SUNY Oneonta Campus Heat Pump Strategy

Final Report | Report Number 24-29 | August 2024

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SUNY Oneonta Campus Heat Pump Strategy

Final Report

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NYSERDA Report 24-29 NYSERDA Contract 171922 August 2024

Notice

Preferred Citation

New York State Energy and Research Development Authority (NYSERDA). 2024. "SUNY Oneonta Campus Heat Pump Strategy, Final Report." NYSERDA Report Number 24-29. Prepared by Ramboll Americas Engineering Solutions, Inc., Syracuse, NY. nyserda.ny.gov/publications.

Abstract

The State University of New York at Oneonta (SUNY Oneonta) operates steam and medium-temperature water (MTW) distribution networks that service over 80% of its campus buildings, totaling approximately 1.9 million gross square feet (GSF). As part of its commitment to transitioning away from fossil fuels, this report outlines the study conducted to support SUNY Oneonta's transition to low-carbon campus energy systems. It evaluates heating and cooling strategies, incorporating a techno-economic analysis of four scenarios, each employing various heat pump technologies and distribution networks. Key findings highlight the cost-efficiency and emissions reduction potential of Scenario 2, which integrates centralized air-source and water-to-water heat pumps. The analysis underscores the importance of balancing baseload and peak energy needs while leveraging existing infrastructure for flexibility and resiliency. Recommendations provide actionable steps for implementing energy-efficient systems, optimizing infrastructure, and achieving carbon reduction goals.

Key Words

air-source heat pump, ground source heat pump, energy recovery chiller, water-to-water heat pump, district thermal network, thermal energy storage, baseload-peaking-backup strategy, centralized system, decarbonization, energy efficiency

Acknowledgments

The following individuals are acknowledged for their participation in the development of this report:

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Acronyms and Abbreviations

°F	degrees Fahrenheit
ΔT	difference between two temperatures
4G	4th generation
4GDHC	4th generation district heating and cooling
AACE	Association for the Advancement of Cost Engineering
ASHP	air-source heat pump
ATES	aquifer thermal energy storage
BAU	business as usual
BESS	battery energy storage system
BH	borehole
BTES	borehole thermal energy storage
Btu	British thermal units
CAPEX	capital expenditures
CBECS	Commercial Buildings Energy Consumption Survey
CEMP	Clean Energy Master Plan
CHP	central heating plant
Climate Act	New York State Climate Leadership and Community Protection Act
CPI	Consumer Price Index
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
COP	coefficient of performance
COVID-19	coronavirus disease 2019
DEC	New York State Department of Environmental Conservation
DHW	domestic hot water
DOE	U.S. Department of Energy
DSIRE	Database of State Incentives for Renewables & Efficiency
DX	direct expansion
EDD	Earth Energy Designer software
EPA	U.S. Environmental Protection Agency
ETS	energy transfer station
FMP	Facility Master Plan
ft	feet
ft per s	feet per second
GCM	geothermal conceptual model
GHG	greenhouse gas
GHX	ground heat exchanger
GPD	gallons per day

GSF	gross square feet
GSHP	ground-source heat pump
GSHP–C	ground-source heat pump–cooling
HDPE	high-density polyethylene
HOB	heat-only boiler
HP	heat pump
HRC	heat recovery chiller
HVAC	heating, ventilation, and air conditioning
HX	heat exchanger
IRA	Inflation Reduction Act
IRC	Instructional Resource Center
KBtu	thousand British thermal units
kcmil	thousand circular mils
kV	kilovolt
kVA	kilovolt-ampere
kw	kilowatt
lb	pound
lf	linear foot
LTHW	low-temperature hot water
MBH	thousands of British thermal units per hour
MMBtu/year	million British thermal units per year
MT	metric tons
MT/year	metric tons/year
MT CO2e	metric ton of carbon dioxide equivalent
MTHW	medium-temperature hot water
MW	megawatt
MWh	megawatt-hour
MWhf	megawatt-hour fuel
MWh-heat	megawatt-hour of heat
NG	natural gas
NYPA	New York Power Authority
NPV	net present value
NYISO	New York Independent System Operator
NYMEX	New York Mercantile Exchange
NYS	New York State
NYSEG	New York State Electric & Gas
NYSERDA	New York State Energy Research & Development Authority
OH&P	overhead and profit
O&M	operation and maintenance

OAT	outdoor air temperature
OGS	NYS Office of General Services
OPEX	operating expenses
PCE	Personal Consumption Expenditures
PEA	Preliminary Energy-Use Analysis
PEX	cross-linked polyethylene
PON	Program Opportunity Notice
PPH	pounds of steam per hour
psi	pounds per square inch
PV	photovoltaic
RNG	renewable natural gas
SUCF	State University Construction Fund
sq ft	square foot
SUNY Oneonta	State University of New York at Oneonta (SUNY Oneonta)
TENs	thermal energy networks
Trophy Point	Trophy Point Construction Services & Consulting
TMY	typical meteorological year
TTES	tank thermal energy storage
UE	Underground Energy, LLC
USD	U.S. dollars
V	volt
W/K	watts per kelvin
WWHP	water-to-water heat pump
WSHP	water-source heat pump
WSHP–DHW	water-source heat pump–domestic hot water
WWTP	wastewater treatment plant
WWHP–C	water-to-water heat pump–cooling
WWHP–H	water-to-water heat pump–heating

Summary

This report presents the background, purpose, and findings of a study that assists the State University of New York at Oneonta (SUNY Oneonta) in transitioning its campus energy systems to low-carbon operations. It includes an analysis of heating and cooling scenarios, a techno-economic evaluation, and recommendations for achieving energy efficiency, resiliency, and carbon reduction goals.

S.1 Background and Purpose

SUNY Oneonta, a midsize, four-year public university near the City of Oneonta, NY, operates steam and medium-temperature hot water (MTHW) distribution networks that serve more than 80% of campus buildings, approximately 1.9 million gross square feet (GSF). These systems provide space heating, domestic hot water (DHW), humidification, and process steam. The heating plant primarily uses natural gas, with No. 2 fuel oil as a backup during interruptible periods. The campus lacks a central chilled water plant; buildings with cooling rely on dedicated chillers or direct expansion (DX) air conditioning systems.

In April 2021, Ramboll Americas Engineering Solutions, Inc. (Ramboll), finalized a Clean Energy Master Plan (CEMP), which recommends transitioning from steam and MTHW to a low-temperature hot water distribution network. This transition would enable the adoption of low-carbon energy supply technologies over the next 10 to 20 years. To supplement the CEMP and guide the campus in adopting heat pump technology, Ramboll conducted a comparative analysis of four scenarios, summarized below, to define the role of heat pump technology in providing heating and cooling for the campus in its long-term transition away from fossil fuel use. Scenario 3, which proposed cooling the campus on a cluster basis, was ruled out in the early phase of the study in a favor of centralized cooling, thus not included for evaluation and analysis.

Table S-1. Scenario Descriptions

Scenario	Description
BAU	• Maintain business as usual
1	• Use a centralized 4-pipe heating and cooling network with a centralized energy center using GSHP and ASHP technologies for comfort heating, cooling, and DHW. • The ASHP or GSHP supplies the baseload, depending on ambient temperature. The ASHP operates at higher ambient temperatures during the summer and shoulder seasons for cost efficiency while reducing its capacity during winter to limit the borehole requirements. • During summer, the ASHP recovers usable heat from cooling to provide DHW (functioning as a heat recovery chiller) and balances the borefield. • Scenario includes TTES to balance energy demand, supply, and costs. • Scenario has two variants that use different: • Variant 1a uses electric boilers for peaking • Variant 1b uses natural gas boilers for peaking • Emergency backup uses natural gas or fuel oil.
2	• Use a centralized 4-pipe heating and cooling network with a centralized energy center that uses a cascading system approach. Combine an ASHP with an in-line WWHP to provide comfort heating, cooling, and DHW. • Operate the ASHP as a heat recovery chiller (same machine as ASHP) during summer months. • Use an electric boiler for peaking and include TTES to balance energy demand, supply, and costs. • Provide natural gas or oil as backup fuel.
4	• Configure individual building heat pumps with a centralized borehole field as the heat source. Equip each building with two WWHPs, each sized at 60% of the load to cover baseload and peaking. • Provide backup power for the heat pumps with building-level emergency generators.

S.2 Baseload, Peaking, and Backup Strategy

A well-defined strategy must prioritize dedicated heating and cooling technologies to support baseload, peaking, and backup (emergency) operations. Serving the annual load with baseload and peaking technologies ensures efficiency because the peak load only occurs annually during limited hours. Sizing the relatively expensive baseload technology to meet only most of the annual rather than the peak load is more cost-efficient.

As a guideline, baseload heating capacity at 50% to 60% of the peak heating load can cover approximately 90% of the annual heating energy. Distinguishing baseload from peak load requirements optimizes cost efficiency and enables financial resources to be redirected to other projects with more significant economic and environmental benefits.

S.3 Scenario Planning

Table S-2 presents the final scenarios selected for techno-economic modeling and analysis.

Table S-2. Final Scenarios for Techno-Economic Modeling and Analysis

Parameter	Scenario[a]			
	BAU	1a & 1b	2	4
Demand	Future	Future	Future	Future
Heat Network Configuration	Current	Centralized	Centralized	Ambient loop
Baseload technology	NG (and fuel oil)	GS + ASHP (+ HRC in summer)	ASHP + WWHP (+ HRC in summer)	Individual WWHPs (BH balancing by ASHP)
Peaking Technology	NG (and fuel oil)	(a) Electric / (b) NG	Electric	Individual WWHPs
Summer, DHW	Centralized/Local	Centralized	Centralized	Local
Winter, DHW	Centralized/Local	Centralized	Centralized	Local
Space Cooling	Local Cooling	Centralized	Centralized	Individual HPs
BTES Balancing	NA	GSHP cooling	NA	Heat from cooling from building-level WWHP
TTES	No	Yes	Yes	Local, building level
Backup Heat (Emergency)	NG	NG	NG	60% x 2 HP + building level emergency generators
Network	1G	4G (4-pipe: heating and cooling)	4G (4-pipe: heating and cooling)	Ambient loop

[a] The assumption is that sufficient natural gas will be available to meet the peak demand for scenarios that include it. However, Oneonta is in a gas-constrained area, and SUNY Oneonta is an interruptible gas consumer, which may result in disconnection in case of limited gas availability in the network. In such circumstances, fuel oil would be used instead.

S.4 Techno-Economic Analysis

The techno-economic analysis identified the most cost-efficient mix of technologies to meet future heating and cooling needs. Figure shows the net present value (NPV) of costs for each scenario on the left axis and total emissions on the right axis. Among the alternative scenarios, Scenario 2 has the lowest overall costs, approximately 10% lower than the most expensive, Scenario 4, which is the ambient loop scenario. A yellow dot indicates the NPV for each scenario without the social cost of carbon for carbon dioxide equivalent (CO_2e) emissions, while a green triangle represents the NPV including the social cost of carbon, following New York State Department of Environmental Conservation (DEC) guidance.

Figure S-1. Carbon Dioxide Equivalent Emissions and Project Net Present Value for the Various Scenarios (2030–2054)

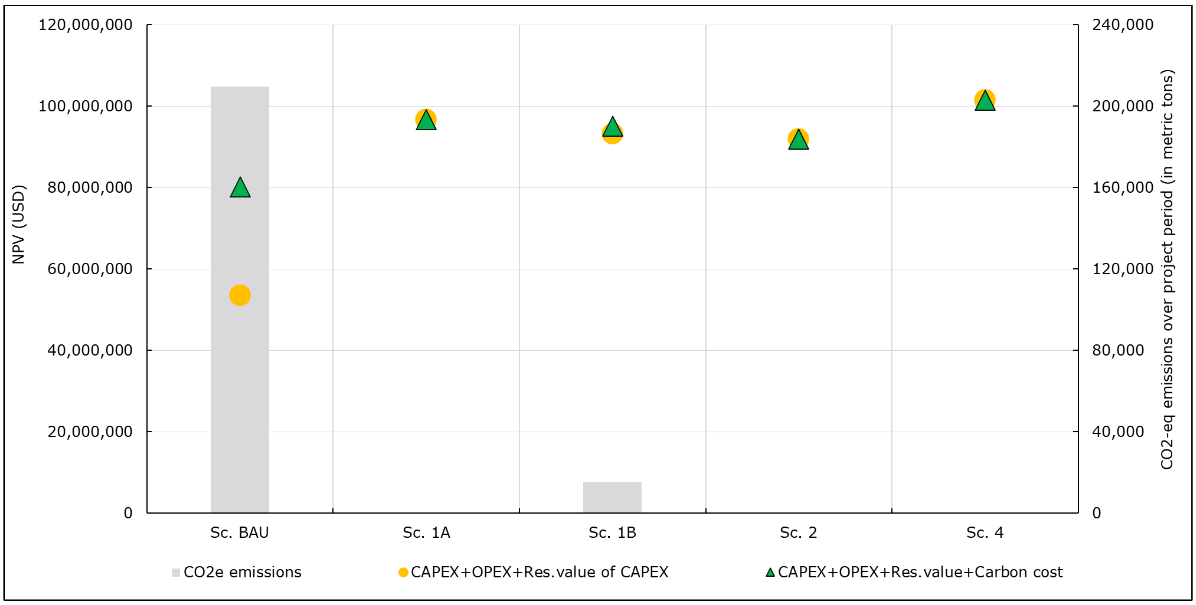


Table S-3 summarizes key topics and associated aspects that emerged during the study. These aspects highlight the complexities and challenges that must be addressed and managed throughout the campus energy transition. They intersect to influence and balance carbon reduction, energy efficiency, flexibility, resiliency, and redundancy pragmatically and cost-effectively.

Table S-3. Key Findings from the Campus Heat Pump Strategy Study

Electrical Demand Impact	• Identify Scenario 1b as the only scenario that may not require further substation and feeder upgrades. • Conduct feeder-by-feeder load analysis to assess the viability of Scenario 1b, ensuring total load remains within the capacity of two of the three substation transformers. • Address significant emergency and standby power requirements without nonelectrical-base backup. • Minimize high CAPEX associated with electrifying peak load in addition to baseload to achieve relatively small carbon emissions reduction.
Natural Gas Peaking Benefits	• Provide flexibility and redundancy for emergencies. • Bridge the fuel gap while electric utility infrastructure advances. • Manage capital spending efficiently. • Align with future New York State plans to transition from NG to RNG and hydrogen. • Reuse existing infrastructure and backup power assets to optimize resources.
Building Improvements	• Develop a strategy for steam-only buildings, such as Morris Hall. • Address humidification needs with dedicated systems to allow central plant MTHW supply temperatures to be lowered. • Determine the lowest possible operating supply temperature based on space heating loads rather than humidifier requirements.
Infrastructure Scenarios	• Evaluate centralized versus decentralized system configurations. • Assess property space requirements for geothermal systems.
Emission Reduction	• Achieve more than an 85% reduction in emissions without fully electrifying the system.

The following summarizes key considerations and strategies for optimizing energy system design and supporting the campus's transition to sustainable energy solutions.

1. Electrical demand impact
   - Identify Scenario 1b as the only scenario that may not require further substation and feeder upgrades.
   - Conduct feeder-by-feeder load analysis to assess the viability of Scenario 1b, ensuring total load remains within the capacity of two of the three substation transformers.

- Address significant emergency and standby power requirements without nonelectrical-based backup.
- Minimize high capital expenditures (CAPEX) associated with electrifying peak load in addition to baseload to achieve relatively small carbon emissions reduction.

2. Natural gas peaking benefits
   - Provide flexibility and redundancy for emergencies.
   - Bridge the fuel gap while electric utility infrastructure advances.
   - Manage capital spending efficiently.
   - Align with future New York State plans to transition from natural gas (NG) to renewable natural gas (RNG) and hydrogen.
   - Reuse existing infrastructure and backup power assets to optimize resources.
3. Building improvements
   - Develop a strategy for steam-only buildings, such as Morris Hall.
   - Address humidification needs with dedicated systems to allow central plant MTHW supply temperatures to be lowered.
   - Determine the lowest possible operating supply temperature based on space heating loads rather than humidifier requirements.
4. Infrastructure scenarios
   - Evaluate centralized versus decentralized system configurations.
   - Assess property space requirements for geothermal systems.
5. Emission reduction
   - Achieve more than an 85% reduction in emissions without fully electrifying the system.

S.5 Recommended Next Steps

To help the campus prioritize projects, influence future systems design, and demonstrate progress toward low-carbon operations and campus carbon reduction goals, the following are recommended next steps:

1. Track data on hot water valve position, supply temperature, and outdoor temperature
2. Develop a strategy to convert the steam portion of the central distribution system to low-temperature hot water
   - Assess alternatives to address the steam needs of Morris Hall (a nonhydronic building)
3. Install electric boosters for buildings with steam kettles for cooking (planned over the next two to three years)
4. If the campus remains centralized:
   - Install heat exchangers (HXs) in the seven remaining hard-piped residence hall buildings
   - Replace three-way valves (bypass of coils) with control valves

- Convert the existing MTHW system from a constant volume system to a variable volume system
- Aim for a delta T (ΔT) of at least 30 degrees Fahrenheit (°F) to 35°F in the distribution system during winter design conditions; a higher ΔT will reduce pipe dimensions and lower distribution system costs
- Further assess the optimal location of the central plant, considering potential electrical upgrades from the current central plant location to the substation

5. Monitor developments and advancements in heat pump technology and U.S. market availability

1 Characterization of the Proposed Community

1.1 Site Description

The State University of New York at Oneonta (SUNY Oneonta), a midsize, four-year public university located near the City of Oneonta, NY, operates steam and medium-temperature water (MTHW) distribution networks that serve more than 80% of campus buildings, covering approximately 1.9 million gross square feet (GSF). These systems provide space heating, domestic hot water (DHW), humidification, and process steam. Campus buildings include a mix of academic facilities (78,000 GSF average size), residential buildings (63,000 GSF average size), and support structures (30,000 GSF average size).

Most buildings were constructed in the 1940s, 1950s, and 1960s. Since 2016, three new buildings have been added. Approximately 25% of the buildings have undergone renovations, and many are slated for inclusion in a deep energy retrofit program within the next 15 to 20 years.

The heating plant uses natural gas as the primary fuel and No. 2 fuel oil as a backup fuel during interruptible periods. The campus lacks a central chilled water plant. Cooling needs are met locally through dedicated chillers or direct expansion (DX) air conditioning systems.

In April 2021, Ramboll finalized a Clean Energy Master Plan (CEMP) for SUNY Oneonta. The CEMP recommends transitioning from steam and MTHW to a low-temperature hot water distribution network. This transition would provide a framework for phasing in low-carbon energy supply technologies over the next 10 to 20 years. A comparative analysis of the following four scenarios supports the campus in identifying how to use heat pump technology to meet heating and cooling needs during the transition away from fossil fuels.

1. Business as usual (BAU)
2. Scenarios 1a and 1b: Centralized energy center using ground-source heat pump (GSHP) and air-source heat pump (ASHP) technologies
3. Scenario 2: Centralized energy center using ASHP and water-to-water heat pump (WWHP)
4. Scenario 4: Ambient geothermal loop that is decentralized with heat pumps located at the building level

1.2 Site Constraints and Opportunities

Oneonta, NY, is the termination node for the DeRuyter natural gas pipeline, which is more than 60 years old and which New York Gas and Electric (NYSEG) has identified for replacement. Several large users, including SUNY Oneonta and A.O. Fox Memorial Hospital, maintain backup fuel oil heating systems because they rely on interruptible natural gas supplies that may not meet demand during peak winter periods.

This project seeks to develop a comprehensive approach to implementing heat pump technology at SUNY Oneonta. Additionally, it provides a nonpipe alternative approach to the aging DeRuyter pipeline, which remains Oneonta's sole source of natural gas. Key aspects considered in this study include:

- Leveraging coincident heating and cooling loads to achieve high coefficients of performance (COP)
- Optimizing ground loop size based on system diversity
- Enhancing redundancy in heating and cooling capacity
- Reducing capital expenditures (CAPEX) through community-based approaches
- Lowering operations and maintenance costs using community-style configurations

2 Baseline Conditions and Assumptions

2.1 Baseline Conditions and Forecasts

These documents provided the baseline reference data for the study:

- *SUNY Oneonta Preliminary Energy-Use Analysis,* March 6, 2020
- *SUNY Oneonta Energy Scenario Planning Report,* September 22, 2020
- *SUNY Oneonta Clean Energy Master Plan,* April 14, 2021

The *Preliminary Energy-Use Analysis* (PEA) developed for the 2020 Energy Assessment Report established the energy-use baseline. Analysts relied on 24 months of utility bill data for electricity, natural gas, fuel oil, and propane, normalized for weather conditions to estimate typical annual campus energy use. They incorporated 12 months of building-level electric submeter data to estimate building-level energy use.

The PEA estimated annual energy use for significant end-uses, including lighting, space heating, space cooling, fans, pumps, plug loads, water heating, process equipment, cooking, and refrigeration. This disaggregation used end-use data from the Commercial Buildings Energy Consumption Survey (CBECS)[1] database for comparable building types. The project baseline started with the PEA's estimates of annual input energy for space heating, water heating, and space cooling for each building.

Using these input energy estimates, the team calculated annual output energy loads for each building's space heating, water heating, and space cooling. They applied typical seasonal conversion efficiencies based on the equipment in each building to represent baseline annual loads by building.

To develop forecast loads, they adjusted baseline loads to reflect planned improvements, including energy efficiency measures, renovations, closures, and cooling installation in previously uncooled spaces.

2.1.1 Heating

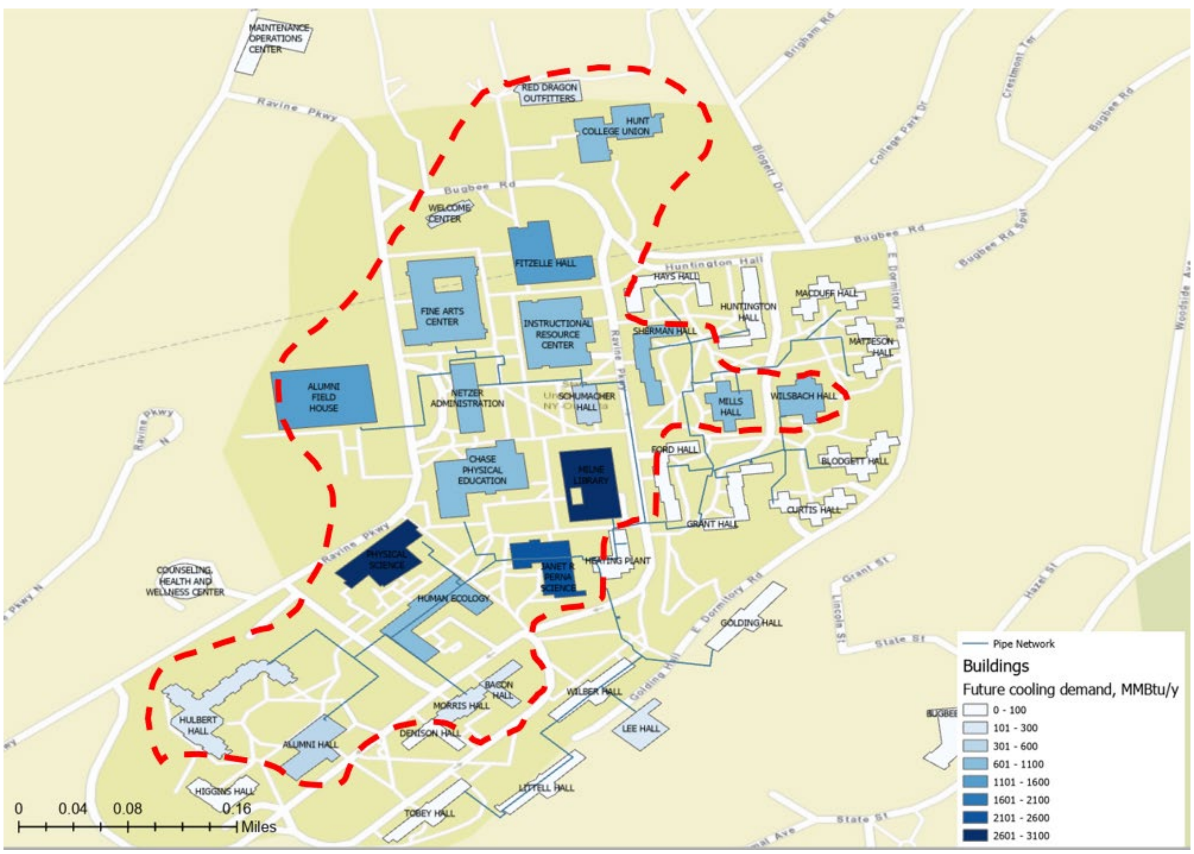
The baseline heat load, including DHW for centrally supplied buildings, is 99,326 million British thermal units (MMBtu) per year. The forecast heat load, including DHW, is 100,047 MMBtu per year. These figures exclude distribution losses.

2.1.2 Cooling

Figure 1 illustrates the long-term cooling strategy discussed between Ramboll and SUNY Oneonta. Buildings within the red dashed boundary line are planned to receive district cooling in the future. While many buildings are already cooled, the strategy accounts for the anticipated increase in cooling needs, the proximity of these buildings, and the benefits of coproducing cooling and heating. This analysis led Ramboll and SUNY Oneonta to conclude that centralized cooling is a practical and efficient option. Additionally, establishing a cooling network creates the opportunity to connect other buildings not currently equipped with cooling systems, including:

- Alumni Field House: Currently cooled but anticipated to require increased cooling capacity
- Bacon Hall: Not currently cooled
- Chase Physical Education: Largely uncooled, with only localized cooling in some areas
- Sherman Hall: Not currently cooled

Figure 1. Long-Term Cooling Strategy



The estimated baseline cooling load for all buildings is 18,045 MMBtu per year, while the long-term forecasted cooling load for all buildings is estimated to be 20,529 MMBtu per year. For the 21 buildings outlined in Figure 1, which are expected to connect to district cooling over time; the baseline annual cooling load is estimated at 17,442 MMBtu per year, and the forecast load is 19,927 MMBtu per year. The projected increase in cooling load reflects the planned expansion of space cooling to areas currently without it. Discussions with the campus indicate a phased approach to building out the cooling network over the next 20 years, ultimately connecting these buildings and transitioning to a centralized 4-pipe heating and cooling distribution network.

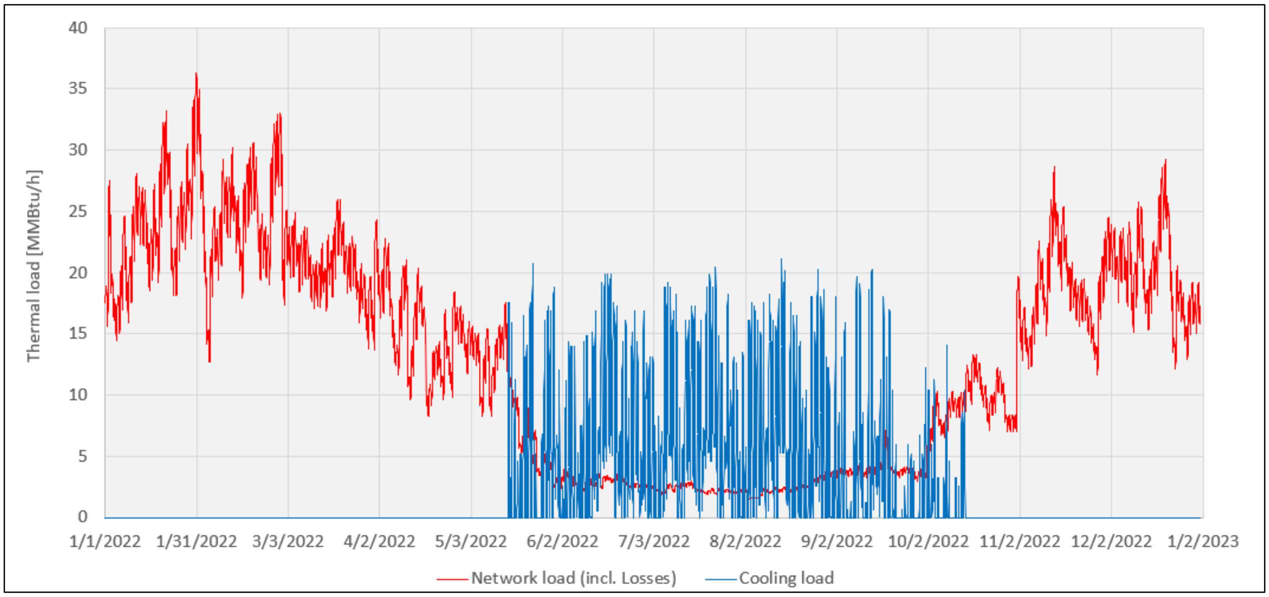
2.1.3 Simultaneous Heating and Cooling Loads

Figure 2 illustrates the forecasted hourly heating and cooling loads, with the heat load representing energy produced by the central heating plant (CHP). During the summer, the cooling load significantly exceeds the heating load, which DHW primarily drives needs that decrease when students are not in the residence halls.

The team applied an hourly profile to the annual combined forecast of space heating and water heating loads, mapping campus space heating and cooling loads to a dimensionless load shape derived from a similar campus with hourly interval heating demand data. They estimated the distribution network's heating losses at 10% annually, distributing these losses evenly as a constant hourly value across the system.

To develop the hourly forecast cooling profile, the team used a combination of outdoor air temperature (OAT) dependency, occupancy mode, and the academic calendar to determine whether the school was in regular session. They assumed occupied hours to be 12 hours per day on weekdays and 8 hours per day on weekends. During occupied hours, they increased the load proportionally with outdoor air temperature to account for internal loads. They also assumed cooling availability from May 15 through October 14 and reduced the calculated load by 20% when the campus was not in regular session.

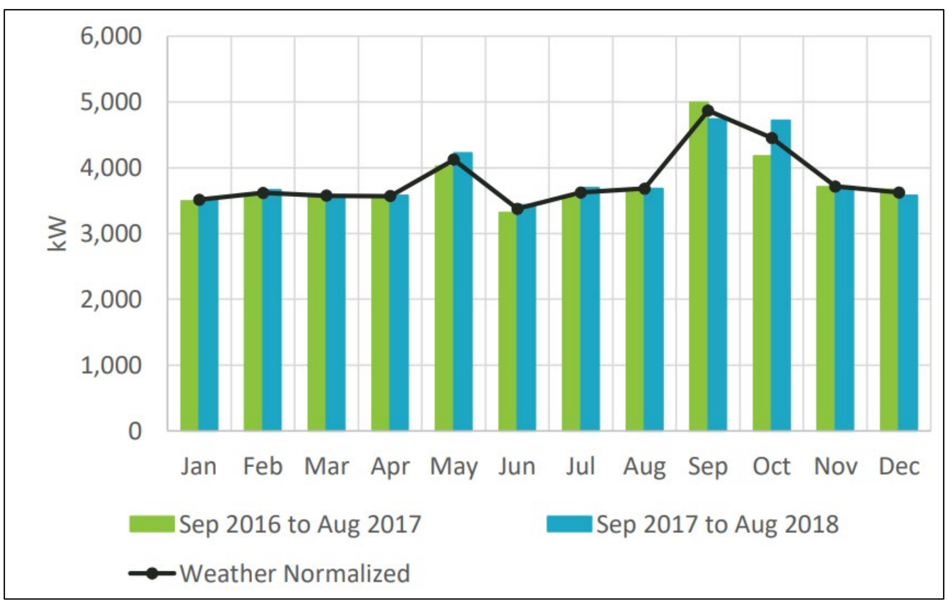
Figure 2. Simultaneous Heating and Cooling Loads



2.1.4 Electricity

The team analyzed the PEA report from 2020 to determine the monthly peak electrical demand as Figure 3 shows.

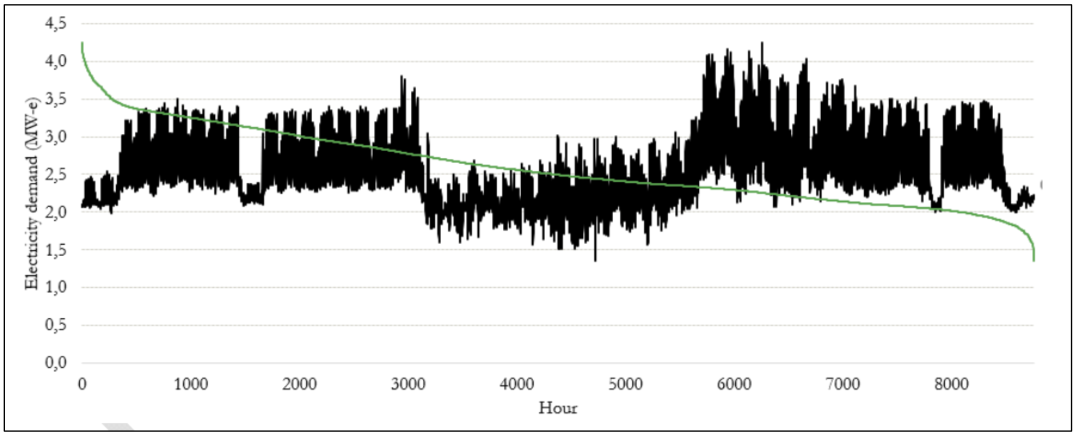
Figure 3. Electric Demand



The campus experienced its peak electrical demand in September when students returned from summer break, and ambient temperatures remained relatively high. The data includes total campus electrical demand, including electricity for chillers.

Figure 4 excludes electricity used for the chillers, based on the end-use estimates from the SUNY Oneonta energy modeling report. Base electrical consumption averages approximately 2.0 megawatts (MW), as shown in Figure 4.

Figure 4. Electrical Load Excluding Electricity for Chillers



2.1.5 Carbon Dioxide Equivalents

Table 1 shows the CO_2e emission factors for campus fuels. These factors remain constant for natural gas, distillate fuel oil, and propane. However, the electricity factor will drop to 0 pounds (lb) of CO_2e per megawatt-hour (MWh) by 2030, aligning with New York State (NYS) Executive Order 22, which mandates that electricity for State agencies derive entirely from renewable energy sources by that year.

Table 1. Cardon Dioxide Equivalent Emission Factors

CO_2e Emissions	2020	2030	2040
Electricity[a]	234.5 lbCO_2e per MWh	0 lbCO_2e per MWh	0 lbCO_2e per MWh
Natural Gas[b]	0.053 MTCO_2e per MMBtu 11.7 lb CO_2e per Therm 117.1 lb per MMBtu	0.053 MTCO_2e per MMBtu 11.7 lb CO_2e per Therm 117.1 lb per MMBtu	0.053 MTCO_2e per MMBtu 11.7 lb CO_2e per Therm 117.1 lb per MMBtu
Distillate Fuel Oil[b]	0.0742 MTCO_2e per MMBtu 163.61 lbCO_2e per MMBtu	0.0742 MTCO_2e per MMBtu 163.61 lb CO_2e per MMBtu	0.0742 MTCO_2e per MMBtu 163.61 lb CO_2e per MMBtu
Propane[b]	0.0631 MTCO_2e per MMBtu 139.16 lb CO_2e per MMBtu	MTCO_2e per MMBtu 139.16 lb CO_2e per MMBtu	MTCO_2e per MMBtu 139.16 lb CO_2e per MMBtu

[a] The emission factors are based on the State University Construction Fund (SUCF) instruction to use data from eGrid 2020, available at https://www.epa.gov/egrid/download-data; https://www.epa.gov/egrid/summary-data

[b] The emission factors are based on the U.S. Environmental Protection Agency (EPA) Greenhouse Gas (GHG) Emission Factors Hub, accessible at https://www.epa.gov/climateleadership/ghg-emission-factors-hub; https://www.suny.edu/sustainability/resources/; https://www.suny.edu/media/suny/content-assets/documents/capital-facilities/energy/SUNY-Standard-Energy-Conversion-Factors-fun-factsv3_2021.docx

2.2 Campus Energy Supply

2.2.1 Building Heating Supply

SUNY Oneonta centrally supplies heat through MTHW and steam networks, serving more than 80% (approximately 1.9 million GSF) of campus buildings. The MTHW network operates at approximately 275 degrees Fahrenheit (°F) during the winter and 200°F during the summer. These systems provide space heating, DHW, humidification, and process steam to academic, residential, and support buildings.

The buildings within the scope are a mix of academic (78,000 GSF average size), residential (63,000 GSF average size), and support (30,000 GSF average size) structures. The CHP fires natural gas as the primary fuel and uses No. 2 fuel oil as a backup fuel during interruptible periods. When the ambient temperature drops below 20°F during cold winter times, NYSEG requests the campus to switch from firing natural gas to firing No. 2 fuel oil.

The December 2019 Energy Assessment Report notes that the CHP is in excellent condition overall, with the boilers estimated to have a useful life of 20 years. However, burners may need to be replaced within 10 years. Under a centralized configuration, the existing CHP would serve an essential operational resiliency role, using existing assets during the energy transition, including providing for peak load management and emergency backup. The report also highlights that the MTHW distribution piping system is in good condition. According to the September 2020 Energy Scenario Planning analysis, the MTHW distribution system should be reusable under a lower-temperature hot water configuration. This will need confirmation in subsequent design stages, assuming the campus continues to operate as a centralized thermal energy network.

2.2.2 Domestic Hot Water

Historically, the CHP has produced DHW year-round, which has kept the plant in operation during the summer months to serve a relatively small water heating demand. However, during summer 2023, the campus shut down the plant for 14 days. Several issues must be resolved before the campus fully implements a longer summer shutdown, including addressing DHW and steam generation for dining halls and air conditioning reheats. Electrification scenarios in this study considered how DHW would be produced in the future.

2.2.3 Building Cooling Supply

The campus does not have a central chilled water plant. Buildings with cooling are cooled locally by dedicated chillers or direct expansion air conditioning systems.

2.3 Modernization Plans

The following summarizes the campus modernization plans discussed during the study:

- **Fine Arts:** Added a new electric steam boiler in April 2023 to assist with humidification during the shoulder seasons.
- **Mills Hall:** Planned the installation of an electric hot water booster.
- **Ford Hall and McDuff Hall:** Put renovations on hold for 5 to 7 years due to a significant drop in enrollment caused by a recent decline in the market share of college students.
- **Instructional Resource Center (IRC):** Requires additional cooling in a future renovation; the IRC is heavily used during the summer.
- **Chase Physical Education**: Lacks internal cooling and is largely uncooled, with only slight localized cooling. The planned renovation will include direct expansion cooling for dehumidification. Considered the potential for a new wing expansion as part of the Chiang O’Brien Architects Facilities Master Plan (FMP) project.
- **Netzer Administration:** Plans a deep energy retrofit to begin construction in May 2025, including a geothermal borefield. Installed a 660-ft test borehole in January 2024, which included a thermal conductivity test measuring 1.86 British thermal units (Btu) per hour per foot per °F.
- **Schumacher Hall**: JMZ Architects completed a programming study with concept alternatives aligned with SUCF Directive 1B-2.

- **Alumni Field House**: Currently cooled, but will add more cooling. Purchased temporary cooling during the coronavirus disease 2019 (COVID-19) pandemic, which became permanent. Used for major events only.
- **Milne Library**: Has reheat from central plant hot water but needs a solution for providing reheat if the central plant is shut down during the summer. Considering the use of a small heat pump.

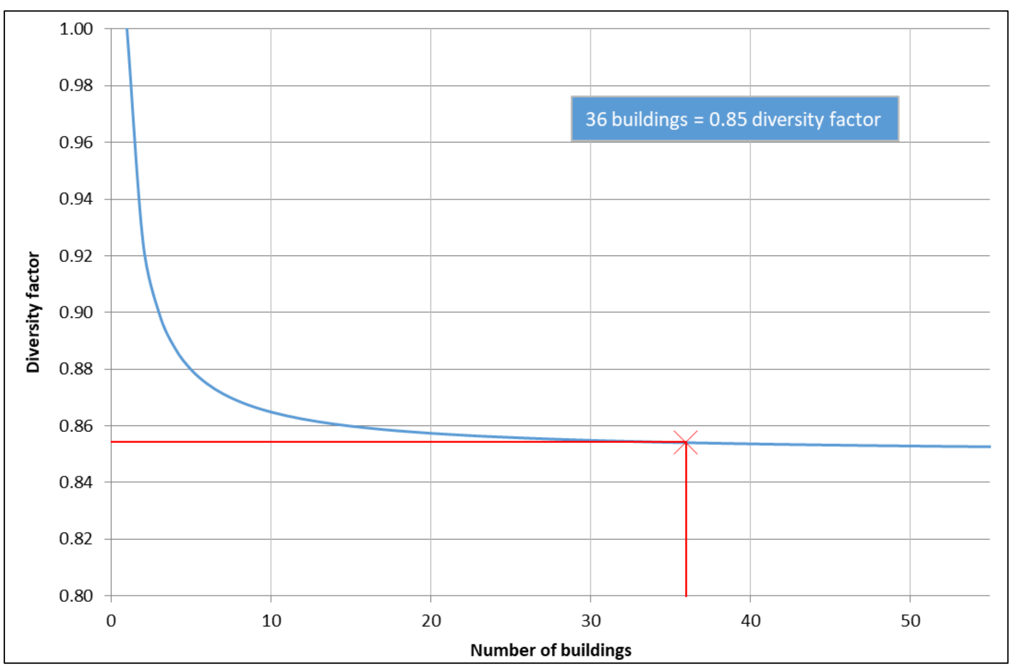
2.4 Overall Design Considerations

This section outlines key design considerations for establishing a decarbonization transition strategy.

2.4.1 Diversity Factor

The centralized system's peak heating demand will be lower than the sum of the peaks for all buildings because they do not peak simultaneously. The share of the peak heating demand in the central solution is called the diversity factor compared to the sum of the peaks in the individual solution. This factor typically ranges from 0.85 to 0.95, depending on the number of buildings. Accounting for the diversity factor offers an economic advantage for a central solution because it lowers the required production capacity to a building-level solution. Figure 5 illustrates an example of a diversity factor curve for space heating based on experience from previous projects.

Figure 5. Example of Diversity Factor for Space Heating



2.4.2 Baseload, Peaking, and Backup Considerations

Baseload technologies, such as heat pumps, are typically expensive to install, while suitable peak load technologies, such as existing boilers, have lower costs. Boilers are established assets with long lifetimes. When operated as peak load technologies, they will run during the coldest winter times, limiting their annual operating hours. Therefore, their technical lifetimes are extended.

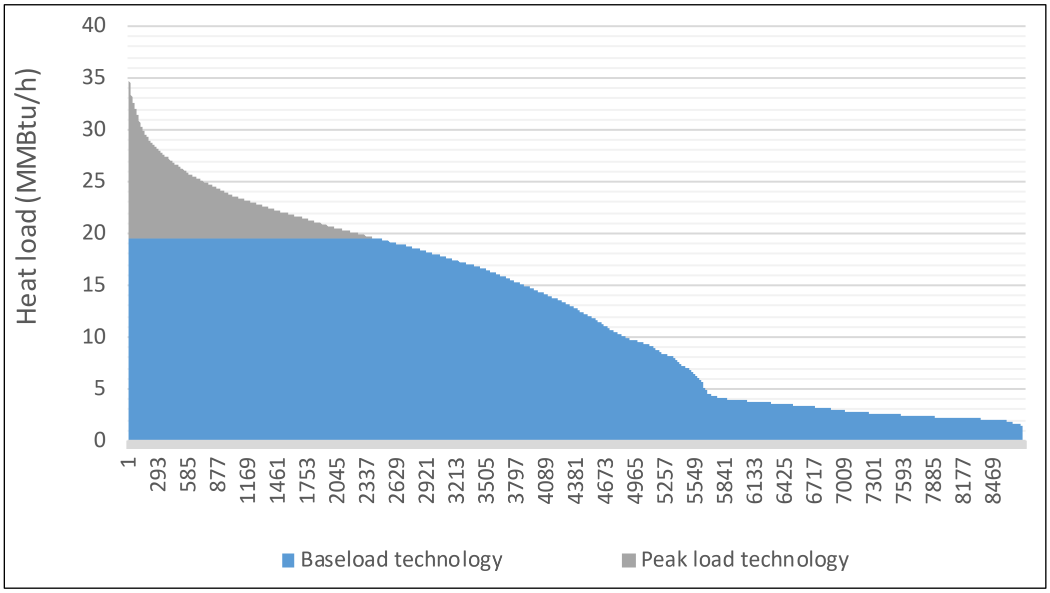
Baseload technologies, which should operate for many hours annually, require a strategy for low operating costs. Since peaking technologies operate for fewer annual hours, their potentially higher operational costs have a limited impact on the overall economy. In some cases, multiple baseload technologies may be required if the preferred supply source is restricted, or they may be selected if they are more economical to operate.

The reason for using dedicated baseload and peaking technologies is that peaking occurs in limited annual hours of the year, but requires a high capacity (see Figure 6). Establishing how much of the total annual heat demand a baseload technology should cover is an optimization exercise. Generally, if baseload technology covers 50% to 60% of the peak heating load, it will meet approximately 90% of the annual heating load. For example, using a ground-heat source system as baseload technology would require nearly double the number of boreholes to increase the load from 90% to 100%, but at a significantly high cost. Using existing assets or lower cost peaking technologies, such as natural gas boilers, is more economical. This approach also provides resilience in both fuel diversification and capital cost management. Therefore, establishing a baseload and peak load strategy is more cost-effective and allows financial resources to be allocated to other projects.

The future energy system will increasingly use more intermittent sources in nature (i.e., wind and solar) and, therefore, will move from being very stable to being more unstable where electricity backup is crucial. This shift may affect grid reliability, and backup heat production should be considered. Key planning considerations include:

- If baseload technology operates on electricity, then the heating system backup should rely on another fuel, such as a natural-gas–fired boiler.
- The backup technology should be highly reliable and cost-effective to install.
- The backup fuel supply should be noninterruptible and dependable.
- The operation staff should be familiar with the backup technology.

Figure 6. Baseload and Peak Load Technology



2.4.3 Potential Reuse of Medium-Temperature Water Pipes and Building Upgrade and Modification Considerations

The central portions of the existing MTHW system are in good condition and could be reused to carry lower-temperature heating. A lower delta T (the difference between two temperatures, ΔT) would be expected by reducing the system's supply temperature to allow production from heat pumps. The ΔT directly impacts the capacity the pipes can carry. Ramboll evaluated the ΔT in the system based on campus-provided data from February 2022 (during the third and fourth quarters of 2022) for the CHP, Alumni Hall, Milne Library, Mills, Fine Arts, IRC, Netzer, and Wilsbach. Ramboll presented the results of this review to SUNY Oneonta on January 20, 2023, which included key takeaways and recommendations. Ramboll assumes that the MTHW pipes could be repurposed to carry lower-temperature heating water in the distribution system as outlined in the following recommendations:

1. Optimize the system's efficiency and heating capacity by applying appropriate supply temperature reset schedules, ensuring proper hydronic balancing, and avoiding active bypass flows, as the CHP return temperature from the district loop is impacted by outdoor air temperature.
2. Install heat exchangers (HXs) in the seven remaining residence hall buildings connected to the MTHW network with three-way mixing valves:
   - Convert the existing MTHW system from constant flow to variable flow
   - Replace the three-way valves with two-way valves

3. For new buildings and heating, ventilation, and air conditioning (HVAC) replacements, use a design hot water supply temperature of 140°F or less, as the SUCF recommends.
4. Target a ΔT of 30°F to 35°F in the distribution system for a winter design conditions. A higher ΔT will reduce pipe dimensions and distribution system costs.

2.4.3.1 Existing Medium-Temperature Water Supply Temperature Observations

Historically, the supply and return temperatures of the CHP have been as follows:

- 275°F (November 1 through May 1)
- 200°F (May 1 through November 1)
- Maximum ΔT of 55°F on the coldest days (return temperature of 220°F)
- Typical ΔT of 25°F to 30°F during normal operations (average outside temperature of 40°F)

The need for steam to supply humidifiers in Fine Arts and Milne Library has driven the operation at a supply temperature of 275°F during winter. During the first quarter of 2023, Fine Arts added a new electric steam boiler, 100 pounds of steam per hour (PPH), for humidification. The Milne Library humidification system is reportedly no longer required and has ceased to serve as a load for the MTHW system.

During the 2020–2021 heating season, SUNY Oneonta experimented with lowering the CHP supply temperature to assess its impact on the buildings. The MTHW supply temperatures from the CHP during that period are summarized below. The key primary lesson from this experiment was that most buildings maintained comfort at the reduced supply temperatures. Additionally, using dedicated systems for humidification allows the CHP's MTHW supply temperatures to drop below 240°F. The lowest possible operating supply temperature has yet to be determined but can be set based on space heating loads rather than humidifier needs.

- October 2020: 215°F
- November 2020: 215°F until November 9, then raised to 240°F+
- December 2020: 240°F+
- January 2021: 245°F
- February 2021: 240°F
- March 2021: 240°F until March 28, then lowered to 215°F
- April 2021: 215°F
- May 2021: 215°F until May 15, then lowered to 175°F
- June 2021: 215°F starting June 1
- July 2021: 215°F

- August 2021: 215°F
- September 2021: 215°F
- October 2021: 215°F
- November 2021: 215°F until November 8, then raised to 280°F

2.4.4 Supply Temperature Considerations for Heat Pumps

To introduce low-carbon heating technologies such as heat pumps, reducing the supply temperature to some or all the systems and buildings may be necessary since heat pumps have operating temperature limits. Furthermore, lower supply temperatures enhance the efficiency and capacity of heat pumps. When applying heat pumps to existing buildings, the cost and time for early HVAC replacements to further reduce supply temperature should be weighed against the savings.

Industrial heat pumps commonly available in the U.S. typically produce district hot water temperatures up to 170°F. However, exceptions exist, and the market is rapidly developing to include more multistage heat pumps and other refrigerant options, which are more common in different parts of the world. High-temperature heat pump offerings usually come in larger sizes, making them more suited for centralized solutions in individual buildings. The expansion of size offerings will likely be a future development, and market offerings should be monitored throughout the study's implementation.

2.4.4.1 Building Design Temperature Considerations

As mentioned in Section 2.2.1, SUNY Oneonta's centralized heat supply consists of two existing networks: an MTHW network and a steam network. Most campus buildings are designed for a hot water supply temperature of approximately 180°F at a ΔT of 20°F.

Hot water supply temperatures should reset lower than the maximum when loads fall below design conditions. Since a heat pump's efficiency improves with reduced supply temperature, the campus should consider the optimal lowest temperature that could be reached, including resetting the set-point for off-design conditions.

The campus should focus on increasing the ΔT in the buildings, which will improve the overall energy system efficiency and capacity of the distribution system. New buildings at SUNY Oneonta should be designed for lower supply temperatures (at a higher ΔT) at 125°F or less. For buildings undergoing HVAC system renovations, SUCF recommends designing those systems for building-level supply temperatures of 140°F. See also Section 2.5.3.

2.4.4.2 Heating Supply Temperature Recommendations

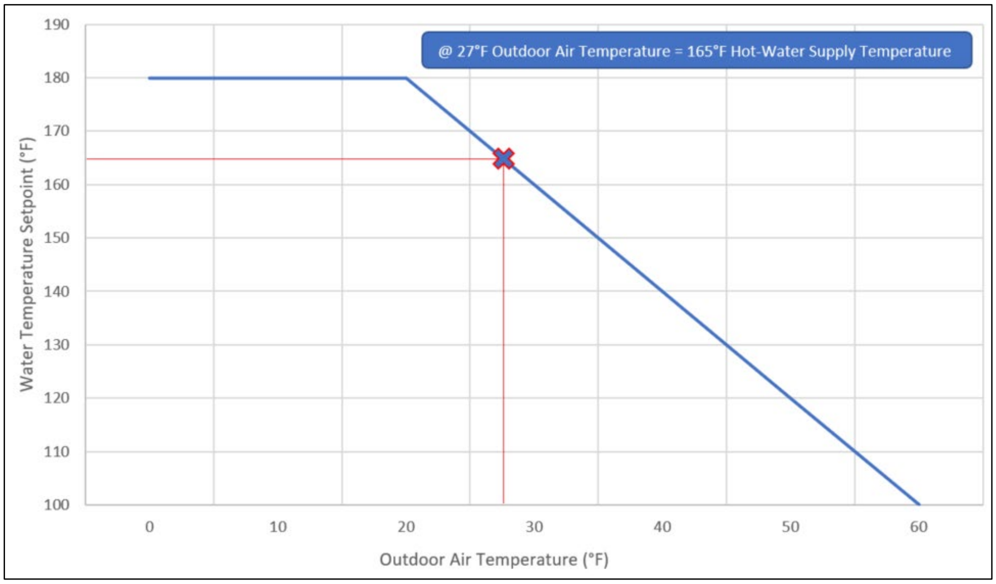
In the central plant scenarios, the central plant will initially supply heat at around 170°F at peak load and adjust based on an outdoor air temperature reset schedule. This approach reduces distribution temperatures as the outdoor temperature rises, increasing overall seasonal efficiency.

At a 170°F supply temperature from the central plant, distribution losses and building HX losses will likely result in building operating temperatures of approximately 165°F. While this temperature will exceed the needs of some campus buildings, the supply temperature can likely be reduced as more campus buildings are modified.

Most campus heating systems are designed to meet peak load with 180°F building hot water. However, as mentioned previously, Ramboll suspects that many campus buildings can meet design heating loads with lower supply temperatures produced by the heat pumps. Design supply temperatures are only required during peak conditions, which occur during the coldest periods and represent a small percentage of the heating season. For example, typical meteorological year (TMY) weather data from Binghamton, NY—the closest weather station to Oneonta, NY, with TMY data—indicates only 783 annual hours (9%) with outdoor air temperatures below 20°F. Hot water supply temperatures are typically reset to lower levels as outdoor air temperatures rise, which reduces distribution losses, improves temperature control, and, in the case of heat pumps, increases efficiency.

Figure 7 illustrates an example supply temperature reset schedule. A typical schedule may set a supply temperature of 180°F for outdoor air temperatures below 20°F and then decrease linearly to 120°F for outdoor air temperatures above 50°F. According to Figure 8, an outdoor air temperature of 27°F would require a hot water supply temperature of 165°F. Binghamton TMY weather data shows approximately 1,457 hours (17% of the year) at or below 27°F outdoor air temperature.

Figure 7. Outdoor Air Temperature Reset Schedule Example



The capacity of a distribution network depends on flow, supply temperature, and return temperature within the system. Building systems influence these supply temperature requirements and the return water temperatures of the distribution system. Each campus building has a designed heating demand from a central distribution system and reduces the supply temperature of the circulating hot water through its HX by a ΔT, which varies based on the design of the building's hot water coils.

Efforts to enhance the efficiency and performance of the distribution system should prioritize the following actions:

- Target buildings with low heat demand and high ΔT to minimize adverse effects on the system's overall ΔT.
- Address buildings with high heat demand and low ΔT because they reduce the overall ΔT.
- Prioritize building renovations for buildings most likely to reduce the distribution system's overall ΔT.
- Focus on a limited number of buildings if necessary. As is mentioned in Section 2.5.3, a ΔT assessment of supply and return data was completed for seven buildings with a high influence on the overall district network.

High return temperatures reduce the heat pumps' contribution to the heating load at higher supply temperatures. When the return temperature at design conditions exceeds the maximum heat pump supply temperature, the heat pump cannot operate, requiring the peaking technology to meet the full design load independently. This scenario significantly impacts the design capacity of peaking technology design capacity and, for electric peaking, increases the required electrical infrastructure. Additionally, regional electric system capacity constraints and potential transmission upgrade costs identified through the NYISO interconnection process may present challenges.

As campus buildings are modernized and renovated, central design supply temperatures will gradually decrease over the long term. Accounting for temperature losses in HXs and pipes, the central plant should aim for a maximum operating temperature of 155° to 160°F in the long term.

Reducing central hot water supply temperatures offers several benefits, including the following:

- Achieving long-term economic savings with lower-temperature systems
- Enabling integration of diverse low-carbon or renewable technologies, such as heat pumps, geothermal, waste heat, solar thermal, and thermal storage
- Reducing heat distribution losses by minimizing the temperature difference between the circulating fluid and its surrounding environment
- Decreasing the overall temperature drop from the heat source to the most hydraulically remote building
- Transitioning to alternative piping systems, such as cross-linked polyethylene (PEX) or high-density polyethylene (HDPE), once the network fully converts to lower temperature (steel piping may initially be required to bridge the gap between high-temperature and future low-temperature systems
- Improving heat pump efficiency by reducing the required temperature lift
- Limiting reliance on fossil fuels by further reducing annual peaking operations
- Extending the lifespan of steel pipes by lowering thermal stresses

2.4.4.3 Building-level Temperature Monitoring to Support Low-Temperature Hot Water Transition

Building-level temperature monitoring is crucial in informing future design decisions and further prioritizing building renovations to reduce hot water supply temperatures. Although heat pumps can be configured to supply hot water at conventional design supply temperatures (approximately 180°F), doing so increases the cost of the heat pump and reduces both its capacity and efficiency compared to lower design supply temperatures.

If the campus monitors the building's hot water supply and return temperatures over at least one heating season, the collected data will be valuable in defining the design parameters for the proposed heat pump solutions. Additionally, this data will help identify loads that require a higher supply temperature for possible coil retrofits. For example, if the data show that most buildings can meet design loads with a

160°F supply temperature (and can be further reduced for off-design conditions), but some buildings still require 180°F supply temperature on a design day, replacing the hot water coils in those buildings may be a more cost-effective solution. This retrofit would allow the central system to operate more efficiently at a lower supply temperature. Without monitored temperature data, however, the central supply temperature must be set high enough to meet the current building design conditions.

SUNY Oneonta monitors hot water supply and return temperatures in its building automation system for most hot water loops, although the data may not be trended or stored. As part of the monitoring effort, it should verify the accuracy of building hot water supply and return points and configure them for trend data collection. Additionally, it should configure the hot water supply setpoints for outdoor air temperature reset functionality. During most of the heating season, the supply temperature can be lower than the design point, significantly improving heat pump capacity and efficiency.

The original design hot water supply reset schedules can be adjusted to optimize the reset, which is more critical for heat pump applications than for fossil-fuel-fired supply equipment. For example, the original reset schedule may require adjusting the supply temperature from 180°F at 0°F outdoor air temperature down to 120°F at 60°F outdoor air temperature. This adjustment improves heat pump performance compared to a constant design supply temperature. However, the reset schedule can likely be further optimized while meeting building needs. For example, a reset of 160°F at 0°F outdoor air temperature down to 110°F at 60°F outdoor air temperature may provide sufficient coil capacity. Optimizing the reset schedules is critical in heat pump system design and operation. Gathering trend data for hot water valve positions will also help optimize the hot water reset schedules. Campus staff or outside energy consultants should regularly review the data and reset schedule optimization at least monthly through one heating season.

Monitored temperature data reveals the system temperature difference (ΔT), defined as the difference between hot water supply and return temperatures throughout the season. Understanding ΔT defines design parameters and identifies buildings with low ΔT that may benefit from retrofitting. A low ΔT reduces heating capacity, increases pumping power, and requires larger pipes in the distribution system.

2.4.5 Piping Material Considerations

Lower supply temperatures in the heating network allow the use of polymeric materials. However, selecting polymeric materials requires careful consideration of several factors:

- **Temperature transition:** How will the network transition from higher to lower temperature? Will certain parts of the campus require higher temperatures for extended periods?
- **System pressure:** What system pressure is necessary? Polymeric materials cannot withstand high temperatures and high pressures for extended periods. Does campus elevation increase system pressure?
- **Pipe service life:** What is the expected life of the pipe, and how do short exceedances in temperature or pressure gradients affect it? For example, EN253 design standards specify a 30-year service life for pre-insulated steel pipes operating at 248°F and 50 years at temperatures below 240°F. Plastic pipes often have more than 60 years of service life, but specific project conditions may affect this estimate.
- **Insulation:** Regardless of material, pipes should be insulated to improve efficiency. Preinsulated pipes reduce installation costs.
- **Leak detection:** Pipes should include leak detection systems for quick identification and repair.

The final material selection will occur in subsequent design phases, where these considerations and associated costs will be further assessed.

2.4.6 Energy Transfer Stations in Buildings

If SUNY Oneonta remains centralized, the plan involves connecting each building through an indirect heating connection. Each building will receive a new HX to separate the distribution network from the internal building installations. This setup, known as an energy transfer station (ETS), provides hydraulic isolation between the two systems.

This arrangement enhances system security compared to a direct connection. In the event of an internal leak, hydraulic isolation prevents large amounts of water from the distribution network from entering the building, which could cause significant damage. A hydraulically isolated connection thus removes this risk. Hydraulic isolation also enables higher pressures in the distribution network if necessary.

However, a direct connection avoids temperature loss (approach temperature) through the HX, which can lower the central supply temperature and improve heat pump efficiency. It also reduces the return temperature in the distribution network.

Depending on space availability, the DHW can be supplied instantaneously through a HX or stored in a tank. Installing a DHW hot water storage tank reduces the required DHW heating load to the building by using the tank volume as a buffer for the network. This approach decreases pipe dimensions in the district heating network, especially branch connections to each building. However, more space within the buildings is required to accommodate the tank. The selection of the type of DHW heater will depend on the building's DHW demand.

The energy transfer station will be a prefabricated packaged unit tailored to the heating demand. For example, a skid-mounted unit suits larger demands, while a wall-mounted energy transfer station fits smaller demands (see the image in Figure 8 for a typical installation). If the system simultaneously produces heating and cooling, two HXs will be necessary: one for the heat supply and one for the cooling supply. The same HX can be used if no requirements exist to produce heating and cooling simultaneously (e.g., when another unit produces DHW during the summer).

Figure 8. Typical Energy Transfer Station Installation

Source: Danfoss, Substation, date not specified, Danfoss District Heating and Cooling for Buildings, Danfoss District Heating and Cooling for Buildings

2.4.7 Resiliency Considerations

The following outlines key factors and recommendations to enhance the resiliency of SUNY Oneonta's energy infrastructure:

Energy Supply

- **Maintaining backup fuel system:** Oneonta, NY, is the termination node for the DeRuyter natural gas pipeline, which is more than 60 years old and which NYSEG has identified for replacement. Large users, including SUNY Oneonta and A.O. Fox Memorial Hospital, maintain backup fuel oil heating systems to address limitations in interruptible gas supply during peak winter demand. When ambient temperatures drop below 20°F, NYSEG typically requests the campus to switch from natural gas to No. 2 fuel oil, which increases operational costs during these periods.
- **Receiving electrical power:** NYSEG supplies the campus with 46,000 volts (V) through a single incoming utility feeder. This feeder powers three separate 3,750-kilovolt-ampere (kVA) transformers that step down the voltage to 4,800 V for campus distribution. Five 4,800 V feeders deliver electricity to campus buildings in a dual radial configuration, with each building connected to two feeders. Substation Buses 200 and 300 operate with two feeders, while Bus 100 uses a single feeder.

Infrastructure Upgrades

- **Upgrading electrical infrastructure:** In 2021, RMF Engineering recommended several upgrades to the electrical infrastructure:
  - Replacing five campus feeders with 15 kV-rated 350 thousand circular mils (kcmil) cables
  - Replacing building switches with 15 kV-rated switches
  - Replacing building transformers with dual primary 5- to 15-kV–rated transformers
  - Enhancing and replacing portions of the duct bank system

  By November 2023, the project had reached 90% design completion. A contract change order is expected in the third quarter of 2024. Cable replacement is targeted for spring 2025, and building upgrades are expected to start in May 2025.

Capacity Management

- **Managing electrical capacity:** Two active transformers provide a total capacity of 7,500 kVA, exceeding the September 2020 peak of 5,100 kVA and the February 2020 winter peak of 3,800 kVA. Campus load appears to be trending downward. Long-term trends should guide decisions on sizing new electrical loads and substation equipment. Dual feeds on each building transformer allow campus staff to balance loads across existing feeder systems and substation buses as needed.
- **Addressing single points of failure:** NYSEG's off-campus 46-kV system feeds the main substation through a single feeder, creating a single point of failure.

Backup Systems

- **Using boilers for backup**: Boilers offer fast startup times, familiarity for operational staff, and low installation costs.
- **Enhancing heating backup:** Increasing the focus on electrification requires maintaining full heating backup from a secondary fuel source. Diversified fuel use supports flexibility and cost resiliency.
- **Establishing centralized heating backup:** The current district energy system relies on central plant boilers for heating backup. Backup boilers, powered by natural gas or liquid fuel, supply peak heating loads (5% to 10 % of the annual demand) under regular operation. In case of planned heat pump failures, peaking boilers operate as backup boilers to produce the required load for connected buildings. Emergency generators power circulation pumps and control systems during electricity outages.
- **Using boilers for backup:** Boilers offer fast startup time, familiarity for operational staff, and low installation costs.

Building-Level Solutions

- **Evaluating building-level heat pumps:** The campus does not support:
  - Installing building-level natural-gas-fired boilers because a firm gas supply from NYSEG appears unlikely, and most buildings lack natural gas infrastructure
  - Installing building-level No. 2 fuel-oil-fired boilers due to storage, environmental regulatory, and space challenges
  - Using electric boilers due to potential electrical service impacts

  If building-level heat pumps were selected as the approach, the campus would support:

  - Deploying modular, redundant heat pumps in a cascade sequence
  - Installing new diesel-fired emergency generators sized to cover full building loads or serve multiple buildings through strategically located generators

Central Generator Options

- **Analyzing central generator options:** The campus currently operates 22 building-level emergency generators for 44 significant buildings. Evaluating the feasibility of a central generator to provide backup power to multiple buildings could enhance efficiency.
- Supporting central heating operations: Emergency generators must power:
  - Main circulating pumps for heating and cooling in the central system
  - Larger circulating pumps within the buildings

Additional Resiliency Measures

- **Incorporating tank thermal energy storage (TTES);** this involves:
  - Storing hot or cold water in insulated tanks to balance energy demand and supply
  - Reducing peak demand, energy consumption, carbon emissions, and costs
  - Disconnecting electricity consumption from heat supply of heat, allowing heat capture during periods of renewable energy availability and heat supply from storage when renewable energy is scarce
  - Referencing Section 3.5 for a broader discussion of this technology and its application
- **Integrating battery storage;** this involves:
  - Providing an uninterruptable power supply during grid outages
  - Recognizing limited capacity, which often supplies power for only a few hours
  - Considering scale because battery storage is not cost-effective at campus scale
  - Backing up buildings or data centers with uninterrupted power supplies to allow sufficient time for generators to start

2.5 Utility Rates

SUNY Oneonta receives electricity and natural gas from NYSEG, which supplies the CHP and individual buildings. Table 2 summarizes the baseline utility rates by major component. Delivery charges include fixed monthly electricity, natural gas, and electric reactive power costs.

Table 2. Baseline Annual Average Utility Prices

Fuel	Supply	Delivery	Total
Electricity[a]	$47 per MWh	$11.9 per MWh	$58.9 per MWh
Natural Gas (Central Plant)[b]	—	—	$17.19 per MWhf
No. 2 Fuel Oil[b]	—	—	$56.57 per MWhf
Propane[1]	—	—	$60.28 per MWhf

[a] Data based on 24-month cost records for applicable accounts, including demand charges in delivery costs.
[b] Data based on 24-month cost records for the main campus.

3 Technology Screening

The technology screening process aims to identify suited technologies and sources for the future production of heating and cooling that align with the carbon reduction goals of the Climate Leadership and Community Protection Act (Climate Act) and NYS Executive Order 22. The evaluation considers both centralized and distributed (decentralized) solutions. The following sections qualitatively describe and evaluate these technologies. Technologies deemed relevant and viable for the campus will advance into the scenario planning phase described in the following sections.

3.1 Fossil Fuel Technologies

SUNY Oneonta uses fossil fuel technologies such as heat-only boilers fueled by natural gas, oil, or grey hydrogen and cogeneration units, including gas turbines, combined cycles, gas engines, and steam turbines).

The SUCF Directive 1B-2 (January 2024 version, subsequently updated March 2026) outlines the following requirements for fossil fuel systems:

1. New or replacement systems and equipment (e.g., HVAC, DHW) must operate on electric power. Onsite combustion of fossil fuels and biofuels is prohibited, except for:
    - Emergency backup power and emergency heat
    - Special cases requiring approval from the SUCF Project Coordinator, such as laboratory process loads, kilns, kitchen equipment
2. Installing new fossil-fueled central heating plants or building-level heating equipment (e.g., boilers, generators) is permitted only if:
    - There is an absolute necessity due to imminent failure of the equipment and non-fossil fuel systems from the Clean Energy Master Plan (CEMP) are unable to be installed due to technical, funding or time restrictions.
    - The fossil fuel equipment being replaced allows itself to be utilized for emergency backup once the non-fossil fuel-based systems from the CEMP are installed.
    - Connections (new or existing) to existing fossil fueled central plants; may only occur or remain if there is a completed CEMP detailing how the campus will meet the goals of the CLCPA or a commitment to decarbonize the central plant prior to 2050 is documented by the campus.

Considering SUCF Directive 1B-2 and the project's focus on developing a CEMP that supports a transition to a low-carbon energy supply, SUNY Oneonta and Ramboll agreed to advance only dual-fuel boilers (natural gas and No. 2 fuel oil) to the next phase. The campus's existing CHP, which includes dual-fuel boilers, supports its centralized steam and hot water system. This technology will continue because it serves both peaking and backup technology and allows for reusing existing assets.

3.2 Renewable Fuel Technologies

Renewable fuel technologies include heat-only boilers powered by renewable natural gas (RNG), biomass, or bio-oil as fuel, and cogeneration units such as bio-oil- or biogas-fired turbine and biomass-fired Organic Rankine Cycle.

The December 2022 New York State Climate Action Council Scoping Plan highlights biofuels, such as RNG, as flexible and dispatchable resources. However, many biofuels remain unproven at commercial scales. For this reason, these technologies were not advanced to the subsequent project phase. Since the campus currently uses No. 2 fuel oil, it should routinely monitor market developments related to biofuels, including bio-oil, to assess their potential suitability.

Other considerations for renewable fuels include:

- **Biogas production:** Anaerobic digestion of organic matter, including food waste, becomes economically viable only at large scales (e.g., city or regional levels) and is not feasible for a campus-level application.
- **Conversion of a heat-only boiler (HOB):** Converting existing fuel oil boilers to bio-oil operation is technically feasible. The campus can perform this conversion if it seeks further reductions in greenhouse gas emissions.
- **Challenges in biofuel supply:** Sourcing and delivering large quantities of biofuels depend on local availability.
- **Environmental impact:** The sourcing and delivering of biomass and bio-oil may have adverse environmental effects.

Recent discussions have emphasized using clean hydrogen (green and blue hydrogen) to support decarbonization across various sectors. Hydrogen and other synthetic fuels are expected to play a significant role in future renewable energy systems. However, because the heating sector operates at low temperatures and already has well-established efficient alternatives, it should not compete for hydrogen resources. Instead, hydrogen should be periodized for more challenging sectors to decarbonize, such as heavy transport, industrial processes, aviation, and the maritime industries.

3.3 Renewable Technologies

Rooftop solar thermal systems produce energy out of phase with heat demand, as their highest output occurs in the summer when heating demand is low. Solar thermal systems may serve as a good source for local DHW hot water production installation during summer months, mainly where high summer DHW summer loads exist.

At SUNY Oneonta, the scenarios evaluated rely on a centralized DHW system. The optimal summer season DHW production depends on annual demand:

- Limited demand: Electric DHW heating may be more suitable
- Higher demand: Heat pumps or solar thermal systems may offer better solutions

Section 3.6.1.2 includes an analysis comparing centralized and decentralized DHW production. It concludes that using planned ASHPs to produce DHW during the summer season is more viable. This approach avoids additional CAPEX while maintaining high efficiency. The same conclusion applies to solar thermal systems for DHW production.

3.4 Electrification Technologies

Electrification technologies include various heat pump systems and electric resistance heating. These technologies can be used for large-scale centralized applications or building-level decentralized applications.

Depending on their availability, heat pumps can use various heat sources, including cooling production, wastewater, geothermal, ambient air, or combinations thereof. Following is an overview of some of the heat sources and sinks.

3.4.1 Borehole Thermal Energy Storage

Borehole thermal energy storage (BTES) systems use closed-loop GHXs as heat sources, heat sinks, and seasonal thermal storage. Compared to conventional ground-source borefields, BTES systems are designed and operated to optimize thermal storage capacity. Both systems exchange heat with the ground and store thermal energy within borefields, each offering distinct advantages and disadvantages.

3.4.1.1 Number of Boreholes

The project envisions the BTES operating alongside an ASHP system to produce the baseload, given the lower CAPEX required for the ASHP system. The ASHP system will supply the majority of the annual load. An average heat extraction rate must be calculated to determine the boreholes needed for the BTES to meet the remaining campus heating or cooling load. However, this project did not include installing or analyzing test bores.

3.4.1.2 Boreholes Balancing

Using the subsoil as BTES causes the ground temperature across the BTES field to vary. Since SUNY Oneonta primarily requires heating (with higher heating demand than cooling), the cooling demand may not be adequate to rebalance the boreholes. As a result, the subsoil may eventually cool from season to season unless the boreholes are balanced. This balancing is envisioned to occur through ASHPs (air-to-water), which can extract heat from outdoor air and transfer it to the boreholes. The system would operate when balancing is needed and outdoor air temperatures are favorable.

3.4.1.3 Geothermal Assessment and Conceptual Model

Underground Energy, LLC (UE), prepared a geothermal assessment report (see Appendix A) for the Oneonta area. This report developed a geothermal conceptual model (GCM) to characterize ground conditions and subsurface heat transfer mechanisms, enabling the conceptual design of Earth-coupled, low-temperature, community-scale heating and cooling systems. Using the GCM and load estimates from Ramboll, UE applied Earth Energy Designer (EED) software to simulate monthly load data and design ground heat exchangers (GHXs) with BTES where appropriate.

The EED output reports for SUNY Oneonta included the following characteristics:

- Number for bores**:** 225 boreholes
- Borefield geometry**:** 15 x 15
- Bore depth**:** 500 ft
- Bore spacing**:** 20 ft
- Average ground temperature**:** 50.6°F

The UE report indicated that SUNY Oneonta’s BTES would be situated entirely in shale bedrock, offering favorable conditions for seasonal storage due to balanced annual thermal loads at the borefield.

3.4.2 Aquifer Thermal Energy Storage

Open-loop shallow geothermal systems, also called aquifer thermal energy storage (ATES), use aquifers as heat sources and sinks for heat pumps. Heat pumps are essential, particularly for heating because groundwater temperatures at applicable depths are low.

UE evaluated the ATES potential for SUNY Oneonta and provided the following findings, which excluded this technology from further consideration:

- The primary hydrogeologic feature in Oneonta is the glacial aquifer within the Susquehanna River valley and its tributaries. This aquifer has more than 400 ft of fine- to coarse-grained sediments deposited during glacial retreat.
- Hydrogeologic data suggest significant advective heat transfer from groundwater flow in the permeable portions of the glacial aquifer but negligible transfer in bedrock.
- The glacial aquifer does not extend to the upland SUNY Oneonta campus, making ATES infeasible.

Preliminary analysis confirmed the absence of suitable aquifers below SUNY Oneonta, eliminating ATES as a viable option.

3.4.3 Air-Source Heat Pumps

ASHPs use ambient air as a heat source. They can operate independently to meet baseload heating demand or supplement GSHPs. Combining ASHPs with ground-source systems can reduce the boreholes needed and assist in borehole load balancing.

ASHPs are effective for building- or district-level hot or chilled water systems. They use ambient air as a heat source and require outdoor installation or evaporators, either on the ground, rooftops for smaller units, or in dedicated horizontal spaces for larger units. The following are key benefits and drawbacks to consider when evaluating ASHPs for specific applications:

Benefits

- Free, unlimited heat source
- Higher efficiency than electric boilers, although efficiency varies with ambient air temperatures
- Generally, less expensive to install compared to geothermal boreholes
- Configurable to achieve hot water supply temperatures up to 180°F

Drawbacks

- High CAPEX compared to technologies such as boilers
- Noise from air-cooling unit fans can affect the surrounding area
- Visual impact on campus or building aesthetic
- Reduced heat output and COP efficiency at lower ambient temperatures, which often coincide with higher heat demand
- Water vapor in the air leads to condensation and frost formation near freezing temperatures
- Defrosting methods, such as the use of hot refrigerant gas, are necessary to consider when designing an ASHP system

3.4.4 Wastewater Heat Recovery

Wastewater can be an effective heat source for heat pump technology if its temperature is at least a few degrees above freezing. The potential for heat extraction increases with higher wastewater temperature and greater flow rates.

Wastewater heat sources can be categorized as either effluent or influent:

- Effluent: Treated wastewater exiting the wastewater treatment (WWTP). This source is typically suited for large heating loads but involves high CAPEX to install long lengths of direct-buried pipe from the WWTP to the heat load.
- Influent: Untreated wastewater, also known as sewer water, leaving a building or facility before treatment. The heat extracted from the influent is typically used for smaller loads near the heat source. For an example of influent heat recurve, see the SHARC Energy assessment Section 3.4.4.1 describes.

3.4.4.1 Campus-level Wastewater Heat Recovery Potential (SHARC Energy Assessment)

The City of Oneonta operates its own WWTP, located approximately 4 miles southwest of the SUNY Oneonta campus. However, the campus's heating load is insufficient to justify the significant cost of installing a piping network to connect the campus to the WWTP. Additionally, such a project would disrupt surrounding neighborhoods, making it unsuitable for further consideration as a heat source for the campus.

The team conducted a high-level comparison between two potential heat sources: (1) extracting heat from influent (untreated wastewater) as it leaves campus and (2) installing additional vertical geothermal boreholes. Both options provide low-temperature heat that heat pumps can use to produce higher-temperature heat.

Figure 9 illustrates the components and operation of a system for extracting heat from influent leaving a campus, based on SHARC Energy's assessment. This system intercepts the influent stream using a wastewater holding tank. While the heat is extracted, the wastewater remains uninterrupted, allowing wastewater to continue flowing out of the campus as usual.

Rotary lobe pumps, augers, and basket screens temporarily extract solids, allowing plate and frame HXs to be used. After the heat exchange process, the solids are reintroduced into the system. The filtered influent flows through one side of the plate and frames HX before being returned to the holding tank. The HX transfers heat from the influent to the low-temperature heat source network piping, which supplies the water-source heat pump (WSHP) in the central energy center. The two sides of the HX are sealed and do not mix. If additional equipment is required, wastewater influent is used as a potential heat source.

Figure 9. Sewage Heat Recovery and Cooling System Influent Wastewater Heat Extraction System

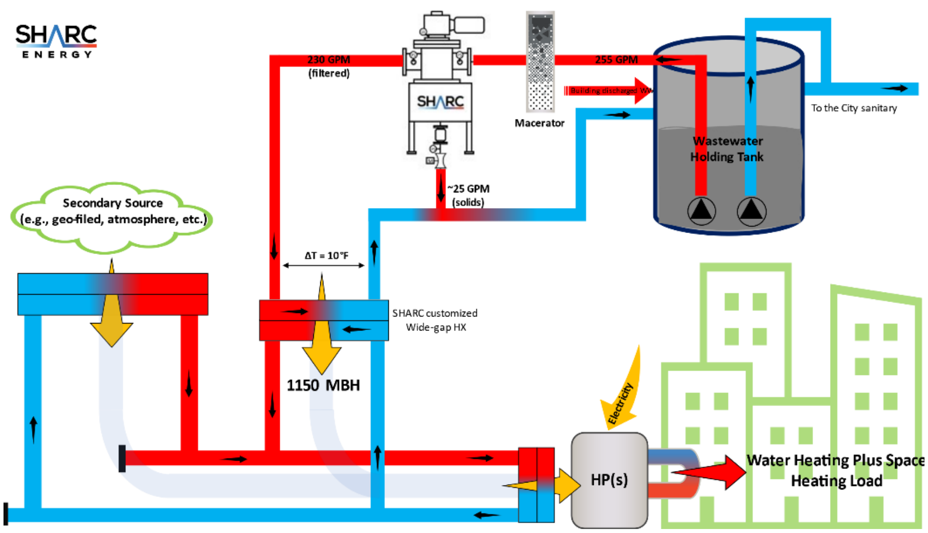


Table 3 presents an economic comparison between campus wastewater and geothermal systems as heat sources for the WWHP. The comparison assumes the following:

- The team estimated the average flow rates of wastewater influent leaving campus based on quarterly water and wastewater bills since the influent is not metered. They used an average flow rate of 97,000 gallons per day (GPD).
- The team used an average heat recovery rate of 16.22 thousand British thermal units (kBtu) per minute to estimate the heat that can be extracted from the influent. They derived this value through discussions with SHARC Energy and based it on an assumed ΔT and specific heat capacity.
- Using the influent for heat recovery reduces the boreholes required for the geothermal field, lowering the CAPEX.

- The team identified additional CAPEX for the following equipment:
  - SHARC Energy HXs
  - Wastewater storage tank
- Solid handling and sludge pumps: To support the wastewater heat extraction system, the following additional equipment is necessary:
  - Distribution pumps
  - Weather enclosure
  - Electrical distribution and service
  - Direct-buried piping from the influent heat extraction point to the central energy center
- The team estimated that the cost to furnish and install the SHARC Energy units and auxiliary equipment is 2.5 times that of the SHARC units.
- The team assumed that the operating costs for additional boreholes are similar to the wastewater heat extraction process and excluded them from the analysis.
- The team estimated the cost to install direct-buried piping, including excavation, bedding, pipe, restoration, general conditions, overhead and profit (OH&P), and labor, at $1,500 per linear foot (lf) of trench.
- The team excluded costs associated with boreholes, such as distribution piping, pumps, and plant connections, because these costs would be required for the base technology. They included only the costs for adding additional boreholes.

Table 3. Economic Comparison of Wastewater and Geothermal Heat Sources

	Wastewater Influent	Boreholes
Cost of Trench (lf)	—	$2,500
Cost of Boreholes	—	$25,000
SHARC 880 System	$495,000	—
SHARC Aux. Equipment and Installation	$1,713,500	—
$ per kw	**$6,006**	**$3,645**

Using influent wastewater as a heat source is not recommended because installing the necessary equipment and piping to capture heat from the influent far exceeds the cost of installing additional boreholes. Furthermore, the disruption caused by installing the new piping network and the small size of the existing sanitary line further support the conclusion that wastewater heat recovery is unlikely to be a viable option at SUNY Oneonta and was not considered for further evaluation.

3.4.4.2 Municipal-level Wastewater Heat Recovery Potential

Under the right circumstances, capturing heat from wastewater effluent can be cost-efficient and provide significantly higher heat capacity. Heat can be recovered using a heat pump before the WWTP effluent is discharged into the neighboring Susquehanna River. However, this must be balanced against factors such as the site's heating load, the amount of heating load the WWTP can cover, the distance to the WWTP, and the required CAPEX investment, including potential disruptions to the area.

The City of Oneonta's WWTP is approximately 4 miles from the campus. Due to this distance, including centralized wastewater as a heat source in the centralized scenarios is not considered viable. Additionally, discussions with SUCF emphasized the desire for project solutions that could be controlled directly on-site. This preference aligns with SUCF's broader direction, so this study excluded WWTP heat recovery from further consideration.

3.5 Energy Storage

The following types of energy storage were considered for SUNY Oneonta:

- Battery energy storage system (BESS)
- BTES, discussed in Section 3.4.1
- ATES, discussed in Section 3.4.2
- TTES

While BESS is well-suited for managing short-term fluctuations in frequency, it is less effective for long-term storage. The energy content of a BESS is limited compared to other storage types, and its CAPEX per energy unit is high. Additionally, the technical BESS lifetime is relatively short. Therefore, BESS is not considered part of the energy system for the scenarios analyzed.

TTES, however, will be included in the proposed energy system. It is a crucial component for improving the cost-effectiveness of energy systems, especially in district heating and cooling. TTES involves storing hot or cold water in insulated tanks to balance energy demand and supply, ultimately reducing peak demand, carbon emissions, and costs.

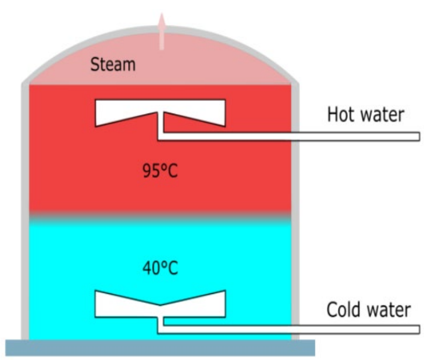
TTES is designed for day-to-day storage and can be discharged during high electricity prices or charged when electricity prices are low. The total storage volume depends on system needs and the desired function. TTES helps mitigate daily fluctuations, whereas other storage types are better suited for seasonal fluctuations. TTES can also serve as cooling storage during the summer season.

The benefits of TTES include the following:

- Lower operating costs for the energy system since the storage allows operation during off-peak electricity hours.
- Reduced need for peak production, which can reduce greenhouse gas emissions if peak production comes from fossil fuels.
- Backup capabilities for the system if pumps and ancillary equipment are connected to a secured electrical supply or emergency generator.
- Functionality as a “virtual battery” in energy systems dominated by intermittent renewable energy production and fluctuations in hourly electricity prices. TTES offers similar advantages to a chemical battery (using electricity at low prices and curtailing consumption when prices are high), but provides significantly more energy content at a lower overall cost.

TTES is typically implemented in cylindrical steel tanks (often above ground) or concrete tanks (which can be partially buried if necessary). In both cases, the tanks are insulated. In most installations, the temperature supplied to the storage is the supply temperature from the district heating network. Temperature stratification—having distinct layers of water at different temperatures within the storage tank rather than a uniform temperature throughout—can be achieved through multiple inlets, improving storage performance. Figure 10 illustrates the principles of TTES.

Figure 10. Principles of a Tank Thermal Energy Storage



No physical separation exists between the storage tank’s warm and cold water. Instead, the separation is handled by the difference in density between warm and cold water. The separation layer between the supply and return temperatures should be kept as thin as possible, typically within 6 feet (ft) to 8 ft. To maintain this layer and avoid disturbances, the inlet and outlet velocities are kept low, and diffusers are placed at both the top and bottom of the tank. A tall, slim tank design is preferred since it limits the unusable volume in the separation layer.

To prevent corrosion in a steel tank, steam is sometimes introduced into the space between the water level and the tank structure. However, nitrogen is more commonly used than steam, produced from a small nearby nitrogen generator. Tanks may sometimes be slightly pressurized, but this increases construction costs. In most low-temperature heating systems, the water temperature does not exceed 212°F, meaning the tank is unpressurized. In the example provided, the supply temperature is 203°F, and the return temperature is 104°F.

An unpressurized storage tank helps to maintain minimum static pressure for a district heating network in case of pump failure. Therefore, the team recommends that the water level in the tank always remains above the highest point in the district heating system. If the water level falls below this point, the systems must be separated, complicating the installation and increasing the risk of failure.

Figure 11 illustrates the basic structure for connecting the heat storage tank to the district heating system as a pressure-holding vessel. Including the heat storage tank in the system means the instantaneous heat demand from consumers does not need to match the heating plant output. Instead, the storage component provides operational flexibility, helping achieve energy cost and greenhouse gas emission savings.

Figure 11. Connection of a Tank Thermal Energy Storage: Heat Storage

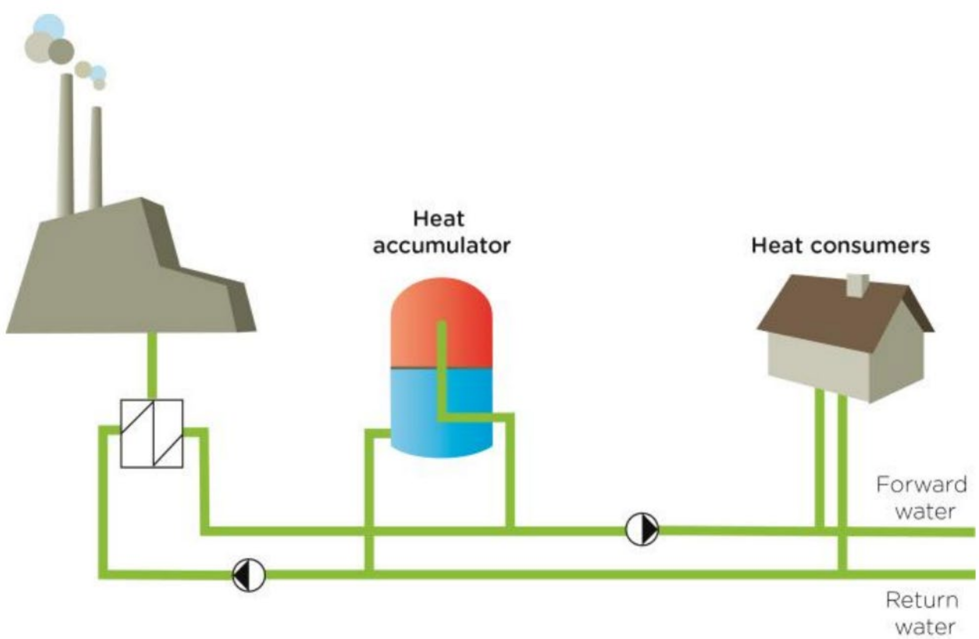
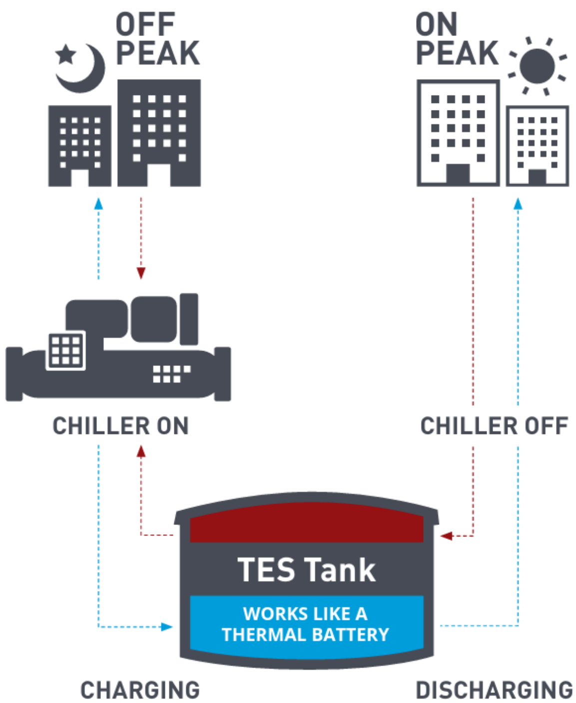


Figure 12 illustrates the process of producing thermal energy (in this case, chilled water) during periods of off-peak electrical demand. The thermal energy is collected in a storage tank and then withdrawn and distributed to the facility during peak periods.

Figure 12. Connection of a Tank Thermal Energy Storage: Cooling Storage

Source: DN Tanks, How TES Works,. DN Tanks Thermal Energy Storage Tanks Brochure.



3.6 Smaller Quantitative and Qualitative Analyses

3.6.1 Domestic Hot Water Generation in Summer

During discussions with campus staff, the question arose about how to generate DHW in the summer for a centralized hot water system. The team assessed two options:

1. Local production at the building level through an electric boiler or ASHP
2. Central production through ASHP and distribution through a campuswide system

3.6.1.1 Electric Boiler or Air-Source Heat Pump

The team conducted the first comparative analysis between local electric boilers and ASHPs for DHW production for a specific building, MacDuff Hall. The study considered both OPEX and CAPEX. The main estimates are shown in Tables 4 and 5.

Table 4. Cost Analysis of Air-Source Heat Pump for Domestic Hot Water Preparation in MacDuff Hall

Component	Capacity (MBH)	CAPEX[a] (USD)	Lifetime (Years)	Annual CAPEX (USD per Year)	OPEX
Nominal capacity of 1 ASHP	329	—	—	—	—
Nominal COP	3.6	—	—	—	—
Design day COP	2.18	—	—	—	—
Output capacity of 1 ASHP	199	—	—	—	—
Total output capacity (2 units)	398	—	—	—	—
Component Breakdown	—	—	—	—	—
ASHP Equipment (2x)	—	235,000	18	19,326	—
Roof Mats	—	624	50	32	—
Membrane Roofing	—	19,900	30	1,222	—
Ductwork Support	—	46,000	50	2,328	—
Instrumentation and Control	—	13,500	18	1,110	—
Tanks (2x 250 gal)	—	3,120	20	240	—
Subtotal	—	**318,144**	—	**24,257**	—
Design Contingency (5%)	—	15,907	—	1,213	—
Markup (40%)	—	133,620	—	10,188	—
Total (with contingency & markups)	—	**467,672**	—	**35,657**	—
OPEX	—	—	—	—	—
Daily DHW Demand	—	—	—	—	9,510 (kBtu per day)
Average COP	—	—	—	—	3
Electricity Use	—	—	—	—	0.93 (MWh per day)
Full Load Days	—	—	—	—	243
Yearly Electricity Use	—	—	—	—	226 (MWh)
Yearly Cost of Electricity	—	—	—	—	13,572 (USD per year)
OPEX + Annual CAPEX	—	—	—	—	**49,230 (USD per year)**

[a] CAPEX values are based on cost information from the Dormitory Authority of the State of New York (DASNY), "*Renovation to MacDuff Hall, State University of New York at Oneonta*", DASNY Project #368190 (2022).

Table 5. Cost Analysis of Electric Boiler for Domestic Hot Water Preparation in MacDuff Hall

Component	Capacity (MBH)	Capacity (kW)	CAPEX[a] (USD)	Lifetime (Years)	Annual CAPEX (USD per Year)	OPEX
Assumed output capacity	398	117	—	—	—	—
Component Breakdown	—	—	—	—	—	—
DHW electric heater + tank	—	—	53,000	25	3,574	—
Instrumentation and Control	—	—	13,500	18	1110	—
Subtotal	—	—	66,500		4,684	—
Design Contingency (5%)	—	—	3,325		234	—
Markup (40%)	—	—	27,930		1,967	—
Total (with contingency & markups)	—	—	97,755		6,886	—
OPEX	—	—	—	—	—	
Daily DHW Demand	—	—	—	—	—	9,510 (kBtu per day)
Average COP	—	—	—	—	—	1
Electricity Use	—	—	—	—	—	2.79 (MWh per day)
Full Load Days	—	—	—	—	—	243
Yearly Electricity Use	—	—	—	—	—	679 (MWh)
Yearly Cost of Electricity	—	—	—	—	—	40,717 (USD per year)
OPEX + Annual CAPEX	—	—	—	—	—	47,603 (USD per year)

[a] CAPEX estimates were developed using RSMeans CostWorks 2022 cost data.

Given the similar values for OPEX + annualized CAPEX between the two solutions, they can be considered economically equivalent. However, the following section discusses additional considerations.

3.6.1.2 Decentralized Domestic Hot Water Production or Centralized Production

Another comparative analysis examined decentralized DHW production at each building using electric boilers with centralized production through an ASHP. The evaluation for the centralized scenario considered only the OPEX for electricity, excluding CAPEX, since the team assumed the ASHP and distribution system would already be installed for space heating during winter. For the decentralized scenario, only the OPEX of local electric boilers was considered due to the minimal impact of annualized CAPEX on overall costs.

The analysis used the following assumptions:

- Summer DHW for buildings on the low-temperature hot water (LTHW) loop: 8,713 MMBtu per year
- Conservative heat loss coefficient for the LTHW loop: 3,657 watts per kelvin (W/K)
- Summer season: May 30 through October 1
- Network temperatures: 150°F (supply) /122°F (return)
- Heat losses from the LTHW loop in summer: 1,856 MMBtu
- Network heat load in summer: 1856 + 8713 = 10,569 MMBtu

The team evaluated the electricity consumption in the two scenarios as follows:

- Central ASHP (COP = 3.6): 861 MWh
- Local electric boiler (COP = 1): 3,100 MWh

The team concluded that central DHW production during summer is more cost-effective than local production. This approach was applied to all centralized scenarios. Additionally, the analysis considered the savings from shutting down steam and MTHW systems in summer against the investments in local DHW heaters.

3.7 Cooling Strategy Assessment

The analysis considered three cooling approaches:

1. Individual cooling supply for each building
2. A clustered approach where several buildings share cooling production units
3. A centralized cooling approach

The first approach was deemed suitable only if a few buildings required cooling because low cooling density increases costs, resulting in higher specific investment costs for a chilled water system. A more centralized approach would balance borehole use during the summer and reduce costs associated with capturing excess heat from cooling. Discussions with the campus staff determined that most buildings would eventually require cooling, enabling higher energy density. Consequently, a centralized cooling approach was adopted, detailed in Section 5.1.2.

3.8 Discussions of 4-Pipe versus 2-Pipe System

District energy systems are often characterized by system generation, whether a 4G system for heating and cooling (4GDHC) or an ambient system using energy close to ambient temperatures with decentralized heat pumps, supplying heating and cooling through the same network. In contrast, 4GDHC systems can use either 2-pipe or 4-pipe configurations:

- **2-pipe system:** Provides heating in winter and switches to cooling at a specific date. The main benefit of this system is that buildings that receive heating can also receive cooling. This setup avoids the additional cost of chilled water pipes but cannot produce heating and cooling simultaneously. Additionally, forecasting the mode switch is challenging, and DHW must rely on local water heaters in summer.
- **4-pipe system**: Two sets of pipes are installed, one set for heating (supply and return) and the other set for cooling (supply and return). The two networks can be operated independent of each other. Aa 4-pipe network benefits from the diversity of thermal demands by enabling heat recovery. It can repurpose waste heat from cooling to meet simultaneous heating needs across different buildings, making it highly suited for thermal networks with complementary heating and cooling profiles. For economic reasons, the cooling network may not extend to all the buildings served by the heating network; cooling could also be provided through a combination of areas served by networked cooling and the remainder by stand-alone cooling systems.

SUNY Oneonta preferred the flexibility of a 4-pipe system, especially during spring and fall when heating and cooling needs fluctuate. Therefore, the 4-pipe configuration was assumed for 4G centralized scenarios.

3.9 Scenarios for Techno-Economic Modeling and Analysis

Based on the technology screening process and discussions with the campus staff, the scenarios outlined in Table 6 and Table 7 presents the final scenarios selected for techno-economic modeling and analysis.

Table 6 summarizes the preliminary scenario descriptions developed for the analysis. These scenarios represent different campus energy system configurations and technology combinations considered for further evaluation, including variations in heat pump applications, distribution approaches, and supporting infrastructure.

Table 6. Scenario Descriptions

Scenario	Description
BAU	• Maintain business as usual
1	• Use a centralized 4-pipe heating and cooling network with a centralized energy center using GSHP and ASHP technologies for comfort heating, cooling, and DHW. • The ASHP or GSHP supplies the baseload, depending on ambient temperature. The ASHP operates at higher ambient temperatures during the summer and shoulder seasons for cost efficiency while reducing its capacity during winter to limit borehole requirements. • During summer, the ASHP recovers usable heat from cooling to provide DHW (functioning as a heat recovery chiller) and balances the borefield. • Scenario variant 1a uses electric boilers for peaking, while Scenario variant 1b uses natural gas boilers. Both variants include TTES to balance energy demand, supply, and costs. • Emergency backup uses natural gas or fuel oil.
2	• Use a centralized 4-pipe heating and cooling network with a centralized energy center that uses a cascading system approach. Combine an ASHP with an in-line WWHP to provide comfortable heating, cooling, and DHW. • Operate the ASHP as a heat recovery chiller (same machine as ASHP) during summer months. • Use an electric boiler for peaking and include TTES to balance energy demand, supply, and costs. • Provide backup fuel, which is natural gas or oil.
4	• Configure individual building heat pumps with a centralized borehole field as the heat source. Equip each building with two WWHPs, each sized at 60% of the load to cover the baseload and peaking. • Provide backup power for the heat pumps with building-level emergency generators.

Table 7 presents the final scenarios selected for techno-economic modeling and analysis. These scenarios build on the preliminary screening summarized in Table 6 and define the specific system configurations evaluated for technical performance, emissions reduction potential, and life-cycle economic impact.

Table 7. Final Scenarios for Techno-Economic Modeling and Analysis

Parameter[a]	BAU	1a & 1b	2	4
Demand	Future	Future	Future	Future
Heat network configuration	Current	Centralized	Centralized	Ambient loop
Baseload technology	NG (and fuel oil)	GS + AS HP (+ HRC in summer)	ASHP + WWHP (+ HRC in summer)	Individual WWHPs (BH balancing by ASHP)
Peaking Technology	NG (and fuel oil)	(1) Electric (2) NG	Electric	Individual WWHPs
Summer, DHW	Centralized and Local	Centralized	Centralized	Local
Winter, DHW	Centralized and Local	Centralized	Centralized	Local
Space cooling	Local Cooling	Centralized	Centralized	Individual HPs
BTES Balancing	N/A	GSHP cooling	N/A	Heat from cooling from building-level w-/w HP
TTES	No	Yes	Yes	Local, building level
Backup heat (Emergency)	NG	NG	NG	60% x2 HP + building level emergency generators
Network	1G	4G (4-pipe: heating and cooling)	4G (4-pipe: heating and cooling)	Ambient loop

[a] This analysis assumes sufficient natural gas is available to meet the peak demand in scenarios that include it. However, because Oneonta is in a gas-constrained area, SUNY Oneonta, an interruptible gas consumer, may face disconnection during periods of limited gas availability in the gas network. In such cases, fuel oil would replace natural gas.

Given the campus's greater heat demand than its cooling demand, Scenarios 1a and 1b propose combining production from centralized GSHP with centralized ASHP. This approach reduces the need for borehole balancing and minimizes the number of boreholes. The heat pump units remain the same but operate using air (through air coolers) or ground (through boreholes) as the heat source.

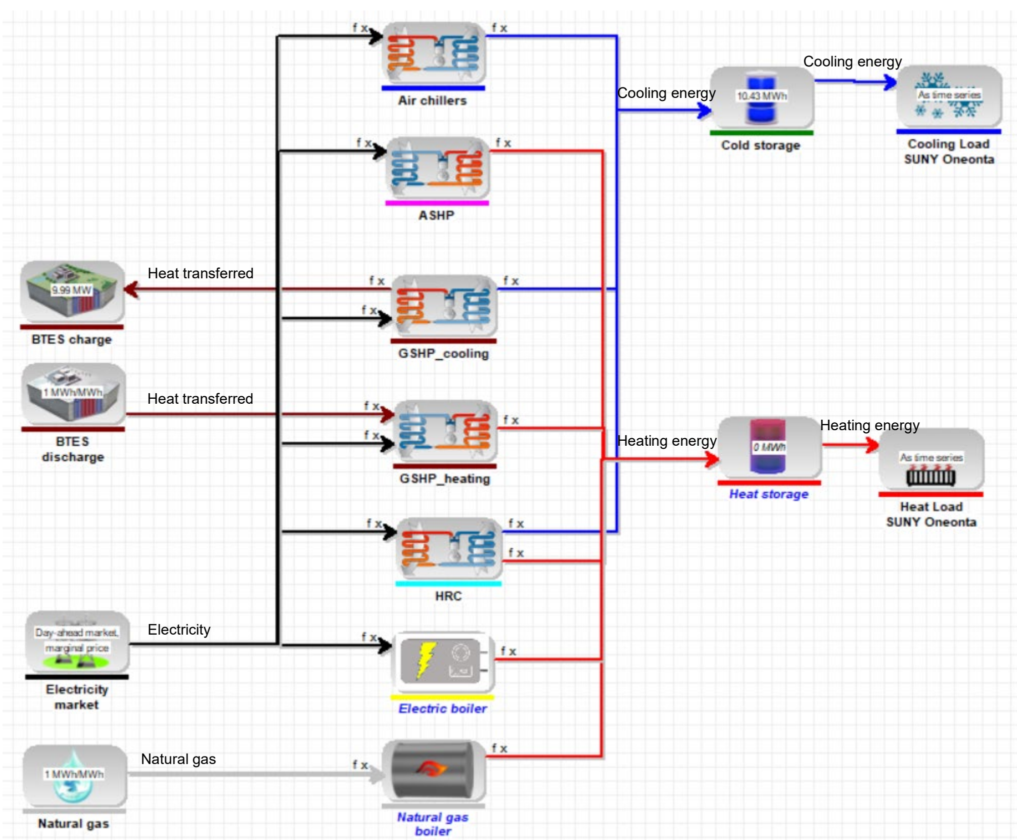
4 Analytical Methods

The section summarizes the analytical methods and modeling used for the techno-economic assessment. While this study did not include the installation of a specific exploratory ground borehole, UE relied on the results from a 500-ft geothermal test bore and thermal response test conducted in 2019 for the SUNY Oneonta Alumni Center. The results informed the geothermal assessment report.

4.1 EnergyPRO

Conducting a techno-economic assessment of the proposed alternative scenarios involved using EnergyPRO, a modeling software designed to optimize the operation of energy systems with multiple production units by minimizing operating costs. The model incorporates financial aspects such as fuel prices, investment costs, operation and maintenance (O&M) costs, and environmental costs. For example, Figure 13 illustrates the EnergyPRO model for Scenario 1. The model for Scenario 2 was derived from the Scenario 1 model by deactivating the GSHP components. Additionally, a separate model was developed to analyze the ambient loop scenario.

Figure 13. EnergyPRO Model for SUNY Oneonta (Scenarios 1 and 2)



EnergyPRO uses different color-coded lines to represent energy flows in the system. The energy flows are also marked on the diagram:

- Red: Heating energy
- Blue: Cooling energy
- Black: Electricity
- Maroon: Heating energy at a low temperature
- Grey: Natural gas[2]

The right side of the EnergyPRO diagram includes the cooling load and heat load blocks, which represent energy demands to be met. The left side lists the energy sources, such as electricity, gas, and geothermal energy.

Aligned vertically in the center of the diagram, the production units connect the energy sources to the energy demand. Between production units and the loads, short-term thermal energy storage tanks buffer between energy supply and energy demand. Thermal storage allows the system to operate at full capacity and take advantage of lower electricity prices on the market when the electric-drive machines can run at full capacity to meet demand and charge the storage tanks. When electricity price increases, stored energy discharges to meet demand, reducing output from energy-production-and-conversion units.

In Scenario 1, the heat pump units (ASHP, GSHP, heat recovery chiller [HRC], and air chillers) share compressors but operate with different heat sources and sinks. EnergyPRO optimizes the operation of production units to meetheating and cooling demands are met at the lowest annual operating cost.

Each technology in the model is linked to an operating efficiency and a cost per unit of energy input (natural gas or electricity) for every hour of the year. This approach enables the program to determine each production unit's sequencing accurately. The model also evaluates outdoor air temperatures and their effects on the system load and production unit efficiency.

Units with the lowest marginal production cost activate first. If additional capacity is required to meet demand, units with progressively higher marginal production costs come into operation.

The optimization process in EnergyPRO incorporates optimal utilization of the energy storage systems and accounts for technical constraints, including unavailability periods and minimum operating duration. Section 5.2.1 presents the results from the EnergyPRO calculations.

4.2 TERMIS

TERMIS software by Schneider Electric provides hydraulic modeling to simulate flow, pressure, and thermal behavior in a distribution piping network. Ramboll used TERMIS to size and model the proposed low-temperature hot water and chilled water distribution networks on the campus.

The software facilitated evaluating cost-effective piping arrangements and pipe sizing under various conditions. It also helped estimate system pressure losses during peak conditions, enabling more accurate sizing of distribution pumps at the Central Energy Plant and supporting the assessment of electricity consumption for pumping.

Friction in the central circulation pumps, which slightly increases supply temperatures at full load, was not considered. These circulation pumps operate at full load only a few hours per year, making the temperature increase negligible. Consequently, the required temperature lift for the main heat pumps is slightly reduced, resulting in lower electricity consumption.

4.3 ArcGIS

ArcGIS provided visualization for building demand data. Figure 14 illustrates an example of ArcGIS output, showing heat demand per building by color coding. The distribution network layout is also displayed for reference.

Figure 14. Heat Mapping of SUNY Oneonta in ArcGIS

4.4 Excel Cash-Flow Modeling

The techno-economic analysis compares scenarios and identifies the most cost-efficient mix of technologies for providing future heating and cooling. This process informs major capital decisions, such as installing building-level heat pumps or pursuing a more centralized solution.

Significant uncertainties exist in cash-flow cost components. CAPEX estimates adhere to the Association for the Advancement of Cost Engineering (AACE) Class 4 "Association for the Advancement of Cost Engineering." These estimates include a lower uncertainty range of -15% to -30% and a higher range of + 20% to + 50%. Ramboll conducted a sensitivity analysis (detailed Section 5.2.6), by varying key inputs—gas prices, electricity prices, and CAPEX—to evaluate their impact on the net present value (NPV).

Energy prices, known for their extreme volatility, are excluded from price indices such as the Consumer Price Index (CPI) and the core Personal Consumption Expenditures (PCE) price index, which tracks price trends over time. Volatility in energy prices can result in substantial confidence bands. For example, comparing the New York Mercantile Exchange (NYMEX) 95% confidence intervals for Henry Hub natural gas price forecasts between October 2023 and December 2024 reveal an average lower confidence bound at 51% of the forecast and an average upper confidence bound at 226%.[3]

For this study, analysts escalated energy prices at the inflation rate to provide a stable basis for comparison and mitigate the effects of energy price volatility.

EnergyPRO and TERMIS modeling outputs serve as inputs to the Excel cash-flow model. The model incorporates technical and economic inputs and outputs an economic lifetime of 25 years. The following costs are estimated in the model:

- Fuel costs (electricity, natural gas, and oil)
- O&M costs
- CAPEX
- Emission costs

4.4.1 Estimation of CAPEX

Ramboll completed cost estimates using key unit-based cost metrics from Trophy Point Construction Services & Consulting (Trophy Point) to complete cost estimates. Trophy Point developed these metrics as a third-party estimating firm working with Ramboll and other consultants during the 2022–2023 development of SUNY CEMPs. The cost estimates account for raw labor, material, and the following markups, consistent with SUNY CEMPs:

- General conditions: 15%
- OH&P: 10%
- Design contingency: 20%
- Bid contingency: 5%
- Phasing: 10%

4.4.2 Residual Value of CAPEX

The model attributes residual value to capital expenditure assets with a technical lifetime exceeding the 20-year project period. This approach aligns costs to the project's conclusion, treating the residual value as a fictitious revenue (incoming cash flow) at the end of the project period. Residual value assumes linear depreciation of the asset's original CAPEX over its technical lifetime. For example, an asset with a technical lifetime of 30 years and a CAPEX of $3,000,000, installed in the project's first year, retains a residual value equal to $1,000,000 (one-third of the original CAPEX) at the project's end.

Assets with technical lifetimes ending before 20 years require additional investments for replacement or major overhauls. These replacement costs and their associated residual values are included in the cash-flow analysis.

4.4.3 Modeling: Cash Flow and Net Present Value

The cash-flow model integrates operating costs from EnergyPRO simulations, Excel calculations, and CAPEX estimates to evaluate scenarios over 25 years. The NPV method, combined with asset residual values, enables equitable comparisons of scenarios regardless of asset technical lifetimes.

The cash-flow model aims to evaluate each scenario's long-term economic and environmental performance by assigning an NPV of the overall costs over the project period to each scenario. The model simplifies the analysis by neglecting aspects such as project phasing and assuming energy system assets are installed and their CAPEX are fully paid in the first year of the 25-year project period.

Cash flows are expressed in the actual 2022 U.S. dollars (USD) value throughout the project period. This approach assumes cost components increase at the same rate as inflation, except for the social cost of carbon, which is calculated based on New York State guidelines.[4] Social cost values in 2020 USD are inflated by 14% to convert them to 2022 USD.

Using absolute currency values, the O&M cost of a production unit remains consistent in the cash-flow model for all years. For example, the nominal dollar amount paid in 2050 reflects the same purchasing power as that paid in 2030. Prices expected to change at rates different from the inflation rate are indexed to express them in 2022 USD.

5 Results: System Design and Impact

5.1 Hydraulic Modeling

The following sections summarize the hydraulic modeling activities completed to assess the potential to reuse existing MTHW piping and identify new heating and cooling distribution networks.

5.1.1 Low-Temperature Hot Water Distribution

The team used the following inputs to generate the model of the low-temperature hot water distribution network:

- Temperature difference between supply and return at peak load conditions: 25°F
- Minimum pressure difference at each building:7.25 pounds per square inch (psi)
- Sizing criteria: The more stringent criterion between:
    - Maximum pressure gradient for new pipes: 0.0066 psi per ft
    - Maximum pressure gradient for existing pipes: 0.0088 psi per ft
    - Maximum flow velocity: 8.2 ft per second; lower maximum velocities at smaller diameters)

Figure 15 illustrates the proposed low-temperature hot water piping system, which follows the existing steam and hot water system route as closely as possible.

Figure 15. Low-Temperature Hot Water Distribution Network in TERMIS

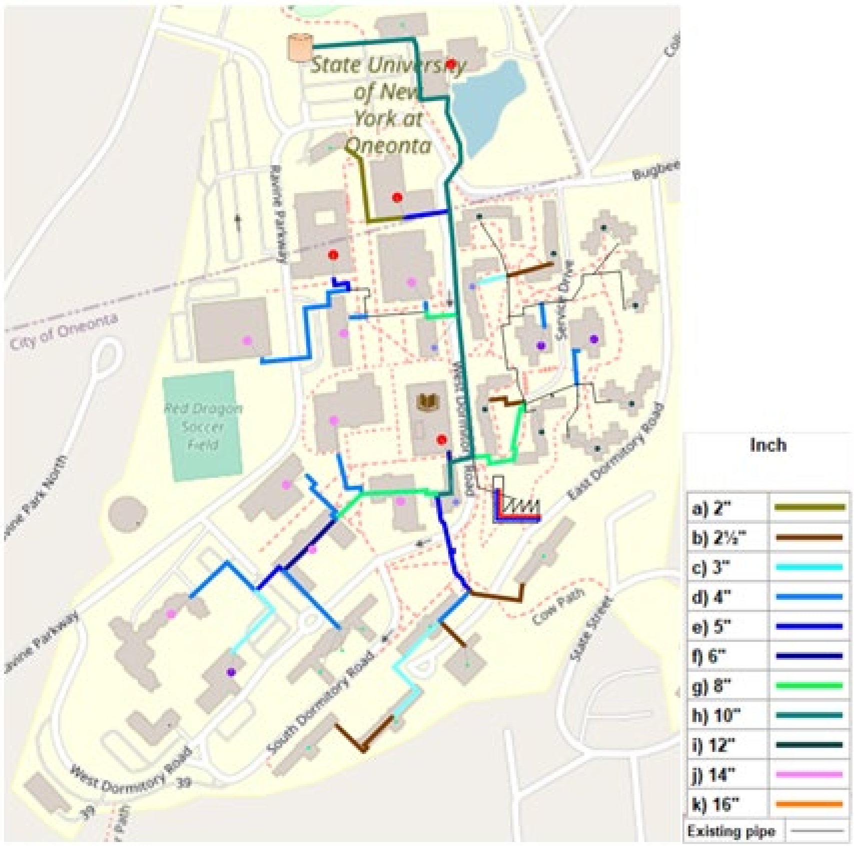


Figure 15 identifies a new energy center on the opposite side of West Dormitory Road from the existing heating plant. However, after further discussions with SUNY Oneonta staff, the space could accommodate new heat pump equipment if the new energy center extends the heating plant. Air coolers for the ASHP would still be located on the east side of West Dormitory Road.

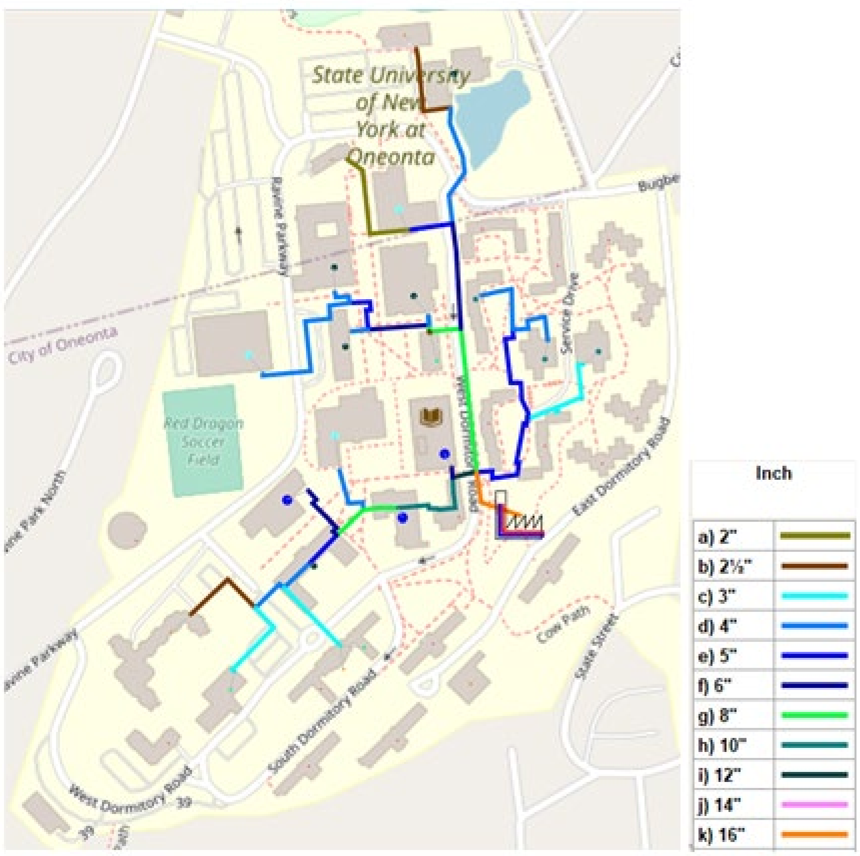
Given the elevation differences across the campus from the northern part to the proposed location for the new energy center, the tank storage should be located in the north end, as indicated in Figure 15. This placement maintains the tank water level above the highest point on campus. The distribution pipe following the central spline on the campus considers carrying the load to and from the tank.

5.1.2 Chilled Water Distribution

As noted in Section 2.1.2, several buildings are currently cooled. Given the expected increase in cooling needs, the proximity of the buildings, and the achievable benefit from coproducing cooling and heating, Ramboll and SUNY Oneonta agreed that centralized cooling is a practical option. Figure 16 illustrates the path of the proposed chilled water piping system. The team used the following inputs to develop the chilled water distribution network:

- Temperature difference between supply and return at peak load conditions: 10°F
- Minimum pressure difference at each building: 7.25 psi
- Sizing criteria: The more stringent criterion between:
  - Maximum pressure gradient for new pipes: 0.0133 psi per ft
  - Maximum flow velocity: 9.8 ft per second (lower maximum velocities at smaller diameters)

Figure 16. Chilled Water Distribution Network in TERMIS



5.1.3 Ambient Loop

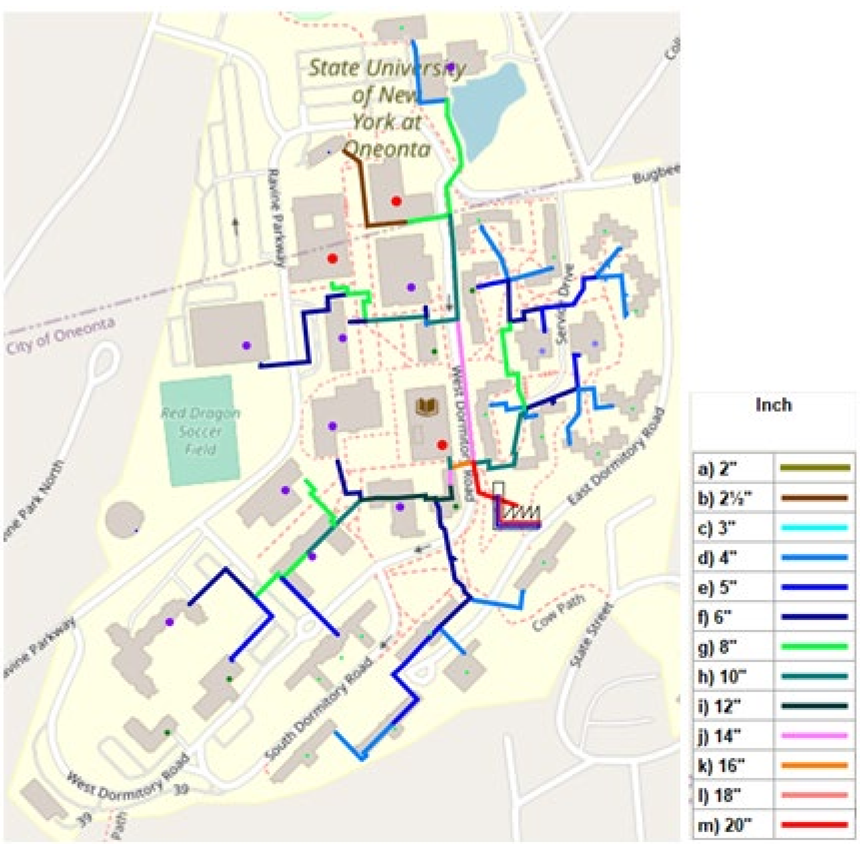
The ambient loop uses a 2-pipe system as a heat sink, and source for decentralized building-level heat pumps that provide heating and cooling to each building. To size the ambient loop, the end-user thermal demands were converted into thermal demands on the network side based on the heat pump's conversion efficiency in heating and cooling mode.

In TERMIS, two ambient loop networks are preliminarily sized: one for peak heating load and another for peak cooling load. The team used the following inputs for sizing:

- Temperature difference between the two pipes (both heating and cooling): 7°F
- Minimum pressure difference at each building: 7.25 psi
- Sizing criteria: The more stringent criterion between:
  - Maximum pressure gradient for new pipes: 0.0066 psi per ft
  - Maximum flow velocity: 9.8 ft per s (lower maximum velocities at smaller diameters)

The larger diameter is used for the final network sizing. Figure 17 illustrates the proposed ambient loop piping system where the two networks overlap.

Figure 17. Ambient Loop Distribution Network in TERMIS



Based on discussions with the campus, Ramboll included two local heat pumps per building, each with 60% capacity and building-level emergency generators. The heat source for the heat pumps will be the ambient loop.

Existing emergency generators in the buildings are not expected to have adequate capacity to operate local heat pumps. Therefore, the generators need upgrades or replacements. The economic evaluation does not include CAPEX for upgrading or installing new emergency generators.

Since the campus is located in a natural gas–constrained area and is used for interruptible service, emergency natural gas is not currently viable without further discussion with NYSEG. Therefore, diesel is assumed as an emergency backup fuel for the generators.

5.2 Techno-Economic Analysis

5.2.1 Technical Results

Figure 18 and Figure 19 show the annual heating and cooling production from the leading technologies in the various scenarios based on outputs from EnergyPRO. Although the end-user heat demand is the same across all scenarios (107,400 MMBtu per year, or 31,485 MWh-heat), the total heat production varies by scenario due to differences in heat losses from the various distribution network (steam, MTHW, low-temperature hot water, and ambient loop). Consequently, the BAU scenario exhibits higher thermal production due to higher steam and MTHW network losses. Scenarios 1 and 2 use low-temperature distribution networks, which result in lower thermal losses and, consequently, lower thermal production. The team assumed the ambient loop operates loss-free due to its low temperature.

Figure 18. Annual Heating Production by Production Unit

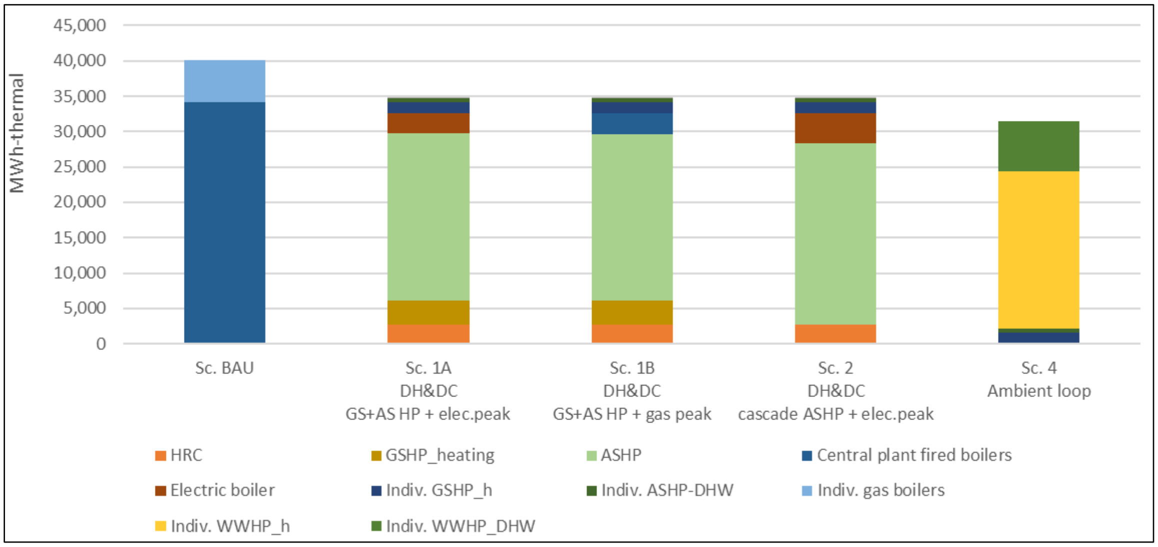
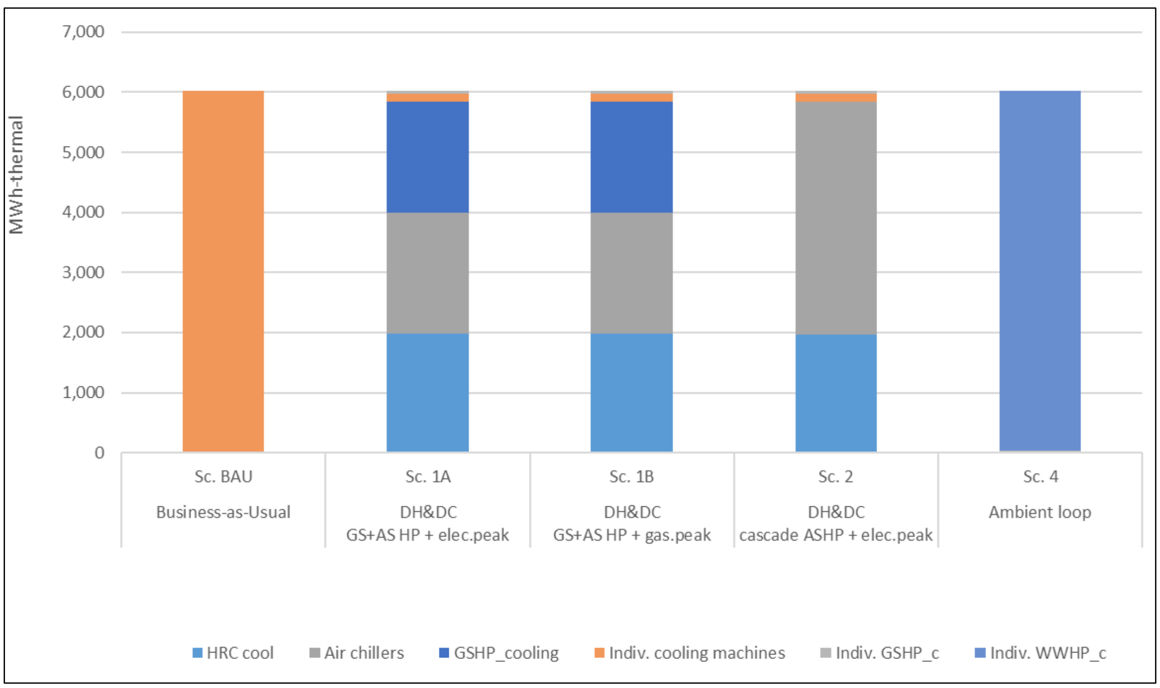


Figure 19. Annual Cooling Production by Production Unit



5.2.2 Environmental Results

Table 8 shows the yearly carbon emissions across various scenarios. The SUNY Oneonta team assumes access to renewable or carbon-free electricity by 2030, and the project period spans from 2030 to 2054.

As a result, electricity consumption generates no carbon emissions. Therefore, Table 8 lists emissions only for scenarios that use fossil fuels.

Table 8. Yearly Emissions of Carbon Dioxide Equivalent in the Various Scenarios

Scenario	Annual Emission (MT per year)	Reduction vs. BAU
BAU	8,386	—
1a	0	100%
1b	616	92.7%
2	0	100%
4	0	100%

5.2.3 Economic Results: Energy Costs

Table 9 summarizes each production unit's annual energy and carbon costs (expressed in 2022 USD) for each production unit across various scenarios. All scenarios exhibit similar energy costs, ranging from approximately $2.1 million to $2.3 million USD annually. However, social costs associated with carbon emissions vary significantly. The BAU scenario, which relies primarily on natural gas and partially fuel oil for heat production, incurs the highest social costs. Fully electrified scenarios have the lowest social costs, registering as null. In contrast, Scenario 1b, which uses natural gas for peaking, incurs social costs of approximately $110,000 USD per year, less than 10% of the carbon costs in the BAU scenario.

Because the actual value (in 2022 USD) of the social cost of carbon increases slightly over time based on NYS guidelines, the table shows the average value over the project period.

Table 9. Yearly Energy Costs in the Various Scenarios

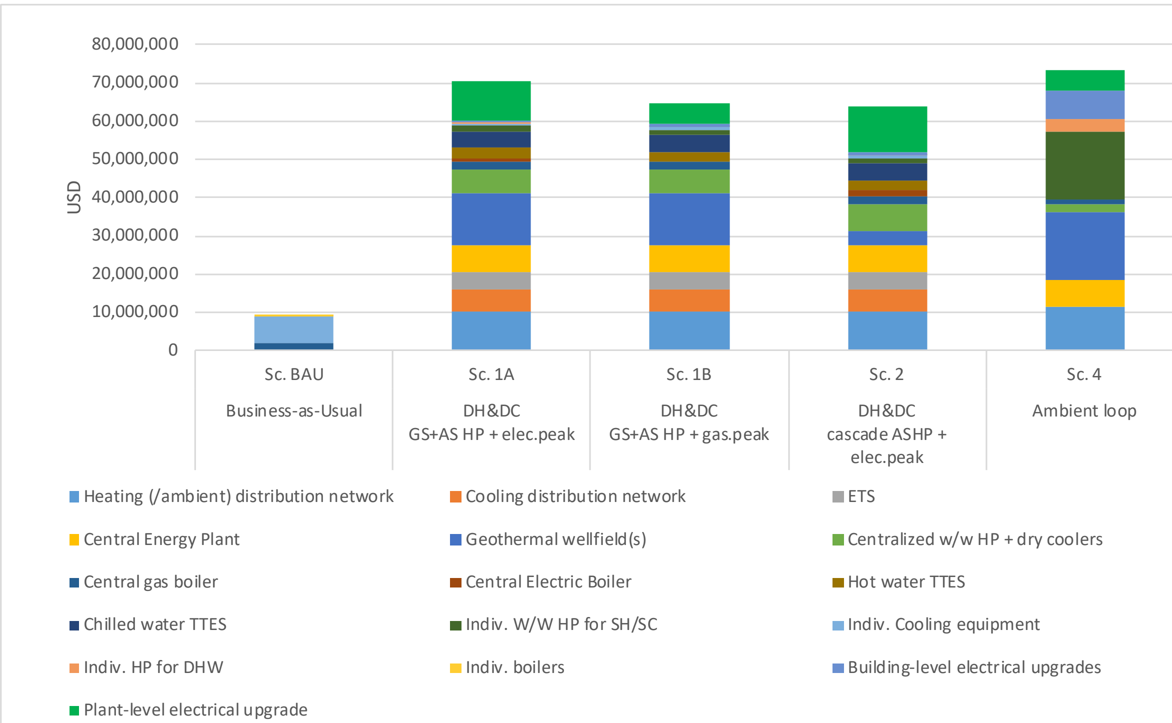
	Scenario				
Cost Categories[a]	**BAU**	**1a**	**1b**	**2**	**4**
HRC	$0	$39,204	$39,204	$39,392	$0
Air chillers	$0	$21,988	$21,988	$46,499	$29,791
GSHP-H	$0	$56,863	$56,863	$0	$0
GSHP-C	$0	$22,424	$22,424	$0	$0
ASHP	$0	$501,292	$491,726	$544,512	$156,200
NG boiler	$0	$0	$58,428	$0	$0
Electric boiler	$0	$146,785	$0	$222,916	$0
Current NG boiler	$609,741	$0	$0	$0	$0
Current fuel oil boiler	$142,673	$0	$0	$0	$0
Indiv. GSHP–H	$0	$29,214	$29,214	$29,214	$29,214
Indiv. ASHP–DHW	$0	$13,583	$13,583	$13,583	$13,583
Indiv. gas boilers	$124,961	$0	$0	$0	$0
Indiv. cooling machines	$118,100	$2,741	$2,741	$2,741	$0
Indiv. GSHP–C	$0	$453	$453	$453	$0
Indiv. WWHP–H	$0	$0	$0	$0	$427,338
Indiv. WWHP–C	$0	$0	$0	$0	$54,165
Indiv. WWHP–DHW	$0	$0	$0	$0	$112,311
Pumping electricity for distribution	$20,154	$32,520	$32,520	$32,520	$63,699
Electricity for other uses than heating and cooling	$1,297,221	$1,297,221	$1,297,221	$1,297,221	$1,297,221
Total	**$2,312,850**	**$2,164,288**	**$2,066,365**	**$2,229,051**	**$2,183,522**
Social costs of carbon	$1,512,870	$0	$111,128	$0	$0

[a] Cost is given in 2022 USD.

5.2.4 Economic Results: Capital Expenditures

Figure 20 shows the CAPEX for the BAU and alternative scenarios over the 25-year project period, broken down by components (markups included). As expected, CAPEX in the BAU scenario is low, whereas the alternative scenarios are more CAPEX-intensive. Scenario 4 is the most CAPEX intensive, with approximately $73.2 million in overall investments (including markups).

Figure 20. Capital Expenditures over Project Period in the Various Scenarios



For Scenario 1, comparing the electric peaking variant (1a) with the natural gas peaking variant (1b) provides insight into the CAPEX impact of covering 100% of the annual heating load through electrification technologies. Existing natural gas boilers will remain even in variants with electric boilers, serving as backup during extended power outages. In the gas peaking Scenario 1b, the same gas boilers will also be used as peaking and backup units.

Scenario 4, the decentralized scenario, has the largest CAPEX due to the many decentralized heat pumps and a higher number of boreholes compared to the centralized scenario with GSHP (Scenarios 1a and 1b). Scenarios 1a, 2, and 4 would require upgrades to the NYSEG electrical service feed to campus and campus substation upgrades. Those costs have not been captured in this study and will require subsequent investigation by NYSEG.

5.2.5 Economic Results: Net Present Value

Table 10 provides an overview of the economic performance of the various scenarios, showing the NPV of costs over the project lifetime.

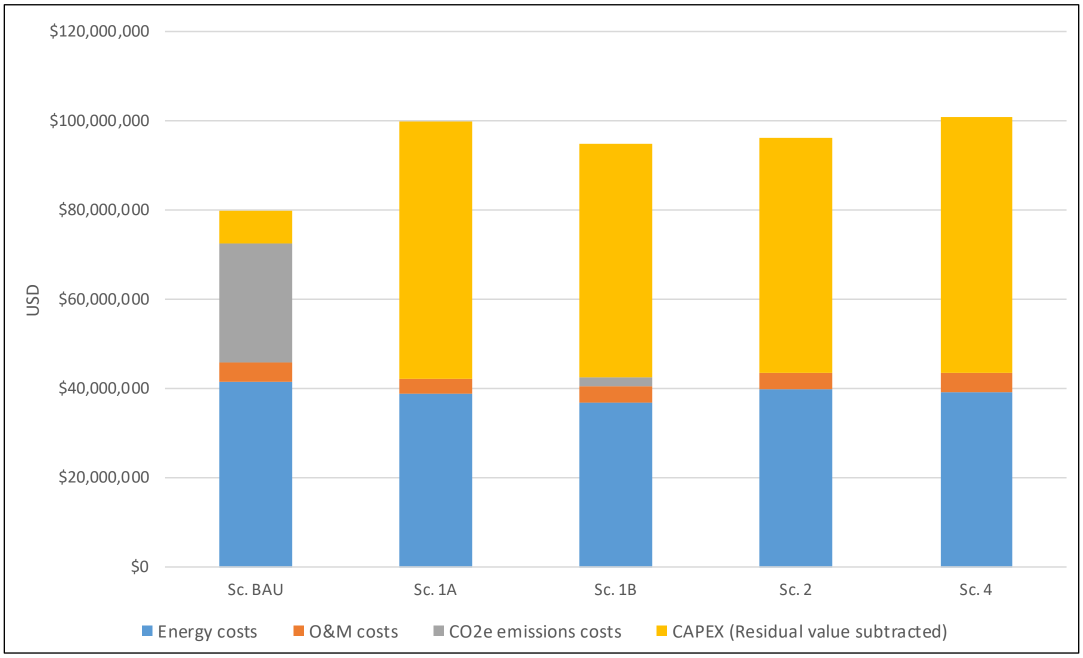
Table 10. Net Present Value of Costs over Project Lifetime by Macro Component

Cost Categories[a]	Scenario				
	BAU	1a	1b	2	4
OPEX - Energy costs	$41,482,218	$38,817,685	$37,061,383	$39,979,245	$39,162,644
Centralized assets	$13,856,422	$14,726,442	$12,970,140	$15,888,001	$4,478,329
Decentralized assets	$4,359,427	$824,874	$824,874	$824,874	$11,417,945
Electricity for other uses than heat per cooling generation	$23,266,369	$23,266,369	$23,266,369	$23,266,369	$23,266,369
OPEX - O&M costs	$4,324,381	$3,558,142	$3,446,206	$3,567,973	$4,534,510
Centralized assets	$2,479,494	$3,304,351	$3,192,415	$3,314,182	$1,700,017
Decentralized assets	$1,844,887	$253,791	$253,791	$253,791	$2,834,493
CAPEX	$9,439,528	$70,634,393	$64,495,084	$63,811,019	$73,172,223
Centralized assets	$2,121,481	$63,242,806	$57,103,497	$56,419,432	$44,548,448
Decentralized assets	$7,318,048	$7,391,587	$7,391,587	$7,391,587	$28,623,774
CAPEX + OPEX	$55,246,127	$113,010,221	$105,002,673	$107,358,236	$116,869,376
Residual value of CAPEX	-$1,773,066	-$13,167,280	-$11,894,402	-$11,074,493	-$15,956,897
CAPEX + OPEX + Res. value	$53,473,062	$99,842,940	$93,108,271	$96,283,743	$100,912,479
Social cost of carbon	$26,663,944	$0	$1,958,606	$0	$0
CAPEX + OPEX + Res. value + Carbon cost	$80,137,005	$99,842,940	$95,066,878	$96,283,743	$100,912,479

[a] Cost is given in 2022 USD.

The BAU scenario has the lowest NPV of costs, even when factoring in the social costs of carbon. This is due to the very low CAPEX requirements and the relatively low cost of natural gas. Among the alternative scenarios, Scenario 2 has the lowest overall costs, approximately 10% lower than the most expensive Scenario 4, representing the ambient loop scenario. Importantly, emergency generators are not included in the cost estimates (see Section 5.2.8). Including the cost of emergency generators would increase the total costs in the ambient scenario compared to the other scenarios.

Figure 21. Net Present Value of Costs over Project Lifetime by Macro Component

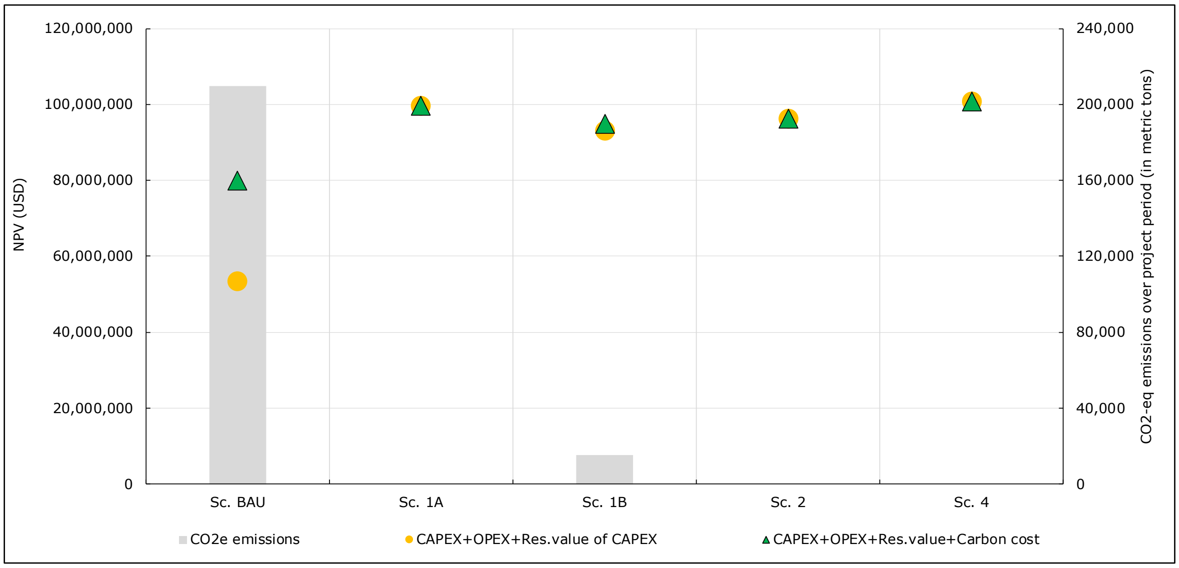


The network in Scenarios 1a, 1b, and 2 is designed with a ΔT of 25°F, which is close to what the buildings can achieve today with minimal modifications. However, using a ΔT of 25°F as a design criterion will result in larger pipe dimensions than necessary, leading to higher thermal losses and fuel costs for the network throughout its lifetime. The team recommends designing the network with the highest possible ΔT, incorporating the building upgrades as discussed in Section 2.5.3. During limited hours each year, when the network operates at full load, a higher supply temperature should be allowed, which would affect the ΔT. A design with a higher ΔT will reduce the pipe dimensions and, in turn, lower the CAPEX for Scenarios 1a, 1b, and 2.

As noted in Section 5.2.8, emergency generators are not included in the CAPEX for any scenario. This omission negatively impacts the ambient loop scenario, increasing the cost difference between the centralized and the ambient loop scenarios.

Figure 22 focuses on the NPV of costs for each scenario, shown on the left axis, and the total emissions, on the right axis. Compared to the previous figure, the NPV here includes the residual value.

Figure 22. Carbon Dioxide Equivalent Emissions and Project Net Present Value for the Various Scenarios



The figure shows that, without including the cost of carbon, the BAU scenario has significantly lower costs than the other scenarios but with high emissions. When the cost of carbon is included, the BAU scenario's economic performance aligns more closely with the other scenarios.

5.2.6 Sensitivity Analysis

Ramboll conducted a sensitivity analysis to assess the impact of varying key inputs (gas, oil, and electricity prices, and CAPEX) on NPV. Changes in the operation and maintenance costs have a minor impact on NPV and are thus excluded from the sensitivity analysis. Figure 22 illustrates the effects of changes in the price of carbon dioxide (CO_2).

The electricity costs are calculated in EnergyPRO based on hourly electricity prices. Higher electricity prices increase heat production costs with heat pumps in the scenarios. As mentioned in Section 4.1, EnergyPRO optimizes the operation of the production units to meet energy demands (heating and cooling) at the lowest annual operating cost. Units with the lowest marginal cost are called into operation first, and higher electricity prices could make alternative production with a boiler more favorable than using a heat pump. However, an evaluation of cost changes for heat pump production shows that changes in the production priority between the heat pump and the boiler occur only in a few hours per year. Therefore, the analysis assumes that changes in NPV are proportional to changes in electricity prices. The same assumption is made for changes in the natural gas price.

Table 11 summarizes the key multiplier assumptions and the results of the sensitivity analysis.

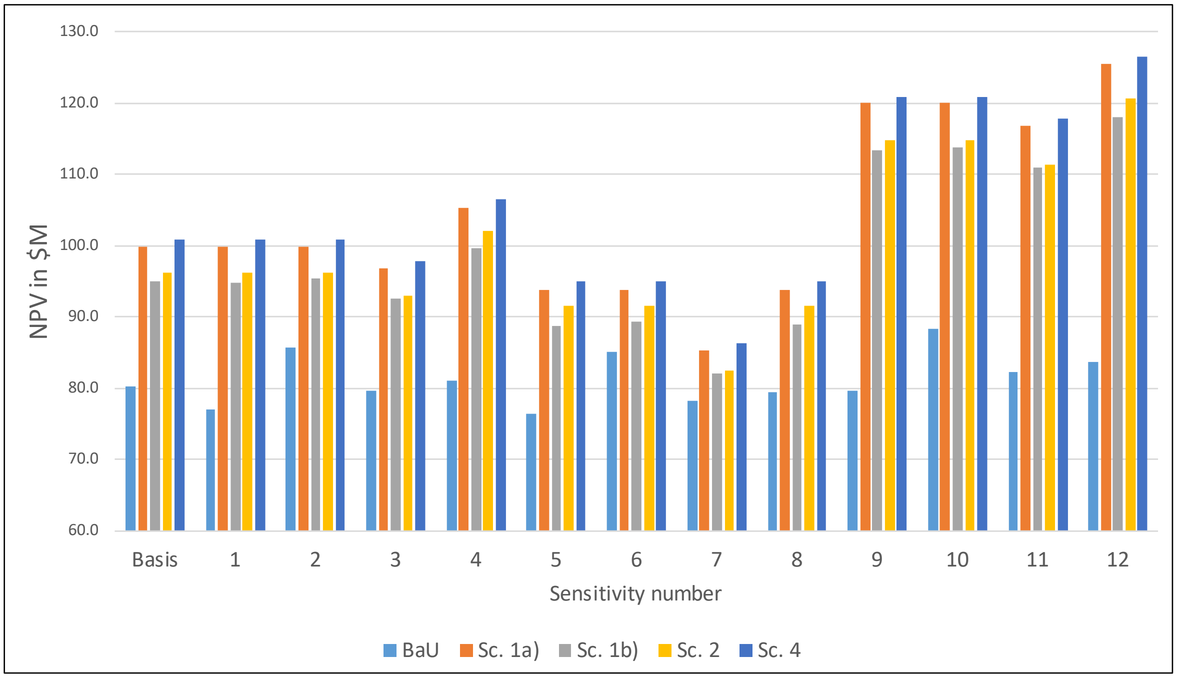
Table 11. Sensitivity Analysis Summary of Key Multipliers and Results

Sensitivity	Electricity rate multiplier	Natural gas rate multiplier	CAPEX multiplier	Scenario			
				1a	1b	2	4
0 (base NPV)				$99.8M	$95.1M	$96.3M	$100.9M
1	1	0.80	1	$99.8M	$94.9M	$96.3M	$100.9M
2	1	1.35	1	$99.8M	$95.4M	$96.3M	$100.9M
3	0.80	1	1	$96.7M	$92.5M	$92.9M	$97.7M
4	1.35	1	1	$105.3M	$99.5M	$102.1M	$106.5M
5	1	0.80	0.80	$93.8M	$88.8M	$91.6M	$95.0M
6	1	1.35	0.80	$93.8M	$89.4M	$91.6M	$95.0M
7	0.80	1	0.80	$85.2M	$82.0M	$82.4M	$86.3M
8	1.35	1	0.80	$93.8M	$89.0M	$91.6M	$95.0M
9	1	0.80	1.35	$120.0M	$113.3M	$114.7M	$120.9M
10	1	1.35	1.35	$120.0M	$113.8M	$114.7M	$120.9M
11	0.80	1	1.35	$116.8M	$110.9M	$111.4M	$117.8M
12	1.35	1	1.35	$125.4M	$117.9M	$120.6M	$126.5M

The study calculates the variation in assumptions based on the average AACE Class 4 cost estimates. Specifically, the team established the upper range between + 20% and + 50%, using a factor of 1.35 in Table 11. The team set the lower range between -15% to -30%, rounding the average to 20%, corresponding to a factor of 0.80.

Figure 23 provides a graphical overview of the results from the sensitivity analysis.

Figure 23. Graphical Overview of the Sensitivity Analysis Results



The sensitivities requiring special attention involve those that lead to significantly higher costs:

- Sensitivity 2 assumes a higher gas rate. The BAU scenario, characterized by high gas consumption, is impacted more than other scenarios with limited gas consumption.
- Sensitivity 4 anticipates a 35% increase in the average electricity rate, affecting all scenarios; however, scenarios with the least flexibility and the highest electricity consumption experience the most significant impact.
- Sensitivities 5 through 8 predict a 25% reduction in CAPEX costs, resulting in an overall economic improvement.
- Sensitivities 9 through 12 project a 35% increase in CAPEX, leading to a general cost increase, with scenarios based on high CAPEX facing the most significant effects.

Today, and for many years, a strong correlation exists between natural gas and electricity prices. This correlation will diminish as more renewable energy is integrated. Although the sensitivity analysis does not consider this correlation, it would reduce the impacts of fluctuating natural gas prices and electricity prices. Consequently, as indicated in the basis sensitivity, the results would become more robust against these changes.

5.2.7 Shadow Price of Carbon

The "shadow price of carbon" reflects the cost of carbon that equalizes the NPV of each alternative scenario with the NPV of the BAU scenario. It directly indicates the costs of reducing one ton of carbon, making it a valuable measure of the cost-effectiveness of each scenario. This price can be compared with the social cost of carbon; if the shadow price exceeds the social cost of carbon, the social cost is insufficient to offset the scenario's BAU costs.

The shadow price calculation involves:

$$\text{Shadow price (Sc. X)} = -\frac{\text{NPV(Scenario X cost)} - \text{NPV(BaU cost)}}{\text{NPV(Sc. X CO2e emissions)} - \text{NPV(BaU CO2e emissions)}}$$

The NPV of costs in this equation includes:

- CAPEX
- Residual value of CAPEX
- OPEX (energy costs and O&M costs)

The calculation excludes the social cost of carbon to avoid "double counting" carbon costs. A lower shadow price of carbon for a scenario indicates greater cost-efficiency in reducing carbon emissions.

Table 12 compares the shadow price of carbon across scenarios. A shadow price between $256 and $320 per metric ton balances the economy between the BAU scenario and the alternatives. As noted in previous sections, Scenario 2 represents the most cost-effective option. In Scenario 2, an electric boiler is assumed for peaking. If a gas boiler is used for peaking instead, the overall costs will decrease due to a reduced requirement for electrical upgrades.

Table 12. Shadow Price of Carbon Compared to Business as Usual

Parameter	Units	Scenario				
		BAU	1a	1b	2	4
Shadow price	$ per MT	—	$308	$284	$285	$315

5.2.8 Resiliency Considerations

The centralized scenarios (1a, 1b, and 2) incorporate backup units, specifically gas boilers, that are sized to meet the campus's entire heating peak. This setup provides redundancy by allowing centralized heat production and distribution to buildings to continue in the event failure of a heat pump or electric boiler failure. This mechanism is also effective during electrical grid failures, as heat generation can transition from electrification technologies to boilers. If an electrical grid blackout occurs, emergency generators are needed to operate pumps and controls to maintain the delivery and circulation of heat throughout the buildings. Therefore, the centralized scenarios show significant resiliency due to the redundancy of production assets.

Conversely, Scenario 4, the ambient loop scenario, demonstrates a considerably lower level of resiliency. The proposed installation of two heat pumps provides a specific strategy for maintaining functionality during electrical grid failures. While installing boilers at the building level could be a solution, the campus opted against this for several reasons:

- Building-level natural-gas–fired boilers require a steady gas supply from NYSEG, necessitating further investigation further investigation with the utility. Additionally, most buildings lack the necessary natural gas infrastructure.
- Installing No. 2 fuel oil–fire boilers would introduce complications such as the need for fuel oil storage tanks, compliance with environmental regulations, and additional space requirements.

After discussions with the campus staff, the consensus was to install two heat pumps in each building, each sized for 60% of the peak load. This arrangement provides redundancy, allowing the remaining heat pump to meet up to 60% of the peak demand if one unit is unavailable. Therefore, the group decided that the resiliency approach for buildings connected to the ambient loop would incorporate emergency generators capable of powering the heat pumps and other critical electric loads.

The campus is also considering strategically placing generators to serve multiple buildings or clusters instead of assigning an emergency generator to each building.

Importantly, the costs associated with emergency generators were not included in the CAPEX estimates for any scenarios. Although emergency generators would be necessary at the building level across the scenarios, they will need to be substantially more significant in the ambient loop scenario due to previously mentioned factors. Therefore, including emergency generators would significantly increase the CAPEX for Scenario 4 compared to that presented in Section 5.2.4.

5.3 Maximum Electric Loads

From the hourly modeling in EnergyPRO, the hour with the peak electrical load for energy production can be determined by aggregating the electrical demands from the various technologies, including the ASHP, GSHP, and electric boiler. These results are summarized in Table 13. A key source of uncertainty regarding these figures is the efficiency of the GSHP. As a result, the reported electrical load is presented as a range, indicating both minimum and maximum values.

Table 13. Load Estimates for Circulation Pumps and Ancillary Equipment per Scenario

Parameter	Units	Scenario				
		1a	1b	2a	2ba	4
Description	—	Centralized, GSHP/ASHP, Electric Peak	Centralized, GSHP/ASHP, NG Peak	Centralized ASHP/WWHP, electric peak	Centralized ASHP/WWHP, Gas Peak	Ambient Loop
Electric load from EPRO	MW	8.2	2.7	12.9	2.7	4.7
Pumps etc.	MW	0.2	0.2	0.2	0.2	0.3
Total	**MW**	**8.4**	**2.9**	**13.1**	**2.9**	**5.0**
Worst case	MW	9.0	3.0	14.2	3.0	5.2
Conventional electric use	MW	3.1	3.1	3.1	3.1	3.1
Minimum capacity requirement	MW	12.1	6.1	17.3	6.1	8.3
Conversion (cos φ = 0.95)	MVA	12.8	6.4	18.2	6.4	8.7
Maximum capacity today (two out of three)	MVA	7.5	7.5	7.5	7.5	7.5

[a] Scenario 2B is not a modeled scenario. Electric load from EnergyPRO is based on Scenario 1B, where the COP is assumed to be the same to estimate electrical load.

The estimated load for circulation pumps and ancillary equipment in Scenario 4 (ambient loop) considers a slightly higher demand because adding glycol to the water increases viscosity, leading to higher pressure loss.

Scenario 1a uses GSHP as baseload technology, supplemented by an ASHP for balancing purposes, but also to operate when possible for cost efficiency. When the ASHP cannot operate due to too low ambient temperature, the electric boiler produces instead.

Based on the values in Table 13 and the planned upgrades to the feeders outlined in RMF Engineering's report, Scenario 1b appears to be the only scenario that may not require further upgrades to substations and feeders. Further analysis of feeder-by-feeder loads will help determine the viability of Scenario 1b. In contrast, the total expected load remains below the operational capability of two of the three transformers at the substation.

Ramboll coordinated a conference call on January 12, 2024, with NYSERDA, SUNY Oneonta, and the City of Oneonta. During this call, participants shared and discussed the results of the electrification scenarios to understand the potential impact of the proposed scenarios on electrical service within the Oneonta area. This also included discussions about limits imposed by distribution, substations, or transmission systems.

During the call, NYSEG provided information on the North Oneonta Reliability Project, a multiyear electric transmission line initiative consisting of approximately 61.2 miles of new 115 kV and 46 kV lines across portions of Chenango, Otsego, and Delaware counties.

NYSEG requested additional details from Ramboll, including a map showing the estimated locations of maximum load increases. NYSEG intends to use this map for internal discussions related to the North Oneonta Reliability Project and to establish an estimate of costs for the substation upgrades in fully electrified scenarios.

NYSEG could not provide input during this study. In January 2024, NYSEG announced that the North Oneonta Reliability Project was suspended indefinitely after the NYS Public Service Commission deemed it ineligible as a Climate Act project, citing insufficient capacity to support renewable energy interconnections to the electric transmission grid.

5.4 Additional Technology Assessments

5.4.1 Proposed Solar Photovoltaic and Battery Storage

Utility outages are becoming increasingly frequent due to aging infrastructure and the need for more significant investment. SUNY Oneonta is transferring a 59-acre parcel of land from the jurisdiction of the NYS Office of General Services (OGS) and SUNY. Figure 24 shows the parcel located along West Street

at the western boundary of the campus. Figure 25 shows the lower 8 acres of the parcel, which consists of cleared land visible in the OGS aerial photo, provided as Figure 25. The project is scheduled for completion in 2025.

Figure 24. Plan View Layout of Solar Photovoltaic and Battery Storage Location

Source: Phil Bidwell, Plan View Layout of Solar Photovoltaic and Battery Storage Location, 2023, NYS Office of General Services.

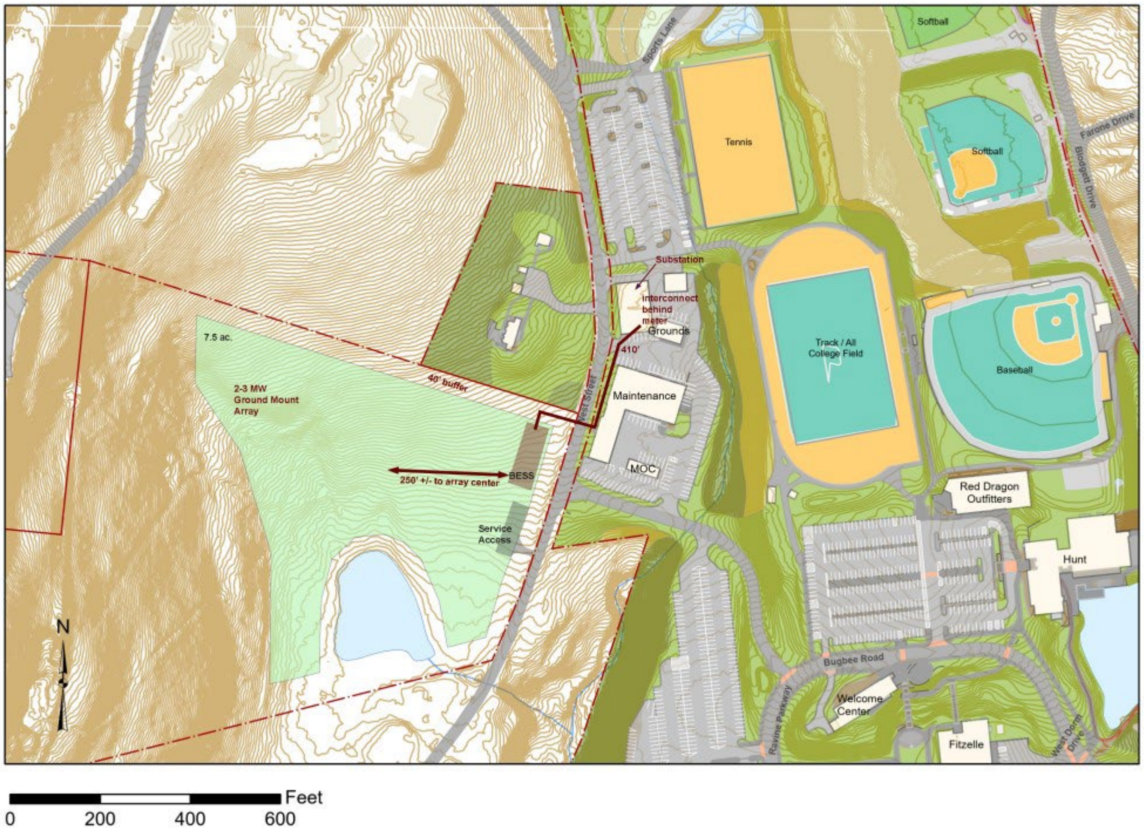


Figure 25. Aerial Photo of Area Designated to Solar PV and Battery Storage Construction

Source: Phil Bidwell, Aerial Photo of Area Designated to Solar PV and Battery Storage Construction, 2023, NYS Office of General Services.

The campus collaborates with the New York Power Authority (NYPA) to propose constructing a battery storage system off West Street, as shown in Figure 24. This project includes constructing approximately 400 ft of electrical duct bank to connect the battery storage and the campus substation, Transformer 300. The battery storage location will consist of a parking/visitor area off West Street. Additionally, the campus plans to construct approximately 1.5 MW of ground-mounted solar panels in the open field adjacent to the battery storage system, designed to meet minimum summer load.

SUNY Oneonta views the battery storage system as a means to charge during off-peak times from substation Transformer 300 and discharge during peak times or as needed during peak load management programs back into the 300 transformer. The battery will also receive power from the solar array. Power from the solar array will the Transformer 300, which has a maximum capacity of 5,250 kVA. The Transformer 300 typically has winter consumption of 450 KW and summer consumption of 1250 KW, but can support additional loads.

In the event of a prolonged utility outage, the campus expects the battery to disconnect from the grid automatically. The campus will manually shed loads and balance critical building loads onto the 301/302 feeders. The total loads applied to the 301/302 feeders will not exceed 250 kW and will focus solely on life safety and freeze protection for buildings lacking generation. The campus aims for the battery to discharge 300 kW over 10 hours to support long-term power to the 300 substation and the 301/302 feeders, providing power for freeze protection and life safety systems. During a long-term outage, SUNY Oneonta wants the solar field to recharge the battery as much as possible.

6 Results: Business Model

6.1 Ownership, Funding, and Contractual Framework

SUNY will own and maintain operational control of the heating and cooling assets. SUFC will most likely manage project implementation phases, from design through construction. Contractual agreements will exist between SUCF and private sector consultants and contractors.

The project and its associated phases typically receive funding through annual capital program appropriations during the NYS fiscal year, which runs from April (current year) through March (the following year). These clean energy projects accompany other critical maintenance and capital improvement projects. Capital project proposals that SUCF evaluates and funds undergo assessment through a scoring system, which allocates points for projects that support decarbonization.

The project's value proposition aligns with Executive Order 22 (for NYS agencies) and the Climate Act to decrease carbon emissions. This project study identifies investment alternatives to achieve those carbon emission reductions. Further assessment will be needed for potential supplemental funding consideration under the federal Inflation Reduction Act (IRA), especially after the college selects a preferred scenario.

6.2 Regulatory Review

The geothermal wells considered in the scenario analysis use a closed-loop design. The NYS Department of Environmental Conservation (DEC) Division of Water regulates wells less than 500 ft deep. On September 21, 2023, Governor Hochul signed the 500-ft geothermal drilling law, which exempts closed-loop geothermal boreholes deeper than 500 ft from the oil and gas regulations previously enforced by the DEC Division of Mineral Resources. The Governor reached an agreement with the Legislature, granting the DEC the authority to create new and appropriate regulations for closed-loop geothermal boreholes deeper than 500 ft. The DEC is expected to develop these regulations as quickly as possible.

6.3 Funding Source and Incentives

Several funding sources and incentive programs are available to support energy projects or activities on the campus. These programs often have specific application deadlines and expiration dates, so monitoring them to confirm eligibility periodically is essential. Following are some key resources to consider.

1. **NYSERDA**: NYSERDA offers various programs that can assist with energy-related projects, including:
   - Overview of all programs: https://www.nyserda.ny.gov/All-Programs#category=schools-colleges-universities
   - Community Heat Pump Systems (Program Opportunity Notice [PON] 4614): Although solicitation is currently closed, NYSERDA plans a replacement program associated with thermal energy networks (TENs)
   - Large-Scale Thermal Program (PON 5614)
   - NY-Sun Commercial/Industrial Incentive Program (PON 3082)
   - Building Cleaner Communities Competition
2. **Database of State Incentives for Renewables & Efficiency (DSIRE)**
   The Database of State Incentives for Renewables & Efficiency (DSIRE) provides information on incentives and programs. For New York State, visit: https://programs.dsireusa.org/system/program/ny
3. **U.S. Department of Energy (DOE)**
   The DOE offers funding opportunities for energy efficiency and renewable energy. Explore available programs at https://www.energy.gov/eere/funding/eere-funding-opportunities
4. **IRA**: The IRA introduces new credit delivery mechanisms to help state, local, and Indigenous nation governments; nonprofit organizations; U.S. territories: and other entities access clean energy tax credits. Rocky Mountain Institute (RMI), an independent, nonprofit organization that transforms global energy systems through market-driven solutions, has developed a detailed breakdown of IRA programs and incentives, including:
   - RMI IRA breakdown by incentive
   - Production Tax Credit for Electricity from Renewables

The campus can potentially secure funding for energy efficiency and renewable energy projects by monitoring and applying for these resources.

7 Key Findings and Recommended Next Steps

7.1 Key Findings

Table 14 summarizes important topics and associated aspects identified during the study. These topics inform the complexities and challenges the team must consider and manage during the transition. They intersect to influence and balance carbon reduction, energy efficiency, flexibility, resiliency, and redundancy in a pragmatic and cost-effective manner.

Table 14. Key Findings from the Campus Heat Pump Strategy Study

Topic	Key Findings
Electrical Demand Impact	• Determine if Scenario 1b requires further substation and feeder upgrades • Analyze feeder-by-feeder loads and assess the viability of Scenario 1b, considering that the total expected load is below the capability of two of the three transformers at the substation • Address significant emergency and standby power requirements without nonelectrical-based backup • Minimize CAPEX while achieving a relatively small carbon emissions reduction by electrify peak load in addition to baseload
Natural Gas Peaking Benefits	• Provides flexibility and redundancy for emergencies • Bridges the fuel gap while electric utility infrastructure catches up • Manages capital spending effectively • Aligns with future NYS plans to transition from NG to RNG and hydrogen • Reuses existing infrastructure and backup power assets
Building Improvements	• Develop a strategy for steam-only buildings, such as Morris Hall • Address humidification needs (currently provided by steam) with dedicated systems, which allows the central plant's MTHW supply temperature to be lowered • Determine the lowest possible operating supply temperature, which can be set by space heating loads rather than humidifier requirements
Infrastructure Scenarios	• Evaluate centralized versus decentralized systems • Assess property for geothermal systems
Emission Reduction	• Achieve more than 85% reduction in emissions without fully electrifying the system

7.2 Recommended Next Steps

The following recommended next steps aim to help the campus prioritize projects that can influence future systems design and demonstrate progress toward transitioning to low-carbon operations and achieving campus carbon reduction goals.

1. Trend data on hot water valve position along with supply temperature and outdoor temperature
2. Establish a steam-to-low-temperature hot water conversion strategy for the steam portion of the central distribution system
3. Assess alternatives to address the steam needs of Morris Hall, a nonhydronic building
4. Consider electric boosters for buildings with steam kettles for cooking (planned for the next 2–3 years)
5. If the campus stays with a centralized solution:
    - Install HXs in seven remaining hard-piped residence hall buildings
    - Replace three-way valves (bypass of coils) with control valves
    - Convert the existing MTHW system from a constant volume system to a variable volume system
    - Target a ΔT of a minimum of 30°F–35°F in the distribution system for winter design conditions; a higher ΔT will reduce pipe dimensions and distribution system costs
    - Further assess the optimal location for the central plant because it may be impacted by potential electrical upgrades from the current central plant location to the substation
6. Monitor market developments and advancements in heat pump technology and U.S. market availability

Endnotes

[1] U.S. Energy Information Administration (EIA), 2012, *2012 Commercial Buildings Energy Consumption Survey,* accessed August 2024. https://www.eia.gov/consumption/commercial/reports/2012/energyusage/

[2] The calculation assumes scenarios with gas boilers for peak demand have unlimited gas availability. However, SUNY Oneonta is in a gas-constrained area and may face disconnection during limited gas availability. In such cases, fuel oil would be used as an alternative. To reflect this reality, the OPEX can be adjusted by replacing some natural gas costs with fuel oil costs.

[3] U.S. Energy Information Administration (EIA). 2024. “Short-Term Energy Outlook.” Accessed August 2024. https://www.eia.gov/outlooks/steo/archives/aug24.pdf

[4] New York State Department of Environmental Conservation (DEC). 2022. *VOC Guidance Document*. Accessed August 2024. https://www.dec.ny.gov/docs/administration_pdf/vocguid22.pdf.

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