disposal of drilling fluids and ground water to the City sewers generated during drilling/construction.[94]

For discharges of 10,000 gallons of groundwater per day or less, a self-certification form must be submitted to the Bureau of Customer Services.[95] If the discharge exceeds 10,000 gallons of groundwater per day into a public sewer, a groundwater discharge permit from the Department's Bureau of Customer Services is required. Prior approvals from the Bureau of Water and Sewer Operations and Bureau of Wastewater Treatment are also required.[96] Bureau of Wastewater Treatment will review the water quality of the proposed discharge to determine if pre-treatment is necessary and Bureau of Water and Sewer Operations reviews the proposed water quantity discharge to ensure that the local sewer mains have the capacity to handle the discharge.[97]

Discharges to storm sewers must be approved by NYSDEC prior to applying for a discharge permit from the Bureau of Customer Services.[98]

Average approval time from the Bureau of Wastewater Treatment is two to four weeks, although approval from the Bureau of Water and Sewer Operations may take longer.

C.29 Use of Sewer System as Thermal Source/Sink

A variation of the geothermal system design proposes to exploit the project's sewage stream as a source and sink for heat. The proposed system would divert sewage through a bypass pipe that is coupled with a heat exchange unit. Sewage would return to the main line and travel outward to the edge of the property where it passes to the municipal sewage lines.

NYC Department of Environmental Protection administers the sewer regulations.

Based on the proposed system, we assume the following:

- The system would be entirely closed without possible discharge into the environment.
- The sewage stream would not be changed by addition or removal of any of its original components, including changes in bio-chemical oxygen demand (BOD), total suspended solids (TSS), pH, fecal or total coliform bacteria, phosphate and phosphorus compounds, fats, oils, and greases of animal or vegetable origin, and the sewage stream would conform to these requirements.
- The only change in the diverted and return sewage stream would be changes in temperature.
- System cleaning and maintenance uses ordinary water and mild degreasing agents and would not introduce any substances that would be prohibited.
- System operation would not involve any significant additional water use.
- System operation would not change the concentration of viscosity of waste streams.
- System design and connections to the sewer system will confirm with all applicable codes, include NYSDEC regulations, for materials and system design of sewage systems.

Regulations for sewers are primarily municipal law governing sewer use, building, and construction codes, which, where appropriate draw upon or be supplemented by county, NYSDEC, New York State Plumbing Codes, and U.S. Environmental Protection Agency requirements.

C.30 Right of Way

If the sewage thermal exchange unit is entirely located on the project premises and serviced without going beyond the project premises, no easements or other property rights of way would be required for the thermal exchange unit, beyond those required for the conventional sewer system. By confining the thermal exchange system in this manner, the project confines the approval required to meet ordinary design and right of way requirements.

C.31 Sewer Connection Permit

New York City will require a sewer connection permit for the development to connect to the City sewer system, issued by the Bureau of Water and Sewer Operations. Additionally, a sewer certification is required for any new connection to a City sewer, a private sewer, a private drain, a septic system, or an approves outlet sewer certification may also be required for an alteration or renovation that increases the sanitary and/or storm flow generated on the site.[99] The purpose of a sewer availability certification is to verify the adequacy of the existing abutting sewer to receive site storm and sanity discharge from a development.[100]

Although the proposed heat exchange system will not change the ultimate flows to the City sewer, the installation of this equipment will require disclosure to and approval by City authorities. Any replacement of sewer mains in the streets and any additional infrastructure necessitated by the project infrastructure, particularly outside the property boundaries, will require disclosure, approvals, and potentially, negotiations as to how such work is carried out that may delay the issuance of the sewer connection permit.

C.32 Temperature of Discharge

Municipal regulations specify a default range for the temperatures of outflow in the public sewer system, which can be varied by the sewer authority if such temperatures could harm the sewer system, treatment process, or otherwise have an adverse effect. Temperatures are regulated at the point of entering the municipal system pipes and at the sewage treatment plant.

According to New York City regulations:

1. Sewage streams may not exceed 150 degrees Fahrenheit (150° F) (65° C).
2. Sewage streams should be above freezing so as not to be ice.[101]
3. New York City does not specify default temperatures for the temperature of streams at the point of reaching the treatment plant.

Together these requirements would confine the use of sewage streams as a heat source and sink to outflow that enters the public sewer within the range of above 0° C (32° F) and below (150° F) (65° C). The sewer authority may specify a narrower range of temperature as part of the review process.

C.33 System Construction

The construction of sewage systems must be built to contain waste and prevent it from polluting the environment. Accordingly, connections between the diversion and main line connected to the sewer must conform to regular NYSDEC requirements for sewer construction and be made watertight so that no leakage into or out of such connections shall occur. New York City sewer construction requirements would apply to the heat exchange component of the project's proposed sewer system.[102]

The system design and materials will be reviewed as part of the ordinary permitting process. Although there are no specific geothermal requirements, lack of familiarity with these systems will potentially require additional time for review.

C.34 New York City Building Decarbonization Requirements

New York City's Local Law 97 of 2019 requires buildings over 25,000 square feet in ten categories of building classes to reduce greenhouse gas emissions by 40% by 2030, and 80% average reduction by 2050. For multifamily housing, including cooperatives, condominiums, and rental buildings, the law sets some of the most stringent reduction requirements effective in 2024 with further reductions required in 2029, calculated on an emissions per square foot basis.

As a simple rule of thumb, residential buildings of 25–30 units or more will very likely trigger the 25,000 square feet threshold requirements. Group R-2 multifamily housing is subject to emissions caps of 0.00675 tCO_2e per square foot from 2024–2029, and 0.00407 tCO_2e per square foot from 2029–2034.[103]

Buildings failing to comply face penalties, unless they qualify for exception, and may be required to purchase carbon offsets in a yet to be established market at an uncertain price. Almost 26,000 buildings in NYC are subject to the law.

Buildings that include affordable housing, rent regulated and income-restricted housing are not exempt from Local Law 97, however these buildings are provided certain accommodations under the law such as delayed compliance dates or alternative compliance methods.

Local Law 97 builds on prior New York City laws that require buildings to insulate pipes and install energy efficient lighting, and phase out dirtier forms of fuel oil, eventually eliminating all heavy fuel oils by 2030, requiring all new boiler or burner installations utilize natural gas, ultra-low sulfur 2 oil, biodiesel, or steam. Local Law 97's separate requirements effectively further require the phase out of natural gas or, at very least, penalizes its continued use.

The proposed geothermal system will help avoid or reduce penalties under Local Law 97.

C.35 New York City Gas Ban

Complementing Local Law 97 of 2019, New York City amended its administrative code to prohibit City authorities approving new building construction permits that involve heating systems that burn natural gas, with several limited exceptions. The gas ban takes effect for applications for building approvals submitted starting in June 2023, 2025 and 2027 depending on size and zoning of characteristics of the building.[104]

C.36 Relevant Precedents

Saint Patrick's Cathedral in New York City installed a closed-loop geothermal system with boreholes deeper than 500 feet. This project has different characteristics than this project, however it is useful precedent for New York City that can be drawn upon with City officials and permitting authority.

Appendix D. Authorities Having Jurisdiction

D.1 Governmental Stakeholder Approvals or Consents

AHJ	Permit or Approval Required	Description	Estimated Time of Approval	Risks
Federal				
Housing and Urban Development	Regulation and potential enforcement	Compliance with affordable housing rules	Follows State process unless complications	Public complaint or lawsuit
State				
State Historic Preservation Office	Approval	Protected historical or cultural resources	Concurrent with SEQRA review	Design decisions
NYSDOT Transportation	Road closure, Easement	Approval to encroach upon or work in road or railroad track	Weeks	No significant risks
Office of Renewable Energy Siting	Approval for projects over 25 MW_{th}	ORES approval if geothermal system is greater or equal to 25 MW_{th}	Up to 12 months	No significant risks provided consultation with City government and compliance with laws
Public Service Commission	Home Energy Fair Practices Act (HEFPA) and submetering approvals	Approval of submetering applications	6 months to 1 year	Pricing and ability to comply with submetering service requirements Submetering regulations not designed for non-electric services
Department of Public Service	Submetering and notices	Approval of submetering under Residential Electrical Submetering Regulations, notice of historical artefacts on project site	6 months to 1 year	Pricing and ability to comply with submetering service requirements Submetering regulations not designed for non-electric services
New York State Homes and Community Renewal	Regulation	Provision and cost of heat, compliance with affordable housing rules	None unless complaint	Pricing and public opposition

Table D.1 continued

AHJ	Permit or Approval Required	Description	Estimated Time of Approval	Risks
Local				
NYC Department of Buildings	Building Permit	Geothermal reviewed in building or mechanical permit application	Months	Design, communications
NYC Department of Environmental Protection	Permits and approvals Verification of underground water tunnels	Must be notified of drilling (depth and use of the wells, and a map) Groundwater discharge permit for drilling fluids Drilling and excavation permit for depths exceeding 50 ft. Connect to water or sewer systems – temperature control and impact on system operation Verify location of underground water tunnels and other infrastructure with Bureau of Water and Sewer Operations in all boroughs	Subsumed within local project permitting	Design
NYC Department of Health	Approval	Impact on water and sewer system Provision of heating services	Subsumed within project permitting None unless complaints	Design Reliability of heating services
NYC Department of Transportation	Revocable Consent/Permits Road and sidewalk closures	Revocable consent agreements for installations under sidewalks Street/sidewalk permits for construction-related activity Road closure, right of way to encroach or temporary work	4 weeks	Design
NYC Department of Parks and Recreation	Permits	Construction permit for drilling in public park Tree work permit for city-owned trees	6 weeks	Design

Table D.1 continued

AHJ	Permit or Approval Required	Description	Estimated Time of Approval	Risks
NYC Landmark Preservation Commission	Consultation/potential investigation	Possible presence of archaeological resources Archaeological field testing/permits may be required	10 days	Design
Metropolitan Transportation Authority	Notification/approval	Must approve drilling within 200 feet of a transportation structure		Design
NYC Department of Housing Preservation and Development and NYCHA	Rent regulation and tenant rights enforcement	Provision and cost of heat, compliance with affordable housing rules	None unless opposition	Public opposition, compliance with regulations
Courts	Adjudication	Landlord-tenant disputes over provision of heat and cost	None unless opposition, then months to years	Public opposition, force change of business model

D.2 Non-Government Stakeholder Approvals or Consents

Stakeholder	Approval or Consent Required	Description	Estimated Time of Approval	Risks
Project Development Investors	Agreement by all investors to commonly managed elements of project.	Development is presently controlled by a single developer. Once subdivided, a common management agreement for the geothermal and other elements of the development among uniquely owned buildings would be necessary or desirable.	Months. Agreement should be developed once geothermal system and other infrastructure is finalized and prior to subdivision and accepting third party investors.	Acceptance of investors prior to resolution of common agreement presents several risks, including: Failure to disclose material terms resulting in investor liability. Incomplete agreement or delay in agreement could result in delay, cost and/or deadlock.
Electric and Gas Utility	Submetering	Coordinate submetering for electric heat under HEFPA	6 months to year	See NY Public Service Commission

Table D.2 continued

Stakeholder	Approval or Consent Required	Description	Estimated Time of Approval	Risks
All Utilities • Electricity • Gas • Water • Sewer • Cable • Telephone	Right of Way Franchise	Encroachment or access across utility infrastructure. Confirm no interference with utility franchise agreements. Agreement on compensation, maintenance, decommissioning, and liability.	Weeks to months	Negotiations in absence of default regulations could require time to negotiation consent and agreement on liability and compensation.
Electrical Utility	Electric load	Electrical approval and expansion to accommodate equipment like heat pumps and exchangers.	Weeks	No significant risks
NGO/Community	Participation in public hearings and consultation		Not quantifiable	Public opposition

Appendix E. Anticipated Challenges and Risks

E.1 Lack of Municipal Regulatory Regime for District Geothermal Systems

In New York State, few municipalities have developed permitting guidelines for geothermal systems, and no municipality has developed guidelines for multi-property district systems,

Without a permitting regime and standards for equipment, developers and municipal officials are left to navigate the various zoning, building, mechanical, environmental, and other regulations that may a pply to geothermal systems but were not designed specifically for these systems.

This ad hoc approach in the absence of a dedicated geothermal permitting regime increases costs, uncertainty, and risks, and delays the approval process. For project designs in which multiple stakeholders—property owners, utilities, and government agencies—must consent or grant approval, lack of a permitting regime and standards risks the inability of stakeholders to reach decisions or consensus, resulting in deadlock and bureaucratic paralysis. Application of zoning and other regulations not designed for geothermal systems, such as setback requirements, may even block geothermal projects altogether in dense urban and peri-urban areas where small lot sizes are common.

To address this challenge, project developers should start educating municipal permitting authorities and elected officials about the benefits of the geothermal features of the project and the measures to mitigate any potential risks to the environment or other subsurface infrastructure as early as possible. This educational effort should commence as soon as the developer has approved a proposed geothermal design and the assessment of mitigation measures is completed. The project developer should also be prepared to engage with environmental and community groups interested in the project.

E.2 Rights of Way and Approvals

Developers must obtain either fee simple ownership or easements in order to drill and install a shared ground loop across multiple properties. Crossing property lines, streets, railroad tracks, existing utility infrastructure all will require the grant of an easement and approval by the owner or authority responsible for their operation.

The costs of acquiring rights of way can be expensive and time-consuming. Each utility that has installed infrastructure in the subsurface should be consulted as part of the approval process to ensure that proposed designs and implementation will not disturb their operations. To safely install geothermal piping in the subsurface without interfering with other utilities will likely require site visits to individual properties by these other utilities. The costs and risk of damage incurred by these utilities will likely generate resistance to granting their approval.

Granting easements over a property limits the property owner's ability to use its own property, and can adversely affect private property rights, or diminish private property values. Compensating the grant of an easement and its impact on the servient property can be difficult to value,[105] potentially resulting in deadlock in negotiations.

Without government intervention, geothermal developers must negotiate with property owners and affected utilities to grant approval, which may be conditioned upon agreement on compensation, maintenance, decommissioning, and indemnification for liability.

The costs of obtaining rights of way have been well documented for roads, pipelines,[106] telecommunications, railroads, subways and intracity surface rail, and other types of infrastructure that necessarily crosses property lines. These costs may include a one-time acquisition fee, annual fees, excessive or escalating fees,[107] and the time and cost of organizational staff and legal professionals to procure rights.

In New York State investor-owned electric and gas utilities resolve rights of way issues by entering into franchise agreements with municipalities.

E.3 Drilling Regulatory Restrictions

New York State imposes different requirements for geothermal wells drilled less than 500 feet and wells over 500 feet. Permitting requirements for wells over 500 feet in depth are considerably more rigorous and costly.

New York City further imposes additional restrictions at more shallow depths and within the vicinity of a water tunnel shaft, without obtaining permits.

The different permitting regimes effectively limit geothermal system design to shallower depths for many developers of residential and individual building systems. Consequently, more wells must be drilled than would be required if deeper wells were employed to support the same system capacity. The greater number of wells increases overall costs due to greater drilling time, materials requirements, particularly costly well casing, expanded site restoration area, and increased production of cuttings and water.

The decision whether to drill beyond the State's 500-foot depth threshold requires a benefit-cost analysis of the potential additional thermal capacity and more efficient use of limited land weighed against the costs of compliance with the regulatory regime.

The project developer has elected to limit drilling to 500 feet in order to avoid the significant costs of compliance with additional regulation, foregoing a more energy efficient design.

E.4 Drilling Barrier Cost and Liability

Geothermal drilling operations may encounter several complicating conditions that have significant safety and regulatory consequences. Heightened operating complexities combined with traditional legal liability rules and regulatory requirements drive increasing costs for labor due to enhanced safety precautions and specialized equipment, slower work progress, more stringent permitting requirements, and higher insurance premiums.

Manmade subsurface infrastructure often complicates drilling, particularly in urban areas. The proximity of water, gas and other infrastructure in public streets may affect the design of a geothermal system. If any No Drilling and/or Excavation Zones exist in the project vicinity, NYCDEP may ultimately prohibit the installation of a ground loop system within those zones.

Furthermore, the proximity of the development to MTA transit infrastructure necessitates additional approval from the MTA prior to drilling and/or excavating. MTA may require alternative system designs to mitigate any potential adverse impacts on transit infrastructure or may deny approval for the project. If approved, the owner and drilling firm may also have to procure additional insurance coverage and vibration monitoring may be required depending on the proximity to the site.

E.5 Business Model

Geothermal development can follow one or more of several business models that exhibit differing technical economies relative to transactional diseconomies. Utilizing the continuum of business models set out in the NYSERDA-sponsored Pace Energy and Climate Center *Overcoming Legal and Regulatory Barriers to District Geothermal in New York State* (2021), the present project is classified as a "Multiple Properties—Multiple Owners Under a Common Agreement" business model.

In this model, each building sits or will sit on its own individual property for tax purposes, each building is its own entity and operates independent of the others.

However, unlike our paradigmatic model case, the buildings are unique in size, use and energy use, and are not presently subject to common management or an agreement bringing the geothermal system and other aspects of the development under common management.

Geothermal development following this model involves more complex property rights arrangements as such a system will cross property boundaries and require cooperation across properties and organizations. A common agreement for maintenance, management, pricing, and financial and other responsibilities of the system, and a common management body such as an owner's association or similar entity would be needed to be established for this purpose and supported by association charges.

E.6 Submetering and Tenant Billing

If the project plans to submeter heating services so that individual tenants control their usage and pay for their heat services on an individual basis, the developer or a third-party energy services provider must apply with the Public Service Commission for approval of submetering tenant units. Public Service Commission submetering regulations require compliance with metering, billing, dispute resolution and other requirements.

Obtaining submetering approval for a new development is far less complex a process than submetering a building with existing tenants. If submetering is introduced to an existing tenant relationship, this will require additional public hearing and amendment of leases.

Presently, New York's submetering regulations apply to electricity and electric heating services. No regulatory arrangement exists for billing heating services in measured in thermal units.

Accordingly, to simplify submetering arrangements, the project should introduce submetering prior to entering into agreements with any prospective tenants and, preferably prior to advertising rental units. Further, the project should measure and bill heat services as electric heat following established guidelines to conform to the current regulations as closely as possible. If the project proposes to measure and bill services on a submeter basis, it should at the earliest possible time consult the New York Public Service Commission and the New York Department of Public Service for guidance as this request will raise novel issues likely requiring adaptation of existing rules.

Appendix F. Summary of Recommendations to Overcome

F.1 Preliminary Commercial Terms/Contractual Relationships and Recommendations

Certain of these challenges can be addressed through contractual arrangements between the developer and other stakeholders. Recommended contractual arrangement include:

- **Common Agreement**. A common agreement should specifically address the ownership, operation and maintenance of the geothermal system as the geothermal system will cross project property boundaries and require cooperation across separated properties and ownership structures. A common agreement for maintenance, management, pricing, and financial contributions and other responsibilities to operating the system, and a common management body such as an owner's association or similar entity would be needed to be established for this purpose and supported by association charges.
- **Third-Party Energy Services**. The common agreement would facilitate the project entering into a third-party energy services agreement with a geothermal system operator. The third party could provide a turnkey solution or perform discrete tasks on behalf of the project's common management association. Any arrangements with a third-party energy services provider should require performance and compliance consistent with developer obligations to tenants and requirements that may be imposed by the New York Public Service Commission or other government agencies in relation to provision of heat to tenants.
- **Submetering and Tenant Leases.** If the project plans to submeter heating services so that individual tenants control their usage and pay for their heat services on an individual basis, submetering arrangements should be approved by the Public Service Commission prior to entering into leases with any tenants. Leases should then be drafted with language clearly allocating financial responsibility for billed to the tenant.
- **Submeter Billing.** The developer or a third-party energy service provider operating the system will be required to use an approved form of bill and maintain billing service and dispute mechanisms as required by New York's submetering regulations. The developer or third-party energy service provider may desire to contract with a third-party billing provider in order to comply with these requirements. Such arrangements must provide compliance with any applicable landlord-tenant laws.
- **Tax Optimization**. The geothermal system is a depreciable asset that provides opportunities for tax-advantaged financing. The form of ownership for those assets can be separated from the project and its phases in order to exploit tax advantages. A separate geothermal financing structure potentially improves the financial return of the overall project; however, this must be weighed against the additional complexity and legal risk in the event of a failure to meet obligations for any reasons or a legal dispute.

Endnotes

1 Heat of compression refers to the portion of input electrical energy to the compressor that gets released as thermal energy due to mechanical inefficiency. With hermetically sealed compressors, this thermal energy is absorbed on the condenser side and can be used as thermal input for spaces that require heating. In cooling mode, thermal energy is being removed from conditioned spaces and rejected to the GLHE. The amount of thermal energy rejected to the GLHE is actually 20-30% more than is removed from conditioned spaces due to the heat of compression factor. The same happens in heating mode. Due to the heat of compression factor from the heat pump, only 70-80% of the thermal energy required by the conditioned spaces is extracted from the GLHE.

2 The centralized configuration assumes a 4-pipe distribution and the decentralized system assumes a 2-pipe distribution.

3 The centralized configuration assumes a 4-pipe distribution and the decentralized system assumes a 2-pipe distribution.

4 New York State Clean Heat State-wide Heat Pump Program Manual - Version 5, October 2021 NYS-Clean-Heat-Program-Manual.pdf

5 The Joint Utilities of New York is a regulatory framework developed to suppport coordination amongst utilities in response to NYS's Climate leadership and Community Protection Act. https://jointutilitiesofny.org/

6 The Tax Cuts and Jobs Act of 2017.

7 26 U.S. Code § 48 - Energy credit.

8 ITC estimates are based on the decentralized geothermal hybrid capital cost estimates.

9 ITC estimates are based on the decentralized SHX capital cost estimates.

10 Endurant Energy develops VDER credit estimates using an in-house calculator that builds off the NYSERDA Value Stack Calculator logic for estimating VDER revenue from energy, capacity, demand reduction, community credits and environmental value delivered to the local grid.

11 Ken Krich et al., Biomethane from Dairy Waste: A Sourcebook for the Production and Utilization of Renewable Natural Gas in California, USDA Rural Devel., at 135 (July 2005).

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14 33 U.S.C. § 1313(c)(2)(A); NYS Dep't of Envtl. Conservation, Division of Environmental Planning and Protection, Clean Water Act Section 401 Certification for Commercial Vessel and Large Recreation Vessel General Permit (Nov. 3, 2008, https://www.nwf.org/Regional-Centers/~/media/PDFs/Regional/Great-Lakes/DEC_VGP_401_Certification_final.ashx

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17 Technology based standards are "performance standards" developed by the EPA within a specific industrial category aimed at determining what levels of discharge pollutant by pollutant, can be achieved using the most cost-effective set of available pollution prevention and control techniques applicable to those types of facilities. Each subcategory of dischargers within an industrial category are required to meet these end of pipe limits, regardless of the condition of the water into which they discharge. Technology standards differ based on the type of pollutant and whether the discharge is new or existing at the time the standards is established. EPA, *Watershed Academy Web, Introduction to the Clean Water Act*, https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=2734&object_id=2738 (last accessed Oct. 12, 2021)

18 Since meeting the technology standards does not guarantee that a discharge will not create or contribute to exceedance of the state's ambient water quality standards for the receiving waterbody, regulators must examine the impact of a discharge on water quality even though the discharge will be restricted by the applicable technology limit. If the regulator determines that exceedance is possible even with the applicable technological requirements in place, a more stringent effluent limit (a water quality based effluent limit) must be incorporated into the permit. New York Water Environment Association, Regulatory Overview and Legal Responsibilities, in Handbook on Wastewater Management at 4-56 (Jan. 2013), https://efc.syr.edu/wp-content/uploads/2015/03/Chapter4-web.pdf

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20 6 N.Y.C.R.R. § 700.1

21 6 N.Y.C.R.R. § 704.1

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