Attachment B

Eastern Washington University Decarbonization Plan

For HB1390 Compliance

Version 1

May 16th, 2025

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Section 1

Executive Summary

Key Takeaways

- The proposed decarbonization plan has expected implementation costs of $330M-$370M
- The existing steam heating system accounts for 95% of Scope 1 campus carbon emissions and ~70% of Scope 1 and 2 carbon emissions.
- Campus and utility electrical infrastructure can support the added load of the first phase of this plan, however added load from additional phases will necessitate a new utility service substation.
- The proposed decarbonization plan describes a path to compliance with HB1390 requirements

Introduction and Report Purpose

Eastern Washington University is developing a decarbonization plan with the long-term goal of eliminating fossil fuel carbon emissions at its central heating plant. This plan will not only help EWU achieve its goal of becoming a carbon neutral institution but will also align with the requirements of Washington State's House Bill 1390 (HB1390). A qualitative comparison of different decarbonization pathways was completed in the early stages of Decarbonization Plan development, along with the costs to convert nine buildings to decarbonized buildings systems, as summarized in the Capital Request Report delivered in August 2024. The decarbonized mechanical system selected to reduce operation of the fossil fuel-based steam central plant is a nodal open-loop ground-source system with 4-pipe distribution. The nodal plants are referred to as "GeoEco Plants (GEP)" throughout. This report is the culmination of the Decarbonization Planning effort, expanding on the recommendations of the Capital Request Report to include campus-wide costs and an implementation roadmap for the decarbonized system. The content of the Capital Request Report is included in this report, which will be used for HB 1390 compliance.

Key Considerations

- House Bill 1390 Compliance: This report serves as the Decarbonization Plan required for HB 1390 compliance, for submittal to the Washington Department of Commerce. In addition to the long-term goal of removing natural gas, the campus will also need to meet an EUI target of 112 kBtu/sf-yr and establish Energy Management and Operations & Maintenance Plans (EMPOM). *Implementing the projects outlined in this plan will meet the EUI target required for HB 1390 compliance.* Key dates for 1390 compliance include:
  - 6/1/25: EMPOM period for buildings over 220,000 sf starts (outside the scope of this project)
  - 6/30/25: Decarbonization plan due to Commerce (this report)
  - 2026 and 2027: EMPOM periods start for buildings 90,000 sf - 220,000 sf and 50,000 sf - 90,000 sf (outside the scope of this project)
  - 2030 and 2035: Decarbonization Plan update due to Commerce
  - 2040: Decarbonized campus, EUI target met
- Funding: Design and construction of the preferred decarbonized system depends on the State of Washington's continued support of decarbonization efforts (including open-loop ground-source technology). Ground-source projects may be eligible for federal funding via the Inflation Reduction Act. A tax consultant can quantify the exact funding amount, depending on project phasing and construction. This report does not quantify those benefits.
- Phasing: The preferred open-loop ground-source system has several smaller interconnected plants, or "nodes", and is ideal for long-term phasing. This allows for the cost to be spread out over multiple biennia, allows for technology to improve, and provides flexibility in project implementation and sequencing. Lessons learned on the construction and operation of the first node can be carried to subsequent future nodes.
- Campus master planning: The decarbonization plan and master planning will be strategically aligned. For instance, the demolition of older, less efficient, underutilized buildings not only supports the decarbonization objectives by reducing campus energy consumption but also offsets the costs associated with upgrading these less efficient structures to the new decarbonized system.

Decarbonization Implementation Roadmap

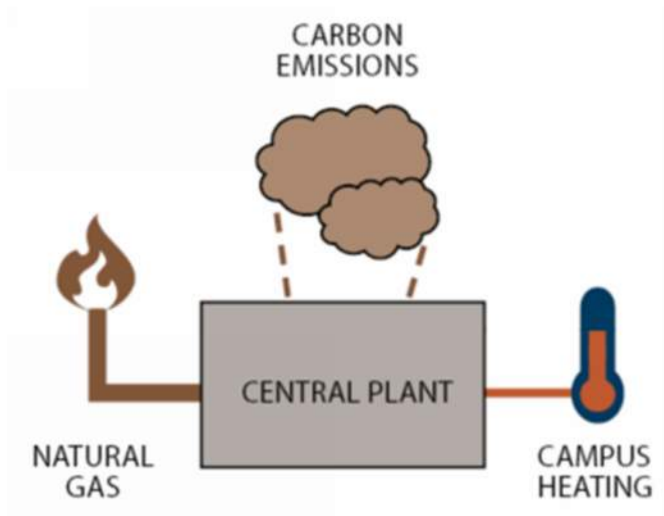
The roadmap below summarizes the decarbonization plan, providing construction costs, timing, and carbon reductions for each implementation phase. This roadmap assumes an aggressive timeline in which the decarbonized system is implemented by 2032. A more conservative timeline is included later in the report. The various components of this roadmap are described in detail below:

- Section 2: Campus Existing Conditions | This section describes the existing mechanical, electrical, and plumbing systems, as well as current energy use and carbon emissions.
- Section 3: Decarbonization Solutions – Energy Plant | This section details the proposed open-loop ground-source heating/cooling plants and distribution piping.
- Section 4: Decarbonization Solutions – Building Conversions | This section details the retrofits needed in the existing buildings to accommodate the proposed thermal systems.
- Section 5: Energy & Carbon Analysis | This section projects the future energy use, carbon emissions, and utility costs of the proposed decarbonized system.
- Section 6: Implementation Costs & Roadmap | This final section details the total system costs and breaks the projects into phases, showing how implementation occurs over time.

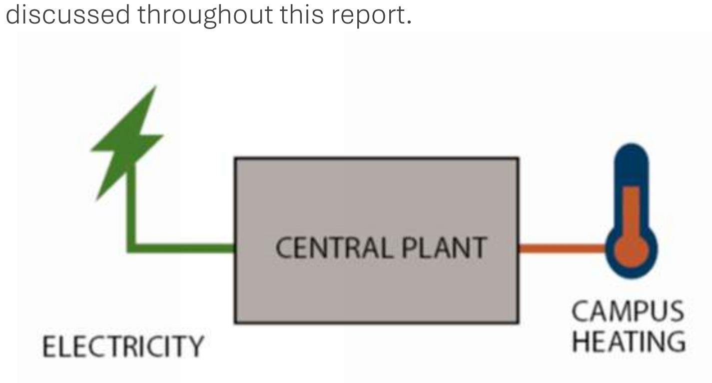
Figure 1: Decarbonization Implementation Roadmap with Aggressive 2032 Timeline

Where Are We Now and Where Are We Going?

EWU's current heating system uses fossil fuels (natural gas) to create heating that is distributed to campus buildings. This is a large source of not only Scope 1 carbon emissions, which are the emissions resulting directly from burning fossil fuels on site, but also a source of campus pollution.

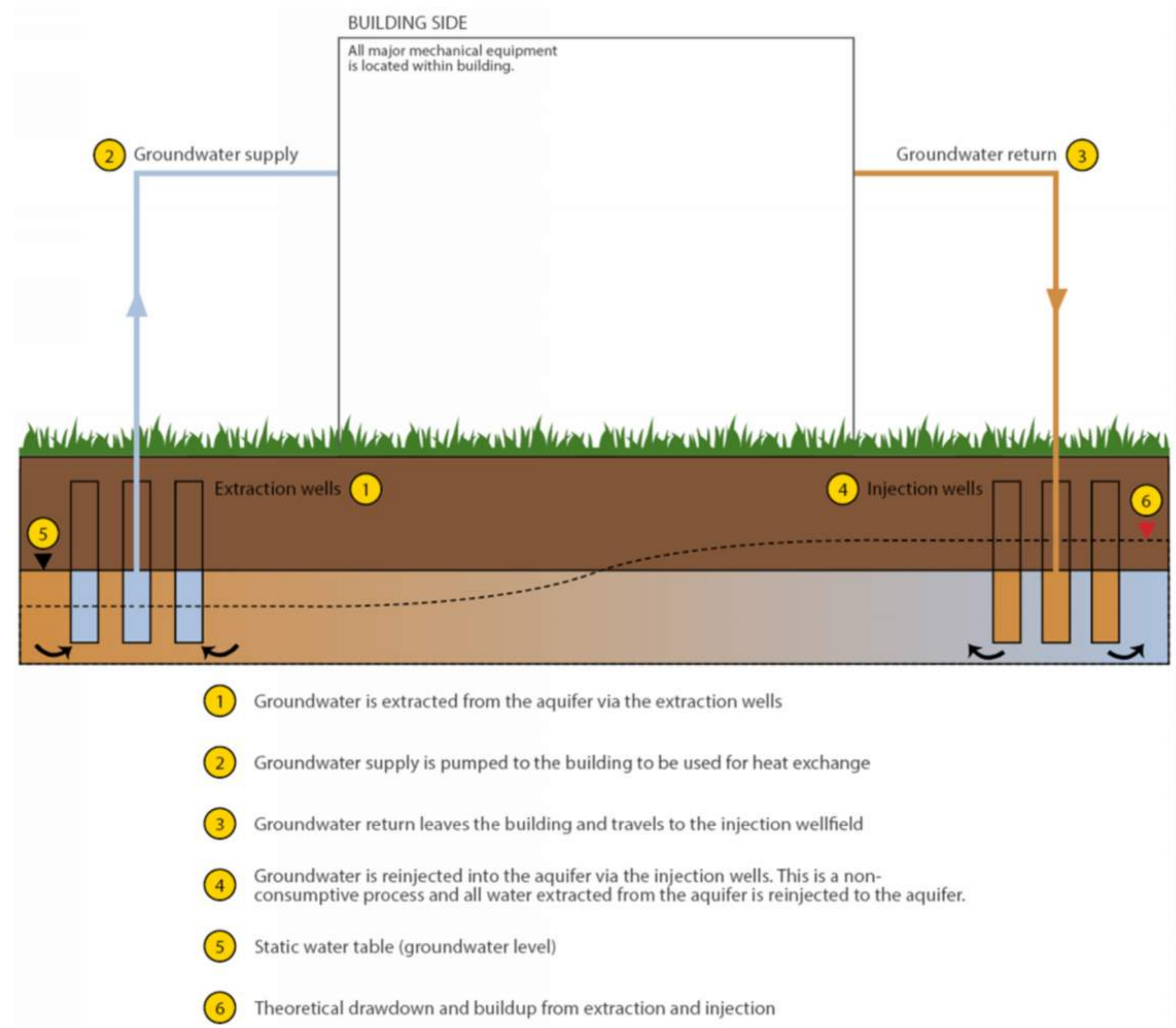


House Bill 1390 requires all state-owned district energy systems to remove most fossil fuels from their systems by 2040, meaning the central heating systems must be transitioned to an electrified system. Using electricity for heating removes the Scope 1 emissions created by the existing fossil fuel-based heating plant and also improves campus air quality by removing on-site burning. While the input to the heating system will change, going from natural gas to electricity, the output of reliable campus heating will remain the same. The role of the existing steam system as the heating system transitions is discussed throughout this report.



What is Ground-Source?

As discussed later in this report, there are many different methods of using electricity to generate heating. This study found the best option for EWU's decarbonized system is one that employs open-loop ground-source for heating and cooling. As shown below, open-loop ground-source would use the aquifer beneath campus to provide most of the campus' heating and cooling.



Decarbonized System Characteristics

The proposed decarbonized system is a nodal open-loop ground-source mechanical system. The key components of this system include:

- Open-Loop Ground-Source : The system will extract and reject heat to and from the aquifer beneath the campus. Electrically-powered water-to-water heat pumps will create heating hot and chilled water, as well as recover heat during times of simultaneous heating and cooling, and distribute to individual buildings. This is opposed to the current heating system, which creates heat by burning fossil fuels. This recommendation is based on the analysis performed in the previous geothermal study; aquifer conditions will need to be validated by a geothermal test well.

- Nodal Plants: The mechanical equipment needed to transfer the heating/cooling to the buildings will be in several smaller plants distributed across campus. This is opposed to the current plant configuration, which houses all heating/cooling equipment in a single central plant building. This approach allows for construction phasing, flexibility, and increased campus resilience.

- Transitioning from Steam to Hot Water: The current central system provides building heating primarily via steam. The proposed system will provide heating to buildings via hot water, removing steam as the primary source of heating. This will require new hot water distribution piping across campus. This will most likely employ a mix of low temperature hot water (i.e. 120-130°F) and high temperature hot water (i.e. 160-180°F), depending on the existing mechanical systems in the buildings.

- Resilience: The existing central steam plant will remain in-place to provide backup and peaking to the decarbonized system. This complies with HB 1390 requirements, which allow for up to 10% of annual heating energy to be met by fossil fuels or electric resistance. These emissions will be mitigated by EWU's carbon capture system on the existing fossil fuel-fired steam plant, which was in design at the time of this report, thereby exceeding the requirements of HB 1390. In addition, if economics and supply become viable, the steam plant could be fired by renewable natural gas.

- Cost, Incentives, Construction: The proposed strategy's modular nature enables a gradual rollout that can be synchronized with the capital budget cycle, building renovations, and new construction, allowing for less impact to campus. The system is well-positioned for funding from the Inflation Reduction Act, ensuring the most cost-effective use of resources.

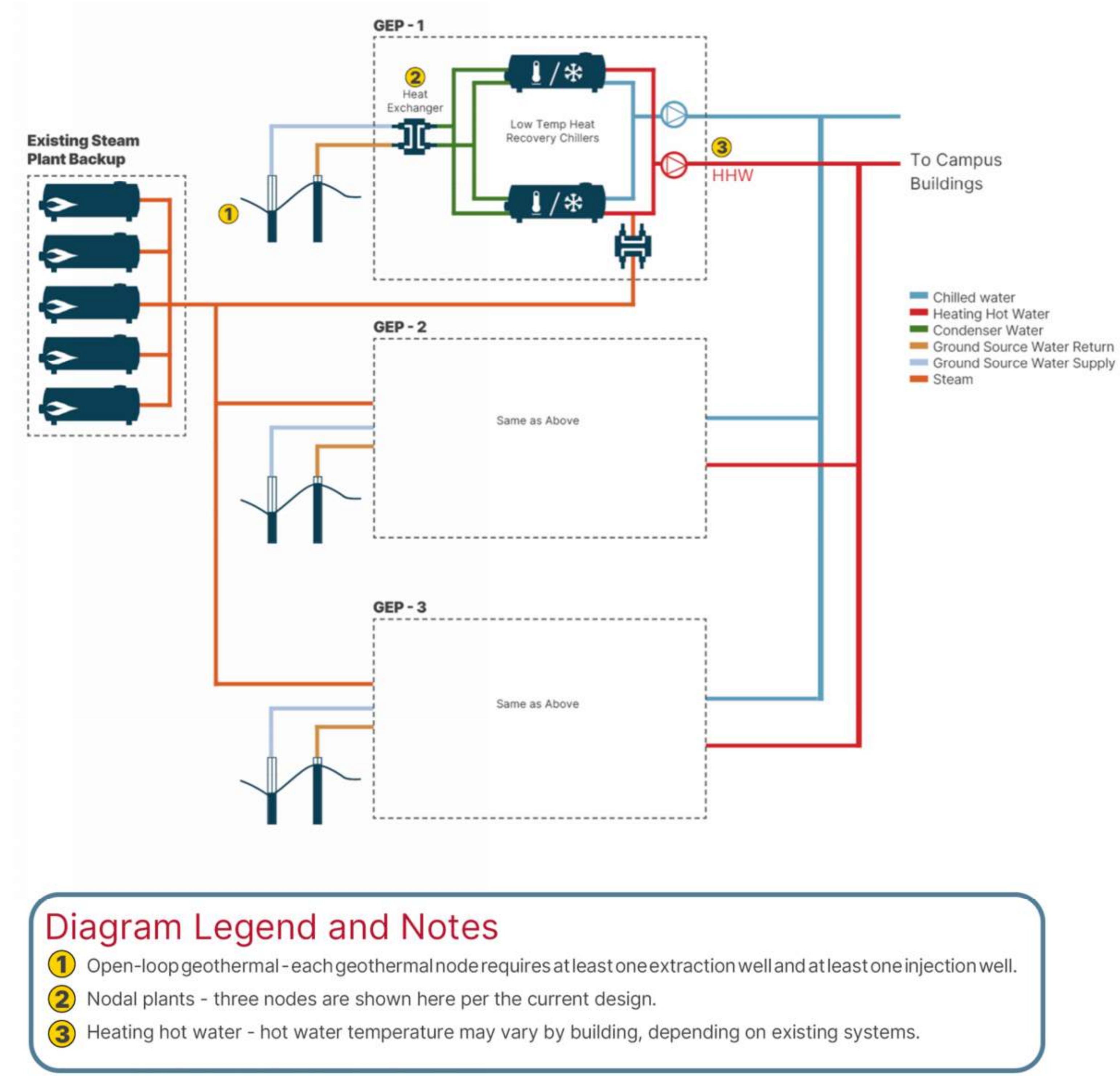


Figure 2: Proposed Nodal Plant Configuration

Construction Cost

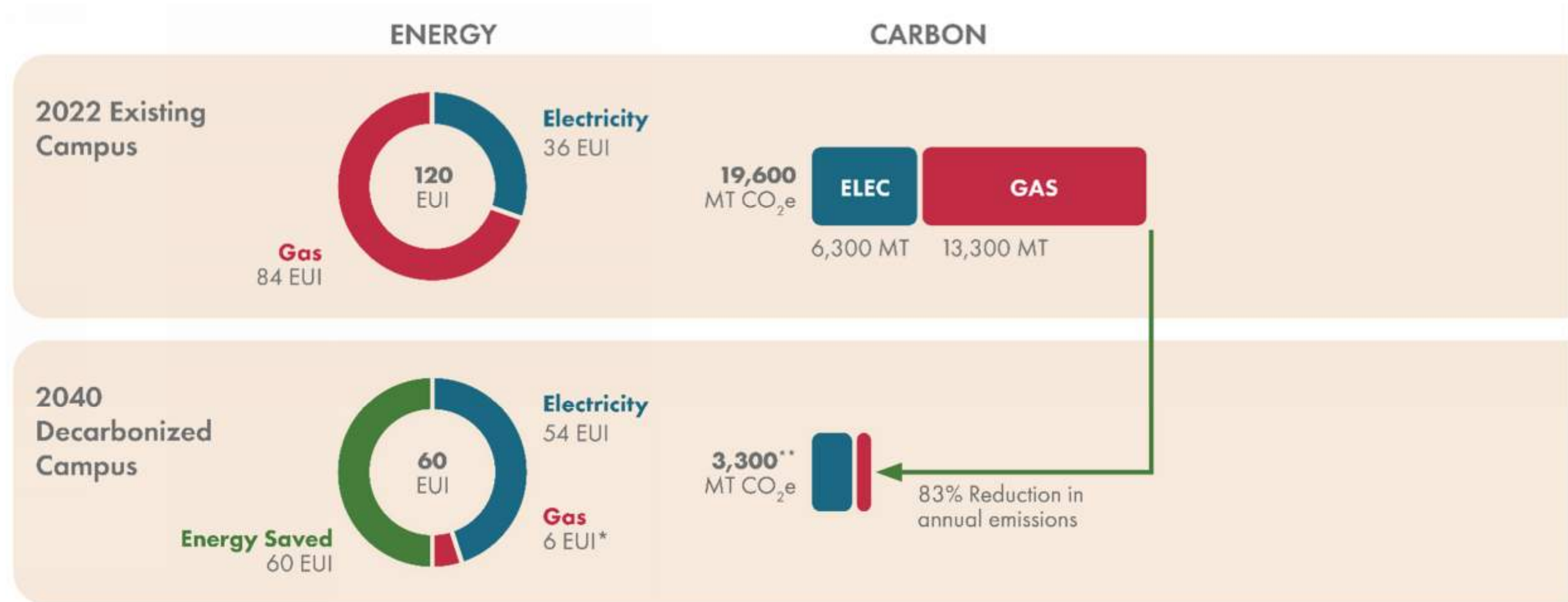
The cost section of this report provides a rough order of magnitude (ROM) cost , estimating total implementation costs for the decarbonization plan across the campus over time. These high-level costs are intended for directional guidance and will need to be validated and refined via detailed design prior to requesting funding for implementation. These extrapolated costs cover the entire campus and are estimated to range between $330 million and $370 million. As shown in the table below, the low end of this range results from faster implementation than required by HB1390.

Table 1. Implementation Construction Costs with Scenarios.

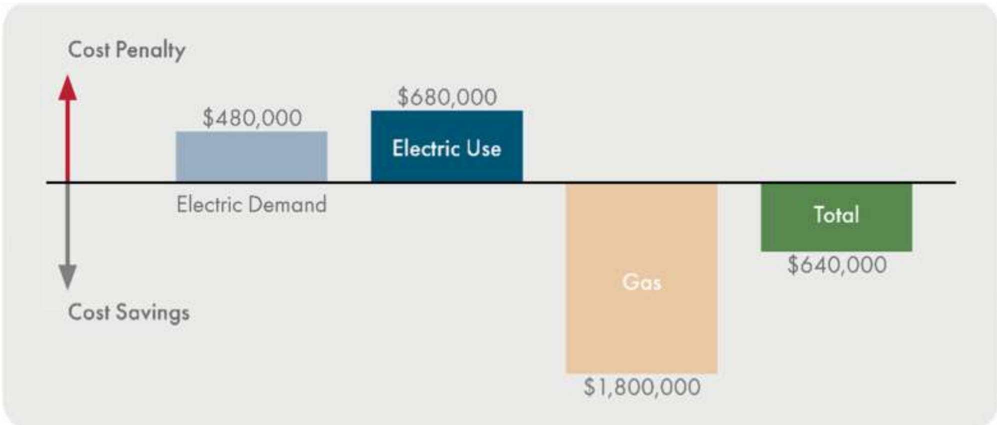
EWU Decarbonization Cost Summary		
	Total	
Nodal ground-source system costs (incl. Elec)	$	195,130,000
In-Building Conversion Costs	$	94,895,000
Cost Subtotal (without escalation)	$	290,025,000
Total Costs for Expedited 2032 Implementation	$	330,834,000
Total Costs for 2040 Implementation (HB1390 Minimum Timeline)	$	369,513,000
Cost Savings from expedited implementation	$	38,679,000

Energy Use, Carbon Emissions, and Utility Cost

Transitioning from the current steam central plant to an electrified plant not only fulfills HB 1390's mandate to eliminate natural gas but also inherently meets an additional requirement to reduce campus energy consumption. Currently, the campus Energy Use Intensity (EUI) stands at 120 kbtu/sf-year, whereas the HB 1390 target for 2040 is 112 kbtu/sf-year. By replacing gas-fired boilers with more efficient ground-source heat pump heating, the campus EUI is projected to decrease to approximately 60 kbtu/sf-year. Increased electrification of the central plant also yields substantial savings in operating emissions, reducing the annual emissions by 84% when accounting for forward looking emissions factors for electricity. **While overall electricity use will increase between now and 2040 due to electrification of campus heating, the carbon emissions from electricity will decrease as the power grid becomes cleaner between now and 2040.



**Note: The remaining gas use in the 2040 decarbonized scenario includes gas used for peak heating loads and additional smaller gas heating loads. This complies with HB 1390 requirements, which allow for up to 10% of annual heating energy to be met by fossil fuels or electric resistance.*



The electrification and increased efficiency of the ground-source system result in annual utility cost savings around $640,000 per year upon full implementation (using current rates). As a result of the Climate Commitment Act (CCA), the natural gas supplier is expected to pass along CCA fees to customers. In addition to the annual utility cost savings, EWU will avoid these additional fees as a result of reducing natural gas usage. These avoided costs are not included in this analysis. This savings is a result of the ground-source system being close to 5 times more efficient than the existing steam plant in providing heat to the buildings. Although there is an increased cost to added electrical use charges and electrical demand charges, those cost penalties are fully offset by the savings in natural gas utility cost

How to Use This Report

This report offers EWU a conceptual framework for achieving its decarbonization objectives and gives an approximate cost for long-term implementation. **Additional design and analysis at the implementation stage are necessary to provide greater certainty to the cost estimates in this plan.** The project phases and roadmap are based on existing conditions at the time of this report and coordination with EWU stakeholders. The phasing is predicated on current circumstances and specific assumptions and is unlikely to occur in the precise order outlined in this plan. Factors such as unforeseen equipment failures, technological advancements, and economic changes will influence the actual implementation of this plan.

Use This Plan:

- For compliance with the requirements for a Decarbonization Plan as outlined in HB 1390
- For conceptual scoping of the projects requested as part of capital requests.
- For long-term capital planning related to building decarbonization.
- To communicate the big picture costs and savings of building decarbonization.

Do Not Use This Plan:

- For guaranteed campus or building-level cost, energy, or carbon savings.
- For guaranteed first cost estimates.
- As a direct input for detailed design and associated costs of future capital requests. The costs and projects need to be revised and updated for detailed design phases.
- As a static document. This should be revisited and revised every few years as the campus and technology evolve.
- As a detailed assessment of existing conditions. All existing conditions need to be further studied and validated, and the cost estimates in this plan need to be updated accordingly.

Implementation Considerations

The below considerations will assist with implementation and potentially reduce overall costs.

- Prior to the design and implementation of building conversions, test the heating hot water supply temperatures to determine the minimum allowable setpoints during the winter. If the setpoints can be reduced without causing comfort complaints, it may be possible to lower building conversion costs.
- To better inform the design approach outlined in this report, begin metering and trending building-level thermal loads immediately.
- As nodes are deployed and the energy district starts serving larger portions of the campus, future nodes and building connections might be sized with less capacity, depending on metered data and the system's operational performance.

Project Next Steps

- Complete the Energy Management and Operations & Maintenance (EMP/OM) Plans for 1390 compliance.
- Submit documentation to Commerce for 1390 Compliance before June 30, 2025.
- In the Winter of 2025/2026, test heating hot water temperatures for the nine focus buildings, as described in the “implementation considerations” section.
- Confirm metering/trending is in place for building heating, cooling, and electrical loads.

Pending capital request funding, begin project Implementation. The 2025-2027 capital request included requests for construction of GEP-1 and converting the nine focus buildings.

Section 2

Campus Existing Conditions

Key Takeaways

- The existing steam heating system accounts for 95% of Scope 1 campus carbon emissions and ~70% of Scope 1 and 2 carbon emissions.
- The campus is heating-dominated with significant spare steam capacity at the Rozell Central Plant.
- While the campus-wide electrical distribution system currently has capacity to accommodate some added loads, it is still limited by the load the utility can deliver.

Benchmarking Configuration

EWU will comply with the House Bill 1390 (HB1390) via the "Campus level" pathway which requires the campus to perform lower than the target EUI of 112 kbtu/sf-yr.

Campus Energy Metrics

The EWU campus is served by electricity from the City of Cheney and natural gas from Avista. The central plant provides most of the heating and cooling on campus. Natural gas is consumed at the central utility plant to produce campus steam. Natural gas is also used in a smaller magnitude throughout campus at individual buildings for domestic hot water heating systems, process loads, and for cooking. Campus data below is based on 2022 utility bill data for electricity and natural gas.

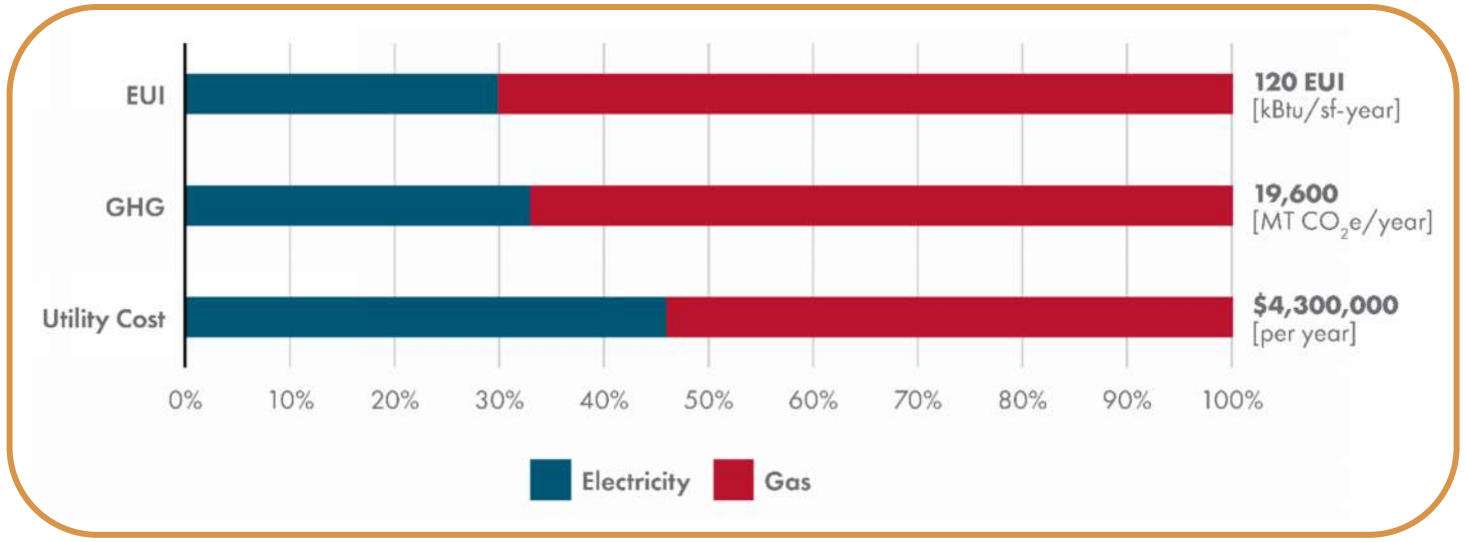


Figure 3: Annual Primary Energy Use

Campus Energy - Enduse Breakdown

The sankey diagram to the right shows how energy is used across the EWU campus. While there are some disparate fossil fuel (natural gas) uses across campus, the majority of fossil fuel use is attributed to the central steam plant loop. Note this diagram does not include campus vehicles using fossil fuels, as that usage is outside the scope of this project. For the electricity and gas breakouts in this chart, data is based on:

- Natural gas: the breakout between district heat and remaining gas is based on utility data.
- Electricity: the breakout between electricity and district cooling is based on similar campuses. It has been adjusted to account for Cheney's cooling degree days.

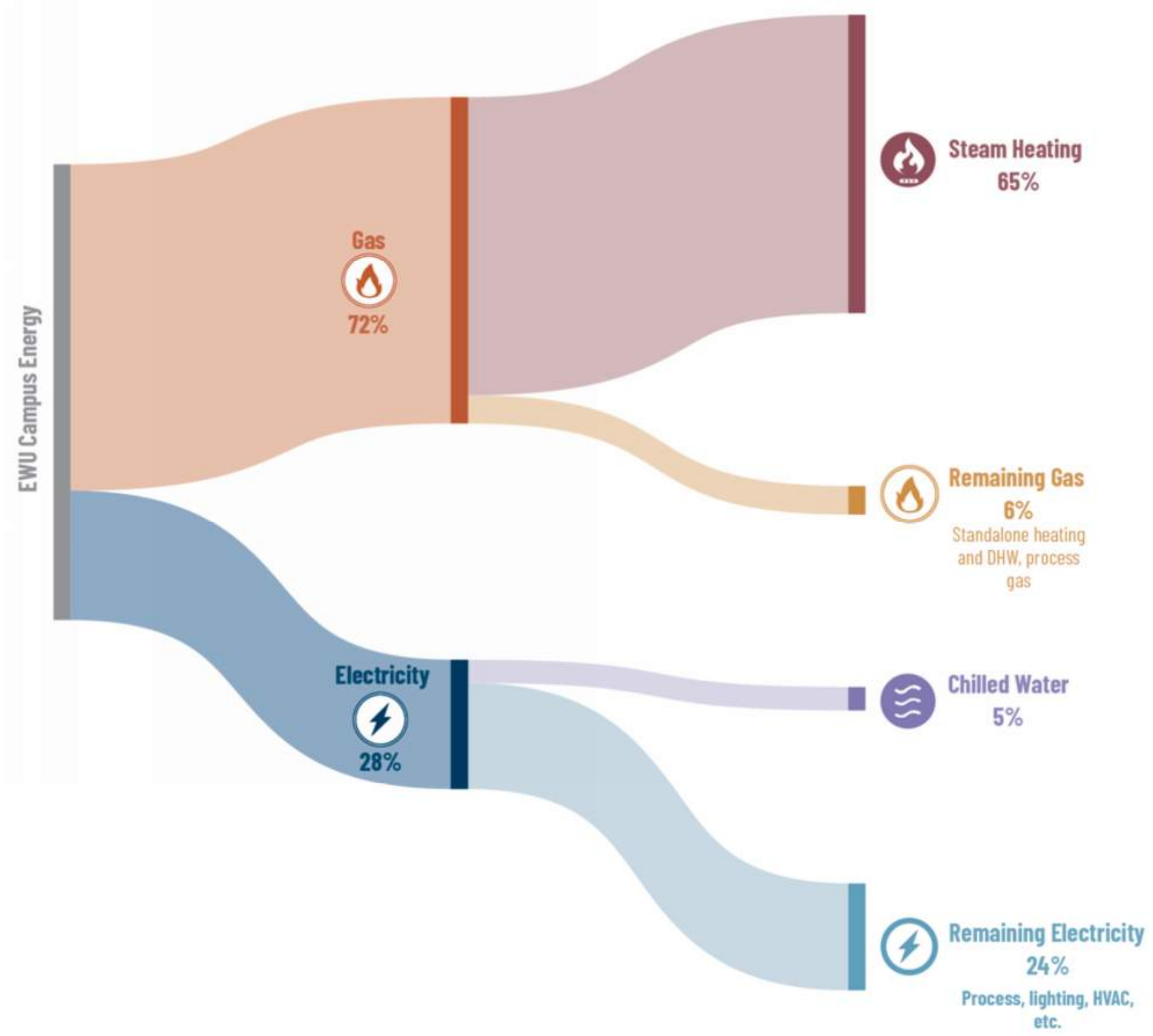


Figure 4: EWU Sankey Diagram of Campus Primary Energy Use

Building Inventory

The table in Appendix D describes the existing building systems and capacities.

Existing Mechanical Plant

Figure 5 presents a schematic of the existing central heating equipment as of 2024.

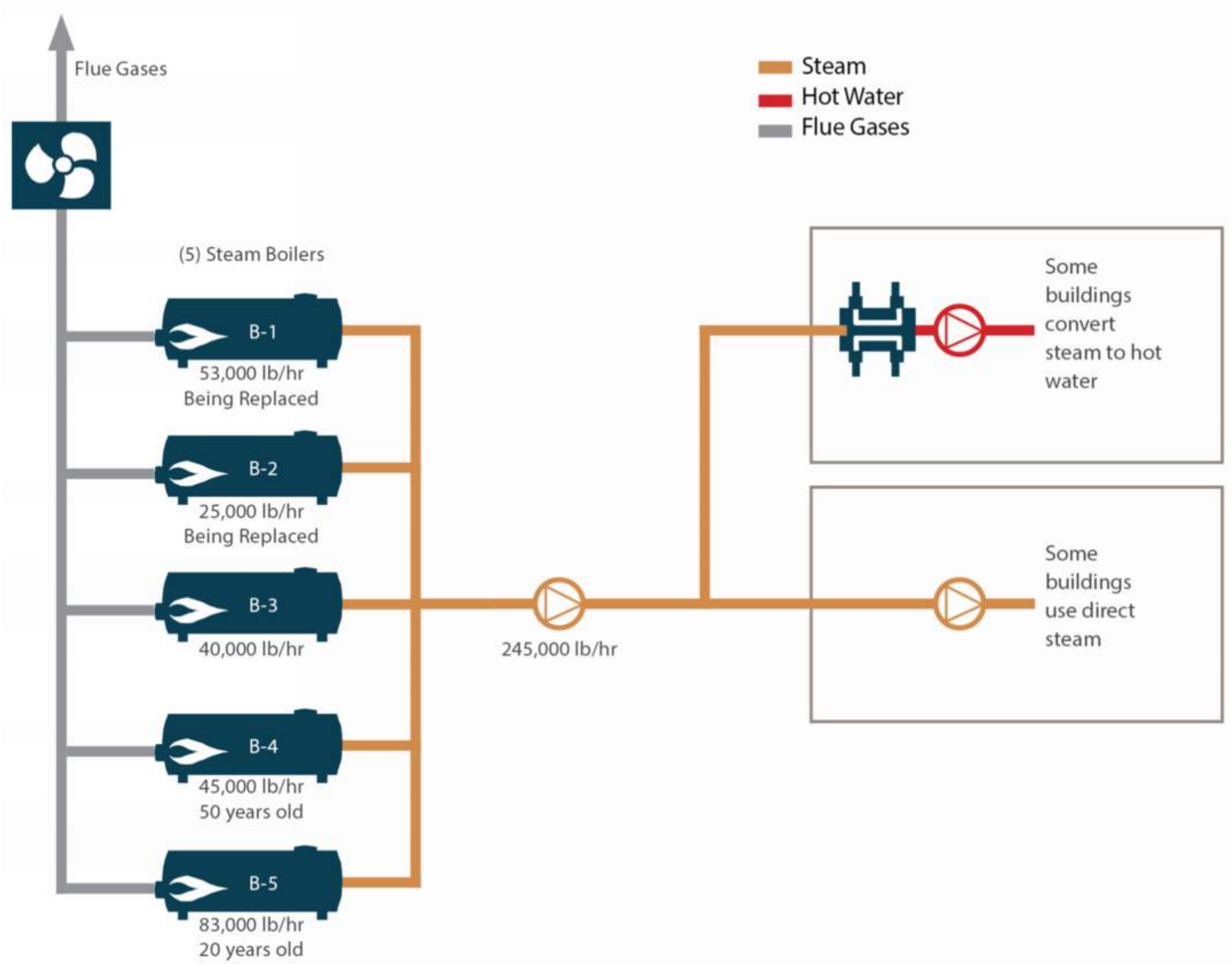


Figure 5: Diagram of Existing Campus Heating System

Campus Heating

Most of the campus (2.6 million sf) is served by the central steam heating plant at the Central Rozell Energy Plant. This plant consists of five (5) high-pressure steam boilers with a total capacity of 245,000 lb/hr. The boiler ages vary, and boilers 1 and 2 are in the process of being replaced with new gas-fired boilers. The highest observed steam load on campus was approximately 75,000 lb/hr. Steam is distributed to campus via the utilidor system. While some buildings have hydronic heating via steam to hot water converters, many buildings receive heating via direct steam coils. Steam condensate is pumped back to the central plant for collection, at an estimated return rate of 92%.

Figure 6 presents a diagram of the existing central cooling equipment as of 2024.

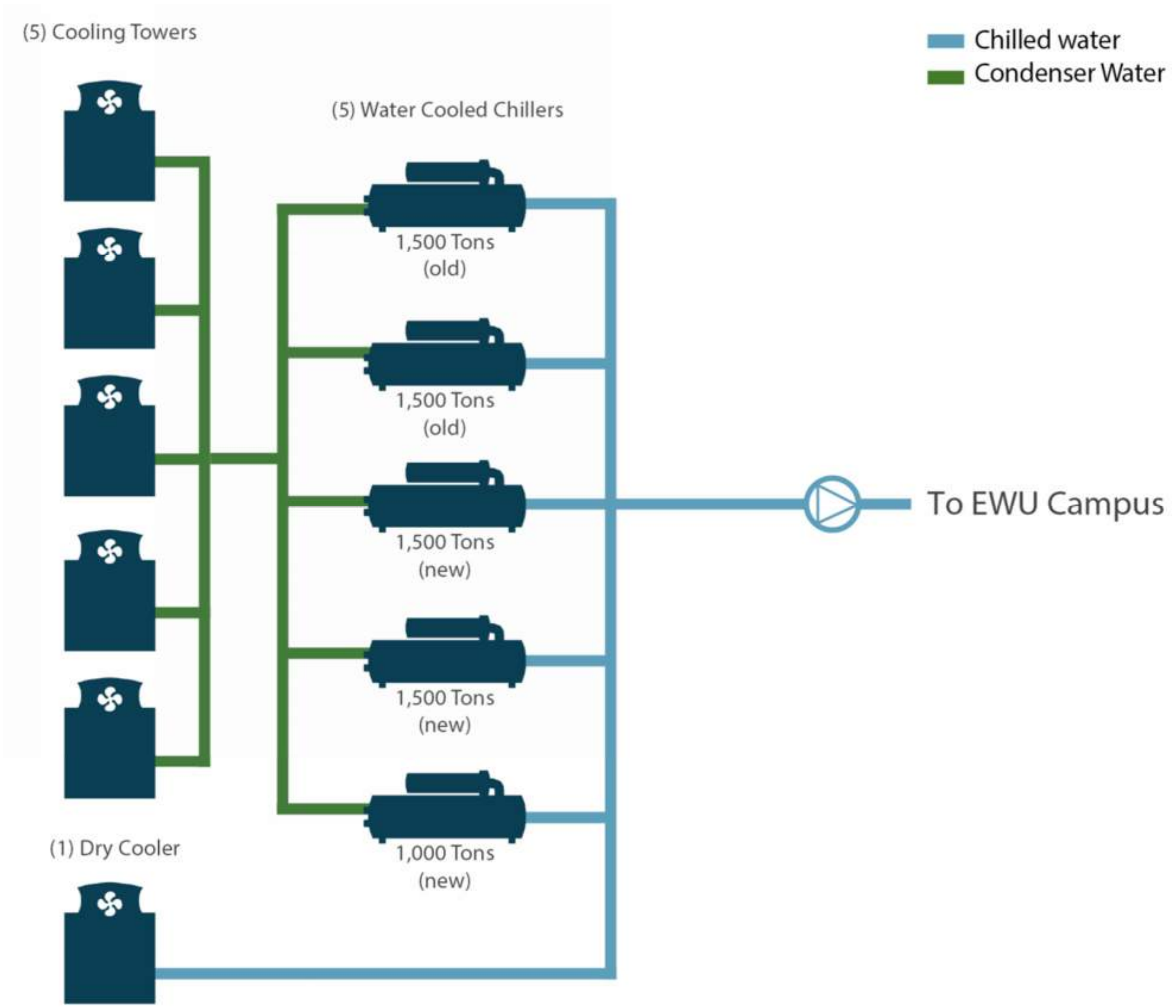


Figure 6: Diagram of Existing Campus Cooling System

Campus Cooling

Most of the campus (2.1 million sf) is served by the central chilled water system at the Central Rozell Energy Plant. Residence halls are the main exception, as most do not have cooling. This plant consists of five (5) water-cooled chillers and open draw-thru cooling towers for a total capacity of 7,000 tons. The chiller plant is in the process of several modernization and energy upgrades, including water-side economizers and variable speed chillers and pumps. The chillers are turned off October thru April, and winter cooling is provided by a separate dry-cooler unit, with glycol anti-freeze protection. The connected buildings do not have heat exchangers for isolation, and chilled water is typically fed directly into the building’s HVAC systems.

Campus Electrical Infrastructure

The existing campus electrical infrastructure at Eastern Washington University is powered via two service entrance points from two different City of Cheney Substations. Each service consists of a 1200A, 13.2kV metal enclosed switchgear served by feeders and fuses rated for 600A. Both services are located at Rozell and powered from two different utility substations - the 4 Lakes Substation and Turnbull Substation. Each of the two services feeds either of the two busses within a double-ended 1200A 13.2kV switchgear, which has a tiebreaker that is normally open. This switchgear provides distribution to the remainder of the campus.

Each service has the theoretical capacity to deliver a maximum of 11 MVA to the campus, for a total combined capacity of 22 MVA. Utility metering data was reviewed over the course of the year from May 2023 to April 2024 and the peak electrical demand was observed for both services. These values helped to determine the existing utilization of each of the electrical services. Significant capacity exists on both services to accommodate additional electrical load, and the campus loop is designed to allow for physical expansion on either end of the service switchgear busses. However, through coordination with the local utility it was determined that the total electrical load delivered to campus is limited further by the capacity of the upstream utility feeders and the utility substations. Due to these limitations, the total capacity that can be delivered to the campus is limited to roughly 10.5 MVA and the services are unlikely to be able to accommodate a significant increase in load without utility service upgrades.

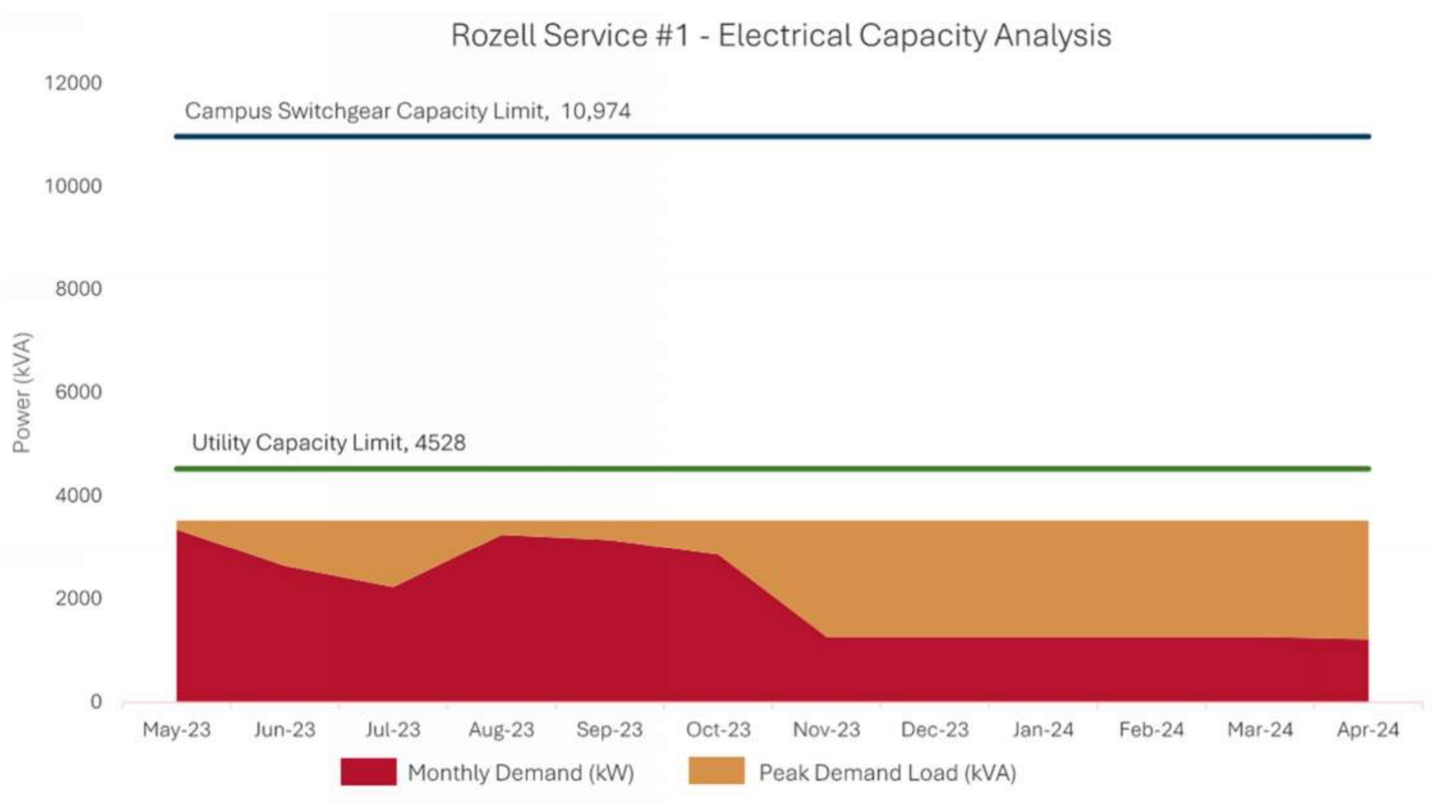


Figure 7: Rozell Service #1 Electrical Capacity Analysis

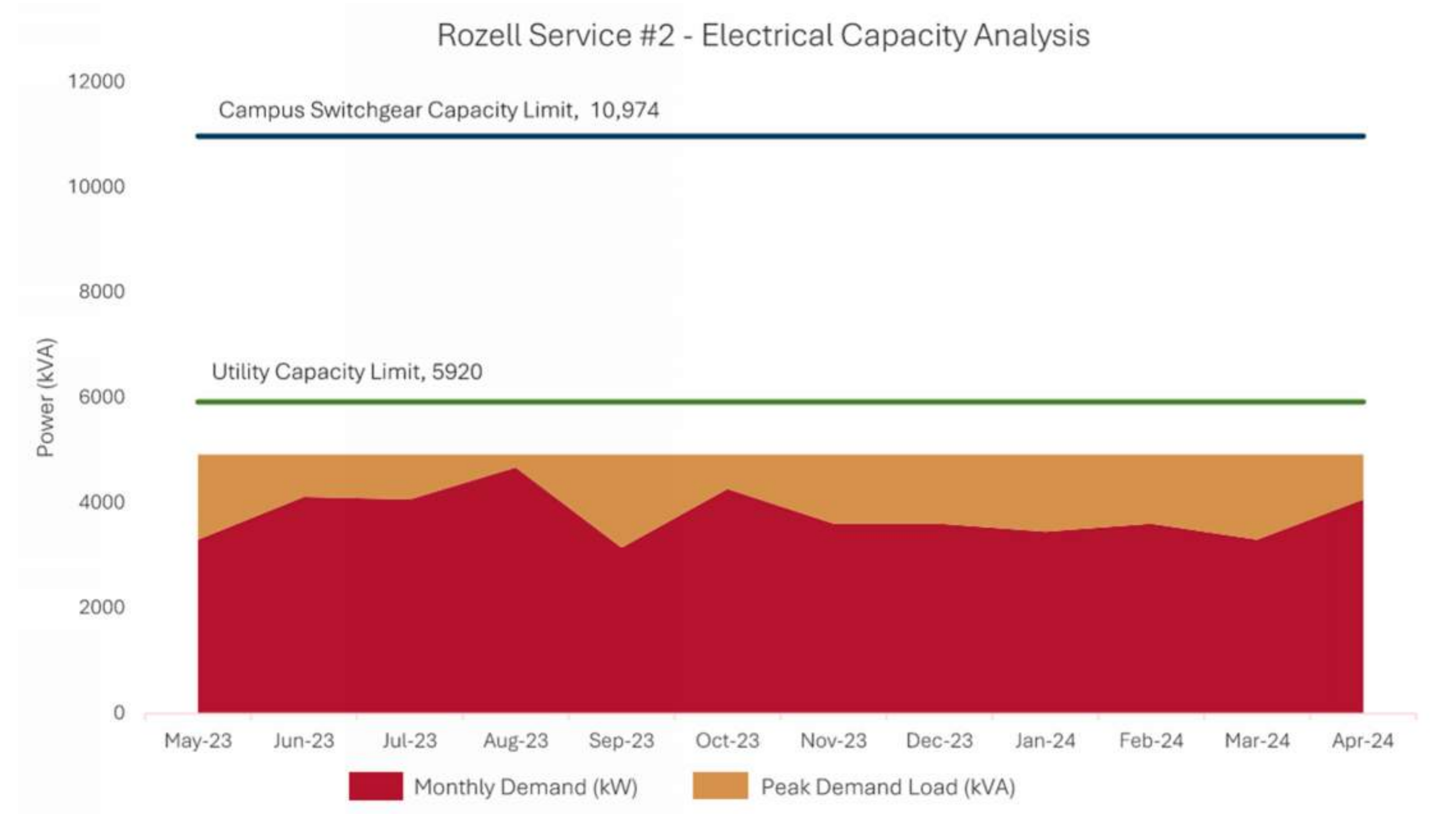


Figure 8: Rozell Service #2 Electrical Capacity Analysis

Section 3

Decarbonization Solutions – Energy Plant

Key Takeaways

- The study considered a wide variety of heat sources and sinks and qualitatively compared three overall system options. The recommended solution is open loop ground-source wells serving three nodal plants.
- Each nodal plant will contribute chilled and heating water to a district piping system. Nodes and distribution piping installation will be phased over time to align with funding and decarbonization goals.
- Each nodal plant will also be connected to the existing campus steam system for supplemental and backup heating.
- While the campus-wide electrical distribution system currently has capacity to accommodate some added loads, limitations on the utility-side will necessitate electrical upgrades for full deployment of this plan.

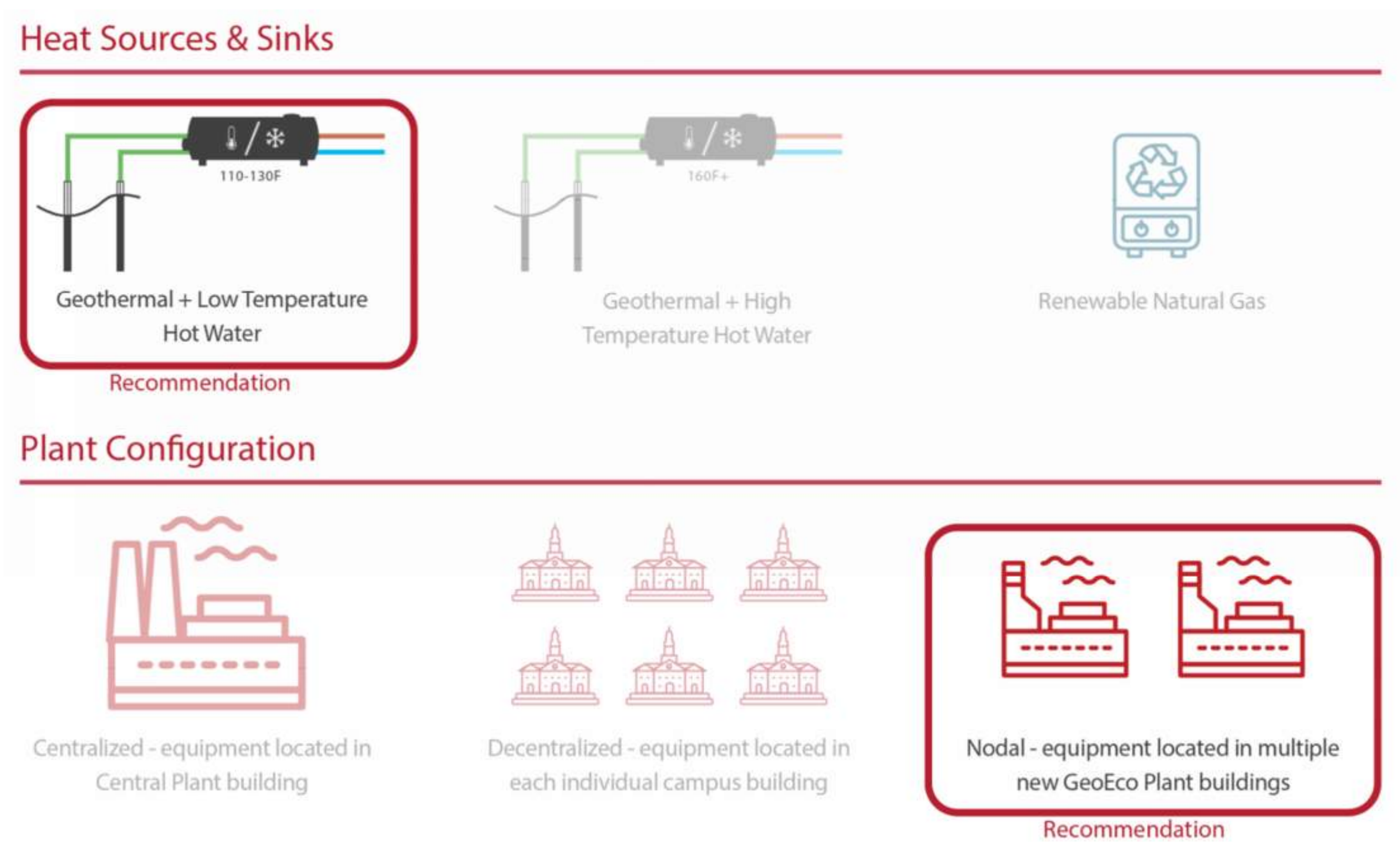
System Scoring Summary

As described in the following pages, several system options were considered for heat sources/sinks and plant configuration. For each system component, the options analysis answered the following key questions:

Heat Sources and Sinks: How will EWU generate heating and cooling?

Plant Configuration: Will the decarbonized system have a central location, or will it be dispersed across campus?

Based on this exercise, and with the approval of EWU, the preferred system is a nodal open-loop ground-source system.



System Scoring Criteria

Table 2 presents the scoring criteria and weightings used to determine the preferred system. These criteria were developed with EWU Construction, Planning, and Facilities groups input and consider the University's priorities and preferences.

Table 2: Relative Weights for Scoring Criteria

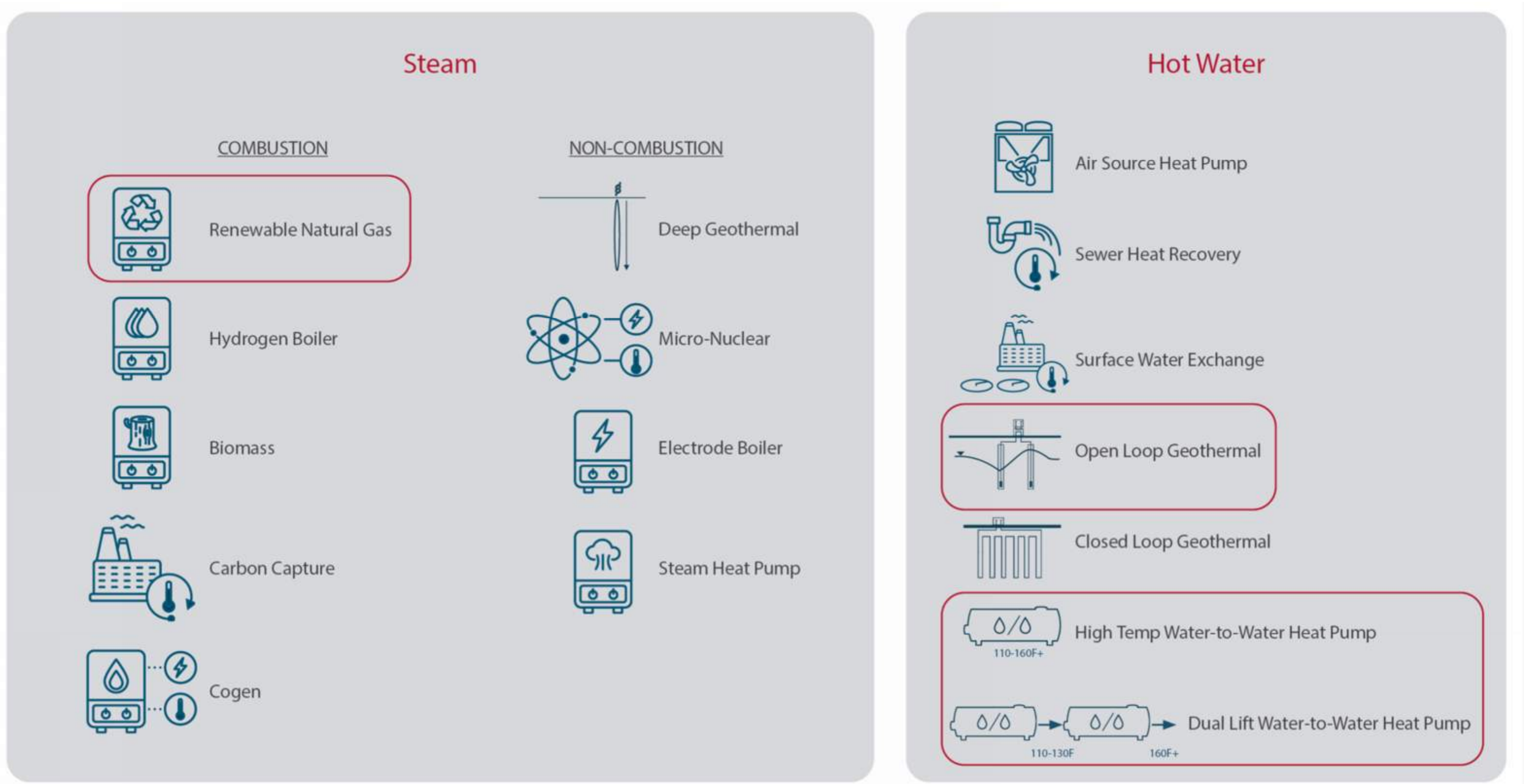
Scoring Variable	Weighting
First Cost	**30%**
Utility Cost	**20%**
Maintenance Cost	**20%**
Carbon Cost Effectiveness	**10%**
Teaching / Curriculum Opportunity	**20%**

System Considerations

Heating is currently provided by fossil fuel-fired steam boilers, which are a prime source of scope 1 carbon emissions. Since EWU receives electricity from a utility that is powered predominantly by hydropower, transitioning the gas-based system to an electrified system is a key strategy for decarbonization. The system options list below summarizes the systems considered for electrification of the EWU heating system. Qualitative scoring for three options is included on the next page, followed by a complete list of options with further context. **Based on this analysis, open-loop ground-source is the preferred electrified system. Note: this recommendation must be validated by favorable results from an open-loop ground-source test well.**

System Options

Systems that would maintain the steam distribution system, as well as those that would transition heating from steam to hot water were considered. In addition, the temperature of the hot water was considered, as different technologies have different capabilities. Based on guidance from EWU, the systems in red boxes in the figure below were compared qualitatively, as shown on the next page.



Low Temperature vs High Temperature Hot Water

When switching from steam to hot water the temperature of that water is a critical consideration. Many of EWU's buildings currently have mechanical systems with direct steam heating. These buildings will require more invasive mechanical system retrofits to switch from steam to hot water, and the retrofitted system should provide low temperature hot water. Other scenarios will need to be considered on a case-by-case basis.

Low Temperature Hot Water (LTHW)

- Least amount of mechanical plant equipment needed.
- Some existing hot water systems may be able to operate on lower temperatures, requiring minimal in-building upgrade. For those that can't, and for existing steam systems, LTHW may require significant in-building retrofits.
- Mandated for new construction buildings in Washington State.

High Temperature Hot Water (HTHW)

- Requires either two-stage heating systems (with two pieces of equipment), or high temperature heat pumps, which are an emerging technology.
- Does not usually require invasive retrofits to existing in-building mechanical systems.
- Of the buildings that currently have hot water, most operate with HTHW.

Decarbonization Solution | Heat Sources & Sinks Scoring

The heat source/sink analysis compared the relative merits of three systems qualitatively and scored them against performance criteria identified in collaboration with EWU stakeholders. Scoring is done on a scale of 1 to 5 and a higher score is better. Table 3 presents the results of the scoring analysis.

Table 3: Relative Scoring of Decarbonization Strategies

Geo + Low Temperature Hot Water (LTHW)	Geo + High Temperature Hot Water (HTHW)	Steam via Renewable Natural Gas
	Recommendation	
While low temperature hot water is the best-scoring option, most likely the solution will use a mix of low temperature and high temperature hot water, depending on existing building systems. A low temperature hot water system depends on the operating conditions of in-building heating systems, as some buildings may need extensive retrofit to accommodate a low temperature heating system.		
	Description	
Open loop geothermal with water-to-water heat pumps providing 110-130F hot water.	Open loop geothermal with water-to-water heat pump(s) providing 160F+ hot water. Bringing hot water up to high temperatures may be achievable with a single heat pump or may require two heat pumps in a dual-lift configuration.	Renewable natural gas (RNG) boilers to provide steam to existing systems. As it is currently written, HB 1390 only allows for 10% of annual heating to be provided by gas or electric resistance. Commerce has not yet provided guidance on alternative fuels.
	First Cost	
$$$$	$$$$	$
	Utility Cost	
$	$$	$$$$$
	Maintenance Cost	
$$$	$$$$	$$$$$
	Carbon Cost Effectiveness	
High	Medium	Low
	Teaching / Curriculum Opportunity	
High	High	Low
	Overall Score	
3.70	**3.10**	**2.20**
	Advantages	
- More efficient - Less electrical load - Fewer pieces of equipment - Provides cooling and heat recovery	- Fewer pieces of equipment - Avoids potentially expensive in-building retrofits - Provides cooling and heat recovery	- Familiar Technology - Avoids potentially expensive in-building retrofits
	Disadvantages	
- Will require some substantial/significant building retrofits to convert to LTHW - Assuming new pipes can't fit in existing tunnel, will require sitework to install new distribution piping.	- High temperature heat pumps are an emerging technology - Higher equipment first cost - Higher O&M costs - Dual-lift systems would need additional space - Assuming new pipes can't fit in existing tunnel, will require sitework to install new distribution piping.	- Current RNG price 5 to 7 times higher than natural gas. Price needs to come down significantly. - RNG supply is not currently mature. System is reliant on utility's ability to provide sufficient RNG. - Boiler System is a heating-only solution that offers no benefit to the central chilled systems. Does not allow for heat recovery. - High maintenance costs in the plant, distribution piping, and in-building systems.

Decarbonization Solution | Heat Sources & Sinks Technology Options

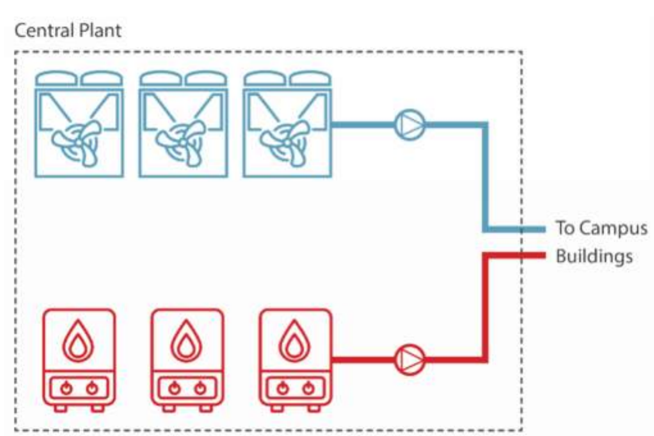
Heat can be introduced to the campus from a wide variety of possible sources via a wide variety of technology. Table 4 presents the options considered for the EWU campus and considerations for their applicability.

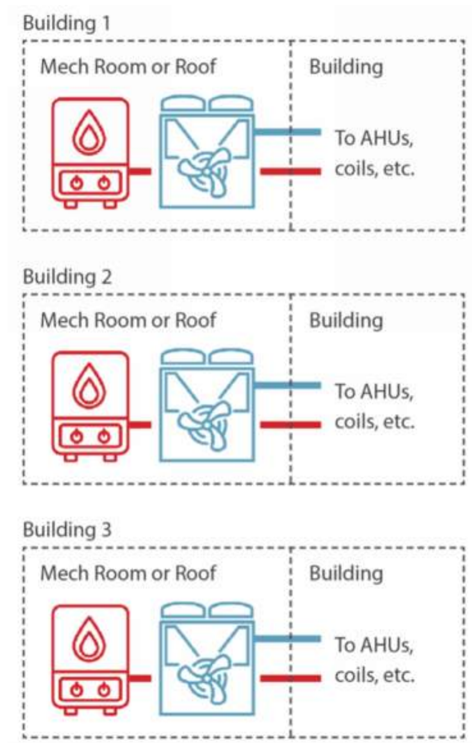
Table 4: Heating Technology Options

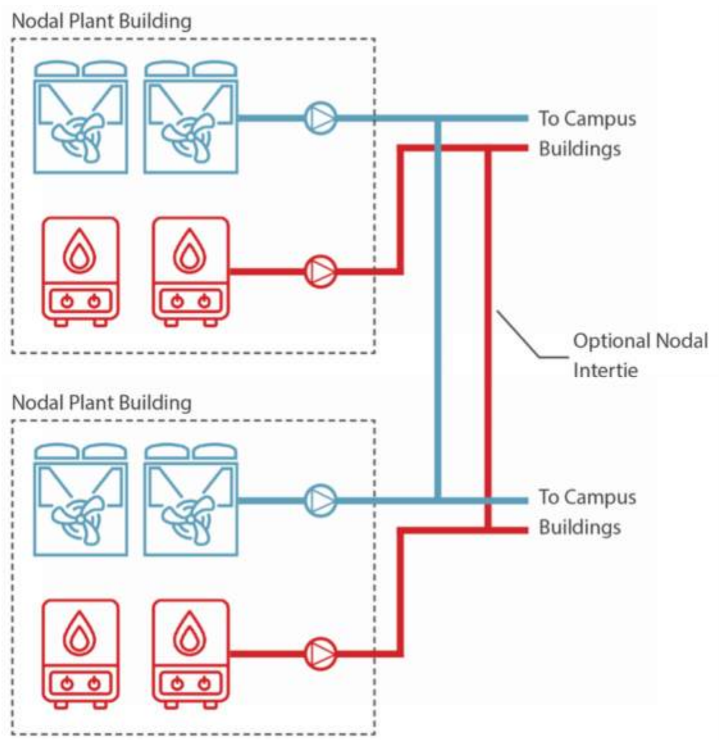
		Concept	Heating?	Cooling?	Suggested Action	Notes
Steam	Combustion	**Renewable Natural Gas Boilers**	Yes	No	Evaluate Qualitatively	Currently utility RNG market is not mature in local market. With HB 1589 passed, gas utilities may evolve in the near future. Limitation of current options puts resiliency at risk. Additionally, HB 1390 has not ruled on validity of alternative fuels that use combustion. Gasification of biomass is possible, but will be space intensive and have similar challenges as biomass boilers.
		Biomass Boilers	Yes	No	Fast Fail	Requires consistent supply, is labor-intensive, and requires large footprint for boiler feed. There is also debate as to whether biomass is carbon-free. Additionally, HB 1390 has not ruled on validity of alternative fuels that use combustion.
		Hydrogen Boilers	Yes	No	Fast Fail - Not At Scale Yet	Provides resiliency through hydrogen storage, but is not commercially viable at scale yet. CU Boulder is currently undertaking a pilot program for research purposes. Additionally, HB1390 has not ruled on validity of alternative fuels that use combustion.
		Cogeneration Boilers	Yes	No	Fast Fail	Provides campus resiliency though on-site power generation, and also reduces electrical load on City Utility. Burns fossil fuels to create heating, so cannot be used for HB 1390 compliance
		Carbon Capture	Yes	No	Pilot Project Underway	EWU was recently awarded grant funding to design and construct a carbon capture system for the existing fossil fuel-based steam boilers.
	Non-Combustion	**Deep Geothermal**	Yes	No	Fast Fail	Deep geothermal is possibly feasible, but requires further study and would most likely have a large first cost. It is currently more suited for utility scale.
		Micro-Nuclear	Yes	No	Fast Fail	Microreactors (5-10 MW) are currently in early stage of design/development. Won't be available until late 2020's/early 2030's at the earliest
		Electrode Boiler	Yes	No	Fast Fail - Not Allowed by 1390	Can only contribute 10% of annual heat input per HB 1390 requirements, not a solution on its own. Likely improves overall plant heating efficiency ~15-20%. EWU already evaluated this (before 1390) and found it too expensive.
Hot Water	High Temp	**Heat Exchange Source + High Temp Heat Pump (Single Lift)**	Yes	Yes	Evaluate Qualitatively	High-temperature heat pumps are a quickly emerging technology. While typically used for industrial applications, manufacturers are quickly providing new models with better performance for higher education applications.
		Low Temp HW (LTHW) + Secondary Heat Pump (Dual Lift)	Yes	Yes		1st step heating can be any LTHW concept (e.g. geothermal). 2nd step heat from LTHW to HTHW achieved via water-to-water heat pumps (WWHP) in each building or at certain nodes. In-building WWHPs limited by available mech room space and electrical capacity.
		Steam Heat Pump (Single Lift)	Yes	No	Future Consideration	Similar to High Temp heat pump, these are being seen first in industrial applications and emerging quickly. Development for commercial applications is slightly lagging behind high temp heat pumps.
		Low Temp HW + In-Building Elec Boiler (Dual Lift)	Yes	No	Future Consideration	In-building electric heating is not limited by HB 1390. 1st step heating can be any LTHW concept (e.g. geothermal). 2nd step heat from LTHW to HTHW achieved via electric boiler/heating in each building or at certain nodes. In-building electric heating limited by available mech room space and electrical capacity. Electric boilers are significantly less efficient than WWHPs and aren't ideal for two-step controllability. Could be considered in future phase if mechanical room space becomes a limiting factor for the WWHP option.
	Low Temp	**Open Loop Geo-Exchange**	Yes	Yes	Evaluate Qualitatively	EWU conducted a geothermal evaluation with system options, which found the aquifer beneath campus could have capacity to meet campus heating/cooling needs. The findings of the evaluation are based on computer modeling and available data, and need to be validated via geothermal test well.
		Closed Loop Geo-Exchange	Yes	Yes	Fast Fail - Open Loop is More Viable	More costly per unit capacity than open loop and requires significantly more site area. Viable option for sites that don't have a viable open loop aquifer.
		Air-to-Water Heat Pump	Yes	Yes	Future Consideration	Could be included for peaking heating/cooling loads in campus system, depending on aquifer viability and total system cost. Viable option for standalone buildings not connected to campus system.
		Surface Water Exchange	No	Yes	Fast Fail	EWU campus is not directly adjacent to a significant body of water.
		Campus Sewer Heat Recovery	Yes	Yes	Fast Fail	Campus sewer line would have insufficient flow to make a meaningful impact. Makes more sense for sites that are near very large citywide sewer lines. Otherwise, the added maintenance and cost are not worth the energy recovered.

Plant Configuration Options

The plant configuration dictates where the heating/cooling equipment is located and the general quantity of pieces of equipment. The existing heating/cooling system is centralized, with all the main equipment located in the Rozell Energy Plant. The main tradeoffs between a centralized plant and several smaller distributed plants include maintenance, phasing, and space requirements. **The nodal system is preferred, largely due to its flexibility and phase-ability, as well as the opportunity to showcase decarbonization to the campus.**







Centralized

A centralized system houses all heating and cooling equipment in a single location. This allows for larger equipment with less maintenance but is not ideal for phasing and flexibility.

Decentralized

A decentralized system houses all heating and cooling equipment in individual buildings. All buildings are independent of a central loop and mechanical equipment is standalone. In essence, the existing central heating/cooling loop would be abandoned. While this reduces overall pumping energy, it also significantly increases maintenance costs. It is also difficult from a constructability perspective since existing buildings don't typically have extra space or electrical capacity for large new equipment. This approach is also challenging to integrate with ground-source as it is impractical for each building to have its own wells.

Nodal

A nodal system houses all heating and cooling equipment in several smaller distributed plant buildings, meaning new plant buildings would be built across campus. This approach is a blend of centralized and decentralized, and each plant building would house mid-size mechanical equipment.

Decarbonization Solution | Plant Configuration Scoring

The plant configuration analysis compared three options for the distribution of central plant equipment and distribution of thermal energy across the campus. These options were scored against performance criteria identified in collaboration with EWU stakeholders, and the results are shown in Table 5. Scoring is done on a scale of 1 to 5 and a higher score is better.

Table 5: Relative Scoring for Plant Distribution Strategies

Centralized	Decentralized	Nodal
	Recommendation	
The nodal configuration is recommended as it has many of the benefits of the centralized system while being flexible and well-suited to phasing.		
	Description	
This option is most similar to the existing central plant configuration, with all major mechanical equipment located in one central location.	This option would employ major pieces of mechanical equipment (i.e. water-to-water heat pumps, air-source heat pumps) at each building to produce heating and cooling at the building level.	This option would utilize multiple "nodal" plants, each with major mechanical equipment, spread across campus.
	First Cost	
$$	$$$$$	$$$
	Utility Cost	
$	$$	$
	Maintenance Cost	
$	$$$$	$$
	Carbon Cost Effectiveness	
High	Medium	High
	Teaching / Curriculum Opportunity	
Medium	Low	High
	Overall Score	
4.10	**2.00**	**4.20**
	Advantages	
- Fewer pieces of major mechanical equipment mean less maintenance - Fewer wells - Reduced well maintenance - Reduced infrastructure costs - Doesn't require new buildings across campus	- Doesn't require new or modified distribution piping - Buildings can be built and operated independently of each other - No new dedicated building for plant equipment needed	- Better for phasing than central plant - Flexible to evolving campus plans - Lower conveyance piping costs for geothermal - Lower likelihood of overdesigning wellfields - Provides opportunity to showcase decarbonization
	Disadvantages	
- Higher conveyance piping costs for geothermal - Fewer pieces of equipment mean less redundancy/resiliency - Harder to phase, resulting in larger capital requests - New hot water distribution piping across campus has high campus impact	- Higher O&M costs from increased quantity of equipment - Reduced Space/roof area in buildings to fit mechanical equipment - Most likely requires substantial electrical upgrades at most buildings - Abandons existing infrastructure - No heat sharing	- More maintenance than central system - Requires small new plant buildings and new hot water distribution piping

Total Heat Pump Capacity & HB1390 Compliance

HB1390 requires the fully implemented district energy system to meet 90% or more of the total annual heating load from non-fossil fuel and non-electric resistance sources. Annual heating energy use calculations were performed to estimate heating demand throughout the year. These calculations are used to determine the total capacity of the water-to-water heat pumps that, over the course of the calendar year, will ensure this performance requirement is met. Annual heating demand met by heat pump is illustrated by the orange area in Figure 9. The unshaded area under the red curve represents the annual heating load to be met by the existing gas-fired steam boilers. **Meeting the 90% of heating demand requirement will require a total of 4,200 tons (50,400 MBH) of heat pump capacity deployed between the three expected nodes.**

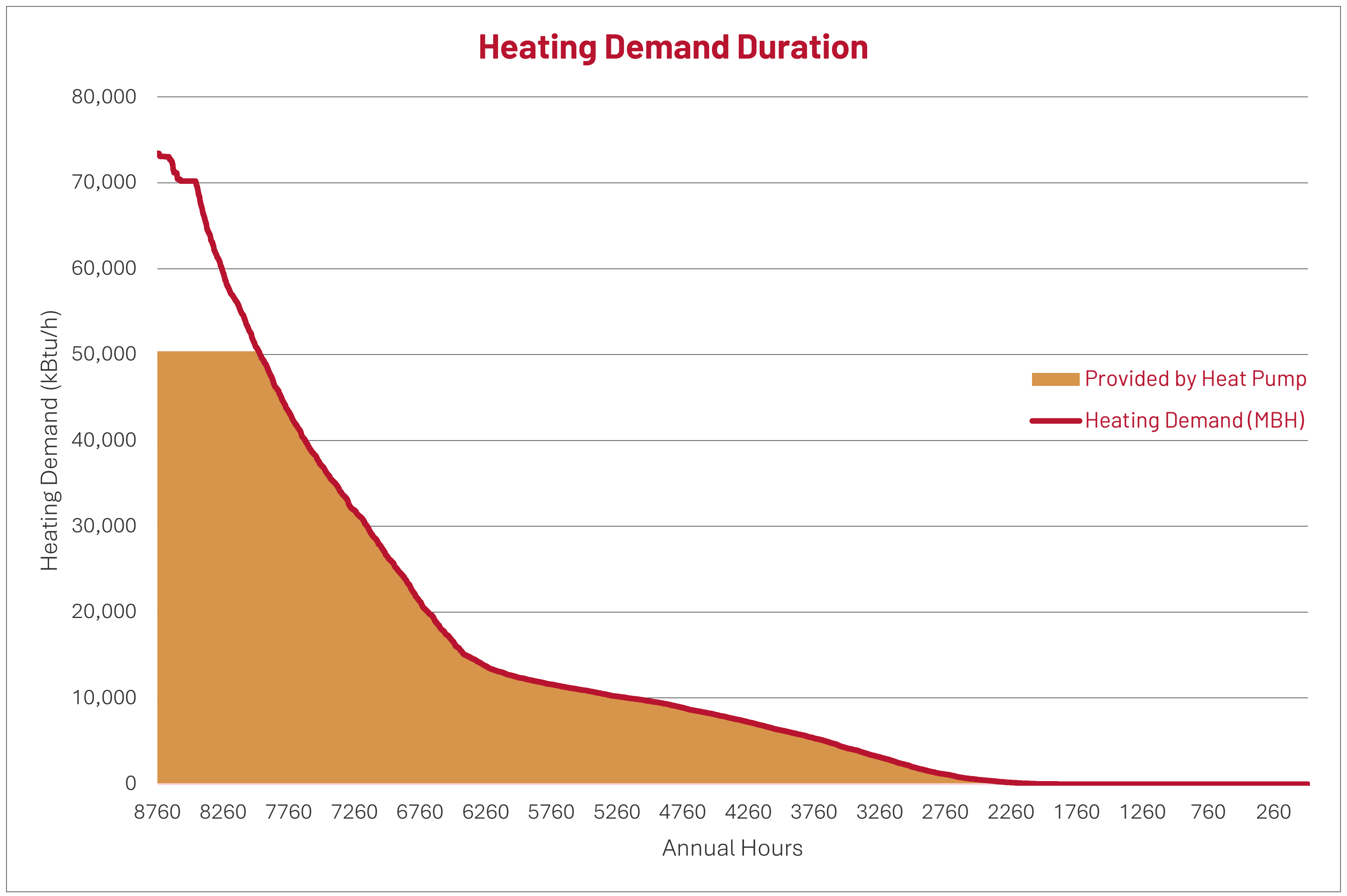


Figure 9: Annual heating demand duration, sorted by magnitude.

Node Size & Phasing

The 2025-2027 Capital Request included planning and funding for the first proposed GeoEco Plant (GEP), which included a total of 1,600 tons of heat pump capacity. The remaining two proposed GEP nodes are planned considering this capacity, the additional buildings connected over time, and total heat pump capacity required by HB1390.

Table 6: Approximate GEP Node Capacity & Infrastructure

Nodal Capacity					
Type	Units	Node 1	Node 2	Node 3	System Total
Total Ground-Source Heat Pump Capacity	Tons	1,600	1,600	1,000	4,200
	MBH	19,200	19,200	12,000	50,400
Quantity of 1,000ft Ground Wells**	#	10	10	6	26
Electrical Demand Allowance*	kVA	3,140	3,140	1,962	8,242
Supplemental Steam Capacity	MBH	25,000	25,000	25,000	75,000

*The electrical loads in this table only include the added load at the GEP's themselves. Additional in-building electrical loads are not included in this number and are discussed in the next section.

**Includes both extraction and injection wells.

The capacities noted in this plan are preliminary in nature and present a starting point for planning and funding. The capacity and specific mix of equipment and thermal energy sources should be revisited in more detail during the design phase of each node. In addition, more detailed analysis of the buildings expected to connect to each node will also be needed at the time of development. Campus-wide metering is under investigation and will help understand the minimum necessary size and cost for the future node infrastructure and equipment. The first GEP will serve as a living lab and detailed trending can be used to help inform the future GEP nodes. Furthermore, nodes can be designed and built with only a portion of their ultimate expected capacity available on day one, allowing for more flexible financing and/or better alignment with other campus construction projects.

Backup & Supplemental Heating Type & Capacity

As noted previously, the proposed design for each GEP includes shell & tube heat exchangers to accommodate injecting heat from the existing campus steam system into the new district heating system. The existing campus steam boilers have significant remaining life and are expected to remain in service throughout the implementation of the decarbonization plan. The existing steam boilers are natural gas fueled and have a rated thermal efficiency of approximately 75%-82% depending on part load and combustion air temperature. At the time of this report, EWU is undertaking an innovative carbon capture system for installation on the existing boilers, helping to reduce the carbon footprint of the fossil fuel plant.

During implementation, the campus steam system will continue to provide steam to buildings across the campus, ensuring minimal disruption to campus activities while decarbonization projects implemented.

GeoEco Plant (GEP) Node Design

As described in the 2025-2027 Capital Request report, each GeoEco Plant(GEP) provides both heating hot water and chilled water to a subset of campus buildings. Each GEP performs three primary functions:

1. Thermal energy exchange with open-loop groundwater wells, alternately referred to as ground-source heating and cooling.
2. Thermal energy exchange between campus heating hot water and campus chilled water, alternately referred to as "simultaneous heating & cooling".
3. Distribution of supplemental heating provided by the campus steam system, primarily for periods of extreme peak demand or during maintenance periods.

A preliminary GEP concept design was developed for the 2025-2027 Capital Request, for pricing and planning purposes. Additional design and development of the plant will take place during the detailed design phase. The preliminary concept design for each GEP includes the following elements:

- 6-pipe water-to-water heat pumps to accommodate thermal energy exchange between the ground, or between the heating and chilled water loops. At time of this report, these are commonly provided as modular units with scroll compressors.
- Buffer tanks on each hydronic loop interfacing with heat pump equipment
- Primary heating and chilled water pumps serving the heat pump equipment
- Secondary heating and chilled water pumps distributing heating and chilled water to the campus buildings
- Plate and frame ground-water heat exchangers separating ground water from heat pump source water
- Primary ground water pumps contained inside the individual ground water wells
- Secondary heat pump source water pumps, between the heat exchanger and the heat pumps
- Shell & tube steam heat exchangers to provide heat from campus steam into heating water distribution piping
- Steam condensate pumps returning to the campus steam plant
- Extensive valving, bypass, and controls infrastructure

Typically, all pumps should be selected in an N+1 configuration and piped in parallel, and all heat exchangers should be piped in parallel and include excess capacity to accommodate maintenance periods. Additional considerations for more detailed design should revisit the following considerations:

- Water-to-water heat pumps utilizing natural refrigerants (such as CO_2 or ammonia). This shift may reveal operating cost efficiencies and reduced Global Warming Potential (GWP)
- Limit the use of modular equipment with scroll compressors in favor of larger centrifugal or screw compressor ground-source heat pumps equipped with changeover valves to accommodate switching between heat recovery or ground-source operating modes. This shift may reveal capital and operating cost efficiencies.
- Individual primary pumps serving individual pieces of equipment. This may reveal capital cost efficiencies depending on the total capacity, quantity of equipment, and turndown.
- Phasing of equipment within each GEP based on the anticipated connections to campus buildings. This may allow for flexibility in the deployment of capital cost.

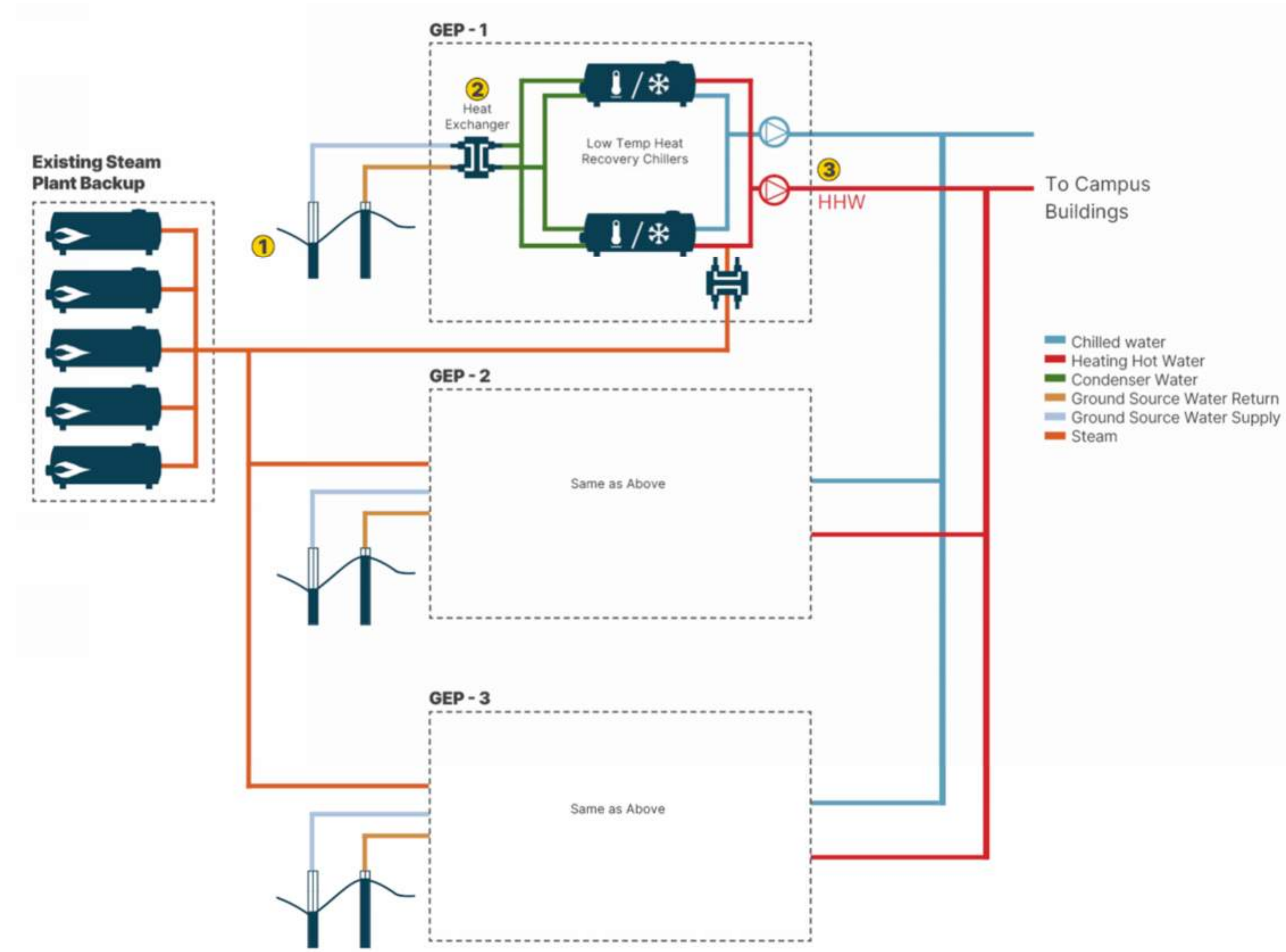


Diagram Legend and Notes

1. Open-loop geothermal - each geothermal node requires at least one extraction well and at least one injection well.
2. Nodal plants - three nodes are shown here per the current design.
3. Heating hot water -- hot water temperature may vary by building, depending on existing systems.

Figure 10 GEP Configuration

Distibution Piping Upgrades

Harnessing ground-source energy to each nodal plant and distributing that thermal energy campus-wide will require an extensive distribution network of direct-buried hydronic piping, both from the ground-source wells to the plants, and from the plants to the buildings. The current steam and chilled water piping, most of which is distributed through a utilidor, will remain in place and in service with minor modifications based on the recommended building conversions (described in Section 4). This study assumes the new low temperature hot water piping will not physically fit in the existing utilidor and will be direct-buried in parallel to the utilidor.

Ground-source Well Piping

The installation of groundwater piping from each open-loop ground-source well back to the respective GEP node is largely driven by the total heat pump capacity provided by each node (as listed previously in Table 6). This piping is typically uninsulated, SDR13 HDPE piping rated for direct burial. The following lengths and sizes are provided as a basis for piping and are aligned with quantities identified in the 2025-2027 Capital request. These estimates will vary based on further design exercises supporting the development of each node.

Groundwater Piping Allowances					
Type	Size	Node 1	Node 2	Node 3	System Total
Groundwell to GEP, Uninsulated (linear ft)	12"	6,000	6,000	4,000	16,000

Hydronic Distribution Piping

The installation of low temperature hot water piping from each GEP to the campus buildings will occur in concert with the development of each node and will be driven by the approximate quantity and location of campus buildings to be connected. This piping is typically pre-insulated, SDR13 HDPE piping rated for direct burial. Based on the layout shown in Figure 11, the following lengths and sizes are provided as a basis for piping. These estimates will vary based on further design exercises supporting the development of each node. Minimal new chilled water piping will be needed, and the existing piping will remain in use.

Hydronic Distribution Piping Allowances					
Type	Size	Node 1	Node 2	Node 3	System Total
Campus Distribution, Uninsulated (linear ft)	12"	3,383	6,596	2,543	12,522
	10"	1,412	842	694	2,948
	8"	1,242	645	443	2,330
	6"	1,543	688	353	2,583
	4"	514	229	118	861

Figure 11: New Distribution Piping Deployment by Node

Campus Electrical Infrastructure Impacts

The ability of the existing campus power system to serve the added electrical load of the GeoEco Plants and the associated building upgrades was studied to determine if campus upgrades are required.

Utility Coordination

The design team met with the local electric utility, City of Cheney, three times during the time period of November 2024 through January 2025 to coordinate the anticipated increase in electrical load over the course of the project timeline. The team also met with the supplier of power to City of Cheney, Bonneville Power Administration, once on December 6th, 2024 to review any anticipated impacts to their infrastructure. The projected increase in demand due to decarbonization efforts was communicated to the City of Cheney and their electrical engineer studied the impacts this increase would have on their infrastructure.

It was determined that there are several limitations on the utility infrastructure currently serving the campus services that limit the ability to increase the electrical demand beyond 1-2MVA above what is currently being utilized. These limitations include voltage regulation concerns at the existing substations, feeder capacity issues with the existing overhead lines to the campus, and existing substation capacity. These issues greatly limit the campus's ability to increase the demand on the electrical grid and became the limiting factor in serving the increased electrical load from existing campus infrastructure.

To address these concerns, the utility indicated that a new utility substation and service point to the campus will be required to serve the new campus demand once it increases beyond the utility limit. Rough costs were provided by the utility for the portion of the new substation construction that would be passed onto the university, but these conversations were preliminary and should be discussed further.

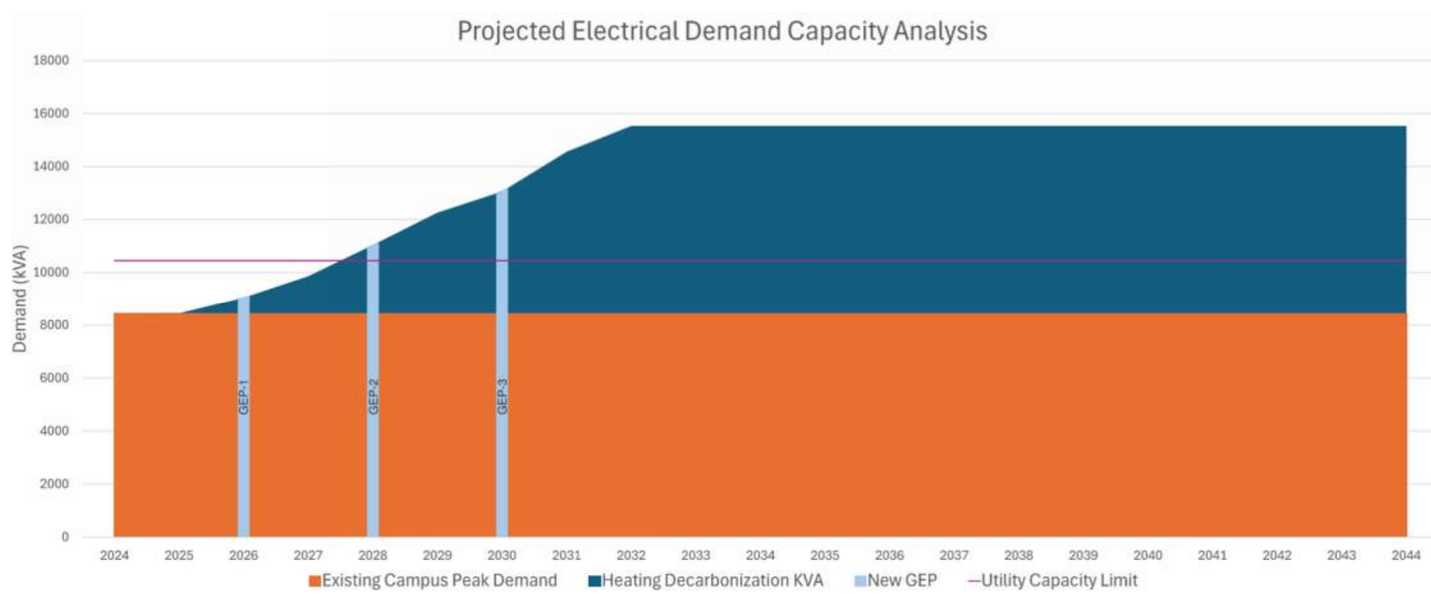


Figure 12: Projected increase in electrical demand on the campus infrastructure associated with the proposed decarbonization plan.

Campus Electrical Capacity

The existing electrical infrastructure on the campus has a peak demand load of 8.5MVA and a total capacity of 22MVA. Per discussions with the City of Cheney, the campus cannot accommodate more than 10.5 MVA. Based on the projected increase in electrical demand due to the decarbonization plan, this limit will be exceeded after the construction of GEP-1 in 2026. To address this issue with utility capacity, the utility has indicated that a new utility substation is required.

Campus Utility Upgrades

The proposed solution to increase the available capacity of the campus electrical system is to provide a third service with a new feeder from the new utility substation. The new electrical service to the campus is to be sized at 600A to match the existing services. Further coordination will be required to determine the location of the new service and substation.

Nodal Plant Design

Each nodal plant will be provided with two 480Y/277V 3-Phase electrical services: one 3000A service to serve the majority of the plant equipment and building loads, and one 1000A service dedicated to the groundwater extraction well loads. Each of these services will be powered from the existing campus loop via a pad-mounted transformer from a single pad-mounted switch.

Each nodal plant will be provided emergency power via an emergency backup diesel generator, sized to serve life-safety equipment and select mechanical equipment. The majority of the plant equipment will not be backed up by the generator and would not operate in the case of a power outage.

Energy Metering Strategy

Campus-wide energy use is currently trended via the two electricity utility meters and the natural gas utility meter, which are used to calculate the campus-wide EUI. While building-level energy metering is not required for 1390, the campus currently employs building-level energy metering, which meters and trends each energy source entering each building. This system is currently under investigation to ensure meters and trending data are functioning properly. Gas/energy use trending from the backup plant will be achieved via the existing utility gas meters. The backup heating plant usage will be trended via the gas utility meter serving the existing central plant.

Energy Storage

Solar and battery storage are currently under consideration via a campus-wide study. Any additions of solar and/or battery storage would further reduce campus EUI, carbon emissions, and utility costs, provided any energy produced is also consumed on the campus and not delivered back to the grid.

Section 4

Decarbonization Solution – Building Conversions

Key Takeaways

- In-building space heating and domestic water heating systems across campus will need to be upgraded for compatibility with the ground-source heating system. The buildings that currently have cooling are already compatible with ground-source cooling.
- Nine focus buildings were studied in detail to determine the upgrades needed in each. These results were extrapolated across the campus to determine the upgrades needed for all buildings currently connected to the steam system.
- None of the focus buildings were found to require significant electrical service upgrades.

Building Renovations

Achieving decarbonization at EWU hinges on ensuring that the existing buildings can utilize thermal energy from the proposed nodal ground-source plants. To evaluate the campus-wide costs for converting buildings over time, a two-step approach was used. The first step included detailed evaluation of the renovations and associated costs at the nine (9) buildings proposed to connect to GEP-1 (hereafter referred to as “focus buildings”). The second step included extrapolating the results from the detailed evaluation to the remaining buildings on campus (hereafter referred to as “campus-wide deployment”). The conversion costs of the focus buildings, along with costs of energy efficiency measures in each building, were included in the 2025-2027 capital request. The exact implementation of building renovations is dependent on the funding received. Figure 13 below shows the focus buildings considered for connection to GEP-1. The specific renovations required are discussed in the following pages.

Figure 13: Focus Buildings Studied for Connection to GEP-1

Mechanical Decarbonization Strategies

Table 7 and Table 8 below describe the recommended strategies for decarbonizing the space heating and DHW systems. The proposed in-building solutions assume low temperature hot water (LTHW) is provided to the buildings at approximately 120°F. The appendices include detailed descriptions of the existing systems in each building.

Table 7: Space Heating Decarbonization Strategies

Decarbonization Strategy	Existing Mechanical System	Proposed Mechanical System	Applies To
HHW Strategy 1 High Temp Hot Water (HTHW) Double Lift	Many heating coils served by HTHW.	Add in-building water-to-water heat pump to boost district energy LTHW supply up to 180°F to serve existing coils. No coil replacement.	JFK - Kennedy Library SUT - Sutton Hall
HHW Strategy 2 Coil Replacement	Relatively few heating coils. All coils are either direct steam OR HTHW.	Replace coils and piping with LTHW. Replace existing fans with new fan walls.	CEB - Computer & Engineering CMC - Communications HUS - Huston Hall MUS - Music Building RTV - Radio & TV
HHW Strategy 3 - Hybrid Coil Replacement & Double Lift	Direct steam heating coils AND HTHW coils.	Replace steam coils with LTHW piping and coils. Add in-building water-to-water heat pump to boost district energy LTHW supply up to 180°F to serve existing HTHW coils	ART - Art Building THE - Theater

Table 8:Domestic Hot Water Decarbonization Strategies

Decarbonization Strategy	Strategy Description	Applies To
DHW Strategy 1 Existing Electric DHW Heater	Maintain existing electric DHW heater(s), tanks(s) and infrastructure.	CMC - Communications MUS - Music Building RTV - Radio & TV SUT - Sutton Hall THE - Theater
DHW Strategy 2 DHW Double Lift Heat Pump	Add an in-building DHW heat pump and storage tank to use district energy LTHW and maintain DHW @ 140°F. Existing steam converter to be left in place for optional backup.	JFK - Kennedy Library CEB - Computer & Engineering HUS - Huston Hall ART - Art Building

Building Decarbonization Strategy #1

Mechanical

Strategy 1 will add an in-building water-to-water heat pump to boost district energy LTHW and supply up to 180°F to serve the existing coils. All existing coils will remain, which will limit the scope of work to the main mechanical room near the existing steam converter. The existing steam converter will be left in place for backup to allow for sizing the booster WWHP for 60-80% of the true building peak load, saving cost, while still delivering ~90-95% of annual building heat. The hot water reset schedule should be optimized to maintain the lowest temperature HW necessary to provide heat to the building.

Domestic Hot Water

If the building currently utilizes electric boilers or electric tank style heaters for domestic hot water, they are to remain in place. If campus steam is used to heat domestic hot water, a new in-building DHW heat pump and storage tank will be added to use district energy LTHW and maintain DHW @ 140°F. The existing steam converter to be left in place for optional backup and can be removed if campus steam becomes obsolete.

Application

Strategy 1 is applicable for buildings without direct steam use, where there exists a large quantity of hot water coils requiring High Temperature Hot Water. The Kennedy Library (JFK) is shown in Figure 14, but this strategy can also be applied to Sutton Hall (SUT) which has similar systems.

Additional Considerations

While this option is still highly efficient, it is slightly less efficient than other options since it requires additional energy to boost the hot water to a higher temperature. This is accounted for in the energy/carbon analysis and first costs discussed later in this report. Further study of the actual building loads will impact how this strategy is implemented. The continued use of steam provides flexibility and resiliency while decarbonized systems are implemented and commissioned. In some cases, it may be possible to decommission the steam system once the decarbonized system is operational and demonstrates the ability to meet the building loads. Depending on the timeline for implementation, new technologies in high-temperature heat pumps may eliminate the need for building-level water-to-water booster heat pumps.

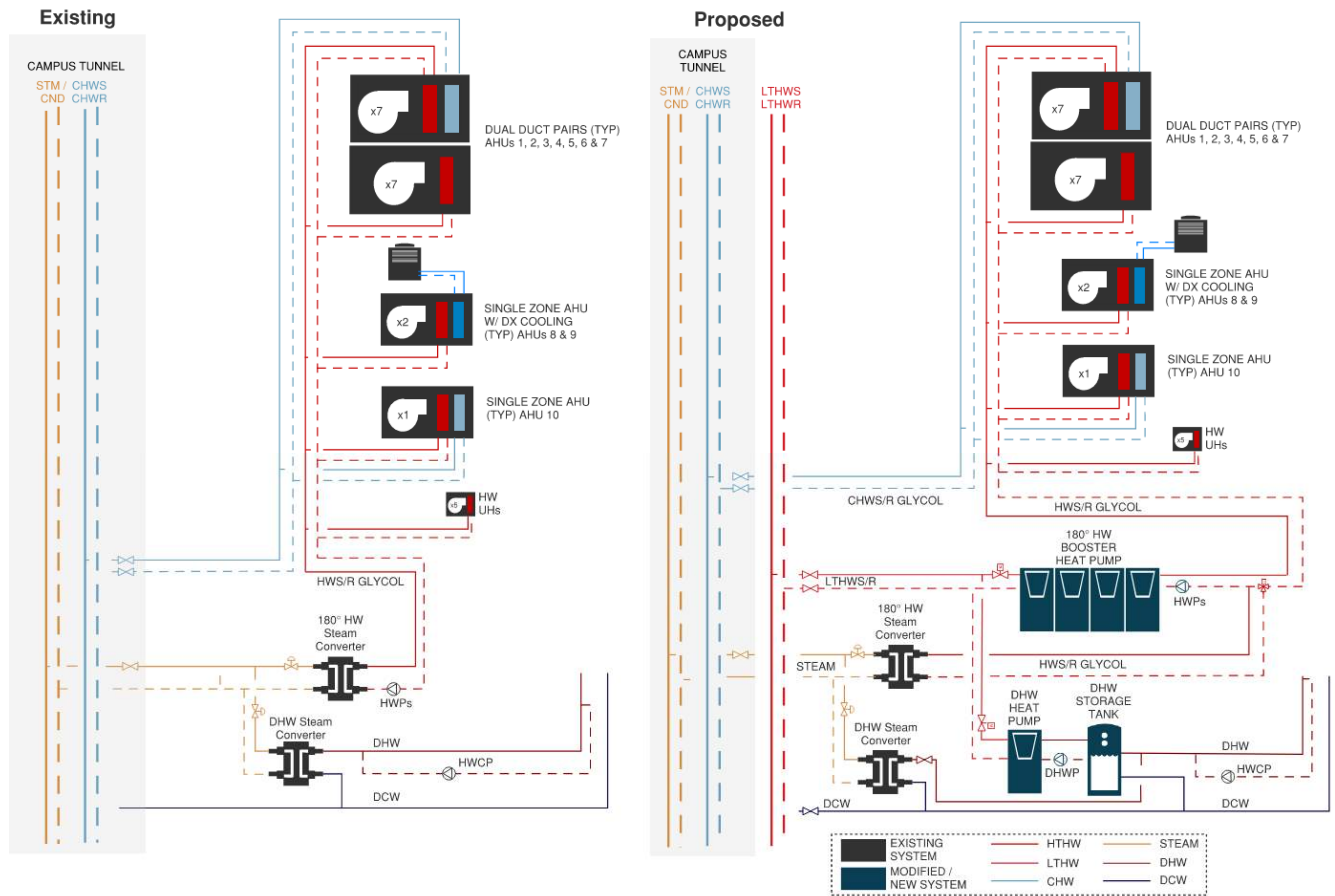


Figure 14: Strategy 1 Mechanical Diagrams

Building Decarbonization Strategy #2

Mechanical

Strategy 2 will replace all steam coils and piping with low temperature hot water (LTHW) coils and piping to utilize district energy LTHW. A new heat exchanger will be necessary to isolate building LTHW loop from district LTHW loop and allow for glycol freeze protection in the building loop. To allow both space and capacity for new LTHW coils, the fans will need to be replaced with new fan walls.

Domestic Hot Water

If the building currently utilizes electric boilers or electric tank style heaters utilizes for domestic hot water, they are to remain in place. If campus steam is used to heat domestic hot water, a new in-building DHW heat pump and storage tank will be added to use district energy LTHW and maintain DHW @ 140°F. The existing steam converter to be left in place for optional backup and can be removed if campus steam becomes obsolete.

Application

Strategy 2 applies to buildings that have steam heating and limited or no terminal systems with coils. These systems are ideally suited to change out steam coils and piping and serve with district energy LTHW. The Computer & Engineering Building (CEB) is shown in the diagram below, but this strategy can also be applied to Communications (CMC), Huston Hall (HUS), Music (MUS) and the Radio & TV Building (RTV), which have similar systems.

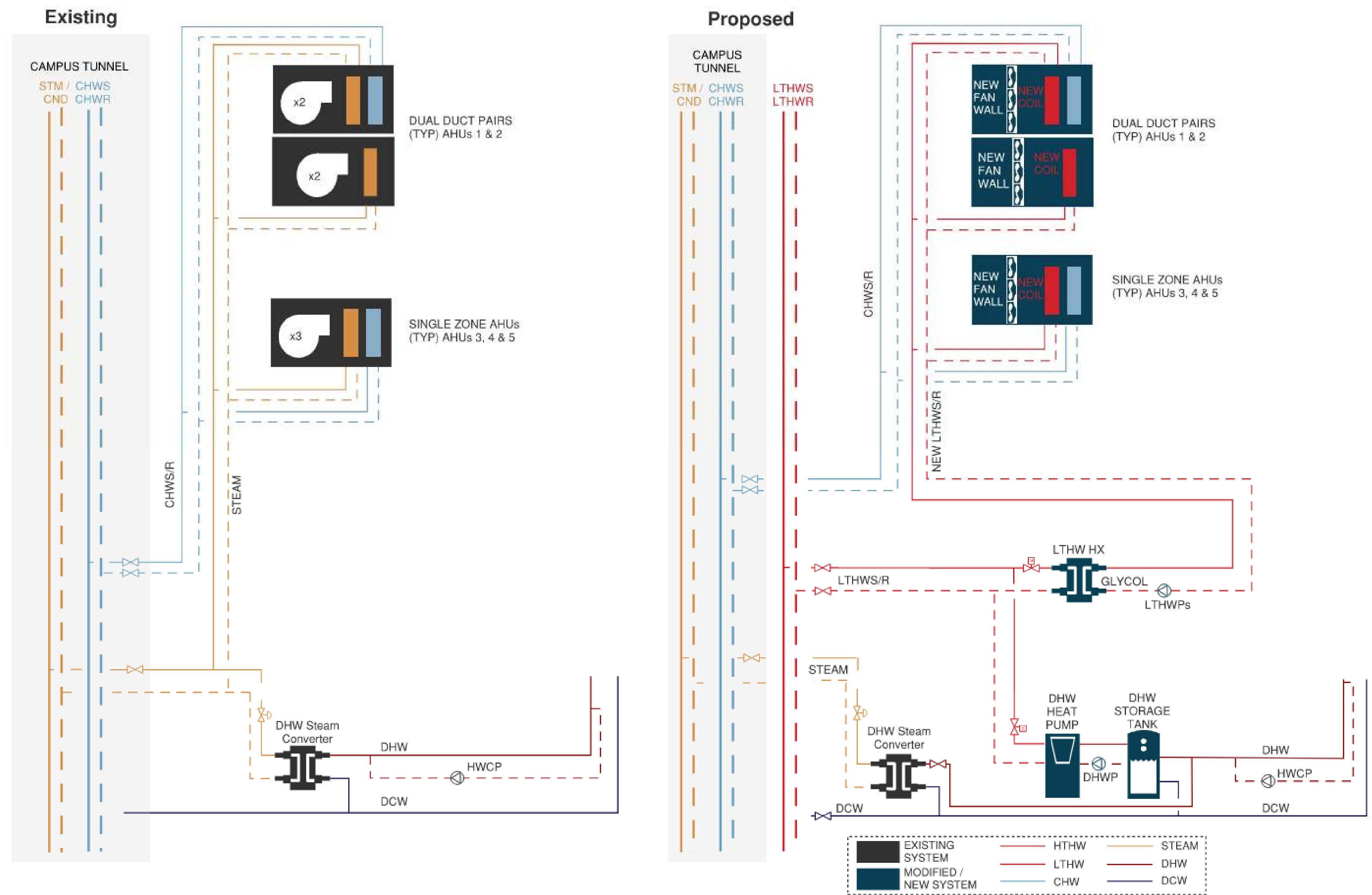


Figure 15: Strategy 2 Mechanical Diagrams

Building Decarbonization Strategy #3

Mechanical

Strategy 3 will replace large steam coils in air handlers with low temperature hot water (LTHW) coils to utilize district energy LTHW. To allow both space and capacity for new LTHW coils, the air handler fans will need to be replaced with new fan walls. A new heat exchanger will be necessary to isolate the building LTHW loop from the district LTHW loop and allow for glycol freeze protection in the building loop.

Terminal heating systems will be served by a new in-building water-to-water heat pump to boost district energy LTHW up to180°F HW. The hot water reset schedule should be optimized to maintain the lowest temperature HW necessary to provide heat to the building. The existing steam converter to be left in place as back up to allow for sizing the booster WWHP for 60-80% of the true building peak load, saving cost, while still delivering ~90-95% of annual building heat.

Domestic Hot Water

If the building currently utilizes electric boilers or electric tank style heaters utilizes for domestic hot water, they are to remain in place. If campus steam is used to heat domestic hot water, a new in-building DHW heat pump and storage tank will be added to use district energy LTHW and maintain DHW @ 140°F. The existing steam converter to be left in place for optional backup and can be removed if campus steam becomes obsolete.

Application

While this option is still highly efficient, it is slightly less efficient than other options since it requires additional energy to boost the hot water to a higher temperature. This is accounted for in the energy/carbon analysis and first costs discussed later in this report. Strategy 3 applies to buildings that have steam heating and hot water terminal heating. These systems are ideally suited to change out steam coils and serve directly with district energy LTHW but will also require an in-building heat pump to maintain the terminal heating hot water loop temperature up to 180°F. The Art Building (ART) is shown in the diagram below, but this strategy can also be applied to the Theater Building (THE), which has similar systems.

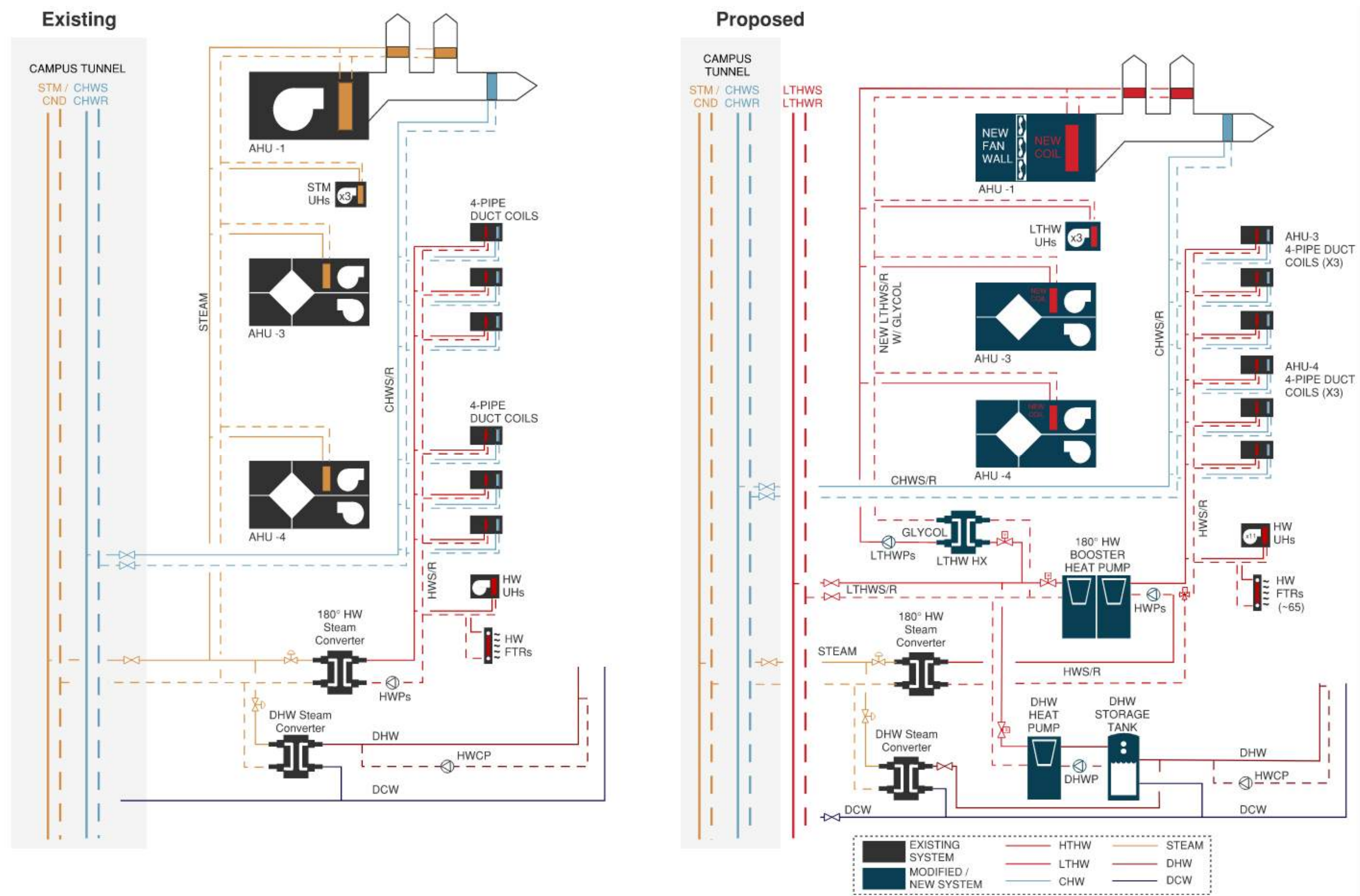


Figure 16: Strategy 3 Mechanical Diagrams

Summary of In-Building Infrastructure

The available electrical capacity and the increased load required to accommodate the proposed upgrades was reviewed at the nine focus buildings. Metering data was reviewed at each of the buildings, where available, and compared to the capacity as determined from the building service nameplate ratings. **All buildings reviewed were found to have sufficient electrical capacity available and can accommodate the proposed mechanical revisions without requiring a new electrical service.**

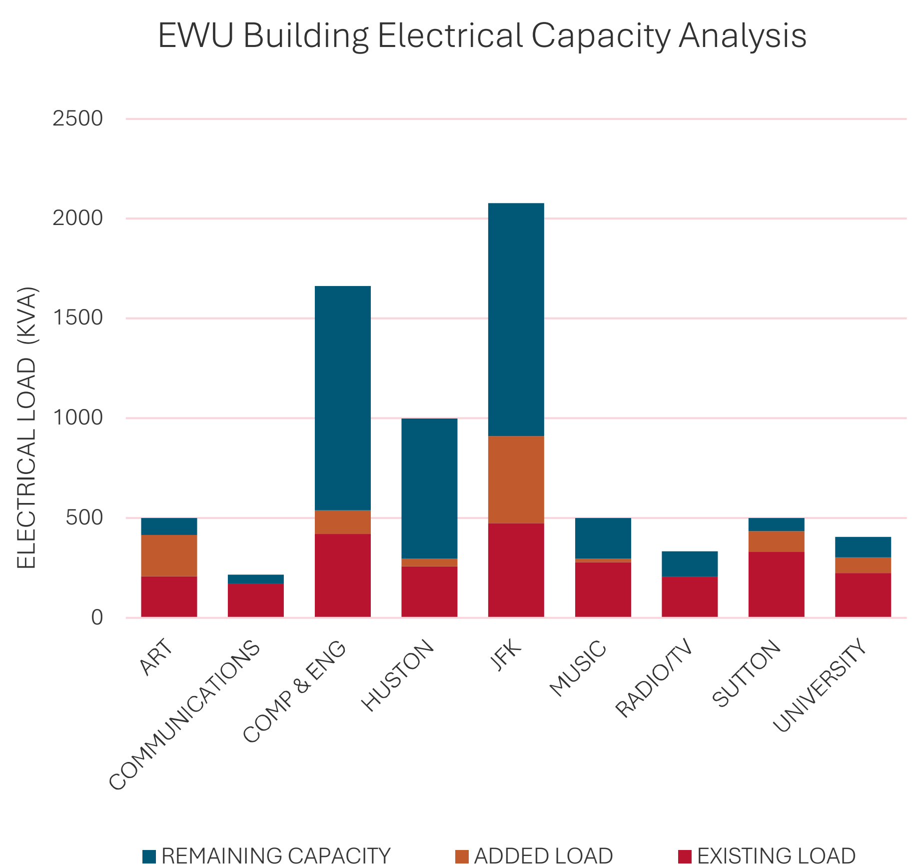


Figure 17: Summary of Existing Electrical Capacity Analysis

Table 9: Summary of Building Electrical Services

Description			Existing Electrical Summary			Decarbonized Electrical Summary			
	Building	Building Area [s.f.]	Existing Electrical Service	Total Electrical Capacity (KVA)	Existing Demand Load (KVA)	Added Electrical Load (KVA)	Total Decarbonized Electrical Load (KVA)	Percentage of Electrical Capacity Utilized	Electrical Service Upgrade Required? (Y/N)
JFK	JFK Library	124,496	2500A, 480Y/277V,3Ø	2078	473	436	910	44%	N
CEB	Computing & Engineering Building	98,476	2000A, 480Y/277V,3Ø	1663	419	119	538	32%	N
MUS	Music Building	47,618	600A, 480Y/277V,3Ø	499	278	18	296	59%	N
THE	University Theater	41,164	1125A, 208Y/120V,3Ø	405	223	79	303	75%	N
ART	Art Building	34,469	600A, 480Y/277V,3Ø	499	208	207	415	83%	N
SUT	Sutton Hall	31,927	600A, 480Y/277V,3Ø	499	331	102	433	87%	N
HUS	Huston Hall	27,424	1200A, 480Y/277V,3Ø	998	258	38	295	30%	N
CMC	Communications Building	19,289	600A, 208Y/120V,3Ø	216	169	0	169	78%	N
RTV	Radio/TV Building	16,980	400A, 480Y/277V,3Ø	333	205	0	205	62%	N

Summary of In-Building Renovations

The costs listed below are "all in" costs, reflective of the total cost EWU can expect when implementing these projects. They include the building conversion strategies listed below as well as the energy efficiency measures listed in Table 11. They are ROM costs (+/- 50%) for budgetary purposes and will need to be refined during the next stage of development/implementation. The appendix provides additional cost information.

Table 10: Building Conversion Summary and ROM Costs.

	Building	Building Area [s.f.]	Existing System	Decarbonized System	Decarbonized System Cost
JFK	JFK Library	124,496	HVAC: High Temp Hot Water serving mostly dual duct systems DHW: Electric DHW Heaters & Steam to DHW Converter	HHW Strategy 1 - Booster Heat Pump DHW Strategy 2 - Booster Heat Pump	$2,800,000
CEB	Computing & Engineering Building	98,476	HVAC: Direct steam serving dual duct systems and large single zone AHUs DHW: Steam to DHW converter	HHW Strategy 2 - Steam to LTHW Coil Replacement DHW Strategy 2 - Booster Heat Pump	$4,600,000
MUS	Music Building	47,618	HVAC: Direct steam serving air handlers and unit heaters DHW: Electric DHW Heaters	HHW Strategy 2 - Steam to LTHW Coil Replacement DHW Strategy 1 - Existing Electric DHW	$2,400,000
THE	University Theater	41,164	HVAC: Direct steam serving air handlers and HTHW serving terminal heating DHW: Electric DHW Heaters	HHW Strategy 3 - Hybrid Coil Replacement and Dual Lift Heat Pump DHW Strategy 1 - Existing Electric DHW	$1,900,000
ART	Art Building	34,469	HVAC: Direct steam serving air handlers and HTHW serving terminal heating DHW: Electric DHW Heaters & Steam to DHW converter	HHW Strategy 3 - Hybrid Coil Replacement and Dual Lift Heat Pump DHW Strategy 2 - Booster Heat Pump	$3,300,000
SUT	Sutton Hall	31,927	HVAC: HTHW serving air handlers and radiators DHW: Electric DHW Heaters	HHW Strategy 1 - Booster Heat Pump DHW Strategy 1 - Existing Electric DHW	$900,000
HUS	Huston Hall	27,424	HVAC: Direct steam serving air handlers DHW: Steam to DHW converter	HHW Strategy 2 - Steam to LTHW Coil Replacement DHW Strategy 2 - Booster Heat Pump	$1,700,000
CMC	Communications Building	19,289	HVAC: Direct steam serving air handlers DHW: Electric DHW Heaters	HHW Strategy 2 - Steam to LTHW Coil Replacement DHW Strategy 1 - Existing Electric DHW	$1,100,000
RTV	Radio/TV Building	16,980	HVAC: Direct steam serving air handlers DHW: Electric DHW Heaters	HHW Strategy 2 - Steam to LTHW Coil Replacement DHW Strategy 1 - Existing Electric DHW	$1,100,000

Summary of Energy Efficiency Measures – Focus Buildings

In addition to the building conversions allowing the existing buildings to connect to the new low temp hot water loop, the energy efficiency measures below are recommended for implementation in the nine focus buildings. While these measures can occur independently of the decarbonization conversions, they should happen concurrently to capture complementary benefits. Similar measures can also be implemented in the remaining buildings as they are converted and will need to be evaluated at that time.

Table 11: Energy Efficiency Measures by Building

Energy Efficiency Measure	Strategy Description	Applies to	
Lighting Upgrade	Savings is a result of decreased power draw of LED lamps versus fluorescent lamps	JFK - Kennedy Library CEB - Computer & Engineering HUS - Huston Hall SUT - Sutton Hall ART - Art Building	MUS - Music Building THE - Theater Building RTV - Radio & TV CMC - Communications Building
Lighting Controls	Room- or luminaire-based occupancy sensors will reduce lighting runtime. Recommend installing in study rooms, conference rooms, restrooms, etc..	JFK - Kennedy Library CEB - Computer & Engineering HUS - Huston Hall SUT - Sutton Hall ART - Art Building	MUS - Music Building THE - Theater Building RTV - Radio & TV CMC - Communications Building
Window Upgrade	Energy savings is a result of reduced heat loss through energy efficient windows	ART - Art Building MUS - Music Building	
Demand Control Ventilation (DCV)	DCV automatically reduce ventilation intensity during off-peak hours, saving energy. Consists of sensors and controllers that adjust ventilation based on indoor air quality (CO2)	JFK - Kennedy Library MUS - Music Building	
Damaged Duct / Coil Connections	Savings will be a result of decreased heat loss from AHU at damaged ductwork as well as water savings from leaking coil(s).	THE - Theater Building CMC - Communications Building	
Constant Volume to Variable Volume Fans and Pumps	Savings result from ability to throttle pumps, fans, and valves when viable. Increased ability for zone control and scheduling.	ART - Art Building	
Air System Testing and Balancing	Process of measuring, adjusting, and verifying HVAC systems to ensure they are functioning effectively and efficiently.	CEB - Computer & Engineering	
Unoccupied Turndown Schedule	Unoccupied turndowns will result in reduced heating/cooling load as well as reduced fan energy.	JFK - Kennedy Library HUS - Huston Hall SUT - Sutton Hall	ART - Art Building MUS - Music Building RTV - Radio & TV

Decarbonization Solution | Campus-Wide Building Conversion Deployment

Selection of Campus-Wide HVAC Retrofits

The remainder of buildings across campus were assigned one of the three main strategies for HVAC decarbonization retrofits shown in Table 12.

HVAC strategy 1 is applied to buildings that have a large quantity of medium or high temperature heating water coils. This strategy will install a secondary water-to-water heat pump to boost district energy water to medium or high temperature heating water. A secondary heat pump is preferred as the additional cost of replacing all the coils is expected to exceed the costs for an additional piece of equipment.

HVAC strategy 2 is applied to buildings that only have steam coils or buildings that have a small quantity of medium or high temperature heating water coils. This strategy will replace all heating coils with new low temperature hot water coils. The costs to replace the limited number of coils is expected to be less than the costs for an additional piece of equipment to boost heating water temperature.

HVAC strategy 3 is applied to buildings that have a mix of centralized steam coils and a large quantity of distributed medium or high temperature heating water coils. This strategy will replace the steam coils with low temperature hot water coils and install a secondary water-to-water heat pump to boost district energy water to medium or high temperature heating water. This strategy is intended to replace steam coils or centralized heating water coils where possible but provide medium to high temperature heating water to numerous terminals throughout the building.

There are two notable exceptions to these three strategies: Martin/Williamson Hall which, once renovated, will primarily heat with low temperature heating water, and the Grounds Storage Building which is small and not connected to the central plant.

While building electrical infrastructure was evaluated for the nine focus buildings, it was not evaluated for this extrapolation effort. **The project costs in this study assume the existing electrical infrastructure can accommodate any added electrical loads from new mechanical equipment. This assumption will need to be vetted during detailed design before implementation.**

Nine buildings have been excluded from the decarbonization plan as shown on the rightmost column in the table. The Washington State Digital Archives, State Patrol Crime Lab, and EWU Children's Center are accounted for when determining campus loads and GEP sizing; however, the costs for converting those buildings is not included in this study.

Appendix D contains additional information, including building size, target implementation year and system heating capacities.

Table 12: EWU Buildings by HVAC Decarbonization Strategy

HVAC Strategy 1: Boost WWHP No Steam Large number of coils		HVAC Strategy 2: Replace Coils All steam coils Small number of coils		HVAC Strategy 3: Hybrid Coils & WWHP Limited / Centralized Steam Coils Distributed and/or Terminal HHW		Outside of Project Scope (Costs not Included)	
CHN	Cheney Hall	ALB	Albers Court	ART	Art Building	Under Consideration in Future Plans (Existing Systems Remain)	
HAR	Hargreaves Hall	AQT	Aquatics Building	PEA	P.E. Activities Building	DRY	Dryden Hall
ISC	Interdisciplinary Science Center	CMC	Communications Building	PEC	P.E. Classrooms Building	ISL	Isle Hall
JFK	JFK Library	CEB	Computing & Engineering Building	PAT	Patterson Hall	LAH	Louise Anderson Hall
KGS	Kingston Hall	DRE	Dressler Hall	PUB	Pence Union Building	MOR	Morrison Hall
SUT	Sutton Hall	HUS	Huston Hall	SNR	Senior Hall	STR	Streeter Hall
HVAC Exception 1: Direct LTHW		JTF	Jim Thorpe Fieldhouse	SNY	Snyamncut Hall	CAD	Cadet
Set up for LTHW		MUS	Music Building	TAW	Tawanka Commons	Not Owned by EWU	
MAR	Martin Hall	PAV	Pavilion (Reese Court)	THE	University Theater	ARC	Washington State Digital Archives
WLM	Williamson Hall	PRC	Pearce Hall			WSP	Washington State Patrol Crime Lab
HVAC Exception 2: Electric Only		RTV	Radio/TV Building			Under 20,000 sf	
Not connected to central plant		SCI	Science Building			ECC	EWU Childrens Center
GSB	Grounds Storage Building	SHO	Showalter Hall				
SUR	Surbeck Services	URC	University Recreation Center				

Selection of Campus-Wide DHW Retrofits

The remainder of buildings across campus were assigned one of four domestic hot water strategies for domestic hot water decarbonization retrofits as shown in Table 13. The first two strategies were developed for the focused buildings, with two additional strategies needed to accommodate campus wide deployment.

DHW Strategy 1 leaves the existing DHW systems in place and applies to all buildings where DHW heaters are already electrified and do not need to be upgraded for decarbonization purposes. DHW strategies 2, 3 or 4 are more efficient solutions. It is recommended that as these systems reach the end of their useful life, each individual building should be evaluated at that time to see which alternative solution should be applied.

DHW Strategy 2 applies to buildings with a large DHW load that don't need a fast recovery rate. This solution includes low temperature hot water preheat from the district energy loop while adding an additional water-to-water heat pump to boost the temperature to 140°.

DHW Strategy 3 applies to residential or recreational buildings where a faster recovery rate is needed. This solution includes low temperature hot water preheat from the district energy loop while adding an additional electric DHW heater to boost the temperature to 140°.

DHW Strategy 4 applies to buildings with a relatively small DHW load, and a slower recovery rate is tolerable. This solution provides an air source heat pump hybrid hot water heater.

While building electrical infrastructure was evaluated for the nine focus buildings, it was not evaluated for this extrapolation effort. **The project costs in this study assume the existing electrical infrastructure can accommodate any added electrical loads from new domestic water heating equipment. This assumption will need to be vetted during detailed design before implementation.**

Buildings not listed in Table 13 are not included in the decarbonization study for the reasons shown in Table 12. The Washington State Digital Archives, State Patrol Crime Lab, and EWU Children's Center are accounted for when determining campus loads and GEP sizing; however, the costs for converting those buildings is not included in this study.

Table 13: EWU Buildings by DHW Decarbonization Strategy

DHW Strategy 1: Existing EHW to Remain Already Decarbonized		DHW Strategy 2: New LTHW Preheat and WWHP Larger DHW Load Lower Recovery Rate		DHW Strategy 3: New LTHW Preheat & Elec DHW Residential & Recreation High Recovery Rates		DHW Strategy 4: Hybrid ASHP DHW Smaller DHW Load Lower Recovery Rate	
CMC	Communications Building	ART	Art Building	ALB	Albers Court	CHN	Cheney Hall
GSB	Grounds Storage Building	CEB	Computing & Engineering Building	AQT	Aquatics Building	HAR	Hargreaves Hall
JFK	JFK Library	HUS	Huston Hall	DRE	Dressler Hall	KGS	Kingston Hall
JTF	Jim Thorpe Fieldhouse	ISC	Interdisciplinary Science Center	PRC	Pearce Hall	MAR	Martin Hall
MUS	Music Building	PEA	P.E. Activities Building	SNY	Snyamncut Hall	SNR	Senior Hall
PEC	P.E. Classrooms Building	PAT	Patterson Hall			TAW	Tawanka Commons
RTV	Radio/TV Building	PAV	Pavilion (Reese Court)			WLM	Williamson Hall
SHO	Showalter Hall	PUB	Pence Union Building				
SUR	Surbeck Services	SCI	Science Building				
THE	University Theater	URC	University Recreation Center				

Adding Cooling to Buildings

Buildings that currently have cooling are already compatible with the proposed ground-source cooling system. There are five buildings included in this study without cooling. Costs for adding cooling where it does not currently exist are not included in this study.

Pearce and Dressler are residence halls where cooling should be considered if the buildings are to continue housing students into the future. If cooling is desired in these buildings, new chilled water piping will need to be installed when the LTHW piping is installed. This system can be converted to a two-pipe changeover system by adding a changeover valve, allowing CHW to flow through the HW pipes and coils. While this system will have comfort issues in the shoulder seasons, it will still increase overall annual comfort cost-effectively. Alternatively, new CHW coils and piping could be installed to improve comfort for additional cost.

Jim Thorpe Field House and the Aquatics buildings are both recreational buildings where cooling is likely to remain optional. Cooling systems in these facilities would most likely require adding CHW coils to existing air handlers and installing additional piping.

The Grounds Storage Building will not require cooling as it is unoccupied storage.

Connecting Additional Buildings to Loop

The only buildings included in this study not connected to the central loop are Surbeck Services and the Grounds Storage Building. Existing buildings that are not currently connected to the loop will not be connected in the foreseeable future. New capital projects and buildings replacing existing buildings will most likely be connected to the loop as they are constructed.

Table 14: EWU Buildings without Cooling

	Buildings without Cooling
PRC	Pearce Hall - Housing
DRE	Dressler Hall - Housing
JTF	Jim Thorpe Fieldhouse - Recreation
AQT	Aquatics Building - Recreation
GSB	Grounds Storage Building - Support

Section 5

Energy & Carbon Analysis

Key Takeaways

- The Decarbonization of the central plant will result in the campus meeting the HB 1390 EUI target of 112 kBtu/sf-year.
- Campus energy use will be reduced by **50%** and campus operational emissions will be reduced by **83%** in 2040 with the proposed ground-source system.
- Annual utility cost savings from the increased efficiency of the geothermal system will result in annual savings of around **$640,000 per year.**

Energy Modeling & Analysis Methodology

A central plant model was developed to estimate the campus-level heating and cooling loads and energy consumption. Hourly load profiles for heating and cooling were developed using historical utility data provided by EWU. Based on the data provided, 2022 was selected as the base study year. For heating and cooling, utility data for gas and electricity use was provided in monthly intervals. Energy by end use analysis for the campus and climate was used to estimate which percentage of gas was associated with space heating and domestic hot water and what percentage of electricity use is associated with space cooling. This data was then converted to hourly loads by morphing the monthly energy by end use data into hourly use profiles from prototype energy models that represent area weighted building typologies within the campus including academic, residential, and dining building types.

The hourly load results were aggregated and imported into a plant model to estimate the energy, carbon, and utility cost impact of the proposed geothermal plant. The output of the plant model includes estimates of the proposed plant heating and cooling efficiencies and utility cost impact. The outputs of the plant model were then applied to the existing building results to calculate proposed savings for heating, domestic hot water, and cooling for each building within scope. Additional in-building HVAC and DHW equipment was added to the proposed model where appropriate.

Decarbonization Saving Strategies

The following summarizes the main decarbonization strategies:

Space Heating Improvements

HVAC Strategy 1: Campus Geothermal with Boost from WWHP
Boosting heating water from the geothermal energy district results in a 3x increase in efficiency when compared to the existing campus steam system.

HVAC Strategy 2: Direct Campus Geothermal
Conversion to low temperature heating coils and utilizing heating water directly from the energy district results in a 4.5x increase in efficiency when compared to the existing campus steam system.

HVAC Strategy 3: Hybrid Coils and WWHP
A hybrid approach with converted LTHW coils and WWHP boost results in a 4x increase in efficiency when compared to existing campus steam system.

DHW Improvements

DHW Strategy 2: Campus Geothermal with Boost from WWHP
Boosting domestic hot water from the geothermal energy district with a WWHP results in a 3.6x increase in efficiency when compared to the existing campus steam system.

DHW Strategy 3: Campus Geothermal with Boost from EWH
Boosting domestic hot water from the geothermal energy district with an EWH results in a 3.3x increase in efficiency when compared to the existing campus steam system.

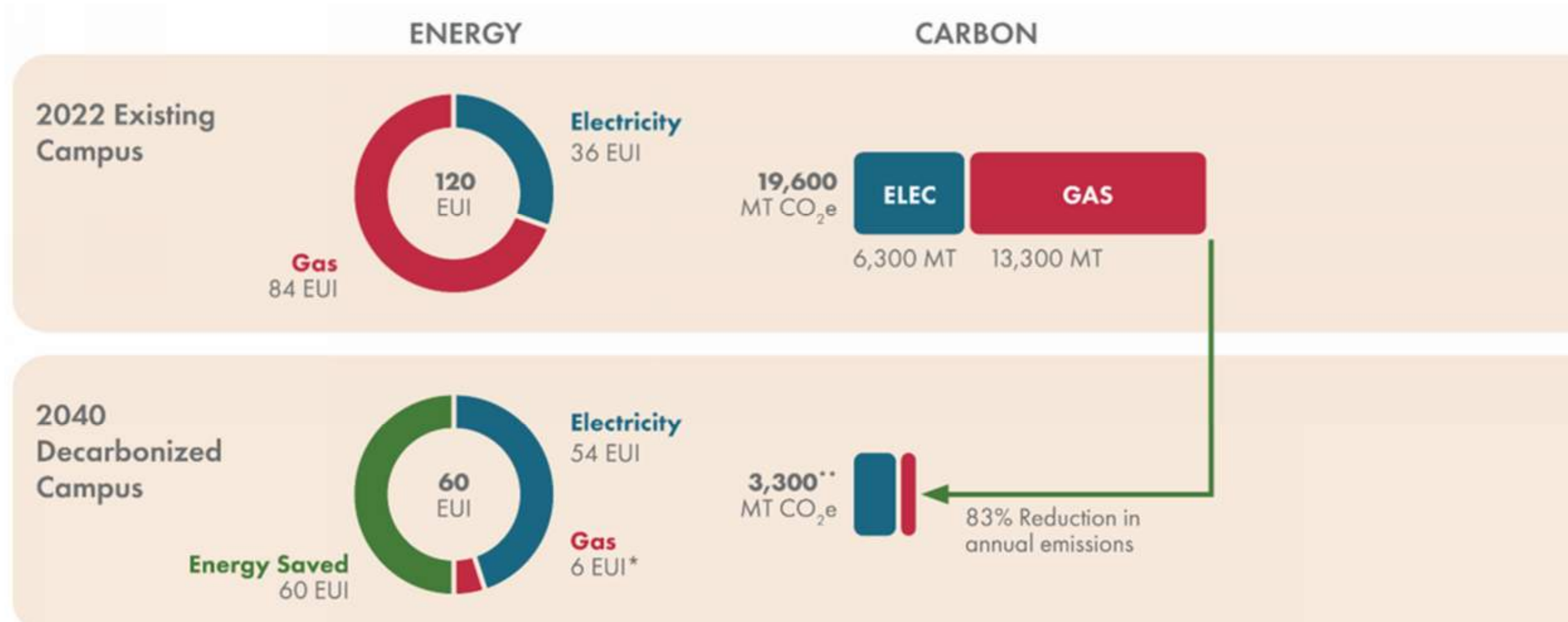
DHW Strategy 4: Hybrid ASHP DHW
A hybrid air-source heat pump water heater results in a 4x increase in efficiency when compared to existing campus steam system

Space Cooling Improvements

Campus Geothermal and Heat Recovery
Utilizing the geothermal system to create chilled water increases the annual average cooling COP from 4.0 from 4.5. Using the ground as a stable source for heat exchange results in an increase efficiency when compared to existing water-cooled chillers that use cooling towers to reject heat into the atmosphere. Additionally, heat recovery boosts the efficiency of the heating system by enabling direct heat rejection to the heating water loop when simultaneous loads are present.

Energy and Carbon Results

The Washington Department of Ecology requires annual emissions reporting to use state average carbon emissions intensity factors for electricity, rather than local market utility reported emissions factors. For 2022, the Department of Ecology reported a statewide average emissions factor for electricity at 0.4406 lb CO2e/kwh, and a natural gas emissions factor of 11.6 lb CO2e/therm. For forward-looking emissions, the state average factor was reduced based on the Washington Clean Energy Transformation Act (CETA) requirements. Emissions for electricity in 2040 are projected at 0.1049 lb CO2e/kwh. HB1390 requires a campus-wide EUI of 112 kbtu/sf-year by 2040. As shown in the graphic below, fully implementing this decarbonization plan will result in an EUI of 60 kbtu/sf-year, meeting HB 1390 requirements. **While overall electricity use increases due to electrification of campus heating, the carbon emissions from electricity decrease as the power grid becomes cleaner between now and 2040.

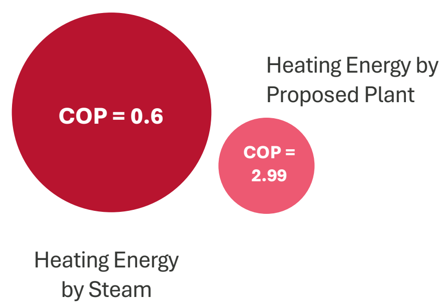


**Note: The remaining gas use in the 2040 decarbonized scenario includes gas used for peak heating loads and additional smaller gas heating loads. This complies with HB 1390 requirements, which allow for up to 10% of annual heating energy to be met by fossil fuels or electric resistance.*

Ground-Source Plant Model

A central plant model was developed to calculate the annual energy use and efficiencies of the proposed system. The model calculated the annual Coefficient of Performance (COP) of the proposed plant. COP is an industry-standard measure of the amount of energy/heat a system outputs, divided by the amount of energy input into the system. A higher COP is better and leads to lower energy use. The following items were included in the plant modeling process:

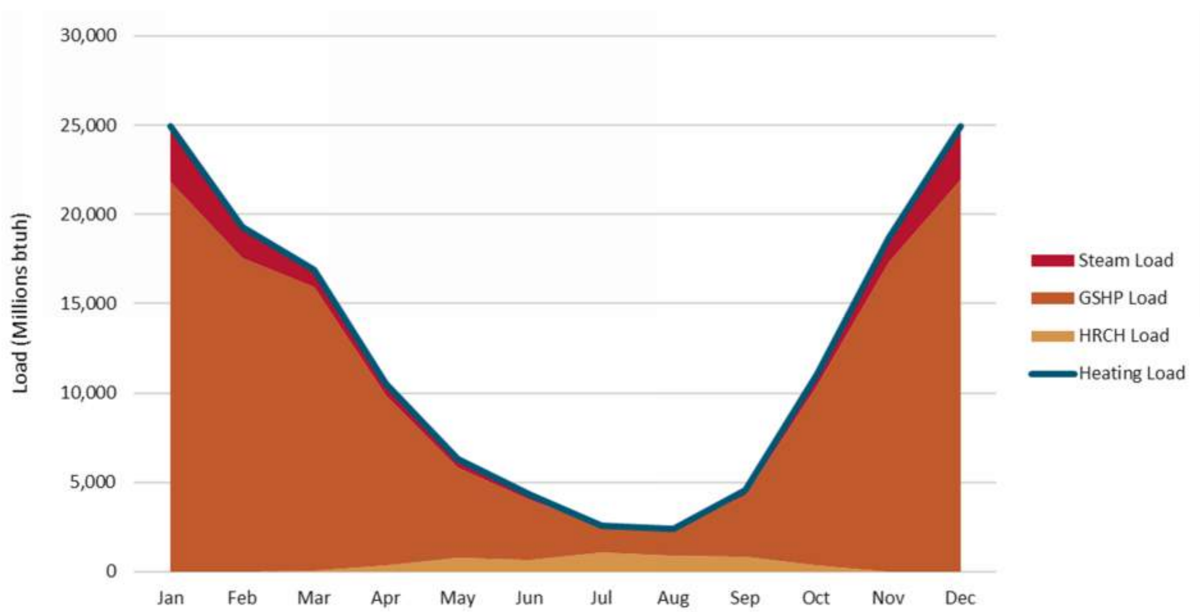
- Heating, cooling, and heat recovery capacities and efficiencies of proposed equipment
- Pumping energy impacts, including geothermal extraction pumps and all distribution pumps
- Distribution savings associated with converting steam to heating hot water
- Energy penalty from utilizing gas boilers associated with peak heating load



Projected Campus Heating System Operation

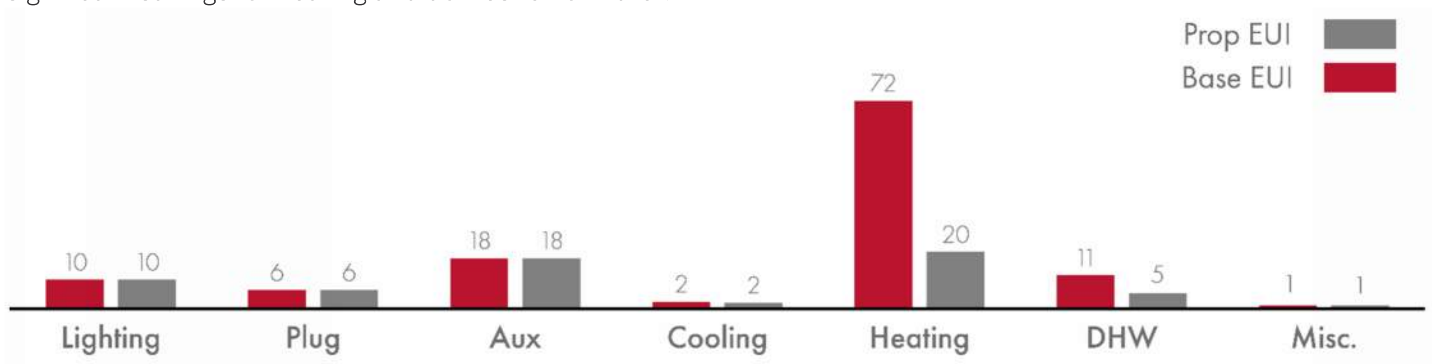
After full implementation of the electrified heating system, the campus heating load will be met via the following sequence:

- Heating and cooling loads will be met first by the heat recovery chillers (HRCH) when simultaneous heating and cooling are present.
- The remaining load will be met by the ground-source heat pumps (GSHP). If there is no simultaneous heating and cooling load, the ground-source heat pumps will come on first to provide heating/cooling.
- The steam system will be used only during peak load conditions.



Energy by End Use Savings

Energy end-uses are shown below for the existing campus and decarbonized campus. As discussed, there are significant savings for heating and domestic hot water.

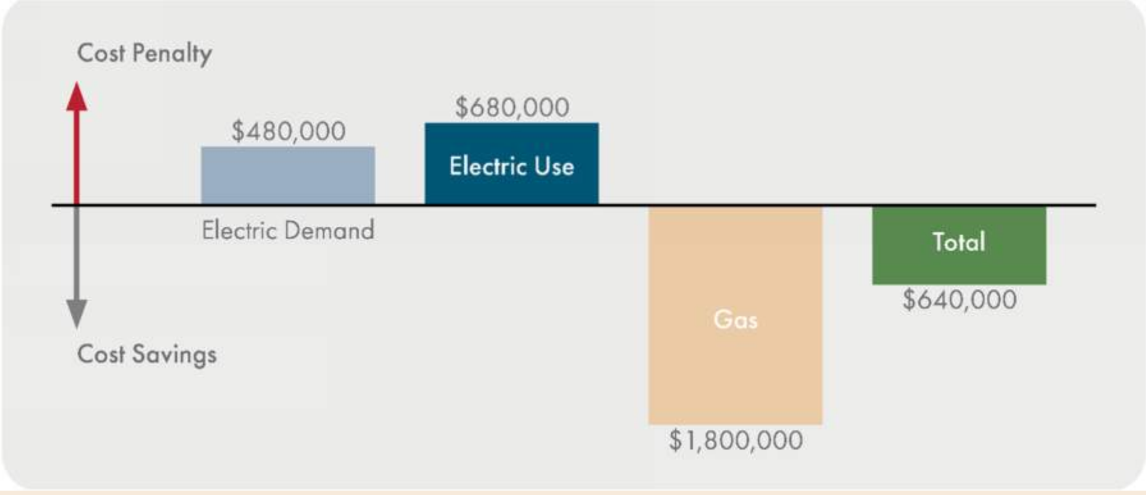


Utility Cost Impact

It is not uncommon for electrification projects to result in low annual utility cost savings or even a utility cost penalty, due to two factors:

1. Usage charges - Electricity is typically more expensive than gas on a per unit basis under the existing market prices. Based on 2023 utility rates for EWU, the cost of electricity is 1.5x the cost of gas for the same unit of energy.
2. Demand charges - In cold climates, electrification typically increases electric demand charges ($/kW) because of added electrical load during peak heating demands.

However, while both electricity usage and demand charges will increase as the ground-source system is implemented, these increases are offset by the reduction in gas costs, leading to an overall utility cost savings. The decarbonized system is projected to save $640k/year (15%). This assumes today's rates, which will need updating as utility rates change over time. As a result of the Climate Commitment Act (CCA), the natural gas supplier is expected to pass along CCA fees to customers. In addition to the annual utility cost savings, EWU will avoid these additional fees as a result of reducing natural gas usage. These avoided costs are not included in this analysis.



Section 6

Implementation Costs & Roadmap

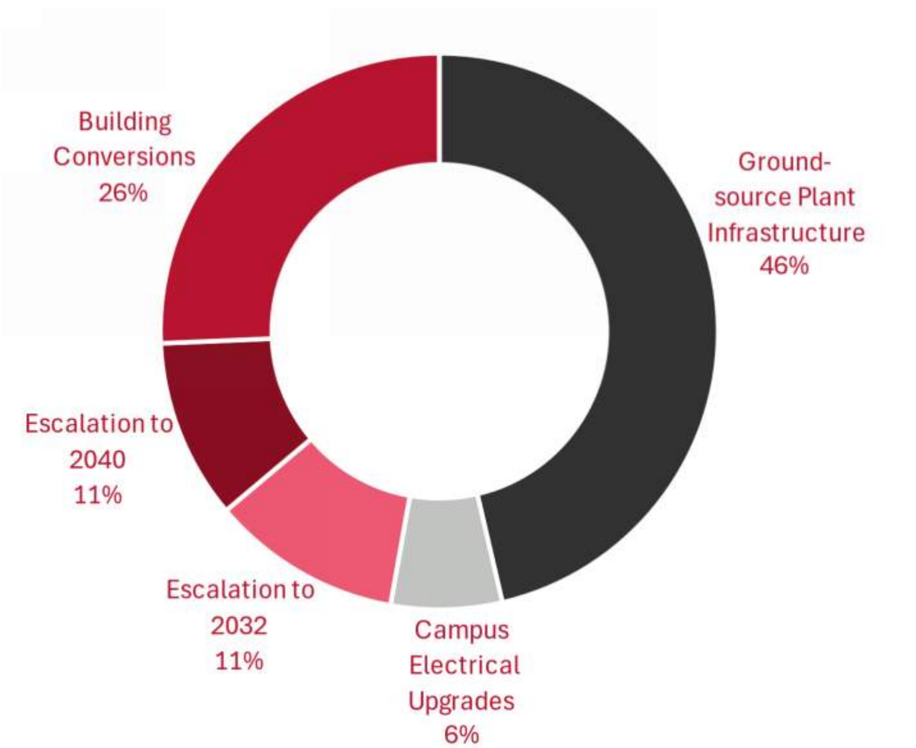
Key Takeaways

- The decarbonization roadmap for EWU prioritizes phased upgrades, campus heating and power resiliency, long-range planning, deferred maintenance, and regulatory compliance with HB1390.
- The plan ensures realistic progress by spreading capital requirements over time, using existing steam infrastructure as a backup, and prioritizing buildings with higher energy and carbon use for maximum savings.
- The overall ROM cost for EWU's heating decarbonization plan ranges from **$330M to $370M**, with an annual cost escalation of 3.3%.
- Ground-source infrastructure accounts for **46%** of the overall costs, with building conversions estimated to be **26%** of the costs. Electrical upgrades and escalation account for the remaining 28%.

Campus Decarbonization Costs

Based on the analysis and scoping presented throughout this plan, a "Rough Order of Magnitude" (ROM) cost of decarbonization was developed to inform EWU's financial planning. Unless indicated otherwise, the prices given in this report are a ROM level of detail, as defined by AACE class 4/5 (see below section for more detail). This pricing exercise sought to balance sensible and conservative costs while evaluating the conceptual scope. **The overall ROM cost associated with heating decarbonization outlined in this plan ranges from $330M to $369M depending on when implementation occurs.** Escalation is assumed to be 3.3% per year (per C-100 guidelines), with two separate timelines considered.

The costs outlined in this section are "all-in" costs and include construction costs and all design and oversight "soft costs". While a ground-source system may be eligible for federal funding via the Inflation Reduction Act (IRA), this has not been factored into the costs estimate.



Summary of Costs

EWU Decarbonization Costs				
Scope	Node 1 Design and Construction	Node 2 Design and Construction	Node 3 Design and Construction	Total
Equipment Costs				
Nodal Central Plant Costs				
GEP Building/Mech/Electrical	$ 17,085,000	$ 17,085,000	$ 12,983,000	$ 47,153,000
Distribution Piping	$ 4,011,000	$ 5,297,000	$ 3,976,000	$ 13,284,000
Geothermal Wells/Pumps	$ 26,259,000	$ 26,259,000	$ 16,412,000	$ 68,930,000
Electrical Service Upgrades	$ -	$ 23,792,000	$ -	$ 23,792,000
Soft Costs	$ 12,977,000	$ 19,849,000	$ 9,145,000	$ 41,971,000
GEP Plant+Piping Sub-Total	**$ 60,332,000**	**$ 92,282,000**	**$ 42,516,000**	**$ 195,130,000**
In-Building System Upgrades				
In-Building Conversions	$ 22,971,000	$ 40,650,000	$ 13,805,000	$ 77,426,000
Soft Costs	$ 5,183,000	$ 9,171,000	$ 3,115,000	$ 17,469,000
In Building Sub-Total	**$ 28,154,000**	**$ 49,821,000**	**$ 16,920,000**	**$ 94,895,000**
Implementation Timeline Scenerios and Total Costs				
Scenario 1: Expedited Implementation (Fastest & Least Cost Timeline to Decarbonization)				
Implementation Year	*2027*	*2029*	*2032*	
Escalation	$ 5,936,000	$ 19,707,000	$ 15,166,000	$ 40,809,000
Total Costs	**$ 94,422,000**	**$ 161,810,000**	**$ 74,602,000**	**$ 330,834,000**
Scenario 2: HB1390 Required Implementation Timeline				
Implementation Year	*2027*	*2032*	*2040*	
Escalation	$ 5,936,000	$ 36,260,000	$ 37,292,000	$ 79,488,000
Total Costs	**$ 94,422,000**	**$ 178,363,000**	**$ 96,728,000**	**$ 369,513,000**
Cost Savings from expedited implementation	$ -	$ 16,553,000	$ 22,126,000	**$ 38,679,000**

Nodal Ground-Source

Costs for the nodal ground-source infrastructure encompass all costs associated with the ground-source wells (the wells themselves, distribution pumps and piping to the GEP, etc.), the GEP nodal plant buildings (the building itself, all mechanical and electrical equipment, etc.), and distribution piping to the buildings. Costs for the first node (GEP-1) were provided by DCW Cost Management as part of the 2025-2027 state capital request. Costs for GEP-2 and GEP-3 were extrapolated from the GEP-1 costs and include costs for distribution piping based on the anticipated node location.

While the existing campus electrical infrastructure is sufficient to power GEP-1, a new utility substation and service point will be required to serve the added load starting with GEP-2. A placeholder cost for this substation of $23M is included, based on preliminary conversations with the utility and ROM costs from similar utility upgrades. This number includes both the cost to upgrade the campus electrical infrastructure, and the costs passed down from the utility to construct a new substation.

In-Building System Upgrades

All existing buildings were evaluated for compatibility with the planned ground-source system as detailed in the "Building Conversion" section. Cost estimates were developed for both mechanical/electrical system conversions and energy efficiency measures in the nine focus buildings. While the costs for energy efficiency measures were identified and included in the 2025-2027 capital request, they were not included in the decarbonization costs shown in this section. The costs in this section only reflect the MEP system conversion costs necessary for the transition to the ground-source system. The cost estimates for the rest of the campus buildings were extrapolated from the detailed costs of the nine buildings that were initially assessed and based on the selected strategy for each building. For buildings utilizing the boost water-to-water heat pump as their decarbonization method, replacing all existing coils would generally be about 25-50% more costly. A coil swap out would also be significantly more invasive and disruptive. The electrical system was not evaluated for the buildings outside of the nine focus buildings, and electrical upgrade costs are not included in the extrapolation. This assumption needs to be validated via detailed design prior to implementation.

Cost Estimating Level of Detail

This study uses cost estimating classes as defined by the Cost Estimate Classification System developed by the Association for the Advancement of Cost Engineering. Figure 18 outlines the uses and definitions for each class. The cost development for the nine focus buildings was more detailed and falls into Class 4. All other costs in this study, including the GEP plants, ground-source wells, distribution piping, electrical upgrades, and extrapolated building conversions, fall into Class 5. The building conversion costs can be broken into two categories, as described in the "Building Conversion" section of this report:

- Costs from nine focus buildings - Class 4 - these costs were included in the 2025-2027 capital request
- Costs from campus-wide deployment - Class 5

				Expected Range of Accuracy		
AACE Class	**ANSI Classification**	**Typical Use**	**Project Definition**	**Low Expected Actual Cost**	**High Expected Actual Cost**	**Other Terms**
Class 5	Order-of-Magnitude	Strategic Planning; Concept Screening	0% to 2%	-50% to -20%	+30% to +100%	ROM; Ballpark; Blue Sky; Ratio
Class 4		Feasibility Study	1% to 15%	-30% to -15%	+20% to +50%	Feasibility; Top-down; Screening; Pre-design
Class 3	Budgetary	Budgeting	10% to 40%	-20% to -10%	+10% to +30%	Budget; Basic Engineering Phase; Semi-detailed
Class 2	Definitive	Bidding; Project Controls; Change Management	30% to 75%	-15% to -5%	+5% to +20%	Engineering; Bid; Detailed Control; Forced Detail
Class 1		Bidding; Project Controls; Change Management	65% to 100%	-10% to -3%	+3% to +15%	Bottoms Up; Full Detail; Firm Price

Figure 18: AACE Cost Estimating Detail Ranges

What is a Decarbonization Roadmap?

The decarbonization roadmap charts a path for EWU to meet carbon reduction targets and comply with current state regulatory requirements such as HB1390. Roadmap development included engagement from stakeholders throughout to ensure the plan is actionable and implementable. The following items were prioritized in the planning process.

Implementation Phasing:

Upgrades to convert the fossil fuel based central steam plant are made in phases over time, aligned with the timeline allowed by HB 1390. Phasing the project over time allows for realistic and actionable progress by spreading the capital requirements over multiple years.

Campus Heating and Power Resiliency:

Ensuring that the campus has stable and reliable heating and electrical power is a key priority for EWU. The existing steam plant infrastructure will be used as a backup heating source, used only on the coldest days of the year or when there are outages that impact the ground-source heating plants

Long Range Campus Planning:

The roadmap was coordinated with EWU Facilities and capital planning groups to ensure it aligns with the long-range campus master planning. The roadmap accounts for the energy and carbon impact of new construction campus expansion as well as a demo of existing buildings

Deferred Maintenance:

Campus phasing considered the age of equipment and age of buildings when prioritizing the order of upgrades at buildings. In general, the plan addresses deferred maintenance by replacing equipment near or at its end-of-life with the decarbonized solutions. It is not recommended to early-retire equipment.

Carbon Savings Impact:

Buildings that have higher energy and carbon use tensity are prioritized to maximize carbon savings potential

Central Plant Design Complexity:

The decarbonization roadmap considered the mechanical and electrical design implications of building the ground-source heat pump plants over time

Regulatory Compliance:

The decarbonization roadmap ensures EWU will comply with the current requirements of HB 1390. This includes not only removing fossil fuels at the central plant but also meeting the campus-wide EUI target of 112 kbtu/sf-year. This will be easily met when transitioning the heating system from steam to ground-source.

Table 15: Key Analysis Variables

Variable	Input
Existing Campus Area [ft2]	3,014,637
Existing Campus Energy [kBtu]	360,881,047
Existing Campus Electricity [kBtu]	108,798,990
Existing Campus Gas [kBtu]	252,082,057
Existing Campus Elec Utility Spend [$]	$1,961,213
Existing Campus Gas Utility Spend [$]	$2,327,241
Campus Peak Demand [kW]	8,128
Annual First Cost Escalation	3.3%

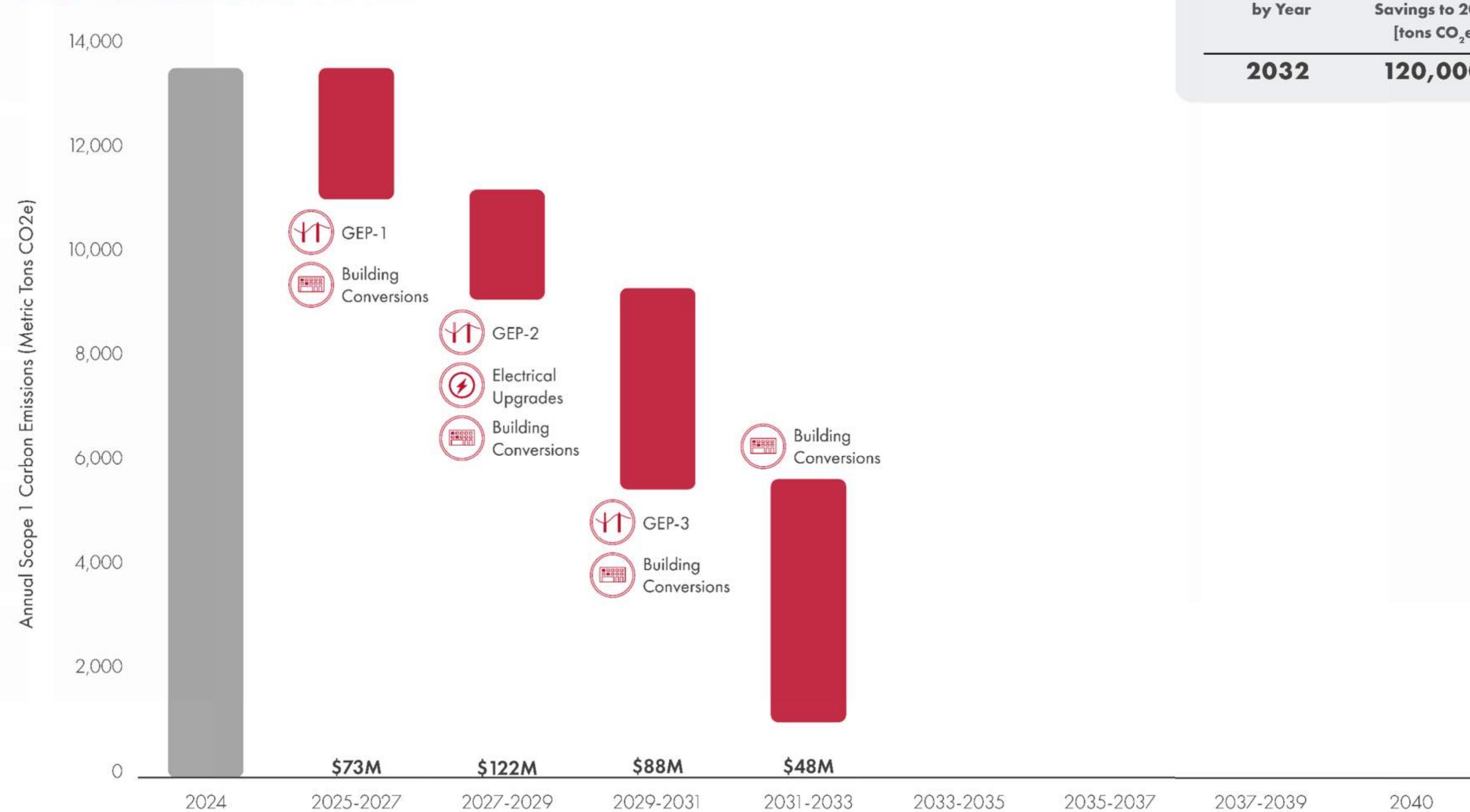
Decarbonization Roadmap Timeline Scenario 1 – Fastest & Lowest Cost

The roadmap below identifies the cost and phasing to fully transition the existing fossil fuel-fired system to a low-temperature ground-source system by 2032, thereby complying with HB 1390. As mentioned previously, this implementation timeline has a lower cost than the HB 1390-mandated timeline of 2040.The building conversion and GEP construction timelines below are based on current knowledge, and are flexible as changes in funding, technology, and campus conditions occur.

Key Performance Metrics

Decarbonization by Year	Total Carbon Savings to 2040 [tons CO_2e]	Total Utility Cost Savings to 2040 [$]	Total Construction Cost [$]	Average Annual Construction Costs [$/year]
2032	120,000	$7.5M	$331M	$41M

Scope 1 Carbon Emissions Over Time



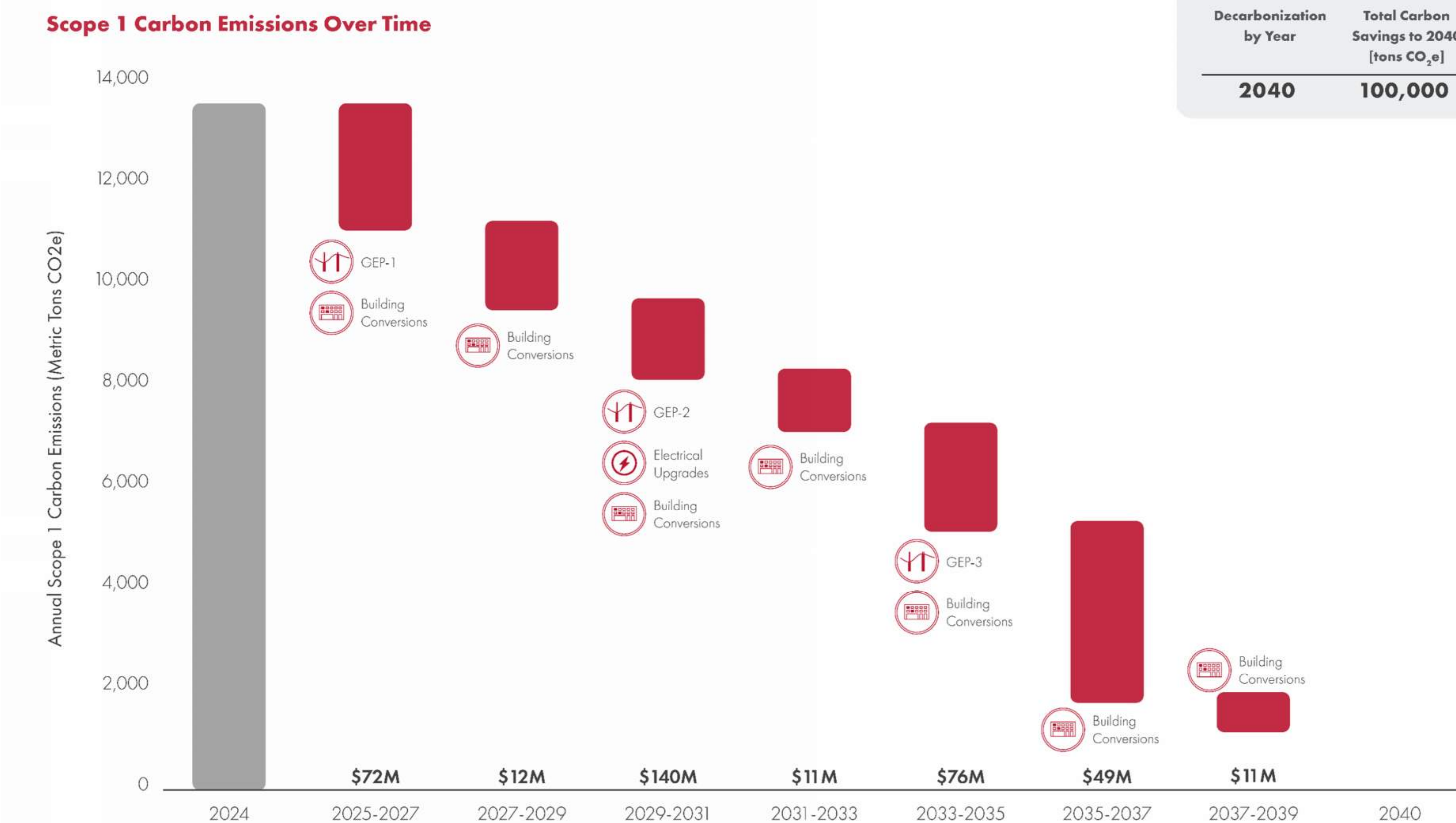
Details	Year
GEP-1	2026
Building Transition: Computing & Engineering Building, Communications Building, Radio/TV Building, Martin Hall, Williamson Hall	2026
Building Transition: Music Building, University Theater, Art Building	2027
Building Transition: JFK Library, Sutton Hall	2028
Building Transition: Hutson Hall, Showalter Hall, Cheney Hall	2029
GEP-2	2028
Building Transition: Tawanka commons, Surbeck Services, Grounds storage building	2028
Building Transition: Building Transition: Patterson Hall, Kingston Hall, Hargreaves Hall, Senior Hall	2029
Building Transition: University Recreation Center, Interdisciplinary Science Center, Dressler Hall	2030
Building Transition: Pence Building, Syamncut Hall, Pearce Hall	2031
Building Transition: Science Building	2032
GEP-3	2030
Building Transition: Jim Thorpe Fieldhouse, Acquatics Building	2031
Building Transition: Reese Court, PE Activities Building, PE Classrooms Building, Albers Court	2032

Decarbonization Roadmap Timeline Scenario 2 – 1390 Requirement

The roadmap below identifies the cost and phasing to fully transition the existing fossil fuel-fired system to a low-temperature ground-source system by 2040, thereby complying with HB 1390. As mentioned previously, this implementation timeline has a higher cost than the aggressive timeline shown in the previous section. The building conversion and GEP construction timelines below are based on current knowledge, and are flexible as changes in funding, technology, and campus conditions occur.

Key Performance Metrics

Decarbonization by Year	Total Carbon Savings to 2040 [tons CO_2e]	Total Utility Cost Savings to 2040 [$]	Total Construction Cost [$]	Average Annual Construction Costs [$/year]
2040	100,000	$6M	$370M	$24M



Details	Year
GEP-1	2026
Building Transition: Computing & Engineering Building, Communications Building, Radio/TV Building, Martin Hall, Williamson Hall	2026
Building Transition: Music Building, University Theater, Art Building	2027
Building Transition: JFK Library, Sutton Hall	2028
Building Transition: Hutson Hall, Showalter Hall, Cheney Hall	2029
GEP-2	2029
Building Transition: Tawanka commons, Surbeck Services, Grounds storage building	2030
Building Transition: Building Transition: Kingston Hall, Senior Hall	2031
Building Transition: University Recreation Center, Hargreaves Hall	2032
Building Transition: Patterson Hall, Snyamncut Hall	2033
Building Transition: Interdisciplinary Science Center	2034
Building Transition: Pence Union Building, Science Building, Pearce Hall, Dressler Hall	2035
GEP-3	2032
Building Transition: Reese Court, Aquatics Building	2036
Building Transition: PE Activities Building	2037
Building Transition: Jim Thorpe Fieldhouse, Albers Court	2038
Building Transition: PE Classrooms Building	2039

Section 7

Appendix

A.Cost Estimate by Category

B.Existing System Description by Building

C.Renovation Scope by Building – Focus Buildings

D.Renovation Scope by Building – Campus Wide Deployment

Appendix A | Cost Estimate by Category – Focus Buildings

	Building	Building Area [s.f.]	Mechanical Labor	Electrical Labor	Energy Management & Controls	Complete Lighting	Window Upgrades	Equipment	Other	Complete Plumbing	Contingency	Construction Sub-total	Turnkey Estimate	Turnkey Cost / S.F.
JFK	JFK Library	124,496	$ 193,500	$ 96,750	$ 128,000	$ 596,336	$ -	$ 478,500	$ 50,000	$ 44,000	$ 158,709	$ 1,745,794	$ 2,880,561	$ 23.14
CEB	Computing & Engineering	98,476	$ 849,000	$ 197,501	$ 340,392	$ 262,981	$ -	$ 658,834	$ 50,000	$ 74,000	$ 243,271	$ 2,675,979	$ 4,415,365	$ 80.42
MUS	Music Building	47,618	$ 385,167	$ 92,543	$ 244,680	$ 117,202	$ 114,108	$ 288,791	$ 50,000	$ -	$ 129,249	$ 1,421,740	$ 2,345,872	$ 95.88
THE	University Theater	41,164	$ 362,333	$ 78,508	$ 201,640	$ 96,586	$ -	$ 249,408	$ 50,000	$ -	$ 103,847	$ 1,142,322	$ 1,884,831	$ 93.48
ART	Art Building	34,469	$ 521,113	$ 61,095	$ 243,944	$ 98,161	$ 199,689	$ 442,941	$ 50,000	$ 44,000	$ 166,094	$ 1,827,038	$ 3,014,612	$ 147.10
SUT	Sutton Hall	31,927	$ 65,000	$ 32,500	$ 123,879	$ 60,349	$ -	$ 167,500	$ 25,000	$ -	$ 47,423	$ 521,651	$ 860,723	$ 68.32
HUS	Huston Hall	27,424	$ 378,500	$ 53,748	$ 148,460	$ 72,324	$ -	$ 177,395	$ 25,000	$ 44,000	$ 89,943	$ 989,370	$ 1,632,460	$ 108.12
CMC	Communications Building	19,289	$ 255,042	$ 43,406	$ 97,550	$ 46,726	$ -	$ 119,619	$ 25,000	$ -	$ 58,734	$ 646,078	$ 1,066,028	$ 109.28
RTV	Radio/TV Building	16,980	$ 255,917	$ 38,805	$ 87,210	$ 41,774	$ -	$ 118,435	$ 25,000	$ -	$ 56,714	$ 623,855	$ 1,029,361	$ 118.03

Building		Heating						Cooling				Summary of Existing System
		System Type	Quantity	Coil Type	CFM	Coil MBH	GPM	Type	CFM	Coil MBH	GPM	
John F. Kennedy Library	AHU-1 C	Dual Duct	1	HW 180	8,000	608	60	CHW	22,345	686	130	(7) Dual duct systems with (7) 180° HW heating AHUs and (7) CHW cooling AHUs (14 total). 180° HW is provided from campus steam through a 9,800 MBH 850 GPM steam converter. CHW is provided by campus CHW.
	AHU-1 H	Dual Duct		HW 180	14,120	749	75					
	AHU-2 C	Dual Duct	1	HW 180	6,500	458	35	CHW	16,950	554	110	
	AHU-2 H	Dual Duct		HW 180	11,005	625	65					
	AHU-3 C	Dual Duct	1	HW 180	9,000	680	60	CHW	25,825	994	220	
	AHU-3 H	Dual Duct		HW 180	16,800	906	95					
	AHU-4 C	Dual Duct	1	HW 180	7,000	503	40	CHW	20,440	602	145	
	AHU-4 H	Dual Duct		HW 180	11,580	623	60					
	AHU-5 C	Dual Duct	1	HW 180	7,000	503	40	CHW	16,150	568	125	
	AHU-5 H	Dual Duct		HW 180	10,625	586	50					
	AHU-6 C	Dual Duct	1	HW 180	7,000	518	40	CHW	19,660	638	140	
	AHU-6 H	Dual Duct		HW 180	12,650	672	65					
	AHU-7 C	Dual Duct	1	HW 180	6,500	482	40	CHW	18,250	614	135	
	AHU-7 H	Dual Duct		HW 180	13,420	745	70					
	AHU-8	Single Zone	1	HW 180	2,000	50	5	DX	2,000	55	-	(2) small single zone systems with 180°F HW heating and DX cooling.
	AHU-9	Single Zone	1	HW 180	1,000	24	3	DX	1,000	26	-	
	AHU-10	Single Zone	1	HW 180	1,000	24	3	CHW	1,000	26	-	Small single zone AHU with 180°F HW heating & CHW cooling.
	UHs	UH	5	HW 180		75		-	-	-	-	(5) 180°HW Unit Heaters
	DHW	DHW										DHW is provided by multiple sources, a 800 MBH steam to HW converter, a 50 gallon 2.5 kW electric tank and a 80 gallon 10 kW electric tank.

Building		System Type	Quantity	Heating				Cooling				Summary of Existing System
				Coil Type	CFM	Coil MBH	GPM	Type	CFM	Coil MBH	GPM	
Computer & Engineering Building	AHU-1 C	Dual Duct	1	Steam	16,000	1,042	-	CHW	49,000	1,275	213	(2) Large dual duct systems with separate heating (steam) and cooling (CHW) AHUs.
	AHU-1 H	Dual Duct	1	Steam	27,000	586						
	AHU-2 C	Dual Duct	1	Steam	14,000	907	-	CHW	27,000	1,180	197	
	AHU-2 H	Dual Duct	1	Steam	51,000	1,102						
	AHU-3	Single Zone	1	Steam	20,000	432	-	CHW	20,000	475	79	(3) Large single zone AHUs with steam and CHW coils.
	AHU-4	Single Zone	1	Steam	10,000	216	-	CHW	10,000	270	45	
	AHU-5	Single Zone	1	Steam	15,000	324	-	CHW	15,000	540	90	
	DHW	DHW										(1) Steam to DHW Converter 1500 lbs./hr
Music Building	AH-1	Dual Duct	1	Steam	*30000*	1552	-	CHW	*40000*	*864*	*156*	(1) Large dual duct system with a single fan and separate (steam) heating and (CHW) cooling decks.
	AH-2	Single Zone	1	Steam	*18000*	597	-	CHW	*18000*	*389*	*115*	(1) Large single zone AHU with steam and CHW coils.
	UHs	Unit Heater	1	Steam								(1) Steam UHs in Mechanical Space
	DHW	DHW										Existing 12 kW 50 Gal Tank & 24 kW 80 Gal Tank

	Building	System Type	Quantity	Heating: Coil Type	Heating: CFM	Heating: Coil MBH	Heating: GPM	Cooling: Type	Cooling: CFM	Cooling: Coil MBH	Cooling: GPM	Summary of Existing System
University Theater	AHU-1	Dual Duct	1	Steam	21000	1009		CHW	21000	453.6	60.48	AHU-1 is a large dual duct system with a steam heating coil and chilled water coil.
	AHU-2	Single Zone	1	-	-	-	-	CHW	13860	299.38	39.917	AHU-2 appears to only have cooling and rely on terminal heating for heat.
	Steam Converter		Unavailable	180° HW	-	620	62	-				An existing steam to HW converter provides heat from campus steam as 180°F HW to a multiple terminal units and fin tube radiators. Steam UH's serve mechanical spaces.
	Reheat Terminals	Duct Coils	Unavailable	Unavailable	Unavailable							
	Radiators	FTR	Unavailable	Unavailable	-			-				
	CUHs	Cabinet Heater	1	Unavailable	-			-				
	UHs	Unit Heater	3	Steam	-			-				(3) Steam UHs in Mechanical Spaces
	DHW	DHW										DHW is provided by an existing 60 kW electric boiler and an existing 18 kW 50 Gal Tank.
Art Building	AHU-1	Dual Duct	1	Steam Preheat	36085	3106	-	CHW	32000	1554	212	AHU-1 is a large (~36,000 CFM) Dual Duct AHU w/ steam preheat coil, (2) steam duct coils and a CHW coil serving ~62 Zones
	AHU 1 - Duct Coil 7	Duct Coil	1	Steam	6000	382.08	-	-	-	-	-	
	AHU 1 - Duct Coil 8	Duct Coil	1	Steam	21000	656.7	-	-	-	-	-	
	AHU-3	RTU	1	Steam Preheat	8950	782	-	-	-	-	-	AHUs 3 & 4 are Large RTUs (~10,000 CFM) with steam preheat serving (3 each, 6 total) Duct Coil Zones with HW & CHW coils. A Steam to HW Converter serves perimeter radiators, unit heaters & convectors.
	AHU 3 - Duct Coil 1	Duct Coil	1	180° HW	2800	100.5	6.7	CHW	2800	107.25	14.3	
	AHU 3 - Duct Coil 2	Duct Coil	1	180° HW	3350	87	5.8	CHW	3350	116.25	15.5	
	AHU 3 - Duct Coil 3	Duct Coil	1	180° HW	2800	100.5	6.7	CHW	2800	107.25	14.3	
	AHU-4	RTU	1	Steam Preheat	8550	767	-	-	-	-	-	
	AHU 4 - Duct Coil 4	Duct Coil	1	180° HW	2950	106.5	7.1	CHW	2950	114.75	15.3	
	AHU 4 - Duct Coil 5	Duct Coil	1	180° HW	2800	100.5	6.7	CHW	2800	107.25	14.3	
	AHU 4 - Duct Coil 6	Duct Coil	1	180° HW	2800	100.5	6.7	CHW	2800	107.25	14.3	
	Steam UHs	Unit Heaters	3	Steam	-	235.6	-	-	-	-	-	(3) Steam Unit Heaters
	Perimeter Steam to HW Converter					1397.5	140					A Steam to HW Converter serves perimeter radiators, unit heaters & convectors.
	HW Convectors	Convectors	15	180° HW	-	73.7	7	-	-	-	-	
	HW UHs	Unit Heaters	11	180° HW	-	170.8	17	-	-	-	-	
	HW Wall Fin	Wall Fintube	49	180° HW	-	1153	115	-	-	-	-	
	DHW	DHW										DHW is provided by a steam converter connected to campus steam.

Building				Heating				Cooling				Summary of Existing System
		System Type	Quantity	Coil Type	CFM	Coil MBH	GPM	Type	CFM	Coil MBH	GPM	
Sutton Hall	AHU-1	VAV AHU	1	HW	11140	600	40		26000	950	200	An existing steam to HW converter provides heat from campus steam as 180°F HW to a single AHU and large array of fin tube radiators.
	Steam to HW HX	Steam HX	1	Steam		891	242					
	VAV RH Coil	Reheat Coil	1	HW		42	5					
	FTR	Fin Tube Radiator	195	HW		540						
	FCU-1	Fan Coil Unit	1	HW	145	11.5	1					
	DHW	DHW										DHW is provided by an existing 9 kW 50 Gal Tank.
Huston Hall	AHU-1	Multizone	1	Steam	16000	864	-	CHW	16000	345.6	57.6	(1) ~20,000 CFM 2 Zone Multizone AHU with Steam & CHW Coils for each zone. - Zone 2 appears capped off. Fan @ 80% or ~16,000 CFM remaining on Zone 1.
	AHU-2	Dual Duct	1	Steam	9000	450	-	-	-	-	-	
	AHU-3	Dual Duct	1	-	-	-	-	CHW	15000	345	60	(1) Dual Duct System with a ~15,000 CFM ~350 MBH CHW Cold Deck AHU & ~9,000 CFM ~ 450 MBH Steam Hot Deck AHU ~ 50 Zones
	SF-5	Fan Coil?	1	-	-	-	-	CHW	1500	36	6	(1) Small FCU with 36 MBH CHW
	CRAC-1	CRAC	4	-	-	-	-	DX				(4) DX CRAC Units (Assume replace former AHU1-Zn2)
	DHW	DHW										DHW is provided by a steam converter connected to campus steam.
Communications	AHU	Dual Duct	1	Steam	10150	384		CHW		219	29	Information included on Music Building drawing set. A single dual duct AHU with a steam coil and campus CHW provides heating and cooling to 28 dual duct zones.
	DHW	DHW										Existing 50 Gal 4.5 kW Electric DHW
Radio / TV	AHU-1	Dual Duct	1	Steam	*10,500*	397	-	CHW	*10,500*	*284*	38	Dual Duct AHU with steam heating coil and CHW cooling coil.
	DHW	DHW										Existing 30 kW Electric Boiler

Building		Summary of Retrofit	Pipe Replacement	Coil Replacement	Fan Replacement	Booster Heat pump	Steam Converter	HX & Hydronic Pump(s)	Electrical Impacts
John F. Kennedy Library	AHU-1 C AHU-1 H AHU-2 C AHU-2 H AHU-3 C AHU-3 H AHU-4 C AHU-4 H AHU-5 C AHU-5 H AHU-6 C AHU-6 H AHU-7 C AHU-7 H AHU-8 AHU-9 AHU-10 UHs	Deploy a high temperature booster heat pump using the proposed campus LTHW as a source, and creating HTHW for the building. The existing steam converter and pump infrastructure shall remain in place as backup. HW & CHW piping infrastructure and coils will remain unchanged.	N/A	N/A	N/A	Provide a (4x)SBH300 90 ton modular water to water heat pump located in the existing mechanical room. The combined total is 4,420 MBH which will provide for the system load the majority of the year. The existing steam converter will be left in place as a supplemental and backup source. Connect in sidecar configuration to existing building piping loop. Provide new controls for WWHP and accessories, tie into existing building BAS. Assume (20) physical points & (80) virtual points.	Existing convertor, associated pumps and accessories to remain. Reconfigure piping to tie into the building HWS/R loop downstream of the proposed new WWHP in a sidecar configuration.	Install (2) x 500 gpm end suction pumps with VFDs, fully grouted isolation bases, suction diffusers and other appurtenances. Pipe in parallel and tie into existing hydronic piping loop.	337.2 kW new total load for (4x)SBH300 Modular WSHP (2) New 10 HP Pumps
	DHW	Electric tank type heater are to remain. Add a new WSHP DHW heater to offset the DHW capacity from the steam converter. The steam converter should be left in place as back up.	New supply and return piping from campus LTHW to new DHW Heat Pump. New DHW piping to integrate storage tank.			Provide new Transom SWH200 WSHPs using the proposed campus LTHW to provide DHW to facility. Provide 100 gallon storage tank. Provide new 20 GPM B&G EcoCirc Pump. Tie into existing DHW system. Existing to remain in place as back up.			33.7 kW power for new Transom SWH150 WSHP. New 1/2 HP Circ Pump

Building		Summary of Retrofit	Pipe Replacement	Coil Replacement	Fan Replacement	Booster Heat pump	Steam Converter	HX & Hydronic Pump(s)	Electrical Impacts
Computer & Engineering Building	AHU-1 C	Replace (7) existing AHU steam coils with new LTHW coils. Provide (7) new fan wall sections for AHUs. Provide new hydronic heat exchanger, new hydronic pumps, new piping to all existing AHUs. Retain steam connection at building, provide new steam-HW converter and pipe into new hydronic piping.	Route approximately 1500ft of new cast iron & copper HW piping to each AHU, with sizes ranging from 5" at the pump header to 2" at the coil connection. Provide all new coil appurtenances (shutoffs, P/T ports, strainers, etc.) and fill with 30% glycol solution.	Retrofit new 1100 MBH LTHW coil into existing AHU cabinet and provide new control valve.	Retrofit new 49000 cfm fan wall array into existing AHU cabinet, including new flow sensors, VFDs, and control accessories	N/A	Provide new 3000MBH shell & tube steam to HW converter, pipe in sidecar configuration to building primary variable LTHW loop.	Install new plate & frame HX between campus LTHW and new building LTHW loops. Install (2)x400gpm end suction pumps with VFDs, fully grouted isolation bases, suction diffusers and other appurtenances. Pipe in parallel and tie into new construction hydronic piping loop. Provide typical pump appurtenances (shutoff valves, strainers, P/T ports, etc.)	(2) New 10 HP Building HW Pumps (7) New Fan Wall arrays, expected to remain with existing electrical capacity.
	AHU-1 H			Retrofit new 600 MBH LTHW coil into existing AHU cabinet and provide new control valve.	Retrofit new 14000 cfm fan wall array into existing AHU cabinet, including new flow sensors, VFDs, and control accessories				
	AHU-2 C			Retrofit new 1000 MBH LTHW coil into existing AHU cabinet and provide new control valve.	Retrofit new 51000 cfm fan wall array into existing AHU cabinet, including new flow sensors, VFDs, and control accessories				
	AHU-2 H			Retrofit new 1200 MBH LTHW coil into existing AHU cabinet and provide new control valve.	Retrofit new 20000 cfm fan wall array into existing AHU cabinet, including new flow sensors, VFDs, and control accessories				
	AHU-3			Retrofit new 500 MBH LTHW coil into existing AHU cabinet and provide new control valve.	Retrofit new 20000 cfm fan wall array into existing AHU cabinet, including new flow sensors, VFDs, and control accessories				
	AHU-4			Retrofit new 300 MBH LTHW coil into existing AHU cabinet and provide new control valve.	Retrofit new 10000 cfm fan wall array into existing AHU cabinet, including new flow sensors, VFDs, and control accessories				
	AHU-5			Retrofit new 400 MBH LTHW coil into existing AHU cabinet and provide new control valve.	Retrofit new 15000 cfm fan wall array into existing AHU cabinet, including new flow sensors, VFDs, and control accessories				
	DHW	Add a new WSHP DHW heater to offset the DHW capacity from the steam converter. The steam converter should be left in place as back up.	New supply and return piping from campus LTHW to new DHW Heat Pump. New DHW piping to integrate storage tank.			Provide (2) new Transom SWH250 WSHPs using the proposed campus LTHW to provide DHW to facility. Provide 100 gallon storage tank. Provide new 20 GPM B&G EcoCirc Pump. Tie into existing DHW system. Existing steam converter to remain in place as back up.			85.4 kW power for new Transom SWH150 WSHP. New 1/2 HP Circ Pump

Building		Summary of Retrofit	Pipe Replacement	Coil Replacement	Fan Replacement	Booster Heat pump	Steam Converter	HX & Hydronic Pump(s)	Electrical Impacts
Music Building	AH-1	Replace existing AHU steam coils with new LTHW coils. Provide new fan wall sections for all AHUs. Provide new hydronic heat exchanger, new hydronic pumps, new piping to all existing AHUs. Retain steam connection at building, provide new steam-HW converter and pipe into new hydronic piping.	Route approximately 1000ft of new cast iron & copper HW piping to each AHU, with sizes ranging from 4" at the pump header to 2" at the coil connection. Provide all new coil appurtenances (shutoffs, P/T ports, strainers, etc.) and fill with 30% glycol solution.	Retrofit new 1600 MBH LTHW coil into existing AHU cabinet and provide new control valve.	Retrofit new 40000 cfm fan wall array into existing AHU cabinet, including new flow sensors, VFDs, and control accessories	N/A	Provide new 2000MBH shell & tube steam to HW converter, pipe in sidecar configuration to building primary variable LTHW loop.	Install new plate & frame HX between campus LTHW and new building LTHW loops. Install (2)x220 gpm end suction pumps with VFDs, fully grouted isolation bases, suction diffusers and other appurtenances. Pipe in parallel and tie into new construction hydronic piping loop. Provide typical pump appurtenances (shutoff valves, strainers, P/T ports, etc.)	(2) New 7.5 HP Building HW Pumps (2) New Fan Wall arrays, expected to remain with existing electrical capacity.
	AH-2			Retrofit new 600 MBH LTHW coil into existing AHU cabinet and provide new control valve.	Retrofit new 18000 cfm fan wall array into existing AHU cabinet, including new flow sensors, VFDs, and control accessories				
	UHs			Replace existing UH with new LTHW UH. Provide new control valve.	Provide new LTHW UH.				
	DHW	Existing electric DHW to remain in place.							N/A

	Building	Summary of Retrofit	Pipe Replacement	Coil Replacement	Fan Replacement	Booster Heat pump	Steam Converter	HX & Hydronic Pump(s)	Electrical Impacts
University Theater	AHU-1	1) Replace existing AHU steam coils with new LTHW coils. Provide new fan wall sections for all AHUs. Provide new hydronic heat exchanger, new hydronic pumps, new piping to all existing AHUs. 2) Deploy a high temperature booster heat pump using the proposed campus LTHW as a source, and creating HTHW for the existing terminal HW loop. The existing steam converter and pump infrastructure shall remain in place as backup. HW & CHW piping infrastructure and coils will remain unchanged. Replace steam UH with LTHW	Route approximately 1000ft of new cast iron & copper HW piping to each AHU, with sizes ranging from 4" at the pump header to 2" at the coil connection. Provide all new coil appurtenances (shutoffs, P/T ports, strainers, etc) and fill with 30% glycol solution. New piping for LTHW loop to existing terminal HWR for back up heating to AHU coils.	Retrofit new 1100 MBH LTHW coil into existing AHU cabinet and provide new control valve.	Retrofit new 21000 cfm fan wall array into existing AHU cabinet, including new flow sensors, VFDs, and control accessories	N/A	The existing steam converter will be left in place as a supplemental and backup source. Existing convertor, associated pumps and accessories to remain. Reconfigure piping to tie into the building HWS/R loop downstream of the proposed new WWHP in a sidecar configuration.	Install new plate & frame HX between campus LTHW and new building LTHW loops. Install (2) x 5 HP 60 gpm end suction pumps with VFDs, fully grouted isolation bases, suction diffusers and other appurtenances.	(2) New 5 HP Building HW Pumps (1) New Fan Wall arrays, expected to remain within existing electrical capacity.
	AHU-2			N/A Cooling Only	N/A Cooling Only				
	Steam Converter			N/A All terminal device coils remain.	N/A All terminal device coils remain.	Provide a (2) SBH100 30 ton modular water to water heat pump located in the existing mechanical room. The combined total is 750 MBH which will provide for the system load the majority of the year. Connect in sidecar configuration to existing building piping loop. Provide new controls for WWHP and accessories, tie into existing building BAS. Assume (20) physical points & (40) virtual points.		Provide new duplex ECM circulator pump array serving the WWHP, B&G EcoCirc 375XL or similar. Pipe in parallel and tie into existing hydronic piping loop.	53 kW new (2)SBH100 Modular WSHP (2) 3 HP B&G EcoCirc 375XL or similar.
	Reheat Terminals								
	Radiators								
	CUHs								
	UHs		Route 100ft of new copper HW piping to branch to new UHs in Mechanical spaces. Provide all new coil appurtenances (shutoffs, P/T ports, strainers, etc.)	Replace existing UH with new LTHW UH. Provide new control valve.	Provide new LTHW UH.	N/A			(3) New UHs expected to remain within existing electrical capacity.
	DHW	Existing electric DHW to remain in place.							N/A

	Building	Summary of Retrofit	Pipe Replacement	Coil Replacement	Fan Replacement	Booster Heat pump	Steam Converter	HX & Hydronic Pump(s)	Electrical Impacts
Art Building	AHU-1	1) Replace existing AHU steam coils with new LTHW coils. AHU-1 Preheat, AHU 1 Duct Coils 7 & 8, AHU 3 & 4 Preheat Coils. Provide new fan wall sections for AHUs 1, 3 & 4. *(New AHU preheat coils are downsized to reflect realistic loads that account for heat recovery & 4°F OSA design temp.)* 2) Replace (6) 180°F duct coils with 120°F duct coils served by LTHW. Provide new hydronic heat exchanger, new hydronic pumps, new piping to all existing AHUs.	Route approximately 500ft of new cast iron & copper HW piping to each AHU, with sizes ranging from 3" at the pump header to 2.5" & 2" at the coil connections. Provide all new coil appurtenances (shutoffs, P/T ports, strainers, etc.) and fill with 30% glycol solution.	Retrofit new 1800 MBH LTHW coil into existing AHU cabinet and provide new control valve.	Retrofit new 36085 cfm fan wall array into existing AHU cabinet, including new flow sensors, VFDs, and control accessories	N/A	The existing steam converter will be left in place as a supplemental and backup source. Existing convertor, associated pumps and accessories to remain. Reconfigure piping to tie into the building HWS/R loop downstream of the proposed new WWHP in a sidecar configuration.	Install new plate & frame HX between campus LTHW and new building LTHW loops. Install (2) x 20 HP 450 gpm end suction pumps with VFDs, fully grouted isolation bases, suction diffusers and other appurtenances.	(2) New 20 HP Building HW Pumps (3) New Fan Walls expected to remain within existing electrical capacity.
	AHU 1 - Duct Coil 7			Retrofit new 400 MBH LTHW coil into existing duct.	N/A - No Fan				
	AHU 1 - Duct Coil 8			Retrofit new 700 MBH LTHW coil into existing duct.					
	AHU-3		Route approximately 500ft of new cast iron & copper HW piping to each AHU, with sizes ranging from 3" at the pump header to 2" at the coil connections. Provide all new coil appurtenances (shutoffs, P/T ports, strainers, etc.) and fill with 30% glycol solution.	Retrofit new 400 MBH LTHW coil into existing AHU cabinet and provide new control valve.	Retrofit new 8950 cfm fan wall array into existing AHU cabinet, including new flow sensors, VFDs, and control accessories				
	AHU 3 - Duct Coil 1		N/A maintain HWS/R piping.	Retrofit new 200 MBH LTHW coil into existing duct.	N/A - No Fan				
	AHU 3 - Duct Coil 2			Retrofit new 100 MBH LTHW coil into existing duct.					
	AHU 3 - Duct Coil 3			Retrofit new 200 MBH LTHW coil into existing duct.					
	AHU-4		Route approximately 500ft of new cast iron & copper HW piping to each AHU, with sizes ranging from 3" at the pump header to 2" at the coil connections. Provide all new coil appurtenances (shutoffs, P/T ports, strainers, etc.) and fill with 30% glycol solution.	Retrofit new 400 MBH LTHW coil into existing AHU cabinet and provide new control valve.	Retrofit new 8550 cfm fan wall array into existing AHU cabinet, including new flow sensors, VFDs, and control accessories				
	AHU 4 - Duct Coil 4		N/A maintain HWS/R piping.	Retrofit new 200 MBH LTHW coil into existing duct.	N/A - No Fan				
	AHU 4 - Duct Coil 5			Retrofit new 200 MBH LTHW coil into existing duct.					
	AHU 4 - Duct Coil 6			Retrofit new 200 MBH LTHW coil into existing duct.					

Art Building (continued)

Building	Summary of Retrofit	Pipe Replacement	Coil Replacement	Fan Replacement	Booster Heat pump	Steam Converter	HX & Hydronic Pump(s)	Electrical Impacts
Steam UHs	Replace (3) steam UHs with new LTHW UHs.	Route approximately 100ft of new copper HW piping to each UH, with sizes ranging from 1 1/2" 1" at the coil connections. Provide all new coil appurtenances (shutoffs, P/T ports, strainers, etc.) and fill with 30% glycol solution.	Replace existing UH with new LTHW UH. Provide new control valve.	Provide new LTHW UH.	N/A	The existing steam converter will be left in place as a supplemental and backup source. Existing convertor, associated pumps and accessories to remain. Reconfigure piping to tie into the building HWS/R loop downstream of the proposed new WWHP in a sidecar configuration.	Install new plate & frame HX between campus LTHW and new building LTHW loops. Install (2) x 20 HP 450 gpm end suction pumps with VFDs, fully grouted isolation bases, suction diffusers and other appurtenances.	(3) New UH's expected to remain within existing electrical capacity.
Perimeter Steam to HW Converter HW Convectors HW UHs HW Wall Fin	Deploy a high temperature booster heat pump using the proposed campus LTHW as a source, and creating HTHW for the existing perimeter HW loop. The existing steam converter and pump infrastructure shall remain in place as backup. HW & CHW piping infrastructure and coils will remain unchanged.	N/A maintain HWS/R piping.	N/A	N/A	Provide a (2) SBH200 60 ton modular water to water heat pump located in the existing mechanical room. The combined total is 1450 MBH which will provide for the system load the majority of the year. Connect in sidecar configuration to existing building piping loop. Provide new controls for WWHP and accessories, tie into existing building BAS. Assume (20) physical points & (40) virtual points.		Provide new duplex ECM circulator pump array serving the WWHP, B&G EcoCirc 375XL or similar. Provide dedicated magnetic filter on header. Provide typical pump appurtenances (shutoff valves, strainers, P/T ports, etc.)	112 kW new (2)SBH200 Modular WSHP (2) 3 HP B&G EcoCirc 375XL or similar.
DHW	Add a new WSHP DHW heater to offset the DHW capacity from the steam converter. The steam converter should be left in place as back up.	New supply and return piping from campus LTHW to new DHW Heat Pump. New DHW piping to integrate storage tank.			Provide new Transom SWH150 WSHPs using the proposed campus LTHW to provide DHW to facility. Provide 100 gallon storage tank. Provide new 20 GPM B&G EcoCirc Pump. Tie into existing DHW system. Existing to remain in place as back up.			25.8 kW power for new Transom SWH150 WSHP. New 1/2 HP Circ Pump

Building		Summary of Retrofit	Pipe Replacement	Coil Replacement	Fan Replacement	Booster Heat pump	Steam Converter	HX & Hydronic Pump(s)	Electrical Impacts
Sutton Hall	AHU-1 Steam to HW HX VAV RH Coil FTR FCU-1	Deploy a high temperature booster heat pump using the proposed campus LTHW as a source, and creating HTHW for the building. The existing steam converter and pump infrastructure shall remain in place as backup.	N/A	N/A	N/A	Provide a (2) SBH150 45 ton modular water to water heat pump located in the existing mechanical room. The combined total is 1115 MBH which will provide for the system load the majority of the year. Connect in sidecar configuration to existing building piping loop. Provide new controls for WWHP and accessories, tie into existing building BAS. Assume (20) physical points & (40) virtual points.	The existing steam converter will be left in place as a supplemental and backup source. Existing convertor, associated pumps and accessories to remain. Reconfigure piping to tie into the building HWS/R loop downstream of the proposed new WWHP in a sidecar configuration.	Provide new duplex ECM circulator pump array serving the WWHP, B&G EcoCirc 375XL or similar. Provide dedicated magnetic filter on header. Provide typical pump appurtenances (shutoff valves, strainers, P/T ports, etc.)	85 kW new (2)xSBH150 Modular WSHP (2) New 3HP Pumps
	DHW	Existing electric DHW to remain in place.				N/A			N/A
Huston Hall	AHU-1	Demolish existing steam piping at AHUs Add steam to HW converter for backup? For AHU 1 & 2 Add (2) new AHU LTHW coils Add (2) new fan walls	Route approximately 1500ft of new cast iron & copper HW piping to each AHU, with sizes ranging from 4" at the pump header to 3" & 2.5" at the coil connections. Provide all new coil appurtenances (shutoffs, P/T ports, strainers, etc.) and fill with 30% glycol solution.	Retrofit new 900 MBH LTHW coil into existing AHU cabinet and provide new control valve.	Retrofit new 16000 cfm fan wall array into existing AHU cabinet, including new flow sensors, VFDs, and control accessories	N/A	Provide new 3000MBH shell & tube steam to HW converter, pipe in sidecar configuration to building primary variable LTHW loop.	Install new plate & frame HX between campus LTHW and new building LTHW loops. (2) New 130 GPM LTHW Pumps	(2) New 7.5 HP Pumps (2) New Fan Walls expected to remain within existing electrical capacity.
	AHU-2			Retrofit new 500 MBH LTHW coil into existing AHU cabinet and provide new control valve.	Retrofit new 9000 cfm fan wall array into existing AHU cabinet, including new flow sensors, VFDs, and control accessories				
	AHU-3			N/A Cooing Only	N/A Cooing Only				
	SF-5			N/A Cooing Only	N/A Cooing Only				
	CRAC-1			N/A Cooing Only	N/A Cooing Only				
	DHW	Add a new WSHP DHW heater to offset the DHW capacity from the steam converter. The steam converter should be left in place as back up.	New supply and return piping from campus LTHW to new DHW Heat Pump. New DHW piping to integrate storage tank.			Provide new Transom SWH100 WSHPs using the proposed campus LTHW to provide DHW to facility. Provide 100 gallon storage tank. Provide new 20 GPM B&G EcoCirc Pump. Tie into existing DHW system. Existing to remain in place as back up.			16.7 kW power for new Transom SWH100 WSHP. New 1/2 HP Circ Pump

Building		Summary of Retrofit	Pipe Replacement	Coil Replacement	Fan Replacement	Booster Heat pump	Steam Converter	HX & Hydronic Pump(s)	Electrical Impacts
Communications	AHU	Demolish existing steam piping at AHU Add steam to HW converter for backup? New AHU LTHW coil New fan wall	Route approximately 1000ft of new cast iron & copper 2.5" HW piping to the AHU, with sizes. Provide all new coil appurtenances (shutoffs, P/T ports, strainers, etc.) and fill with 30% glycol solution.	Retrofit new 400 MBH LTHW coil into existing AHU cabinet and provide new control valve.	Retrofit new 10150 cfm fan wall array into existing AHU cabinet, including new flow sensors, VFDs, and control accessories	N/A	Provide new 400MBH shell & tube steam to HW converter, pipe in sidecar configuration to building primary variable LTHW loop.	Install new plate & frame HX between campus LTHW and new building LTHW loops. Install new duplex ECM circulator pump array, with peak design flow of 60gpm. Provide dedicated magnetic filter on header. Provide typical pump appurtenances (shutoff valves, strainers, P/T ports, etc.) Pipe in parallel and tie into existing hydronic piping loop.	(2) x 2HP motors with ECM drives New Fan Wall expected to remain within existing electrical capacity.
	DHW	Existing electric DHW to remain in place.				N/A			N/A
Radio / TV Building	AHU-1	Demolish existing steam piping at AHU Add steam to HW converter for backup. New AHU LTHW coil New fan wall	Route approximately 1000ft of new cast iron & copper 2.5" HW piping to the AHU, with sizes. Provide all new coil appurtenances (shutoffs, P/T ports, strainers, etc.) and fill with 30% glycol solution.	Retrofit new 400 MBH LTHW coil into existing AHU cabinet and provide new control valve.	Retrofit new 10500 cfm fan wall array into existing AHU cabinet, including new flow sensors, VFDs, and control accessories	N/A	Provide new 400MBH shell & tube steam to HW converter, pipe in sidecar configuration to building primary variable LTHW loop.	Install new plate & frame HX between campus LTHW and new building LTHW loops. Provide new duplex ECM circulator pump array serving the WWHP, B&G EcoCirc 375XL or similar .Provide dedicated magnetic filter on header. Provide typical pump appurtenances (shutoff valves, strainers, P/T ports, etc.) Pipe in parallel and tie into existing hydronic piping loop.	(2) x 2HP motors with ECM drives New Fan Wall expected to remain within existing electrical capacity.
	DHW	Existing electric DHW to remain in place.				N/A			N/A

Appendix D | Renovation Scope by Building – Campus-Wide Deployment

Note: The below costs only include the cost to convert the existing HVAC and DHW systems to a decarbonized in-building solution. They do not include the costs of the Energy Efficiency Measures referenced elsewhere in the report.

	Building	Type	Area [s.f.]	Estimated Peak Heating Load (MBH)	Estimated Peak Cooling Load (Tons)	DHW Capacity (MBH)	Node / Phase	Year	Existing Mechanical & DHW System	Decarbonized Mechanical System	Decarbonized System Cost
MAR	Martin Hall	Academic	57,793	1,172	165	120	1	2026	HVAC: LTHW serving air handlers and LTHW serving terminal heating. DHW: Steam to DHW converter	HHW Strategy 4 - Run Campus LTHW through Existing Coils DHW Strategy 4 - Hybrid ASHP DHW	N/A, included in separate renovation scope
WLM	Williamson Hall	Academic	31,599	641	90	70	1	2026	HVAC: HTHW serving air handlers and radiators DHW: Steam to DHW converter	HHW Strategy 1 - Replace Coils DHW Strategy 4 - Hybrid ASHP DHW	N/A
CEB	Computing & Engineering Building	Science	98,476	2,178	281	1,000	1	2026	HVAC: Direct steam serving dual duct systems and large single zone AHUs. DHW: Steam to DHW converter	HHW Strategy 2 - Steam to LTHW Coil Replacement DHW Strategy 2 - Booster Heat Pump	$3,560,223
CMC	Communications Building	Academic	19,289	391	55	N/A	1	2026	HVAC: Direct steam serving air handlers DHW: Electric DHW Heaters	HHW Strategy 2 - Steam to LTHW Coil Replacement DHW Strategy 1 - Existing Electric DHW	$888,010
RTV	Radio/TV Building	Academic	16,980	344	49	N/A	1	2026	HVAC: Direct steam serving air handlers DHW: Electric DHW Heaters	HHW Strategy 2 - Steam to LTHW Coil Replacement DHW Strategy 1 - Existing Electric DHW	$781,710
MUS	Music Building	Academic	47,618	965	136	N/A	1	2027	HVAC: Direct steam serving air handlers and unit heaters. DHW: Electric DHW Heaters	HHW Strategy 2 - Steam to LTHW Coil Replacement DHW Strategy 1 - Existing Electric DHW	$1,594,324
THE	University Theater	Other	41,164	791	118	N/A	1	2027	HVAC: Direct steam serving air handlers and HTHW serving terminal heating. DHW: Electric DHW Heaters	HHW Strategy 3 - Steam to LTHW Coil Replacement & Booster Heat Pump DHW Strategy 1 - Existing Electric DHW	$1,570,023

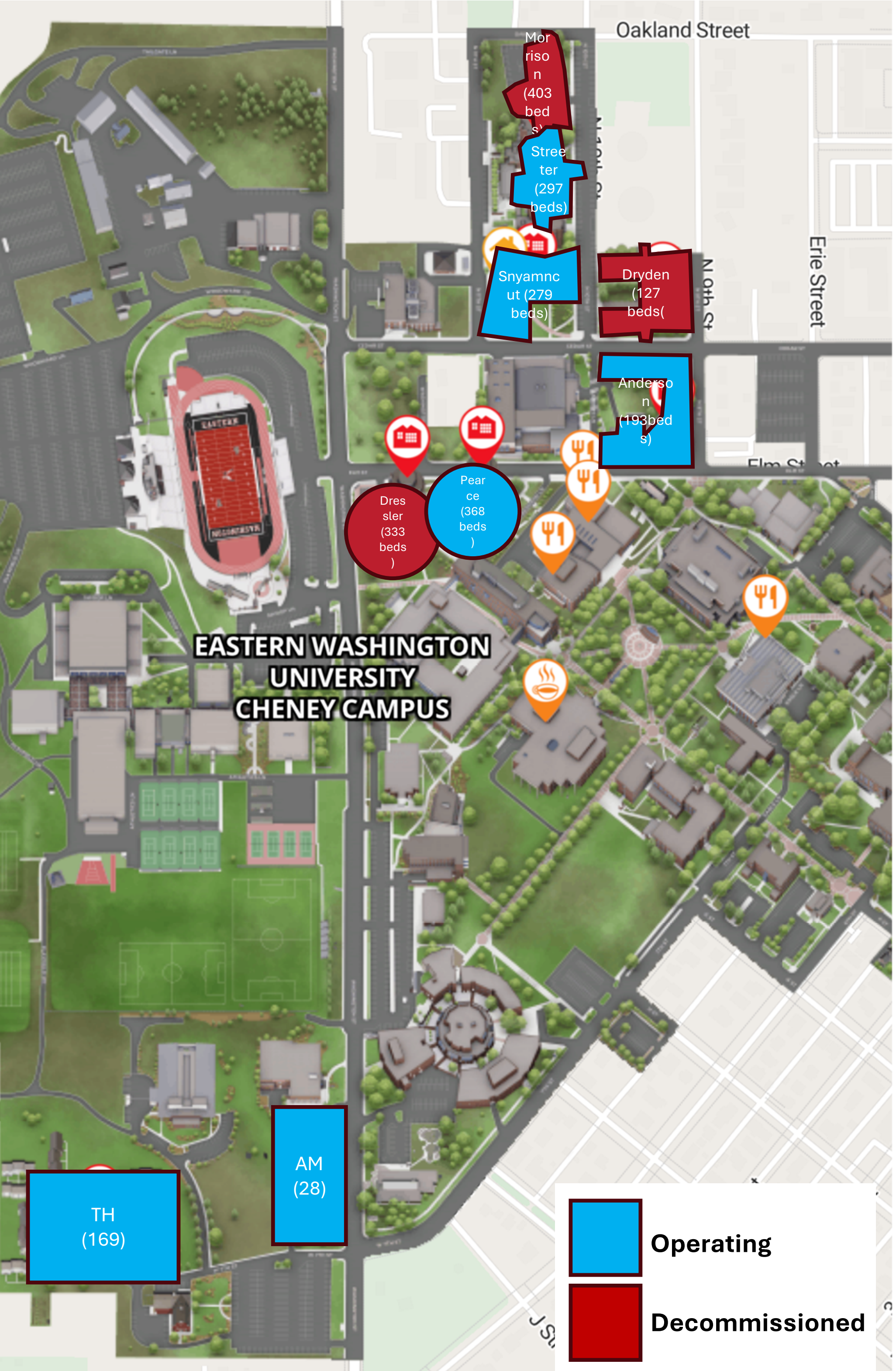
Appendix D | Renovation Scope by Building – Campus-Wide Deployment

	Building	Type	Area [s.f.]	Estimated Peak Heating Load (MBH)	Estimated Peak Cooling Load (Tons)	DHW Capacity (MBH)	Node / Phase	Year	Existing Mechanical & DHW System	Decarbonized Mechanical System	Decarbonized System Cost
ART	Art Building	Science	34,469	762	98	300	1	2027	HVAC: Direct steam serving air handlers and HTHW serving terminal heating. DHW: Electric DHW Heaters & Steam to DHW converter	HHW Strategy 3 - Steam to LTHW Coil Replacement & Booster Heat Pump DHW Strategy 2 - Booster Heat Pump	$2,581,705
JFK	JFK Library	Library	124,496	2,458	457	400	1	2028	HVAC: High Temp Hot Water serving mostly dual duct systems. DHW: Electric DHW Heaters	HHW Strategy 1 - Booster Heat Pump DHW Strategy 1 - Existing Electric DHW	$1,829,998
SUT	Sutton Hall	Administrative	31,927	622	91	N/A	1	2028	HVAC: HTHW serving air handlers and radiators DHW: Electric DHW Heaters	HHW Strategy 1 - Booster Heat Pump DHW Strategy 1 - Existing Electric DHW	$698,491
HUS	Huston Hall	Administrative	27,424	534	78	200	1	2029	HVAC: Direct steam serving air handlers DHW: Steam to DHW converter	HHW Strategy 2 - Steam to LTHW Coil Replacement DHW Strategy 2 - Booster Heat Pump	$1,398,608
SHO	Showalter Hall	Administrative	99,723	1,943	285	N/A	1	2029	HVAC: Direct steam serving air handlers & terminals DHW: Electric DHW Heaters	HHW Strategy 2 - Steam to LTHW Coil Replacement DHW Strategy 1 - Existing Electric DHW	$6,677,760
CHN	Cheney Hall	Academic	31,018	629	89	70	1	2029	HVAC: HTHW serving air handlers and VAV reheat DHW: Steam to DHW converter	HHW Strategy 1 - Booster Heat Pump DHW Strategy 4 - Hybrid ASHP DHW	$544,529

	Building	Type	Area [s.f.]	Estimated Peak Heating Load (MBH)	Estimated Peak Cooling Load (Tons)	DHW Capacity (MBH)	Node / Phase	Year	Existing Mechanical & DHW System	Decarbonized Mechanical System	Decarbonized System Cost
SUR	Surbeck Services	Support	21,932	422	N/A	0	2	2030	HVAC: Packaged RTU - Natural Gas DHW: Electric DHW Heaters	HHW Strategy 5 - ASHP & Electric Coils DHW Strategy 1 - Existing Electric DHW	$219,320
GSB	Grounds Storage Building	Support	20,478	394	N/A	0	2	2030	HVAC: Gas Unit Heaters DHW: Electric DHW Heaters	HHW Strategy 5 - Electric Coils DHW Strategy 1 - Existing Electric DHW	$71,673
TAW	Tawanka Commons	Administrative	73,733	1,437	211	150	2	2030	HVAC: Direct steam serving air handlers and MTHW serving terminal heating. DHW: Steam to DHW converter	HHW Strategy 3 - Steam to LTHW Coil Replacement & Booster Heat Pump DHW Strategy 4 - Hybrid ASHP DHW	$2,065,203
KGS	Kingston Hall	Academic	61,275	1,242	175	120	2	2031	HVAC: HTHW serving air handlers and VAV reheat DHW: Steam to DHW converter	HHW Strategy 1 - Booster Heat Pump DHW Strategy 4 - Hybrid ASHP DHW	$731,039
SNR	Senior Hall	Administrative	52,618	1,025	150	100	2	2031	HVAC: Direct steam serving air handlers and HTHW serving terminal heating. DHW: Steam to DHW converter	HHW Strategy 3 - Steam to LTHW Coil Replacement & Booster Heat Pump DHW Strategy 4 - Hybrid ASHP DHW	$1,470,267
HAR	Hargreaves Hall	Administrative	56,616	1,103	162	120	2	2032	HVAC: HTHW serving air handlers and VAV reheat DHW: Steam to DHW converter	HHW Strategy 1 - Booster Heat Pump DHW Strategy 4 - Hybrid ASHP DHW	$671,993
URC	University Recreation Center	Recreation	115,490	2,098	330	700	2	2032	HVAC: HTHW serving air handlers, Steam serving Ice Rink AHU DHW: Steam to DHW converter	HHW Strategy 2 - Steam to LTHW Coil Replacement DHW Strategy 2 - Booster Heat Pump	$4,094,117

	Building	Type	Area [s.f.]	Estimated Peak Heating Load (MBH)	Estimated Peak Cooling Load (Tons)	DHW Capacity (MBH)	Node / Phase	Year	Existing Mechanical & DHW System	Decarbonized Mechanical System	Decarbonized System Cost
PAT	Patterson Hall	Academic	161,873	3,282	462	500	2	2033	HVAC: Direct steam serving air handlers and HTHW serving terminal heating. DHW: Steam to DHW converter	HHW Strategy 3 - Steam to LTHW Coil Replacement & Booster Heat Pump DHW Strategy 2 - Booster Heat Pump	$4,657,468
SNY	Snyamncut Hall	Housing	125,758	2,119	359	1,200	2	2033	HVAC: Direct steam serving air handlers and HTHW serving terminal heating. DHW: Steam to DHW converter	HHW Strategy 3 - Steam to LTHW Coil Replacement & Booster Heat Pump DHW Strategy 3 - New Electric DHW	$3,728,070
PUB	Pence Union Building	Dining	176,731	3,211	505	800	2	2034	HVAC: Direct steam serving air handlers and HTHW serving terminal heating. DHW: Steam to DHW converter	HHW Strategy 3 - Steam to LTHW Coil Replacement & Booster Heat Pump DHW Strategy 2 - Booster Heat Pump	$4,846,453
ISC	Interdisciplinary Science Center	Academic	99,302	2,013	284	300	2	2034	HVAC: HTHW serving air handlers and VAV reheat DHW: Steam to DHW converter	HHW Strategy 1 - Booster Heat Pump DHW Strategy 2 - Booster Heat Pump	$1,248,154
SCI	Science Building	Academic	148,212	3,005	423	450	2	2035	HVAC: Direct steam serving air handlers and LTHW serving terminal heating. DHW: Steam to DHW converter	HHW Strategy 2 - Steam to LTHW Coil Replacement DHW Strategy 2 - Booster Heat Pump	$4,272,758
DRE	Dressler Hall	Housing	78,756	1,327	0	800	2	2035	HVAC: Direct steam serving air handlers & terminals DHW: Steam to DHW converter	HHW Strategy 2 - Steam to LTHW Coil Replacement DHW Strategy 3 - New Electric DHW	$5,753,972
PRC	Pearce Hall	Housing	93,975	1,584	0	1,000	2	2035	HVAC: Direct steam serving air handlers & terminals DHW: Steam to DHW converter	HHW Strategy 2 - Steam to LTHW Coil Replacement DHW Strategy 3 - New Electric DHW	$6,819,045

	Building	Type	Area [s.f.]	Estimated Peak Heating Load (MBH)	Estimated Peak Cooling Load (Tons)	DHW Capacity (MBH)	Node / Phase	Year	Existing Mechanical & DHW System	Decarbonized Mechanical System	Decarbonized System Cost
PAV	Pavilion (Reese Court)	Recreation	169,926	3,087	486	600	3	2036	HVAC: Direct steam serving air handlers & terminals DHW: Steam to DHW converter	HHW Strategy 2 - Steam to LTHW Coil Replacement DHW Strategy 2 - Booster Heat Pump	$5,902,808
AQT	Aquatics Building	Recreation	21,237	386	0	80	3	2036	HVAC: Direct steam serving air handlers & terminals DHW: Steam to DHW converter	HHW Strategy 2 - Steam to LTHW Coil Replacement DHW Strategy 3 - New Electric DHW	$1,164,693
PEA	P.E. Activities Building	Recreation	93,859	1,705	268	500	3	2037	HVAC: Direct steam serving air handlers and HTHW serving terminal heating. DHW: Steam to DHW converter	HHW Strategy 3 - Steam to LTHW Coil Replacement & Booster Heat Pump DHW Strategy 2 - Booster Heat Pump	$2,644,419
JTF	Jim Thorpe Fieldhouse	Recreation	51,316	932	0	N/A	3	2038	HVAC: HTHW serving air handlers DHW: Electric DHW Heaters	HHW Strategy 2 - Steam to LTHW Coil Replacement DHW Strategy 1 - Existing Electric DHW	$1,718,139
ALB	Albers Court	Recreation	29,180	530	83	50	3	2038	HVAC: HTHW serving air handlers, CUHs & UHs DHW: Steam to DHW converter	HHW Strategy 2 - Steam to LTHW Coil Replacement DHW Strategy 3 - New Electric DHW	$1,497,618
PEC	P.E. Classrooms Building	Academic	31,848	646	91	N/A	3	2039	HVAC: Direct steam serving air handlers and MTHW serving terminal heating. DHW: Electric DHW Heaters	HHW Strategy 3 - Steam to LTHW Coil Replacement & Booster Heat Pump DHW Strategy 1 - Existing Electric DHW	$877,373



Current Housing Inventory

Facility	Built	Renov	Designated Capacity
Anderson Hall	1951	2001	193
Pearce Hall	1966		368
snyamncut	2013		344
Streeter Hall	1968		279
Dressler	1966		333
Dryden	1966		127
Morrison	1971		403
Townhouses	1993		169
Anna Maria	1968		28