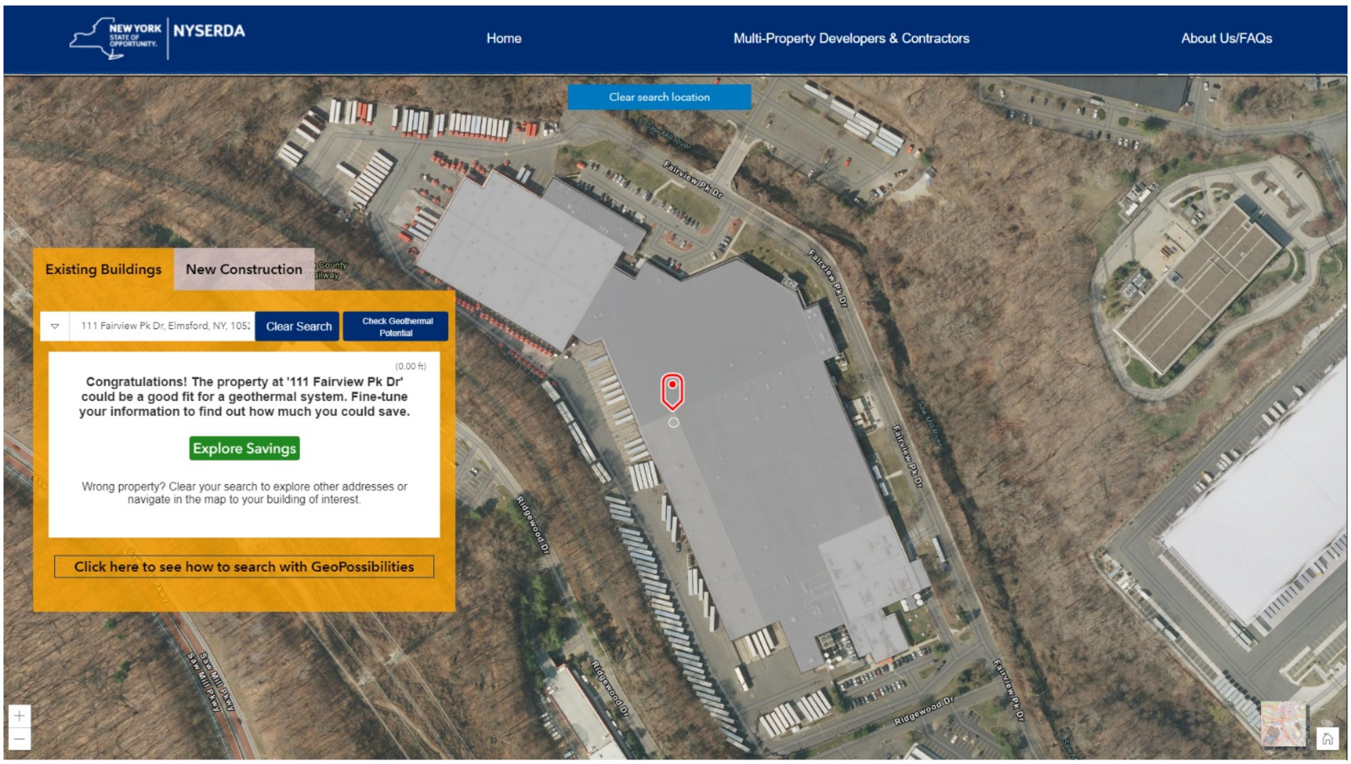
Westchester GeoPossiblities: A Ground Source Heat Pump Pre-Screening Tool

Methodology Specification Document



Prepared for:
New York State Energy Research and Development Authority

Prepared by:
Stone Environmental, Inc.
Over Morgen
Flux Tailor LLC
Goldman Copeland Associated, PC
Rhyner Consulting

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1. Introduction

GeoPossibilities was developed to provide an initial geothermal feasibility screening tool for all buildings in Westchester County. While the primary target audience for the tool is large buildings and building owners, the tool presents results for all building types. The tool presents users with the ability to navigate an interactive map of Westchester County in New York State, to interact with and view results regarding an initial screening for the feasibility of implementing a geothermal heating/cooling system on their building or property. Users can choose to either start from an existing property, or an existing parcel on which they plan to construct a new property. The Multi-Property/Contractor option provides a higher level of clusters of buildings with a high return-on-investment value, allowing the user to view the results in an aggregate manner rather than an individualized building/address search. The final output of the tool compares Capital Expenditure (CAPEX) and Operating Expenditure (OPEX) between two scenarios:

- **Baseline Scenario**: Assuming the baseline system will be replaced with one of the currently used fuel types
- **GSHP Scenario:** Assuming a GSHP system is installed for the full capacity needed for the property

1.1. Terminology

Table 1: The following terms are used throughout the document:

Acronym	Term	Definition
GSHP	Ground Source Heat Pump	A geothermal heat pump (GHP) or ground source heat pump (GSHP) is a central heating and/or cooling system that transfers heat to or from the ground. It uses the earth all the time, without any intermittency, as a heat source (in the winter) or a heat sink (in the summer).
GIS	Geographic Information Systems	A geographic information system (**GIS**) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface. By relating seemingly unrelated data, **GIS** can help individuals and organizations better understand spatial patterns and relationships.
ROI	Return on Investment	Return on Investment is a calculation indicating the

		potential value or savings of an up-front investment.
HVAC	Heating, ventilation, and air conditioning	Heating, ventilation, and air conditioning is the technology of indoor and vehicular environmental comfort. Its goal is to provide thermal comfort and acceptable indoor air quality.
CAPEX	Capital Expenditure	Capital expenditure, in the context of this document is the money an organization or entity spends to buy, maintain, or improve its building’s heating/cooling systems.
OPEX	Operating Expenditure	Operation Expenditure, in the context of this document is the money an organization or entity spends to operate and maintain its building’s heating/cooling systems.

2. Methodology Overview

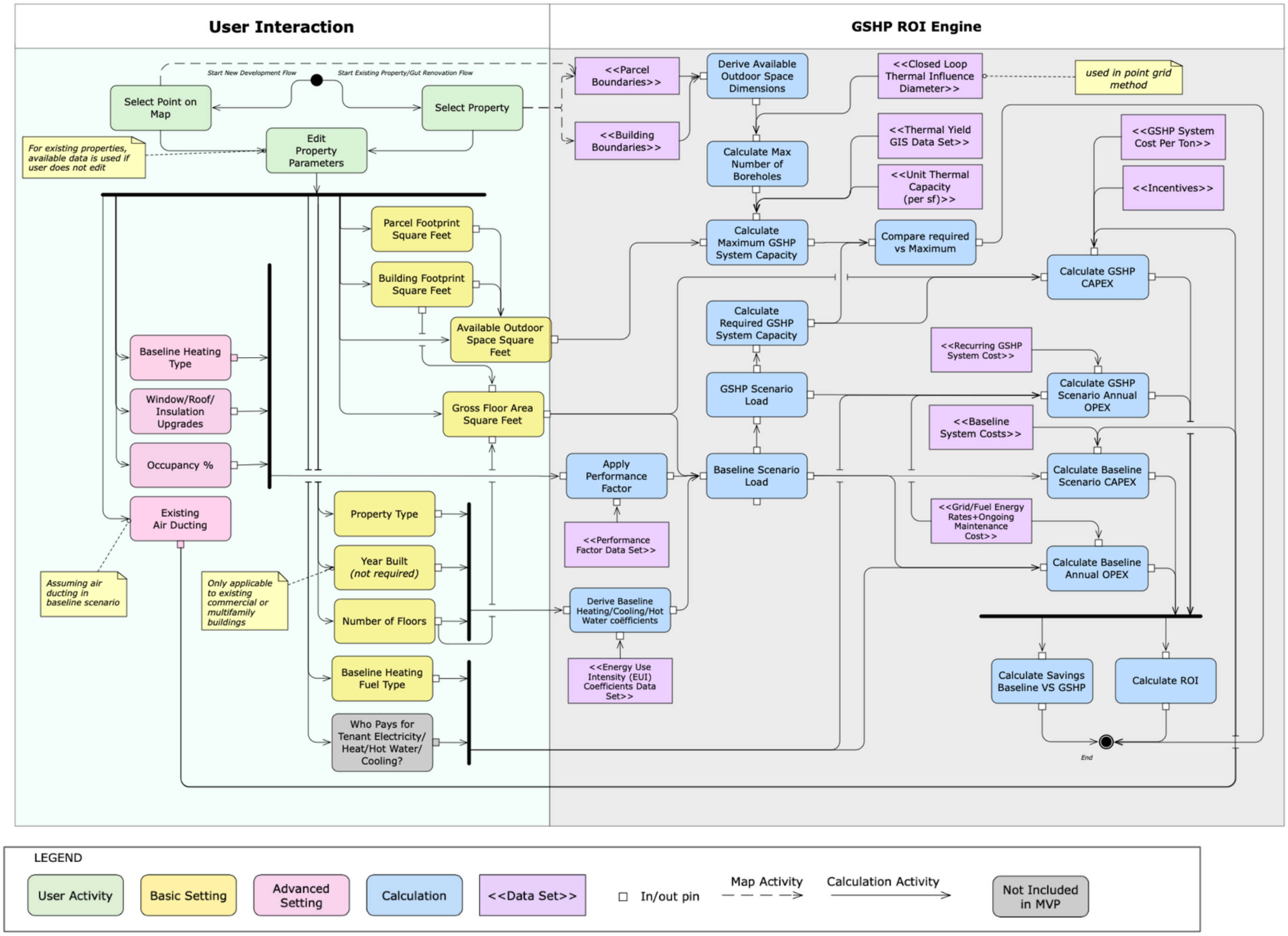

Figure 1: The flow from user inputs and data inputs to calculations

2.1. Calculation Inputs and Outputs

If the user starts with an existing property, the GSHP calculator uses available property attributes from source data sets. If enough data is available, the tool provides users with an estimate comparing GSHP with a replacement heating and cooling system. Once the user has selected a property on the map, a popup appears presenting key feasibility calculator results for installing a Ground Source Heat Pump (GSHP) system at their site and a link to continue to the GSHP Calculator Dashboard. Feasibility is calculated using the following inputs:

Table 2: GIS data inputs used

Parcel Boundary Polygon	From NYS parcel dataset
Building Boundary Polygon	From Westchester County and Bing, processed to group building footprints from the same owner.
Calculated Number of Boreholes for site	Calculated using parcel and building boundary polygons

On the GSHP Calculator dashboard, the tool presents users with a set of property-related parameters (called “Basic/Advanced Settings” in the user interface) which change the feasibility results. If the basic set of parameters needed for a calculation is not available, the user will be prompted to enter the required data points. For the Existing Buildings option, data parameters are automatically loaded, where available, from the buildings data table. For the New Construction option, only parcel square footage is known, as there is no existing building data table to pull from. For all New Construction searches, the user will be prompted to enter the relevant parameters to complete the calculations.

Table 3: Basic Tool Inputs and Settings

Property Category	A simplified categorization of the property, choice between: • 1 - 4 Family • Commercial • Educational • Hospital and Health Facilities • Institutional General • Multifamily
Year Built	The year the property was built (where the parcel dataset contains multiple years, the most recent is used)
Baseline Heating Fuel Type	Assumed based on building type, see Table 6.
Gross Floor Area Square Feet (estimate)	Calculated using building height and building footprint square feet (10 ft = 1 floor; multiply building footprint area by number of floors)
Available Outdoor Space Square Feet	Calculated using parcel and building boundary polygons
Number of Floors	Not including basements if not heated & cooled, used to calculate gross floor area
Parcel Footprint Square Feet	Used to calculate available outdoor space

Building Footprint Square Feet	The total square feet of the footprint of the building - counting only one floor if there are multiple floors. This and the parcel footprint are used to calculate outdoor space available for placing Ground Source Heat Pump boreholes. Used to calculate available outdoor space and gross floor area

Advanced Settings:
Users can further change the feasibility results by customizing additional “advanced” settings, which apply a performance factor or adjust the input parameters.

Table 4: Advanced Settings Options

Window/Roof/Insulation Upgrades
Occupancy %
Baseline Fuel Type

2.2. Calculation Steps

The primary calculation steps are as follows:

1. Calculate the baseline heating and cooling energy load, cost to replace current system, and energy and operating cost.
2. Calculate the available outdoor space and the number of boreholes that fit within it, calculate the percentage of outdoor space used by a GSHP system.
3. Calculate the size, capital cost, and operating cost required of the GSHP system required to serve heating and cooling for the property.
4. Calculate the estimate of the ROI of installing a geothermal system at the selected property.

2.3. Assumptions and Limitations

The mechanical systems proposed for the conventional systems were assumed to be energy code compliant high efficiency centralized systems. Although the existing buildings may not currently have a centralized system (i.e. window units or no air conditioning at all), the only way to justify the economic cost of installing a geothermal system was to compare it with a full renovation of the HVAC system in the building. For the 8 building types, three conventional cooling systems and four conventional heating systems were analyzed and applied to the appropriate buildings.

For cooling, a cooling tower and heat pump system was the most comparable technology to a geothermal system. Similarly, for commercial buildings, the conventional system was assumed to be a cooling tower with packaged AC units. Although buildings normally have a chiller to perform cooling in the summer, packaged AC units were used for ease of comparison with geothermal heat pump systems as the refrigeration cycle is similar throughout and the relevant piece of equipment is the cooling tower which is performing the heat rejection. The smaller Multifamily(<7 stories), Educational, and 1-4 Family Buildings were the only building types assumed to use air-cooled packaged units. These units are less efficient than the water-cooled packaged units and therefore an air-cooled kW/ton penalty was attributed to the energy consumption.

Heating was assumed to be heating hot water throughout with the only difference being the type of boiler being used. Condensing boilers were used for all building types.

See Table 5 below for a full breakdown of building types and associated assumed heating and cooling types.

Table 5: Building types and their assumed associated heating and cooling types

Building Type	Building Description	Assumed Cooling System	Assumed Heating System
C3	Commercial, Post-war > 7 Stories	Water Cooled + WSHPs	Condensing Boiler + WSHPs
C4	Commercial, Post-war up to 7 Stories	Water Cooled + WSHPs	Condensing Boiler + WSHPs
IN1	Hospital and Health Facilities	Water Cooled + WSHPs	Condensing Boiler + WSHPs
IN2	Institutional General	Water Cooled + WSHPs	Condensing Boiler + WSHPs
IN5	Educational	Water Cooled + WSHPs	Condensing Boiler + WSHPs
MF3	Multifamily Post-war > 7 stories	Water Cooled + WSHPs	Condensing Boiler + WSHPs
MF4	Multifamily Post-war up to 7 Stories	Split A/C Rooftop	Condensing Boiler
SF1	1 - 4 Family, Free Standing Wood Frame	Split A/C Rooftop	Condensing Boiler

3. ROI Calculation Factors

Economic analysis was a comparison between the installation of a geothermal system and the installation of an energy code compliant, high efficiency centralized system. However, both system types may be beyond the financial capacity of some building owners. With incentives in place to support the installation of geothermal systems, a full economic analysis should be completed in advance of any decision.

Other considerations in implementing a geothermal system might include preserving building aesthetics or making a statement for clean energy as a public relations initiative. As such, in addition to economic feasibility, the final tool presents the user with technical feasibility. This provides the end user with the option of pursuing a geothermal solution where it may not be viable to install a cooling tower on the roof or a boiler in the basement. The geothermal systems perform all heat rejection and absorption within the ground and utilize minimal building square footage which is appealing to buildings that suffer from the constraints mentioned above.

3.1. Data Inputs

3.1.1. Property Data

Table 6: Property data sources used in the GSHP tool

Data Set Description	Organization	Description
NYS Tax Parcels	NYS GIS Clearinghouse	Data sets created as part of the NYS Statewide Parcel Map Program. Cadastral (tax parcels)
Bing Building Perimeter Data	Microsoft	Building Outline data set, used only for building outlines not covered by the Westchester County data set
Westchester Parcel data with DataFinity fuel type	NYS GIS Clearinghouse / DataFinity	Data set was used to enrich fuel type values
Westchester Base Map Planimetric Building Data	Westchester County GIS / Stone Environmental	Westchester County Building data with gross floor area estimation, assuming 10 ft high floors and based on floor area in Westchester Building data set.

3.1.3. Energy Consumption

For the previous iteration of this tool, building types were divided into 16 categories based on findings by the New York City Buildings Technical Working Group (TWG). Based on the available property data for Westchester County(Table 6), building types have been refined to the following categories in Table 7 below.

Table 7: Building Type Breakdown

Building Type	Building Description	Building Type	Building Description
C3	Commercial, > 7 Stories	IN5	Educational
C4	Commercial up to 7 Stories	MF3	Multifamily > 7 Stories
IN1	Hospital and Health Facilities	MF4	Multifamily up to 7 Stories
IN2	Institutional General	SF1	1 - 4 Family, Free Standing Wood Frame

A spreadsheet model was created for each building type based on typical parameters to size heating and cooling systems to meet building peak heating and cooling requirements. Cooling load was estimated based on typical tons/SF, and heating load was based on approximate building surface area, volume, and ventilation rates. Factors were added to account for window to wall ratio, building envelope, and building usage. Bin weather analysis was then used to estimate approximate annual heating and cooling loads. This information was tabulated into peak and annual heating and cooling loads per 1,000 ft^2 for the various building types. For this version of this tool, in Westchester County, many of the assumptions were retained, however binned Typical Meteorological Year 3 (TMY3) data from Westchester County Airport was used to model heating and cooling load rather than NYC TMY3 data. Due to limited information regarding date of building construction, residential and commercial building categories with assumptions based on Post war, i.e. 1946-1980, were used.

The feasibility calculation imported the load data to determine geological feasibility for the closed loop geothermal system. After confirming the feasibility of each system for the site, the thermal capacity of the site for the given system was compared with the required capacity. If this requirement was met, the annual heating and cooling loads were compared to confirm that an appropriate balance was achieved. A factor of 1.2 was applied to the total cooling load in this phase to account for compressor heat rejection into the heat transfer fluid. If the heating and cooling systems were found to be appropriately balanced, the system was deemed feasible. If they were found to be nearly appropriately balanced, a hybrid system was deemed feasible. It should be noted that, as this tool is intended only to determine potential, somewhat optimistic figures were selected in terms of heating/cooling balance. A detailed study specific to the site would be necessary to confirm that the system will not be saturated over time.

Where geothermal systems were found to be geologically feasible, we completed follow-up calculations to determine economic feasibility. To enable a generalization of all buildings in Westchester County into the very few categories listed above, it was necessary to make a number of assumptions in the development of this tool. The first assumption was that any building considering an upgrade to a geothermal system was already committed to an upgrade of heating and cooling equipment to a centralized system meeting current code requirements. The cost of the installation would never be justified by payback period alone unless considered incrementally against the installation of an alternative conventional centralized system. As actual buildings often have more antiquated systems, this means that the initial version's baseline energy projections were somewhat lower than actual findings as reported by New York City's Technical Work Group.

To model total annual heating and cooling energy in commercial and residential buildings, HVAC systems were modeled to run only during expected occupied hours. This was achievable because we modeled heating and cooling demand figures based on weather data binned in three periods per day, 12-8:00AM, 8-4:00PM and 4PM – 12:00AM. Heating and cooling hours for demand associated with each temperature bin was based on the proportion of the temperature bin hours within these times that coincided with time of expected occupancy.

3.1.4. Energy Cost Data Source References

All cost, energy content, and greenhouse gases of electricity and heating fuels data were retrieved March 3rd, 2020 from the following sources:

Electric Cost: December 2018 - November 2019 New York Statewide Average Cost/kWh,
https://www.nyserda.ny.gov/Researchers-and-Policymakers/Energy-Prices/Electricity/Monthly-Avg-Electricity-Commercial
https://www.nyserda.ny.gov/Researchers-and-Policymakers/Energy-Prices/Electricity/Monthly-Avg-Electricity-Residential

Natural gas commercial and residential costs were also calculated as annual averages between Dec-2018 through Nov. 2019.
https://www.nyserda.ny.gov/Researchers-and-Policymakers/Energy-Prices/Natural-Gas/Monthly-Average-Price-of-Natural-Gas-Commercial
https://www.nyserda.ny.gov/Researchers-and-Policymakers/Energy-Prices/Natural-Gas/Monthly-Average-Price-of-Natural-Gas-Residential

Propane
https://www.nyserda.ny.gov/Researchers-and-Policymakers/Energy-Prices/Propane

Fuel Oilhttps://www.nyserda.ny.gov/Researchers-and-Policymakers/Energy-Prices/Home-Heating-Oil/Monthly-Average-Home-Heating-Oil-Prices#statewide

Wood Cost Estimate http://yonkersgranite.com/firewood.html

Wood Btu content: https://forestry.usu.edu/forest-products/wood-heating

Green House Gas Emissions: CO_2 Equivalents -Values represented here are those published by New York City in Local Law 97 of 2019. The tCO_2/kWh conversion approximation based on adjacent location within common grid, NYISO. Site: https://www1.nyc.gov/assets/buildings/local_laws/ll97of2019.pdf

Table 8: Electricity Rates

Electricity			
Customer	**$/kWh**	**MBtu/kWh**	**$/MBtu**
Residential	0.2	3.4121	0.05253363
Commercial	0.1	3.4121	0.040932759

Table 9: Heating Fuel Rates

Natural Gas			
Customer	**$/MCF**	**MBtu/MCF**	**$/MBtu**
Residential	14.92	1036	0.01440557
Commercial	6.92	1036	0.00667603
Fuel Oil			
Customer	**$/gal**	**MBtu/gal**	**$/MBtu**
Residential	3.20	137.381	0.02328318
Commercial	2.5	137.381	0.01819757
Natural Gas to Fuel Oil Cost Change Multiplier			
Residential			1.6162628
Commercial			2.72580806

Note: for English Units, M is prefix for 1,000

Propane			
	$/gal	**MBtu/gal**	**$/MBtu**
	2.869	91.333	0.031414348
Wood			
	$/Cord	**MBtu/cord**	**$/MBtu**
	400	23,767	0.0168

Wood	
Tree	MMBtu/Cord
Walnut	22.2
Oak Red	24.6
Oak White	29.1
Maple	25.5
Cherry	20.4
Birch	20.8
Average	23.8

Table 10: Green House Gas (GHG) Emissions

Carbon Equivalents			Unit Conversion Table			
Fuel	**Carbon Equivalent**	**Units**	**From Unit**	**Multiply by**	**to Obtain**	**Mbtu**
Electricity	0.000288962	tCO2e/kWh	kWh	1	kWh	3.412
Nat Gas	0.00005311	tCO2e/MBtu	Therm	100	MBtu	100
Dist Steam	0.00004493	tCO2e/MBtu	Mlb	1194	MBtu	1194
Oil #2	0.00007421	tCO2e/MBtu	Gal	138	MBtu	138
Oil #4	0.00007529	tCO2e/MBtu	Gal	146	MBtu	146

Note: for English Units, M is prefix for 1,000

3.2. Building Energy Profile (BEP) Calculation

3.2.1. Baseline Consumption

Based on this assumption, we developed a baseline for each building type based on the conventional system most likely to be installed for that building type. Commercial buildings were assumed to operate with cooling towers and packaged water-cooled AC Units, and natural gas fired condensing boilers or district steam for heating. Institutional sites were assumed to primarily have cooling towers and packaged water-cooled AC units for cooling, and condensing boilers for heating, with the exception of schools which were assumed to have packaged air-cooled units and standard boilers. High-rise residential buildings were assumed to have cooling towers and heat pumps, while low-rise residential buildings were assumed to have split system AC units and condensing boilers. Single family homes were assumed to have split system AC units and condensing boilers. Warehouses are typically heating-only facilities and were disqualified in all cases based on heating/cooling balance issues.

Once the system types were determined, a comparison between energy costs for the geothermal and the conventional systems were developed. Only the portions of the heating and cooling load that were impacted by the system type were considered in this portion of the study. Pump and fan peak energy consumption was determined based on ASHRAE standards for all cases, and weather bin data analysis was applied to determine annual consumption. For compressor energy consumption, factors were applied to the conventional case to reflect efficiency penalties in the summer for the relatively hot heat transfer fluid. In building types where heat pumps were utilized as a baseline, these factors were partially offset by efficiency gains from the hot heat transfer fluid in the winter. Boiler consumption was based on an assumed average condensing boiler efficiency of 90%. While this relatively high efficiency may not be consistently achieved in practice, it was deemed logical to assume that a building considering conversion to a geothermal system would be optimally run with either upgrade. Boiler consumption was also calculated based on weather bin data.

Once energy consumption data had been developed for each building type on a per SF basis, previous iteration results were compared to the findings of the TWG. As expected, our results were comparable but somewhat more efficient than those findings. A major exception, also as expected, was for older residential buildings. As these buildings are currently cooled primarily by window AC units, cooling is primarily logged as a basic plug load and does not show up in the TWG data. As our calculation assumes conversion to a centralized system, cooling is more in line with other building types.

The same building types were also evaluated with envelope upgrades. To verify the building heating and cooling energy values calculated with new building envelopes, the results were compared with a CBECS supported model using expected values based on meeting ASHRAE 90.1 2004.

3.3. Energy Cost Calculation

Economic analysis was a comparison between the installation of a geothermal system and the installation of an energy code compliant high efficiency centralized system. However, both system types may be beyond the financial capacity of some building owners. With incentives in place to support the installation of geothermal systems, a full economic analysis should be completed in advance of any decision.

Other considerations in implementing a geothermal system might include preserving building aesthetics or making a statement for clean energy as a public relations initiative. As such, in addition to economic feasibility, the final tool presents the user with technical and geological feasibility. This provides the end user with the option of pursuing a geothermal solution where it may not be viable to install a cooling tower on the roof or a boiler in the basement. The geothermal systems perform all heat rejection and absorption within the ground and utilize minimal building square footage which is appealing to buildings that suffer from the constraints mentioned above.

3.4. Geothermal System Supply Calculation

3.4.1. Point Grid Method

As part of the closed loop systems, modeling was performed to size the borefields needed to meet the estimated heating and cooling load profiles. Separate model runs were made for each building type as well as a summary run for the entire development. In summary, for the closed loop option under the baseline/default condition, the maximum number of individual closed loops that could “fit” within the outdoor area of a site was determined and multiplied by the average thermal capacity of a standard loop.

The potential capacity is calculated by calculating the number of loops that fit onto the available space times the thermal capacity per loop. The calculation does the following for each of the (quarter million) parcels in the dataset:

1. First, it subtracts the building footprint from the parcel geometry to leave only the ‘garden’ geometry available where actual boreholes could be placed.
2. A hexagon grid is overlaid on top of all parcels. The hexagon grid corresponds to the tightest possible arrangement of non-overlapping boreholes with the chosen 30ft diameter.
3. For each parcel, the number of hexagon center points that fall within the parcel, but not within the building outline, is calculated and joined to the parcel.
4. Step 2 and 3 are repeated 15 times with 15 different hexagon grids, transposed 15 times in x and y directions.
5. For each parcel the average and maximum number of boreholes, out of 16 grid-checks, is calculated. The maximum is used for further calculations.

Below are two images to clarify this. In the first, you’ll see an example parcel with the maximum number of boreholes that fit into the parcel according to the above logic. Note that none of the borehole centers are outside the parcel or inside the building footprint.

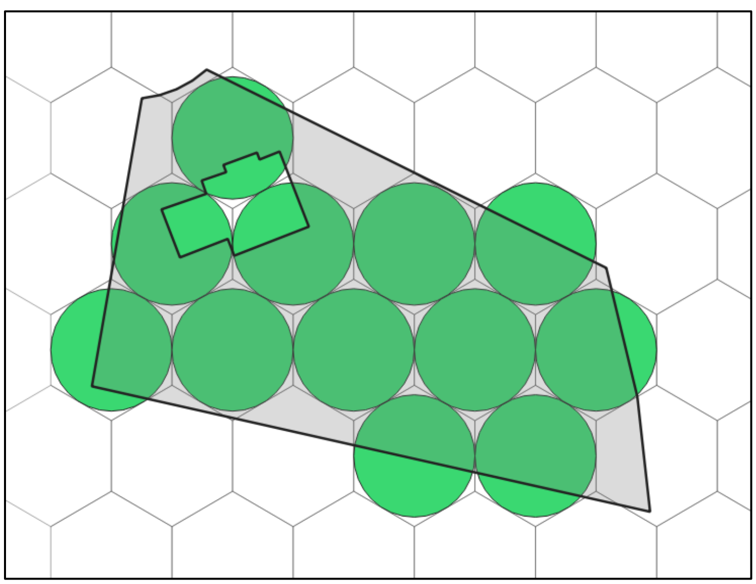

Figure 2. Example of filling available space in a parcel not occupied by a building with closed loops.

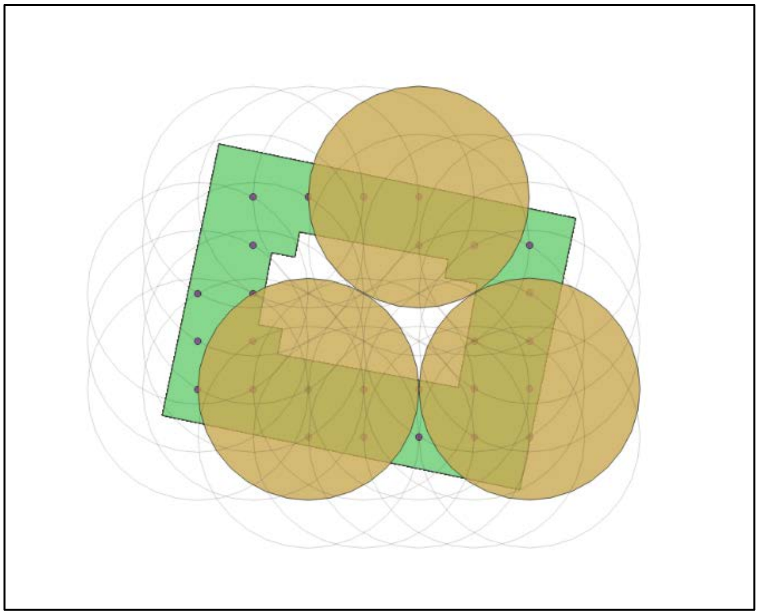

Figure 3 Example of filling random area with closed loops

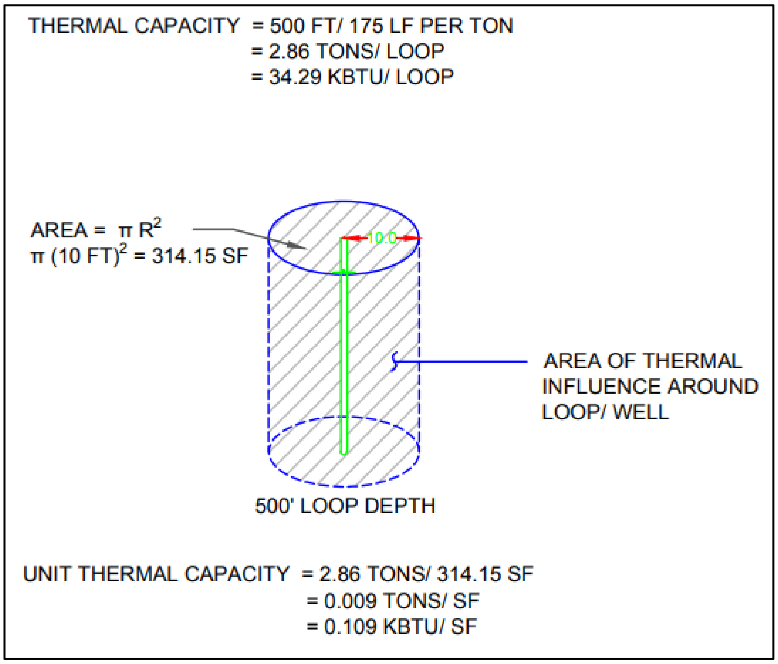

Figure 4 - Thermal capacity calculation (P.W. Grosser Consulting, Inc)

3.4.2. Limitations

- The maximum number of points is calculated per parcel. If two adjacent parcels both opt for a closed loop system, some can interfere.

- When the required Closed Loops exceed the Potential Closed Loops a tooltip is displayed. Geothermal systems are best suited for properties with sufficient space for a loop field. If you have questions or would like a more detailed assessment, apply for a free screening or consult a NYSERDA Flextech contractor.

4. Payback Time Calculations

Where sites were deemed to be feasible as above for a geothermal system, further review was completed to determine economic feasibility of the system as follows:

1. Based on the calculations described in Section 3, the cost savings based on energy savings and maintenance savings for each building type was determined. Values were calculated on a per square foot per building type, then applied to all buildings.
    a. Required heating and cooling as well as maximum heating demand (to heat building at coldest time of year) and maximum cooling demand for each building type/vintage were calculated. This was based on both how buildings are used, e.g. number of people per 1,000 square feet and typical hours/time of day of operation, as well as envelope construction.
2. The cost savings due to equipment maintenance was based on maintenance costs for typical systems of the size of the baseline HVAC equipment and proposed HVAC systems with ground source heat pumps.
3. Based on the ground thermal capacity and required system size calculations as described above, where feasible, incremental installation costs were developed per square foot per building type, then applied to all buildings.
4. Although greenhouse gas emissions were not factored into the payback calculation, annual tons of carbon dioxide equivalent (CO2e) greenhouse gas emissions savings for each building type were also calculated based on the fuel type of and amount of energy use reduction from baseline to ground source heat pumps. Site to source energy ratios for electricity and other utilities were used to assure that the full scope of GHG emissions was accounted for.
5. Simple payback was determined by dividing incremental installation costs by the combined annual cost savings due to energy savings and comparative reduced maintenance.
6. Results and a general recommendation were provided based on these findings.

In summary, after development of the energy consumption analysis for the various building types, this data was applied to the actual buildings to determine economic feasibility of the ground source heat pump systems. Tables, like Table 11, based on the weather bin data analysis summarized the energy consumption per 1,000 ft² for the various building types for both conventional and geothermal systems. This information was then individualized for the buildings based on type and square footage. Energy savings from the geothermal system was thus determined for each system in terms of both energy (Btus) and cost ($).

4.1. Assumptions

Installation costs were estimated based on tons for cooling equipment (including geothermal systems), horsepower for pumps, and kBtu for boilers. These assumptions are all based on prior work and rules of thumb. Actual costs vary considerably for each site, so it should be extensively reviewed during an individualized feasibility study before any decisions are implemented. Additionally, tool output provides payback period without the carbon credits or energy efficiency/renewable energy rebates, but as these can significantly reduce system cost, should be reviewed with an individualized feasibility study.

An incremental payback period is then determined by comparing the cost of the conventional system to the cost of the geothermal system, and then dividing by the cost savings due to energy savings and reduced maintenance costs.

All economic evaluations were completed presenting this as an alternative to a current high efficiency, code compliant centralized heating and cooling system. Essentially, it is assumed that the building is due for or planning a large heating/cooling system upgrade, e.g. main equipment approaching end of life, building is new, etc. As such, the investment and payback are based on the incremental or additional cost of a ground source heat pump system.

5. GIS Specification

This section contains specifics regarding the Geographic Information Systems (GIS) aspects of the GSHP tool.

ArcGIS Online is used to host GIS layers. The ArcGIS Online platform provides fully scalable data storage combined with a broad set of customizable web applications that enable the visualization of the results of the GSHP analyses on many devices. WGS84 is used as datum and coordinate system, in the Web Mercator projection.

The results of the analysis are stored in multiple feature layers. For visualization, a layer with building outlines is uploaded and styled according to the return-on-investment periods. For the query tool, whereby users can look up the used datapoints for a particular location and go to the Calculation Dashboard to further investigate the possibilities of GSHP, a point layer has been created and published as a feature layer for all of Westchester county. Finally, the result of a custom clustering algorithm that clusters buildings with low return on investment for specific building types has also been uploaded as a polygon feature layer to ArcGIS Online.

Two web maps are used for the tool. One contains the visualization polygon layer with the building footprints, as well as the point layer with all data associated with those buildings. On the user-facing tool, this web map is loaded. Whenever a user enters a location, the point layer is queried for the nearest points and the closest point from the point layer in this web map is shown with all of its attributes.

The second web map features multiple visualizations of the same clustering data layer for the Multi-Property Map Tool. This tool then shows one of these visualizations at a time, based on which layer the user wants to see. The clustering data feature layer also contains information about the number of properties that fall within the cluster. This is stored as attributes in the cluster data layer and is shown when users click on a cluster in the Multi-Property Map Tool. The clustering of buildings into ‘islands’ is calculated with the DBSCAN algorithm (https://en.wikipedia.org/wiki/DBSCAN). To form a potency island, criteria for distance and minimum size are used.