

White Hawk Ecovillage Networked Community Geothermal System

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White Hawk Ecovillage Networked Community Geothermal System

Final Report

Prepared for:

New York State Energy Research and Development Authority

Albany, NY

Sue Dougherty
Senior Project Manager

Prepared by:

LaBella Associates, DPC

Rochester, NY

Austin Crosby
Energy Engineer

Additional Contributors:

The GreyEdge Group, LLC

South Jordan, UT

Aztech Geothermal

Ballston Spa, NY

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Abstract

This study explores the potential of a district geothermal system at the residential White Hawk EcoVillage located in Ithaca, NY. A district geothermal system would reduce the community’s energy consumption by leveraging thermal resources such as ground-source heat exchangers to meet the heating, cooling, and domestic hot water loads of the buildings. The economic and technical feasibility of several different system layouts and ownership structures were compared. Additionally, assessments on photovoltaics and electric vehicle charging stations were included in an analysis of potential business models. Results indicate that while a district geothermal system generates energy savings when compared with existing conditions, the economic payback is not favorable due to a lack of load diversity. Including distributed energy resources such as photovoltaics that generate a cash flow would need to be included to make the system economically viable.

Keywords

District geothermal system, ground-source heat exchanger, photovoltaics, electrification, life-cycle cost analysis

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Acronyms and Abbreviations

°F	degrees Fahrenheit
ACCA	Air Conditioning Contractors of America
ADEU	Alexandra District Energy Utility
ASHP	Air-Source Heat Pump
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
ATL	Ambient Temperature Loop
Btu	British Thermal Unit
Btu/h/ft/°F	British Thermal Units per foot per Degree Fahrenheit
CBECS	Commercial Building Energy Consumption Survey
CDD	Cooling Degree Day, 65°F base temperature
COP	Coefficient of Performance
CO ₂	Carbon Dioxide
CO ₂ e	Carbon Dioxide Equivalent
CAP	Concentrated Solar Power
CWA	Clean Water Act
DAC	Disadvantaged Community
DEC	New York State Department of Environmental Conservation
DER	Distributed Energy Resource
DER-CAM	Distributed Energy Resources Customer Adoption Model
DHW	Domestic Hot Water
EER	Energy Efficiency Ratio
EERE	Office of Energy Efficiency and Renewable Energy
EPA	U.S. Environmental Protection Agency
EUI	Energy Utilization Index
EUL	Effective Useful Life
EV	Electric Vehicle
EWT	Entering Water Temperature
GLD	Ground Loop Design software
GHX	Ground Source Heat Exchanger
GSHP	Ground Source Heat Pump
HDD	Heating Degree Day, 65°F base temperature
HEEHR	High-Efficiency Electric Home Rebate Act
HOA	Homeowners Association
HOMES	Homeowner Managing Energy Savings
HP	Heat Pump
HVAC	Heating, Ventilation, and Air Conditioning
IRA	Inflation Reduction Act

IRS	Internal Revenue Service
ITC	investment tax credit
KBtu	thousand British thermal units
kW	kilowatt (1,000 W)
kg	kilogram
kWh	kilowatt hours
LMI	low-to-moderate-income
MACRS	Modified Accelerated Cost Recovery System
MBH	one thousand British Thermal Units per Hour
MMBtu	million British thermal units
MMBtu/cord	million British thermal units per cord
MT	metric tons
MW	megawatts
NG	natural gas
NPV	net present value
NREL	National Renewable Energy Laboratory
NYS	New York State
NYSEG	New York State Electric & Gas Corporation
NYSERDA	New York State Energy Research & Development Authority
O&M	Operation & Maintenance
PON	Program Opportunity Notice
PTC	Production tax credit
PV	Photovoltaic
PVT	Photovoltaic Thermal
PVWatts	Photovoltaic Watts Calculator
ResStock	Residential Stock
RFP	Request for Proposal
SF	Square Foot
SDWA	Safe Drinking Water Act
SPDES	State Pollutant Discharge Elimination System Permit
TPO	third-party ownership
Treasury	U.S. Department of Treasury
UTEN	Utility Thermal Energy Network and Jobs Act
VDER	Value of Distributed Energy Resources
VFD	Variable Frequency Drive
W	Watt
WSHP	Water-Source Heat Pump

Executive Summary

The White Hawk EcoVillage has engaged LaBella Associates, Aztech Geothermal, and the GreyEdge Group, LLC. to conduct a networked geothermal feasibility study through the New York State Energy Research and Development Authority (NYSERDA) Program Opportunity Notice (PON) 4614 Community Heat Pump Systems program. The community seeks to electrify using clean and renewable energy sources while reducing its carbon footprint.

As a part of this feasibility study, the team evaluated the technical viability of implementing a networked geothermal system. This evaluation included:

- Developing preliminary networked geothermal system designs
- Assessing the economic impact
- Calculating carbon emissions reductions
- Analyzing various ownership models and their associated regulatory considerations

The project team acquired information on existing utility energy consumption, occupancy schedules, and building construction through a survey sent to the community. This information helped develop energy models for the buildings. After establishing the base thermal load profiles through these energy models, an on-site geology investigation determined the number of boreholes required to service the community. Using Ground Loop Design (GLD) software, additional energy modeling compared different system configurations: networked vertical borefields with and without supplemental heating, networked horizontal trenches, and individual vertical borefield systems.

During the study, the team evaluated the potential for several geothermal systems. They determined that vertical boreholes, drilled down to 500 feet, would be feasible based on the existing subsurface geology. The team also concluded that a networked geothermal system could be implemented using vertical boreholes or horizontal trenches. However, this system would not significantly benefit from peak load reduction through load diversity, which is a desirable attribute for a networked geothermal system. The networked system could be sized to incorporate future homes, avoiding the need for additional borefield construction. Additionally, the networked system offers ownership and maintenance benefits unavailable to individual systems. However, the networked system would have the highest upfront cost.

An individual vertical borefield system for each building could be implemented, and it would have the lowest upfront cost for the White Hawk EcoVillage. In this model, each home would have its own borehole for heating and cooling loads. Regardless of the geothermal system configuration, the project economics indicate long payback periods. The project team also explored the addition of community solar photovoltaics (PV) to provide additional revenue and improve project economics.

Table ES-1 shows the economic comparison of the options.

Table ES-1. District Geothermal Financial Comparison

Financial Summary	Upfront Cost (\$)	Annual Energy Cost Savings Partial/Full Build-out (\$)^a	Payback (Years)^b	NPV (\$, 25 years, 4%)
In-Kind Replacement	\$0	\$0/\$0	—	-\$793,896
In-Kind Replacement with 450 kW PV	\$552,834	\$80,860/\$77,147	7	-\$153,740
Individual Geothermal System	\$1,258,423	\$5,658/\$12,323	102	-\$1,523,677
Individual Geothermal System with 450 kW PV	\$1,811,257	\$86,518/\$89,470	20	-\$883,521
District Geothermal System	\$1,526,997	\$5,658/\$12,323	124	-\$1,758,772
District Geothermal System with 450 kW PV	\$2,079,831	\$86,518/\$89,470	23	-\$1,017,736

^a Full build-out estimated in 2035.

^b Payback is based on the first build-out energy cost savings.

1 Project Overview

The White Hawk EcoVillage spans 120 acres of land in Danby, NY, focusing on implementing ecologically sustainable principles. The community currently consists of 15 built homes plus 5 leased lots, with the potential to expand to 31 homes.

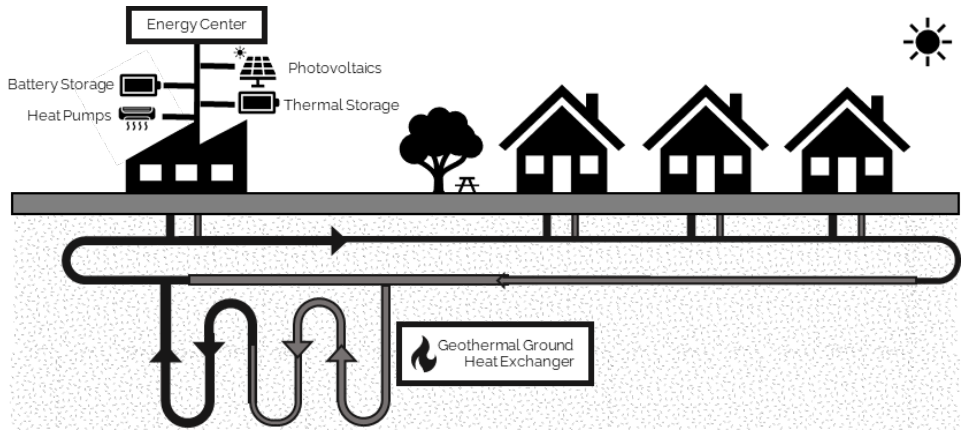
Figure 1. White Hawk EcoVillage



1.1 Study Objectives

The study assesses the feasibility of implementing a community geothermal system at White Hawk. The geothermal system would harness renewable thermal energy from the ground using vertical boreholes or horizontal trenches to heat and cool the homes. The study will also evaluate additional distributed energy resources (DERs), such as solar photovoltaics (PV), to offset the increase in electricity demand due to the geothermal heat pump system. Figure 2 provides a graphic outlining the main components of a geothermal system.

Figure 2. Components of Geothermal System



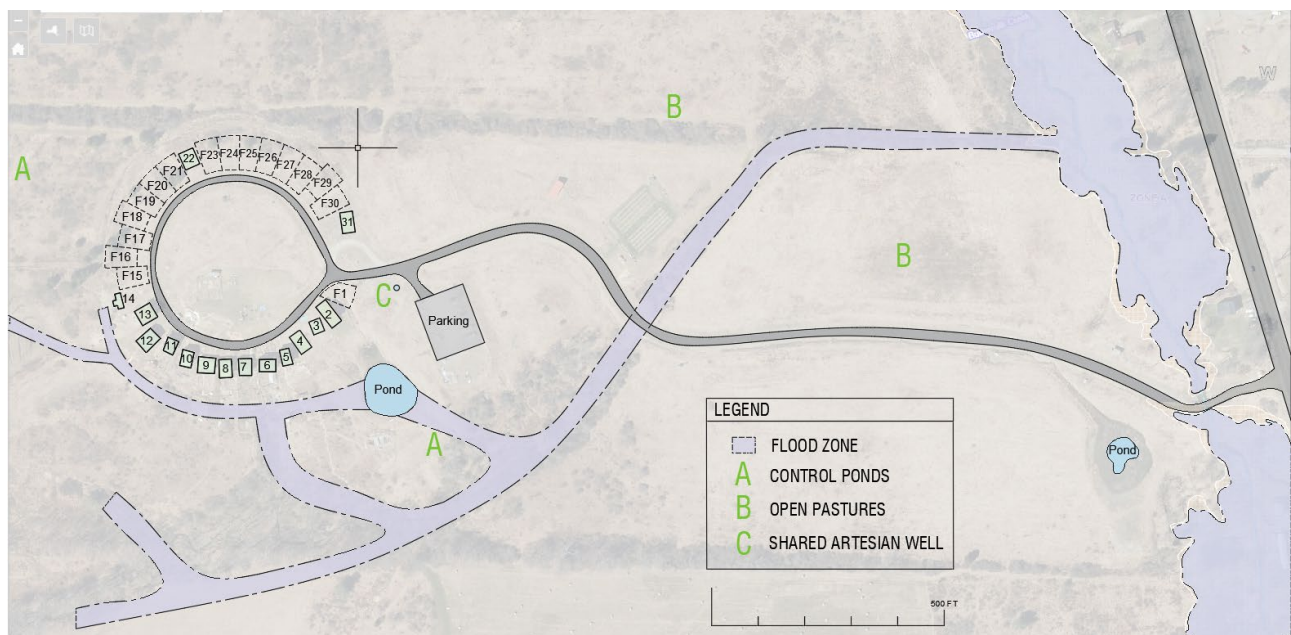
LaBella Associates' approach to this study involves evaluating existing energy use at White Hawk EcoVillage and projecting future electric consumption with an implemented geothermal system. The study will also account for potential expansion on the remaining plots of land in the community and explore using DERs to offset any increase in electric usage.

2 Community Characterization

2.1 Baseline Conditions

The White Hawk EcoVillage, located in Danby, NY, currently consists of 15 residential homes, with plots reserved for 16 additional homes. The community has access to 2 control ponds and 120 acres of land. The baseline conditions documented in this study reflect the existing 15 homes, while the geothermal system design will account for potential expansion on the remaining available lots.

Figure 3. White Hawk EcoVillage Site Map



The community has access to several thermal energy resources. Two control ponds are available and could potentially serve as surface water heat exchangers. Additionally, the community has open fields and parking lots that can house geothermal boreholes. As shown in Figure 3, the site is partially within a flood zone, which will influence the location of potential geothermal equipment.

To determine baseline conditions, the team distributed a survey to all current residents of the community. The survey collected information on their home's heating, ventilation, and air conditioning (HVAC) systems and heating and cooling habits. The survey questions and responses are included in Appendix A. Homes are served by various HVAC systems using natural gas, electricity, or wood as primary fuel sources. The majority of the homes do not use central air conditioning. Table 1 summarizes the existing White Hawk home systems.

Table 1. Existing White Hawk EcoVillage Building Descriptions

House Number	SF	Existing System Description
2	1,500	Wood furnace, electric in supplemental, electric DHW
3	992	ASHP, HP DHW
4	1,500	Wood furnace, HP DHW
5	1,200	NG furnace, NG DHW ^a
6	1,536	Wood furnace, electric supplemental, electric DHW
7	1,008	Radiant floor electric heating, NG DHW
8	1,248	NG furnace, NG DHW
9	1,400	NG furnace ^a , NG DHW ^a
10	1,200	Wood furnace, NG DHW
11	1,200	NG furnace ^a , NG DHW ^a
12	1,380	Wood furnace, electric supplemental, NG DHW
13	2,200	NG furnace ^a , NG DHW ^a
14	500	NG furnace ^a , NG DHW ^a
22	1,700	NG furnace ^a , NG DHW ^a
31	1,830	ASHP, HP DSW

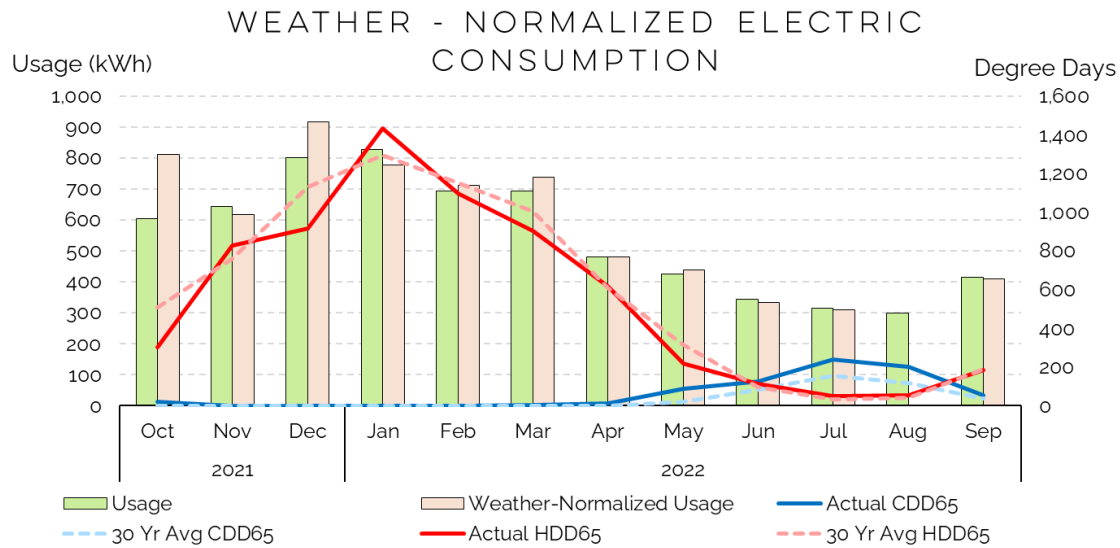
^a Estimated system types.

In addition to completing the survey, some residents provided 12 consecutive months of utility data to quantify energy usage. An overview of resident energy consumption is provided in the following section.

2.2 Baseline Energy Use

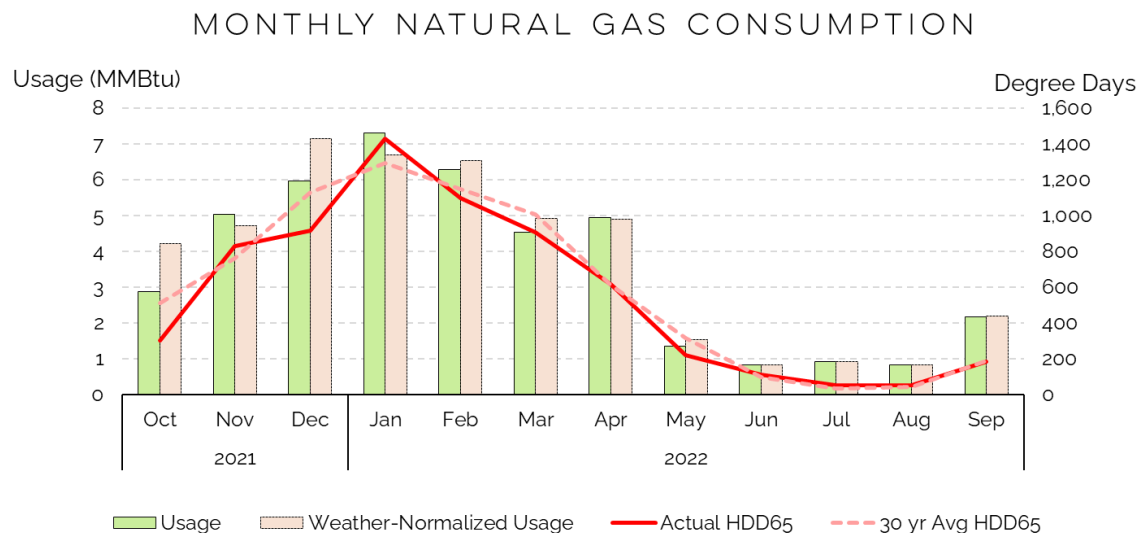
Figure 4 shows a sample of one resident's electric usage. Because utility data was unavailable for some homes, the electric consumption of this resident was assumed to reflect the other homes in the community.

Figure 4. Resident Electric Load Profile



The resident uses radiant slab heating, served by a natural gas (NG) boiler, with electric supplemental heating for space heating and a natural gas boiler for domestic hot water (DHW). The electric usage has been normalized by comparing the heating degree days (HDD) and cooling degree days (CDD) from 2021–2022 to the previous 30-year average. The home uses a window air conditioning unit for cooling but does not have central cooling. As Figure 4 illustrates, electric usage increases during the winter due to supplemental heating, and a similar trend is observed in the residents’ natural gas usage.

Figure 5. Resident Natural Gas Load Profile



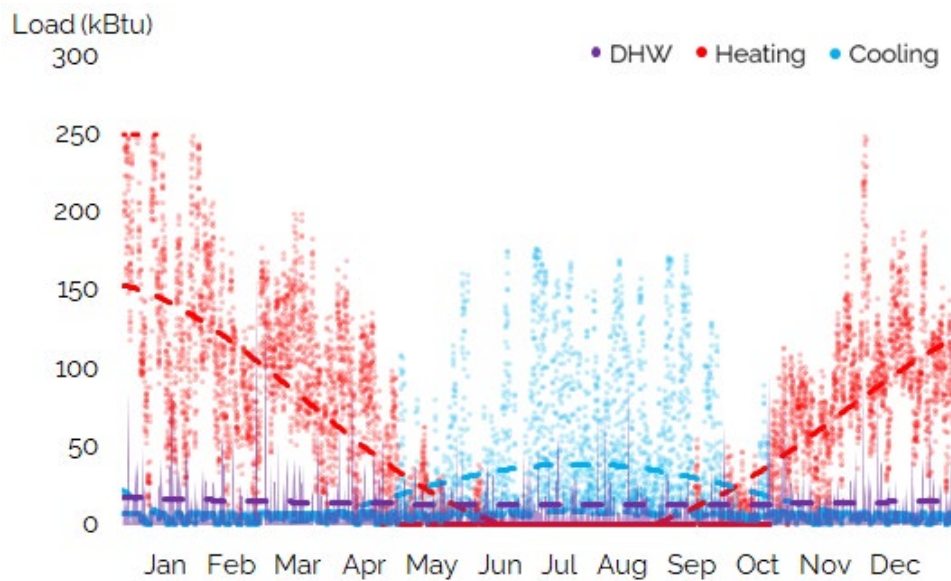
During winter months, natural gas usage increases due to the radiant slab heating system. During the summer months, natural gas usage is attributed to domestic hot water and kitchen equipment. The natural gas usage has been normalized by comparing the heating degree days from 2021–2022 to the previous 30-year average.

Utility data from the EcoVillage residents, combined with an Air Conditioning Contractors of America (ACCA) Manual J energy model, were used to scale a Residential Stock (ResStock) load profile and create an annual load estimate for each home in the community. ResStock, an analysis tool the National Renewable Energy Laboratory (NREL) developed with support from the U.S. Department of Energy, models end-use consumption for residential homes. The base load profile from ResStock represented a residential home in Tompkins County, NY, using natural gas for heating and domestic hot water.

By scaling the ResStock heating and domestic hot water load profiles to match the natural gas usage found on the utility bills, and by adjusting for peak loads from the energy model, thermal load estimates for each existing and future home in the community were determined. Figure 6 shows an annual hourly load profile for the combined system loads for the 15 existing homes.

Figure 6. Thermal Load Profile: Existing Community

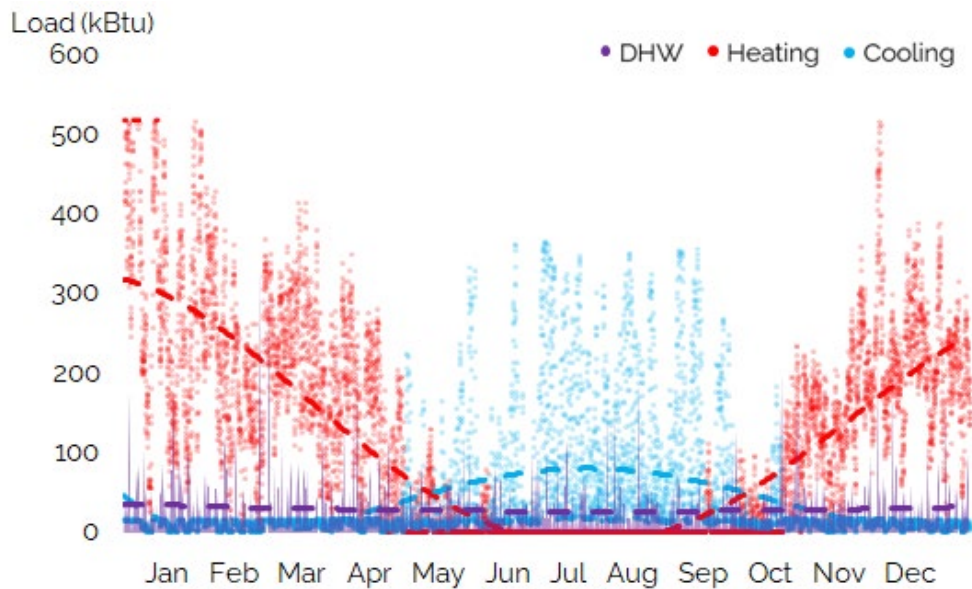
Annual thermal load profile for the existing 15 homes in the White Hawk EcoVillage, showing peak heating and cooling demands.



The existing community has a peak heating load of 25 tons and a peak cooling load of 15 tons. With plans to add 16 homes in adjacent lots over the next several years, the networked geothermal system must be sized to accommodate this future thermal load. Figure 7 shows the combined loads for the 15 existing and 16 future homes. The fully built-out community will have a peak heating load of 50 tons and a peak cooling load of 31 tons.

Figure 7. Thermal Load Profile: Fully Built Community

The annual thermal load profile for the fully built-out White Hawk EcoVillage, including the combined loads for 31 homes, shows peak heating and cooling demands.



The geothermal system will be appropriately sized for a fully built-out community, and the report’s energy and carbon savings sections are based on this fully built-out scenario. Figures 6 and 7 illustrate that the geothermal loop has a heating dominance. Due to the lack of building diversity within the White Hawk EcoVillage, aggregating multiple buildings does not reduce the peak load of the overall system because residential homes are likely to experience peak building loads simultaneously. Although diversity exists in residential homes based on work schedules (day shift versus night shift) and temperature setpoint operations, the modeled load profiles assume a consistent scenario. Therefore, the district load profile magnitude matches the sum of the individual load profiles.

After quantifying the thermal load profiles for each existing home in the White Hawk EcoVillage, the loads were allocated into electric, natural gas, and wood consumption profiles based on the specific equipment used in each home. For homes that did not provide information on their heating, cooling,

and domestic hot water equipment, the team assumed that these homes use natural gas for heating and domestic hot water, with no central air conditioning, consistent with the existing homes in the community.

Table 2 summarizes the assumed proportions and subsequent energy consumption for electricity, natural gas, and wood.

Table 2. Existing Load Distribution and Annual Energy Consumption

House #	Heating			Cooling	DHW%		Annual Consumption		
	Electric	NG	Wood	Electric	Electric	NG	Electric (kWh)	NG (MMBtu)	Wood (MMBtu)
2	50%	0%	50%	0%	100%	0%	11,805	0	22
3	100%	0%	0%	100%	100%	0%	7,946	0	0
4	0%	0%	100%	0%	100%	0%	5,294	0	44
5	0%	100%	0%	0% ^a	0% ^a	100% ^a	3,130	39	0
6	64%	0%	36%	0%	100%	0%	19,669	0	12
7	12%	88%	0%	0%	0%	100%	1,706	35	0
8	0%	100%	0%	0%	0%	100%	3,256	41	0
9	0% ^a	100% ^a	0% ^a	0% ^a	0% ^a	100% ^a	3,652	46	0
10	0%	0%	100%	0%	0%	100%	3,130	8	35
11	0% ^a	100% ^a	0% ^a	0% ^a	0% ^a	100% ^a	3,130	39	0
12	28%	72%	0%	0%	0%	100%	6,249	35	0
13	0% ^a	100% ^a	0% ^a	0% ^a	0% ^a	100% ^a	5,739	72	0
14	0% ^a	100% ^a	0% ^a	0% ^a	0% ^a	100%	1,304	16	0
22	0% ^a	100% ^a	0% ^a	0% ^a	0% ^a	100% ^a	4,435	56	0
31	100%	0%	0%	100%	100%	0%	14,658	0	0
Future	0% ^a	100% ^a	0% ^a	0% ^a	0% ^a	100% ^a	56,749	716	0

^a Unknown buildings are assumed NG heating and NG DHW, no cooling.

As shown in the preceding figures and tables, many buildings are single-family residences with similar expected load profiles. Although the energy modeling assumes similar load profiles for these homes, the inherent differences in occupancy schedules and occupant behavior will create load diversification, or “flattening.” This diversification will enhance the technical feasibility of a networked system compared to an individual building approach. Variations in building loads throughout the day will result in a coincident peak lower than the sum of the individual peaks of the buildings.

2.3 In-Kind Replacement Energy Model

The baseline electric, natural gas, and wood profiles were used to estimate baseline energy costs. New York State Electric & Gas Corporation (NYSEG), the White Hawk EcoVillage utility, provided the residential electric and natural gas tariff structures used in this analysis. Appendix B includes a summary of the rates for these tariff structures. To estimate the cost of wood, the team assumed that the homes use green ash wood. Utah State University conducted a study to determine the heat content factor for green ash wood, expressed in million British thermal units per cord (MMBtu/cord). Using this factor and the cost of wood per cord, the team could estimate annual wood costs with reasonable accuracy.

Table 3. White Hawk EcoVillage Baseline Energy Costs

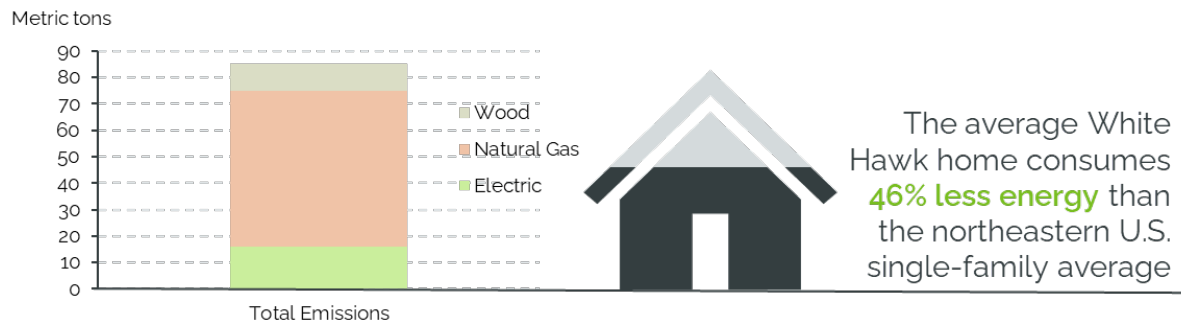
The White Hawk EcoVillage baseline energy costs are shown as annual estimated costs (AEC).

House #	SF	Existing System Description	Electric (AEC)	NG (AEC)	Wood (AEC)
2	1,500	Wood furnace, electric in supplemental, electric DHW	\$1,776	\$0	\$328
3	992	ASHP, HP DHW	\$1,265	\$0	\$0
4	1,500	Wood furnace, HP DHW	\$915	\$0	\$656
5	1,200	NG furnace, NG DHW ^a	\$629	\$682	\$0
6	1,536	Wood furnace, electric supplemental, electric DHW	\$2,816	\$0	\$182
7	1,008	Radiant floor electric heating, NG DHW	\$440	\$613	\$0
8	1,248	NG furnace, NG DHW	\$645	\$727	\$0
9	1,400	NG furnace ^a , NG DHW ^a	\$698	\$777	\$0
10	1,200	Wood furnace, NG DHW	\$629	\$274	\$525
11	1,200	NG furnace ^a , NG DHW ^a	\$629	\$274	\$0
12	1,380	Wood furnace, electric supplemental, NG DHW	\$1,041	\$585	\$0
13	2,200	NG furnace ^a , NG DHW ^a	\$974	\$1,071	\$0
14	500	NG furnace ^a , NG DHW ^a	\$387	\$350	\$0
22	1,700	NG furnace ^a , NG DHW ^a	\$801	\$904	\$0
31	1,830	ASHP, HPDSW	\$2,153	\$0	\$0
Future	21,754	NG furnace ^a , NG DHW ^a	\$7,718	\$7,913	\$0

^a Estimated.

We used the electric, natural gas, and wood profiles, along with U.S. Environmental Protection Agency emissions factors, to estimate the existing emissions for the White Hawk EcoVillage. Figure 8 shows the estimated emissions and a comparison of energy consumption between the average for a White Hawk EcoVillage home and the northeastern U.S. average for a single-family home.

Figure 8. White Hawk EcoVillage Carbon Dioxide Equivalent Emissions Summary



The White Hawk community consumes on average 56 MMBtu of energy per home, per year.

Figure 8 represents a 46% reduction compared to the northeastern U.S. average of 120.7 MMBtu¹ single-family home.

The team estimated in-kind replacement costs for the existing HVAC systems to establish a baseline for financial analysis of a community geothermal system. Table 4 shows these costs derived from RSMeans data.

In addition to the upfront costs, the life-cycle analysis includes estimated annual energy and maintenance costs based on square footage. By projecting the upfront costs, annual energy costs, and maintenance costs for the next 25 years at a 4% discount rate, a net present value (NPV) can be calculated. The study uses NPV as the metric for life-cycle cost analysis. NPV is the difference between the present value of cash inflows and the present value of cash outflows over a specific period. This term is commonly used in investment planning to assess the profitability of a project throughout its lifespan. A positive NPV indicates that the projected earnings or savings from the project exceed the anticipated costs. NPV is evaluated against the rate of return that could be achieved in alternative investments. In this case, a 4% rate of return is used.

Equation 1.
$$NPV = \sum_{t=0}^n \left(\frac{\text{Net Cash Flow per Year}}{(1+(\text{rate of return}))^t} \right)$$

Table 4. White Hawk EcoVillage Existing System Cost Summary

Note: Replacing existing systems in-kind will not yield significant cost savings to offset the initial capital cost; therefore, the NPV for these investments is negative over a 25-year period.

House Vintage	House #	SF	Existing System Description	Annual Energy Cost	Annual Maintenance Cost	In-Kind Replacement Cost ^a	NPV, 25 Years, 4%
2015	2	1,500	Wood furnace, electric in supplemental, electric DHW	\$2,1041	\$100	\$12,575 ^c	-\$42,923
2022	3	992	ASHP, HP DHW	1,265\$	\$100	\$7,700	-\$25,284
2021	4	1,500	Wood furnace, HP DHW	\$1,571	\$100	\$12,125 ^c	-\$32,579
2015 ^b	5	1,200	NG furnace, NG DHW ^b	\$1,311	\$100	\$12,125 ^c	-\$30,303
2008	6	1,536	Wood furnace, electric supplemental, electric DHW	\$2,998	\$100	\$12,125 ^c	-\$59,575
2009	7	1,008	Radiant floor electric heating, NG DHW	\$1,053	\$100	\$11,450 ^c	-\$27,806
2210	8	1,248	NG furnace, NG DHW	\$1,372	\$100	\$12,225 ^c	-\$33,042
2014	9	1,400	NG furnace ^b , NG DHW ^b	\$1,474	\$10	\$12,225 ^c	-\$33,184
2018	10	1,200	Wood furnace, NG DHW	\$1,428	\$100	\$13,900 ^c	-\$32,216
2012	11	1,200	NG furnace ^b , NG DHW ^b	\$1,311	\$100	\$12,225 ^c	-\$31,334
2016	12	1,380	Wood furnace, electric supplemental, NG DHW	\$1,626	\$100	\$14,350 ^c	-\$36,279
2016	13	2,200	NG furnace ^b , NG DHW ^b	\$2,044	\$100	\$12,225 ^c	-\$41,439
2015 ^b	14	500	NG furnace ^b , NG DHW ^b	\$737	\$100	\$12,225 ^c	-\$21,331
2021	22	1,700	NG furnace ^b , NG DHW ^b	\$1,706	\$100	\$12,225 ^c	-\$34,735
2020	31	1,830	ASHP, HP DHW	\$2,153	\$100	\$7,700	-\$39,472
2035	Future	21,754	NG furnace ^b , NG DHW ^b	\$15,532	\$1,600	\$195,600 ^c	-\$272,393

^a Replacing existing systems in-kind will not yield significant cost savings to offset the initial capital cost; therefore, the NPV for these investments is negative over a 25-year period.

^b Estimated.

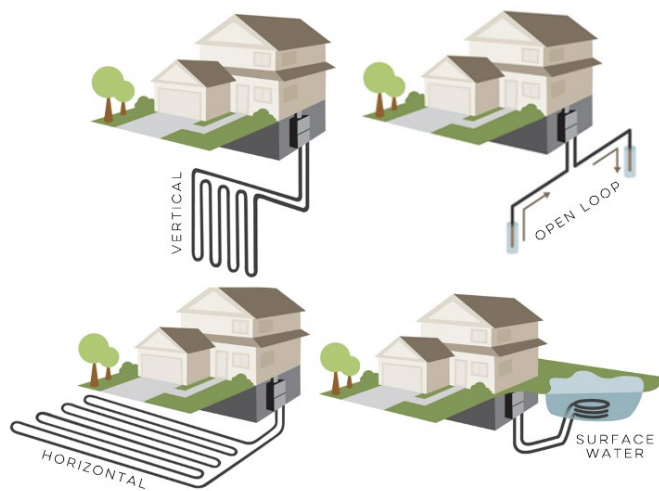
^c Includes installing central air conditioning for homes that do not currently have cooling.

3 Assessment of Technologies

3.1 Thermal Energy Sources

Several thermal resources can be integrated into networked geothermal systems. The site's geology, the availability of wastewater mains, and proximity to rivers, lakes, and ponds all influence the heat source for the loop. While White Hawk EcoVillage will primarily use ground-source heat exchangers (GHX) for the preliminary networked geothermal design, this section provides an overview of other thermal resources.

Figure 9. Example Ground-Source Heat Exchanger Configurations



3.1.1 Ground-Source Heat Exchangers

Ground-source heat exchanger (GHX) systems are the most efficient building electrification technology available today. Traditional vertical GHX systems use closed-loop systems. A vertical borehole, typically drilled to depths of up to 500 feet, houses two pipes connected with a U-shaped joint, sealed in place with grout. These systems generally are spaced boreholes approximately 15 to 25 feet apart in a grid to maximize long-term thermal performance between the loop and the ground.

Horizontal ground-source systems are another variation. These systems are typically installed in trenches or more extensive excavations at least 4 feet to 6 feet deep below the finished grade. As shown in Figure 9, this option does not require drilling but does require significantly more surface area for trenching or excavation to bury the piping.

3.1.2 Surface Water

The connection to surface water typically takes one of two configurations: placing a closed-loop heat exchanger directly in the body of water or pumping water to a heat exchanger where energy transfer occurs.

Surface water heat exchangers take two primary forms:

1. Plate-type heat exchangers consist of multiple flat-plate heat exchangers through which the heat transfer fluid circulates in a closed loop to either reject or absorb heat. Plate construction typically uses stainless steel or titanium, depending on water chemistry (freshwater versus seawater). These systems are compact for their capacity and arrive factory-assembled for field piping and placement.
2. Coiled-pipe heat exchangers can be configured as flat arrangements or individual coil bundles. If the primary loop uses non-potable water chemicals or antifreeze, separating the surface water heat exchanger from the primary loop with a separate heat exchanger is recommended. This ensures protection against potential leaks in the surface water heat exchanger.

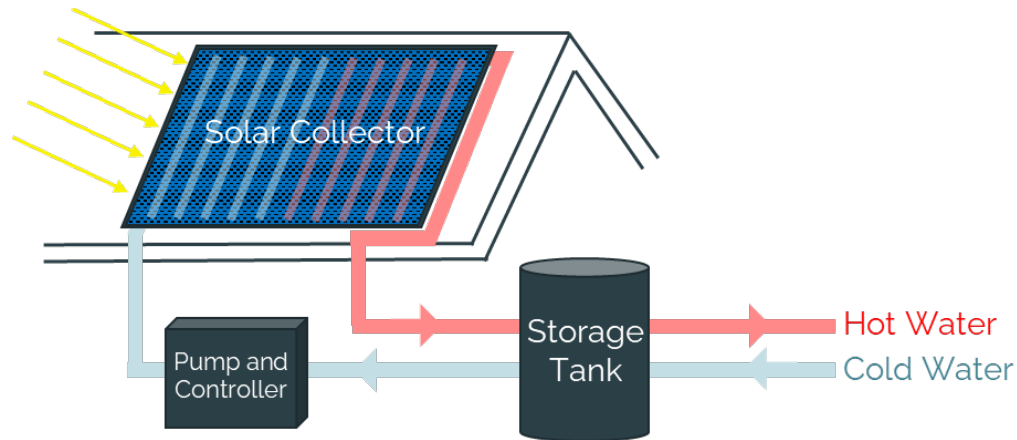
When pumping surface water to a heat exchanger, position the intake structure to minimize the potential for thermal cross-contamination. In flowing bodies of water (e.g., rivers), place the intake upstream, ideally in areas with higher flow rather than at the riverbank. Position the return downstream of the intake. Caution is necessary if the intake or discharge structures are in areas where boats may anchor.

The piping configuration typically involves supply and return connections to the primary loop with a dedicated circulating pump. To meter the quantity of thermal contribution, install a flow meter and two temperature sensors or use a smart pump variable frequency drive (VFD), which calculates flow +/- 3% to 5% accuracy with two temperature sensors.

3.1.3 Solar Thermal

Solar thermal (PVT) systems attach a hydronic heat transfer panel to the back of each solar PV collector. These panels connect via tubing to a pump and heat exchanger, allowing the solar thermal panels to provide thermal energy instead of the electrical energy typical PV panel. Figure 10 illustrates solar thermal operation.

Figure 10. Solar Thermal Operation



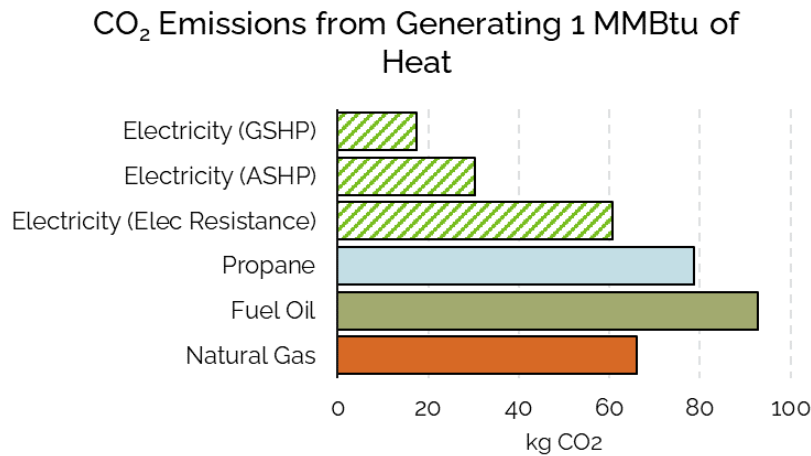
In the heating mode, the hydronic panel absorbs heat from the backside of the solar PV panel. At night or during favorable air temperatures, these hydronic panels can also provide heat rejection (nominally 1 ton per 10 square meters). Although solar panels that generate electrical and thermal energy exist, they have not yet achieved mainstream adoption due to cost-effectiveness issues.

PVT systems connect to an ambient temperature loop (ATL) with a heat exchanger, enabling an antifreeze solution in the hydronic panels. A pump circulates the PVT fluid through one side of the heat exchanger when the hydronic panels transfer heat, either in heating or cooling mode. A second pump moves thermal energy from the heat exchanger to the ATL.

3.1.4 System Resiliency

The piping for these systems is typically installed underground, using high-density polyethylene piping resistant to earthquakes and other tectonic forces. This type of piping is also resistant to freezing and uses heat-fused joints, which are stronger than the pipe itself.

Figure 11. Typical Emissions from Heating, Ventilation, and Air Conditioning Heat Sources



Coexistence with existing gas infrastructure enables the networked geothermal system to relieve pressure on the distribution during peak events. Standby generation can be integrated to maintain the operation of circulation pumps or power buildings in the event of power outages. All building-side HVAC systems depend on electrical supply, regardless of the fuel used. Therefore, electric HVAC equipment (e.g., heat pumps) is not inherently less resilient than fossil fuel HVAC equipment (e.g., gas furnaces with electric fans). All HVAC systems depend on the surrounding electric infrastructure for reliability. However, options exist to increase overall system resiliency through battery storage and backup generation. In addition, redundant pumps can ensure that the networked geothermal system remains operational even if a component fails.

The repair and replacement of parts involve servicing a mechanical room. The underground piping includes strategically placed isolation valves and crossover piping, which protect the system and enable repairs shutting down the entire loop.

3.2 Heating, Ventilation, and Air Conditioning System Integration

The primary motivation for converting to electric HVAC systems is their ability to replace fossil fuel equipment with electric equipment. With New York State’s goal of providing 100% carbon-free electricity by 2040, electric grid-connected systems can achieve carbon neutrality, significantly reducing carbon emissions across the State. Figure 11 shows current emissions associated with generating 1 MMBtu of heat, which will eventually become emission-free with 100% carbon-free electricity. These emissions represent typical combustion equipment used in commercial buildings.

Current electric heating and cooling technologies include water-source heat pumps (WSHP), ground-source heat pumps (GSHP), air-source heat pumps (ASHP), and multi-source heat pumps. Heat pumps deliver temperature control using hot and cold water, air ducts, or ductless fan coils, similar to the popular mini split heat pump systems. Given overall system efficiency and the expected increase in electric consumption from a widespread conversion to electric heating, a highly efficient network of WSHPs or GSHPs offers an opportunity to leverage existing thermal resources and mitigate peak electric load increase.

3.2.1 Air-Source Heat Pumps

ASHPs (without modification) cannot be integrated into a networked geothermal system; however, dual-, multi-, and poly-modal heat pumps can be integrated. These systems consist of refrigeration with a compressor and copper or aluminum coils with fins to transfer heat. In heating mode, liquid refrigerant in the outside coil absorbs heat from the air and evaporates into gas, releasing heat as it condenses into liquid. Equipped with a reversing valve, the direction of the refrigerant flow can be changed to reverse the cycle and alternate between heating and cooling modes.

ASHPs typically have a seasonal coefficient of performance (COP) between 1.5 and 2.5 in cold climates, representing a significant improvement over electric resistance heating, although they are less efficient than GSHPs. ASHPs also lose efficiency at lower temperatures and often require supplemental heating, such as electric resistance, to meet heating demands. The typical lifespan of ASHPs is 15 years, as listed in the New York State Technical Resource Manual (TRM).

3.2.2 Ductwork and Mini-Split Distribution Systems

Central ductwork systems move conditioned air from a central location to one or more rooms, while ductless systems move refrigerants via copper tubing to condition air or a hydronic fluid.

Ductless mini-split heat pump systems work well for homes with non-ducted heating systems, such as baseboard water or standing radiators fed by a combustion boiler. These systems are more accessible to implement when installing additional ductwork is difficult or impractical.

Like standard ASHPs and GSHPs, ductless systems consist of a compressor or condenser (outdoor for ASHP, indoor for GSHP) connected to one or more “refrigerant split” distribution heads or air handlers. Water-source compressor units can connect to a ground-source network. Split systems, including ductless mini-split, multiheaded mini-splits, and variable refrigerant flow systems, can contain a significantly higher volume of refrigerants than packaged GSHP systems.

3.2.3 Ground-Source Heat Pumps

GSHPs are typically a subset of WSHPs that use the ground or earth as both the heat source and sink. For this study, GSHPs are unitary devices (i.e., a single packaged unit that both heats and cools) controlled by the building.

These heat pumps are connected to a hydronic system, whether the system uses an ambient temperature loop or a loop served by mechanical equipment such as a boiler or cooling tower arrangement. The heat pump unit receives preconditioned water, which allows it to operate more efficiently than an ASHP, often exceeding a COP of 4. This increase in efficiency reduces energy consumption, significantly impacting seasonal electric usage and electric loads during peak hours.

GSHPs do not need supplemental systems when adequately sized for their application. The networked geothermal loop supplies a more favorable temperature range than individual building GHXs, ensuring higher efficiencies and higher capacities for GSHPs and WSHPs most of the time. In contrast, when exposed to extreme air temperatures, ASHPs lose a significant portion of their efficiency and capacity. The effective useful life (EUL) for GSHPs is listed as 25 years in the TRM.

3.3 Other Distributed Energy Sources

To mitigate potential increases in electric usage and demand, the team investigated various DERs.

3.3.1 Solar Photovoltaics

Solar PVs convert solar energy into electricity using PV panels. Typically, these PV panels are installed on rooftops, carports, or open fields and are affected by potential shading from surrounding buildings, trees, and other structures. PV production varies with cloud cover, and potential electric demand impacts occur only during the day. Despite this variability, PV arrays’ relatively low capital and maintenance costs have led to widespread adoption in commercial and residential buildings.

3.3.2 Battery Storage

Battery storage modules store electricity for extended periods and discharge it during favorable periods. Buildings with demand-based or time-of-use electric rates can use battery storage to enable cost-saving strategies such as demand peak shaving and demand load shifting. Understanding a building's utility rate structure is essential when assessing the viability of battery storage technology. The two main types of battery storage modules—lithium-ion batteries and flow batteries—each have their respective benefits and drawbacks.

In addition to cost savings, battery storage modules provide resilience by offering backup power when needed. However, the high upfront cost associated with these modules limits their viability in specific applications. NYSEG does not offer residential electric rates that fully capitalize on individual home battery storage. Nevertheless, battery storage enhances reliability and resiliency, particularly when integrated with a community solar array.

A community can use solar array production without exporting excess energy to the grid by implementing battery storage. This system allows batteries to charge during the day, storing energy for use overnight when the solar array does not generate power. Although battery operation incurs additional energy consumption due to inefficiency, this setup reduces community dependence on the grid and increases internal sustainability. In communities without solar arrays, the benefits of battery storage still apply, with the grid charging the batteries in place of the solar array.

3.3.3 Electric Vehicle Charging

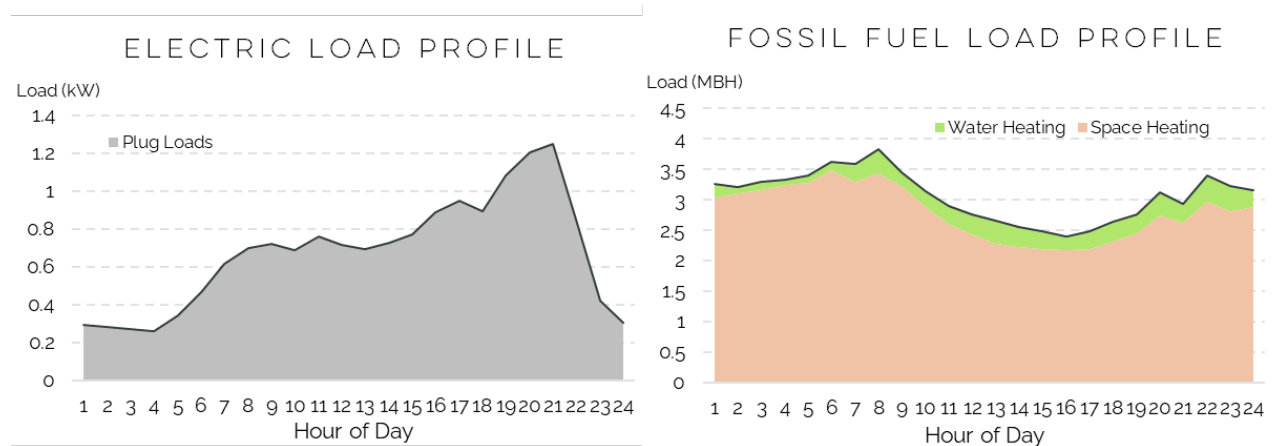
The popularity of electric vehicles (EVs) has surged in recent years. From 2020 to 2022, global sales of EVs increased from 4% to 14%, with projections of 18% by the end of 2023.² As EV adoption increases, the need for EV chargers grows. Several types of EV chargers exist, each with distinct benefits and drawbacks. When implementing EV charging stations, a facility must decide how to own and operate the charging stations and determine the financial strategy, ranging from a loss leader to a profit-making model. Coordination among solar PV, electric battery storage, and electric vehicles with associated charging stations is essential to optimize the interactions between these electric systems.

4 Analytical Methods

The primary software used to model the networked geothermal system includes GLD software, ACCA Manual J, and Excel spreadsheet calculations. Excel calculations work with Manual J energy models, community utility data, and the NREL ResStock database to develop the existing and proposed load profiles for the White Hawk EcoVillage community. Figure 12 provides a sample of a residential home’s electric and fossil fuel load profiles with typical existing equipment.

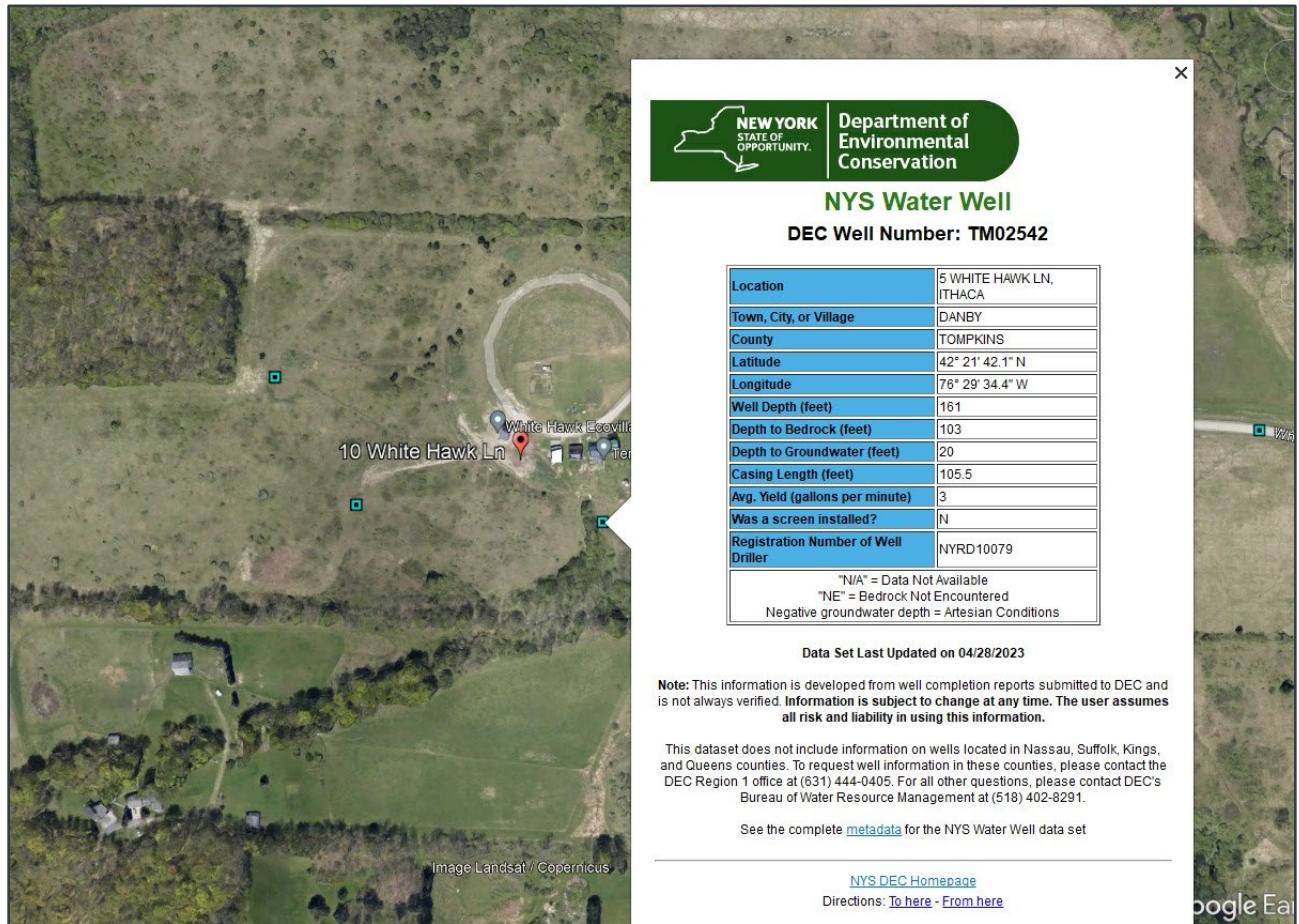
Figure 12. Sample EcoVillage Home Electric and Fossil Fuel Load Profile

For this example, the home uses natural gas for domestic hot water and space heating with no cooling, which the team found to be a common setup in the community.



A test borehole and thermal conductivity testing of the formation were not conducted during this feasibility study. Instead, research on nearby geology informed the assignment of thermal conductivity based on geological findings. According to the New York State Department of Environmental Conservation (DEC) water well information for the White Hawk site, the depth to bedrock varies from 40 feet to 103 feet for the three wells identified. Figure 13 illustrates one of these wells as reported by the DEC’s water well database.³

Figure 13. New York State Department of Environmental Conservation Water Well Information of Nearby Well



Given this site geology, the vertical boreholes were set to a depth of 500 feet, with thermal conductivity assumed to be 1.57 British thermal units per foot per degree Fahrenheit (Btu/(h/ft/°F)). A test bore will be included in the future detailed engineering design phase to confirm the geology and hydrology outlined in the report and provide more accurate thermal conductivity measurements for optimizing the GHX system sizing.

After developing building load profiles and investigating site geology, GLD software modeled the networked geothermal loop. Section 5 details the system design as determined by the GLD software. Appendix D has a full breakdown of the GLD reports.

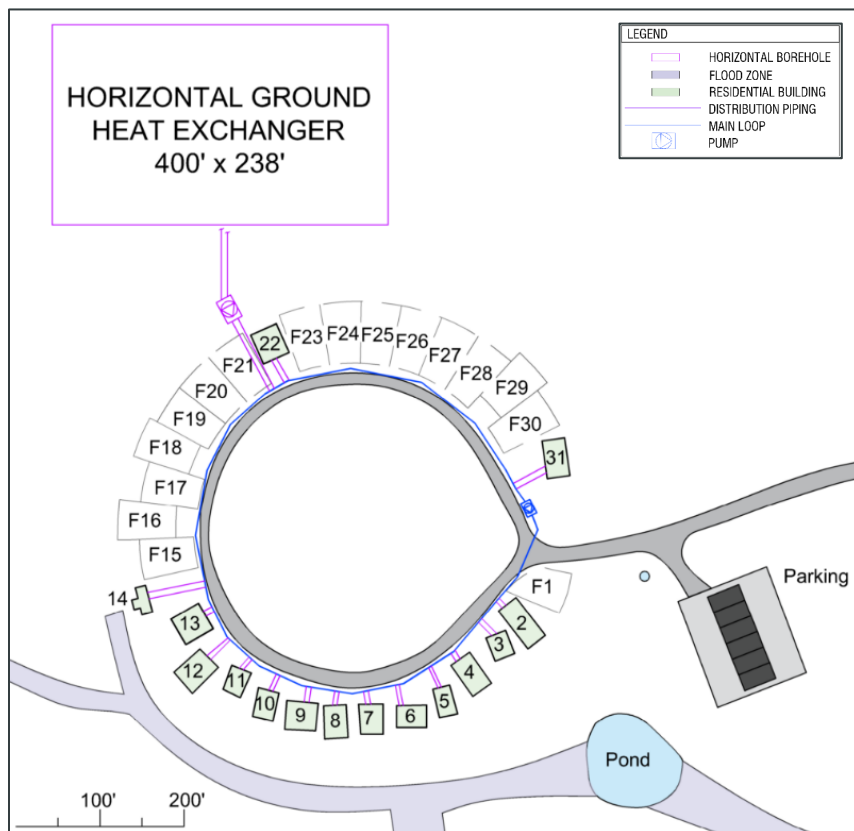
During the preliminary design process, individual boreholes were spaced 25 feet apart to avoid the ground’s thermal saturation. The main piping, sized at 3 inches, would route along the center roadway, with 1.25-inch distribution piping used for service connections to each home. Because this system is sized for the fully built-out community, future homes must connect to the main line for support. This networked geothermal system was designed not to require supplemental thermal systems, ensuring that the ground does not become thermally saturated over time. While supplemental thermal systems could increase overall system resiliency, relying on them for base loading instead of the networked geothermal system would increase its overall carbon emissions.

5.2 Horizontal Ground Heat Exchanger

To support a fully built-out community, 63,298 feet of piping, arranged in slinky formations at a depth of 8 feet, would be required. This can be divided into several arrays as needed. Figure 15 shows a conceptual site plan outlining potential horizontal trench locations for a fully built-out community.

Figure 15. Conceptual Site Plan: Horizontal Ground Heat Exchanger

Horizontal excavation with slinky configurations for the White Hawk EcoVillage.



During the preliminary design process, the slinky formations would occupy a combined 95,160 square feet of space. White Hawk EcoVillage has access to approximately 32 acres of land north of the community, with the land required for the horizontal GHXs occupying about 7% of the combined space. The property lines where 3-inch main piping would route along the center roadway, with 1.25-inch distribution piping servicing each home. Because this system is sized for the fully built-out community, future homes must connect to the main line for support. This networked geothermal system was also designed to not require supplemental thermal systems.

While supplemental thermal systems would improve overall system resiliency, relying on them for building conditioning instead of the networked geothermal system would increase carbon emissions.

As discussed, the design spaced the boreholes to avoid thermal saturation. Figures 16 and 17 show a 15-year analysis of the entering water temperature in the geothermal loop. As shown in the graphics, the networked geothermal water temperatures remain relatively constant over a 15-year period.

Figure 16. Life-Cycle Entering Temperatures for Vertical Designs

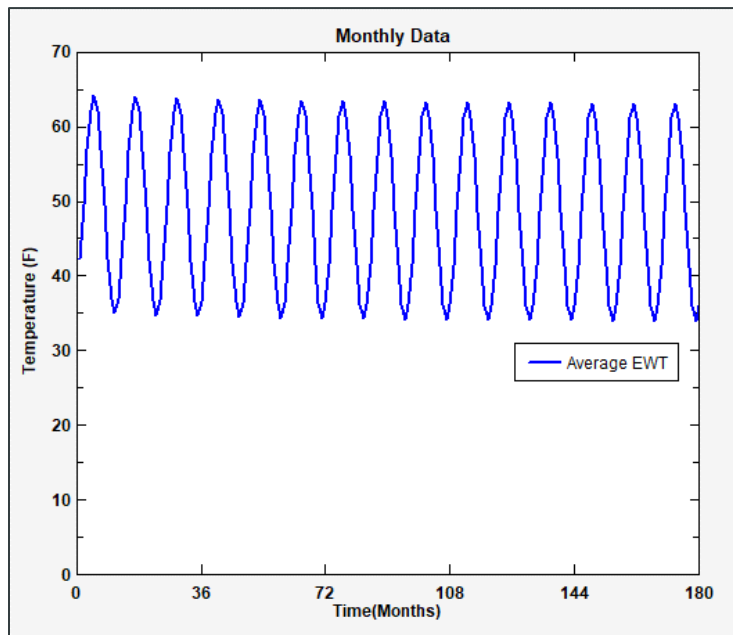
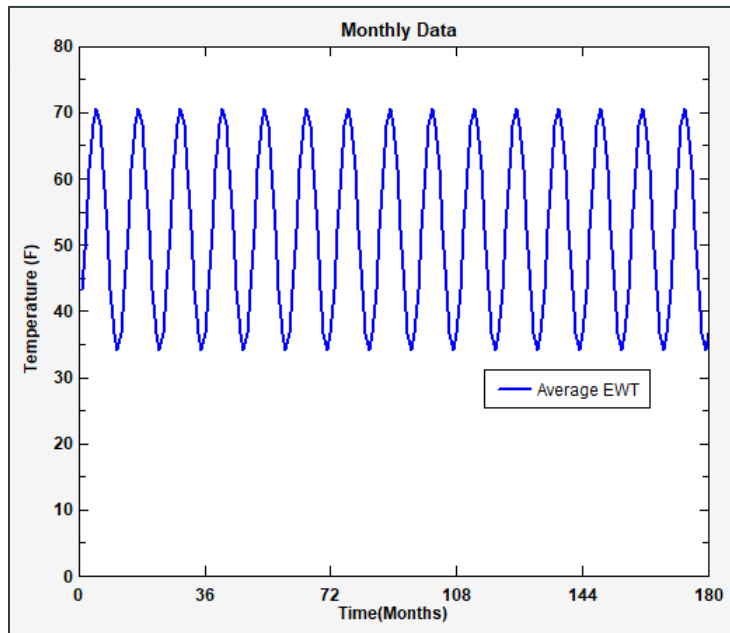


Figure 17. Life-Cycle Entering Temperatures for Horizontal Designs



The networked geothermal system will be implemented in phases, starting with the construction of a fully built-out borefield and central loop. Subsequent phases will upgrade the mechanical equipment in each home and install service line piping from the buildings to the central loop. During these phases, temporary thermal energy sources will condition the buildings under construction, minimizing disruption to individual building owners.

5.3 Networked Geothermal System—Hybrid Approach

The team investigated a hybrid approach in which the borefield was reduced by 50%, resulting in approximately \$320,000 in cost savings. This reduction did not include the operating cost of auxiliary heating. To compensate for the smaller borefield, they added auxiliary heating from a gas boiler to augment the closed-loop boreholes until the system reached a comparable heating fluid temperature. The GLD software estimated that the borefield size could be reduced by 50% by introducing 365 thousand British thermal units per hour (MBH) of auxiliary heating. While this supplemental heating would meet 50% of the heating load at peak, it would only be used for about 4% of the total heating load over a year. No supplemental cooling would be required because the networked geothermal system would be sized to handle the larger heating loads. Although this approach would be more cost-effective, it would also operate less efficiently, resulting in a higher carbon footprint than a system with no auxiliary sources.

5.4 Networked System versus Individual Systems

When comparing individual building geothermal systems and networked geothermal systems, the required infrastructure for each design must be considered. Networked geothermal systems require additional horizontal piping between homes, whereas individual systems only require horizontal piping between each home and its respective borehole(s). In homes with insufficient land area for a horizontal heat exchanger, this horizontal pipe distance may be substantial. For the White Hawk EcoVillage networked system, approximately \$282,000 can be attributed to additional horizontal piping required for a networked system.

The additional horizontal piping main in the networked system slightly increases annual performance. However, the performance of the borefield would otherwise be similar to that of individual geothermal systems.

While the building types at the site are limited to residential homes, inherent diversity exists among these homes. This diversity in occupancy schedules, temperature setpoints, and building construction can slightly reduce the required borefield size. However, this reduction is difficult to quantify. Compared to the overall capacity needed for individual geothermal systems, the reduction in capacity from a networked system is almost negligible, which is a conservative assumption.

5.4.1 Benefits of Networked Systems Compared to Individual Systems

Networked geothermal systems offer several advantages compared to individual systems, particularly in system resiliency, efficiency, and cost-effectiveness. A networked system uses a centralized geothermal borefield influenced by the aggregate thermal loads of the entire community. The combined thermal loads of these buildings remain more constant than the thermal load of any specific building, mainly due to the increased volume of the system. This increased thermal inertia reduces the potential for the ground loop to become thermally saturated and helps maintain more efficient operating conditions for all connected systems.

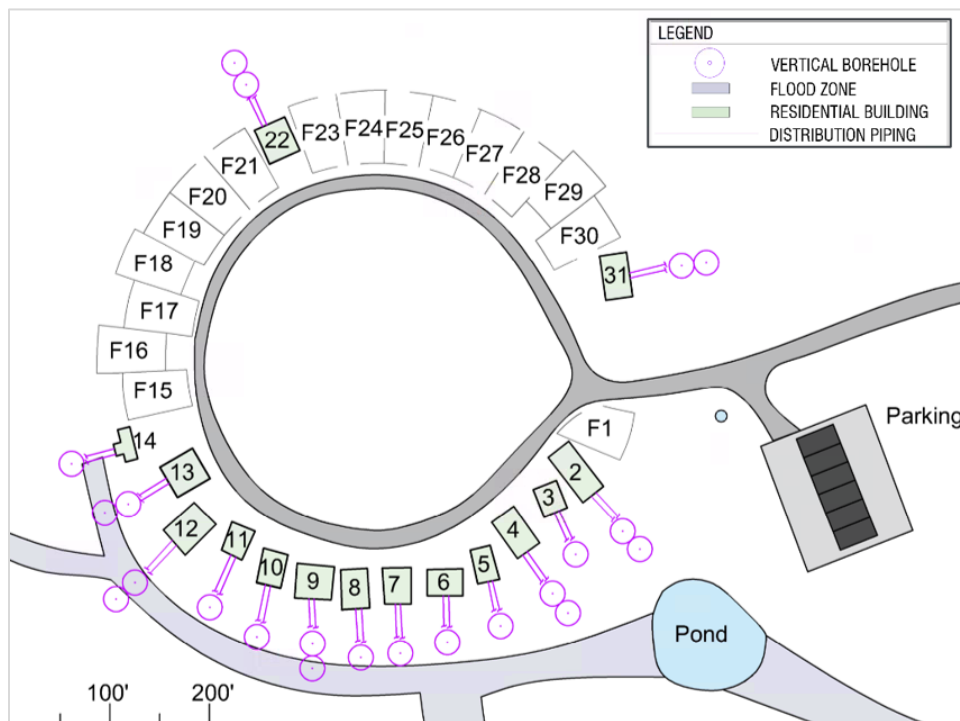
In addition to increased resiliency, the networked geothermal system may offer greater accessibility to the most efficient electrification technology to the individual building owners. While individual building owners would need to fund individual geothermal systems, a networked geothermal system allows a third party to own and operate the system, similar to a utility. The third party handles the upfront cost, and individual owners pay the third party a utility rate. This structure allows residents to benefit from

geothermal heating and cooling even if they lack the capital to fund an individual geothermal system. The business model section of the report investigates this option in detail. Note that some incentives, such as the New York State Clean Heat program, are only available for individual geothermal systems, not networked ones.

To support the 15 existing homes, each home would require between one and two vertical boreholes. Figure 18 shows a conceptual site plan outlining potential vertical borehole locations for individual geothermal systems.

Figure 18. Conceptual Site Plan: Vertical Borehole Locations

Vertical borehole locations for individual geothermal systems at White Hawk EcoVillage.



During the preliminary design process, the team spaced individual boreholes 25 feet apart to prevent thermal saturation of the ground. The horizontal runs back to each house would use 1.5-inch piping for two boreholes and 1.25-inch piping for single boreholes. Because this system is sized for each home, future homes must install additional boreholes. Each geothermal system is designed to meet 100% of the heating and cooling loads for the house, without relying on supplemental thermal systems, to maximize carbon emissions reductions.

6 Business Model

6.1 Business Model Options

Several approaches exist for structuring renewable energy systems for the White Hawk EcoVillage and its for-profit development company, Red Tail, LLC. This section references four existing community heat pump projects in North America, summarized in Table 5.

Table 5. Community Heat Pump Business Model Comparisons

Community Heat Pump Model	GHX Type	Heat Pump Installation & Ownership	GHX Ownership	GHX O&M	Owner Payment Type
Orca Energy	Individual	Homeowner	Private Utility	Private Utility	Utility Bill
Trilith	Individual	Homeowner	Homeowner or Developer	Homeowner or Developer	N/A or HOA Fee
Whisper Valley	Networked	Homeowner	Private Utility	Private Utility	HOA Fee
ADEU	Networked	Homeowner	Municipal	Municipal	Utility Bill

6.2 Individual Ground Heat Exchanger per Home: Homeowner Ownership

The simplest but potentially least accessible option involves homeowners installing their own GSHP system on their property. Assistance could help identify incentives and financing options, but each homeowner would require a substantial investment. For both GSHP and solar PV utility rebates, state and federal tax incentives require homeowners to pay or finance the entire system cost upfront, with incentives appearing either at the end of the project or the following year after filing taxes. Since this approach may be least accessible to White Hawk residents, the team explored several other models based on existing community heat pump systems business models.

6.3 Individual Ground Heat Exchanger per Home: Private Utility or Third-Party Ownership

The team first explored the Orca model, which involves a private utility structure. However, this model may not be permissible depending on the Internal Revenue Service’s (IRS) and U.S. Department of Treasury’s (Treasury) recent interpretations of tax law. The second model, the Trilith model, is more flexible and allows individual homeowners to own their ground loop or have the development company invest. Both models involve a ground loop per building and are not networked systems.

Orca Model: Orca Energy, a company based in Seattle, WA, operates a business model that finances and installs a borehole (or two) per building, typically in new construction. Orca charges the building owner for the use of the thermal energy. They typically acquire “thermal rights” to the entire development and commit to installing boreholes for all the buildings in exchange for the exclusivity of providing thermal energy. Neither the building owner nor the developer pays the upfront cost of the boreholes. Instead, a monthly utility charge covers the cost with two components: a large fixed charge (~80%) and a smaller usage charge (~20%) determined by metering the electric use of the heat pump and translating that into a thermal usage charge.

The Orca model could be applied to the White Hawk community, where Red Tail or another private third party would hold thermal rights to the entire development. In this model, each home would have boreholes sized and installed exclusively for that home’s use.

Trilith Model: Trilith is a new community in Fayetteville, GA, where all new homes must use a GSHP system for heating and cooling. One primary goal of this requirement is to eliminate outdoor air conditioning condensers, creating a quieter and more tranquil outdoor environment during the long air conditioning season. Trilith initially considered working with Orca but ultimately chose a more flexible model. In the Trilith model, new homeowners can either fully own their geothermal borehole or have the developer provide a borehole with a monthly access fee. The entire community commits to using geothermal energy. Homeowners can either own the borehole dedicated to their house or lease it (or acquire it through a loan arrangement) from the developer, Red Tail. Red Tail would front the capital cost and recover it through a maintenance fee or other thermal charge.

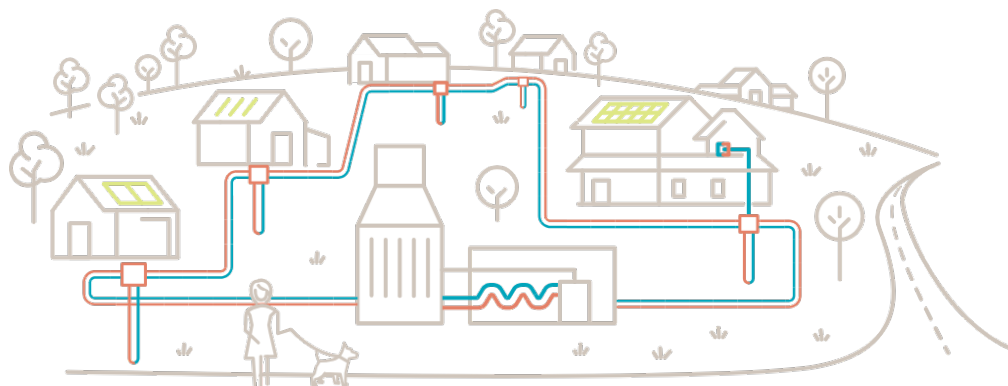
6.4 Networked Geothermal: Private Utility or Third-Party Ownership

The two networked geothermal business models the team considered are from Whisper Valley outside of Austin, TX, installed and operated by a private energy services company, and the Alexandra District Energy Utility (ADEU), which is owned and operated by a municipality just outside of Vancouver, BC.

Whisper Valley Model: Whisper Valley, located outside of Austin, TX, is a new residential community with single-family homes and townhomes. Every home connects to a networked geothermal system called the GeoGrid. Homeowners are billed a fixed monthly charge for access to the thermal energy provided by

the networked geothermal system. Each building has a vertical ground loop on its lot, but the homes are interconnected, allowing energy sharing among the buildings. The community also provides centralized auxiliary cooling through a cooling tower operated during the hottest summer months. In addition, solar PV systems are installed in every home, and each home is prewired for EV charging.

Figure 19. Simple Concept of Whisper Valley's GeoGrid



Red Tail or a private developer will cover the cost of installing one borehole per home. Each borehole will connect to a central plant with an auxiliary heating source, such as a boiler. For White Hawk, linking homes this way could provide auxiliary heating, potentially reducing the need for additional borehole infrastructure. While this approach is significantly more complicated, it could help bypass the IRS's limited-use provision.

ADEU: ADEU operates a municipally-owned system in Vancouver, BC. The system includes two central borefields that serve 12 large apartment buildings, more than 2,000 residential units, and commercial buildings, including a Walmart. The billing structure is outlined in the bylaws, which include a combination of fixed connection charges based on square footage, a usage charge based on BTU metering, and an excess thermal charge if a building exceeds a predetermined thermal energy draw. The municipal utility bills the large connected buildings, while the building owners charge individual residential units a fixed flat thermal charge.

Regulated Utility Ownership: Since the signing of the Utility Thermal Energy Network and Jobs Act (UTEN) by Governor Hochul in the summer of 2022, New York State Public Service Law now permits electric and gas utilities to establish new thermal utilities. Major utilities, including NYSEG, have proposed UTEN pilot projects in its service areas. These projects focus on areas with a mix of

residential and commercial buildings, emphasizing the diversity of load profiles across different building types. White Hawk would not be a strong candidate for an early pilot because these projects are targeted at denser urban and suburban communities that offer broader opportunities for expansion.

6.5 Preferred Business Model for White Hawk EcoVillage

An individual ground loop model, similar to the Trilith model, offers the most flexibility and involves two principal options: (1) Trilith A model, homeowner-funded systems, or (2) Trilith B model, developer-funded systems. If Red Tail is the developer, homeowners/members who choose to have the developer finance the system will repay the developer through a structured loan payment over an extended period.

A networked geothermal model with a cooperative ownership approach can also provide accessibility and affordability, similar to the Whisper Valley model. This model could feature for-profit ownership with Red Tail or potentially not-for-profit ownership through White Hawk EcoVillage. To ensure eligibility for federal investment tax credits (ITC), this model would likely require common or shared ownership of all expenses, based on recent Treasury guidance.

More options exist for community ownership models for Solar PV. Red Tail could design and procure a solar system for the community, with any excess power being sold to the local utility. Solar PV would provide a good return, lower energy costs, and benefit homeowners with loan payments for their geothermal installations.

Section 5.10 compares individual GHX systems versus networked geothermal systems, focusing on initial investment, ownership, operations and maintenance (O&M) responsibilities, and scalability considerations for the community.

6.6 Individual Ground Heat Exchanger, Fully Homeowner Funded: Trilith A Model

- **Initial investment:** In the Trilith A model, the homeowner makes the entire investment and claims all available incentives. Ideally, the ground loop stays within the property boundaries, although agreements could allow the GHX to cross into community-owned land. This model works well for homeowners who can afford the initial investment and have a tax appetite for New York State and federal tax credits.

- **Ownership and O&M responsibility:** The homeowner assumes all ownership and O&M responsibilities since this model is fully homeowner-owned. The community may select one or two HVAC companies for service and maintenance, with each participant paying their fair share.
- **Expandability and scalability:** This model requires substantial homeowner investment and the ability to quickly monetize tax credits, limiting its scalability. However, it could remain an option if multiple models coexist within the community.

6.7 Individual Ground Heat Exchanger, Developer Funded: Trilith B Model

- **Initial investment:** In the Trilith B model, the homeowner’s GSHP system is funded by a long-term loan from the developer. The developer may finance the inside and outside systems or focus on the outside system if a funding gap exists. The home ground loop could be within or outside the homeowner’s property boundaries. Homeowners must claim all available incentives since they own the system and make loan payments. If Treasury guidance changes, the developer may be able to own the GHX or the entire system and claim tax incentives.
- **Ownership and O&M responsibility:** With the system structured as a loan, the homeowner owns the system and assumes all O&M responsibilities. As in other models, the community could select one or two HVAC companies for service and maintenance, with each participant paying their share.
- **Expandability and scalability:** The Trilith B model is more affordable because financing through the developer is less dependent on the homeowner’s ability to pay or secure additional funding. However, the homeowner’s ability to monetize the New York State and federal tax credits remains an issue since the value of these credits depends on significant tax liability. If federal guidance changes to allow third-party ownership (TPO) models, the developer could assume ownership and claim the tax incentives directly.

6.8 Networked Geothermal, Developer Funded: Whisper Valley or Alexandra District Energy Utility (Modified)

- **Initial investment:** Whisper Valley operates as a TPO networked GHX system, with each home in the development paying a connection fee. A modified version of this model would involve the homeowner’s GSHP system being financed through a long-term loan from the developer, similar to Trilith B, but with a networked GHX system rather than a separate GHX for each home. If Treasury guidance changes, the developer may own the networked GHX system or the entire system, including internal heat pump components, and directly claim tax incentives.
- **Ownership and O&M responsibility:** Ownership and O&M responsibility follow the same structure as the Trilith B model but with a networked GHX system rather than individual systems for each home.

- **Expandability and scalability:** This model shares the expandability and scalability considerations of the Trilith B model but with a GHX networked arrangement.

6.9 Issues for Consideration

- **Determining an appropriate monthly charge:** The White Hawk community needs a monthly thermal charge that is low enough to ensure broad accessibility while providing a reasonable return on investment for Red Tail or other private developers. Ideally, the monthly charge would contribute to the recovery of invested capital and support O&M of community systems.
- **Internal GSHP conversions and installations are not included:** Most existing models focus only on installing boreholes or a thermal energy network for the community without considering internal conversion to GSHP systems or installations in new construction. Converting homes to GSHP systems could become a shared community asset and may help with eligibility rules for federal tax incentives.
- **Tax treatment, limited-use provision:** The IRS’s limited-use provision states that if a product installed on a property can only be used by that property and cannot reasonably be recovered, it cannot be owned by a third party and leased to the owner. This limited-use property would need to be structured as a loan, with the building owner also owning the ground loop. If this applies, the homeowner would need to take the tax credit on the cost of the ground loop, not the third-party owner, which may limit the accessibility of individual borehole models. If the group loop is structured as a loan, it would be similar to the individual GSHP ownership model but with financing for the ground loop. To structure as a TPO model, the boreholes may need to be placed outside the homeowner’s lot, such as in the roadway or other community-owned land. This structure would allow the argument that the borehole is not on the homeowner’s property, making repurposing the borehole for another building possible if lease payments became delinquent. This would make the asset “recoverable” or allow it to be “reassigned.”
- **Separately-owned components, federal tax incentive eligibility:** Recent Treasury and IRS guidance⁴ indicates:

(ii) Example 2. Ownership of separate components. X and Y own separate components of a geothermal heat pump equipment, which taken together is a unit of energy property. X owns the coils in the ground and Y owns the heat pump. No section 48 credit may be determined with respect to either X or Y because each owns a separate component of energy property that does not constitute a unit of energy property as defined in §1.48-9(f)(2).

This indicates that a TPO model would require the inclusion of both the internal heat pump and that no TPO structure is possible. This points toward focusing on attractive financing options and packaging all available incentives to make the geothermal heat pump systems affordable.

- **Shared ownership, federal tax incentive eligibility:** Recent Treasury guidance also discussed the possibility of “shared property,” which could allow a community or cooperative structure to own the system, with all the members sharing ownership. According to the guidance:

Multiple energy properties (whether owned by one or more taxpayers) may include shared property that may be considered an integral part of each energy property so long as the cost basis for the shared property is properly allocated

to each energy property. The total cost basis of such shared property divided among the energy properties may not exceed 100 percent of the cost of such shared property.

6.10 Creating a Path to Sustainable Business Models

The project team is exploring these two options to establish sustainable business models for community heat pump systems:

1. **Mechanisms to reduce capital costs:** Reducing capital costs is essential to minimize the cost recovery necessary after project completion. Incentive programs such as the Inflation Reduction Act (IRA) can cover more than 40% of project costs.
2. **Mechanisms to increase energy bill savings:** Implementing mechanisms to reduce energy costs will help offset charges from new renewable thermal resources without increasing the energy expenses of building owners and tenants. Many of these mechanisms will require changes in how energy costs are allocated and are not currently monetizable (e.g., New York State Cap-and-Invest Program and electric peak demand reduction for small residential customers). See section 6.13, Mechanisms to Increase Energy Bill Savings, for details.

6.11 Mechanisms to Decrease Upfront Cost

6.11.1 Federal Incentives: The Inflation Reduction Act

On August 16, 2022, President Biden signed the IRA into law, marking the most significant congressional action on clean energy and climate change in the nation’s history. The IRA increased and extended the commercial geothermal heat pump tax incentives, which the project team is evaluating as a significant mechanism for reducing capital costs for this project. While the foundational structure and eligibility set by the Renewable Energy and Job Creation Tax Act of 2008 remains essentially unchanged, new eligibility provisions and “adders” remain undefined by Treasury guidance at this report’s submission. The following are some eligibility areas that are likely to apply to the White Hawk EcoVillage.

6.11.2 Commercial Geothermal Heat Pump Tax Credit

If a corporation owns the geothermal or solar PV systems, it would be eligible for a 30% ITC with the possibility of an additional 10% ITC if the project meets “domestic content” provisions. A further 10% ITC adder applies for an “energy community,” but this designation is very specific and not applicable in most areas of New York State. Accelerated depreciation can be taken, with half of the ITC amount added to the allowable basis.

- **IRA** includes an elective payment option for the first time if the system’s owner is tax-exempt, such as a municipality.
- **Home Electrification Rebates and Home Efficiency Rebates**, administered by NYSERDA, cannot be combined and will be structured to fit within the existing NYSERDA and utility program offerings for LMI populations. Their applicability will also be influenced by the possibility of a corporation paying for and potentially owning some aspects of the residential building equipment.
- **The Homeowner Managing Energy Savings (HOMES)** rebate program focuses on reducing overall home energy use through weatherization renovations, such as adding insulation and installing more efficient appliances. The rebates are based on the energy saved through modeling, which requires computer software or measured energy savings. LMI households qualify for double the rebate amount and are eligible for up to 80% of project costs, up to \$8,000 if energy use is cut by 35%, and up to \$4,000 if energy use is cut by 20%.
- **The High-Efficiency Electric Home Rebate Act (HEEHR)** offers LMI families as much as \$14,000 per year in point-of-sale discounts for electrification projects—including up to \$8,000 for a heat pump for space heating and cooling, \$840 for an electric stove, and \$1,600 for an insulation project.

6.12 New York State Incentives: Utility and NYSERDA

- **New York State Clean Heat Rebates:** These incentives could cover up to 10% of system costs through larger system custom measures based on projected energy savings or smaller system prescriptive rebates based on installed heat pump capacity. Clean Heat Rebates will end in 2025 unless extended or replaced by a utility program with similar objectives. Note that these incentives are only available for individual systems, not networked systems.
- **NYSERDA Community Heat Pump Systems PON 4614:** This program funded this scoping study but is not currently open. Previously, the program contributed up to \$500,000 for Category B detailed engineering studies and up to \$4 million for Category C construction phase projects. A new funding opportunity for thermal energy network projects is expected to launch in 2024. However, the specific categories, funding levels, and recommended matching funds have not been released during this study.

- **New York State Residential Tax Credit:** A 25% residential tax credit, capped at \$5,000, was introduced in the 2022 New York State budget for qualified residential geothermal heat pump systems. This credit works poorly for building owners with limited New York State tax liability, even though it can be used over five taxable years. This credit would not apply if the developer owns the entire GSHP system (internal and external).

6.13 Mechanisms to Increase Energy Bill Savings

The project team recognizes building electrification involves a complex set of issues. This section highlights potential future savings to help justify investments in clean thermal infrastructure.

- **Solar PV renewable electric sales:** Solar PV renewable electric sales offer a solid mechanism to lower the effective electric rate for the White Hawk community. Significant incentives reduce capital costs, and selling electricity back to the utility—at a discounted rate—can provide a strong return on investment, serving as a long-term source of revenue or a means to lower energy costs for the community.
- **Modifications to electric rate design:** Current electric rates assume most homes use combustion-based heating. Transitioning from combustion heating to efficient electric heating on a broad scale requires reevaluating utility rates. Developing new rate classes is a complex, multistakeholder process. This section suggests evaluating changes to electric rate design through appropriate channels, which may benefit the transition to fully electrified buildings.
- **Carbon valuation by DEC:** DEC has established a value for carbon based on estimated net damages caused by climate change.⁵ The social cost of carbon varies based on the discount rate and year. At a 3% discount rate, the DEC estimates the cost of carbon at approximately \$53 per metric ton of CO₂ (in 2020 dollars). Monetizing carbon reduction could offer mechanisms for customer benefits, such as rate credits or one-time payments to reduce capital costs, potentially based on pre-minted value over a 10-year period.

6.13.1 Governor Hochul’s Energy Affordability Proposals

Governor Hochul introduced several initiatives to improve energy affordability in her 2023 State of the State address. These proposals aim to reduce costs for vulnerable households and support New York State’s climate goals.

- **New York State Cap-and-Invest program:** The Governor will direct the DEC and NYSERDA to advance a statewide Cap-and-Invest program in accordance with the New York State Climate Action Counsel recommendations. The program will balance greenhouse gas emissions reductions, prioritize emissions cuts in disadvantaged communities (DAC), limit costs for economically vulnerable households, and maintain the competitiveness of New York State industries. The program is expected to generate more than \$1 billion annually in future cap-and-invest proceeds, which will be distributed to New Yorkers through a universal Climate Action Rebate. [Read about the New York State Cap-and-Invest program here.](#)

- **Electric bill credit for LMI households:** The proposal includes \$200 million in relief for high electric bills. New York State will credit the more than 800,000 New York State households earning less than \$75,000 annually to ease the burden of rising electric costs.

6.14 Permitting and Regulatory Review

6.14.1 Regulations and Permitting

Like traditional geothermal systems, networked geothermal systems must comply with various environmental laws, regulations, and permitting requirements. The following outlines the statewide and federal implications, excluding local municipal codes and requirements.

- **Coastal Zone Management Act:** Allows coastal states to develop coastal management programs. Projects in coastal lands must comply with the state’s Coastal Zone Management Program.
- **Clean Water Act (CWA):** Empowers the DEC to manage water pollution and develop pretreatment programs. These programs regulate indirect pollutant discharges into municipal waterways.
- **Safe Drinking Water Act (SDWA):** Grants the U.S. Environmental Protection Agency (EPA) authority to set minimum state water quality standards. Under the Underground Injection Control program, standing column wells and open-loop diffusion wells are classified as Class V injection wells. Injection wells are prohibited from introducing contaminants into underground sources of drinking water. Most Class V injections can operate without a permit, provided owners submit inventory information to the EPA and demonstrate compliance with regulations to protect underground freshwater sources.
- **New York State Water Withdrawal Permits:** Apply only to open-loop systems. Water withdrawal permits are required for systems exceeding 100,000 gallons per day of intake.
- **State Pollutant Discharge Elimination System Permit (SPDES):** Regulated by DEC, this permit is required for systems that reject heat or pollutants into a body of water. Depending on the specific circumstances, it applies directly to open-loop systems and may apply to closed-loop systems.
- **Drilling permits:** For wells less than 500 feet deep, DEC’s Division of Water regulates permitting, requiring reports on driller registration, certifications, and well activities. For wells exceeding 500 feet in depth, DEC’s Division of Mineral Resources oversees permitting. A permit application must include details on drilling methodology, and an Environmental Assessment form must be submitted to assess the need for additional permitting. As of September 2023, Senate Bill S6604 exempts closed-loop geothermal wells from additional permitting requirements for wells deeper than 500 feet.

7 Energy and Emissions Impact

7.1 Energy and Carbon Impact

Based on the building loads, the preliminary energy consumption of the networked system is shown in the graphs below. The data highlights an increase in peak electric load from converting the fossil fuel heating systems to electric heat pumps. The impact of energy and emissions assumes a networked system without auxiliary heating.

As discussed in a previous section, the projected increase in peak electric load at the site suggests the potential for collocating PV systems to offset the strain on the surrounding electric infrastructure.

Figure 20. Estimated Electric Impacts at White Hawk EcoVillage (Peak Winter)

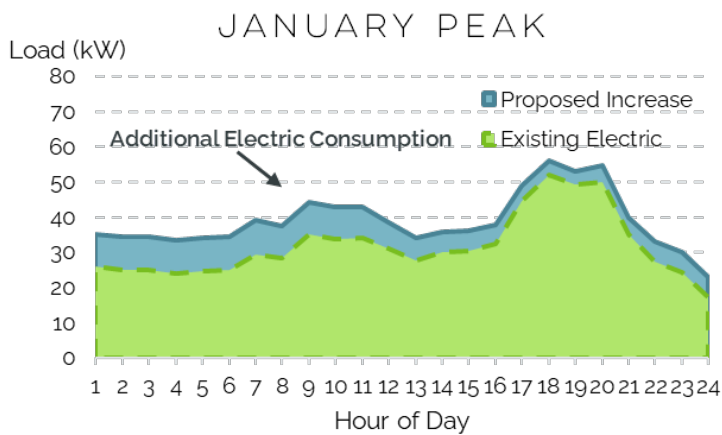


Figure 21. Estimated Electric Impacts at White Hawk EcoVillage (Peak Summer)

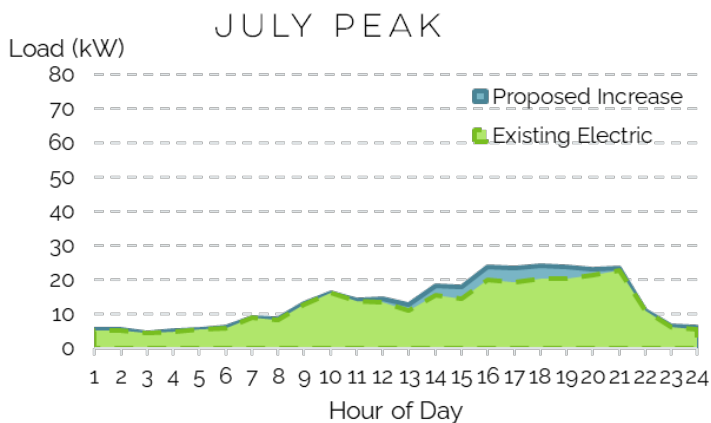


Figure 22. Estimated Annual Electric Impacts at White Hawk EcoVillage

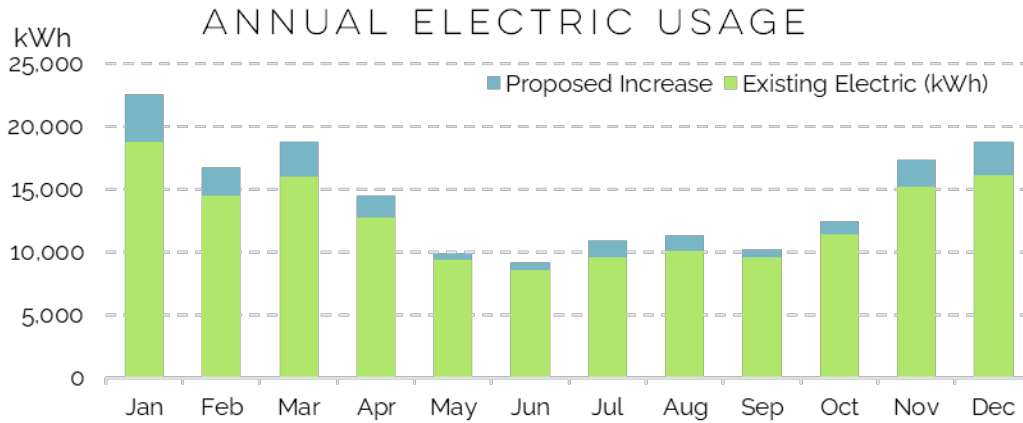


Figure 22 shows that the implementation of the networked geothermal system results in an increase in electricity consumption every month throughout the year. In a typical networked geothermal application, electricity savings from more efficient cooling systems would occur during summer. However, because most homes in the White Hawk EcoVillage do not have cooling, adding cooling through a networked geothermal system will increase electric usage during the summer months.

Figure 23. Estimated Fossil Fuel Impacts at White Hawk EcoVillage (Winter Peak)

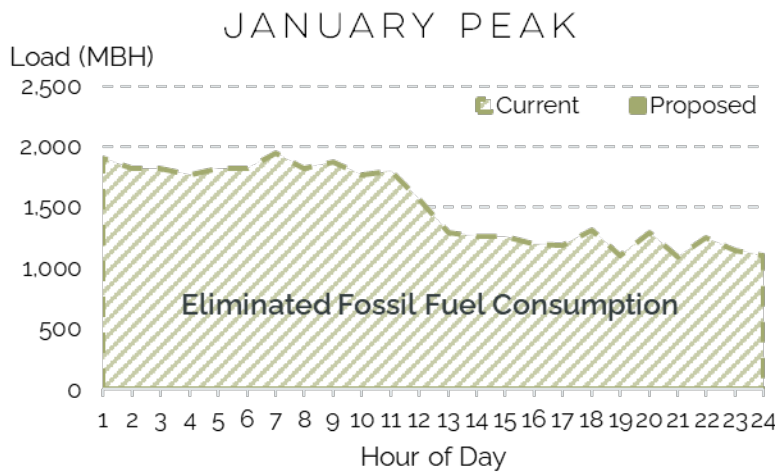


Figure 24. Estimated Fossil Fuel Impacts at White Hawk EcoVillage (Summer Peak)

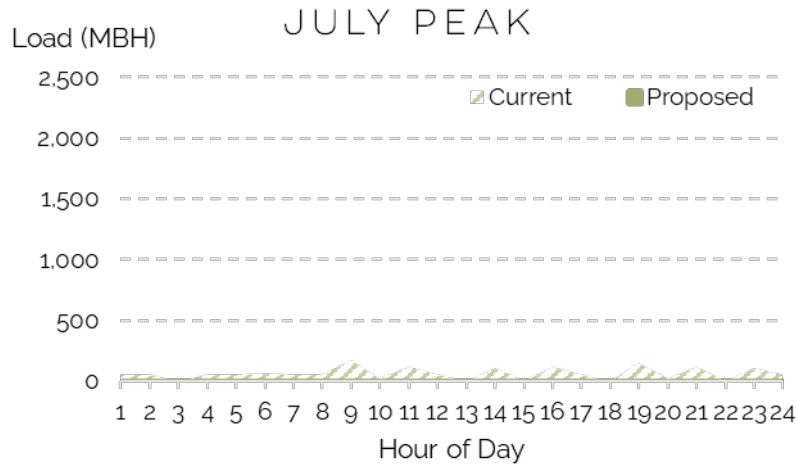


Figure 25. Estimated Annual Fossil Fuel Impacts at White Hawk EcoVillage

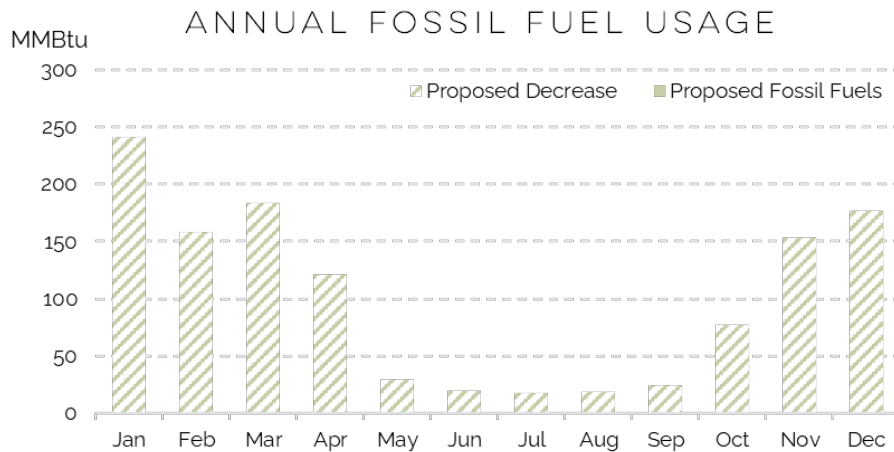


Figure 25 shows the calculated annual carbon dioxide equivalent (CO₂e) emissions savings based on the calculated annual energy savings. The electrification of fossil fuel heating to electric heating is estimated to offset 61 metric tons of carbon emissions for a fully built-out community. Figure 26 indicates equivalent emissions reductions based on EPA emissions data.⁶

Figure 26. Estimated Carbon Dioxide Equivalent Emissions Reduction at White Hawk EcoVillage



7.2 Economic Analysis

Implementing a networked geothermal system resulted in cost savings for all residential homes. Although all homes saw an increase in annual electric usage, annual natural gas and wood usage reductions led to significant cost savings for each residence. Figure 27 outlines estimates for existing and proposed utility costs.

Figure 27. Utility Cost Impact

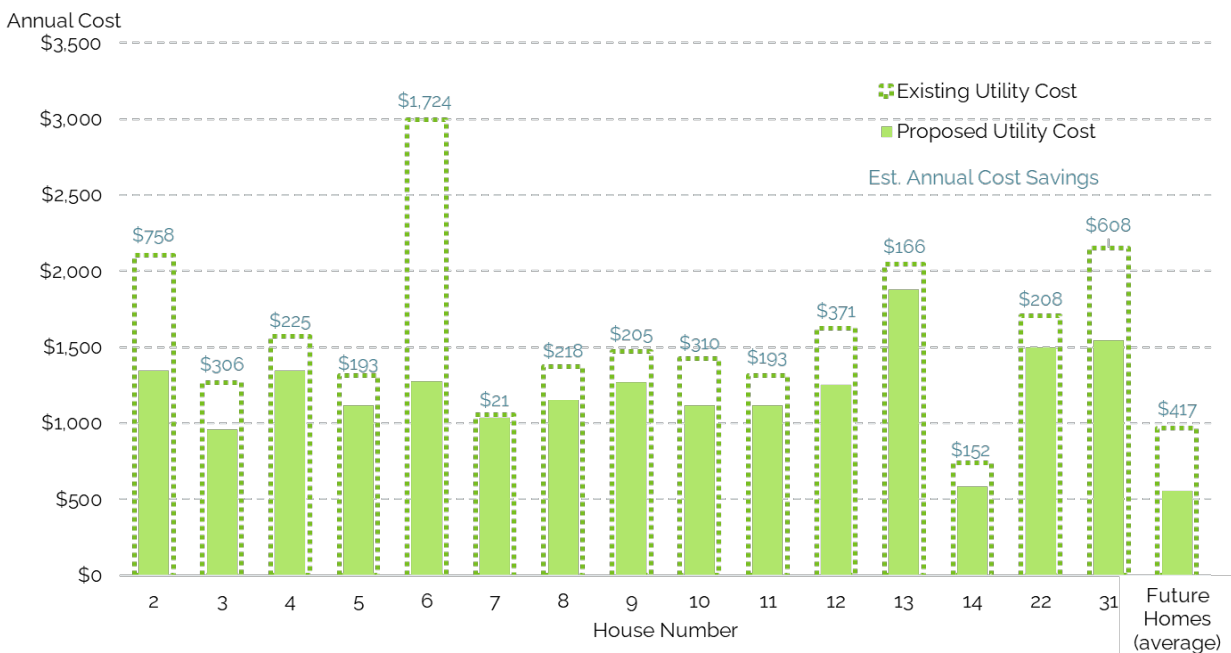
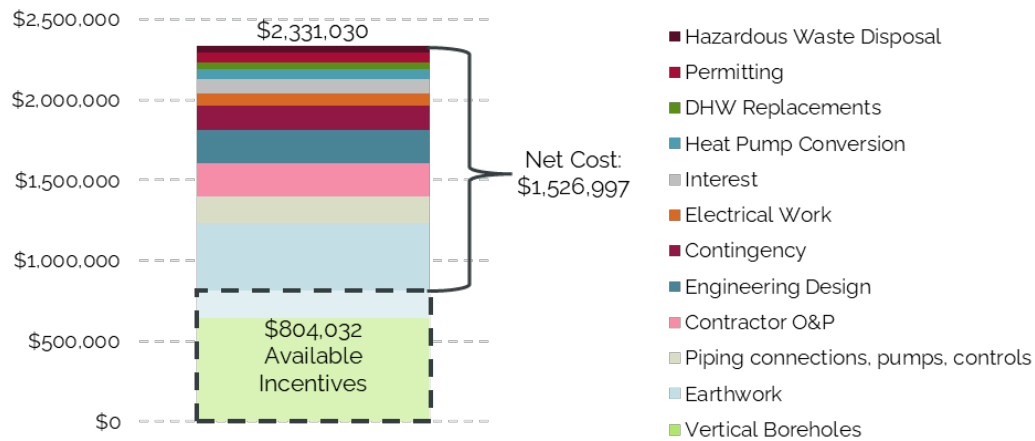


Figure 27 shows that the networked geothermal system saved energy costs for each residential home. Homes with existing cooling, such as houses 2 and 31, experienced the most significant cost reductions because they did not incur additional electric load from cooling. Table 5 lists construction costs for in-kind replacements. Figure 28 shows construction costs for the proposed networked geothermal system, along with potential incentives from state (New York State Clean Heat) and federal (ITC) programs.

Figure 28. Geothermal System Cost Breakdown

This cost reflects a networked geothermal system sized for a fully built-out community.



As discussed, the primary difference in infrastructure requirements between a networked geothermal system and individual geothermal systems is the horizontal main piping that connects each building. Preliminary cost estimates indicate that approximately \$282,000 of the total project cost is attributable to the horizontal main piping. Implementing individual geothermal systems instead of networked ones can eliminate this cost without significantly impacting the overall system’s effectiveness. An added benefit of the networked system is its ability to incorporate future homes. In contrast, individual geothermal systems would require future homes to pay a significant upfront cost to electrify their heating and cooling systems.

The IRA ITC is available for networked geothermal systems like PV systems, as discussed in Section 8, Distributed Energy Resources. Following a similar methodology, Table 6 shows the estimated benefit from this federal incentive.

Table 6. Federal Incentives Summary

Following similar methodology, Table 6 shows the estimated benefit from this federal incentive. For the purposes of this table, only Year-1 tax savings were included.

Year	ITC Tax Savings
2025	\$804,032
2026	\$72,579
2027	\$43,548
2028	\$26,129
2029	\$24,122
2030	\$15,071
2031	\$0
2032	\$0
2033	\$0
2034	\$0
Cumulative Tax Savings	\$985,481
NPV, 4%	\$897,113

The White Hawk EcoVillage can access an incentive through NYSERDA’s New York State Clean Heat program for individual geothermal systems. This program offers \$1,500 per ton of full-load heating capacity for each GSHP. An additional \$250 bonus applies to systems installing space heating and water heating equipment simultaneously. This incentive does not apply to a district geothermal system.

NYSERDA PON 4614 provides an additional incentive to improve the project’s financial viability. This program, which funded the current study, offers various levels of funding for engineering design and construction:

- Allocating up to \$100,000 for Category A feasibility studies
- Providing up to \$500,000 for Category B design projects with a 50% cost share strongly preferred
- Offering up to \$4,000,000 for Category C construction projects with a 50% cost share strongly preferred

The White Hawk EcoVillage can access these incentives during all project phases. However, at the time of this report, solicitations for all three categories have been paused, so the study excludes any potential savings. As mentioned, a new funding opportunity for thermal energy network projects is expected to launch in 2024. However, specific categories, funding levels, and recommended matching funds were unavailable when this study was completed.

The geothermal system is sized to accommodate a fully built-out community of 31 homes, while HVAC conversion costs for the in-kind replacement option are only for the existing homes. Table 7 shows the financial comparison of the configurations investigated in this report, including payback and NPV for each option.

Table 7. White Hawk EcoVillage Geothermal Financial Comparison

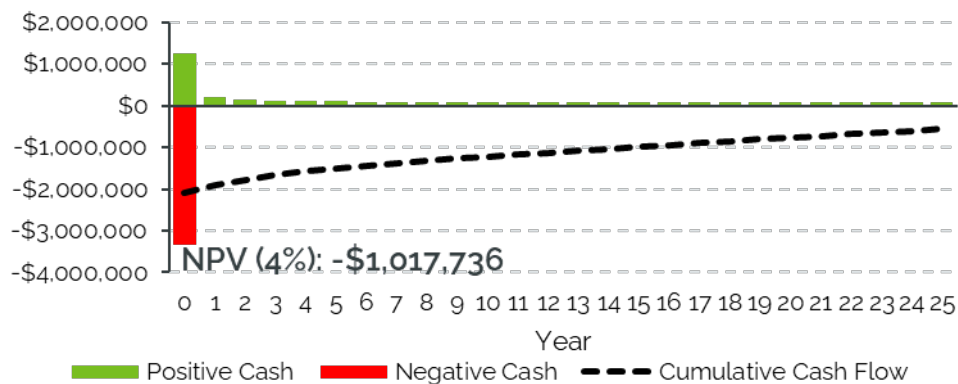
Financial Summary	Upfront Cost (\$)	Annual Energy Cost Savings (Partial/Fully Built-out) ^a	Payback (Years) ^b	NPV (25 Years, 4%)
In-Kind Replacement	\$0	\$0/\$0	—	-\$541,010
In-Kind Replacement with 450 kW PV	\$552,834	\$80,860/\$77,147	7	\$99,147
Individual Geothermal System	\$1,258,423	\$5,658/\$12,323	102	-\$1,523,677
Individual Geothermal System with 450 kW PV	\$1,811,257	\$86,518/\$89,470	20	-\$883,521
District Geothermal System	\$1,526,997	\$5,658/\$12,323	124	-\$1,758,772
District Geothermal System with 450 kW PV	\$2,079,831	\$86,518/\$89,470	23	-\$1,017,736

^a Full build-out is estimated in 2035.

^b Payback based on full build-out energy cost savings.

Figure 29. Geothermal System Life-Cycle Cash Flow

The graphic depicts the 25-year life-cycle cost analysis for the networked geothermal system with 450-kW PV.



Positive cash flow accounts for the previously discussed incentive and revenue generated by the solar array over the 25-year period. Table 8 provides a detailed cash flow outline.

Table 8. Geothermal System Life-Cycle Cost and Savings

Proposed Cash Flow Comparison—District Geothermal with PV

Year	Capital Cost	Energy Cost	Maintenance Cost	Incentives	Solar Revenue	Cash Flow
0	\$3,343,530	\$0	\$0	\$1,263,698	\$0	-\$2,079,831
1	\$0	\$18,495	\$1,500	\$114,073	\$80,860	\$174,938
2	\$0	\$18,495	\$1,500	\$68,444	\$80,448	\$128,896
3	\$0	\$18,495	\$1,500	\$41,066	\$80,035	\$101,106
4	\$0	\$18,495	\$1,500	\$37,912	\$79,623	\$97,540
5	\$0	\$18,495	\$1,500	\$23,687	\$79,210	\$82,902
6	\$0	\$18,495	\$1,500	\$0	\$78,798	\$58,802
7	\$0	\$18,495	\$1,500	\$0	\$78,385	\$58,390
8	\$0	\$18,495	\$1,500	\$0	\$77,972	\$57,977
9	\$0	\$18,495	\$1,500	\$0	\$77,560	\$57,564
10	\$0 ^a	\$27,362 ^a	\$3,100 ^a	\$0 ^a	\$77,147 ^a	\$46,685 ^a
11	\$0	\$27,362	\$3,100	\$0	\$76,735	\$46,273
12	\$0	\$27,362	\$3,100	\$0	\$76,322	\$45,860
13	\$0	\$27,362	\$3,100	\$0	\$75,910	\$45,447
14	\$0	\$27,362	\$3,100	\$0	\$75,497	\$45,035
15	\$0	\$27,362	\$3,100	\$0	\$75,085	\$44,622
16	\$0	\$27,362	\$3,100	\$0	\$74,672	\$44,210
17	\$0	\$27,362	\$3,100	\$0	\$74,259	\$43,797
18	\$0	\$27,362	\$3,100	\$0	\$73,847	\$43,385
19	\$0	\$27,362	\$3,100	\$0	\$73,434	\$42,972
20	\$0	\$27,362	\$3,100	\$0	\$73,022	\$42,560
21	\$0	\$27,362	\$3,100	\$0	\$72,609	\$42,147
22	\$0	\$27,362	\$3,100	\$0	\$72,197	\$41,734
23	\$0	\$27,362	\$3,100	\$0	\$71,784	\$41,322
24	\$0	\$27,362	\$3,100	\$0	\$71,372	\$40,909
25	\$0	\$27,362	\$3,100	\$0	\$70,959	\$40,497

^a Remaining Buildout.

Appendix F contains life-cycle cost tables and figures for all scenarios investigated. Including DERs enhanced the project’s economic viability, as detailed in the following section.

8 Distributed Energy Resources

The analysis for the White Hawk EcoVillage included evaluating the potential for photovoltaics (PV), battery storage, and EV charging. Analysts used Distributed Energy Resources Customer Adoption Model (DER-CAM) software for building modeling required for PV analysis and used Excel spreadsheets to assess EV charging potential.

8.1 Photovoltaics

Based on projected electric load profiles for a fully built-out community with a geothermal system, a 176-kW solar array would offset all electric usage. The community expressed interest in installing a carport solar array over the parking area. Figure 30 shows the footprint of a 176-kW carport solar array using 10 single-column, double-style carports.

Figure 30. 176-kilowatt Carport Solar Array on Existing Parking Lot



These proposed carports can shelter up to 40 vehicles from sunlight and weather while generating sufficient energy to offset the community's electric consumption.

Figure 31. Single-Column, Double-Style Carports



Each double carport accommodates 36 PV modules with a combined capacity of 17.5 kW. Single carports, available as an alternative, accommodate 15 PV modules with a combined capacity of 7.3 kW. Estimates indicate that installing this solar array would produce a combined 208,401 kWh of electricity annually. This production would exceed the proposed annual electric consumption of 178,398 kWh for the existing homes in the White Hawk EcoVillage, achieving net-zero CO₂e.

The solar array size accounts for the annual degradation in efficiency. Figure 32 shows that the 176-kW solar array would offset annual electric usage for the next 25 years.

Figure 32. Potential Solar Production in Kilowatt-hours

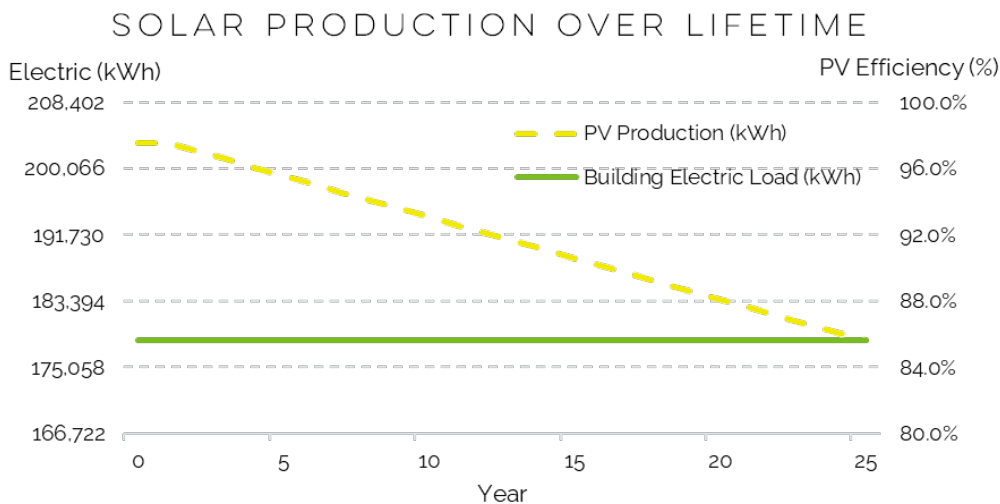
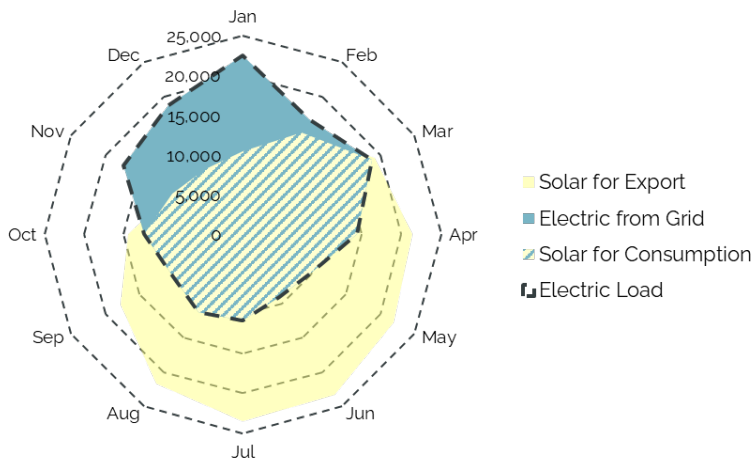


Figure 33 illustrates the monthly solar production estimate, calculated using the NREL Photovoltaic Watts Calculator (PVWatts) software and is region-specific to the White Hawk EcoVillage. This estimate has been validated against other nearby solar arrays.

Figure 33. Potential Monthly Solar Production in Kilowatt-hours



Aggregate data indicates that solar production would exceed the electric load during the summer months, while winter months would require more electricity than solar production can provide. Annually, total solar production (yellow-shaded region) would exceed the total electric consumption (black dashed line) for the next 25 years. To install a 176 kW PV array, the White Hawk EcoVillage must complete an application according to NYSEG Bulletin 86-01, section 3.2.2.⁷

Figures 34 and 35 illustrate projected communitywide electric load profiles for a peak day in January and July, along with a 176-kW solar array.

Figure 34. Combined Electric Load Profile for Peak Winter Day

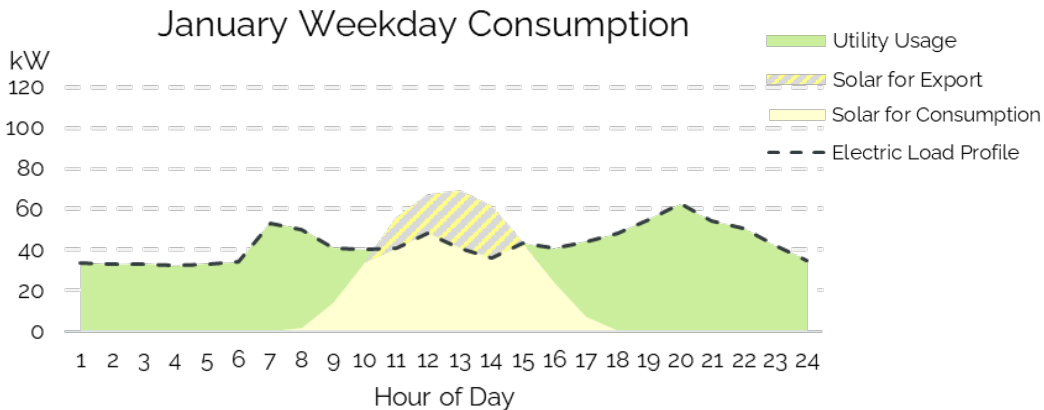


Figure 35. Combined Electric Load Profile for Peak Summer Day

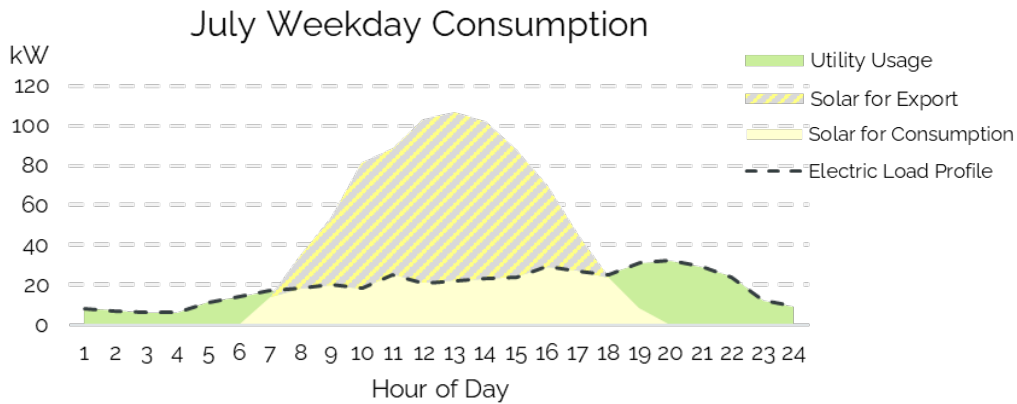
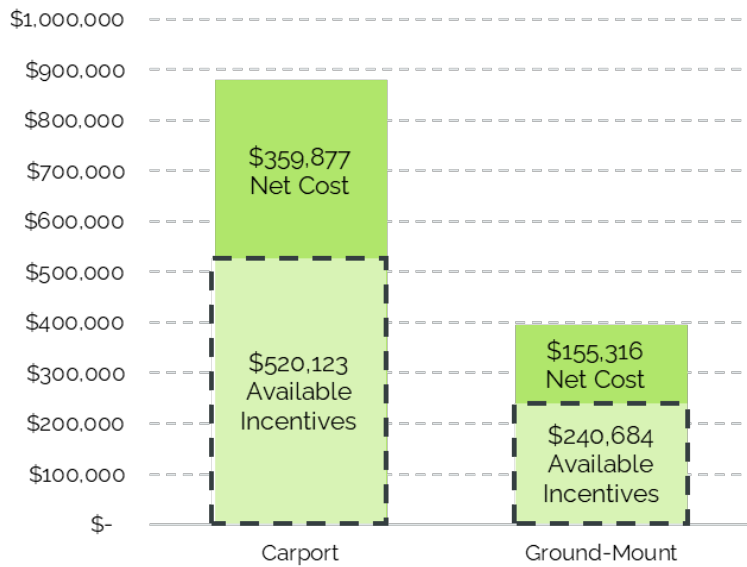


Figure 36 shows the preliminary costs for the proposed solar array for the carport, ground-mount options, and potential incentives discussed in the next section.

Figure 36. Photovoltaic Cost Breakdown



The PV solar array would generate electricity for the community, but a separate solar thermal array would be required to provide a potential thermal source. This solar thermal array would produce water at sufficient temperatures to meet domestic hot water loads throughout the year. However, due to the high efficiency of heat pump domestic hot water units and the PV solar array meeting all electricity needs, adding a solar thermal array is not recommended.

Combined PV panels with solar thermal (known as PVT panels) exist, but they have not achieved mainstream adoption to become cost-effective. For this reason, this technology is also not recommended.

As discussed, the study investigated several incentives, including State incentives through the NY-Sun program and federal incentives such as ITC and PTC. Through the NY-Sun program, \$0.25 per watt of installed solar capacity is available during this study. For a 176-kW solar array, this incentive amounts to approximately \$44,000.

In addition to the NY-Sun incentive, the White Hawk EcoVillage solar array qualifies for either the ITC or the PTC. The ITC reduces the upfront project cost by a percentage of the total cost, while the PTC provides performance-based incentives. Federal programs generally prohibit recipients from benefiting from both the ITC and the PTC simultaneously. The following section includes an overview of the program qualifiers and eligible properties listed by the Office of Energy Efficiency and Renewable Energy.

8.2 Eligibility Requirements

To be eligible for business ITC or PTC, the PV system must:

- Located in the U.S.
- Use new or limited used equipment
- Not being leased to a tax-exempt entity, although tax-exempt entities can receive the ITC by direct payment

8.3 Eligible Property

The following types of property are eligible for this incentive:

- Solar panels, inverters, racking, balance-of-system equipment, and sales and use taxes on the equipment
- Concentrated solar power (CSP) equipment necessary to generate electricity, heat or cool a structure, or provide solar process heat
- Installation costs and certain prorated indirect costs
- Step-up transformers, circuit breakers, and surge arrestors
- Energy storage devices with a capacity rating of 5 kWh or greater, even if not charged by solar. For projects 5 MW or less, interconnected property incurred by the project owner to enable electricity distribution and transmission
- Structures supporting solar PV systems designed primarily for electricity generation, where other uses of the structure are incidental

Table 9 summarizes the rate structure for the ITC and PTC programs.⁸

Table 9. Investment Tax Credit Summary

IRA Available Tax-Credit Summary		Start of Construction			
		2023–2033	The Later of 2034 or 2 Years after Applicable Year ^a	The Later of 2035 or 3 Years after Applicable Year ^a	The Later of 2036 or 4 Years after Applicable Year ^a
ITC					
Full Rate (if project meets labor requirements)	Base credit	30%	22.5%	15%	0%
	Domestic content bonus	10%	7.5%	5%	0%
	Energy community bonus	10%	7.5%	5%	0%
Base Rate (if project does not meet labor requirements)	Base credit	6%	4.5%	3%	0%
	Domestic content bonus	2%	1.5%	1%	0%
	Energy community bonus	2%	1.5%	1%	0%
LMI Bonus (1.8 GW/yr cap)	<5 MW projects in LMI communities or Indigenous land	10%	10%	10%	10%
	Qualified LMI residential building project or qualified LMI economic benefit project	20%	20%	20%	20%
PTC					
Full Rate (if project meets labor requirements)	Base credit	27.5¢	2.00¢	1.30¢	0.00¢
	Domestic content bonus	0.30¢	0.20¢	0.10¢	0.00¢
	Energy community bonus	0.30¢	0.20¢	0.10¢	0.00¢
Base Rate (if project does not meet labor requirements)	Base credit	0.55¢	0.40¢	0.30¢	0.00¢
	Domestic content bonus	0.10¢	0.00¢	0.00¢	0.00¢
	Energy community bonus	0.10¢	0.00¢	0.10¢	0.00¢

^a Applicable year is defined as the later of (1) 2032 or (2) the year the Treasury Secretary determines that annual greenhouse gas emissions from electricity production in the U.S. have decreased by 75% or more compared to the calendar year 2022. Labor requirements involve meeting certain prevailing wage and apprenticeship conditions.

The IRA direct payments are available to taxable and tax-exempt building owners using IRS Form 3468. The following provides an overview of each line item based on industry guidance. A tax attorney should be consulted for rebate administration to ensure compliance.

- **Base rate:** Projects less than 1 MW qualify for a 30% base rate; projects greater than 1 MW qualify for a 6% base rate, provided they meet prevailing wage and apprenticeship requirements.
- **Domestic content bonus:** Projects are eligible for an additional 10% reimbursement of project costs if the products within the project are manufactured in the U.S. For projects exceeding 1 MW, this bonus is reduced to 2% if prevailing wage and apprenticeship requirements are not met. Projects that begin construction after 2026 qualify for an additional 15% if they meet this requirement. Ongoing discussions focus on how domestic companies can prove that their goods and services are sourced domestically. Given this incentive’s uncertainty and the language in the IRA, its potential exclusion as an available incentive should be considered.

- **Energy community bonus:** Areas affected by a coal mine or coal-fired power plant closures or areas economically reliant on the extraction, transport, or storage of coal, oil, and natural gas are eligible for an additional 10% payment. The total incentive cannot exceed 50%, including a 30% base rate and a 10% domestic content bonus.
- **Accelerated depreciation of energy property:** Qualified energy property is classified as a 5-year property under section 168(e)(3)(B)(vi) of the Internal Revenue Code. This allows taxpayers to deduct the system cost on an accelerated Modified Accelerated Cost Recovery System (MACRS) basis. The cost basis must be reduced by half of the energy tax credit. A one-time bonus payment allows taxpayers to receive the depreciation payments as a percentage of initial costs instead of depreciating costs over 39 years on a straight-line basis. Bonus payments begin at 80% in 2023, decrease to 60% in 2024, and gradually reduce to 0% in 2027. Taxpayers may claim these depreciation rates on IRS Form 4562.
- **Additional bonus payments:** Wind and solar projects in LMI communities or on tribal land are eligible for additional bonus payments. More information is available from the IRS. Tax-exempt entities may receive the ITC through direct payments despite the ITC being a tax credit. Through the ITC, the White Hawk EcoVillage could receive up to 40% of PV construction costs.
Incentives available through the PTC vary based on the size of the PV array. Projections of potential incentive cash flow over the next 10 years suggest that the ITC would be the better incentive to pursue. Appendix C has detailed calculations for both federal incentives. Table 11 summarizes the federal tax incentive comparison for a 176-kW carport PV array installed in 2025. Note that the PV upfront cost graphic includes only the tax savings for the first year.

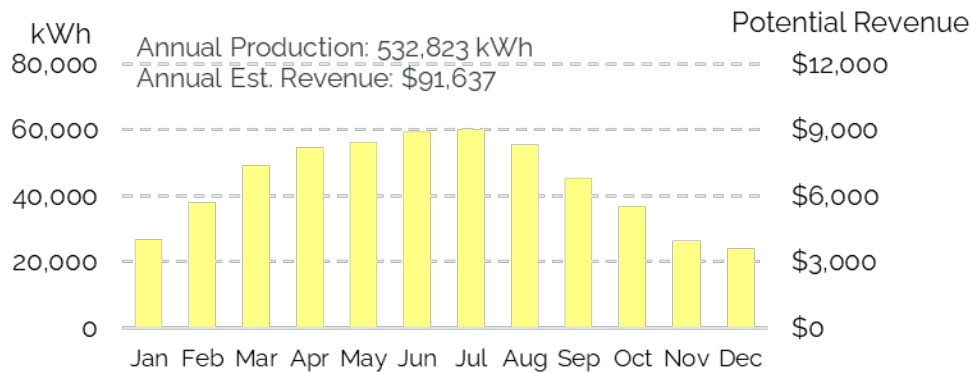
Table 10. Federal Incentives Summary: Carport Photovoltaics

Year	ITC Tax Savings #	PTC Tax Savings
2025	\$467,123	\$150,293
2026	\$55,256	\$43,227
2027	\$33,154	\$28,617
2028	\$19,892	\$22,241
2029	\$18,365	\$22,372
2030	\$0	\$8,859
2031	\$0	\$7,040
2032	\$0	\$7,178
2033	\$0	\$7,319,
2034	\$0	\$7,462
Cumulative Tax Savings	\$605,264	\$304,607
NPV, 4%	\$527,815	\$254,343

8.4 Additional Potential for Photovoltaics

In addition to offsetting all electricity used on-site, the investigation considered adding PV systems as a potential revenue stream to help offset the high upfront costs associated with geothermal systems. As shown in Figure 39, the three-phase power lines running adjacent to the White Hawk EcoVillage have a hosting capacity of 0.50 MW. An additional 0.03 MW is currently queued for this feeder section, which must be deducted from the overall hosting capacity. Based on the existing infrastructure, the White Hawk community can install a 450 kW PV array without upgrading the utility infrastructure. As discussed, a 176-kW solar array would offset all electricity a fully built-out community uses. Production from all installed solar arrays can help offset the large upfront cost of geothermal systems. Figure 37 displays the monthly output of the 450-kW array, along with the estimated revenue generated from the system’s TPO.

Figure 37. Maximum Solar Production with Existing Electric Infrastructure (in Kilowatt-hours)



The solar production estimate is derived from the NREL PVWatts software, tailored to the White Hawk EcoVillage region. This estimate has been validated against other nearby solar arrays. In this economic model, the White Hawk residents would pay incremental rates similar to their current electricity costs. Any excess electricity produced by the solar array would be exported back to the grid. Because the solar array is smaller than the cutoff for a Value of Distributed Energy Resources (VDER) tariff structure, the exported electricity would receive a credit equivalent to the incremental rate the White Hawk community currently pays.

Note that ground-mounted solar was chosen over carport solar to minimize the upfront cost in this revenue-generating strategy. Using a similar cost estimation methodology outlined in previous sections, the total system cost is \$1,012,500. After accounting for incentives through the NY-Sun program and the ITC, the net cost of the 450-kW system is \$524,105. Including this PV array with the geothermal system

enhances the project's economic viability. As discussed, the White Hawk community has access to 120 acres of land. A 450-kW solar array would occupy approximately 0.50 acres. If the community chooses to develop a more extensive PV network, upgrades to utility infrastructure would be necessary.

8.5 Battery Storage

Installing solar arrays offsets total electric consumption in the White Hawk community after the electrification of heating systems. Installing battery storage modules can help reduce peak demand, minimizing grid impact. This report examines two battery storage technologies: lithium-ion batteries and flow batteries.

Lithium-ion batteries use a negatively charged anode, a positively charged cathode, and a membrane that enables the movement of lithium ions between these two battery elements. Electrons travel through an external wire between the anode and the cathode, allowing the battery to charge and discharge.

Flow batteries consist of two separate tanks that store electrolyte liquids. One tank stores positive electrolyte liquids, while the other stores negative ones. Pumps transfer these liquids into a central tank where a process similar to the lithium-ion battery occurs. Electrons move between the tank's two sections through an external wire to perform the charging and discharging functions, while a membrane prevents the solutions from mixing.

The design and materials of lithium-ion and flow batteries have distinct advantages and disadvantages, which impact their effectiveness in various applications. Lithium-ion batteries are compact, residing in a single container, making them ideal for portable applications such as phones, laptops, and EVs. They deliver enormous amounts of energy quickly, typically one to two hours). However, energy stored for more extended periods begins to self-discharge. Fully charged lithium-ion batteries lose approximately 5% of their capacity within the first 24 hours and from 2% to 8% per month, depending on temperature and internal chemical factors. Cold temperatures lower self-discharge rates, and other internal factors impact the battery's chemistry.

Lithium-ion batteries' high-power density is advantageous for applications requiring quick energy delivery, but their short discharge time and self-discharging losses are drawbacks. Their established market presence lowers their upfront costs compared to flow batteries. However, lithium-ion batteries use flammable and toxic materials, necessitating safety precautions to minimize the risk of explosions in applications that use these batteries.

Flow batteries require separate tanks and operate as larger systems compared to lithium-ion batteries, limiting their portability. They also have a lower power density, allowing for longer durations—up to 12 hours, compared to the typical 4-hour duration of lithium-ion batteries. In addition, flow batteries pose no risk of fire or explosion due to the use of nonflammable materials.

White Hawk EcoVillage residents do not currently pay demand charges or time-of-use rates. As a result, peak shifting or peak shaving with battery storage modules would not generate cost savings. No feasible cost recovery mechanism exists without transitioning the community to a different tariff structure. Therefore, battery storage modules are not recommended for the White Hawk EcoVillage.

The primary benefit of battery storage modules for the community would be increased system resiliency. These modules could serve as a backup energy source during outages.

8.6 Electric Vehicle Charging

The feasibility study also assesses the potential for installing EV charges at the White Hawk EcoVillage alongside PV and battery storage modules. The analysis focused on an overview of the two main types of charging stations, as shown in Figure 38.

Figure 38. Comparison of Level II and Level III Electric Vehicle Charging Stations

Level II Charging Stations		Level III Charging Stations
240/208-volt electric source		480/277-volt electric source
Smaller in size		Larger in size
Relatively inexpensive		Expensive

White Hawk EcoVillage residents would use the EV charging stations exclusively. Because residents spend several hours at home daily, the team determined that level II charging stations offer the most appropriate solution. These chargers require a 240/208-volt electric source and 50 amps of current. Based on projected transportation schedules, each level II electric vehicle charging station would incur an additional 9,600 kWh in annual electric usage. The community would need an 8-kW solar array per charger to offset this increase. Based on the population and estimated EV adoption rates, the team determined that 4 EV charging stations would meet the community’s needs. A preliminary assessment of the utility-side electric infrastructure in the area indicates favorable conditions for supporting EV charging.⁹

Figure 39. Utility-Side Electric Infrastructure



The White Hawk EcoVillage qualifies for two potential EV charging incentives. The first incentive is the Make-Ready Program, which covers up to 100% of the costs of electric infrastructure upgrades required for EV charging stations. The funding amount depends on factors such as the charger installed, the type of plug used, and whether the charger is public or private. Table 11 summarizes the Make-Ready Program funding amounts for a nonproprietary plug system.

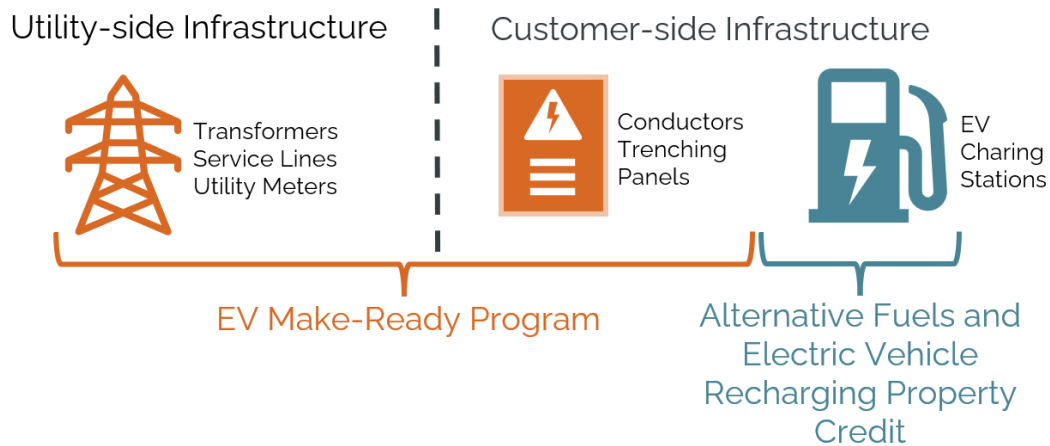
Table 11. Make Ready Program Maximum Incentive Amounts

Charger Type	Nonpublic	Public	Public, DAC
Level II Charging Stations	50%	90%	100% ^a
Level III Charging Stations	50%	90%	100%

^a Must reside in a multiunit dwelling.

Because the White Hawk EcoVillage is not located within a DAC, up to 90% of the electric infrastructure costs for level II public charging stations would qualify for funding through the Make-Ready Program. Additionally, Alternative Fuels and Electric Vehicle Recharging Property Credit offers financial support to assist with the upfront costs of the charging stations themselves, covering the lesser of \$5,000 or 50% of the station’s cost, provided the stations operate for at least half the year and has not been funded by grants. Figure 40 summarizes both incentive programs and what they cover.

Figure 40. Available Incentives Summary



Based on the assumed electric infrastructure at the White Hawk EcoVillage, installing EV chargers will likely require a new panel. The team considered several ownership models for EV charging stations, each varying by ownership of the electric infrastructure and the cost to the end user. One possible model involves the White Hawk EcoVillage purchasing and owning the EV charging stations. Under this model, the EcoVillage can implement various strategies to set the cost of the electricity used. The following summarizes potential financial strategies for a system owned by the White Hawk EcoVillage community:

- **Loss leader strategy:** The EV charging station is provided free of charge to the end user. In this model, the station attracts potential customers, and the additional business generated by the customers provides economic benefits from installing the EV charging stations.
- **Cost-recovery strategy:** The EV charging station charges the end user based on operational expenses and utility electric rates. In this break-even model, the end user incurs lower electric charges, and the owner of the EV charging stations has a neutral cash flow. The owner can adjust electric rates to recover the upfront cost of the station. Based on utility rates and an estimated annual maintenance cost of \$400, a reasonable cost-recovery energy rate is \$0.18/kWh to \$0.25/kWh for a level II charger.
- **Profit-generating strategy:** The EV charging station charges the end user based on operational expenses, utility electric rates, and an added profit margin. In this model, the end user incurs higher electric charges, and the owner of the EV charging station has a positive cash flow. The owner must set competitive electric rates to ensure potential end users do not seek other charging options. Based on utility rates, an estimated annual maintenance cost of \$400, and a 20% profit margin, a reasonable profit-generating rate is \$0.22/kWh to \$0.30/kWh for a level II charger.

The cost-recovery strategy would likely work best for the White Hawk EcoVillage. Another ownership model involves a third party purchasing and operating the EV chargers. In this case, the third party owns and operates the chargers, while the White Hawk EcoVillage community would be responsible for any necessary upgrades to the electric infrastructure. In addition, the profit-generating strategy would need to be implemented, with profits shared between the White Hawk EcoVillage and a third party. In this model, the third party may set their electric rates.

9 Lessons Learned

The development of a PV array presented the primary opportunity to improve the value proposition of this project. Without the solar array, the geothermal system did not generate enough cost savings to justify the high upfront investment or attract potential third-party owner. Incorporating a solar array leverages White Hawk EcoVillage's large open fields for clean energy production and creates an economic mechanism for developing the geothermal system.

LaBella Associates used its existing relationships with Aztech Geothermal and the GreyEdge Group, LLC, to build a cohesive team. If the project advances to the design phase, LaBella plans to consult with local drillers to test bore operations and confirm geologic assumptions made during the feasibility stage. To expand beyond the feasibility team, LaBella would issue a request for proposal (RFP) for the necessary services and evaluate submissions from other companies to identify the best partners for the project.

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Appendix A. Survey Responses

Answers (1 of 3)

236 Townline Rd., Apt 27, Newfield, NY 14867	6 White Hawk Ln.
71	
69	
72	
72	
No	Yes
Sometimes, but not always	Sometimes, but not always
No	No
Electric	Wood
Electric	Electric
Baseboard Heating	
Reduced Environmental Impact	Reduced Environmental Impact
	<p>We heat primarily with wood; as this has no thermostat there is no "set point" for it so I answered n/a. We have no heat distribution system; there are hydronic baseboards no longer connected to a heat source after the house was taken off of natural gas, though we would like to re-plumb it to circulate heat from the wood stove. We use electric space heaters in some rooms to supplement the wood stove. We have a solar hot water system "supplemented" by on-demand electric, but in practice the solar system doesn't generate enough hot water and so we spent a lot of electricity on hot water. Currently evaluating whether a heat pump HWH would be more efficient for our usage. All of our electric is sourced from the Energy Cooperative of New York renewable program.</p>

12 White Hawk Ln	7 White Hawk Ln
69	68
69	55
Yes	Yes
Sometimes, but not always	Sometimes, but not always
No	No
Natural Gas	Natural Gas
Natural Gas	Natural Gas
Radiant Floors	Radiant Floors
Reduced Environmental Impact	Other (please specify)
	I think all three are important
<p>We have both natural gas (on demand boiler with radiant floor heating) and wood stove. We use an A/C window unit for a couple weeks in the summer. We are considering putting in air source heat pumps because our second floor has no heat (except space heaters) and we are concerned about longer periods of heat in the summer.</p>	<p>Our energy consumption is much higher now because we have young kids. I'm not sure if our electricity will go down when kids are older, but I'm guessing out heating bills go down. I am worried about not having any back up heat source.</p>

#15	31 white hawk lane	2 White Hawk Lane, Ithaca 14850
70	68	72
65	68	72
78	64	
73	64	
No	Yes	No
Yes	Yes	Yes
Yes	No	No
Electric	Electric	Electric
Electric	Electric	Electric
Forced Air	Air Source Heat Pumps	
Reduced Environmental Impact	Lower Energy Bills	Reduced Environmental Impact
<p>#15 is not yet built, so I've filled this out for what I plan based on my current residence. I support having a community-scale shallow-loop geothermal heat pump, and also solar carports over the parking lot. Given the amount of stormwater control infrastructure that needs to be built at White Hawk, as the new owner of 88 Gunderman road just uphill to the south, I hope this study will compare electricity storage options -- using batteries and also using small-scale closed loop pumped hydropower, with storage ponds built along the southern boundary of White Hawk and 88 Gunderman Rd. Thank you!</p>	<p>We don't set our heat pumps to a temperature in the summer - we just set them to "dehumidify" and that keeps the house very chilly.</p>	<p>Out heating is electric radiant in ceilings. You don't have that option.</p>

Appendix B. Utility Tariff Structure

Table B-1. New York State Electric and Gas Residential Electric Rate Structure

Category	Charge Type	Unit/Charge Type	Rate
Delivery			
–	Customer Charge	\$	\$17
–	Delivery Charge	\$/kWh	\$0.05095
–	Transition Charge	\$/kWh	-\$0.004806
–	System Benefits Charge	\$/kWh	\$0.004258
–	Rate Decoupling Mechanism	\$/kWh	-\$0.002073
Supply (Utility)			
–	NYSEG Supply Service	\$/kWh	\$0.0822340
–	Bill Issuance Charge	\$	\$0.90
–	Merchant Function Charge	\$/kWh	\$0.001660

Table B-2. New York State Electric and Gas Natural Gas Rate Structure

Category	Charge Type	Unit/Charge Type	Rate
Delivery			
–	Bill Issuance and Payment Processing	\$	\$1
–	First Three Therms or Less (non-heating)	\$/MMBtu	\$14.30
–	First Three Therms or Less (heating)	\$/MMBtu	\$18.30
–	Next 47 Therms	\$/therm	\$0.67375
–	Over 50 Therms	\$/therm	\$0.15846
Supply (Utility)			
–	Gas Supply Charge	\$/therm	\$0.848049
–	Merchant Function Charge	\$/therm	\$0.017430

Table B-3. Green Ash Wood Cost and Heat Content Rate Structure

Charge Type	Unit/Charge Type	Rate
Green Ash Wood Heat Content	MMBtu/cord	20.0
Green Ash Wood Cost ^a	\$/cord	\$300

^a Estimated.

Table B-4. Estimated Peak Heating and Cooling Loads

The estimated peak heating and cooling loads are shown as annual estimated costs (AEC).

House #	SF	Existing System Description	Electric (AEC)	NG (AEC)	Wood (AEC)
2	1,500	Wood furnace, electric in supplemental, electric DHW	\$1,776	\$0	\$328
3	992	ASHP, HP DHW	\$1,265	\$0	\$0
4	1,500	Wood furnace, HP DHW	\$915	\$0	\$656
5	1,200	NG furnace, NG DHW ^a	\$629	\$682	\$0
6	1,536	Wood furnace, electric supplemental, electric DHW	\$2,816	\$0	\$182
7	1,008	Radiant floor electric heating, NG DHW	\$440	\$613	\$0
8	1,248	NG furnace, NG DHW	\$645	\$727	\$0
9	1,400	NG furnace ^a , NG DHW ^a	\$698	\$777	\$0
10	1,200	Wood furnace, NG DHW	\$629	\$274	\$525
11	1,200	NG furnace ^a , NG DHW ^a	\$629	\$274	\$0
12	1,380	Wood furnace, electric supplemental, NG DHW	\$1,041	\$585	\$0
13	2,200	NG furnace ^a , NG DHW ^a	\$974	\$1,071	\$0
14	500	NG furnace ^a , NG DHW ^a	\$387	\$350	\$0
22	1,700	NG furnace ^a , NG DHW ^a	\$801	\$904	\$0
31	1,830	ASHP, HPDSW	\$2,153	\$0	\$0
Future	21,754	NG furnace ^a , NG DHW ^a	\$7,718	\$7,913	\$0

^a Estimated.

Appendix C. Cost Estimates and Incentives

Table C-1. In-Kind Replacement Cost Estimates

Equipment	Material Cost	Labor Cost	Total Cost (Including O&P)	RSMean Line
Wood Furnace	–	–	\$2,900	N/A
Electric Resistance Heating	\$227 ^a	\$135 ^a	\$450 ^a	11 30 15 43-3900
Natural Gas Furnace (45 MBH heating)	\$760 ^a	\$253 ^a	\$1,225 ^a	23 54 16 13-0010
ASHP (5 tons cooling, 27 MBH heating)	\$2656 ^a	\$2,100 ^a	\$6,000 ^a	23 81 43 10-1060
Electric DHW (30 gallon max)	\$1,050 ^a	\$370 ^a	\$1,700 ^a	11 30 15 23-6950
NG DHW (30 gallon max)	\$2,650 ^a	\$385 ^a	\$3,475 ^a	11 30 15 23-7220
HP DHW	\$1,050 ^a	\$370 ^a	\$1,700 ^a	11 30 15 23-6950
Central A/C (estimated 5 tons)	\$5,000 ^a	\$1,350 ^a	\$7,525 ^a	23 81 19 20-0220
GSHP (5 tons cooling, 29 MBH heating)	\$3,575 ^a	\$1,150 ^a	\$5,650 ^a	23 81 46 10-2220

^a RSMean Estimated.

Appendix D. Ground Loop Design Modeling Results

Ground Loop Design

Horizontal Design Project Report - 4/19/2023



Project Name: WhiteHawk EcoVillage Horizontal Borefield	
Designer Name: Stephen Hamstra	
Date: 4/19/2023	Project Start Date: 4/19/2023
Client Name: LaBella	
Address Line 1:	
Address Line 2:	
City:	Phone:
State:	Fax:
Zip:	Email:

Calculation Results

	COOLING	HEATING
Total Area (ft^2):	800000.0	800000.0
Trench Number:	10	10
Single Trench Length (ft):	4000.0	4000.0
Total Pipe Length (ft):	40000.0	40000.0
Single Trench Pipe Length (ft):	4000.0	4000.0
Total Area	800000.0 ft^2	
Unit Inlet (°F):	64.6	41.7
Unit Outlet (°F):	73.9	35.3
Total Unit Capacity (kBtu/Hr):	380.9	250.0
Peak Load (kBtu/Hr):	178.0	250.0
Peak Demand (kW):	6.0	17.2
Heat Pump EER/COP:	29.6	4.3
System EER/COP:	29.6	4.3
System Flow Rate (gpm):	62.5	62.5

Input Parameters

Fluid		Soil		
Flow Rate	3.0 gpm/ton	Ground Temperature:	53.0 °F	
Fluid:	23.3% Propylene Glycol	Thermal Conductivity:	1.57 Btu/(h*ft*°F)	
Specific Heat (Cp):	0.93 Btu/(°F*lbm)	Thermal Diffusivity:	1.13 ft^2/day	
Density (rho):	64.4 lb/ft^3	Regional Air Temperature Swing:	23.0 °F	
			<i>Winter</i>	<i>Summer</i>
		Extreme Day in Year:	34	225
Piping		Modeling Time Period		
Pipe Type:	1 in. (25 mm) - SDR11	Prediction Time:	15 years	
Flow Type:	Turbulent	Long Term Soil Temperatures:		
Pipe Resistance:	0.153 h*ft*°F/Btu		<i>Cooling:</i> 53 °F	
			<i>Heating:</i> 53 °F	

Input Parameters (Cont.)

Trench Layout			Pipe Configuration in Trench		
Trench Number:	10		Piping Style:	Standard	
Separation:	20.0 ft		Pipe Layout [X x Y]:	1 x 1	
Depth:	6.0 ft				
Width:	8.0 in				
Fixed Area	On				
Default Heat Pumps			Optional Hybrid Loads		
Manufacturer:	- Default Generic			Cooling	Heating
Series:	Generic High Efficiency		Geo Peak (%)	100%	100%
Design Heat Pump Inlet Load Temperatures:			Geo Total (%)	100%	100%
	<i>Cooling (WB)</i>	<i>Heating (DB)</i>	Hybrid Peak (%)	0 %	0 %
Water to Air:	67 °F	70 °F	Hybrid Total (%)	0 %	0 %
Water to Water:	55 °F	100 °F			
Extra kW			Loads File		
Pump Power	0.0 kW		<i>WhiteHawkEcoVillage8760Loads.zon</i>		
Cooling Tower Pump:	0.0 kW				
Cooling Tower Fan:	0.0 kW				
Additional Power	0.0 kW				
Comments					
Horizontal GHX. Assumed soil conditions. Hourly loads from LaBella					

Ground Loop Design

Borehole Design Project Report - 7/11/2023



Project Name: WhiteHawk EcoVillage	
Designer Name: Stephen Hamstra	
Date: 4/19/2023	Project Start Date: 4/19/2023
Client Name: LaBella	
Address Line 1:	
Address Line 2:	
City:	Phone:
State:	Fax:
Zip:	Email:

Calculation Results

Design Method:	Design Day	COOLING	HEATING
Total Bore Length (ft):		6300.0	6300.0
Borehole Number:		42	42
Borehole Length (ft):		150.0	150.0
Ground Temperature Change (°F):		-1.4	-1.4
Unit Inlet (°F):		65.0	44.5
Unit Outlet (°F):		73.9	38.4
Total Unit Capacity (kBtu/Hr):		183.0	125.0
Peak Load (kBtu/Hr):		178.0	125.0
Peak Demand (kW):		6.1	8.3
Heat Pump EER/COP:		29.4	4.4
System EER/COP:		29.4	4.4
System Flow Rate (gpm):		44.5	31.3

Input Parameters

Fluid		Soil	
Flow Rate	3.0 gpm/ton	Ground Temperature:	53.0 °F
Fluid:	23.3% Propylene Glycol	Thermal Conductivity:	1.57 Btu/(h*ft*°F)
Specific Heat (Cp):	1.01 Btu/(°F*lbm)	Thermal Diffusivity:	1.13 ft^2/day
Density (rho):	62.4 lb/ft^3		
Piping			
Pipe Type:	1 1/4 in. (32 mm) - SDR11		
Flow Type:	Turbulent		
Pipe Resistance:	0.104 h*ft*°F/Btu		
U-Tube Configuration:	Single		
Radial Pipe Placement:	Average		
Borehole Diameter:	6.25 in		
Grout Thermal Conductivity:	0.88 Btu/(h*ft*°F)		
Borehole Thermal Resistance:	0.250 h*ft*°F/Btu		

Input Parameters (Cont.)

Pattern		Modeling Time Period		
Vertical Grid Arrangement:	3 x 14	Prediction Time:	15.0 years	
Borehole Number:	42	Long Term Soil Temperatures:		
Borehole Separation:	20.0 ft		<i>Cooling:</i> 51.6 °F	
Bores Per Circuit	1		<i>Heating:</i> 51.6 °F	
Fixed Length Mode	On			
Grid File	None			
File:				
Default Heat Pumps		Optional Hybrid Loads		
Manufacturer:	- Default Generic		Cooling	Heating
Series:	Generic High Efficiency	Geo Peak (%)	100%	50%
Design Heat Pump Inlet Load Temperatures:		Geo Total (%)	100%	89%
	<i>Cooling (WB)</i> <i>Heating (DB)</i>	Hybrid Peak (%)	0%	50%
Water to Air:	67 °F 70 °F	Hybrid Total (%)	0%	11%
Water to Water:	55 °F 100 °F			
Extra kW		Loads File		
Pump Power	0.0 kW	<i>WhiteHawkEcoVillage8760Loads.zon</i>		
Cooling Tower Pump:	0.0 kW			
Cooling Tower Fan:	0.0 kW			
Additional Power	0.0 kW			

Vertical Borefield. Hourly loads from LaBella. Assumed soil conditions. Halfsize borefield with auxiliary boiler

Ground Loop Design

Borehole Design Project Report - 4/19/2023



Project Name: WhiteHawk EcoVillage	
Designer Name: Stephen Hamstra	
Date: 4/19/2023	Project Start Date: 4/19/2023
Client Name: LaBella	
Address Line 1:	
Address Line 2:	
City:	Phone:
State:	Fax:
Zip:	Email:

Calculation Results

Design Method: <i>Monthly</i>	COOLING	HEATING
Total Bore Length (ft):	12600.0	12600.0
Borehole Number:	84	84
Borehole Length (ft):	150.0	150.0
Ground Temperature Change (°F):	N/A	N/A
Peak Unit Inlet (°F):	56.3	44.9
Peak Unit Outlet (°F):	62.6	40.3
Total Unit Capacity (kBtu/Hr):	178.0	250.0
Peak Load (kBtu/Hr):	178.0	250.0
Peak Demand (kW):	6.1	12.9
Heat Pump EER/COP:	29.2	5.6
Seasonal Heat Pump EER/COP:	31.6	4.4
Avg. Annual Power (kWh):	4.68E+3	3.13E+4
System Flow Rate (gpm):	44.5	62.5

Input Parameters

Fluid		Soil	
Flow Rate	3.0 gpm/ton	Ground Temperature:	53.0 °F
Fluid:	23.3% Propylene Glycol	Thermal Conductivity:	1.57 Btu/(h*ft*°F)
Specific Heat (Cp):	1.01 Btu/(°F*lbm)	Thermal Diffusivity:	1.13 ft^2/day
Density (rho):	62.4 lb/ft^3		
Piping			
Pipe Type:	1 1/4 in. (32 mm) - SDR11		
Flow Type:	Turbulent		
Pipe Resistance:	0.104 h*ft*°F/Btu		
U-Tube Configuration:	Single		
Radial Pipe Placement:	Average		
Borehole Diameter:	6.25 in		
Grout Thermal Conductivity:	0.88 Btu/(h*ft*°F)		
Borehole Thermal Resistance:	0.250 h*ft*°F/Btu		

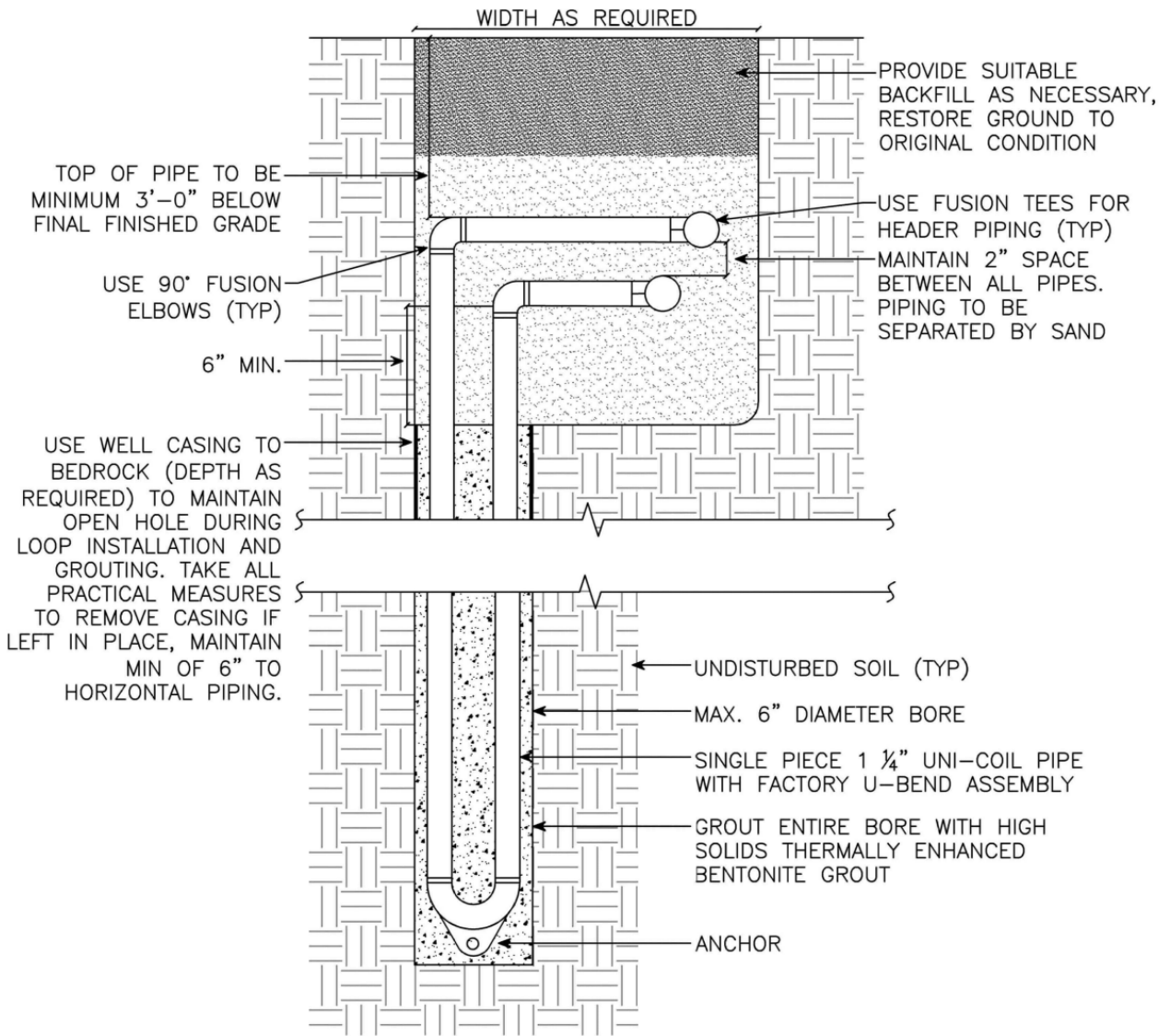
Input Parameters (Cont.)

Pattern		Modeling Time Period		
Vertical Grid Arrangement:	3 x 28	Prediction Time:	15 years	
Borehole Number:	84	Long Term Soil Temperatures:	<i>Cooling:</i> 53 °F	
Borehole Separation:	20.0 ft		<i>Heating:</i> 53 °F	
Bores Per Circuit	1			
Fixed Length Mode	On			
Grid File	None			
File:				
Default Heat Pumps		Optional Hybrid Loads		
Manufacturer:	- Default Generic		Cooling	Heating
Series:	Generic High Efficiency	Geo Peak (%)	100%	100%
Design Heat Pump Inlet Load Temperatures:		Geo Total (%)	100%	100%
	<i>Cooling (WB)</i> <i>Heating (DB)</i>	Hybrid Peak (%)	0 %	0 %
Water to Air:	67 °F 70 °F	Hybrid Total (%)	0 %	0 %
Water to Water:	55 °F 100 °F			
Extra kW		Loads File		
Pump Power	0.0 kW	<i>WhiteHawkEcoVillage8760Loads.zon</i>		
Cooling Tower Pump:	0.0 kW			
Cooling Tower Fan:	0.0 kW			
Additional Power	0.0 kW			

Vertical Borefield. Hourly loads from LaBella. Assumed soil conditions

Appendix E. Typical Geothermal Borehole Detail

Figure E-1. Typical Geothermal Borehole Detail



Appendix F. Life-Cycle Cost Graphics

Table F-1. Life-Cycle Cost: Existing Cash Flow

Year	Capital Cost	Energy Cost	Maintenance Cost	Cash Flow
0	\$0	\$0	\$0	\$0
1	\$0	\$24,153	\$1,500	-\$25,653
2	\$0	\$24,153	\$1,500	-\$25,653
3	\$12,575	\$24,153	\$1,500	-\$38,228
4	\$11,450	\$24,153	\$1,500	-\$37,103
5	\$12,225	\$24,153	\$1,500	-\$37,878
6	\$0	\$24,153	\$1,500	-\$25,653
7	\$12,225	\$24,153	\$1,500	-\$37,878
8	\$0	\$24,153	\$1,500	-\$25,653
9	\$12,225	\$24,153	\$1,500	-\$37,878
10	\$232,625 ^a	\$39,685 ^a	\$3,100 ^a	-\$275,410 ^a
11	\$26,575	\$39,685	\$3,100	-\$69,360
12	\$0	\$39,685	\$3,100	-\$42,785
13	\$13,900	\$39,685	\$3,100	-\$56,685
14	\$0	\$39,685	\$3,100	-\$42,785
15	\$7,700	\$39,685	\$3,100	-\$50,485
16	\$24,350	\$39,685	\$3,100	-\$67,135
17	\$7,700	\$39,685	\$3,100	-\$50,485
18	\$0	\$39,685	\$3,100	-\$42,785
19	\$0	\$39,685	\$3,100	-\$42,785
20	\$0	\$39,685	\$3,100	-\$42,785
21	\$0	\$39,685	\$3,100	-\$42,785
22	\$0	\$39,685	\$3,100	-\$42,785
23	\$0	\$39,685	\$3,100	-\$42,785
24	\$0	\$39,685	\$3,100	-\$42,785
25	\$0	\$39,685	\$3,100	-\$42,785

^a Remaining Buildout.

Figure F-1. Existing Life-Cycle Graphic

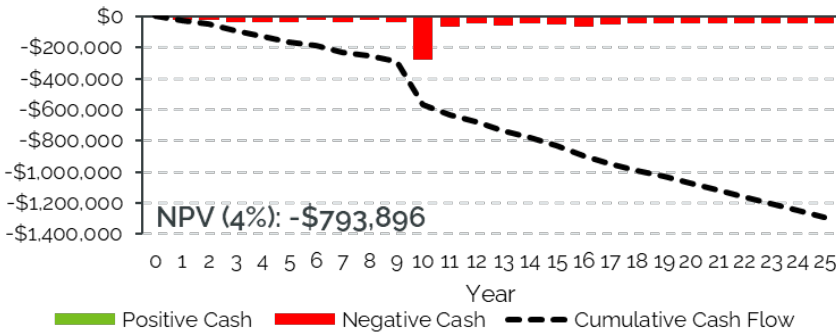


Table F-2. Life-Cycle Cost: Existing Cash Flow with 450 kW Photovoltaics

Year	Capital Cost	Solar Revenue	Energy Cost	Maintenance Cost	Incentives	Cash Flow
0	\$1,012,500	\$0	\$0	\$0	\$459,666	-\$552,834
1	\$0	\$80,860	\$24,153	\$7,958	\$41,494	\$90,243
2	\$0	\$80,448	\$24,153	\$7,958	\$24,896	\$73,233
3	\$12,575	\$80,035	\$24,153	\$7,958	\$14,938	\$50,287
4	\$11,450	\$79,623	\$24,153	\$7,958	\$13,791	\$49,852
5	\$12,225	\$79,210	\$24,153	\$7,958	\$8,616	\$43,490
6	\$0	\$78,798	\$24,153	\$7,958	\$0	\$46,687
7	\$12,225	\$78,385	\$24,153	\$7,958	\$0	\$34,049
8	\$0	\$77,972	\$24,153	\$7,958	\$0	\$45,862
9	\$12,225	\$77,560	\$24,153	\$7,958	\$0	\$33,224
10	\$232,625 ^a	\$77,147 ^a	\$39,685 ^a	\$9,558 ^a	\$0 ^a	-\$204,720 ^a
11	\$26,575	\$76,735	\$39,685	\$9,558	\$0	\$917
12	\$0	\$76,322	\$39,685	\$9,558	\$0	\$27,080
13	\$13,900	\$75,910	\$39,685	\$9,558	\$0	\$12,767
14	\$0	\$75,497	\$39,685	\$9,558	\$0	\$26,255
15	\$7,700	\$75,085	\$39,685	\$9,558	\$0	\$18,142
16	\$24,350	\$74,672	\$39,685	\$9,558	\$0	\$1,080
17	\$7,700	\$74,259	\$39,685	\$9,558	\$0	\$17,317
18	\$0	\$73,847	\$39,685	\$9,558	\$0	\$24,605
19	\$0	\$73,434	\$39,685	\$9,558	\$0	\$24,192
20	\$0	\$73,022	\$39,685	\$9,558	\$0	\$23,779
21	\$0	\$72,609	\$39,685	\$9,558	\$0	\$23,367
22	\$0	\$72,197	\$39,685	\$9,558	\$0	\$22,954
23	\$0	\$71,784	\$39,685	\$9,558	\$0	\$22,542
24	\$0	\$71,372	\$39,685	\$9,558	\$0	\$22,129
25	\$0	\$70,959	\$39,685	\$9,558	\$0	\$21,717

^a Remaining Buildout.

Figure F-2. Existing with 450 kW Life-Cycle Graphic

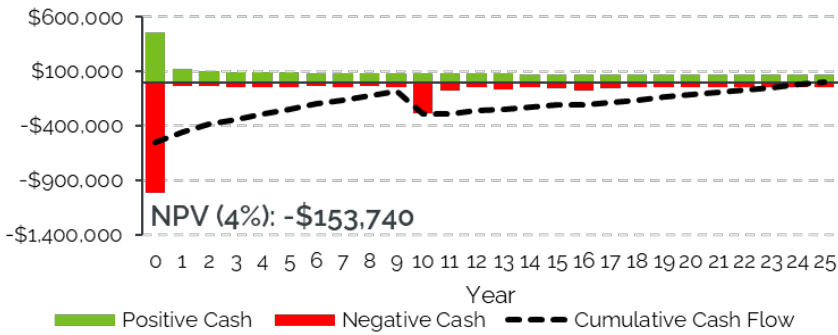


Table F-3. Life-Cycle Cost Individual Geothermal: Proposed Cash Flow

Year	Capital Cost	Energy Cost	Maintenance Cost	Incentives	Cash Flow
0	\$1,900,573	\$0	\$0	\$642,150	-\$1,258,423
1	\$0	\$18,495	\$1,500	\$57,966	\$37,971
2	\$0	\$18,495	\$1,500	\$34,780	\$14,784
3	\$0	\$18,495	\$1,500	\$20,868	\$872
4	\$0	\$18,495	\$1,500	\$19,265	-\$730
5	\$0	\$18,495	\$1,500	\$12,037	-\$7,959
6	\$0	\$18,495	\$1,500	\$0	-\$19,995
7	\$0	\$18,495	\$1,500	\$0	-\$19,995
8	\$0	\$18,495	\$1,500	\$0	-\$19,995
9	\$0	\$18,495	\$1,500	\$0	-\$19,995
10	\$0 ^a	\$27,362 ^a	\$3,100 ^a	\$0 ^a	-\$30,462 ^a
11	\$0	\$27,362	\$3,100	\$0	-\$30,462
12	\$0	\$27,362	\$3,100	\$0	-\$30,462
13	\$0	\$27,362	\$3,100	\$0	-\$30,462
14	\$0	\$27,362	\$3,100	\$0	-\$30,462
15	\$0	\$27,362	\$3,100	\$0	-\$30,462
16	\$0	\$27,362	\$3,100	\$0	-\$30,462
17	\$0	\$27,362	\$3,100	\$0	-\$30,462
18	\$0	\$27,362	\$3,100	\$0	-\$30,462
19	\$0	\$27,362	\$3,100	\$0	-\$30,462
20	\$0	\$27,362	\$3,100	\$0	-\$30,462
21	\$0	\$27,362	\$3,100	\$0	-\$30,462
22	\$0	\$27,362	\$3,100	\$0	-\$30,462
23	\$0	\$27,362	\$3,100	\$0	-\$30,462
24	\$0	\$27,362	\$3,100	\$0	-\$30,462
25	\$0	\$27,362	\$3,100	\$0	-\$30,462

^a Remaining Buildout.

Figure F-3. Individual Geothermal Life-Cycle Graphic

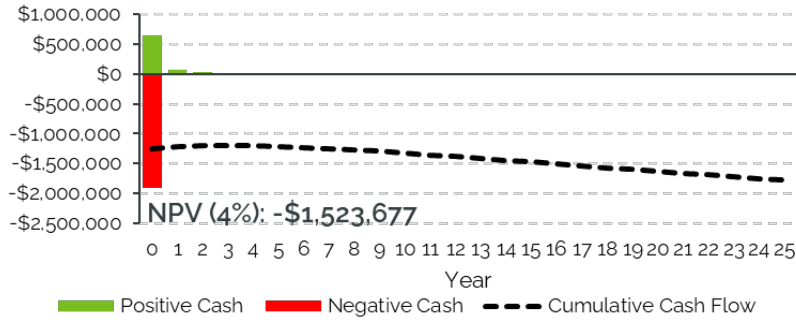


Table F-4. Life-Cycle Cost Individual Geothermal with 450-kW Photovoltaics: Proposed Cash Flow

Year	Capital Cost	Energy Cost	Maintenance Cost	Incentives	Solar Revenue	Cash Flow
0	\$2,913,073	\$0	\$0	\$1,101,816	\$0	-\$1,811,257
1	\$0	\$18,495	\$7,958	\$99,460	\$80,860	\$153,867
2	\$0	\$18,495	\$7,958	\$59,676	\$80,448	\$113,671
3	\$0	\$18,495	\$7,958	\$35,806	\$80,035	\$89,388
4	\$0	\$18,495	\$7,958	\$33,056	\$79,623	\$86,226
5	\$0	\$18,495	\$7,958	\$20,653	\$79,210	\$73,410
6	\$0	\$18,495	\$7,958	\$0	\$78,798	\$52,345
7	\$0	\$18,495	\$7,958	\$0	\$78,385	\$51,932
8	\$0	\$18,495	\$7,958	\$0	\$77,972	\$51,520
9	\$0	\$18,495	\$7,958	\$0	\$77,560	\$51,107
10	\$0 ^a	\$27,362 ^a	\$9,558 ^a	\$0 ^a	\$77,147 ^a	\$40,228 ^a
11	\$0	\$27,362	\$9,558	\$0	\$76,735	\$39,815
12	\$0	\$27,362	\$9,558	\$0	\$76,322	\$39,402
13	\$0	\$27,362	\$9,558	\$0	\$75,910	\$38,990
14	\$0	\$27,362	\$9,558	\$0	\$75,497	\$38,577
15	\$0	\$27,362	\$9,558	\$0	\$75,085	\$38,165
16	\$0	\$27,362	\$9,558	\$0	\$74,672	\$37,752
17	\$0	\$27,362	\$9,558	\$0	\$74,259	\$37,340
18	\$0	\$27,362	\$9,558	\$0	\$73,847	\$36,927
19	\$0	\$27,362	\$9,558	\$0	\$73,434	\$36,515
20	\$0	\$27,362	\$9,558	\$0	\$73,022	\$36,102
21	\$0	\$27,362	\$9,558	\$0	\$72,609	\$35,689
22	\$0	\$27,362	\$9,558	\$0	\$72,197	\$35,277
23	\$0	\$27,362	\$9,558	\$0	\$71,784	\$34,864
24	\$0	\$27,362	\$9,558	\$0	\$71,372	\$34,452
25	\$0	\$27,362	\$9,558	\$0	\$70,959	\$34,039

^a Remaining Buildout.

Figure F-4. Individual Geothermal with 450-kW Life-Cycle Graphic

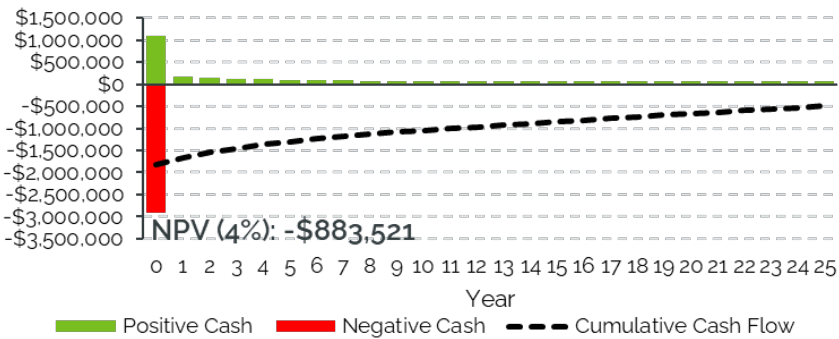


Table F-5. Life-Cycle Cost District Geothermal: Proposed Cash Flow Comparison

Year	Capital Cost	Energy Cost	Maintenance Cost	Incentives	Cash Flow
0	\$2,331,030	\$0	\$0	\$804,032	-\$1,526,997
1	\$0	\$18,495	\$1,500	\$72,579	\$52,584
2	\$0	\$18,495	\$1,500	\$43,548	\$23,552
3	\$0	\$18,495	\$1,500	\$26,129	\$6,133
4	\$0	\$18,495	\$1,500	\$24,122	\$4,127
5	\$0	\$18,495	\$1,500	\$15,071	-\$4,925
6	\$0	\$18,495	\$1,500	\$0	-\$19,995
7	\$0	\$18,495	\$1,500	\$0	-\$19,995
8	\$0	\$18,495	\$1,500	\$0	-\$19,995
9	\$0	\$18,495	\$1,500	\$0	-\$19,995
10	\$0 ^a	\$27,362 ^a	\$3,100 ^a	\$0 ^a	-\$30,462 ^a
11	\$0	\$27,362	\$3,100	\$0	-\$30,462
12	\$0	\$27,362	\$3,100	\$0	-\$30,462
13	\$0	\$27,362	\$3,100	\$0	-\$30,462
14	\$0	\$27,362	\$3,100	\$0	-\$30,462
15	\$0	\$27,362	\$3,100	\$0	-\$30,462
16	\$0	\$27,362	\$3,100	\$0	-\$30,462
17	\$0	\$27,362	\$3,100	\$0	-\$30,462
18	\$0	\$27,362	\$3,100	\$0	-\$30,462
19	\$0	\$27,362	\$3,100	\$0	-\$30,462
20	\$0	\$27,362	\$3,100	\$0	-\$30,462
21	\$0	\$27,362	\$3,100	\$0	-\$30,462
22	\$0	\$27,362	\$3,100	\$0	-\$30,462
23	\$0	\$27,362	\$3,100	\$0	-\$30,462
24	\$0	\$27,362	\$3,100	\$0	-\$30,462
25	\$0	\$27,362	\$3,100	\$0	-\$30,462

^a Remaining Buildout.

Figure F-5. District Geothermal Life-Cycle Graphic

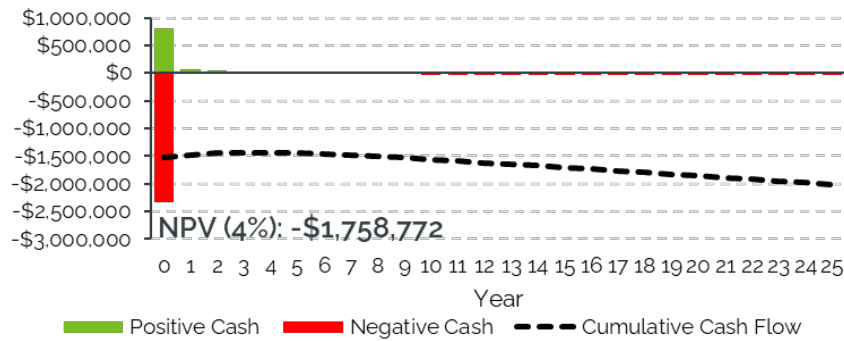
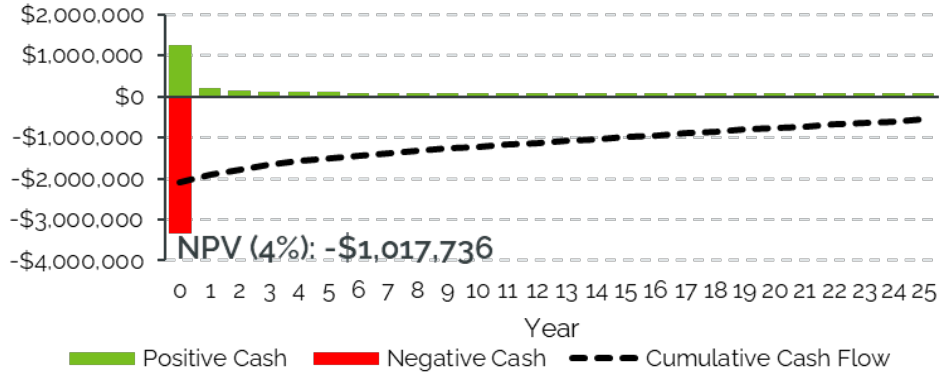


Table F-6. Life-Cycle Cost District Geothermal with 450 kW Photovoltaic: Proposed Cash Flow Comparison

Year	Capital Cost	Energy Cost	Maintenance Cost	Incentives	Solar Revenue	Cash Flow
0	\$3,343,530	\$0	\$0	\$1,263,698	\$0	-\$2,079,831
1	\$0	\$18,495	\$1,500	\$114,073	\$80,860	\$174,938
2	\$0	\$18,495	\$1,500	\$68,444	\$80,448	\$128,896
3	\$0	\$18,495	\$1,500	\$41,066	\$80,035	\$101,106
4	\$0	\$18,495	\$1,500	\$37,912	\$79,623	\$97,540
5	\$0	\$18,495	\$1,500	\$23,687	\$79,210	\$82,902
6	\$0	\$18,495	\$1,500	\$0	\$78,798	\$58,802
7	\$0	\$18,495	\$1,500	\$0	\$78,385	\$58,390
8	\$0	\$18,495	\$1,500	\$0	\$77,972	\$57,977
9	\$0	\$18,495	\$1,500	\$0	\$77,560	\$57,564
10	\$0 ^a	\$27,362 ^a	\$3,100 ^a	\$0 ^a	\$77,147 ^a	\$46,685 ^a
11	\$0	\$27,362	\$3,100	\$0	\$76,735	\$46,273
12	\$0	\$27,362	\$3,100	\$0	\$76,322	\$45,860
13	\$0	\$27,362	\$3,100	\$0	\$75,910	\$45,447
14	\$0	\$27,362	\$3,100	\$0	\$75,497	\$45,035
15	\$0	\$27,362	\$3,100	\$0	\$75,085	\$44,622
16	\$0	\$27,362	\$3,100	\$0	\$74,672	\$44,210
17	\$0	\$27,362	\$3,100	\$0	\$74,259	\$43,797
18	\$0	\$27,362	\$3,100	\$0	\$73,847	\$43,385
19	\$0	\$27,362	\$3,100	\$0	\$73,434	\$42,972
20	\$0	\$27,362	\$3,100	\$0	\$73,022	\$42,560
21	\$0	\$27,362	\$3,100	\$0	\$72,609	\$42,147
22	\$0	\$27,362	\$3,100	\$0	\$72,197	\$41,734
23	\$0	\$27,362	\$3,100	\$0	\$71,784	\$41,322
24	\$0	\$27,362	\$3,100	\$0	\$71,372	\$40,909
25	\$0	\$27,362	\$3,100	\$0	\$70,959	\$40,497

^a Remaining Buildout.

Figure F-6. District Geothermal with 450 kW Photovoltaic Life-Cycle Graphic



Endnotes

- ¹ U.S. Energy Information Administration. (2024, January 2). Residential Energy Consumption Survey (RECS). Retrieved from 2020 RECS Survey Data: <https://www.eia.gov/consumption/residential/data/2020/c&e/pdf/ce1.2.pdf>
- ² International Energy Agency. (2023, July 27). Demand for electric cars is booming, with sales expected to leap 35% this year after a record-breaking 2022. Retrieved from International Energy Agency: <https://www.iea.org/news/demand-for-electric-cars-is-booming-with-sales-expected-to-leap-35-this-year-after-a-record-breaking-2022>
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- ⁵ NYS Department of Environmental Conservation. (2023, August). Establishing a Value of Carbon. Retrieved from Climate Change Guidance Documents: https://extapps.dec.ny.gov/docs/administration_pdf/vocguide23final.pdf
- ⁶ United States Environmental Protection Agency. (2023, July 27). GHG Emission Factors Hub. Retrieved from EPA Center for Corporate Climate Leadership: <https://www.epa.gov/climateleadership/ghg-emission-factors-hub>
- ⁷ Rochester Gas and Electric. (2025, February 17). Retrieved from Requirements for the Interconnection of Generation, Transmission and End-User Facilities: <https://www.rge.com/documents/40137/2123678/Bulletin%2B86-01.pdf/e67130dc-abd3-49af-e617-9adda1009fea?version=1.0&t=1654897507176>
- ⁸ Solar Energy Technologies Office. (2023, July 27). Federal Solar Tax Credits for Businesses. Retrieved from Office of Energy Efficiency & Renewable Energy: <https://www.energy.gov/eere/solar/federal-solar-tax-credits-businesses>
- ⁹ NYSEG/Rochester Gas and Electric. (2023, July 28). PV Hosting Capacity. Retrieved from ArcGIS: <https://www.arcgis.com/apps/instant/portfolio/index.html?appid=5fc7fc4820af48838cb5bdfd54e5baad>

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**New York State
Energy Research and
Development Authority**

17 Columbia Circle
Albany, NY 12203-6399

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

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



State of New York

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