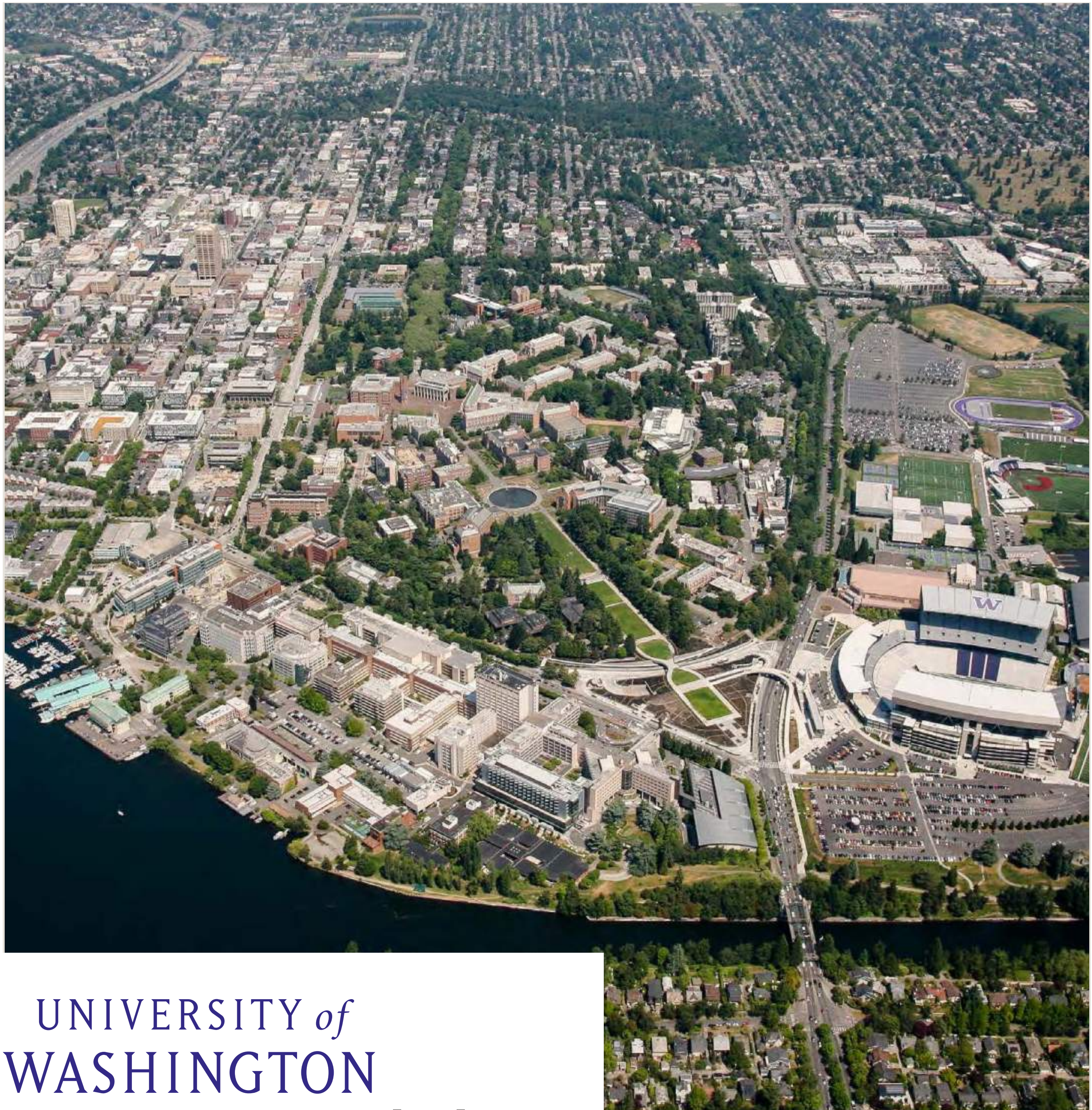

UNIVERSITY *of* WASHINGTON

Energy Renewal Plan

Baseline Assessment Report

AEI PROJECT NO. 24675-00
February 16, 2024

Affiliated Engineers

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1.0 Introduction

1.1 Project Definition and Goals

The University of Washington (UW) Energy Renewal Plan (ERP) will analyze the existing energy infrastructure on the UW campus and define a plan to implement a multi-phase decarbonization and transformation of the UW Energy Systems including transitioning from steam to hot water as the primary source of heating, expansion of the campus cooling water system, and upgrading the electrical systems to provide additional capacity and improved reliability.

When complete, the Energy Renewal Program will provide a phased implementation plan to decarbonize the University campus energy systems including the elimination of fossil fuels used in the production of energy for building heating and air conditioning, water heating, and process uses. The plan will include a funding approach that maximizes the use of available outside funding sources including federal funding (IRA, IIJA, etc.), grant opportunities, Washington State CCA funding, and utility incentives. The stated goal for the project is to have 100% funding from external sources.

This plan represents a major transition from fossil fuel combustion with boilers to electrically driven heat exchange with heat pumps. The technology transition enables the campus to repurpose and share energy amongst various sources and between buildings. With the transition to electricity as a primary heating source, dependency on the electrical grid will increase. Because of this, the plan will also address the efficient use of electricity and enhancements to system resiliency.

This report provides the baseline assessment of existing conditions and is referred to as Phase I. The report summarizes the analysis of existing documentation and operating conditions of campus energy systems, campus site visits, preliminary analysis of regulations and permitting process, and early conceptual development to be refined in Phase II Project Identification and Prioritization (subsequent report to follow). Phase III of the project will include a final implementation plan that will document the decisions determined in Phases I and II and will include a detailed implementation plan with schedules, cost estimates, and funding plans.

A concurrent effort, the Building Renewal Plan (BRP) is underway to study the prioritization of existing building renovation or replacement is being led by Miller Hull. This study is primarily focused on optimizing the utilization of campus building stock and reducing deferred maintenance of existing facilities to an acceptable level. The ERP and BRP teams are coordinating through a series of workshops that will inform the two efforts on prioritization needs from the two perspectives of deferred maintenance and the campus energy system transition.

The Seattle Campus includes buildings that are both owned and leased. Buildings occupied by the University extend beyond the footprint of what is traditionally thought of as the UW campus. The Energy Renewal Plan will exclude leased buildings, undeveloped sections of the East Campus, Husky Stadium, and other properties that are outside of an agreed-upon proximity to existing district energy utilities. Refer to Appendix 5.1.1 for a site plan that indicates which buildings are excluded from the study as well as buildings identified as provisioned for future and studied for future connection (housing/athletics and facilities with stand-alone systems).

1.2 Background

The University of Washington's Seattle campus provides critical functions as a tier 1 research university and a regional hospital in the University of Washington Medical Center (UWMC). Delivery of reliable utilities is a high priority.

The following past reports inform the history of campus infrastructure and building master plans for the ERP study effort:

- 2011 University of Washington South of Pacific Avenue Master Infrastructure Review
- 2014 University of Washington Hot Water Conversion Study
- 2017 University of Washington Hot Water Conversion Study: Phase II
- 2016 South Campus Study
- 2019 University of Washington Seattle Campus Master Plan
- 2021-22 ISES Facilities Condition Assessment
- 2022 Utilities Infrastructure Assessment
- UW Cultural Resources Report

This report is authored by a team with a long history of study, design, and implementation work on campus. Members of the ERP team contributed to the campus infrastructure review, hot water conversion studies, and south campus study.

1.3 Process and Collaboration with University of Washington Staff

The University has an internal team of experts with experience in operations, engineering, sustainability, energy conservation, data management, and experience with transitioning university campuses from steam to hot water. To integrate the ERP consulting team with the University staff, a series of Project Working Teams (PWTs) were organized. The following PWT groups have met regularly throughout the Baseline Assessment phase:

- Funding and Financing
- Central Plant, Thermal Energy Storage, and Distribution
- Thermal Transfer (Lake Interface and Sewer Heat Recovery)
- Buildings
- Electrification

The UW is supporting the planning effort with a highly developed oversight and governance structure, dedicated staff to provide day-to-day direction and oversight, and a series of Project Working Teams (PWTs) that have been formed to support the transfer of knowledge, data gathering, review of proposed concepts, prioritization of tasks, and forming outreach strategies for external entities. This structure will continue through the end of the study effort.

The consultant team supporting the Energy Renewal Program includes the following firms that bring specialty knowledge and experience to this effort:

- Affiliated Engineers, Inc. (AEI) – Prime Consultant and Mechanical and Electrical master planning and engineering
- KPFF – Civil engineering and site utilities planning
- Whiting-Turner (W-T) – Cost estimating, phasing, and logistics analysis
- Shannon & Wilson (S&W) – Lake water technical and permitting specialists
- Ernst & Young (EY) – Financial analysis and funding plans

It is anticipated that as the planning effort moves into the next phases additional consultants will be added to the team to support issues such as Architecture, Landscape Architecture, Deep Lake Water Cooling implementation, and others.

2.0 Executive Summary

The primary goals for the baseline assessment study are:

- Define the existing campus utility load profiles broken down by:
  - Production output at the existing West Campus Utility Plant (WCUP) and Power Plant
  - Building cooling and heating demand load profile (removal of plant and distribution inefficiencies)
  - Electrical demand profile at East and West Receiving Stations

  - Process steam loads
- Project the future campus utility load profiles:
  - Future output from WCUP and Power Plant with new electrified heating systems and improved cooling systems
  - Future building cooling and heating demand profile, including load growth from the transition from building-level cooling equipment to campus chilled water
  - Future electrical demand profile at East and West Receiving Stations
- Identify opportunities for alternative heating sources to be explored further in Phase II
- Preliminary analysis of distribution system options for delivery of new thermal utilities across campus
- Preliminary analysis of state and city regulatory requirements
- Preliminary analysis of permitting strategies
- Identification of funding and financing opportunities

Refer to sections 3.1.1, 3.2.1, 4.1, and 4.2 for the numerical analysis associated with identifying the existing and future utility load projections. Table 2.0-1 summarizes the existing and future loads, which were determined through weather regression analysis rather than direct metering. Refer to section 3.1.1.1 for additional details on the regression analysis.

Table 2.0-1: Existing and Future Campus Load Summary

Utility Category	Existing Conditions	Future Conditions	Comments
Heating Plant Load (MBH)	318,900	283,500	Peak plant output demand. Existing is steam and the future is heating hot water. Based on 2022 data.
Cooling Plant Load (Tons)	17,900	26,000	Required plant output. Existing is current CCW service and future includes consolidation of distributed cooling systems. Based on 2022 data.
Electrical Demand (MW)	60	80	Total campus electrical service including district energy systems. Existing conditions assume non-SCL maintenance mode based on 2021 data.

No options were eliminated as part of the baseline assessment. Screening of options for further development will take place in Phase II. Alternative heating and cooling opportunities that will be explored in further detail for Phase II are:

- Heat recovery chiller technologies with analysis of low global warming potential (GWP) and natural refrigerants
- Heat recovery chillers and air-to-air heat recovery devices for recovered heat from buildings

- Lake Interface as a source for heating and cooling using heat recovery chillers
- Sewer heat recovery as a source for heating and cooling using heat recovery chillers
- Steam-to-hot water converters as part of the interim heating water solution
- Emerging technologies/electrified heating sources including electrode or hydrogen boilers and micro nuclear

3.0 Baseline Conditions

Through meetings with campus staff, site investigations, and data collection, the baseline for campus system capacities, mechanical and electrical loads, and campus and building-level operating conditions was established. The findings and analysis are described in the following sections.

3.1 Mechanical Baseline Assessment

3.1.1 Cooling and Heating Load Assessment

This baseline assessment includes an evaluation of the existing cooling and heating loads on campus to validate peak loads and develop hourly, campus-level, cooling, and heating load profiles. This information will inform options developed for production and distribution upgrades in Phase II of this process. The baseline cooling and heating load assessment is also used to understand the potential campus-level electrical impacts of these upgrades.

UW Facilities staff maintain data on the existing plant cooling and heating output for the Power Plant and WCUP. Data from the WCUP is monitored by the building control system and data is stored in a third-party data historian service. Data from the Power Plant is logged via manual meter readings and utility bills. There are numerous building-level electricity meters, campus chilled water (CCW) meters, and to a lesser extent steam condensate meters. AEI was provided with access to these data sources and was able to validate peak loads and generate hourly profiles for the 2022 heating and cooling production of each plant. This was done either through direct manipulation of building and plant meter data or through supplementing meter data with profiles generated from prototypical building energy models. More realistic building-level cooling and heating demands are also estimated with consideration for distribution and connection losses from the existing systems on campus.

A UW dataset of existing cooling and heating peak loads on a building-by-building basis is not currently maintained due to an incomplete set of existing meter data. Buildings with stand-alone heating or cooling systems do not have metered end-use data. Building level heating and cooling demands are estimated by using the available metered data for steam condensate and CCW with adjustments made for known campus deficiencies, gaps in data, and missing or poor metered data.

3.1.1.1 Campus Cooling Water (CCW) Loads

The following data were used to generate hourly, campus-level existing CCW loads including cooling from the Power Plant and WCUP:

- 15-minute CCW output from WCUP (Nov 2019 – Nov 2023)
- Monthly CCW output from Power Plant (Jan 2009 – Nov 2023)
- 15-minute CCW building demand meters for 52 buildings (Jan 2022 – Dec 2022)

The total existing campus CCW profile considers current Power Plant CCW production (weather adjusted for 2022 peak cooling demand of connected buildings) and current WCUP CCW production. Section 4.1 of this report includes an estimated profile for existing distributed stand-alone cooling systems to be consolidated into the CCW system as part of the Energy Renewal Plan, along with consideration of future climate data and future campus cooling load growth.

The WCUP cooling load profile is generated from 15-minute meter data from the plant validated with building-level meter data for a majority of the nine WCUP CCW-connected facilities (extended historical meter data not available for the ARCF building). An approximation of 32% of the CCW supplied to Magnuson Health Sciences (MHS) was from the WCUP and the remaining 68% by the Power Plant. Further investigation with ongoing metering efforts will continue in Phase II for MHS and UWMC cooling.

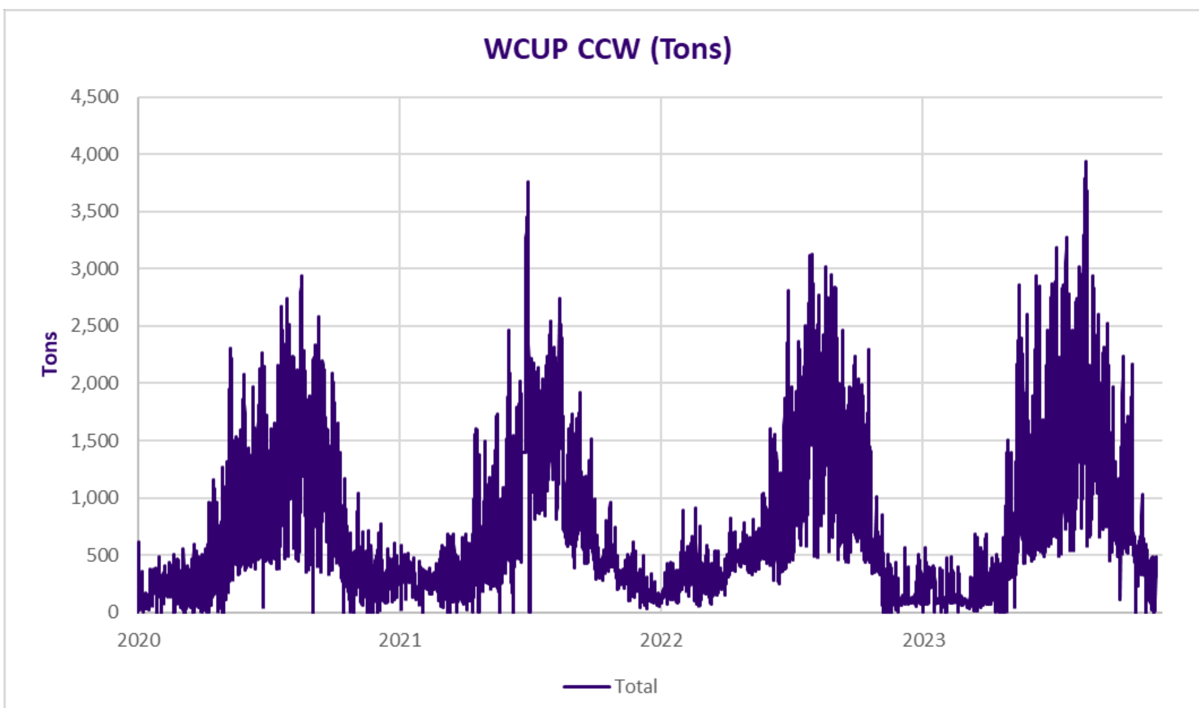


Figure 3.1.1.1-1: *2020-2023 WCUP hourly CCW production.*

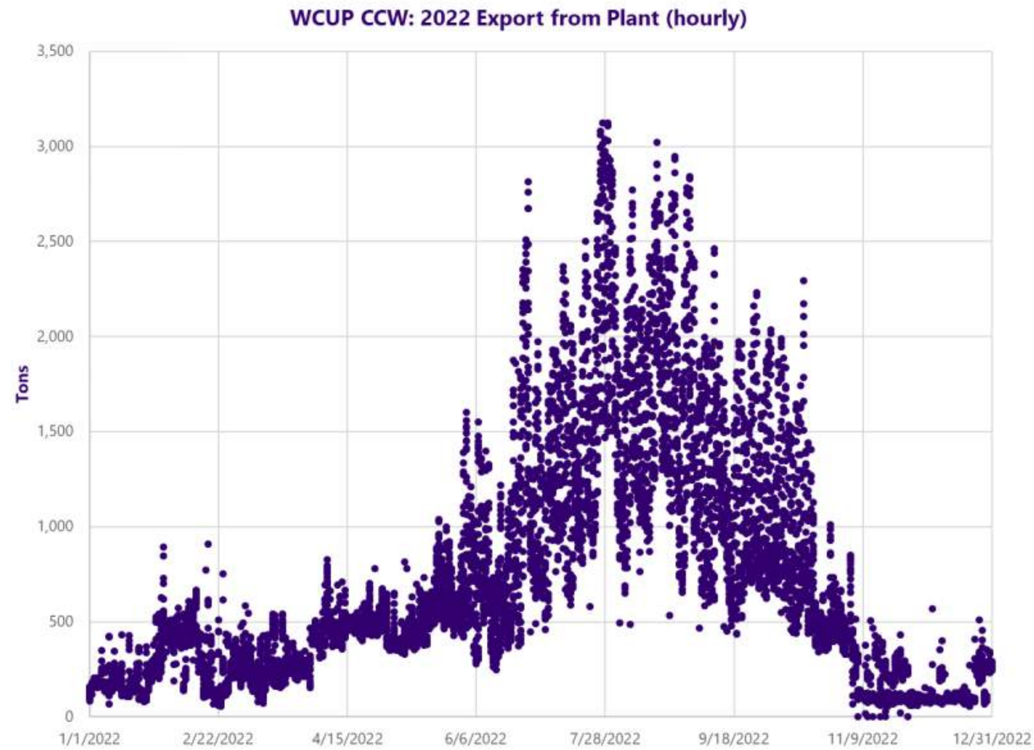
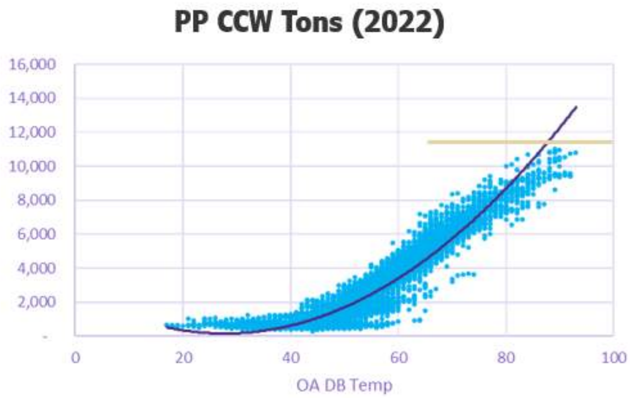


Figure 3.1.1.1-2: *2022 WCUP hourly CCW production.*

The Power Plant cooling load profile is generated with monthly CCW production data. This data was validated against an hourly campus building demand profile generated from the portion of Power Plant CCW connected facilities with meters (a number of buildings CCW meters are still being installed) combined with prototypical building energy models developed by AEI used for the remaining UW building stock.

Historical weather regression analysis was performed on the Power Plant CCW production above outdoor temperatures of 85F, where the existing Power Plant CCW production is known to not satisfy the full campus building CCW demand (confirmed by UW facilities). Outdoor air dry bulb and enthalpy were considered in this analysis. A roughly 11,000-ton peak production is observed with metered 2022 data as compared to an estimated 14,500-ton peak with the weather regression analysis applied. This weather-adjusted data was then applied to the Power Plant CCW production for hours with high outdoor air temperatures only.



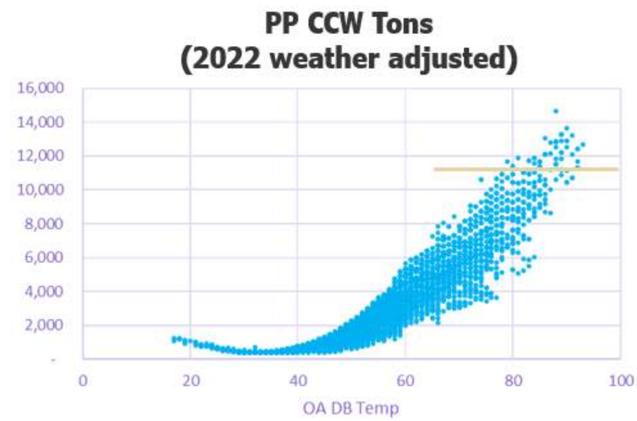


Figure 3.1.1.1-1: *2022 Power Plant CCW hourly weather regression analysis for outdoor dry bulb temperatures (shown) and enthalpy.*

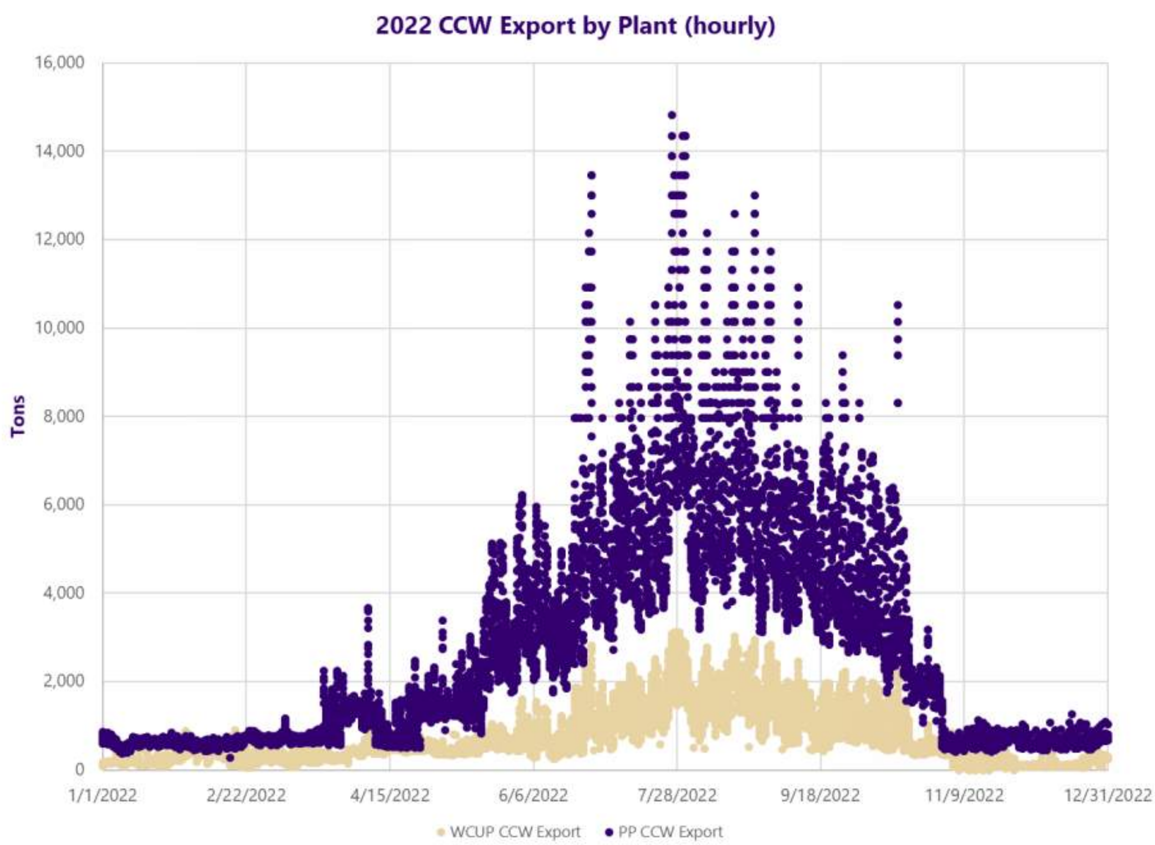


Figure 3.1.1.1-2: *2022 Power Plant and WCUP hourly CCW production.*

3.1.1.2 Steam Loads

Hourly steam loads for the whole campus are not well documented given steam condensate meters are only installed in a limited number of buildings and depending on the configuration and operation of the condensate receiver (gravity vs. pumped), they represent more of an hourly average than an instantaneous value. Available data for the Power Plant includes monthly total steam production, monthly peak steam (24-hour average), and daily natural gas consumption. Additionally, there are much larger distribution losses on the campus steam system as compared to the CCW system, which results in a more significant gap between existing steam data and future campus hot water demands for buildings connected to the Energy Renewal Plan. Estimated annual distribution and conversion loss of 20% is used in the Baseline Assessment.

The approach taken includes analysis of building-level steam condensate data with an understanding of building systems and use characterization. A combination of prototype building energy models and normalized meter data for representative building types were applied on a case-by-case basis. Like the CCW analysis, a consideration for building energy consumption and load density, along with Power Plant peak and monthly steam production was used to affirm the data.

Steam loads driven by process equipment are not explicitly identified or documented. Equipment asset information for existing process equipment was provided to AEI and will be investigated further in Phase II. For the calculations and estimations made in Phase I, the process equipment load is estimated to be a constant 20,000 lbs./hr based on information provided to AEI in previous study efforts with the University of Washington.

Power Plant hourly total campus steam profile for 2022 is shown in Figure 3.1.1.2-1 and compared to available meter data to validate the hourly estimated steam consumption profiles with the monthly meter data from the Power Plant.

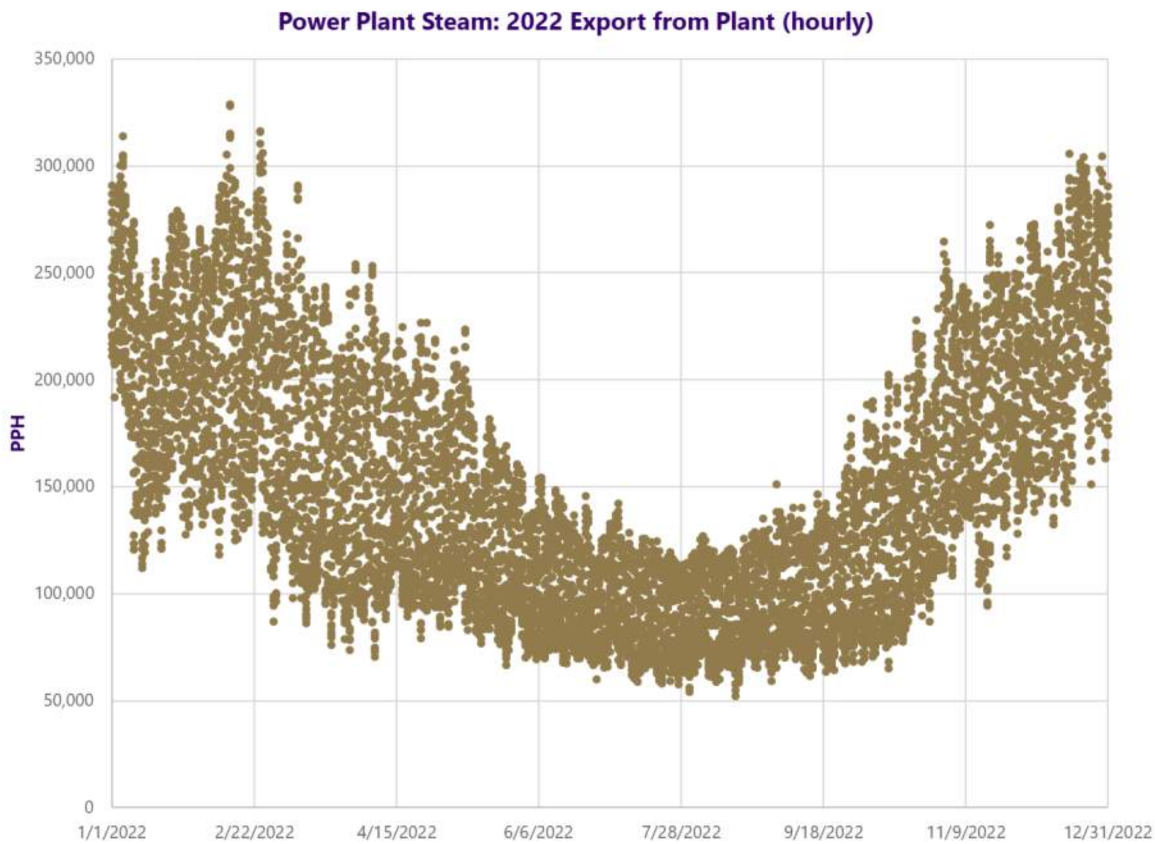


Figure 3.1.1.2-1: *Power Plant total campus hourly steam production for 2022*

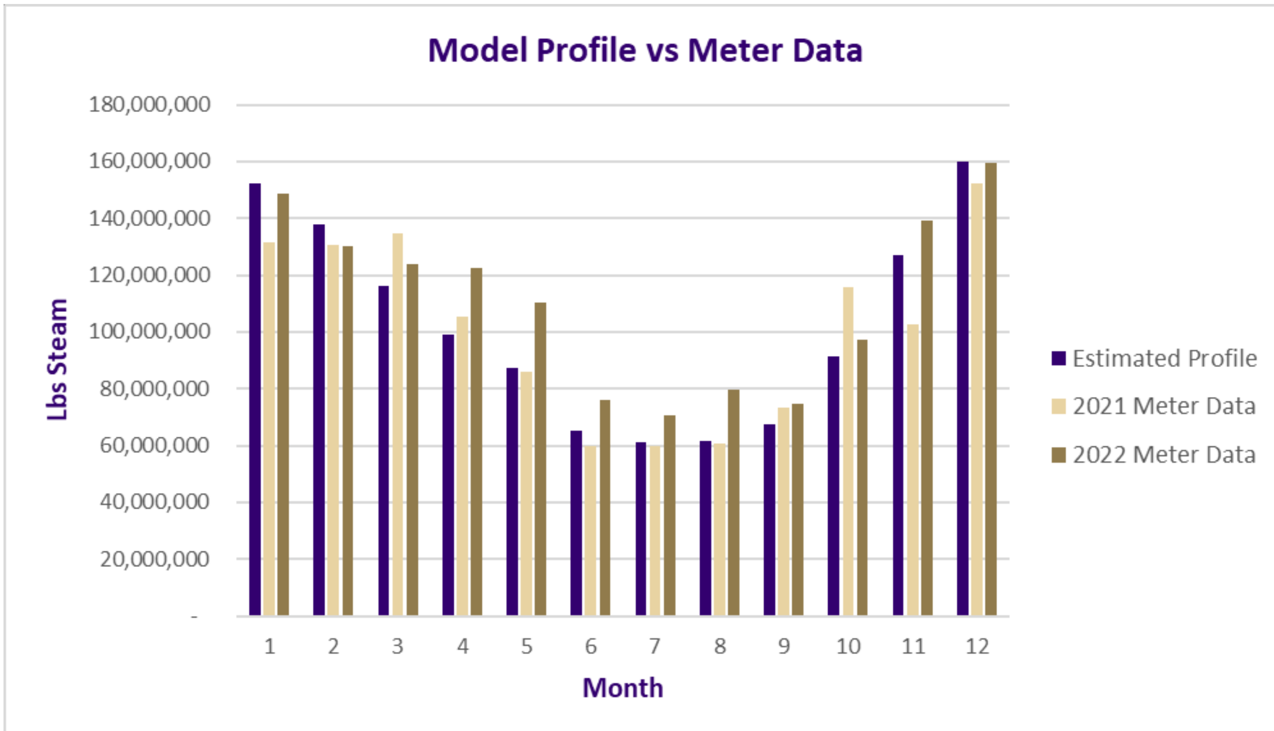


Figure 3.1.1.2-2: *Comparison of estimated steam provided by plant (purple) compared to meter data from 2021 and 2022. This is steam leaving the plant going out to the campus network.*

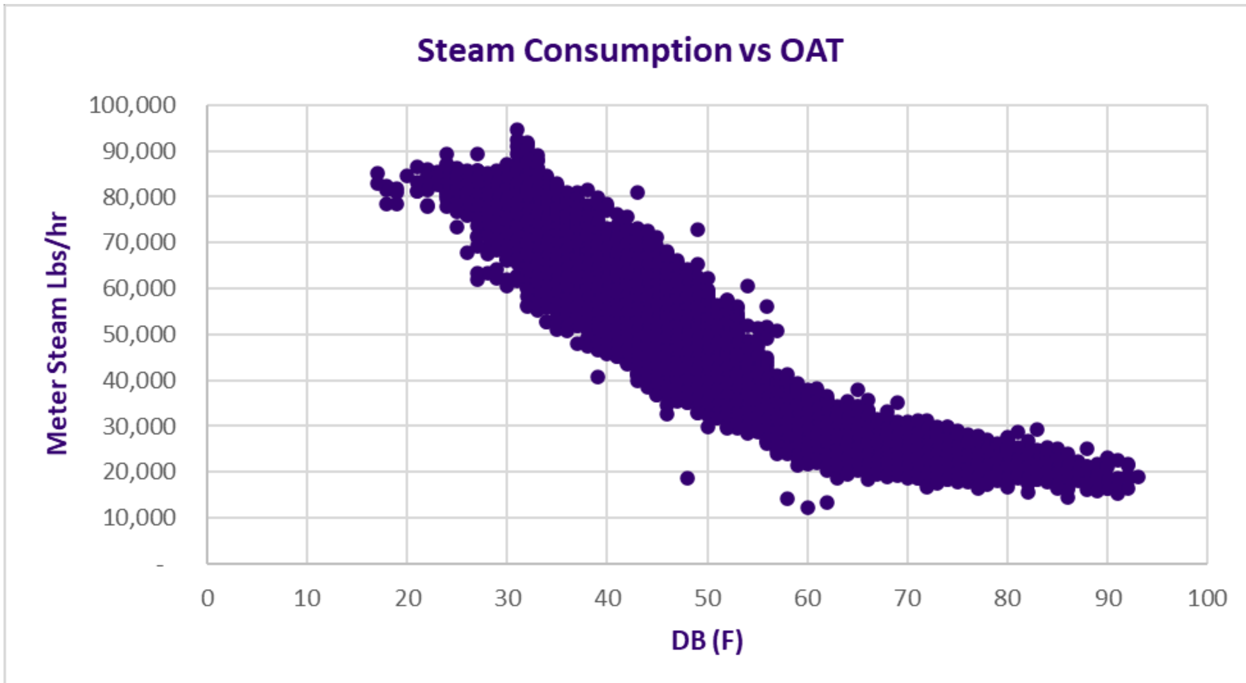


Figure 3.1.1.2-3: *Steam meter data available at building level vs OAT (F).*
This data does not include steam distribution losses or boiler efficiencies.

3.1.2 Mechanical Infrastructure Assessment

Campus Chilled Water (CCW) is supplied by both the Power Plant and WCUP, located at opposite ends of the piped distribution system. The Power Plant houses six centrifugal chillers and one lithium bromide absorption chiller with a total installed capacity of 12,000 tons. Each chiller has a dedicated cooling tower, condenser water pump, and primary chilled water pump. The primary chilled water pumps distribute CCW (between 42°F and 50F°) throughout the campus, in addition to pulling water through the chiller. When demand dictates, additional pumps may be cycled on by the plant operators to provide the required flow to satisfy buildings on campus. The Power Plant CCW system normally operates between April and October, the rest of the year the system is circulated as "warm water loop" used as freeze protection (between 60°F and 70F°). The Power Plant has planned future additions of one centrifugal 2000-ton chiller (CH-8) and additional heat recovery chillers as part of the energy renewal plan. The steam absorption chiller may be phased out at the end of its life, or as campus steam becomes less available. Consideration should be made to maintain at least one chiller that uses low-pressure steam to assist with power generation of the steam turbine generator when heating demand is low, as long as the steam and turbine systems are intended to stay in place. Refer to Table 3.1.2-1 below. The Power Plant currently has issues with the startup of some chillers causing other chillers to trip (CHL 1, 5, and 6 have this issue), reducing peak operational capacity.

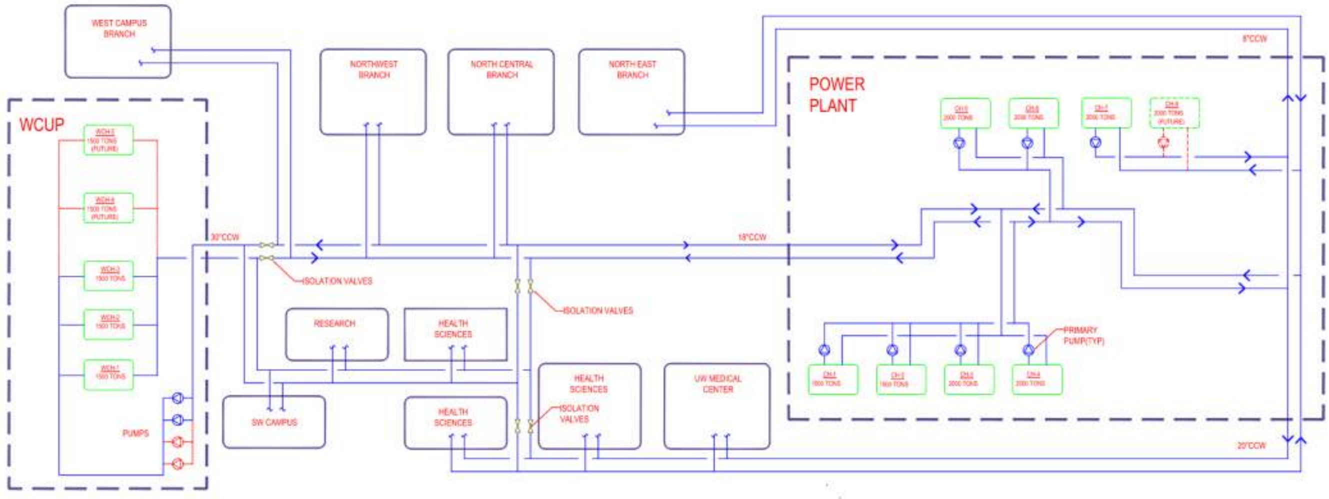
Table 3.1.2-1: Existing and Planned Chilled Water Capacity Summary

Plant	Tag	Status	Existing Tonnage	Phase 1 New Tonnage	Phase 2 New Tonnage	Phase 3 New Tonnage	Year Installed	Replacement Year	Chiller Type	Notes
WCUP	WCH-1	Existing	1500				2016		Centrifugal Conventional	
WCUP	WCH-2	Existing	1500				2016		Centrifugal Conventional	
WCUP	WCH-3	Existing	1500				2016		Centrifugal Conventional	
WCUP	WCH-4	Planned		1500					Centrifugal Conventional	Purchased, not yet installed
WCUP	WCH-5	Planned		1500					Centrifugal Conventional	Purchased, not yet installed
WCUP	WHRC-1	Planned			1500				Centrifugal Heat Recovery	
WCUP	WHRC-2	Planned			1500				Centrifugal Heat Recovery	
PP	CH-1	Existing	1000				2005		Centrifugal Conventional	Constant speed
PP	CH-2	Existing	1000			-1000	1989		Steam Absoption	Lithium Bromide, constant speed
PP	CH-3	Existing	2000				1991		Centrifugal Conventional	York, near Identical to CH-4, variable speed
PP	CH-4	Existing	2000				1991		Centrifugal Conventional	York, near Identical to CH-3, variable speed
PP	CH-5	Existing	2000				1997		Centrifugal Conventional	York, near Identical to CH-6, variable speed
PP	CH-6	Existing	2000				1994		Centrifugal Conventional	York, near Identical to CH-5, variable speed
PP	CH-7	Existing	2000				1999		Centrifugal Conventional	Carrier, constant speed
PP	CH-8	Planned		2000					Centrifugal Conventional	
CP	HRC-1	Future				1500			Heat Recovery	
CP	HRC-2	Future				1500			Heat Recovery	
		Total Tonnage:	16500	5000	3000	2000				
		Total Existing + New Tonnage:		21500	24500	26500				

Three 1,500-ton water-cooled centrifugal chillers are located at the WCUP and provide year-round CCW (reset between 42°F and 50°F based on OA temperature) for the research-intensive South-of-Pacific zone. WCUP chillers are provided with condenser water from cooling towers located on the roof, and the system operates in a common-headered variable primary pumping configuration. The WCUP has planned future additions of two 1,500-ton centrifugal chillers and two 1,500-ton heat recovery chillers.

The WCUP and Power Plant operate as isolated CCW piping systems under normal conditions. Only during maintenance events are isolation valves manually opened and the two systems are allowed to communicate. The Power Plant operates at a CCW delivery pressure of 125-130 psi at the pumps and WCUP approximately 115-135 psi. The CCW system is distributed to 67 buildings through utility tunnels with a few limited sections of buried piping. The most significant known hydraulic bottleneck in the CCW distribution system is between nodes SW-1 and SC-7 between Ocean Sciences and K wing. No other major distribution bottlenecks are currently identified, although there is a known poor hydraulic condition in the Power Plant at the T-junction between the east-west trunk and north-south trunk. The condition of the CCW piping system has not been evaluated by AEI, but anecdotal reports from plant operators indicate that the capacity of the existing piping systems is likely to be impaired due to the age and condition of the pipe.

See Figure 3.1.2-1 for a simplified diagram of the two cooling plants and the major loads that they serve on the CCW system.



SIMPLIFIED CCW DIAGRAM

Figure 3.1.2-1: *Simplified CCW diagram showing the general arrangement of chillers within the plants and the loads that they serve. Refer to Appendix 5.1.2 for a larger format diagram for more detailed information.*

In addition to the two CCW plants, local stand-alone chillers serve buildings across campus where CCW distribution was not available at the time of construction or cooling was required outside of the operational period of the Power Plant's seasonal switchover to a warm water loop. The total installed capacity of the local chillers is estimated at 13,000 tons, based on an inventory provided to AEI from UW Facilities. Refer to section 3.1.4 for additional details.

For the past several years, the CCW system has provided approximately 700 to 1,000 tons of cooling during peak load conditions to the UWMC due to equipment failures within their S-1 plant. An ongoing project is anticipated to increase the reliability of that plant and thus give back that portion of capacity to the Power Plant CCW system.

Steam is supplied at 185 psi and 12.5 psi to the campus for heating and process loads via five natural gas boilers located in the Power Plant, with a total installed nameplate capacity of 880,000 lbs./hr. Refer to Table 3.1.2-2 below. All boilers operate at 185 psi. Some of the oldest boilers are being considered for removal as an initial step in the decarbonization process to free up space at the Power Plant for additional equipment. Low-pressure steam for distribution to the campus is extracted from the high-pressure system by a 3-megawatt (MW) single-stage steam turbine installed in 2023. As a backup to the steam turbine system, pressure-reducing valves are provided to reduce steam pressure from 185 psi to the low-pressure steam system.

Table 3.1.2-2: Existing Heating Equipment Capacity Summary

Plant	Tag	Status	Installed Capacity PPH	Installed Capacity MBH	Adjusted Steam Boiler Capacity	Phase 1 New MBH	Phase 2 New MBH	Year Installed	Removal Year	Chiller Type	Notes
WCUP	SHWHX-1	Planned				20,000				Steam-to-Water HX	
WCUP	SHWHX-2	Planned				20,000				Steam-to-Water HX	
WCUP	SHWHX-3	Planned								Steam-to-Water HX	Redundant HX
WCUP	WHRC-1	Planned					23,940			Heat Recovery Chiller - 1500 Ton	
WCUP	WHRC-2	Planned					23,940			Heat Recovery Chiller - 1500 Ton	
PP	B-3	Existing	100,000	119,800	83,860	-83,860		1948	2026	Steam Boiler (185 psi)	
PP	B-4	Existing	200,000	239,600	167,720			1994		Steam Boiler (185 psi)	
PP	B-5	Existing	130,000	155,740	109,018		-109,018	1958		Steam Boiler (185 psi)	
PP	B-6	Existing	250,000	299,500	209,650			1968		Steam Boiler (185 psi)	
PP	B-7	Existing	200,000	239,600	167,720			2000		Steam Boiler (185 psi)	
Total Heating Capacity(MBH):				1,054,240	737,968	-43,860	-61,138				
Total Existing + New Capacity:						694,108	632,970				

The steam is distributed to 136 buildings via approximately 8 miles of subterranean tunnels. The condition of the steam piping system has not been evaluated by AEI, but anecdotal reports from plant operators indicate that the capacity of the existing piping systems is likely to be impaired due to the age and condition of the pipe.

Compressed air for the campus is supplied from the Power Plant and distributed through the utility tunnels. Compressed air systems are not within the scope of the ERP study.

3.1.3 Building Heating and Cooling Operating Temperatures

An important step in the design of a heating system relying on heat pump systems as the primary heat source is finding the optimum heating water delivery temperature that allows for reliable operation of heat pump equipment maximizes efficiency and minimizes impact to existing campus systems that previously had a simple solution for high-temperature heating water.

The hotter the supply water temperature in a heat pump system, the higher the operating pressure of the refrigerant, which leads to lower efficiencies and lower operational reliability. A heat pump operating at or near its peak capacity will be more susceptible to equipment faults and experience more wear and tear on the machine.

Through interviews with the UW HVAC team and observations at the building automation systems, it was determined that a building hot water supply temperature of 160°F is typical of all but five buildings under the coldest outside air conditions:

- Hutchinson operates at 180°F
- Hansee operates at 180°F but has a local electric boiler
- Haggett operates at 180°F but will be replaced and not connected to campus utilities
- Anderson Hall operates at 170°F

- Life Sciences Building greenhouse operates at 180°F
- South Campus Center operates at 170°F

Campus chilled water at the WCUP and Power Plant is delivered in a range from 42°F–50°F with the warmer temperature range being delivered at colder outdoor air temperatures.

Design supply temperature for chilled water at 42°F and heating water at 160°F will be the basis for the study of equipment and distribution during Phase II. Buildings that cannot operate at 160°F will be provided with recommended solutions for boosting temperature or retrofit of heating systems. This is anticipated to be a very low quantity of building systems and should be avoided due to its impact on campus return water temperature.

A heating system stress test plan to gather additional data on potential reductions below 160°F will be executed in Phase II. The heating stress test will include a selection of buildings with older pneumatic controls at the zone level, likely to include:

- Bagley Hall
- Hutchinson Hall (to pinpoint problem zones)
- Anderson Hall (to pinpoint problem zones)
- Atmospheric Sciences and Geophysics (ATG)
- Hitchcock Hall
- Bloedel Hall

Pneumatic building testing will require portable meters or Internet of Things (IoT) enabled devices coupled with monitoring by UW staff and word-of-mouth reporting.

Similarly, a sample group of buildings with full direct digital controls (DDC) will be tested. These are likely to include:

- Electrical Engineering
- Allen Center for CSE
- Suzzallo Library
- Foege Building (if allowable due to space sensitivity)

In DDC buildings, a list of variables will be trend logged while the temperature is reduced in 5°F increments, likely stopping at 150°F.

Full details are outlined in the Hot Water Testing Plan, dated 2-16-2024, see Appendix 5.5.

3.1.4 DISTRIBUTED HEATING AND COOLING SYSTEMS

The Seattle Campus has a significant portion of its cooling being delivered by stand-alone chillers outside of two campus utility plant locations. In total, there are 14,133 tons of chillers within the scope of this study, which represents 46% of the campus's chilled water production capacity.

Table 3.1.4-1: Existing Stand-Alone Chiller Capacity Summary on Seattle Campus

Campus Region	Chiller Type			Chiller Function (Note 1)		
	Air-Cooled	Water-Cooled	Heat Recovery	HVAC	Process	Redundant
Central	1,596	1,217	768	1,488	788	597
North	408	1,610	0	1,626	275	117
East	679	0	0	679	0	0
South	1,923	5,282	321	5,502	1,183	495
West	250	79	0	90	60	139
SUB-TOTALS	**4,856**	**8,188**	**1,089**	**9,384**	**2,306**	**1,349**
TOTALS	**14,133**			**13,039**		

Note:

1. Heat Recovery chillers excluded from summary by chiller function.

Very few stand-alone boiler systems exist on the Seattle campus. Based on the ISES Asset Information data, there is 21,419 MBH installed capacity on campus buildings consisting of 15 boilers across 11 unique buildings. Each of these buildings will be studied for connection to the campus district heating system to replace their fossil fuel boilers. Refer to Table 3.1.4-2 for details.

Table 3.1.4-2: Existing Boiler Installations on Seattle Campus

FACNUM	ASSET NAME	COMPONENT DESCRIPTION	IDENTIFIER	LOCATION	CAPACITY	UNIT	INSTALL YEAR
1019	3941 UNIVERSITY WAY	BOILER - GAS (221-410 MBH)	B-1	111A	250	MBH	2005
1023	CHILD CARE CTR	BOILER - GAS (131-220 MBH)	B-1	108G	180	MBH	1996
1030	3710 BROOKLYN NE	BOILER - GAS (131-220 MBH)	B-1	106	220	MBH	2003
1031	3716 BROOKLYN NE	BOILER - GAS (131-220 MBH)	B-1	103	220	MBH	2003
1106	PUBLICATIONS SERVICES	BOILER - GAS (221-410 MBH)		315A	399	MBH	1989
1106	PUBLICATIONS SERVICES	BOILER - GAS (221-410 MBH)		315A	399	MBH	1989
1119	WALLACE HALL	BOILER - GAS (411-800 MBH)	B-1		600	MBH	2013
1148	PLANT SERVICES BUILDIN	BOILER - GAS (3,501-5,800 MBH)	B-1	121AB	4000	MBH	2012
1155	TRANSPORTATION SERVI	BOILER - GAS (221-410 MBH)	B-1	125	250	MBH	2018
1159	JONES PLAYHOUSE	BOILER - GAS (411-800 MBH)	B-1	282	650	MBH	2008
4353	BEN HALL INT RSCH	BOILER - GAS (1,501-2,400 MBH)	GAS BOILER	W701	1827	MBH	2006
4353	BEN HALL INT RSCH	BOILER - GAS (5,801-10,000 MBH)	GAS BOILER	W701	5862	MBH	2006
4353	BEN HALL INT RSCH	BOILER - GAS (5,801-10,000 MBH)	GAS BOILER	W701	5862	MBH	2006
6337	ETHNIC CULTURAL CTR	BOILER - ELECTRIC (311-2,100 MBH)	B-1	G01C	350	MBH	2012
6337	ETHNIC CULTURAL CTR	BOILER - ELECTRIC (311-2,100 MBH)	B-2	G01C	350	MBH	2012
TOTALS					**21,419**	**MBH**	

Another common stand-alone system type that has been implemented on some of the newer housing facilities and renovations to existing buildings that previously did not have cooling, is Variable Refrigerant Flow (VRF). This system is entirely refrigerant-based, using proprietary technology from various manufacturers to deliver heating and cooling through electric-driven heat pumps. There is a total installed capacity of nearly 1,000 tons across 15 buildings. Refer to Table 3.1.4-3 for details. VRF is not intended to play a significant role in future building retrofits or new construction.

Table 3.1.4-3: Existing VRF Installations on Seattle Campus

FACNUM	BLDG	DESCRIPTION	TOTAL CAPACITY - TONS
1163	PORTAGE BAY DAYCARE	City Multi	86
1181	DENNY HALL	City Multi - Heat Pump	18
1273	PORTAGE BAY GARAGE	City Multi - Heat Pump	66
1327	SAVERY HALL	Outdoor Rooftop VRF Unit	112
6135	CEDAR WEST	Outdoor Unit	58
6136	CEDAR EAST	Outdoor Unit	76
6138	POPLAR HALL	City Multi	24
6211	TERRY, MAPLE, LANDER	Heat Source Unit	50
6212	TERRY, MAPLE, LANDER	Heat Source Unit	90
6317	MERCER COURT	City Multi	40
6392	UW POLICE DEPARTMENT	VRF System 1	16
6471	MADRONA HALL	VRF System	8
6472	MCCARTY HALL	VRF System	10
6473	WILLOW HALL	VRF System 1	213
6503	OAK HALL	VRF System	49
TOTALS			**915**

3.2 Electrical Baseline Assessment

3.2.1 Electrical Load Assessment

Metered data was obtained from Seattle City Light's (SCL) Meterwatch service for the totalized campus electrical demand over a one-year period (Year 2023). The meter data contains electrical demand captured at 15-minute intervals over a 1-year period from January 2023 to December 2023. This data is represented in Figure 3.2.1-1. During this time interval, the Power Plant steam turbine generator was being replaced, and metered data requires no manipulation or adjustment in accounting for power contribution by this equipment.

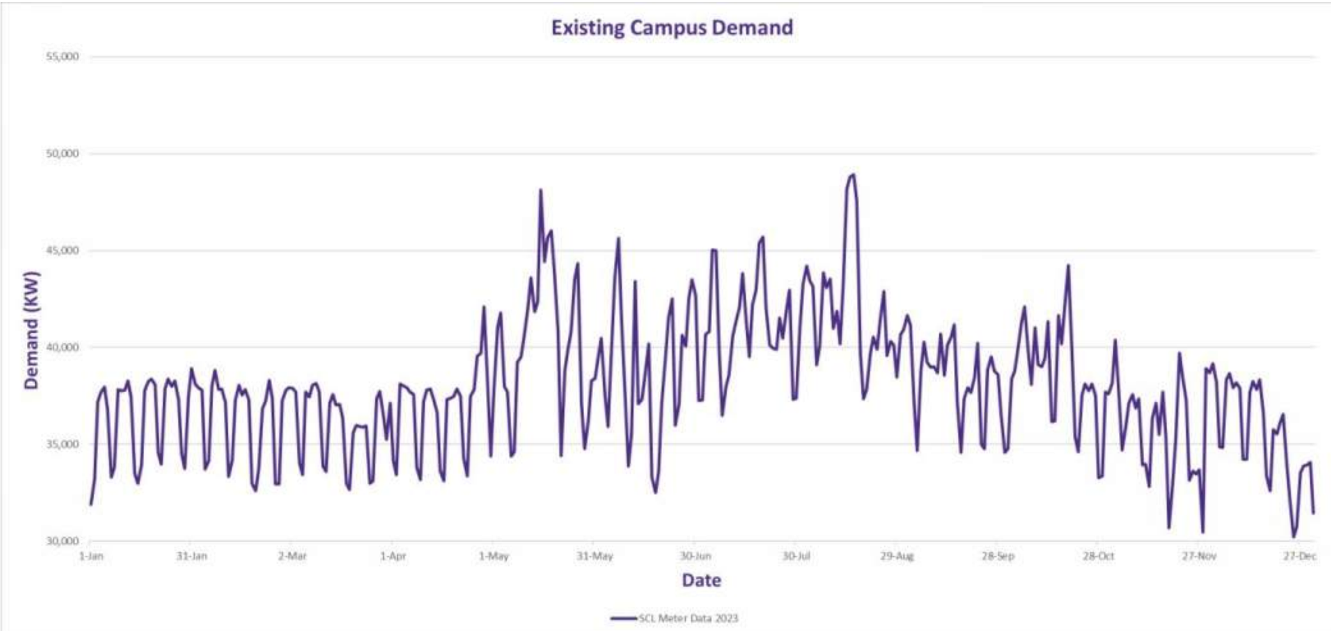


Figure 3.2.1-1: *Electrical meter data available at campus level vs time.*
The data indicates the baseline, existing campus load for the year 2023.

Based on the SCL metering data, the following observations can be made. In the winter, the campus demand is consistent and cyclical. The academic research element of the university remains constant throughout this period and a portion of student housing utilizes electric heat. The difference between summer and winter peaks is relatively small for this campus.

In the summer, the load profile is increased and varies more significantly between maximum and minimum loads throughout a typical week. The electrical load transitions from supporting heating loads to cooling loads. The academic research load portion is still consistent in this period. There is generally a lighter load of students and faculty on the campus in the summer. Cooling is achieved at a campus level via the chillers at the WCUP and Power Plant. Most student housing does not have cooling and only has heating. For this reason, the summer load profile is not as pronounced as might be anticipated for the building area served.

3.2.2 Electrical Infrastructure Assessment

Electricity is served to the campus from two locations, the West Receiving Station (WRS) and East Receiving Station (ERS). The campus receives four services from SCL at the WRS and one service from SCL at the ERS. The primary point of power delivery to the campus is at the WRS and is distributed to campus buildings via a network of utility tunnels and is passed through to the ERS for further distribution or consumption by the Power Plant. The SCL service feeding the ERS mainly powers loads at the Power Plant (primary cooling equipment) but does not power the entire Power Plant.

There are two sets of two underground feeders for a total of four feeders that route from the University Substation (West of I-5) to the WRS for primary metering by SCL at 13.8kV. The first set of two feeders is routed along Burke Gilman Trail, and the second set of two feeders is routed along NE 40th Street. SCL has confirmed that two of the four feeders are rated for 22 MW while the capacity of the other two feeders is unconfirmed by SCL but has been established by SCL to be a minimum of 18 MW and a maximum of 22 MW. It is anticipated this exact value will be documented in Phase II of the study.

Both sets of SCL feeders are routed to the campus in a way that there are two campus feeders in SCL vaults: two feeders in one vault and two feeders in another vault. SCL will de-energize both feeders in a vault to perform maintenance within the vault. This interrupts two feeders to the campus which causes issues with redundancy. Where it appears the campus is set up in an N+1 configuration, it is more accurate in a configuration where it can lose two feeders, not one feeder. Two feeders are routed via SCL vault #V722. The second set of conductors is also routed via a shared vault, but the vault number has not been confirmed yet. In this configuration, if SCL requires maintenance access to either shared vault, SCL will de-energize two UW feeders in the vault. Information gathered on the WRS feeders is listed in Table 3.2.2-1.

Table 3.2.2-1: WRS feeder capacity and comments.

SCL Feeder Number	Capacity	Comments
FDR. #2624	22 MW	SCL maintenance requires the shutdown of both cables #2624 and #2627 because they share Vault V722.
FDR. #2627	22 MW	SCL maintenance requires the shutdown of both cables #2624 and #2627 because they share Vault V722.
FDR. #2668	18-22 MW	Capacity to be confirmed by SCL. Replaced in 2019 with larger cable. Vault number to be confirmed.
FDR. #2669	18-22 MW	Capacity to be confirmed by SCL. Replaced in 2019 with larger cable. Vault number to be confirmed.

The fact that two SCL feeders must be de-energized at the same time for maintenance by SCL has a significant impact on redundancy. The campus strives for N+1 capacity but infrastructure and maintenance practices on the utility side may limit total capacity from SCL to half capacity, not just ~75%.

The SCL transformer at the ERS is rated for 7.5 MW and primarily serves loads at the power plant. The SCL feeder capacity has not been confirmed by SCL, but it is anticipated this value will be documented in Phase II. The transformer at the ERS has been identified as nearing end-of-life by SCL and is recommended for replacement. It is anticipated the project will request a larger transformer and primary cable from SCL.

Reliability has been noted as a recurring issue at both the WRS and ERS because SCL also serves other customers from the same substation that serves the campus via overhead powerlines. When tree branches fall on neighboring power lines, the campus experiences a voltage sag while SCL recloses breakers. Similarly, if an accident were to damage a power pole in the neighboring region of the University District a voltage sag would occur to campus power. These voltage sags occur frequently at about once per month. Each voltage sag is damaging or disrupts the campus operations or facilities.

3.3 Energy and Carbon Baseline Assessment

Building and meter data received from UW has been analyzed to determine the current performance of the campus. This exercise also informed the building loads presented in section 3.1.1 to assist in filling in missing data, particularly for building steam systems. Section 3.3.1 discusses the energy consumption of building types across UW's campus as well as standing and compliance with Washington Clean Buildings Performance Standard. Section 0 discusses the carbon emissions of the Seattle campus related to energy use.

3.3.1 Campus and Building Energy Performance

While driven in part by UW's core values and public sustainability commitments, this study and electrification effort is also a response to the Clean Building Performance Standard (CBPS), passed by Washington state in 2019 (HB1257) and amended in 2022. This legislation requires existing commercial and state-owned buildings to comply with energy usage targets based on building type.

Due to the complexity and high cost of decarbonizing campus district energy systems, particularly those with significant steam-based infrastructure, HB1390 accommodates institutions such as UW with state-owned district energy systems. Buildings connected to a campus energy system may comply together as a group with energy consumed at the campus utility plants (CUP) (such as electricity to provide cooling and natural gas to provide steam heating) and energy consumed directly at the buildings (such as electricity and natural gas at each building) included. Buildings not connected to the campus energy system would comply separately based on their energy consumption on a building-by-building basis. Alternatively, a whole campus compliance option is available whereby UW could comply by meeting a campus EUI target, inclusive of buildings connected to the CUP, the CUP itself, and buildings not connected to the CUP. This study is considered the first compliance path since the focus is on electrifying the CUP for decarbonization. Rulemaking for HB1390 is still occurring in Spring 2024 and the UW and ERP team will continue to follow the HB1390 rulemaking and discuss with WA Commerce exactly how CBPS compliance will be documented for institutional campuses with some buildings connected to district energy systems.

The campus EUI target for buildings connected to the CUPs is calculated based on the area-weighted average of those buildings based on building type; the relevant types for the UW Seattle campus are university, laboratory, and hospital with the last being applied to UW Medical Center. The target EUI for universities in climate zone 4C is 102 which is then increased by 10% to adjust for increased hours of operation. Laboratory and general hospitals have EUI targets of 237 and 215 respectively; research laboratories and hospital buildings were not considered when establishing the university building target for CBPS and are therefore accounted for separately, resulting in the blended average described above. This was established by staff at UW and summarized in the document *EUI Target Description* which was provided to the consultant team by Robert Gaynor at UW. Buildings that are not connected to the CUPs and are not laboratories or hospitals will comply with the university EUI target. This compliance path was confirmed in correspondence with Commerce dating February 2024. HB1390 requires campuses to submit a plan to Washington State Commerce by June 30, 2025. The plan must include decarbonization strategies including removing fossil fuels at the CUPs. Campuses will have to submit these reports every five years for the foreseeable future, documenting progress on decarbonization toward 2040.

Most of the buildings on UW's Seattle Campus are connected to the Power Plant via steam, CCW, or both. These buildings will therefore comply together as a campus. The target EUI for the campus served by the CUPs and the current energy performance are shown below in 3.3.1-1.

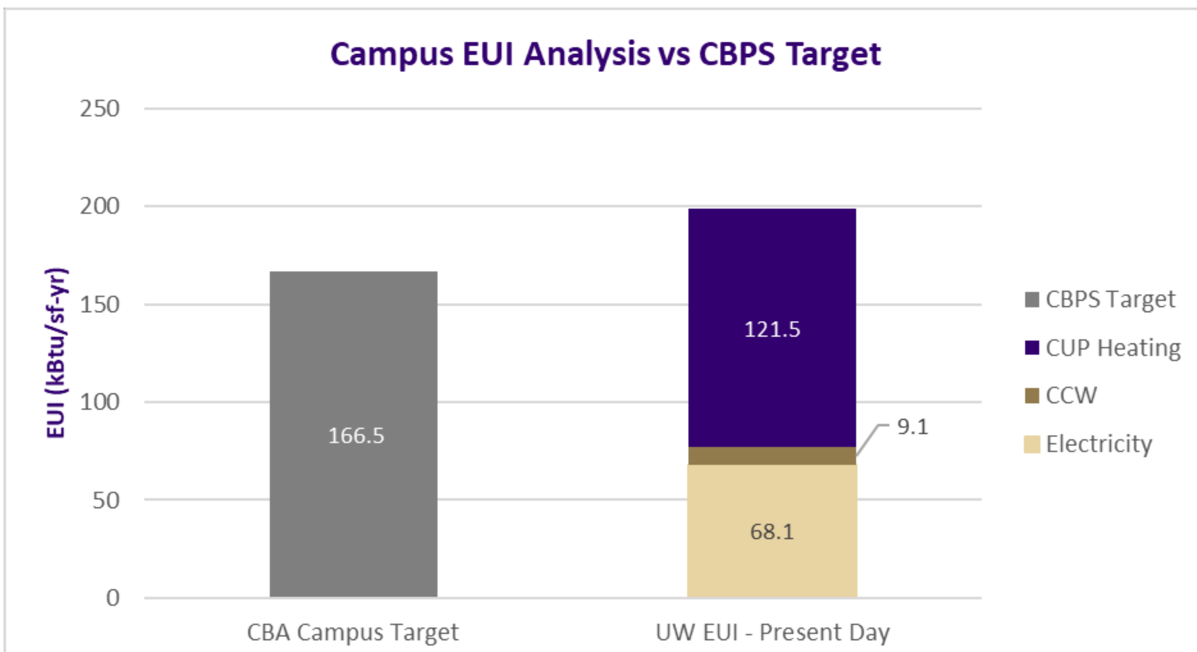


Figure 3.3.1-1: *Energy performance for campus connected to CUPs (including energy consumption of CUPs) and target EUI for compliance with CBPS. Plant efficiencies and distribution losses are accounted for.*

The portion of the campus served by and including the CUPs has a target EUI of 166.5 based on the weighted average calculation described above. The analysis shows a total campus EUI of 198.7 of which 60% is attributed to steam for heating. To comply with CBPS the total EUI must be reduced below the target of 166.5. Chilled water (CCW) has a small contribution to energy consumption for the campus, likely due to the mild climate. The natural gas consumption that occurs directly at the building level across the campus is not reported here because it is very small compared to the CO2 emissions from the Power Plant steam system and the focus of this study is on electrifying the CUPs and those buildings served by the CUPs. These campus-level results assume 80% boiler efficiency and a 20% steam distribution loss.

Table 3.3.1-1 summarizes the energy performance by building type for the buildings on the campus served by the CUPs.

Table 3.3.1-1: Energy performance by building type for buildings served by CUPs.
Note that these numbers are energy consumption at the building level,
they do not include distribution losses or plant efficiency for CCW or steam.

Building Type	SF	Electric EUI	CCW EUI	Steam EUI	Total EUI	Building CBPS EUI Target
Athletics	543,888	42.0	0.0	33.4	75.5	112.2
Hospital	1,465,178	151.1	0.0	154.0	305.1	215.0
Laboratory	4,550,170	88.4	24.3	104.3	217.1	237.0
Library	761,179	39.3	22.8	34.1	96.2	112.2
Medical Clinic	57,794	53.0	4.6	7.0	64.6	112.2
Museum	43,937	79.3	0.0	104.7	184.0	112.2
Office	1,723,908	45.5	32.5	80.8	158.8	112.2
Residential	593,667	24.9	3.7	11.9	40.6	112.2
Student Union	285,978	30.7	12.7	19.0	62.4	112.2
Theater	139,845	24.4	32.4	52.4	109.2	112.2
University	2,885,317	37.8	17.9	44.2	99.9	112.2

The above table summarizes energy performance by building type and includes the CBPS building level target EUI for reference only since these buildings will comply as a campus as discussed above. Laboratories and hospitals have unique EUI targets, everything else falls under the university-type category. The hospital group, which entirely consists of UW Medical Center (UWMC), has the highest total EUI at 305. Note that UWMC has its own chiller plant which serves most of its cooling demand during the year; it is also connected to the CCW loop, but it is not metered, and it only draws from this loop when the local plant can't meet the load. Based on this understanding the contribution of the CCW to UWMC's energy usage is anticipated to be small compared to the large, metered energy consumption. These assumptions will be evaluated further in Phase 2. The laboratory group has an EUI of 216.6 which is below the CBA target of 237. The office and museum categories have high EUIs compared to the university target; this could suggest that systems in these buildings are deficient and need to be replaced or retro-commissioned. It is also possible that some of these buildings have energy-intensive spaces that are unreported.

Detailed energy performance by building is given in the following table. Around 60% of the building-level steam usage had to be estimated because of missing meter data as discussed in Section 3.1.1. Note that some building's names are listed twice because they have multiple FAC numbers and those FAC numbers sometimes have different building types.

Table 3.3.1-2: Buildings connected to CUPs.
Steam and CCW by building do not include distribution losses or plant efficiencies

For Buildings Connected to CUP - Campus Compliance									
			SF	Electric EUI	CCW EUI	Steam EUI	Total EUI	University EUI Target	
Campus Connected to CUP			13,330,830	68.1	9.1	121.5	198.7	166.1	
Campus steam includes boiler and distribution efficiencies; therefore it is significantly higher than the sum of the building consumptions listed below.									
	FACNUM	CBPS Building Type	SF	Electric EUI	CCW EUI	Steam EUI	Total EUI	Building CBPS EUI Target	Missing Meter Data Notes
IMA	1137	Athletics	289,347	42.9		33.4	76.3	112.2	Estimated Steam
CONIBEAR SHELLHSE	1166	Athletics	48,088	0.0		33.4	33.4	112.2	Estimated Steam
HEC ED PAVILION	1195	Athletics	206,453	50.6		33.4	84.0	112.2	Estimated Steam
UW Medical Center	1241	Hospital	80,408	151.1		154.0	305.1	215.0	Estimated Steam
UW Medical Center	1253	Hospital	44,302	151.1		154.0	305.1	215.0	Estimated Steam
UW Medical Center	1254	Hospital	187,132	151.1		154.0	305.1	215.0	Estimated Steam
UW Medical Center	1255	Hospital	88,753	151.1		154.0	305.1	215.0	Estimated Steam
UW Medical Center	1256	Hospital	35,754	151.1		154.0	305.1	215.0	Estimated Steam
UW Medical Center	1257	Hospital	40,442	151.1		154.0	305.1	215.0	Estimated Steam
UW Medical Center	1258	Hospital	122,217	151.1		154.0	305.1	215.0	Estimated Steam
UW Medical Center	1259	Hospital	88,465	151.1		154.0	305.1	215.0	Estimated Steam
UW Medical Center	1260	Hospital	52,439	151.1		154.0	305.1	215.0	Estimated Steam
UW Medical Center	1261	Hospital	73,825	151.1		154.0	305.1	215.0	Estimated Steam
UW Medical Center	1262	Hospital	65,415	151.1		154.0	305.1	215.0	Estimated Steam
UW Medical Center	3958	Hospital	301,070	151.1		154.0	305.1	215.0	Estimated Steam
UW Medical Center	6091	Hospital	284,956	151.1		154.0	305.1	215.0	Estimated Steam
FISH TEACH & RSCH	1104	Laboratory	34,788	58.2		86.7	144.9	237.0	Estimated Steam
CHEMISTRY BLG	1108	Laboratory	130,227	89.7	16.1	24.2	130.0	237.0	
Roberts-Mueller-Wilcox	1345	Laboratory	41,265	70.6	45.2	67.7	183.5	237.0	
FLUKE HALL	1111	Laboratory	73,086	194.3	29.6	86.7	310.6	237.0	Estimated Steam
MARINE STUDIES	1122	Laboratory	31,290	54.2		86.7	141.0	237.0	Estimated Steam
SCHMITZ HALL	1127	Laboratory	99,691	24.9	24.8	37.2	86.9	237.0	
KINCAID HALL	1130	Laboratory	82,709	34.1	0.0	1.3	35.4	237.0	
AERO & ENG RESCH	1131	Laboratory	58,779	63.8	18.3	26.6	108.8	237.0	
GUTHRIE HALL	1134	Laboratory	74,241	63.8	22.1	33.1	119.0	237.0	
Marine Sciences - Ocean Teach	1138	Laboratory	59,570	49.0	29.5	62.6	141.1	237.0	
NPL - Cyclotron	1150	Laboratory	37,148	167.6		15.5	183.1	237.0	
NPL - Cyclotron	1167	Laboratory	13,399	167.6		86.7	254.3	237.0	
HENDERSON HALL	1154	Laboratory	106,340	39.8		86.7	126.5	237.0	Estimated Steam
PORTAGE BAY BLDG	1163	Laboratory	111,226	22.1	29.6	79.1	130.8	237.0	
MHS T-Wing	1168	Laboratory	479,989	176.3	37.1	137.0	350.4	237.0	
WILSON CERAMIC LAB	1170	Laboratory	4,909	46.9		86.7	133.6	237.0	Estimated Steam
More Hall	1171	Laboratory	81,173	64.2		70.3	134.5	237.0	
MHS K-Wing	1173	Laboratory	227,640	88.2	77.1	235.0	400.2	237.0	
MHS J-Wing	1174	Laboratory	170,719	91.5	19.0	146.8	257.3	237.0	
MHS RR-Wing	1175	Laboratory	140,512	73.6	29.6	373.7	476.9	237.0	
ARCHITECTURE	1180	Laboratory	47,485	70.7	6.0	9.0	85.7	237.0	
MEB-EA	1182	Laboratory	28,128	33.9	6.1	86.7	126.7	237.0	
MEB-EA	1347	Laboratory	97,768	38.1		49.0	87.1	237.0	
HARRIS HYDRAULICS	1186	Laboratory	22,933	19.7		86.7	106.4	237.0	Estimated Steam
JOHNSON HALL	1200	Laboratory	121,573	105.3		86.7	192.0	237.0	Estimated Steam
KIRSTEN WIND TUNNEL	1205	Laboratory	23,963	70.7		86.7	157.4	237.0	Estimated Steam

For Buildings Connected to CUP - Campus Compliance	SF	Electric EUI	CCW EUI	Steam EUI	Total EUI	University EUI Target	
Campus Connected to CUP	13,330,830	68.1	9.1	121.5	198.7	166.1	

Campus steam includes boiler and distribution efficiencies; therefore it is significantly higher than the sum of the building consumptions listed below.

	FACNUM	CBPS Building Type	SF	Electric EUI	CCW EUI	Steam EUI	Total EUI	Building CBPS EUI Target	Missing Meter Data Notes
BAGLEY HALL	1206	Laboratory	223,700	65.2	13.0	19.4	97.6	237.0	
MHS Mult	1225	Laboratory	56,540	55.3	40.0	91.0	186.3	237.0	
MHS Mult	1228	Laboratory	221,527	55.3	40.0	91.0	186.3	237.0	
MHS Mult	1300	Laboratory	151,026	55.3	40.0	91.0	186.3	237.0	
MHS Mult	1242	Laboratory	175,930	63.2	38.7	155.3	257.1	237.0	
Benson	1277	Laboratory	76,271	78.6	24.6	36.8	140.0	237.0	
CHEM LIBRARY BLDG	1279	Laboratory	39,363	63.6	11.7	17.5	92.8	237.0	
ART BUILDING	1298	Laboratory	124,082	70.7		86.7	157.4	237.0	Estimated Steam
HUTCHINSON HALL	1302	Laboratory	55,164	14.7		86.7	101.4	237.0	Estimated Steam
OCEAN SCIENCES BLDG	1314	Laboratory	111,276	82.7	36.2	54.3	173.3	237.0	
HITCHCOCK HALL	1324	Laboratory	116,416	51.8	2.1	35.6	89.5	237.0	
NPL CYCLOTRON SHOP	1348	Laboratory	6,914	121.7		86.7	208.4	237.0	Estimated Steam
OCEANOGRAPHY BLDG	1352	Laboratory	25,066	13.2		86.7	99.9	237.0	Estimated Steam
Foege	4057	Laboratory	157,969	182.2		181.9	364.1	237.0	
Foege	4058	Laboratory	133,292	182.2		181.9	364.1	237.0	
Mole-Nano	6105	Laboratory	90,937	119.1		86.7	205.8	237.0	Estimated Steam
Mole-Nano	6428	Laboratory	79,506	71.4		86.7	158.1	237.0	Estimated Steam
ANIMAL RSCH & CARE FAC	6403	Laboratory	100,817	51.7	29.6	100.0	181.4	237.0	
LIFE SCIENCES BUILDING	6513	Laboratory	184,503	99.1	59.2	98.4	256.7	237.0	
LIFE SCIENCES BUILDING	6514	Laboratory	19,320	99.1	59.2	98.4	256.7	237.0	
SIEG HALL	1332	Laboratory	57,180	34.0	110.3	165.4	309.7	237.0	
Allen Library	1107	Library	221,635	38.3	9.9	14.9	63.0	112.2	
ODEGAARD LIBRARY	1125	Library	165,973	33.6	36.3	54.5	124.4	112.2	
SUZZALLO LIBRARY	1193	Library	333,022	42.9	25.9	38.8	107.6	112.2	
ENGR LIBRARY	1325	Library	40,549	38.3	11.9	17.9	68.0	112.2	
HALL HEALTH CTR	1203	Medical Clinic	57,794	53.0	4.6	7.0	64.6	112.2	
Henry Art- ACVA	1317	Museum	43,937	79.3		104.7	184.0	112.2	
Roberts-Mueller-Wilcox	1191	Office	32,471	70.6	45.2	67.7	183.5	112.2	
BLOEDEL HALL	1132	Office	77,316	58.9	119.5	179.3	357.8	112.2	
Marine Sciences - Ocean Teach	1141	Office	51,552	50.6	55.9	62.6	169.1	112.2	
GRAVES HALL	1149	Office	29,313	21.6		50.1	71.8	112.2	Estimated Steam
LEWIS HALL	1177	Office	23,220	14.4		50.1	64.5	112.2	Estimated Steam
CLARK HALL	1178	Office	37,750	0.3		50.1	50.4	112.2	Estimated Steam
PARRINGTON HALL	1179	Office	54,797	25.9		111.5	137.4	112.2	
CUNNINGHAM HALL	1183	Office	5,104	5.1		50.1	55.3	112.2	Estimated Steam
MILLER HALL	1192	Office	72,655	13.3		50.1	63.4	112.2	Estimated Steam
CHDD	1219	Office	70,345	31.8	11.3	16.9	60.0	112.2	
CHDD	1354	Office	45,598	31.8	11.3	16.9	60.0	112.2	
MHS Mult	1221	Office	53,201	55.3	40.0	91.0	186.3	112.2	
MHS Mult	1222	Office	58,820	55.3	40.0	91.0	186.3	112.2	Meter Data
MHS Mult	1223	Office	248,765	55.3	40.0	91.0	186.3	112.2	distributed Across

For Buildings Connected to CUP - Campus Compliance			SF	Electric EUI	CCW EUI	Steam EUI	Total EUI	University EUI Target	
Campus Connected to CUP			13,330,830	68.1	9.1	121.5	198.7	166.1	

Campus steam includes boiler and distribution efficiencies; therefore it is significantly higher than the sum of the building consumptions listed below.

	FACNUM	CBPS Building Type	SF	Electric EUI	CCW EUI	Steam EUI	Total EUI	Building CBPS EUI Target	Missing Meter Data Notes
MHS Mult	1224	Office	48,288	55.3	40.0	91.0	186.3	112.2	Complex; no distinction between reported lab and office spaces
MHS Mult	1226	Office	122,767	55.3	40.0	91.0	186.3	112.2	
MHS Mult	1227	Office	64,594	55.3	40.0	91.0	186.3	112.2	
MHS Mult	1304	Office	117,619	55.3	40.0	91.0	186.3	112.2	
MHS Mult	1328	Office	168,903	55.3	40.0	91.0	186.3	112.2	
PAB	1243	Office	44,010	63.2	38.7	155.3	257.1	112.2	
Raitt	1301	Office	48,148	7.6		78.5	86.0	112.2	
Savery Hall	1327	Office	118,684	44.3		50.1	94.4	112.2	Estimated Steam
THOMSON HALL	1356	Office	62,687	18.1	40.9	50.1	109.1	112.2	Estimated Steam
DEMPSEY HALL	5981	Office	67,301	52.1		50.1	102.2	112.2	Estimated Steam
MCMAHON HALL	1143	Residential	253,748	21.1		0.0	21.1	112.2	Estimated Steam
COMMODORE-DUCHESS	1152	Residential	97,849	14.8		0.0	14.8	112.2	Estimated Steam
LANDER HALL	6210	Residential	242,070	33.0	9.2		42.2	112.2	
HUB STUDENT UNION	1153	Student Union	285,978	30.7	12.7	19.0	62.4	112.2	
MEANY HALL	1126	Theater	124,491	23.8	36.4	54.5	114.6	112.2	
HUGHES PENTHOUSE	1209	Theater	15,354	29.9		35.5	65.4	112.2	Estimated Steam
EE-CSE	1008	University	203,030	54.2	20.9	31.4	106.5	112.2	
EE-CSE	3991	University	168,954	54.2	20.9	31.4	106.5	112.2	
JOHN M WALLACE HALL	1119	University	30,468	18.0	7.2		72.6	112.2	
SOC WK/SP HRNG SCI	1121	University	99,566	39.9		10.3	50.2	112.2	
SOC WK/SP HRNG SCI	1140	University	18,966	39.9		10.3	50.2	112.2	
CONDON HALL	1124	University	132,533	29.4	29.3	47.3	106.0	112.2	Estimated Steam
GOULD HALL	1135	University	115,038	18.8	17.7	26.6	63.1	112.2	
PADELFORD HALL	1136	University	138,555	35.4		47.3	82.7	112.2	Estimated Steam
COMMUNICATIONS	1161	University	106,465	23.7	29.3	47.3	100.3	112.2	Estimated Steam
GERBERDING HALL	1164	University	82,405	24.5	20.1	30.2	74.8	112.2	
Denny	1181	University	86,414	33.7		47.3	81.0	112.2	Estimated Steam
Mary Gates Hall	1197	University	183,435	48.5	50.6	76.0	175.1	112.2	
GUGGENHEIM HALL	1198	University	59,357	39.3		47.3	86.6	112.2	Estimated Steam
Gowen	1201	University	68,925	17.6		20.8	38.3	112.2	
SMITH HALL	1208	University	92,757	20.3		47.3	67.6	112.2	
PAB	1306	University	71,650	63.2	38.7	155.3	257.1	112.2	
KANE HALL	1276	University	153,375	41.9	13.1	19.6	74.7	112.2	
ATMOS SCI/GEOPHYS	1294	University	77,709	70.5	40.4	59.8	170.7	112.2	
MUSIC BLDG	1299	University	73,482	23.3		47.3	70.6	112.2	Estimated Steam
BOA EX ED CT	1316	University	59,461	66.6		47.3	113.9	112.2	Estimated Steam
LOEW HALL	1346	University	58,747	43.8	15.9	23.9	83.5	112.2	
ANDERSON HALL	1351	University	33,543	25.0	29.3	86.7	141.0	112.2	Estimated Steam
FISHERY SCIENCES	1357	University	130,307	42.3	22.1	33.1	97.6	112.2	
PACCAR HALL	5980	University	133,348	33.0		47.3	80.2	112.2	Estimated Steam
GATES CENTER FOR CSE	6502	University	157,864	42.8	24.8	59.8	127.4	112.2	
POPULATION HEALTH FAC	6524	University	291,783	22.8	5.7	19.6	48.1	112.2	

A box-whisker plot is shown below to visualize the EUIs in Table 3.3.1-2. The boxes represent the data that falls in the 25 – 75% interval range (the "middle" 50% of the data range); the bottom whisker is the 0 – 25% range and the top whisker is the 75 – 100% range. Outliers are also given. The "x" is the mean, and the dash is the median. The data below is at the building meter level, it does not factor in distribution losses or plant efficiencies, both of which are important to fully understand actual energy usage for both systems. It is important to distinguish between CCW consumption and cooling; buildings that do not have CCW usage in many cases have their own chillers which would drive up electricity consumption.

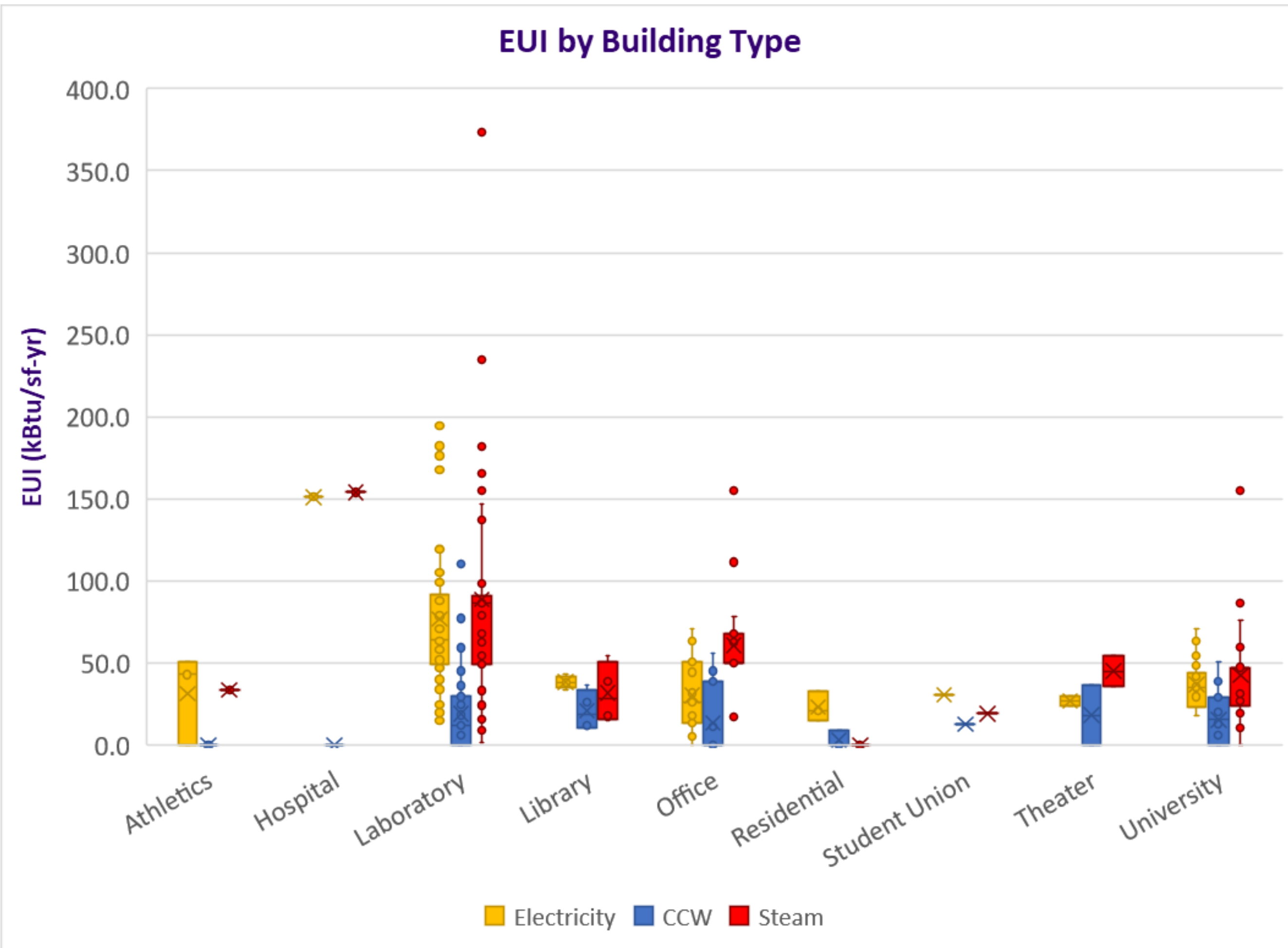


Figure 3.3.1-2: *Box-whisker plot showing EUI by energy source and building type for buildings connected to CUPs. Steam and CCW are building-level metrics, they do not include distribution losses or efficiencies at the plant.*

The hospital and laboratory categories have the highest energy consumption, particularly for steam and electricity. The hospital category is made up of wings of the UW Medical Center which has its own chillers and draws a small portion of unmetered cooling from the CCW loop on an annual basis; this explains this group's very high electric EUI and zero CCW EUI. The laboratory group has a wide range of EUIs for electricity and steam because of the wide variety of labs on campus and the wide range of system ages and operation. A number of the lab buildings are not served by the CCW loop and have their own cooling systems which drives up their electric EUI.

The university and office groups generally contain buildings that do not fall into the other detailed building categories. The office category has a typical steam consumption of 50 – 70 kBtu/sf-yr which may be reflective of old systems, deteriorating operation, and constant volume reheat. Additionally, some of these buildings may have labs that are driving up energy usage. The CCW consumption ranges from 0 – 50 kBtu/sf-yr which might reflect buildings that have their own local chillers, unreported lab space, or deteriorating systems.

The library and theater groups together contain six buildings that have similar energy performance to the office and university categories.

The buildings that are not connected to the CUPs and for which meter data is present are shown in the table below. Most of the buildings are dormitories or apartments, many of which are reported to have electric resistance heating. All the buildings are anticipated to comply with the university EUI target of 112.2. These buildings make up a small minority of the total buildings on campus in terms of square footage as well as energy usage and are not prioritized in this study. Buildings that are not connected to the CUPs and do not have meter data were not included in this assessment.

Table 3.3.1-3: Building Not Connected to CUPs.

Buildings Not Connected to CUP							
	FACNUM	Building Type	SF	Electric EUI	Gas EUI	Total EUI	University EUI Target
GRAVES ANNEX BLDG	1275	Athletics	32,098	61.2	33.4	94.6	112.2
INDOOR PRACTICE FAC	3950	Athletics	95,000	0.0	33.4	33.4	112.2
NEW BURKE MUSEUM	6492	Museum	116,756	45.2		45.2	112.2
GUGGENHEIM ANNEX	1344	Office	3,945	38.7	50.1	88.8	112.2
TERRY HALL	6212	Residential	108,000	22.6	0.0	22.6	112.2
CEDAR EAST APARTMENT	6136	Residential	78,435	41.2	0.0	41.2	112.2
ELM HALL	6137	Residential	145,768	14.4	0.0	14.4	112.2
POPLAR HALL	6138	Residential	97,040	31.6	0.0	31.6	112.2
ALDER HALL	6140	Residential	209,092	26.6	0.0	26.6	112.2
Mercer Court	6353	Residential	9,333	23.9	0.0	23.9	112.2
Mercer Court	6377	Residential	89,978	23.9	0.0	23.9	112.2
Mercer Court	6378	Residential	86,813	23.9	0.0	23.9	112.2
Mercer Court	6379	Residential	64,061	23.9	0.0	23.9	112.2
Mercer Court	6380	Residential	64,469	23.9	0.0	23.9	112.2
MERCER COURT BLDG A	6317	Residential	99,042	23.9	0.0	23.9	112.2
MADRONA HALL	6471	Residential	136,443	14.6	0.0	14.6	112.2
WILLOWS HALL	6473	Residential	215,305	16.7	0.0	16.7	112.2
Oak Hall	6503	Residential	129,435	11.9	0.0	11.9	112.2

3.3.2 Greenhouse Gas Inventory

Annual greenhouse gas emissions are given in this section. A comparison of the analysis results and that reported by the 2021 Greenhouse Gas (GHG) Inventory from UW is given in 3.3.2-1. The analysis matches the 2021 GHG Inventory for natural gas consumption at the Power Plant within 2%. Virtually all the CO2 emissions from operating the buildings are from burning natural gas to generate steam since Seattle City Light (SCL) has a very low carbon power grid served by hydroelectric power. Additional CO2 emissions reported from the 2021 GHG Inventory are also included as a reminder that there are other miscellaneous CO2 emissions outside the scope of this study. The emissions rates used are 11.7 lbs. CO2 / Therm, which is the standard value, and 6.4 lbs CO2 / MWh which comes from the 2021 GHG Report from SCL.

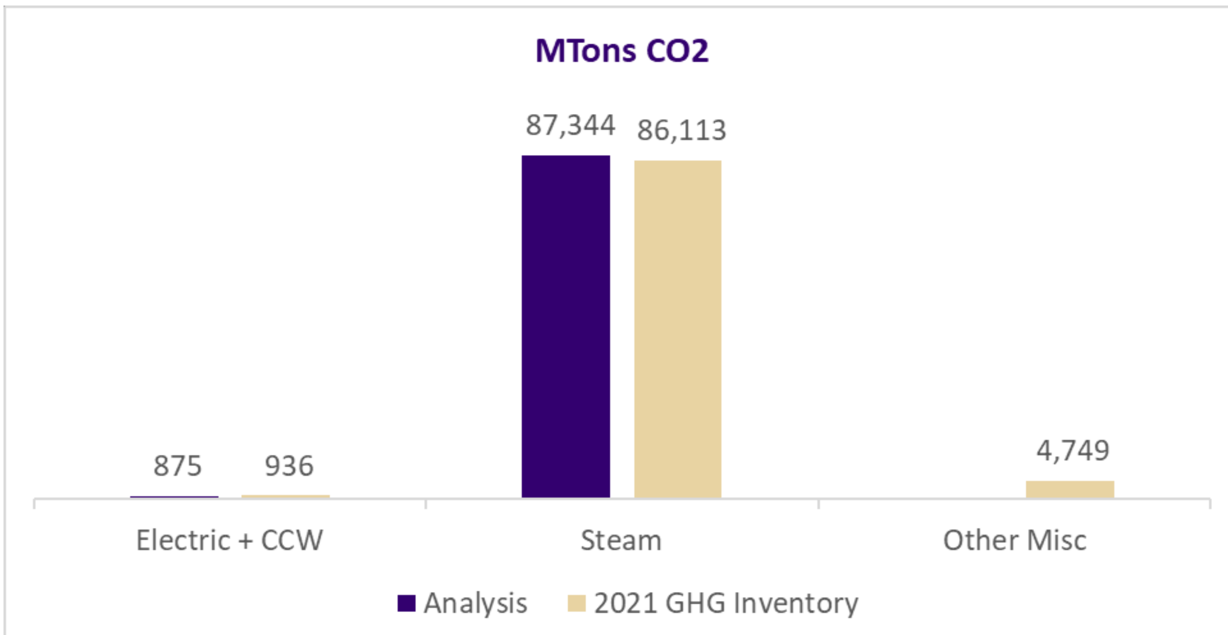


Figure 3.3.2-1: *Breakdown of annual CO2 emissions for the campus; comparison of analysis to 2021 Greenhouse Gas Inventory.*

The Climate Commitment Act passed by Washington state requires campuses that have annual CO2e emissions greater than 25,000 MTons to participate in a cap-and-invest carbon auction program. Electrifying the CUPs will significantly reduce the CO2 emissions associated with operational energy by taking advantage of SCL's renewable electric grid. The impact of the electrification effort is forecasted in Section 4.1.4 The campus emissions and the 25,000 MTon threshold are illustrated below.

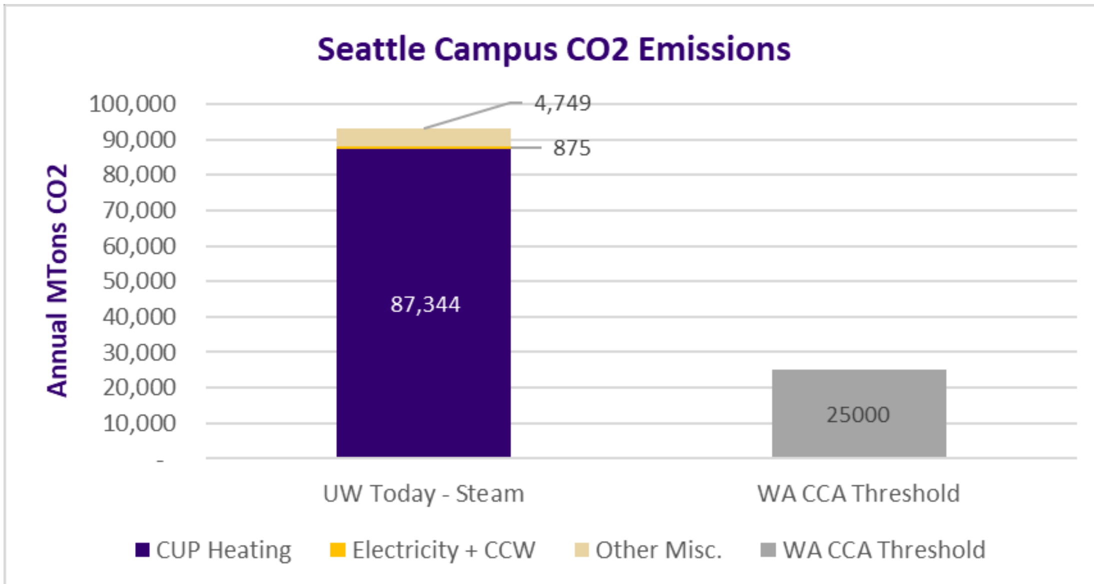


Figure 3.3.2-2: *Current campus emissions vs CCA threshold of 25,000 MTons annually.*

3.4 Site Visit Reports

In Phase I, the ERP team conducted site visits at the two existing heating and cooling plants (WCUP and Power Plant), utility tunnels, as well as the accompanying electrical receiving stations (West and East Receiving Stations). The site visits were led by the respective subject matter experts at the UW: Mark Kirschenbaum (Power Plant), Ryan Trickett (WCUP and Steam/CCW Distribution), and Jeremy Park (Campus Electrical Systems). Additional site visits are planned for targeted building investigations to help assess the scope of the building conversions, assessment of distribution routing, as well as assessing locations for the Thermal Energy Storage tanks.

3.4.1 West Campus Utility Plant (WCUP)

The WCUP is located on the corner of University Way NE and NE Pacific Street, adjacent to the Burke Gillman Trail, West Receiving Station, and the UW Police Department. The facility was designed to provide 9,000 tons of cooling in an N+1 arrangement (seven chillers at 1,500 tons, including heat recovery chillers) and be a jumping-off point into providing district heating hot water with two 1,500 tons heat recovery chillers. Only three 1,500-ton cooling only chillers (and associated cooling towers and pumps) were installed on day 1 (see Figure 3.4.1-1). Due to recent changes in state law, phasing down the use of certain refrigerants, originally planned heat recovery chillers are no longer allowed to be installed and the alternatives are larger than the originally planned footprint. A project is underway to help evaluate and provide an updated build-out plan for WCUP reflecting these changes. Refer to the Mechanical Infrastructure Assessment in section 3.1.2 for additional information on heating and cooling equipment.

A 750-ton waterside economizer is provided and is enabled at 47°F outside air temperature or below.

The facility is being maintained in excellent condition. There are plans to install the remaining two 1,500-ton chillers within the next three years, with the installation of the first chiller project underway. The plant was originally designed to be unstaffed, with remote maintenance teams only entering the facility on an as-needed basis, however, the reality of the situation demanded on-site staff during normal working hours. As a result of this, the space allocated for chillers on the east side of the Level 1 mechanical room floor has been temporarily set up as a plant operations center and equipment storage area (see Figure 3.4.1-2). These uses will need to be accommodated elsewhere before new chillers can be installed. A planned expansion of the WCUP is in the early stages of concept development and funding requests.

Heat exchanger failure has been a problem due to water quality issues. A quarterly testing protocol has been added to the HX maintenance schedule.

Figure 3.4.1-1: *WCUP water-cooled chillers 1 through 3.*

Figure 3.4.1-2: *WCUP space planned for three additional chillers.*
Space is currently occupied by the plant operations center and equipment and parts storage.

Plant operators overviewed the plant control system with AEI (see Figure 3.4.1-3). Operators noted existing chillers have 5:1 turndown. Better turndown will be achieved with chillers 4 & 5 which will have hot gas bypass. As reported by the WCUP plant operators, the plant currently sees a minimum cooling load in the wintertime of 150 tons, and further, during a cold snap experienced during the development of this report, the load dropped to a minimum of 40 tons. Plant efficiency is 2.5 kW/ton with the economizer running. Typical summer efficiency is 0.57 kW/ton. During the 2022 heat dome event (outdoor air temperatures exceeding 105°F), reduced capacity in the cooling towers resulted in a peak output capacity of only 3,800 tons compared to the nominal design capacity of 4,500 tons. The delta-T on CCW during this time rose to above 19°F.

A formal load-shedding plan is in place to curtail specific buildings; however, this procedure has not been executed. Load-shedding options should be reviewed as part of the ERP for future chiller and heat pump systems.

A communications fiber pathway is routed through the tunnels directly from the WCUP to valves and instrumentation located at remote buildings served by the WCUP. Differential pressure sensors, flow meters, and load shed valves are all directly connected back to the WCUP PLC controls system.

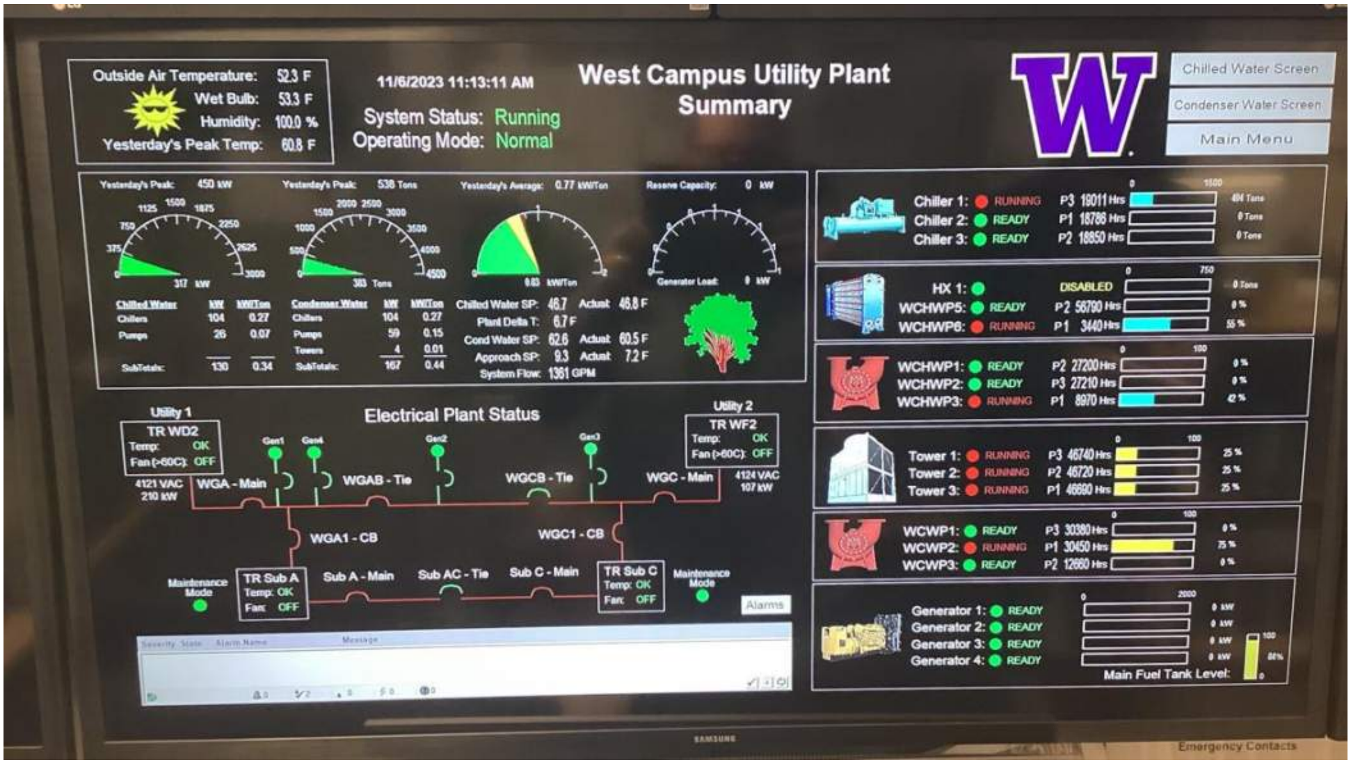


Figure 3.4.1-3: *WCUP summary screen at the graphical user interface to the building control system.*

The WCUP building has cooling towers and emergency generators located on the roof. Per Ryan Trickett, the controls system is currently configured to operate only two of the chillers during a power outage, prioritizing the remaining emergency generation to campus loads over operating additional chillers. Additional chillers could be operated on emergency power, however, the cooling load at the buildings is unlikely to require this since the buildings would also be experiencing a power outage. Future heat recovery chillers rs would need to be fed from 4160V power.

Normal power is fed to the WCUP from the West Receiving Station (WRS) which is located adjacent to the WCUP. The WRS supplies two feeders at 13.8kV. Each feeder feeds a 7.5 MW transformer. The transformer secondaries feed the WCUP switchgear at 4160V. The switchgear is a main-tie-tie-main configuration.

The standby power generators at the WCUP currently consist of four, 2MW diesel generators with room and future plans for two additional 2MW diesel generators. The existing capacity of the generators is 8MW. The generators are connected to the main-tie-tie-main switchgear with paralleling capabilities at 4160V, 3Ph.

Figure 3.4.1-4: *WCUP Diesel generators on the roof. Two of the four pictured.*

Figure 3.4.1-5: *WCUP 4160V switchgear in main electrical room.*

The WCUP currently serves the following buildings:

- Wallace Hall
- Fisheries Sciences
- Ocean Sciences
- Hitchcock
- ARCF
- H-Wing
- I-Wing
- T-Wing
- G-Wing
- C-Wing
- Critical loads in Life Sciences

Plans are in place to extend WCUP service to the following buildings:

- I-Wing process
- J-Wing
- K-Wing
- Ocean Sciences process
- Foege Bioengineering Vivarium and Process
- Foege Genome Process & Data Center
- Oceanography Teaching
- Marine Sciences

3.4.2 WEST RECEIVING STATION

The West Receiving Station (WRS) is an electrical substation that receives four of the five feeders from Seattle City Light which serve the campus. It is located on the west side of the Campus. It is bounded by University Way NE on the West, the Church of Latter-Day Saints on the north, and the WCUP to the West. The WRS is adjacent to the Burke Gilman Trail and NE Pacific Street on the South.

Figure 3.4.2-1: *West Receiving Station (WRS) transformer yard looking South.*

The WRS yard houses 4 SCL-owned transformers. All four transformers have a 26.4KV primary and 13.8KV secondary. Transformers #68, #69, and #70 are rated for 22.4 MVA and are nearing the end of life. Transformer #80 is rated for 25MVA and was installed in 1996 meaning it still has at least 30 years of expected lifespan.

Figure 3.4.2-2: *Capacitor bank at WRS.*

The WRS also houses a recently installed capacitor bank that is intended to correct the campus's power factor. Improving the power factor provides several benefits to the campus. Currently, the capacitor bank is not operational due to an issue with the controls. Once the capacitor bank is operational, the university can expect slightly increased capacity, reduced SCL power factor costs, and increased end-of-line voltage.

Figure 3.4.2-3: *WRS overcurrent protection SEL relays and SCL primary metering.*

3.4.3 Power Plant

The Power Plant (PP) is located on the east side of the campus between Jefferson Road and Mason Road, adjacent to the Burke Gillman Trail, Mechanical Engineering Building, and Bill & Melinda Gates Center for Computer Science & Engineering.

The facility can provide up to 12,000 tons of cooling with all chillers operational and has five boilers with a peak installed capacity of 880,000 lbs/hr. Refer to the Mechanical Infrastructure Assessment in section 3.1.2 for additional information on heating and cooling equipment. Refer to notes on known issues and deficiencies regarding the actual peak operating CCW capacity of the plant.

A project reaching completion in 2023 added a 3MW steam turbine and Diesel Rotary Uninterruptible Power System (DRUPS). The DRUPS provides uninterruptible power to critical systems (not including CCW) and maintains continuous operation of steam systems in the event of power outages. Chillers at the Power Plant are not on standby power. Chillers are served from the East Receiving Station.

Mark Kirschenbaum gave a tour of the plant and provided a wealth of information on the history of the plant as well as current known issues and deficiencies. The deficient items discussed with the ERP team were:

- Actual peak CCW capacity is 9,000 tons out of the nominal installed 12,000 tons under normal operating conditions.
    - Absorption chiller (CH-2 1,000 tons) is not normally operated during peak / abnormally hot weather as it adds too much heat to the tower water system. This chiller does operate during summer to maintain turbine-generator operation.
    - Chillers 5 and 6 (2,000 tons each) cannot operate together due to an electrical issue.
- Chillers 5 and 6 cannot run together due to an electrical issue that arose approximately five years ago (2018). When either chiller is called to start while the other is running, the chiller that is currently operating will lose control of power and shut down. Investigations have yet to reveal the root cause of the issue.
    - Additionally, Chiller 1 starting up will sometimes cause the same behavior if Chiller 5 or 6 is already operating.
- There is no common CCW piping header.
    - There are groups of chillers (Group 1: CH-1,2,3,4, Group 2: CH-5,6, Group 3: CH-7,8) that tie together into a common pipe, then route into the tunnels before connecting to common pipes that eventually communicate all of the chillers together.
    - Connections from the chiller groups to the common piping appear to be typically made with bullhead tees.

- Poor hydraulic performance results from these connections. Chillers tend to have a preference to send water in the direction of the piping system connection point and plant operators have a difficult time redirecting flow to other areas of the campus when a particular chiller is called to serve an area that it does not have an ideal connection to.
  - Group 1: CH-1,2,3,4 flow is directed to flow west through the West Tunnel
  - Group 2: CH-5,6 flow is directed to flow east through the West Tunnel
  - Group 3: CH-7,8 flow is directed to flow south through SE-1

- At moderate-to-low CCW loads (early fall or late spring), upon a decrease in system differential pressure the plant operators will need to start additional pumps beyond those required for the number of chillers that are operating.
  - Since pumps are dedicated to chillers, engaging additional pumps mixes CCW return water with the supply temperature from the operating chillers and artificially increases the system supply temperature.
- As outdoor air temperatures exceed 80°F, the Power Plant loses the ability to keep up with campus CCW demand. The condenser water system overheats, with water temperatures approaching 100°F. Potential causes discussed by plant operators included an issue with the makeup water system not providing adequate makeup to offset evaporative losses. These issues will need to be remedied as part of the replacement of existing chillers and cooling towers at the Power Plant and the potential addition of more cooling towers.
- The cooling tower system was designed for a seasonal shutdown and not intended to operate in the winter.
  - The South tower has a manual freeze protection valve that allows it to operate in winter if the CCW loop operating in "warm mode" or plant cooling loop needs additional cooling.
- Generally, across campus, chemical water treatment has been inconsistent at buildings. Mark provided a sample of piping from roughly 50 years old cooling tower system and a section from the domestic cold-water system. See Figure 3.4.3-1 for photos.

Figure 3.4.3-1: *Sample of Power Plant tower water piping (left) and domestic water piping (right).*

The Power Plant has a lot of unused space/volume from areas of the plant that were dedicated to the previous coal receiving and processing activities (Figure 3.4.3-2). These areas have not yet been identified for a new purpose but present a potential opportunity for new equipment required for the ERP strategy. Additionally, as boilers are able to be decommissioned and removed as steam load is decreased, more space can be made.

Figure 3.4.3-2: *Top (left) and bottom (right) of coal bunkers in basement area of plant. Nearly 20-30 feet of height within the tanks (to be confirmed).*

Chillers are generally installed in tight configurations relative to existing space and other equipment. Chiller 7 is the exception, located with maintenance access doors opening to Mason Rd to the east of the plant. The project that provided Chiller 7 also allocated space for a future Chiller 8 and associated cooling tower and pumps. See Figure 3.4.3-3.

Figure 3.4.3-3: *Chiller 7 and future space allocated for Chiller 8.*

The Power Plant houses the diesel generators that provide backup power for the Medical Center and many of the campus buildings. There are five existing 2 MW / 2.5 MVA diesel generators. Capacity of the existing generators, the paralleling switchgear, and distribution switchgear will be further evaluated in Phase II.

Figure 3.4.3-4: *Emergency and standby generator paralleling gear at the Power Plant.*

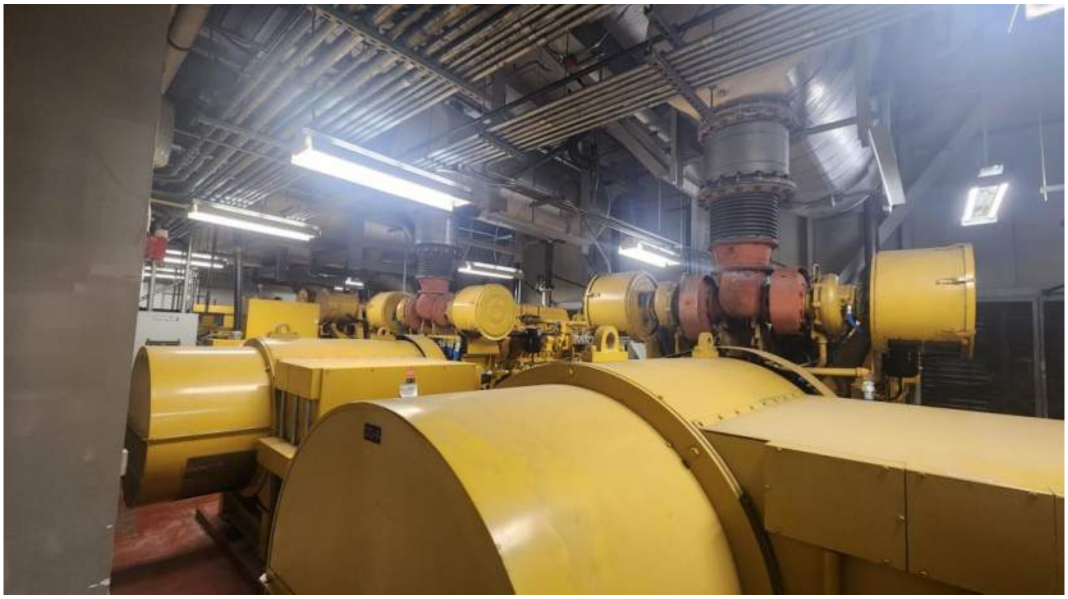


Figure 3.4.3-5: *Diesel generator room.*

3.4.4 East Receiving Station

The East Receiving Station (ERS) is located just north of the Power Plant. The ERS receives feeds from both the West Receiving Station and a utility service feed from SCL. This SCL feed enters a 7.5-megawatt transformer owned by the SCL, which primarily supplies power to chilling system loads. This transformer does not power a majority of the plant; the majority of power for the plant comes from the WRS feeders.

Figure 3.4.4-1: *East Receiving Station (ERS) transformer yard and switchgear.*

The SCL transformer is nearing the end of its lifespan and requires replacement in the near future. It's recommended that the replacement transformer be of a larger capacity to serve future loads at the Power Plant. The primary feed for this transformer is shared with another customer which introduces interruptions and voltage sags to the ERS. For this reason, the service currently lacks redundancy, which emphasizes the need for a robust replacement. However, the replacement transformer does not add redundancy so there is a single point of failure at the primary feeder and transformer.

The SCL service enters the ERS at "ED Main" where SCE primary metering occurs. The ED Main switchgear is adjacent to the ERS transformer yard.

Figure 3.4.4-2: *ED Main where the SCL service enters the ERS.*

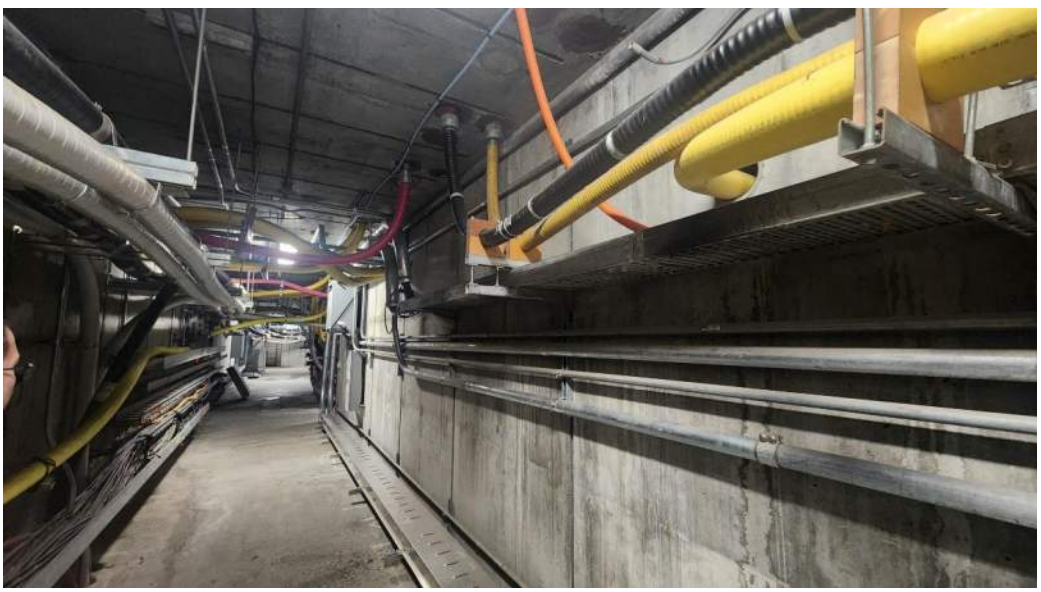


Figure 3.4.4-3: *Cable Gallery under ERS Switchgear. Cables are distributed from the cable gallery to the tunnels.*

3.4.5 Tunnels

The tunnel system at the University of Washington has sections that are over 100 years old. There are approximately eight miles of tunnels. Assessment of the structural integrity, life safety, ventilation, drainage, and lighting systems of existing tunnels that are proposed for re-use is not included in the scope of this study but may be required as part of the design and permitting of future work.

The University's Facility Engineering group maintains an extensive set of Record Utility drawings which provide locations and vintages of the tunnels as well as the utilities routed within them including CCW, steam and condensate piping, compressed air, and electrical.

The West Tunnel stretching from the Power Plant on the east end to the WCUP at WT5 on the west end, acts as a main point of connection between the two plants. Express lines for the steam and CCW systems route from the Power Plant to WT1 before joining into the main piping header.

Generally, there are very few sections of utility tunnel on campus that have what would be considered "spare" room to house new hydronic piping systems without removal of existing systems. Re-use of existing tunnels that currently house steam and CCW piping would require removal of steam and condensate piping prior to installation of new heating water piping. Discussion on sections of tunnel with potential room for new hydronic piping:

- Tunnel section from SW 1 to SC 7 is essentially empty of mechanical piping.

Figure 3.4.5-1: *Tunnel section between SW 1 and SC 7.*

- Tunnel sections between CP 5 and CP 8 and in the north campus loop of NW 3 clockwise to NE 4 only have steam piping and could present an opportunity for installation of heating water piping prior to removal of steam and condensate piping.

Figure 3.4.5-2: *Tunnel section between CP 5 and CP 8*

- The Ash Flume tunnel between SE 0 and AF 1 houses electrical and domestic water piping as well as an outfall trench for storm and sanitary drainage from the tunnel systems. Without removing and re-routing the existing electrical systems within this tunnel, it does not appear to present a significant opportunity for routing of major utilities from the lake to the main campus due to the large, anticipated size of those pipes.

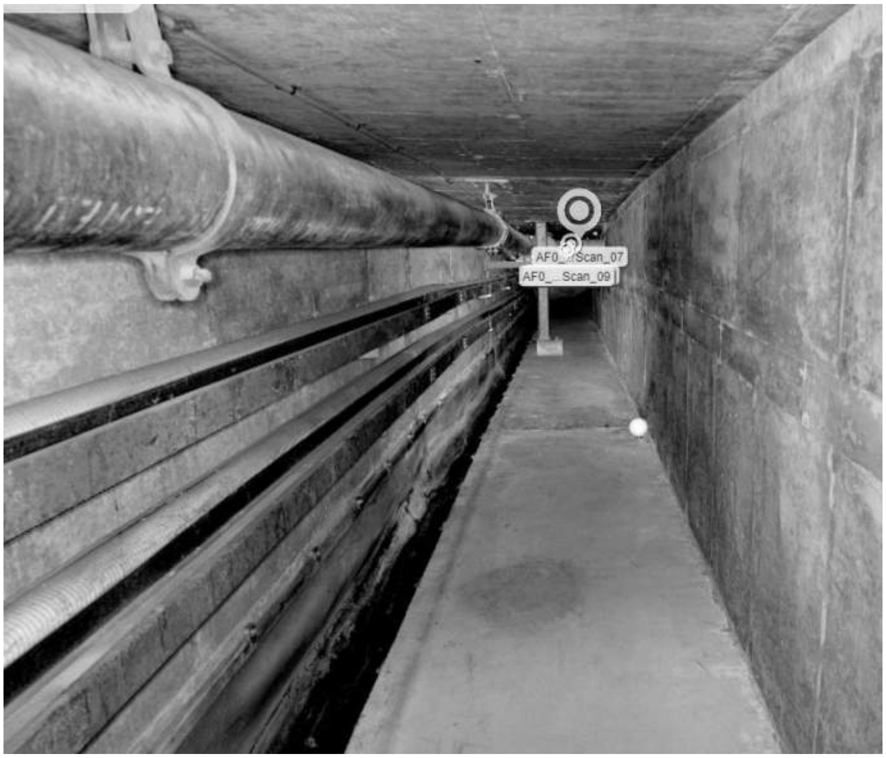


Figure 3.4.5-3: *Tunnel section between AF 0 and AF 1. Domestic water piping routed high, electrical distribution racked along left wall, and drainage trench on bottom left.*

4.0 Looking Forward

Beyond establishing existing conditions and loads, this report documents the initial concepts presented for further study in the next phase, Phase II Project Identification and Prioritization. The following sections explore the estimated future loads and project concepts that will be studied in more detail in Phase II.

4.1 Cooling and Heating Load Projection

4.1.1 Campus Cooling Water (CCW) Load Projections

Using the hourly 2022 CCW load profiles as a starting point, future cooling load projections are being studied relative to the anticipated cooling loads served by the Energy Renewal Plan CCW system.

Future campus cooling load growth is not currently accounted for, however minimum 10% future load growth is the current assumption and will be discussed further in the next phase of plan development. This cooling load growth could occur from factors such as the addition of cooling to buildings that don't currently have mechanical cooling, Building Renewal Project building modification or repurposing to higher load programs, and/or cooling load densification.

Future climate data is not applied to these profiles and will be presented for consideration in the next phase of plan development. An evaluation of IPCC AR5 (Fifth Assessment Report) emissions scenarios and impact to future climate will be analyzed relative to campus loads and Energy Renewal Plan infrastructure.

Distributed Cooling load profile was estimated from the UW Facilities distributed chiller and cooling tower equipment inventory with consideration for buildings and cooling loads likely to be connected to campus CCW systems as part of the Energy Renewal Plan. Process cooling loads were separated from general HVAC space conditioning loads. Equipment or buildings not likely to be in the scope of the ERP were also excluded. A process cooling load of 2,000 tons and a general HVAC cooling load of 9,300 tons (diversified down to 7,000 tons) is estimated for this analysis. Distributed heating and cooling system are further explored in Section 3.1.4 of this report.

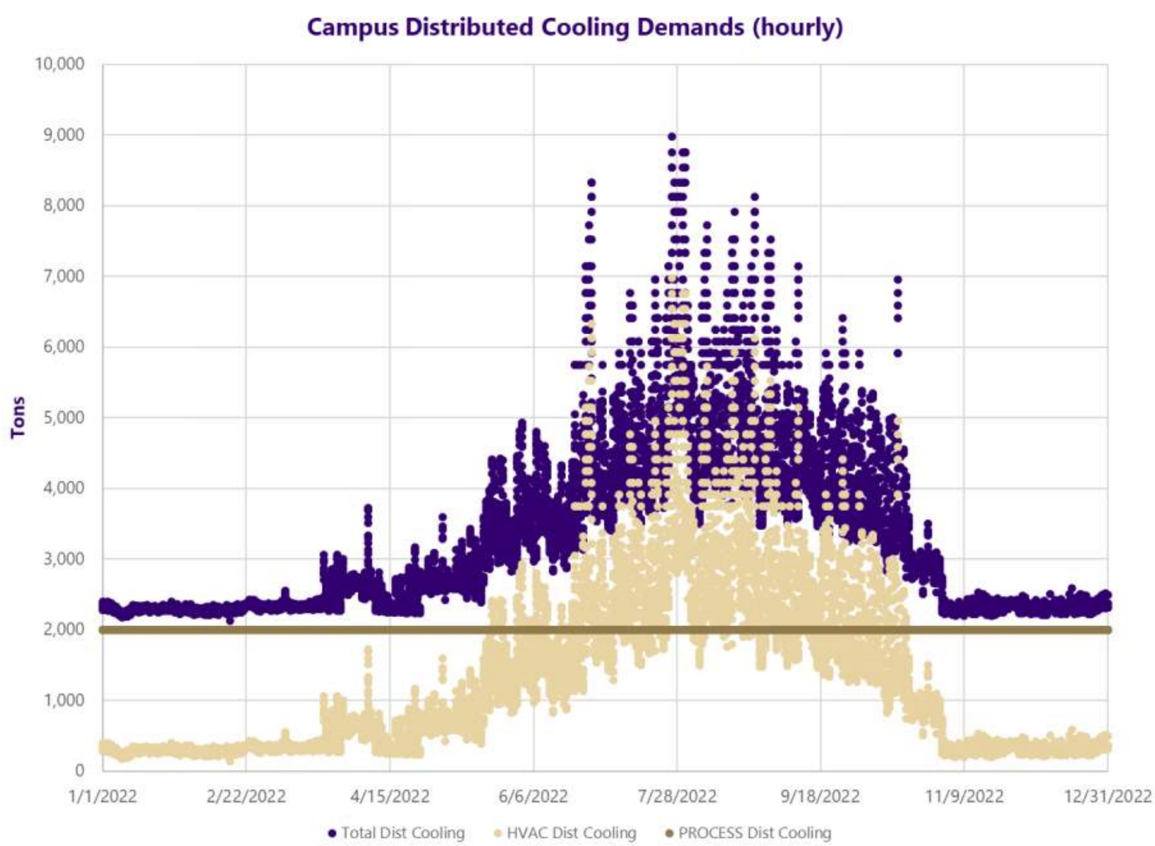


Figure 4.1.1-1: *Estimated hourly CCW production profiles for existing distributed cooling system to be consolidated as part of the Energy Renewal Plan.*

Total Campus CCW load profile shown below is a combination of the hourly Power Plant CCW, WCUP CCW, and distributed cooling CCW with an estimated peak of 26,000 tons as compared to the 2022 historical weather data.

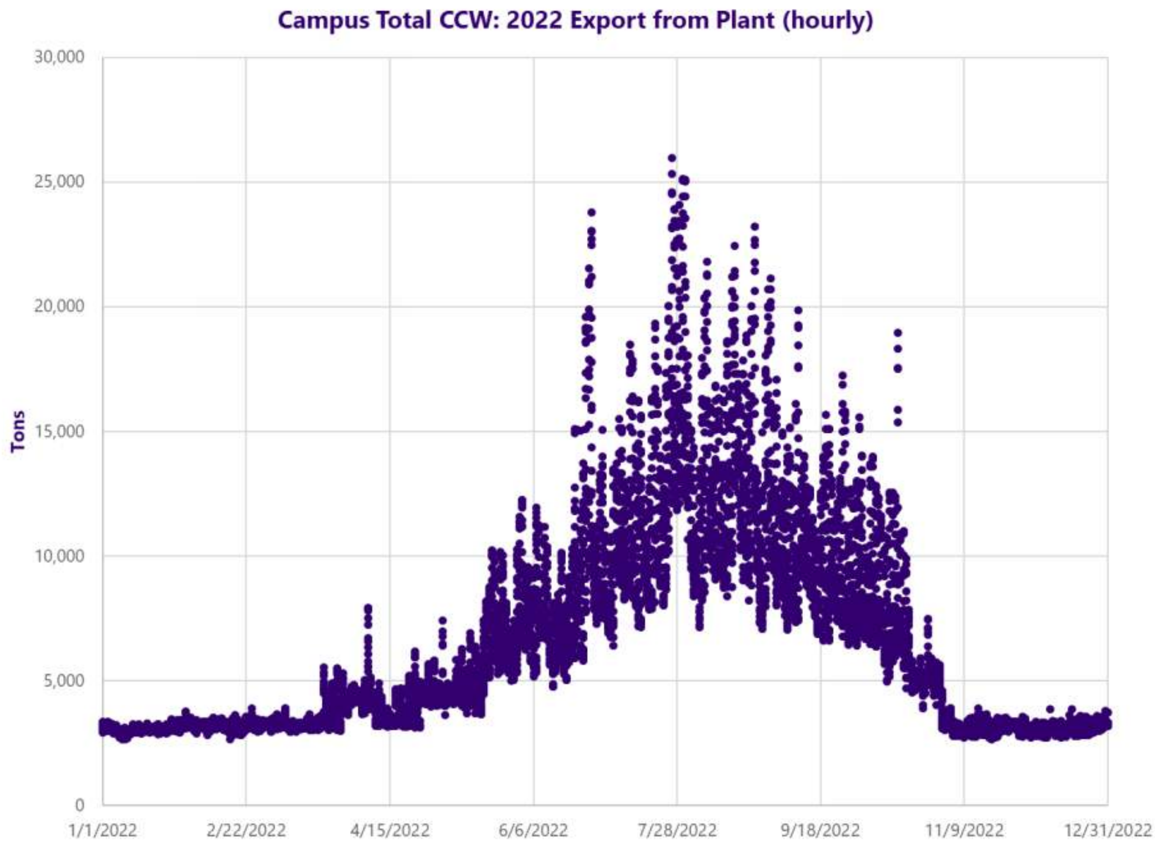


Figure 4.1.1-2: *Estimated total campus hourly CCW production for 2022 weather data.*

The efficiency gain from moving all distributed cooling loads onto the CCW were investigated by looking at how the part load performance of CCW chillers would compare to local building equipment, accounting for diversity of the cooling profiles in the buildings over the year. Moving all distributed cooling onto the CCW is forecasted to reduce cooling energy associated with these building by 14% and yield a reduction of 845,000 kWh annually. These numbers account for 63% of the local chillers being water-cooled as well as 5% CCW distribution losses (distribution losses were not applied for the local equipment scenario).

4.1.2 Campus Hot Water Load Projections

For the calculations and estimations made in Phase I, steam process equipment load is estimated to be a constant 20,000 lbs/hr based on information provided to AEI in previous study efforts with the

University of Washington. Process steam loads are not currently accounted for in the campus hot water calculations. The strategies for addressing steam process loads will be considered in Phase II.

The hourly campus steam heating demand was converted to a future heating hot water demand assuming a 20% distribution loss for campus steam and 10% distribution loss for hot water.

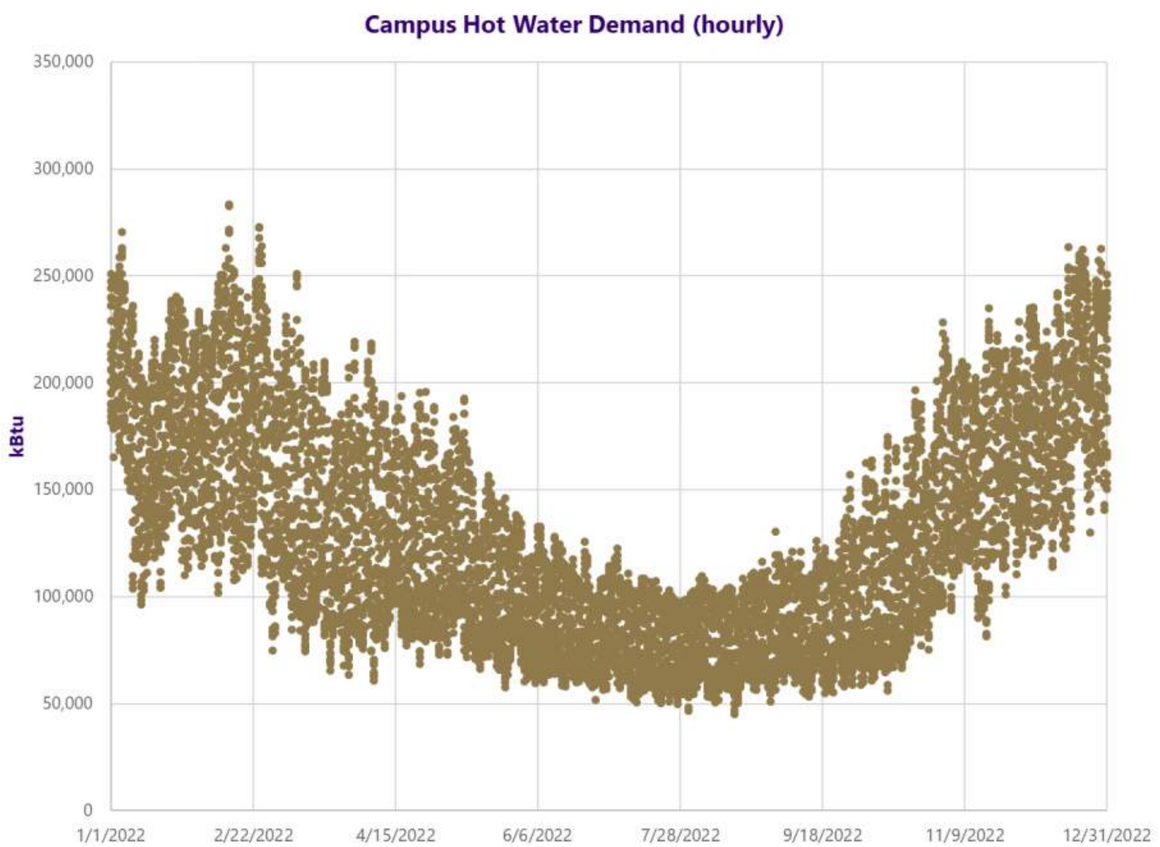


Figure 4.1.2-1: *Estimated total campus hot water demand for 2022 weather data.*

4.1.3 Campus Heating and Cooling Load Projections

The combined hourly load profiles for CCW and steam converted to a campus hot water system are shown in this section. This data was analyzed with respect to load duration, equipment capacity, heating and cooling sources, and potential campus electrification impacts as part of the Energy Renewal Plan.

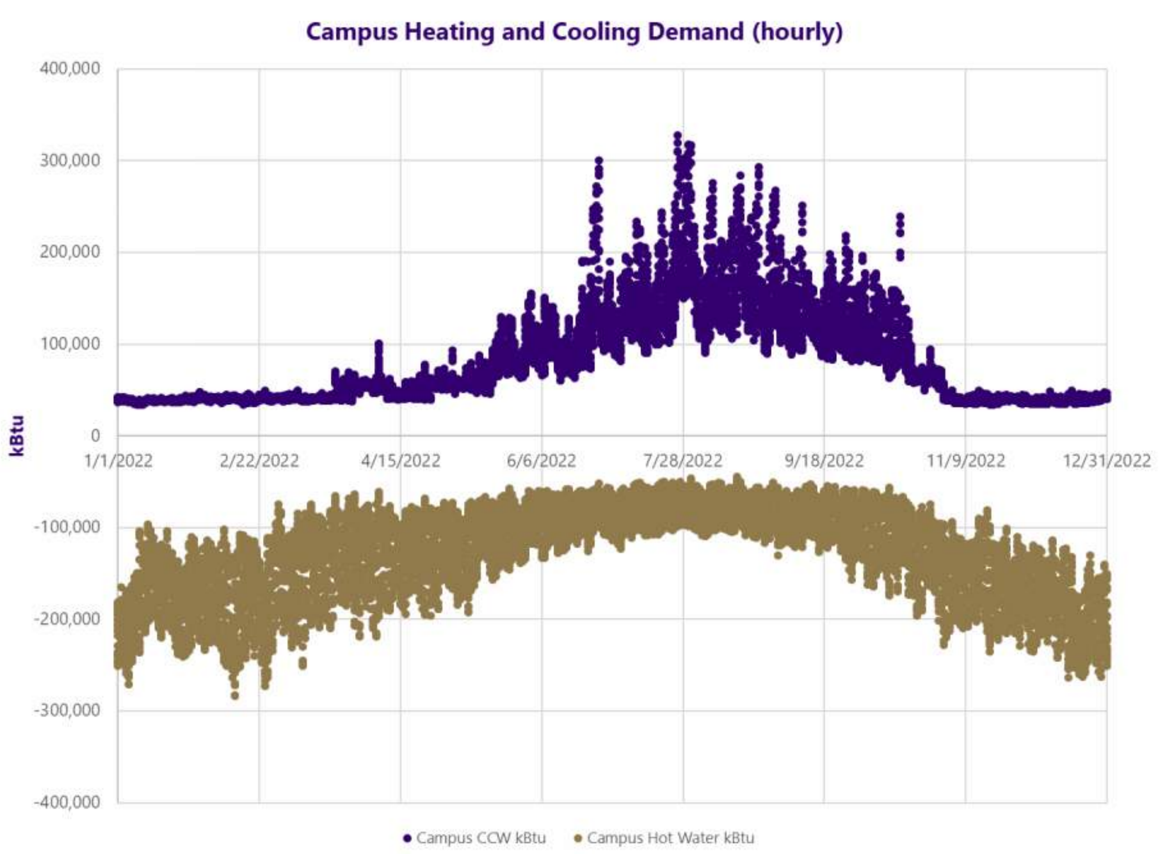


Figure 4.1.3-1: *Hourly total campus CCW and Campus Hot Water load profiles.*

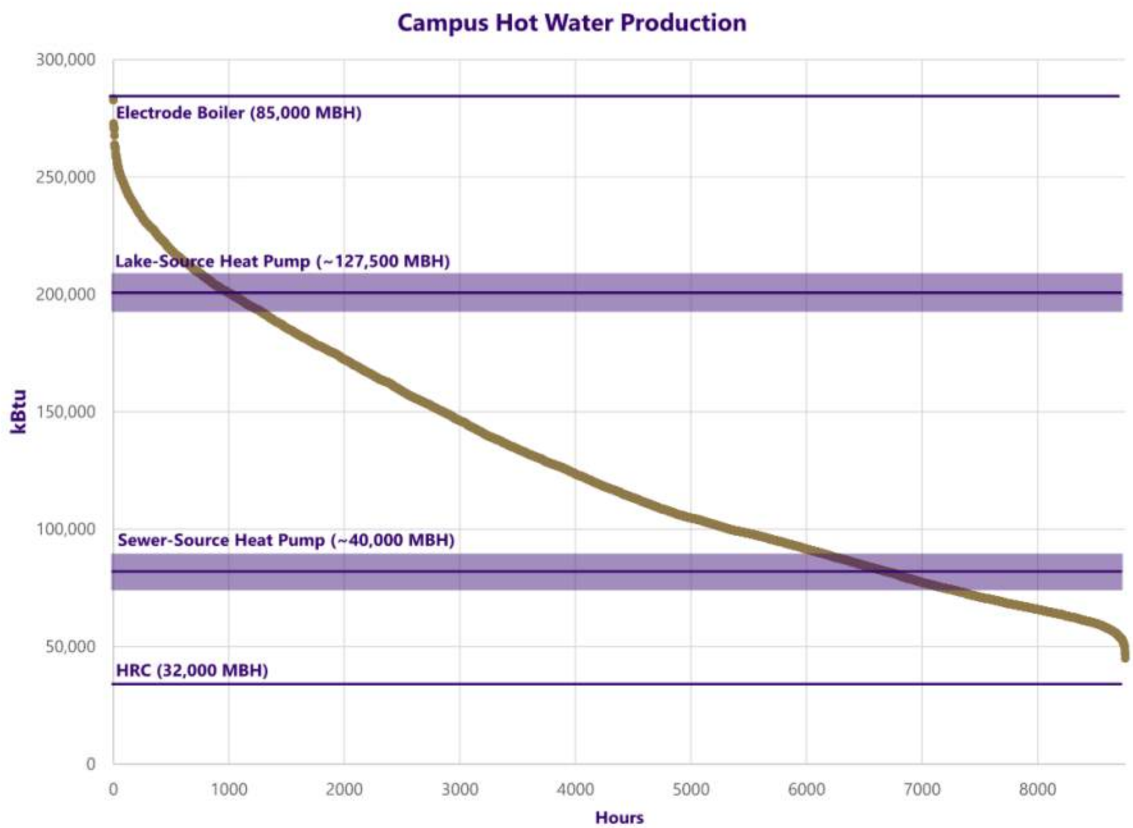


Figure 4.1.3-2: *Total campus hot water hourly load duration and potential equipment heat production capacities.*

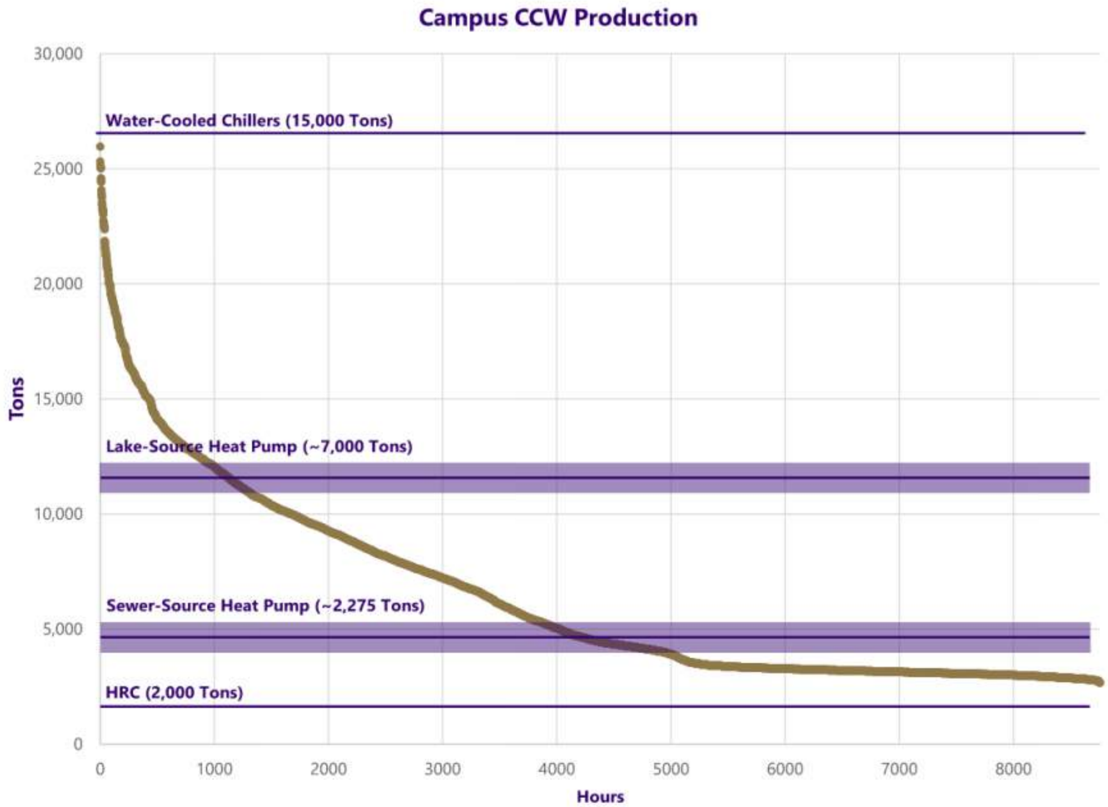


Figure 4.1.3-3: *Total CCW hourly load duration and potential equipment cooling capacities.*

4.1.4 Energy and Carbon Projections

While this report has focused on a baseline assessment that characterizes the energy performance of UW's Seattle Campus today, it is prudent to forecast the broad impacts of the ERP electrification effort on UW's compliance with relevant state legislation as well as UW's core values and public commitments to sustainability.

The energy consumption of the campus served by the CUPs today is shown in Figure 4.1.4-1Figure along with the Clean Buildings Performance Standard (CBPS) EUI target as well as the anticipated performance of the campus after ERP electrification. The campus currently served by the CUPs has a combined EUI of 198.7 which is higher than the campus target of 166.5. After electrifying the campus heating system, which will involve replacing the gas-fired steam with electrified systems, the CUP-connected campus EUI will drop to 125.8, putting UW in compliance with the standard and significantly reducing the campus's energy usage. Not only does the electrification effort push the campus below the CBPS target but it gives a buffer allowing UW to comply with multiple iterations of compliance as the target is reduced every five years.

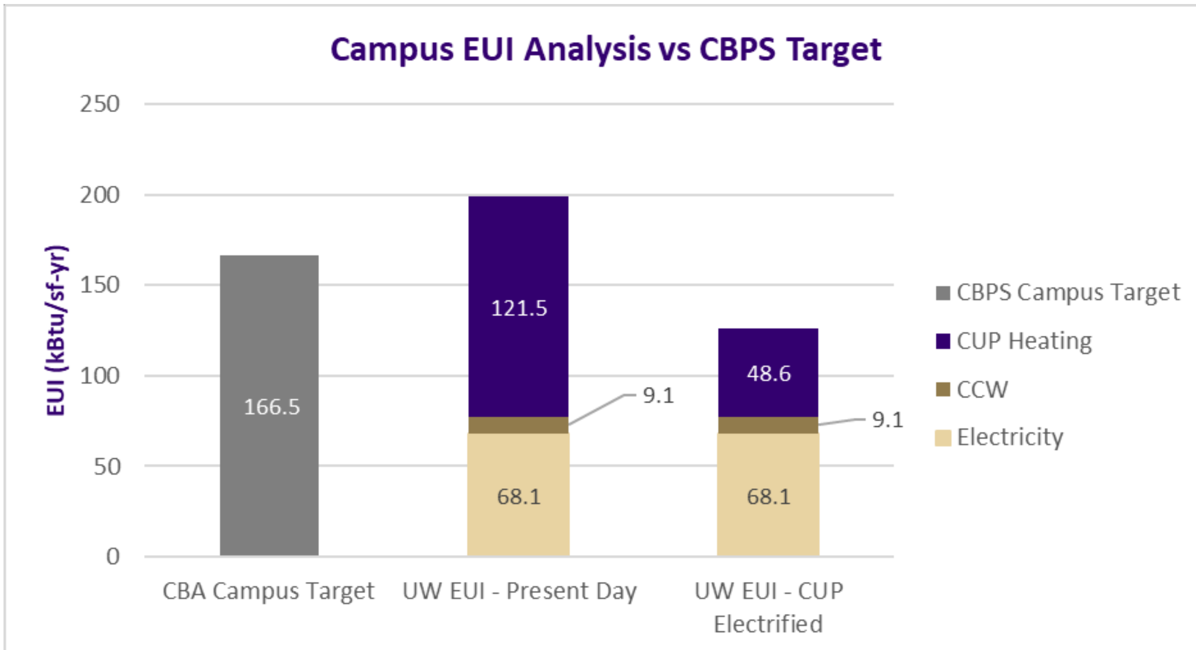


Figure 4.1.4-1: *Energy performance for campus connected to CUPs (including energy consumption of CUPs) and target EUI for compliance with CBPS. Plant efficiencies and distribution losses are accounted for. Results for replacing Power Plant steam heating with an electrified system are shown.*

Compliance with the Climate Commitment Act (CCA) should also be anticipated. The CCA is state legislation in WA that requires entities that have annual CO2 emissions greater than 25,000 MTons to participate in a cap-and-invest carbon auction program. After electrifying the CUPs, the carbon emissions for the Seattle campus will drop below this threshold and UW will no longer be considered a large emitter and covered entity under the CCA. The anticipated Seattle campus emissions are 7024 MTons, giving the Seattle campus a buffer for compliance against the target. This analysis includes emissions from the buildings and CUPs as well as other scope 1 and 2 emissions from the 2021 GHG Inventory.

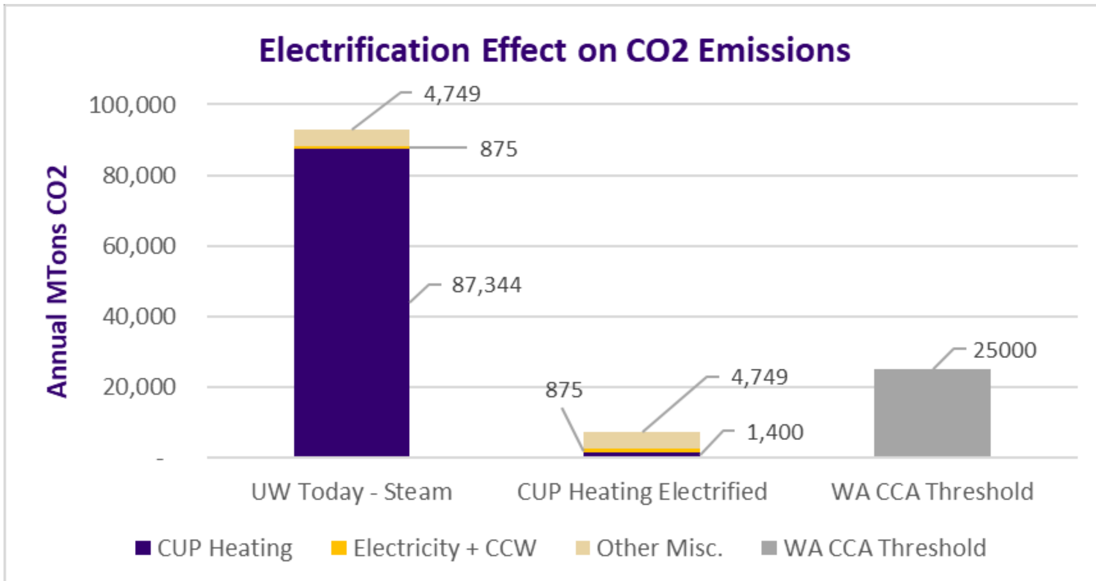


Figure 4.1.4-2: *Reduction in CO2 emissions from replacing gas-fired steam with electrified systems.*

4.2 Electrical Load Projection

Using the annual energy projections for all-electric heating and cooling on the campus, the delta increase over the baseline was added to the existing SCL metered data. In this way, only the additional load to the baseline is plotted. Refer to Figure 4.2-1. In the decarbonized load profile, the winter demand increases and actually exceeds the summer demand. The net demand added to the electrical system in the summer is less than the net demand added to the winter. All predicted modes of operation are higher than the baseline power demand. The increased demand in the winter is approximately 50-60 MW and the increased demand in the summer is about 10 MW above the baseline.

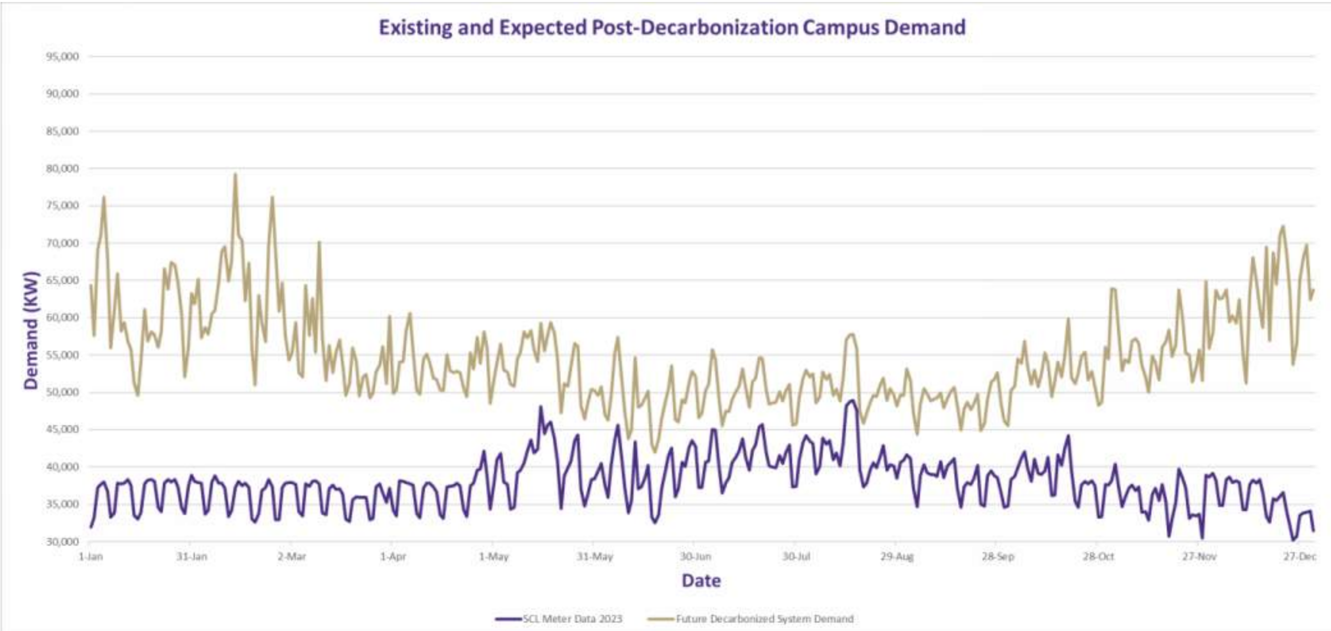


Figure 4.2-1: *SCL meter data for Year 2023 compared to future decarbonized system demand.*

In Figure 4.2-2, the existing capacities of the West Receiving Station in various configurations have been added as horizontal lines to the projected electrical demand. It's critical to remain under the black, "SCL Maintenance Mode" line because of the scenario where SCL may de-energize two feeders for maintenance in the SCL vault. This exact scenario occurred in August 2023. SCL de-energized two feeders for unplanned maintenance, and the campus was left with only two of four feeders serving the WRS. If the plant operators had not shed significant equipment to manage the load below SCL's capacity, the breakers in SCL's substation would have tripped. This would have left the campus completely without normal power causing it to rely on emergency generators. It is predicted these extreme heat events will become more frequent. For that reason, it is essential that the campus prioritize reliability and redundancy with SCL. It's important to note that a significant portion of the year in the decarbonized scenario will be spent operating above the maintenance mode of SCL.

A slightly different scenario occurs when SCL de-energizes one feeder instead of two is shown as a blue band labeled, "SCL – N+1 (62-66MW)". This scenario is as likely to occur as the previous scenario, and the range of the true capacity is unknown because of incomplete information from SCL about the true capacity of their feeders. It is not recommended to operate the campus above the black line and below the blue line but is shown for reference.

The final scenario occurs when the campus is utilizing all four feeders to the WRS at 100% capacity. This is also a range between 80-88MW because of pending confirmation from SCL. It is not recommended to operate the campus in this mode but is shown for reference. Operating the campus at this level has no redundancy from SCL and can overload the SCL substation causing a loss of normal power to the campus.

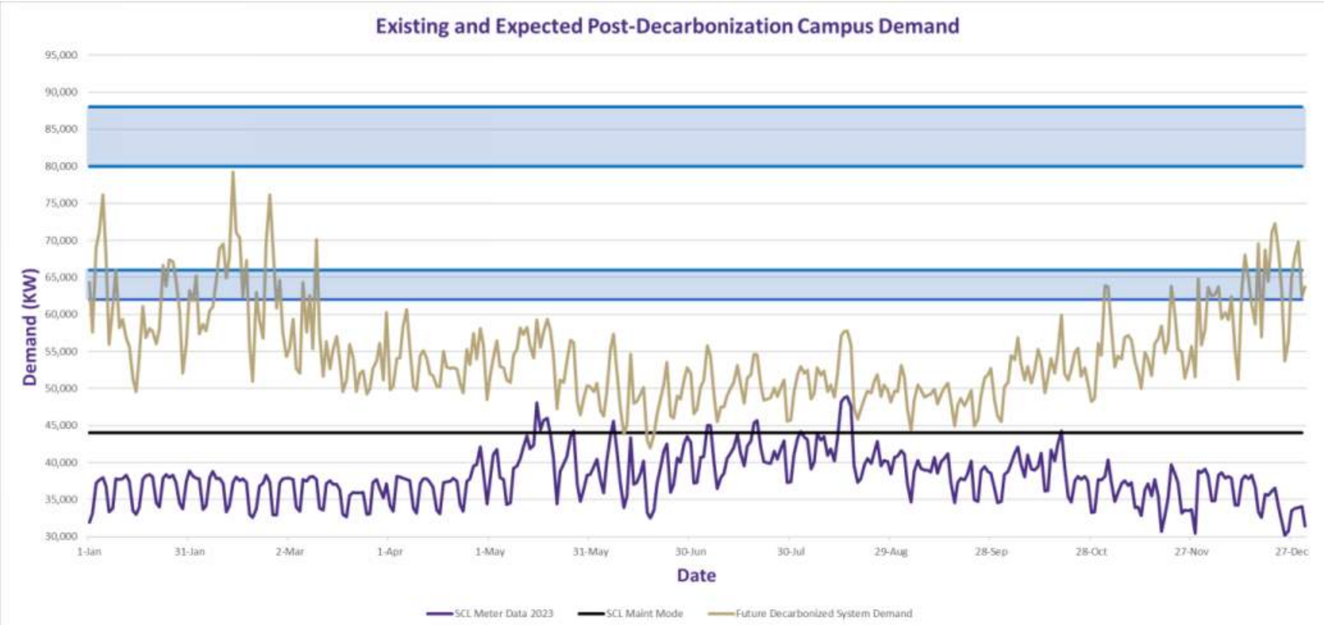


Figure 4.2-2: *SCL Meter Data for Year 2023 compared to future decarbonized system demand with Seattle City Light (SCL) infrastructure limitations overlaid.*

The campus plans to increase Electric Vehicle (EV) charging infrastructure, potentially electrifying fleet vehicles and adding electric vehicle charging stalls to the existing parking areas on the campus. The impact of this additional load on the electrical system is not included in the figures above and the impact will be studied in more detail during Phase II.

Steam used for process loads (humidification, sterilization, cooking) is not currently accounted for in the electrical conversion for decarbonization. These systems will likely become electrified and represent an additional increased load of approximately 6 to 8 MW beyond what is shown in Figure 4.2-1. Phase II assessment will account for this load once the magnitude of these systems is better defined.

4.3 Concepts

The mechanical and electrical projected loads provide the basis for evaluation of the available technologies and system concepts. The concepts presented in this section are the key opportunities for further study towards decarbonizing the existing campus energy systems.

In Phase II Project Identification and Prioritization these concepts will be developed in enough detail to be reviewed with UW staff to filter down the list of options. The options that make it through this screening process will then be evaluated on operational and financial considerations to determine which the net present value of each option. Net present value, first cost, operational and reliability considerations, schedule, and funding opportunities will all be factored in UW's decision to choose which direction to move forward with.

4.3.1 Plant Concepts

At the heart of the district heating and cooling systems are the buildings housing the district energy equipment, often referred to as Campus Utility Plants (CUPs). To eliminate fossil fuels for building space and domestic water heating, heat pumps are often required to be used in some capacity to reduce the impact of the added heat load to the electrical systems in winter. Centralizing the heat pump equipment to a few Campus Utility Plants further reduces the electrical impact through reduced sizing of equipment based on diversity of use.

A benefit of heat pump equipment is that the same device can produce both heating and cooling, either simultaneously, or with change-over operation to produce heating or cooling. This can be helpful in existing facilities since heat pumps / heat recovery chillers can replace existing cooling-only chiller equipment.

The UW campus currently has 10 chillers located across its two campus utility plants, with space already provisioned for five additional chillers. Running through a simple example, if all fifteen chiller locations were occupied by 1,500-ton heat recovery chillers, the estimated campus heating water load would be met with a 25% margin of safety. Heat recovery chillers designed for low-GWP refrigerants do not necessarily fit like-for-like within the same footprint of a like-sized cooling-only machine with R-134a refrigerant, so it's unlikely to be as simple as that but this gives a sense of scale to the challenge.

The role of any steam-driven absorption chillers in the decarbonized future operation will be assessed in Phase II. The absorption chillers provide an important function in allowing the steam turbine to continue to run during periods of low steam demand on the low pressure system, however as steam use on the low pressure system decreases due to building conversions, the absorption chiller will see a higher quantity of run-hours and eventually a decision will need to be made as to whether running the turbine largely to power absorption chillers makes sense.

Space requirements are only one aspect of planning for new heat recovery chillers. The most basic and critical criteria for heat pumps is determining the source of heat to be used by the heat pump to generate useful heat. For the University of Washington, the main sources of heat for heat pump heating are expected to come from, in order of anticipated capacity magnitude:

- Lake water heat exchange
- Sewer water heat recovery

- Simultaneous heating and cooling (heat recovery) between campus heating and cooling loads

Through Phase II of the ERP, the team will be working to assess viability and costs of each the heat pump heat sources. Contingency plans if lake cooling or sewer heat recovery are determined to be unfeasible have not been defined at this time. Alternate strategies would likely consist of increased electric boiler capacity, air-source heat pumps, ground-source heat pumps, or other technologies.

- In addition to heat pumps, the strategies to meet the campus energy system renewal will include:
- Electric / electrode boilers
- Additional water-cooled chillers to replace stand-alone chillers located at buildings
- Thermal Energy Storage – hot and chilled water

A major hurdle for the campus will be to transition the Power Plant CCW system from a seasonal comfort cooling system to a year-round, reliable chilled water system that can be used to replace the distributed chilling equipment that currently exists throughout the main campus. Some of the issues that will need to be addressed include:

- Replacement of the functionality of the current wintertime “heat recovery” mode.
- Alternate freeze protection strategies to current method of circulation and drain-down of building level equipment.
- Required minimum load to enable stable operation of the Power Plant chillers. Existing chillers have minimal turndown capability.

4.3.1.1 Lake Interface – Heat Pump Heating and Cooling

The effectiveness of heat pumps is directly related to the temperature difference between the source and the sink. Heat pumps transfer energy in the form of heat from the source to the sink. Historically, heat pumps used for building heat utilize outdoor air as the source and as the outdoor air approaches freezing temperatures, supplemental heat sources in the form of electric or fossil fuel equipment are then used in place of or in combination with the heat pump.

Using air as a source of heat is not as effective for projects seeking to eliminate fossil fuel use, since supplemental or backup electric heating systems would exceed the capacity of the existing electrical infrastructure, have a high operational cost due to poor efficiency.

Alternative sources for heat pumps can draw heat from the ground or large bodies of water. Heat exchange from the ground is not only expensive, but also space intensive, requiring large acreage of land which is not available in an urban campus environment. Refer to 2017 Hot Water Conversion Study: Phase II for previous study conducted for the University of Washington on geothermal systems.

The University of Washington campus borders Union Bay, Portage Bay, and the Ship Canal bodies of water. Other systems across the world that operate heat pumps to exchange heat with bodies of water draw water from an adequate depth to the point where temperatures do not vary seasonally. Bodies of water immediately adjacent to the campus are not deep enough to see these constant temperatures. Deep enough waters (approximately 82 feet) to see consistent seasonal temperature are located approximately a mile from shore.

In Phase II, the ERP team will evaluate a plan to locate an equipment building on the shore of Union Bay which will house pumps and heat exchangers. A pipe system would be installed beneath the waters of Union Bay with an inlet location in Lake Washington within the vicinity of Webster Point. Once the lake water has passed through a heat exchanger, it will be returned to the body of water in a region where the exit water temperature is no warmer than the surrounding water. Options being considered for the outlet point are:

- **Option 1:** Back to Lake Washington near the intake location, at an elevation consistent with the expected discharge temperatures.
- **Option 2:** Directed towards the Ship Canal, with the intent to deliver cooler water than typically exists in the summer, so as not to make conditions worse for salmon migration.
- **Option 3:** As a source for water to the salmon hatchery near Portage Bay.

Approximate locations of the intake, three discharge options, and lake equipment building are shown in Figure 4.3.1.1-1.

Figure 4.3.1.1-1: *Approximate locations of the intake, three discharge options, and lake equipment building.*

An example of potential lake water intakes and outlets are shown in Figure 4.3.1.1-2.

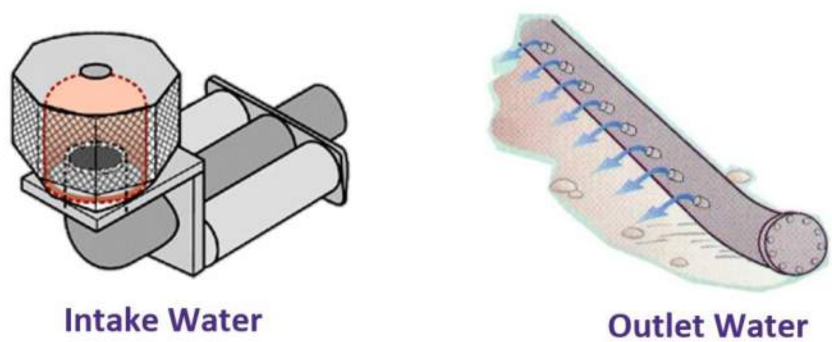


Figure 4.3.1.1-2: *Example intake water and outlet water configurations. Intake and outlet water is configured to minimize velocity of suction and discharge. Examples sourced from Cornell University Facilities and Campus Services.*

Heat pump equipment to transfer heat to and from the lake would be in the form of large (likely 1,500-ton to 2,500 ton) heat recovery chillers. These heat recovery chillers would likely be located within the existing Power Plant facility on the east side of main campus. The chillers would be configured with changeover valves allowing them to operate in a mode of simultaneous heat recovery between the campus heating and cooling loops, lake water heating mode (cooling the lake to provide heat to the campus), or lake water cooling mode (heating the lake to provide cool to the campus).

Implementing a lake water heat pump system will be a massive effort requiring significant funding resources (discussions around a possible public private partnership) and coordination with Tribal, City, State, and Federal agencies to gain approval. The benefits of this system are also significant which justifies further study to confirm viability. Lake water heat pumps will provide a highly efficient electrified source of heating and cooling for the campus with effectively zero water consumption compared to traditional systems.

Refer to Appendix 5.2 Lake Interface Preliminary Permitting / Environmental Considerations Report for additional details on background of Lake Washington, permitting landscape and strategy, environmental and temperature considerations, and analysis of available data sets.

4.3.1.2 Sewer Heat Recovery – Heat Pump Heating and Cooling

A large amount of unutilized heat exists in the King County sewer tunnels that route through, and adjacent to campus. This heat can be captured via sewer water heat exchangers and pumping loops and used as a source to generate heat via heat pumps. In addition to the energy benefits, a heat recovery chiller using sewer water as a source/sink for heating and cooling consumes zero potable water which represents a significant cost and environmental savings opportunity. Running primarily from east to west, a 102” sewer line sourced from the Montlake trunk lines is routed below Pacific Avenue (the Montlake Combined section shown in Figure 4.3.1.2-1) and passes near the WCUP. While there is a large source of heat available in this sewer line, more than double the heat capacity can be found in the same sewer tunnel further west, after a branch coming from the U-District is added (the UW Combined section). Temperatures of the sewer water range from 41.5°F to 78°F throughout the year, with the colder temperatures coming during rain events.

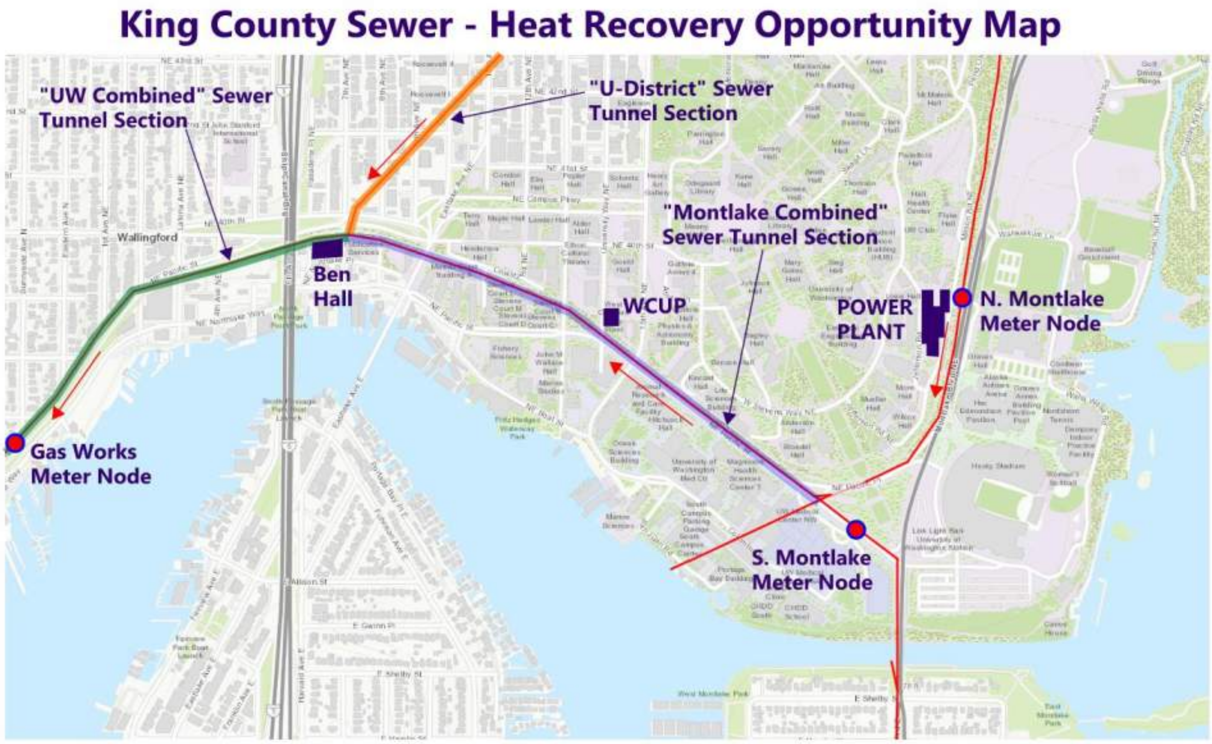


Figure 4.3.1.2-1: *Heat recovery opportunity map.*

Graphs depicting heat recovery capacity for the UW Combined Section are shown in Figs 4.3.1.2-2 and Figs 4.3.1.2-3. It was assumed that 75% of the total sewer water flow could be diverted to the heat recovery system, and a 6°F delta-T in the sewer water was used to calculate the heating capacity. While temporary spikes in the sewer water flow rate indicate a heat recovery availability of up to 70 MW, a base load of approximately 5 MW is available 99% of the hours throughout the year. For this report, an availability of approximately 8MW was assumed for the heating capacity of the sewer water system, which represents 88% of the hours throughout the year.

During periods of either low temperature (below ~47°F) or low flow (below ~9,000 GPM) in the sewer water system, the sewer heat itself will not suffice to meet the 8 MW capacity required (refer to Figure 4.3.1.2-3). This reduced amount of heat will need to be made up somehow, especially since during low temperature events it is likely that the heating load of the campus will be heightened. This heating shortfall could be made up via electric boilers, either pre-heating the heat pump evaporator water, or post-heating the heat pump condenser water. These scenarios will be analyzed in Phase II of the project to determine the optimal strategy.

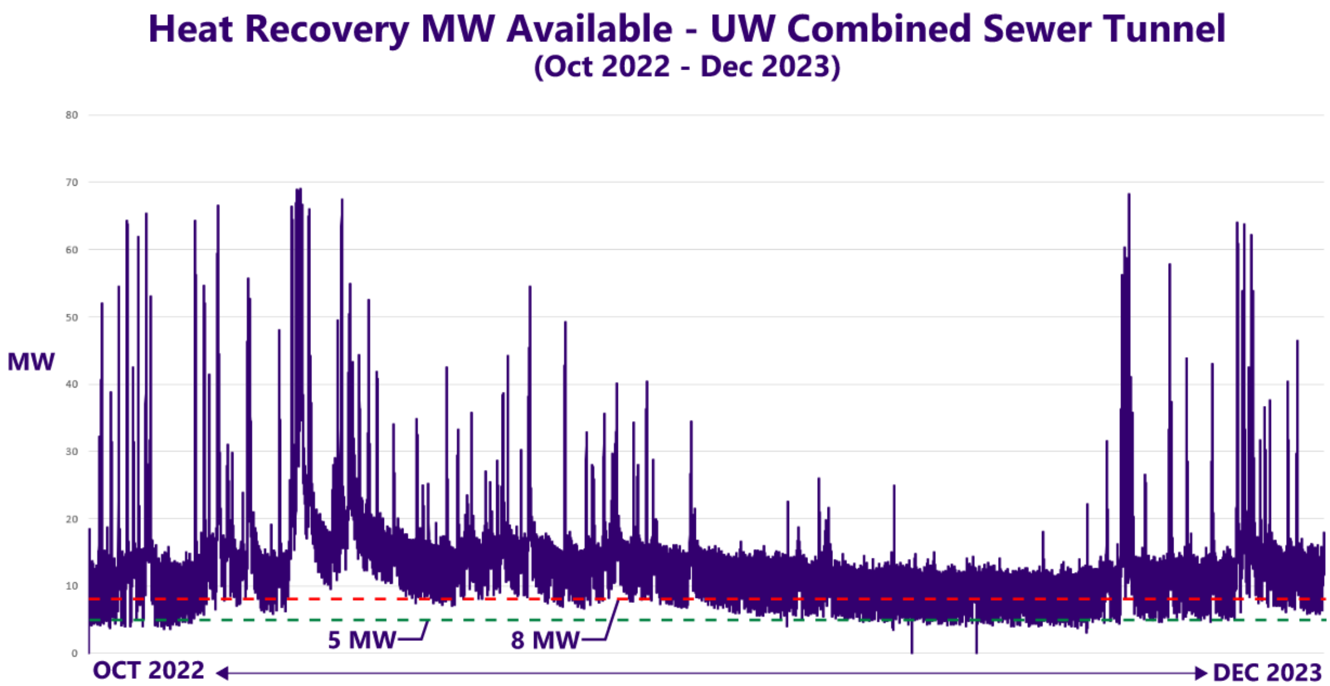


Figure 4.3.1.2-2: *Heat recovery availability, in MW – UW Combined Sewer Tunnel.*

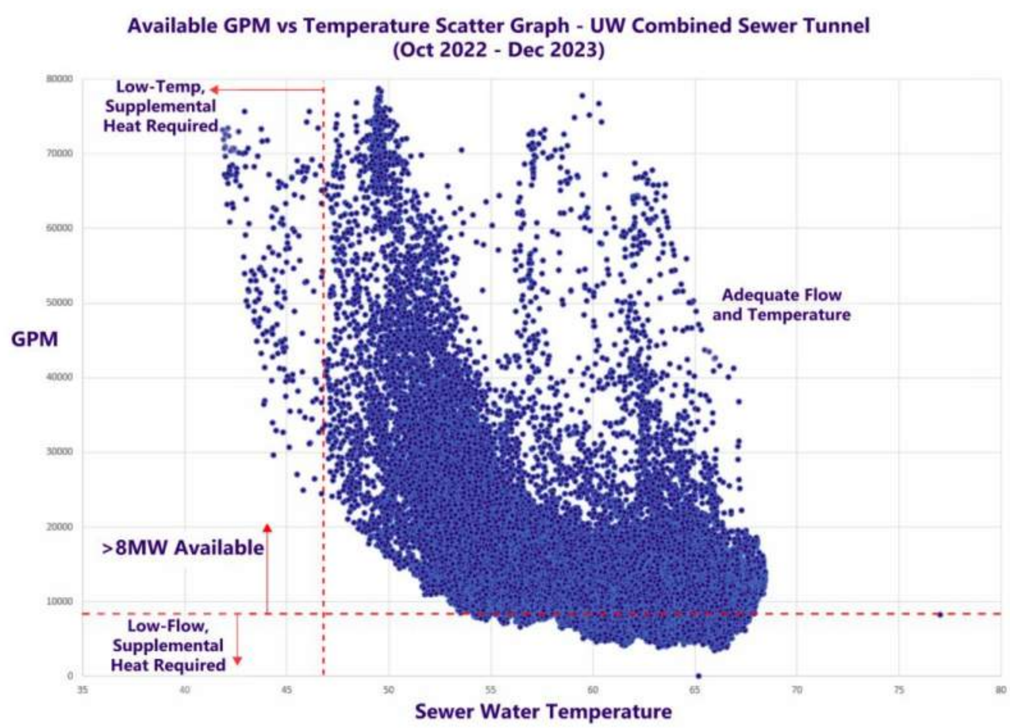


Figure 4.3.1.2-3: *Heat recovery availability scatter graph – UW Combined Sewer Tunnel.*

To capture the BTUs from the sewer system to the campus loop, sewer water must be temporarily diverted from the sewer tunnel into a wet well before being filtered/augured, then pumped through sewer water heat exchanger modules, and finally returned to the sewer tunnel (refer to Figure 4.3.1.2-5). The other side of the sewer water heat exchanger will be a circulated water loop connected to the heat pumps located elsewhere (WCUP is a possible location). This loop will provide the heat pumps with a heat source in winter, and a heat sink to make chilled water in summer. A 3°F-5°F approach is typically attainable with sewer water recovery systems between the sewer water and clean water.

Two manufacturers of heat exchange systems, SHARC (British Colombia) and Huber (Germany), are at the forefront of the emerging sewer heat recovery industry and use slightly different approaches to filtration and heat exchange. SHARC has several large systems up and running in Vancouver, B.C. and a new SHARC 880 system was just installed in Seattle in 2023 (not yet operational). Huber is involved in a large project at Toronto Western Hospital, which is currently under construction. This may be fortuitous, as the lessons learned from these installations could be leveraged for success of this project. The heat exchangers, wet well, sump pumps and distribution pumps would likely be in a satellite facility near the sewer water intake/return in order to minimize the distance that pressurized raw sewage is pumped. A site between I-5 and the University Bridge, across the Burke-Gilman Trail from Benjamin Hall could be a viable location (refer to Figure 4.3.1.2-4).

Figure 4.3.1.2-4: *Sewer water heat exchange facility – Siting Vicinity Plan.*

A more local sewer connection point somewhere along the Montlake Combined section of sewer tunnel (close to the WCUP) is appealing because less large condenser water pipes to/from the heat pumps would be needed. However, this sewer tunnel contains roughly 40% of the capacity of the UW Combined section further west. In addition, a less valuable part of campus may be a more suitable location for the Sewer Water Heat Exchange Facility. The bottom of the wet well for the sewer water intake must be lower than the sewer pipe by a minimum of 10-20'. King County has not yet provided this project with existing drawings of the sewer tunnels in question, but on previous projects we have been involved in, the wet well construction was logistically challenging and costly because of depth, existing utilities, and soil type.

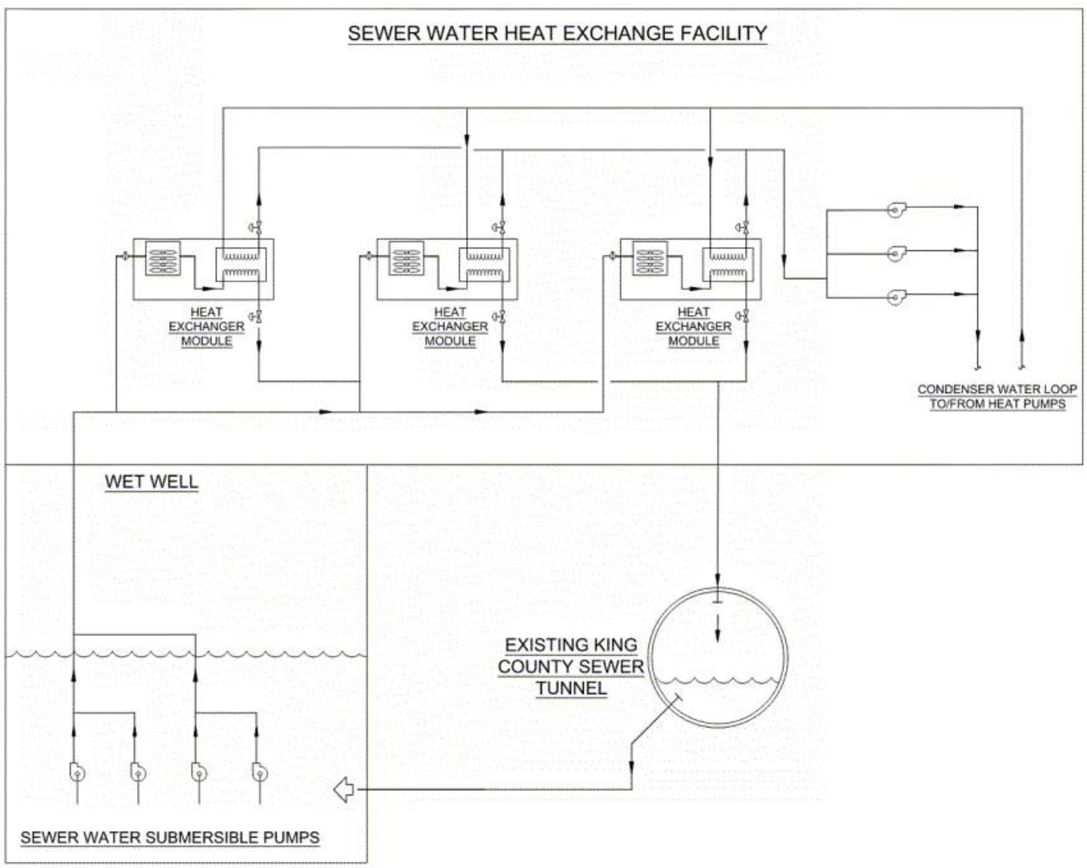


Figure* 4.3.1.2-5*: Simplified Sewer Water Heat Recovery Schematic

4.3.1.3 Boilers – Electric Resistance or Electrode Type

Electrode boilers are relatively simple technology compared to conventional combustion boilers. The principle of operation are electrodes immersed in water, and as current flows through them, the electrical resistance of the water generates the heat directly, producing the desired hot water. The energy conversion efficiency is greater than 99% with only some losses through insulation to the room. These boilers are available in medium voltage feeds up to 13 kVa and have a vertical profile, requiring progressively more clear height as the capacity increases. Electrode boilers do not directly produce hot water and require a closed-loop steam system and heat exchanger to generate hot water.

Electric resistance boilers are available in medium voltage feeds up to 6,600V. Electric resistance boilers use immersion heating elements that heat the water within a pressure vessel. This style of boiler eliminates the closed-loop steam system associated with electrode boilers and have more of a horizontal profile.

The components of a conventional combustion boiler system that are eliminated are:

- Combustion air intakes, louvers, fans, heaters, filters
- Draft fans
- Fuel systems and burners
- Exhaust systems, stacks, emissions monitoring or treatment, feedwater economizers
- On-site emissions

The footprint of electric/electrode boilers is also much smaller than conventional combustion boilers and the turndown is 100:1 instead of a typical 4:1.

Figure 4.3.1.3-1: *Cleaver Brooks Electrode Boiler.*

The barriers to this technology are the electrical infrastructure to support the power demand and the cost of energy. As an example, an 80,000 lbs/hr steam boiler would require 24 MW peak electrical input. During a peak hour that conventional boiler would have utilized 1,000 therms of natural gas at approximately $0.50 per therm for a cost of $500/hour and that electrode boiler would have utilized 24,000 kWh of electricity at approximately $0.15 per kWh for a cost of $3,600/hour. The marginal cost of fuel and marginal cost of electricity during peak winter conditions will vary by location and will change over time. In this example, 5.3 MTCDE of on-site emissions were avoided for that peak hour, so the energy cost difference of $3,200/hour equates to $604/MTCDE of avoided on-site emissions.

Electric/electrode boilers are anticipated as part of the final decarbonized system configuration due to their cost effectiveness when compared to the infrastructure associated with heat pumps sourcing heat from the deep lake or sewer heat recovery. Refer to section 4.1.3 Campus Heating and Cooling Load Projections for information on the projected run hours of electric boilers with an assumed capacity of roughly 30% of the peak heating load. This capacity equates to an equivalent capacity of electric boiler to the smallest steam boiler in the power plant. Electric boilers would be located at each heating plant for trim heating of the heating water supply temperature at near peak winter heating operating conditions.

4.3.1.4 Thermal Energy Storage (TES)

The campus chilled water system at its current capacity is unable to meet load during extremely warm weather. Additionally, the Seattle City Light electrical feed to the main Power Plant experiences voltage sags throughout the year that interrupt chiller operation, requiring manual restarts. On hot days, these restarts can take several hours and cause the plant to be out of control for the entire day as the chillers are unable to catch up to the load.

The addition of TES to the campus chilled water system will address both the issue of peak load during extremely warm weather as well as riding through service interruptions caused by electrical system voltage sags. The existing chillers at the Power Plant will be able to charge the tank during low-load hours (including night-time operation) when the campus load is satisfied, and the demand electrical rates are lower. This additional capacity will allow the plant to ride through extreme weather events and chiller outages caused by voltage sags in the City electrical system, resulting in fewer buildings being shed from chilled water service, and an ability to provide critical cooling to more buildings on campus. Thermal storage also enables the integration of intermittent renewable energy sources, such as sewer water heating/cooling, by mitigating the impact of their variability. As it relates to a heat recovery chiller plant, thermal energy storage can also produce operational benefits by providing a thermal mass (capacitance) to allow heat recovery chillers to run more efficiently and decrease cycling. This is true for both heating water and chilled water sides of the heat recovery system.

Regarding tank sizing with the goal of storage and resilience, basic tank size can be determined by targeting an amount of load desired to be discharged over a given amount of time. Figure 4.3.1.4-1 illustrates tanks sizes versus the amount of thermal storage capacity. This is a simple method to determine a tank size, but in practice the tank location and discharging scheme must be taken into consideration when determining the ideal size and function of the TES tank. Tank discharge capacity is limited by the pipe mains it is connected to and its associated pumping capacity.

"Operational" storage tank sizing differs from a tank providing storage capacity and resilience. This type of storage contributes to extending the lifespan of equipment by preventing rapid cycling, thus reducing wear and tear on components, and providing a more stable and controllable system overall. The sizing of these tanks depends on anticipated load variation and imbalance between simultaneous heating and cooling demands, as well as inherent thermal capacitance available in the piping system. A tank, or set of tanks, could be applied to a heat recovery chiller plant that is not hydraulically connected to a larger tank intended for increased resilience. Operational storage tanks are generally ASME-rated pressure vessels.

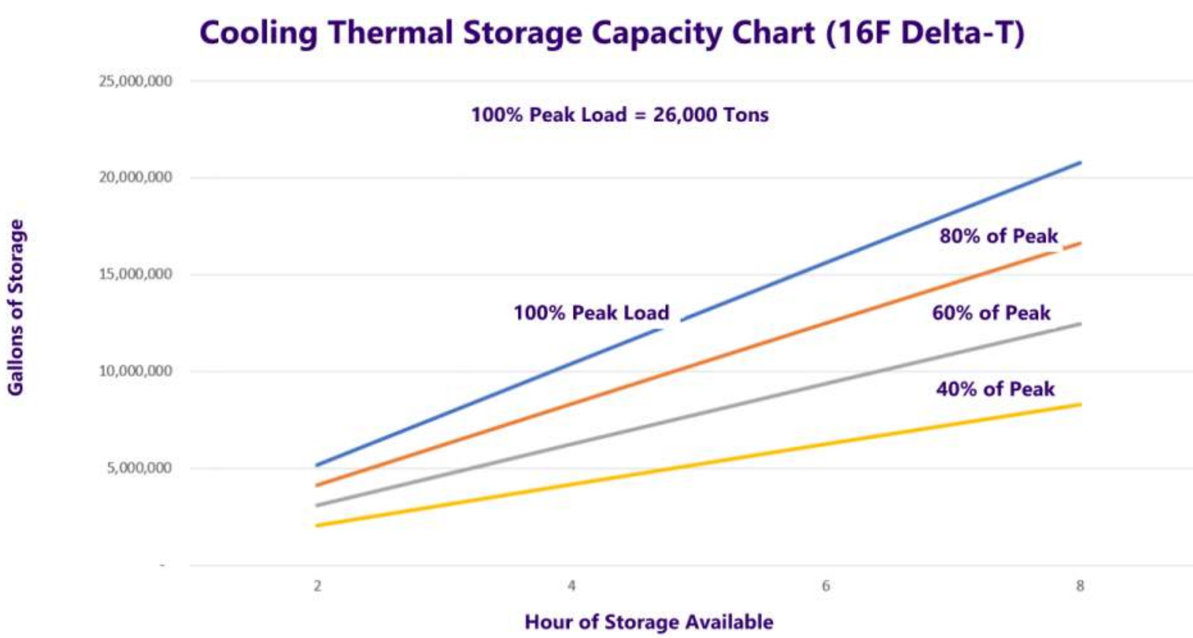


Figure 4.3.1.4-1: *Cooling Thermal Storage Capacity Chart*

TES tank location possibilities were discussed with the Central Plant, TES, and Distribution Project Working Team. Factors taken into consideration when considering TES tank locations are:

- Tank location relative to charging equipment in plants (heat pumps), supply headers, or adequately sized supply mains.

- Tank elevation, and developed pressure imposed on connected buildings.
- Architectural/aesthetic considerations.

Locating the tanks close to the plants is ideal, as this would shorten piping runs, allow the heat recovery chillers to charge both tanks locally and allow the tank to act as a hydraulic decoupler. Locating the tanks near the plants would also allow the discharge pumps to be co-located with the heat recovery equipment and reduce the number of pumps and overall system complexity. Although heat recovery is currently being considered at both plants, it may not be sensible or required to provide tanks at both locations.

Proximity to adequately sized piping mains near the ends of the system would allow the tanks to discharge either into the main supply headers, or at a location such that the tank could serve a high percentage of buildings without back feeding or creating any hydraulic complications.

Three CCW tank locations were identified for preliminary discussion and analysis (refer to Figure 4.3.1.4-2):

- North TES, located at the Burke Museum Parking Lot, either above ground or buried.
- East TES, located above ground just north of the Power Plant, in the location of the existing Annex buildings.
- Central TES, located below ground beneath the Drumheller Fountain.

Although these locations were used for an initial screening, identification of a new plant location could lead us to consider additional locations. And, although not identified on the campus map in Figure 4.3.1.4-2, a West Campus TES was discussed in theory and will remain under consideration and part of the discussion. Refer to Table 4.3.1.4-1 for pros/cons of the identified TES tank locations. Based on initial screening, the East TES appeared to have the most desirable qualities. As such, it was identified as the best candidate for initial project funding via the CPAT process. Assuming large thermal storage is located near the Power Plant, it is anticipated that a certain level of operational thermal storage will be required at the heat recovery plant in the WCUP to ensure efficient operation.

Figure 4.3.1.4-2: *TES Tank Location Map*

Table 4.3.1.4-1: CCW TES Tank Location Pros/Cons

NORTH TES		CENTRAL TES		EAST TES	
Burke Parking Lot - Above or Below Ground		Below Ground, Under Drumheller Fountain		Above Ground, North of Power Plant	
Pros	Cons	Pros	Cons	Pros	Cons
Burke parking lot has flexibility vis-à-vis size, shape, above/below ground	High elevation and pressure of above ground TES may create pressure issues at many buildings	Equidistant to both existing plants	Higher first cost with excavation and shoring requirements	Proximity to existing Power Plant and (3) large bore chilled water pipes	Above ground tank aesthetics
Could effectively act as a new plant for North Campus	Remote from both plants. Would require long runs of large bore pipe to serve tank from plants	Minimal impact with existing campus architecture	May require a dedicated pump house to inject into the middle of the system	Straightforward discharging hydraulics, opportunites to incporporate into/improve plant piping scheme	Difficult to charge from WCUP
	Above ground tank: aesthetics Below ground tank: cost		Central location may present distribution challenges	Lowest impact to building pressurization. "Sweet Spot"	

Large TES tanks are generally atmospheric tanks, thus, if the tank height is at or above the system fill pressure, then the water level of the TES will set the fill pressure in the system. Figure 4.3.1.4-3 depicts the elevations of the TES tank locations considered, and how they relate to the buildings on campus. Certain tank-building interactions could create high pressure conditions that would increase pressures on the CCW system fittings beyond their pressure class rating. The campus buildings are outfitted with piping components of various ages and pressure classes, but changeout of these components throughout the buildings is not sensible. In these high-pressure situations, it may make sense to isolate buildings from the CCW system with a heat exchanger and adding a building-side pumping system. Conversely, if the TES tank is located below the high point of CCW in buildings, this additional pressure would cause a TES tank overflow condition (the Drumheller TES location has ~24 buildings where this is the case). Either those higher elevation buildings would need to be decoupled with a heat exchanger, or a pressure sustaining valve be used on the TES tank return line to prevent tank overflow. Ideally the system will require only a handful of buildings to require hydraulic decoupling. A project goal is to create a system that can be safely interconnected between plants, allowing the TES to benefit the entire campus. Presently, the isolation valves between the plants are only opened during rare maintenance events, and never for more than a few hours. A complete analysis of the CCW TES tank location and its impact on the campus buildings will be determined in Phase II.

Figure 4.3.1.4-3: *Elevations of Buildings Connected to CCW vs. CCW TES Tank Elevations*

In addition to the chilled water TES tank, a hot water tank will provide similar resiliency, operational benefits, and is critical to the efficient operation of the heat recovery system. The size of the heating water tank of similar thermal capacity is smaller given the higher delta-T of the heating water system. Refer to Figure 4.3.1.4-4 for basic hot water tank sizing based on thermal storage capacity. Similar to

CCW tank, proximity the heat generating equipment and large piping distribution pumps and headers would be ideal for the hot water TES location. Aesthetically, locating the tanks adjacent to each other may make sense, as well.

Because the new heating water system will be decoupled from every building on campus, pressure issues are fewer and easier to mitigate. Pressure sustaining valve(s) may still be required on the hot water TES tank, but buildings will not need to be isolated because of over pressurization issues.

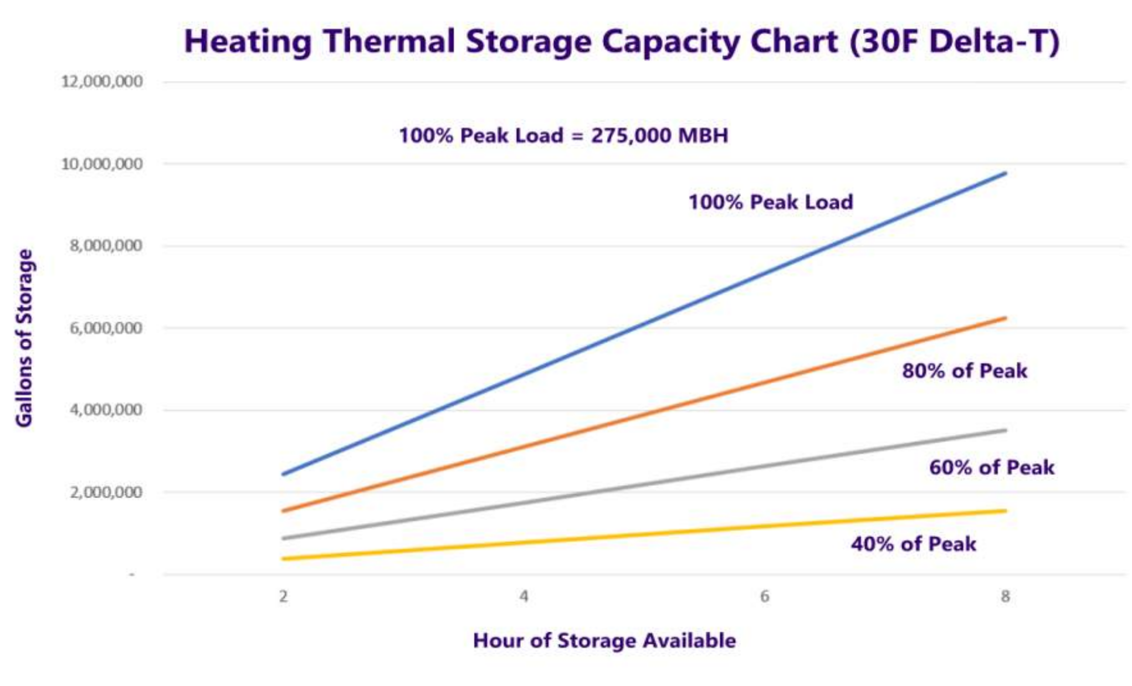


Figure 4.3.1.4-4: *Heating Thermal Storage Capacity Chart*

Although hot water TES has not been discussed in detail with the Central Plant, TES, and Distribution Project Working Team up to this point, evaluation of hot water TES will be an important part of the Phase II effort.

4.3.1.5 Existing Campus Utility Plants with Relation to New Systems

As discussed earlier in this section, heat recovery chillers can be used for both heat recovery, lake water heating/cooling, and sewer water heat recovery. This allows for heat recovery chillers to replace existing cooling-only chillers where space allows and perform both heating and cooling functions.

There are currently five “empty chairs” in existing plants that are provisioned for chiller installations:

- Power Plant has space provisioned for Chiller #8, adjacent to Chiller #7.

- WCUP has space provisioned for four chillers, however two cooling only chillers (Chillers #4 & #5) have already been purchased and currently planned for installation, leaving in theory two spaces for heat recovery chillers.

In addition to the already provisioned space, the power plant frees up approximately 5,000-6,000 square feet in the event that a steam boiler is removed. There is significant height/volume freed up as part of this which could present an opportunity for stacked chiller arrangements to gain even more room for heat recovery chillers. Several heat recovery chillers could be installed in place of one remove steam boiler, though the connectivity of piping to existing systems has not been evaluated.

4.3.1.6 New Campus Utility Plants

Based on the Cooling and Heating Load Projections outlined in section 4.1, there is an anticipated need for an additional 7,000 to 10,000 tons of cooling that would not currently have a home within either existing plant based on space provisioned for future chillers. A new plant is likely to be required to house cooling equipment to meet the increased cooling load associated with transition from stand-alone to centralized equipment as well as anticipated load increases from building densification, future climate conditions, and addition of cooling to buildings not currently provided with cooling.

The location of this new plant will be explored, and recommendations determined in Phase II. Preliminary discussions within the Central Plant, TES, and Distribution Project Working Team have generated concepts for different ways of breaking up the campus into sectors, with the location of a new plant being integral to those conversations. A plant located on the north end of the campus would be practical from the standpoint of reducing piping distribution infrastructure routed to the north where it does not currently exist but has the downside that it invests in a new plant near buildings and loads that are not nearly as critical as those to the south. A plant located south of Pacific Ave would benefit the critical loads of the UW Medical Center and likely improve reliability of utilities to that region.

For the Baseline effort of identifying opportunities and challenges, Figure 4.3.1.6-1 shows the general arrangement of a New Campus Utility Plant along with the new configuration and arrangement of equipment within the existing WCUP and Power Plant buildings based on the addition of heat recovery chillers, heat exchange equipment, electric boilers, and thermal energy storage.

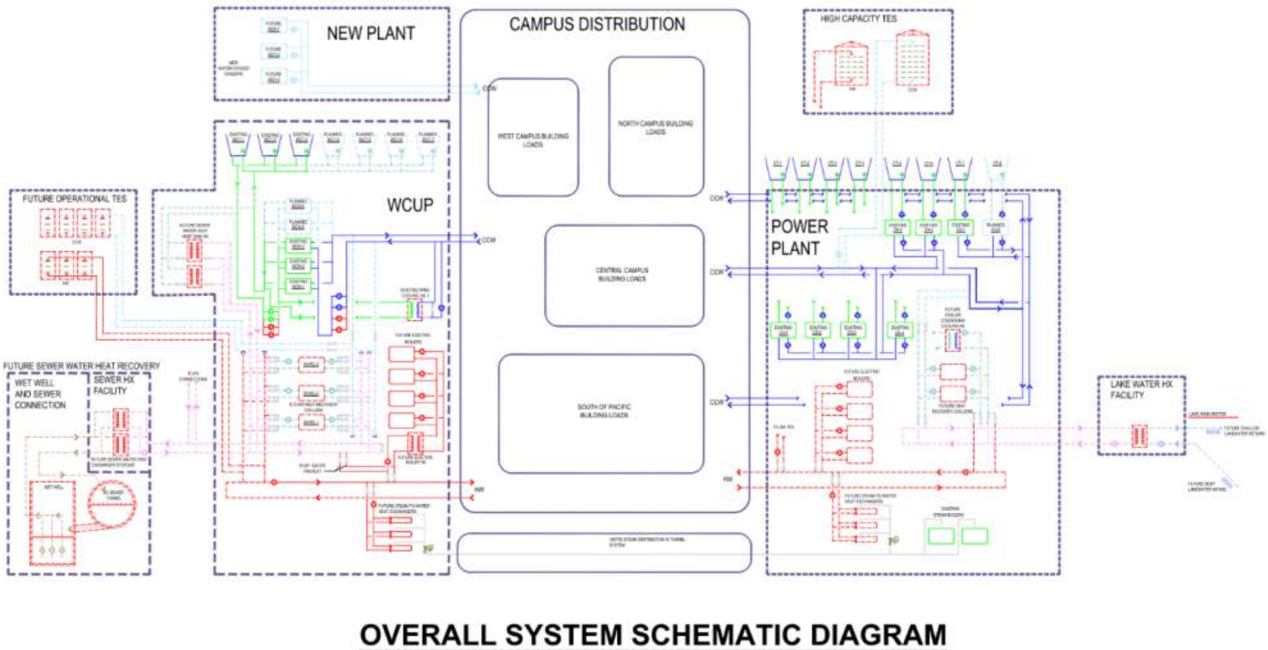


Figure 4.3.1.6-1: *Overall system diagram.*
Refer to Appendix 5.1.3 for a larger format diagram for more detailed information.

4.3.1.7 Operational Considerations

Any increase in effort and responsibility for operations staff is very important to the University, who like most campuses is already overextended maintaining the current systems.

There are aspects of the transition from gas-fired steam boilers to electric heat recovery chillers, boilers, and thermal energy storage that provide tangible maintenance benefits:

- Heating water piping and associated terminal air handling systems require less maintenance than steam piping
- Electric hot water boilers require less annual maintenance than comparable gas-fired steam boilers

However, the complexity of operations for a heating plant relying primarily on heat pumps is significant. The steam system historically used on campus is very simple to operate from the standpoint of staging of equipment with a single primary goal of maintaining steam pressure located in only one campus utility plant. Compressorized equipment is not nearly as robust as gas-fired equipment when it comes to changing system conditions and part-load operation. Additionally, the new proposed systems may operate under different goals depending on the season or regulatory environment. Some of these challenges are offset with adequate thermal energy storage to allow heat pumps to operate at their ideal run condition for an adequate amount of time to avoid short cycling and the issues that come with that. Additionally, the proposed heating systems will also provide a more distributed approach to heating, transitioning from a single centralized heating system to a distributed system consisting of many different heat sources including heat recovery, lake heating/cooling, sewer heating/cooling, electric boilers, air-source heat pumps, geothermal, and management of thermal energy storage tank capacities.

Heat recovery chillers are a double-edged sword when it comes to their ability to operate in multiple modes (heating, cooling, heat recovery). This flexibility comes at a cost of operational and controls complexity. Automated control valves and different pumping and flow criteria are required as the heat recovery chiller moves from a heating mode to a cooling mode. These machines are more sensitive since they are typically running at near full load when they are told to operate.

There will likely be several years, if not a decade, where legacy heating and cooling equipment will be required to operate alongside these new systems. Even with the best commissioning process, this interim period is likely to present unknown issues that will be dealt with by operational staff as they arise.

The proposed primarily heat pump driven heating system will require a significant shift in UW staff which are currently trained to operate a very simple heating system. This will require more staff, additional training of the current staff, and a complete reimagining of how things have been done in the past.

Additionally, the campus’s chemical water treatment program will need to be re-evaluated with respect to the significant added system volume associated with large campus scale Thermal Energy Storage tanks (potentially adding 5-10 million gallons of water to the system).

4.3.1.8 Other Technologies Considered

A short list of alternative technologies that will be considered at a high-level to validate that the best options are being considered is noted below.

- High-lift / high-delta T CO2 heat pumps
  - Attractive from the standpoint of pipe sizing and low GWP refrigerants, but significant drawbacks in energy efficiency operating at high supply water temperatures and apparent limited output capacity at the higher temperatures.
- Hydrogen generation / hydrogen boilers
  - Hydrogen generated by electrolysis using clean energy and burned at 80% efficiency.
- Solar thermal

- Solar thermal arrays can act as a heat source for heat recovery chillers, harvesting the low-grade heat of the sun even on winter days.

- Micro-nuclear

4.3.2 MECHANICAL DISTRIBUTION CONCEPTS

The desired outcome of the campus energy renewal is to provide reliable and efficient heating and cooling from the campus energy systems to all campus buildings that are currently connected to the district energy system or where connection is determined advantageous due to proximity or significant energy and operational benefits.

4.3.2.1 Transition from Steam to Hot Water

To eliminate fossil fuels from the campus energy systems, the use of steam at each building must be evaluated for replacement. Steam typically serves as a source for both building heat and water heating, and in less common cases for process uses such as humidification and sterilization. Refer to section 4.3.4 for additional details on building system assessments.

Eliminating fossil fuels requires a phased removal of the steam system. A major challenge with this work is that the steam system is currently operational and serving campus buildings with varying levels of criticality, so demolition and replacement with heating water piping like-for-like is impractical in a lot of instances. Opportunities to incrementally remove steam from far ends of the steam system and replace in steps with hot water service will be investigated. Phasing of this work will be explored in depth in the Phase II report.

4.3.2.2 Expansion of Campus Cooling Water System

There is an opportunity to improve the building cooling systems at the same time as heating water systems are being retrofitted. As buildings are connected to campus heating, those that are not already provided with campus cooling can be connected to the system as well either through a comprehensive building renewal effort to add cooling to a building that previously did not have it or by replacing building stand-alone chilled water equipment.

By eliminating stand-alone chilled water equipment, a two-fold benefit is realized: increased energy efficiency through highly efficient and well-maintained campus cooling equipment and decreased maintenance costs of centralized campus equipment compared to distributed equipment. Additionally, the net installed capacity of central campus equipment is often 15-25% lower than the total stand-alone equipment required due to the diversity of use across a large array of buildings.

4.3.2.3 Tunnels vs. Buried Piping

As discussed in section 3.4.5, the University has a long history of investing in walkable underground utility tunnels for distribution of its utility infrastructure. The tunnels are readily accessible and allow campus staff to perform preventative and emergency maintenance in a way that would not be feasible with buried utilities.

A decision has not been made as to whether new utilities will be routed through existing tunnels, new tunnels, or buried. Phase II activities will explore the cost and practicality of re-using existing tunnels and the installation of new where tunnels do not exist as compared to direct-buried utilities.

During the Phase I effort, the concept of a direct-bury hot water loop was advanced from the previous Hot Water Transition Study (2017 by Affiliated Engineers Inc.) based on updated site plan layouts to reflect new buildings and site features. The updated concept was then assessed by KPFF and additional routing options added for consideration during Phase II work. Refer to Appendix 5.3 for the KPFF Civil Engineering Technical Report and associated exhibits.

4.3.2.4 Materials for Buried Piping

After installation, buried piping systems are inherently difficult to access, or if not properly installed, can even be difficult to locate. The choice of pipe material, fitting type, insulation system, and leak detection system all play major factors in the system life and long-term maintenance of a direct-buried pipe system.

The University of Washington has very limited sections of direct-buried piping. University staff have experience from other campuses with a brand of thin-wall steel piping certified to standard EN 253 (name brand LOGSTOR) which is a system of piping that comes pre-insulated and a leak detection system that can assist in preventing erosion of insulation and ultimately the corrosion of the buried steel pipe. This type of piping also has benefits in its ability to flex and follow the contours of a road without the use of pipe fittings at every turning of the pipe. Accommodation for thermal expansion is not typically required in this system as it is inherently flexible and due to its thin pipe wall, it does not produce as much internal stress when restrained by the dirt.

Other pipe materials to be evaluated include non-metallic piping systems, typically HDPE for chilled water systems and polypropylene (PP-RCT) or PEXa for hot water systems. The inherent corrosion resistance of these systems makes leak detection less critical compared to steel piping. Corrosion of buried steel piping is typically viewed as an “if not when” scenario. Non-metallic piping offers similar benefits of not requiring thermal expansion accommodation; however, fittings are required and, in some cases, must be field fabricated.

4.3.2.5 System Temperature Differential

System temperature differential impacts the overall flow requirement and has cascading impacts on the size of the pipe distribution systems. Campus energy systems typically aim to maximize achievable temperature differentials to reduce system operational flow and increase the capacity able to be delivered in a given pipe size. Refer to section 4.3.4.3 for discussion on maximizing differential temperature new hydronic systems.

4.3.3 ELECTRICAL SERVICE UPGRADE CONCEPTS

The existing electrical infrastructure from Seattle City Light (SCL) serving the West Receiving Station (WRS) does not meet the current and future demands or reliability standards of The University. The electrical service from SCL has known issues addressing the campus demand in peak events and meeting the campus reliability standards during normal operating conditions. The existing issues include a lack of reliability, insufficient redundancy, and frequent voltage sags.

The Energy Renewal Program (ERP) will remove carbon creating sources of energy from the campus and transfer the heating loads to the electrical system. Electrifying the heating load of the campus creates a new additional load that the electrical system must support. These new electrical loads exceed the recommended level of spare capacity which limits the connection of future loads or future expansion and removes redundancy, a crucial element for reliable power to a Tier 1 research institution and leading medical center. The unreliable and insufficient electrical infrastructure presents a significant obstacle to the campus's ability to achieve its decarbonization goals and maintain operational stability. To support the ERP, the campus needs a new transmission-level service from SCL.

To address the identified problems and create a reliable electrical system that supports the campus goals, the following solution is recommended. To enable the ERP, the University should study, design, coordinate, and construct a new transmission line from SCL to a new substation adjacent to the existing WRS. The project should include the following elements.

- Extension of 115 kV transmission line from Interstate 5 (I-5) and toward the University. This line originates south of the existing University Substation along I-5 and would terminate at a new University-owned substation in the vicinity of the existing WRS.
- New underground transmission lines and looped transmission lines.
- 3,000 feet of underground transmission line construction. The expectation is that this work would be performed by Seattle City Light.
- Construct a new substation as close to the West Receiving Station as possible. The N+1 capacity shall be a minimum of 90 MW. The substation property and secondary lines shall be University-owned. Primary lines entering the substation, the transformers, and gear shall be SCL-owned and maintained. Primary metering for SCL utility billing shall be at this location.
- New University-owned copper feeders from the new substation to the existing WRS.
- Depending on the distance from the new substation to the WRS, the feeders may be required to be superconductors in lieu of copper.

Ongoing coordination with SCL is occurring at regular intervals. The intent of the coordination meetings is to impress upon SCL the importance of reliability to protect our Tier 1 research institutions and medical center. The intent is to create a lasting partnership between the University and SCL to increase reliability for the University.

At the East Receiving Station (ERS), replacement of the existing 7.5 MW transformer should be increased in size. It's recommended to replace the transformer with a 22 MW transformer to align with existing SCL transformers at the WRS.

4.3.4 BUILDING SYSTEM ASSESSMENTS

Most buildings on campus are heated with campus steam and also use campus steam for domestic hot water generation (and in some cases laboratory or kitchen hot water generation). In addition, some buildings, particularly laboratory buildings, use steam either directly or indirectly for process uses such as humidification, sterilization and washing.

4.3.4.1 Building Hot Water Heating

Upon establishment of a campus hot water system, the University will be faced with a variety of connection options. The hot water system may be connected to campus buildings:

1) Directly (with no heat exchanger), or

2) Indirectly via a heat exchanger

The direct connection option, depicted in Figure 4.3.4.1-1, maximizes the temperature available to the building heating coils, and eliminates pressure drop (and energy use) associated with the use of a heat exchanger. Direct use of hot water can also simplify the system overall by reducing the number of pumps (and specialties such as air separators and expansion tanks) necessary across the system. However, since the most common existing building heating system configuration includes steam-to-hot water convertors and building heating hot water pumps and associated specialties, the direct use of hot water would require removal of expansion tanks, and possible removal of hot water pumps (or retention of the pumps which would then operate in series with plant pumps as either secondary or tertiary pumps).

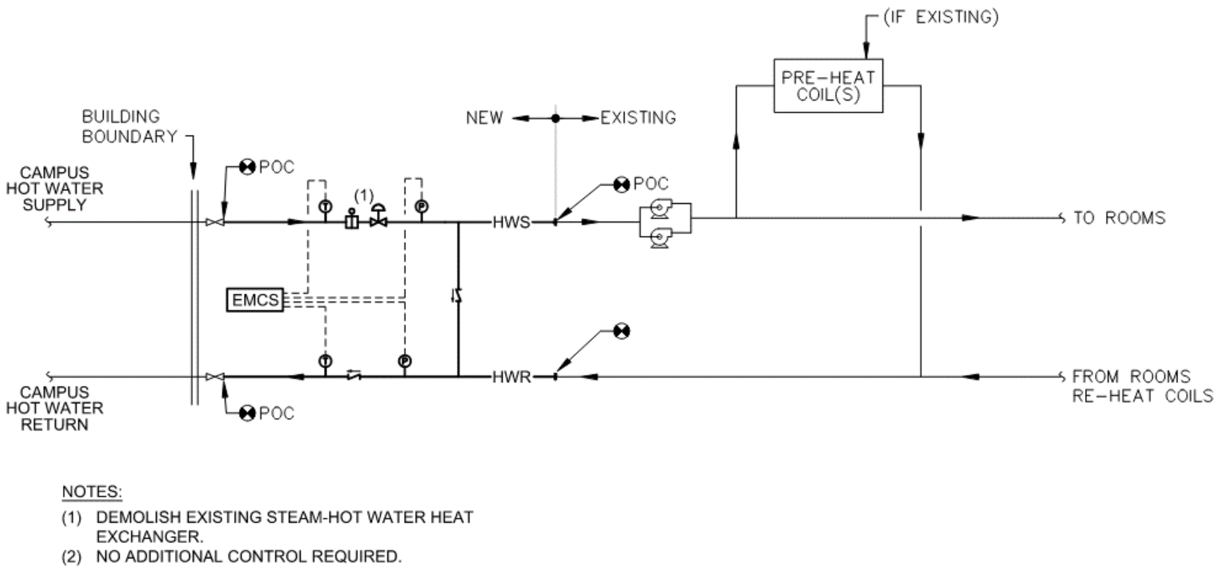


Figure 4.3.4.1-1: *Example direct building hot water connection to campus hot water.*

In initial discussions with UW, the use of the heat exchanger to isolate the campus hot water from building hot water systems, depicted in Figure 4.3.4.1-2, is generally preferred, but a sub-option was proposed for buildings with steam preheat coils at air handling units, in which campus hot water is piped directly to new hot water preheat coils, but a heat exchanger isolates the existing reheat hot water system from campus hot water.

Connection via a heat exchanger isolates the campus hot water system from building hot water systems, most of which have been in place for decades and may have been subject to lack of maintenance and as a result may suffer from poor water quality and pipe quality issues. Regardless of the approach chosen, we recommend a rigorous building water treatment program to be implemented. Plate-and-frame type heat exchangers are most commonly used due to their ability to achieve very close approach temperatures (for building hot water relative to entering campus hot water)

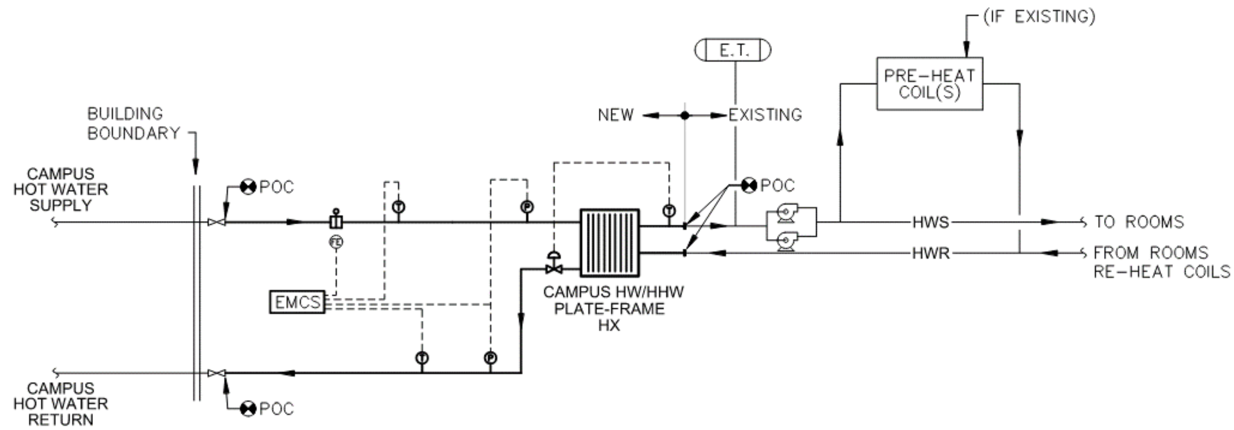


Figure 4.3.4.1-2: *Example building hot water connection to campus hot water via heat exchanger.*

For buildings with both heating hot water and domestic hot water loads, the University will have the option of a single point of interface with the campus hot water system, depicted in Figure 4.3.4.1-3, which may offer simplicity in monitoring and management of system integrity (from the plant side), in which the domestic (and lab or kitchen as applicable) hot water heaters will be located downstream of a primary campus hot water heater (and are fed by building hot water); or, multiple points of interface with each service directly connected to the campus hot water system. The advantage of the latter approach is slightly higher temperature availability at the service hot water systems and reduced building hot water system pressure drop. Based on initial discussions with UW, the latter approach, depicted in Figure 4.3.4.1-4 is preferred.

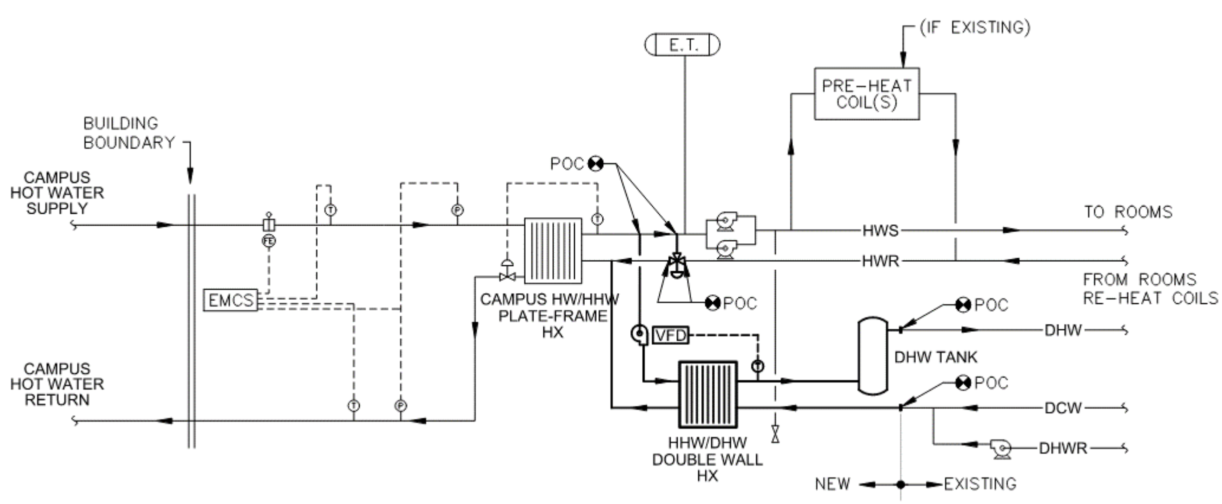


Figure 4.3.4.1-3: *Example single building connection to campus hot water serving multiple downstream services.*

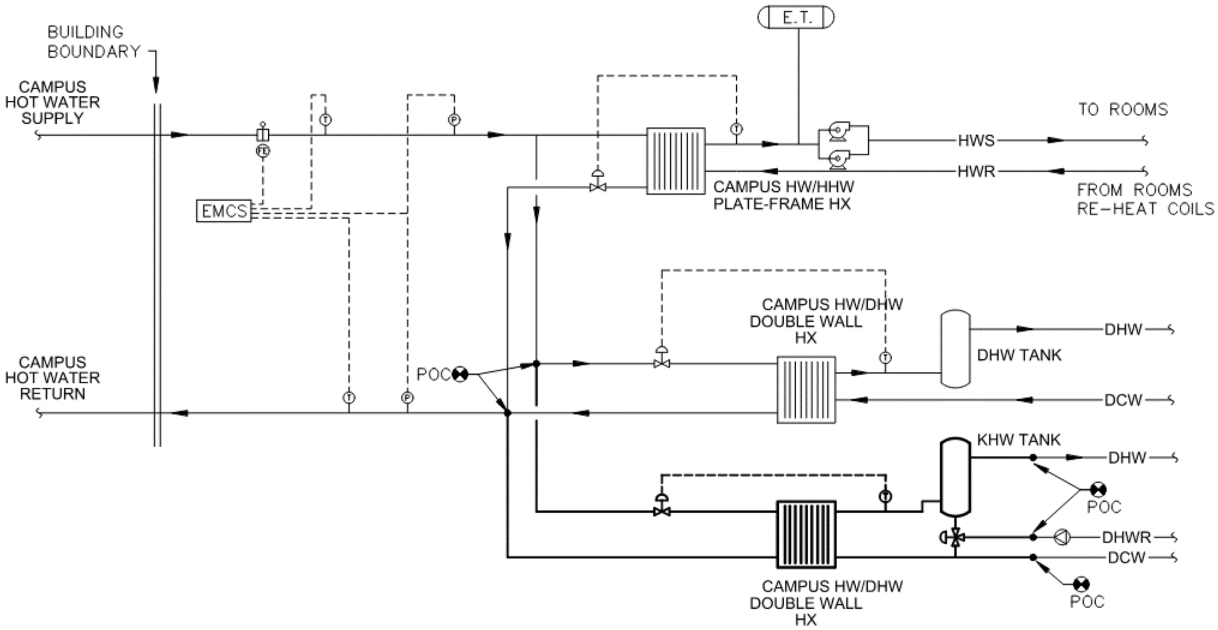


Figure 4.3.4.1-4: *Example of multiple building connections to campus hot water each dedicated to specific service.*

4.3.4.2 Building Domestic Hot Water System Options

Domestic (or laboratory or kitchen) hot water systems may be storage type (Figure 4.3.4.1-4) or semi-instantaneous type (Figure 4.3.4.2-1). The semi-instantaneous approach requires a larger heat exchanger and eliminates the need for a storage tank (and some legionella concerns). The storage tank option reduces heat exchanger size and can reduce exchanger pressure drop. The number of applications of the semi-instantaneous approach should be limited across the campus to minimize impact on peak campus loads, and applied only where space for a storage tank is limited.

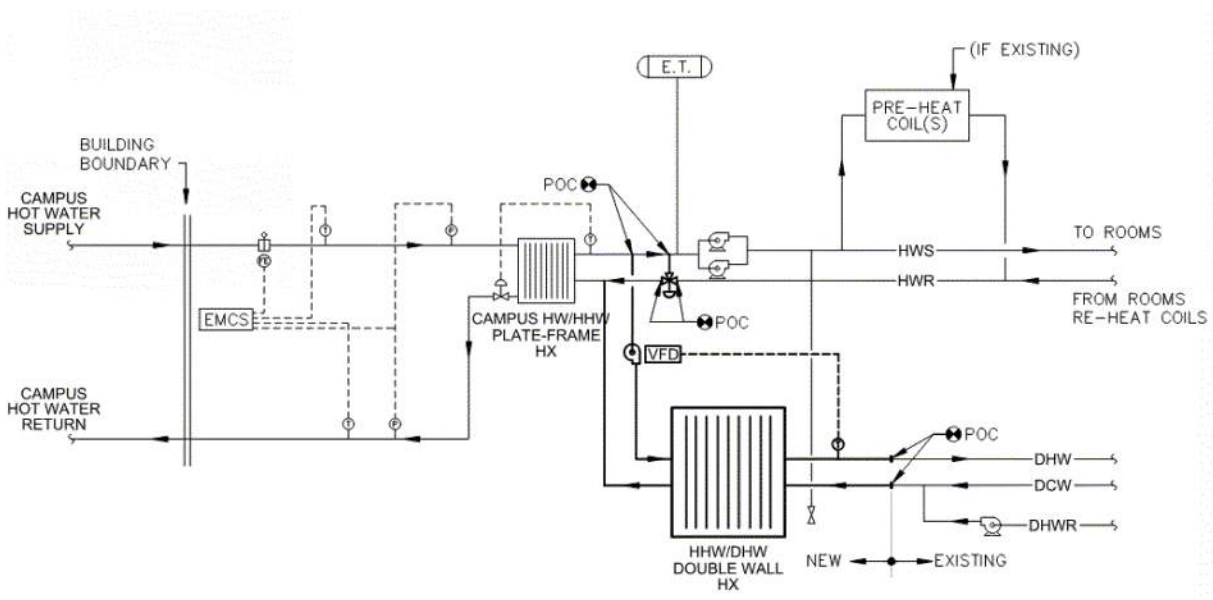


Figure 4.3.4.2-1: *Example of semi-instantaneous DHW heat exchanger (compare to Figure 4.3.4.1-4 above for storage option).*

4.3.4.3 Maximize delta-T on Campus Hot Water and Building Hot Water Systems

In any large campus hydronic water loop, the temperature difference between supply and return water, commonly referred to as “delta-T”, becomes a design focus as a means to minimize pipe size and cost, to minimize the associated pumping energy, and to keep a reasonable delta-T across primary equipment. In addition, heat recovery chillers are sensitive to return hot water temperature and the most likely equipment to be used in the conversion operates optimally with return water temperature of 135°F or lower.

A primary cause for poor delta-T is recirculating supply water into the return system without it being used for heating. A common source of this occurring in older buildings is the use of 3-way control valves at the heating load. These valves recirculate supply water back to the return at all conditions below the design operating point. It is important that any existing hot water systems using 3-way valves be converted to variable flow 2-way operation prior to connection to the new campus hot water system.

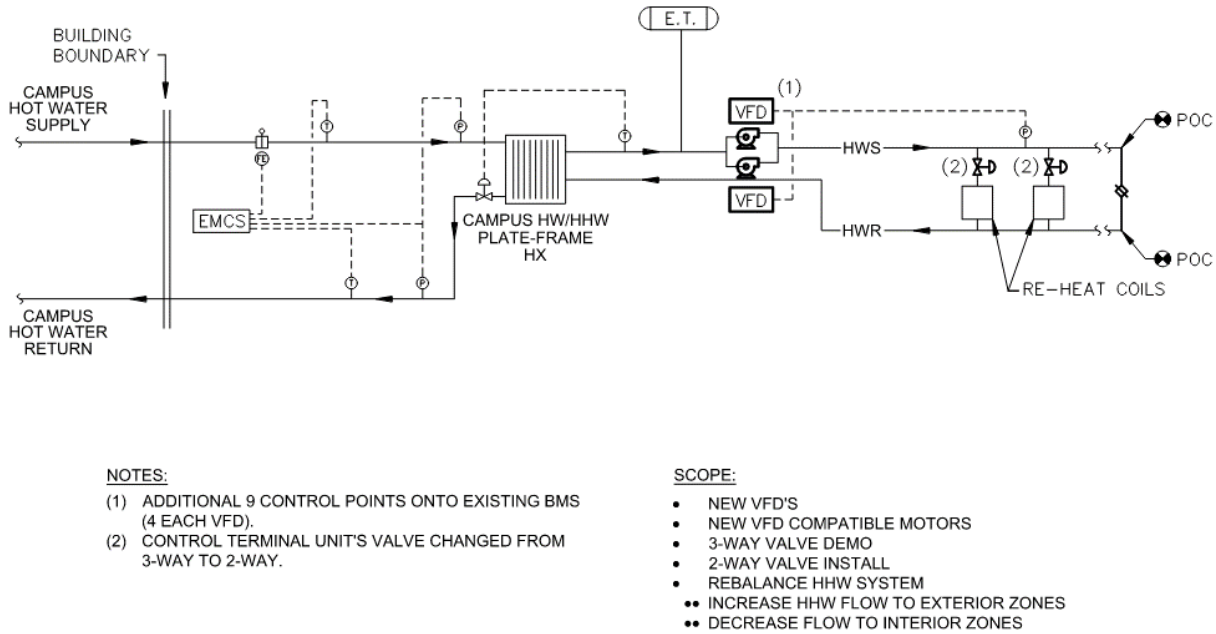


Figure 4.3.4.3-1: *Conversion of a 3-way based building hot water system to 2-way operation.*

Additionally, delta-T may be increased by cascading systems. This can be done by cascading hot water first to reheat uses, then to AHU preheating coil use (an approach that can be used either seasonally or year-round dependent on the ability of the coils to support the altered entering temperatures).

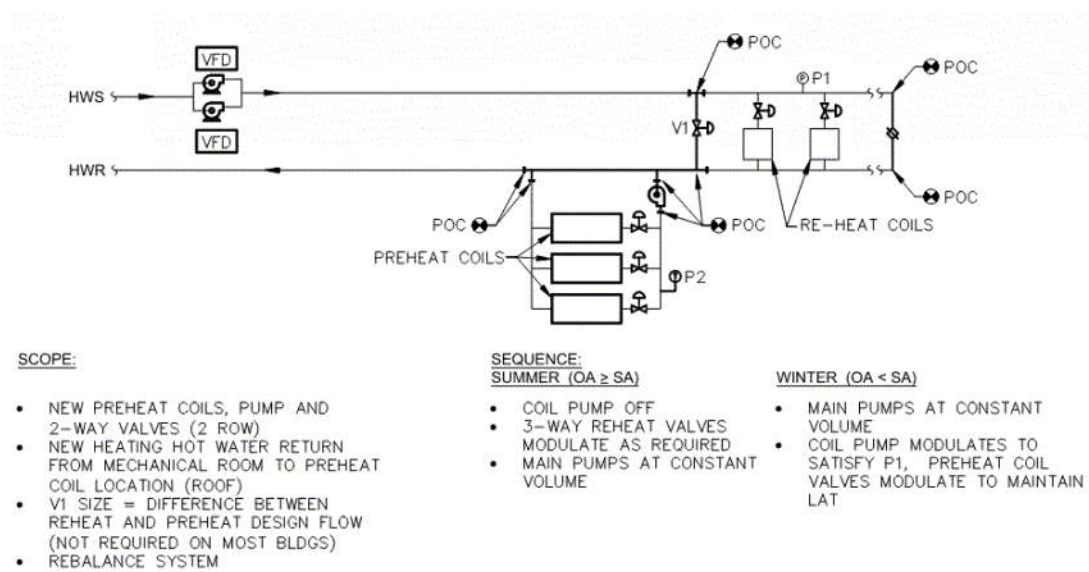


Figure 4.3.4.3-2: *Cascade of building hot water supply from reheat to preheat use.*

Hot water may also be cascaded from building heating use to domestic hot water heating. This becomes a less viable option as the heating hot water design temperature is reduced. Since we have already determined that the campus hot water supply temperature is likely to be 160F (or lower), this makes a full cascade from building heating to DHW unlikely, since DHW will require initial heating to 140F minimum for appropriate biological growth protection.

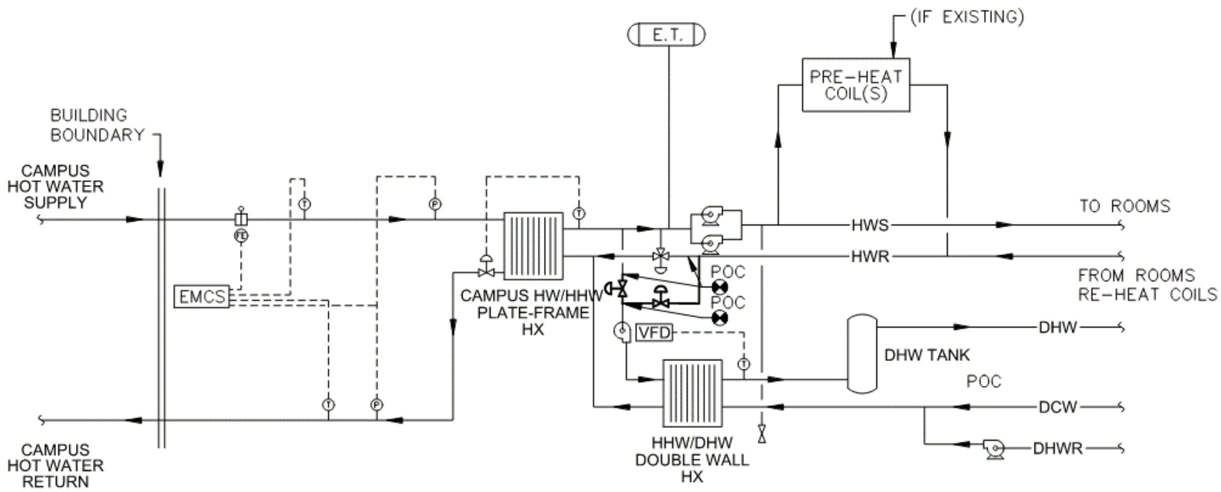


Figure 4.3.4.3-3: *Cascade of building hot water supply from building heating to DHW use.*

4.3.4.4 Steam Radiator Conversion

There are several buildings on campus where perimeter steam radiators are still in use. It is not advised to attempt re-use of these devices, since the piping in those system has never seen pressure over 15 psig, and to subject them to pressures of a closed loop hydronic system would constitute a risk of leaks and pipe failures, and the heat output of those devices diminishes rapidly with reduced supply temperature. As a result, we recommend that radiators be removed and replaced with new hydronic heating coils with 2-way valves and no steam piping should be re-used. This is typically a significant effort since it involves running new supply and return piping to the radiators. Buildings which currently utilize steam radiators will be identified and coordinated with the BRP effort. A steam radiator conversion diagram is presented in Figure 4.3.4.4-1.

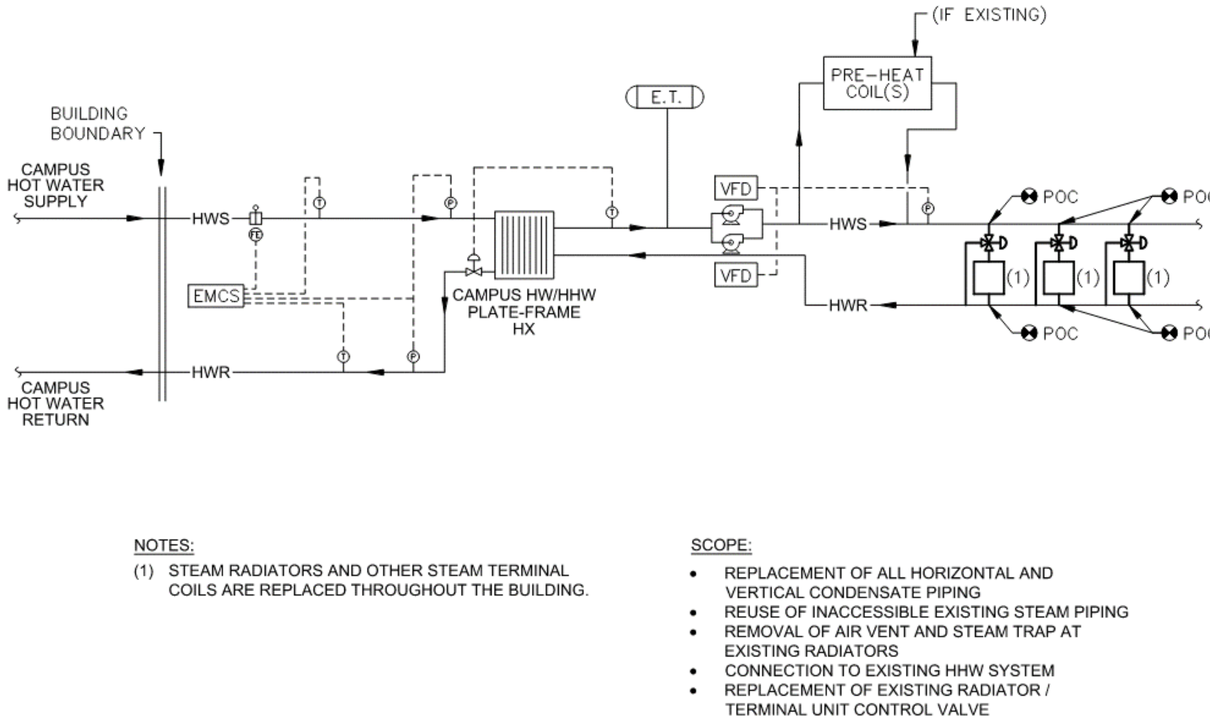


Figure 4.3.4.4-1: *Steam radiator conversion.*

4.3.4.5 Temperature Boost for Problem Buildings

Currently, we have identified just a handful of buildings that may require hot water supply temperatures greater than 160F. To prevent these buildings from driving the system, the two options would be to replace coils so that 160F or lower hot water can be used, or to locally boost the supply hot water temperature (see Figure 4.3.4.5-1), likely with a small electric boiler that would operate seasonally when the higher temperatures are required.

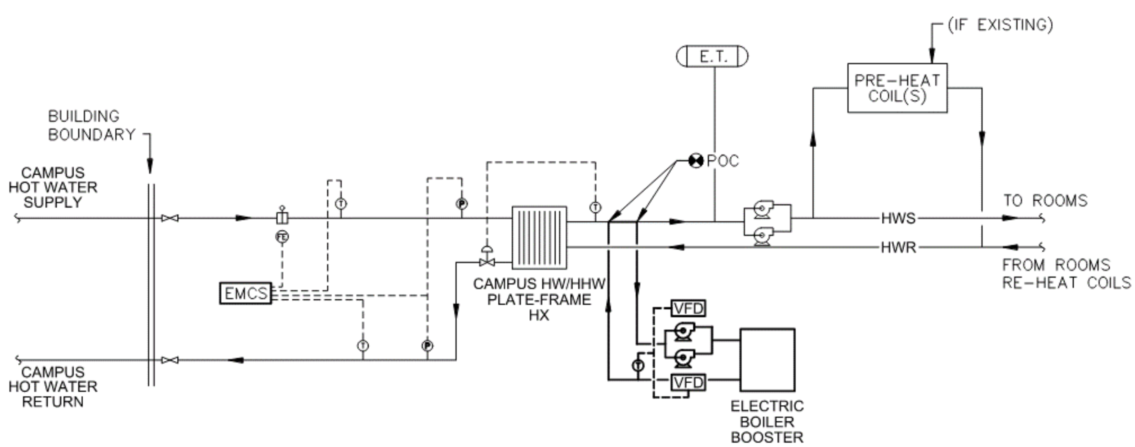


Figure 4.3.4.5-1: *Temperature boost at problem buildings.*

4.3.4.6 Steam Used for Process Loads (Humidification, Sterilization, Cooking)

Steam is used for a variety of process uses on campus, either directly or indirectly (dependent primarily on sensitivity of use to chemicals in campus steam). These process uses are most prominent in laboratory buildings and buildings with kitchen facilities but vary considerably in usage level from one building and area of campus to another. In many situations, a single autoclave, sterilizer, or glasswasher requires process steam. In those cases, we recommend that a local electric steam generator replace campus steam as the heating source for this process use. In areas where process steam use is more concentrated, e.g., at the ARCF, we recommend a replacement gas-fired steam system in order to avoid large incremental increases in local electrical infrastructure. This dedicated system would not be required until the steam line feeding ARCF is ready to be removed as part of the steam system phase-out that will occur towards the end of the decarbonization effort.

4.3.5 Building Energy Efficiency Measures (EEMs) Opportunities

Within the context of any campus decarbonization project, building energy efficiency measures (EEMs) present opportunity to reduce energy consumption and utility costs, reduce operational carbon emissions, and reduce peak loads on campus utility infrastructure which saves cost and further improves energy efficiency.

In the next Phase of plan development, campus building EEM opportunities will be studied with respect to campus heating and cooling load reduction, campus utility plant equipment sizing, and annual energy and carbon emissions. Potential building EEMs include (but are not limited to):

- Low grade heat recovery sources such as building exhaust, transit tunnel ventilation, garage ventilation (red square stacks).
- Evaluate buildings without airside heat recovery and constant volume reheat systems.
- Lab ventilation system optimization.
- Data center and process cooling loads. Prioritize distributed cooling consolidation projects.
- Solar water heating.

Additionally, two-way collaboration with the Building Renewal Project will continue relative to major remodels, retro-commissioning projects, and targeting large consumer buildings, along with EEM opportunity identification.

4.3.6 Phasing

Phasing will be a major focus of the implementation plan, set to occur in Phase II. A few of the key project-specific aspects that will go into the recommendations for phasing are discussed below.

- Building conversions prioritized based on:
  - Proximity to logical locations for early implementation of micro-districts (near WCUP).
  - Review of Building Renewal Plan prioritization for deferred maintenance reductions.
- Relationship between availability of space, opportunities for moving winter cooling loads to campus utility plants, timelines for alternate heat source procurement.
  - Empty chairs created by enabling projects (PP Boiler #3 demolition, WCUP expansion).
  - Identification of winter cooling / process loads.
- Availability of funding from the State through standard funding processes and CCA funds.
- Expected timelines and durations of federal funding opportunities
  - Need to prioritize projects with the highest likelihood and construction timelines that align with funding timelines.
- Prioritize projects that positively impacts reliability of services to the University's Tier 1 research facilities

Ultimately, the prioritization of the many projects that will be associated with this work will depend on the priorities set by UW. Common methods of prioritizing decarbonization efforts include optimizing project cost, minimizing campus disruption / maximizing uptime, and maximizing the carbon impact per dollar invested.

4.4 Regulatory Compliance

4.4.1 Lake Interface

The interface with Lake Washington and the Ship Canal is anticipated to be the largest regulatory hurdle facing the Energy Renewal Plan. There are many agencies with jurisdiction over the lake given it is a Water of the United States, a navigable water, a water of the state, habitat for federally listed species, a Shoreline of Statewide Significance, state-owned aquatic land, and in some areas a federal works project. In addition to the natural environment considerations, the lake and Ship Canal provide important functions for commerce, navigation, and recreation. The multi-agency approval process will be lengthy, and approval is not guaranteed.

There are currently no known large non-residential uses of Lake Washington as a source of heating, cooling, or consumptive uses. The University of Washington Medical Center has an existing surface water right for use of Lake Union / Portage Bay for heating and cooling, which is not directly useful for this endeavor, but shows a previous allowance for institutional use of a natural body of water.

The approach for agency approval is to demonstrate that the proposed system will, at a minimum, "do no harm." Some of the options for the outfall of the lake water may even present a potential benefit to environmental conditions and the University would be willing to consider operating the system in a way that enhances the environmental benefit if it was proven to exist. These claims may be difficult to prove so care must be taken to demonstrate that the complexities and relationships of ecological, hydrological, and chemical effects of the project are understood, and adverse effects are appropriately avoided, minimized, and finally mitigated.

Refer to Appendix 5.2 Lake Interface Preliminary Permitting / Environmental Considerations Report for additional details.

4.4.2 STATE REGULATIONS

4.4.2.1 Washington State Climate Commitment Act (CCA)

Recent State of Washington legislation (in effect as of Jan 1, 2023), referred to as the Climate Commitment Act (CCA), caps and reduces greenhouse gas (GHG) emissions from Washington's largest emitting sources, which includes the University of Washington's Seattle Campus.

As a covered entity, the University must purchase GHG emission allowances to cover at least 30% of their 2023 emissions by November 2024. With each subsequent year requiring the same allowance up to November 2027, at which point the remaining 70% of emissions must be covered, inclusive of all emissions 2023 and later. UW's present approach to compliance with CCA is to purchase 100% of its expected annual allowances in the respective year that the emissions occurred. Purchasing of emissions allowances is done in a quarterly auction format, with special provisions for public entities that provide a flat price not available to the private industry.

Known as the Cap-and-Invest program, the money collected by the State is circulated back to CCA covered entities through the legislature and is expected to in effect act as a source of funding for projects associated with the ERP for the University.

In the event that the University reduces its carbon emissions below the threshold of 25,000 equivalent metric tons of CO2 per year then they would no longer be a covered entity and would be exempt from these regulations. This is expected to happen during the path towards full decarbonization, though the estimate on when this will occur has not yet been determined.

4.4.2.2 Washington State Clean Buildings Performance Standard

Washington state passed the Clean Buildings Act (HB1257) in 2019 which creates the Clean Buildings Performance Standard and requires existing commercial and state-owned buildings to comply with energy usage targets based on building type. The State has released an overlay of ASHRAE 100 – 2018 to be the code for this standard. Compliance is staggered based on building floor area with larger buildings having to comply earlier. The thresholds and deadlines for compliance are given below:

- Greater than 220,000 sf – June 1st, 2026
- 90,000 to 220,000 sf – June 1st, 2027
- 50,000 to 90,000 sf – June 1st, 2028

Building owners must submit their buildings for compliance every five years for the foreseeable future. Buildings that are served by a campus district energy system will comply differently as discussed in the section below. While the original intent of the standard was for buildings to comply based on EUI targets based off detailed building types (office, educational, retail, etc.) the interpretation has been updated such that buildings on university campuses will comply with the University EUI target. As a Tier 1 research institution, the University of Washington will comply with a mix of University and Laboratory EUI targets.

4.4.2.3 Washington State House Bill 1390 – District Energy Systems

Another recent legislative provision, effective July 2023, concerns state-owned campus district energy systems. Final rulemaking with the Department of Commerce for enforcement of these provisions is still ongoing in Spring 2024.

The requirement states that state campus district energy systems must develop a decarbonization plan that provides a strategy to decarbonize the system by 2040. The goal for decarbonization should be based on a timeline of fifteen years, starting from 2025. Decarbonization in this context relates to replacement of fossil fuels and reducing operational carbon emissions for district energy systems. This plan must begin development no later than June 30, 2024, and be submitted to the Department of Commerce no later than June 30, 2025. Subsequently, every five years after the plan is submitted, the plan must be resubmitted along with a progress report on status of implementation.

A potential benefit of this legislation is that campus district energy systems can defer documenting compliance with the Clean Building Performance Standard for connected buildings that would otherwise be subject to the provisions of that law, provided that documentation is provided in the Decarbonization Plan as to when these buildings will be brought into compliance as part of the Decarbonization Plan implementation.

The final report of the Energy Renewal Plan will inform contents of the House Bill 1390 Decarbonization Plan; however, it is not anticipated to be directly used for that purpose.

4.4.3 City Regulations

4.4.3.1 Seattle Department of Construction and Inspections (SDCI) – Substantial Alterations

The City of Seattle requires existing building projects that meet the requirements of a Substantial Alteration to fully upgrade the building to the current building energy code. Capital funding for substantial alterations is rarely available to support the viability of the original existing building project which can become a roadblock to phased implementation of district energy infrastructure and building system improvements.

The Building Renewal Plan will include a wide variety of renovations from full building gut and remodels, to minor improvement projects, to everything in between. There will also be thermal conversion projects at almost all buildings as part of the Energy Renewal Plan implementation including district energy system connections and building HVAC system modification in many buildings.

The University, as part of the BRP and ERP efforts, is seeking to develop a memo of understanding with SDCI to support the permitting of necessary upgrade projects to address deferred maintenance, comply with Washington State legislature, and comply with City of Seattle codes and standards, wherein projects that are implemented as part of the ERP (and relevant BRP projects) do not get classified by SDCI as Substantial Alterations and can be implemented in a phased and logical manner. UW with assistance from the BRP and ERP teams and other consultants specializing in permitting within the City of Seattle will aim to reach an agreement prior to work commencing for these projects.

Permits for building, mechanical, electrical, and structural work may each be required on a building-by-building basis depending on the extent of the conversion work for each building. After preliminary reviews of the codes and non-project specific discussion with City of Seattle Energy Code Advisor, projects that are solely being done to execute the energy renewal/decarbonization plan are not expected to trigger Substantial Alterations provisions, which would incur significant cost and disruption. Additionally, exceptions exist for district energy systems under the provisions of the Energy Code that would normally require addition of new building level heating and cooling equipment. The memo of understanding will aim to address this.

By the end of the campus conversion project, there will be hundreds of permits required to be processed by SDCI for the work within the buildings and tunnels. Another outcome of the memo of understanding with SDCI is to streamline this permitting process and to find and discuss any surprise provisions before they appear on the critical path of project work.

SDCI will also require structural permits for any new underground walkable tunnel sections.

4.4.3.2 Seattle Department of Construction and Inspections (SDCI) – Seattle Building Emissions Performance Standard

Passed by the Seattle City Council and Mayor's office in 2023, the Seattle Building Emissions Performance Standards (BEPS) is meant to complement the state's energy performance standard (Washington State Clean Buildings Act) with a GHG emission standard to decarbonize existing buildings in Seattle. The goal is to reach net-zero emissions by 2045-2050 with 5-year reporting periods and emissions targets that decrease over time.

This would add another layer of operational carbon performance requirements, however this section of legislation states that this chapter shall not apply to covered buildings that are subject to and comply with the requirements under RCW 70A.65 Climate Commitment Act. Since the University of Washington's district energy system is governed by this act, connected buildings are exempt. Non-connected buildings that are not governed by the State CCA will be required to document compliance.

4.4.3.3 Seattle Department of Transportation

Installing direct buried district energy system piping on the UW campus will not require city permits unless walk-through tunnels are proposed, which will require a building (-CN) permit from the Seattle Department of Construction and Inspection (SDCI).
Permits will be required, however, for direct buried or tunnel systems in public right-of-way (ROW). These permits will be issued by the Seattle Department of Transportation and require two separate permits outlined below:

1. Long term annually renewable permit. This Term Permit needs to be approved by the City Council. Refer to SDOT AG 1088: Private Utility Infrastructure - Transportation (available on SDOT's website) for an outline of the permitting process.
2. Right-of-Way Utility permit also known as a Utility Major Permit (UMP). This permit is for the construction of direct buried utilities and is only approved after the long-term permit passes through council and is approved by SDOT. Refer to SDOT Utility Work in the Right of Way – Transportation (available on SDOT's website) for an outline of the permit requirements.

Refer to Appendix 5.3 Civil Engineering Technical Report for more discussion on permitting of utilities in the public right-of-way.

4.4.4 King County Sewer

Interfacing with the King County sewer main as a source of low-grade heat for the campus will require coordination and permitting approval from local agencies, including:

- King County's Wastewater Treatment Division (WTD)
- Seattle Department of Transportation (SDOT)

King County WTD is, at the time of this report, accepting applications for two additional projects across its system to allow the use of the sewer as a source for heating and cooling. The pilot project is a test run for wider use of this strategy across their system. King County WTD requires a 30% Design Review document set to begin the process for application into their sewer heat recovery pilot program and will be involved throughout the design and construction process to review and approve all work related to the connection to their pipeline and transference of sewer water to and from the pipe.

In order to make the connection to the sewer pipe, private utilities will need to be run in the SDOT right-of-way which requires multiple permits to be granted by SDOT with annual renewal. Refer to section 4.4.3 above for additional details on SDOT compliance.

4.5 Funding and Financing Opportunities

University of Washington has set a financial goal to fund the projects associated with the ERP campus energy transformation with 100% external resources.

The primary source of funding identified will be funding from the State legislature which is expected to have more funding than in previous years available through the Climate Commitment Act (see section 4.4.2 for more details). These projects will pursue financial reimbursement through other state, federal, and utility incentive programs at the completion of the project, which can act as a rolling funding source as projects continue to be implemented by the University.

Refer to Appendix 5.4 for a detailed report on Potential Funding, Financing, and Incentive Programs.

Procurement opportunities with potential public private partnerships (P3) for the facilities associated with the lake interface and sewer heat recovery may also provide a benefit to University funding strategies. The initial concept for this would have the private entity fund, construct, and operate the facilities which would include the heat exchange and source-pumping (sewage or lake water) equipment. The private entity would deliver energy in the form of condenser water to the University under a long-term contract.

4.6 Risk / Resiliency Assessment

4.6.1 Project Implementation Risks

Having planned and implemented a number of these projects for similar institutions, we have come to recognize a series of important risks to the project. These include:

- **Building conversion cost and impacts.** This often carries the highest cost risk due to the sheer quantity of buildings and systems involved in a campus hot water conversion.

- **Campus disruption due to site construction.** By definition, the new hot water systems will touch every building on the campus and the chilled water system will be extended to all buildings not currently served. This will necessitate significant new distribution on the campus and must be planned and phased carefully to minimize disruption.

At a minimum the risk analysis in Phase II will address issues associated with design, permitting, construction, technology (current and future), funding sources, relevant legislation, and operations.

4.6.2 OPERATIONAL RESILIENCY

Maintaining consistent operation is important for every campus energy system, but it becomes critically important at Tier 1 research institutes like the University of Washington. When developing options that are to make significant impact on reducing greenhouse gas emissions, these options are required to be developed as not to reduce the current levels of resilience and will seek to improve from the baseline condition. To meet this goal, a review of the current levels of these criteria were reviewed and defined, and specific elements will be studied in Phase II to provide options to maintain or improve current levels.

"Resiliency" is a broad term that can encompass several elements. For this study, AEI has broken down this term into three different elements to allow for more detailed review and discussion. The following definitions are typical for institutions of this scale:

- **Resiliency:** The ability to maintain service (examples: steam, chilled water, hot water, electrical power) to the campus following a major loss of a utility (examples: natural gas outage or electrical outage).
- **Redundancy:** The ability for a failure of a single system component that does not result in the loss of the ability to serve the peak system demand.
- **Reliability:** Robustness of individual equipment in a system to operate when it is required to meet a system demand.

4.6.3 BASELINE RESILIENCY – FUEL SOURCE

University of Washington currently utilizes three main fuel sources to generate their campus utilities. These three fuel sources are natural gas, electricity, and #2 fuel oil. Fuel oil is only used in a natural gas curtailment condition or during a power outage. As defined in the definitions section, resliency is the ability to maintain service to the campus following a major loss of a utility, like a natural gas or electrical outage. In the future electrified condition, the University may also purchase condenser water from private entities operating the lake or sewer energy exhange systems. Outages to any of these utilities will be analyzed in further detail in Phase II to determine the baseline resiliency in the final electrified state of the campus energy systems. It is typical in reviewing resiliency of a well-maintained system like the University of Washington to consider only a single failure at a time (that is, not expecting simultaneous utility failures).

Relative to the Electrical Utility systems, UW, SCL, and AEI are coordinating on infrastructure upgrades that would bring the level of redundancy on the utility feed side to an acceptable level such that failure or a maintenance event of utility circuits does not cause a disruption to the campus. These concepts to upgrade electrical infrastructure will be reviewd in detail in Phase II. Prevention and mitigation of voltage sags from the electrical system leading to shutdowns of cooling equipment must also be studied.

Historically, UW has operated its chilled water system as a “comfort cooling” system, meaning that the system is not to be relied upon for 24/7 or other critical operational cooling needs. During a worst-case scenario of electrical utility failure, the current standby power systems can provide power to chillers in the WCUP equating to a cooling capacity of 3,000 Tons (two chillers maximum per Ryan Trickett). This provides adequate resiliency for the current operating conditions of the CCW system for those loads served by the WCUP. Critical cooling loads in buildings not within the WCUP service area have been maintained by stand-alone chillers located in the buildings they serve. The resiliency for the final electrified system is expected to improve upon this such that service of CCW to critical cooling loads across the campus is maintained.

The steam system is resilient to utility outages through, having a 1.3-million-gallon fuel oil storage tank serve as a backup fuel source for the steam boilers and a diesel rotary uninterruptible power system (DRUPS). The emergency diesel generators provide standby power to the Medical Center and campus buildings. This level of resiliency is required for a plant serving Tier 1 research facilities and a regional hospital. Resiliency for full system heating is often one of the most challenging aspects of an all-electric heating plant. Phase II will study options to provide resiliency for the heating system in the event of an electrical outage through the use of combustion generators and thermal energy storage tanks.

In the event that the University engages with a private entity to provide condenser water, the University will need to negotiate the same level of resiliency of those upstream systems that is expected from the equipment under the control of the University.

4.6.4 Baseline Redundancy

University of Washington currently operates its CCW system as two separate plants.

The WCUP has 4,500-tons of chilled water cooling equipment for a design-day peak load of 3,600-tons. Recent summer conditions have exceeded design-day conditions and resulted in loads of 4,000 tons. This plant is intended to be redundant to an equipment failure and installation of a fourth 1,500-ton chiller and associated cooling tower will restore that.

The Power Plant has 12,000-tons of chilled water-cooling equipment for an estimated load of 14,500 tons (AEI weather regression, see section 3.1.1). This plant has historically operated as a comfort cooling system and whether intended or not, the load is such that the plant cannot deliver the required capacity under peak load conditions, even without an equipment failure. The firm capacity of the Power Plant, when accounting for deficiencies in the existing system discussed in section 3.4.3, is effectively 7,000 tons (Chillers 5 & 6 cannot run together, assume failure of Chiller 3, 4, or 7, plus absorption chiller off during peak summer operation). Refer to section 3.4.3 for additional details on other contributing issues to the Power Plant's inability to meet peak loads.

UW's firm capacity (N+1) across both plants is 10,000 Tons assuming a chiller failure in each of the Campus Utility Plants and all other chillers operating. UW's current peak campus chilled water demand is 18,100 Tons (total of two peak loads noted previously). The current peak chilled water demand is greater than the current Firm N+1 Capacity. It is recommended that options studied in Phase II satisfy peak demands with a Firm Capacity of N+1, which may involve more replacement / addition of chillers than would be obvious based on the current installed capacity.

UW currently has five boilers installed for a total steam generation capacity of 880,000 lbs/hr. UW's steam generation firm capacity (N+1) would be 630,000 lbs/hr (failure of B-6). UW's current highest peak steam demand is 350,000 lbs/hr (December 2021 peak data, per Mark Kirschenbaum). The current peak steam demand will be satisfied with the Firm Capacity (N+1). It is recommended that the options studied in Phase II satisfy peak demands with a Firm Capacity of N+1. Continued use of the existing boilers will be studied for resiliency and peak load.

4.6.5 BASELINE RELIABILITY

In general, existing systems are robust and reliable systems if maintained appropriately. Technology options being proposed are similarly robust and reliable. The level of robustness of low-grade heat sources (building exhaust heat recovery, ambient air source heat pumps, solar (flat plate) heat recovery, wastewater / sewer) may vary depending on capacity and scale. It is expected that lake water options can easily match the robustness and reliability of existing systems. With this, it is not expected that the reliability of the systems being proposed will vary greatly from the systems that are currently installed.

4.6.6 University of Washington's Resiliency Requirements

Table 4.6.6-1: Resiliency, Redundancy, and Reliability Requirements

	Redundancy / Reliability / Resiliency Criteria	AEI Initial Baseline Assumption
	General	Assume maintaining Redundancy / Reliability / Resiliency for heating systems and improving conditions for CCW systems.
Resiliency	Concurrent Failure Scenarios	Assume Single Failure at a Time
Resiliency	Extended Natural Gas Outage	Backup Fuel Storage to be maintained until steam boiler system no part of resiliency backbone
Resiliency	Extended Electrical Power Outage – Entire Campus and CUPs	Campus is without power -> Full heating / minimal cooling demands as required to maintain critical loads (UWMC, Tier 1 research, student housing heat).
Resiliency	Extended Electrical Power Outage – CUPs Only	Heating: Full Heating Capacity Cooling: 3,000 tons (WCUP only) Campus has power -> Must satisfy critical demands
Resiliency	Electrical Power "Blip"	CUPs Momentarily Drops Offline and Requires Manual Restart
Redundancy	Baseline Campus Plant Equipment Redundancy to Satisfy Peak Demand	Heating: N+1 at peak demands Cooling: Unable to meet peak demands
Reliability	Baseline Campus Plant Equipment Reliability	Technology currently being proposed is similarly robust and reliable, though Low-Grade Heat Sources may vary and be individually evaluated.

4.6.7 Electrical Backup Options

Alternative systems will be explored in Phase II to provide backup electrical power for use with chilled water systems and electrified heating systems (heat recovery chillers, heat pump systems, electric boilers, etc.).

All options considered will be evaluated against common criteria developed with UW to determine the best backup power systems to include in any of the pathways developed that involve increased electrification. The options that typically provide the greatest benefit are backup reciprocating engines (diesel or natural gas-fired backup generators) and redundant electrical feeds from the utility, fed from separate substations. Both of these options are expected to be integral to maintaining or improving the resiliency of the CUP systems at UW.

In summary, as systems electrify, backup systems are required to maintain the same level of resiliency and reliability to produce thermal utilities for campus. Simple, inexpensive, and responsive options are preferred. The backup reciprocating engines meet these requirements and will be included as required for the options and pathways developed in the study.

In addition, maintaining a level of steam production with combustion boilers utilizing both natural gas and backup diesel fuel for limited usage can allow for a gradual transition from a totally fossil fuel-based heating system to one that utilizes sustainably generated electricity while maintaining the level of resilient backup power that having a dual fuel system provides (as opposed to relying solely on electrical system resiliency and backup). Long-term resiliency will come in the form of thermal energy storage on both the CCW and campus hot water systems as well as backup generators.

4.7 Life Cycle Cost Analysis Parameters

Life cycle cost analysis (LCCA) will be utilized to compare the financial performance of proposed alternatives during the detailed analysis phase of the Energy Renewal Plan development. LCCA input parameters and sensitivity analysis for key assumptions will be vetted with the University during Phase II. The comparative LCCA will also consider deferred maintenance, fines for regulatory non-compliance (such as WA Clean Buildings Performance Standard), and other investments needed to maintain a business-as-usual case so the incremental cost of proposed solutions can be assessed.

The following example LCCA parameters will be discussed and validated:

- Duration / lifecycle of the analysis.
- Utility cost escalation rates for electricity, natural gas, water, sewer, and sewer energy.
- Cost of carbon (CCA auction pricing).
- Operations and maintenance cost framework and inflation rate.
- Material and labor cost inflation rates.
- Design contingency and owner soft costs.
- Discount rate and internal rates of return.
- Integration of potential funding sources from local, state, and federal programs.
- Increase or decrease in maintenance staff required FTE.

5.0 Appendices

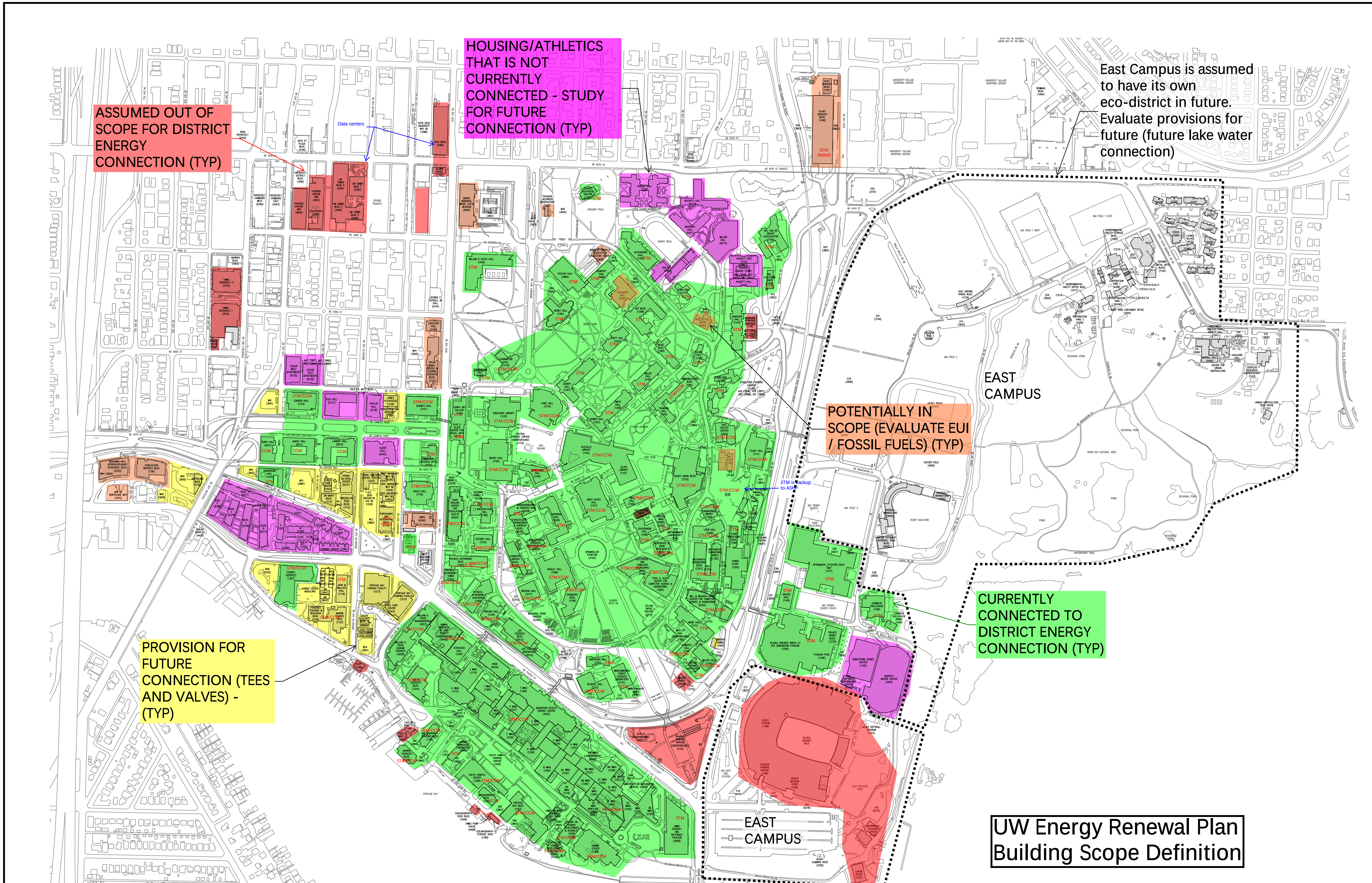
5.1 Diagrams

5.1.1 Building Scope Definition

5.1.2 Simplified CCW Schematic Diagram

5.1.3 Overall System Schematic Diagram

5.1.1: Building Scope Definition



Project No.

ENERGY RENEWAL PLAN
BUILDING SCOPE DEFINITION

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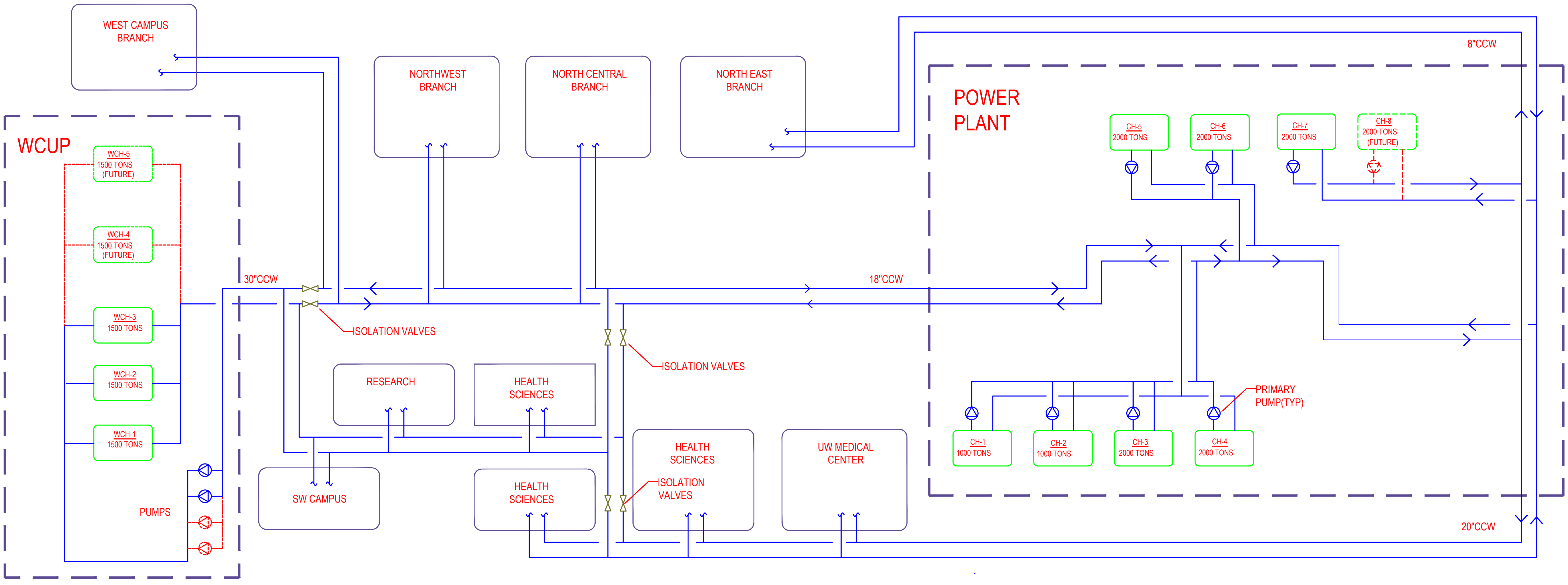
5.1.2: Simplified CCW Schematic Diagram



SIMPLIFIED CCW DIAGRAM

Project No.

SIMPLIFIED CCW DIAGRAM

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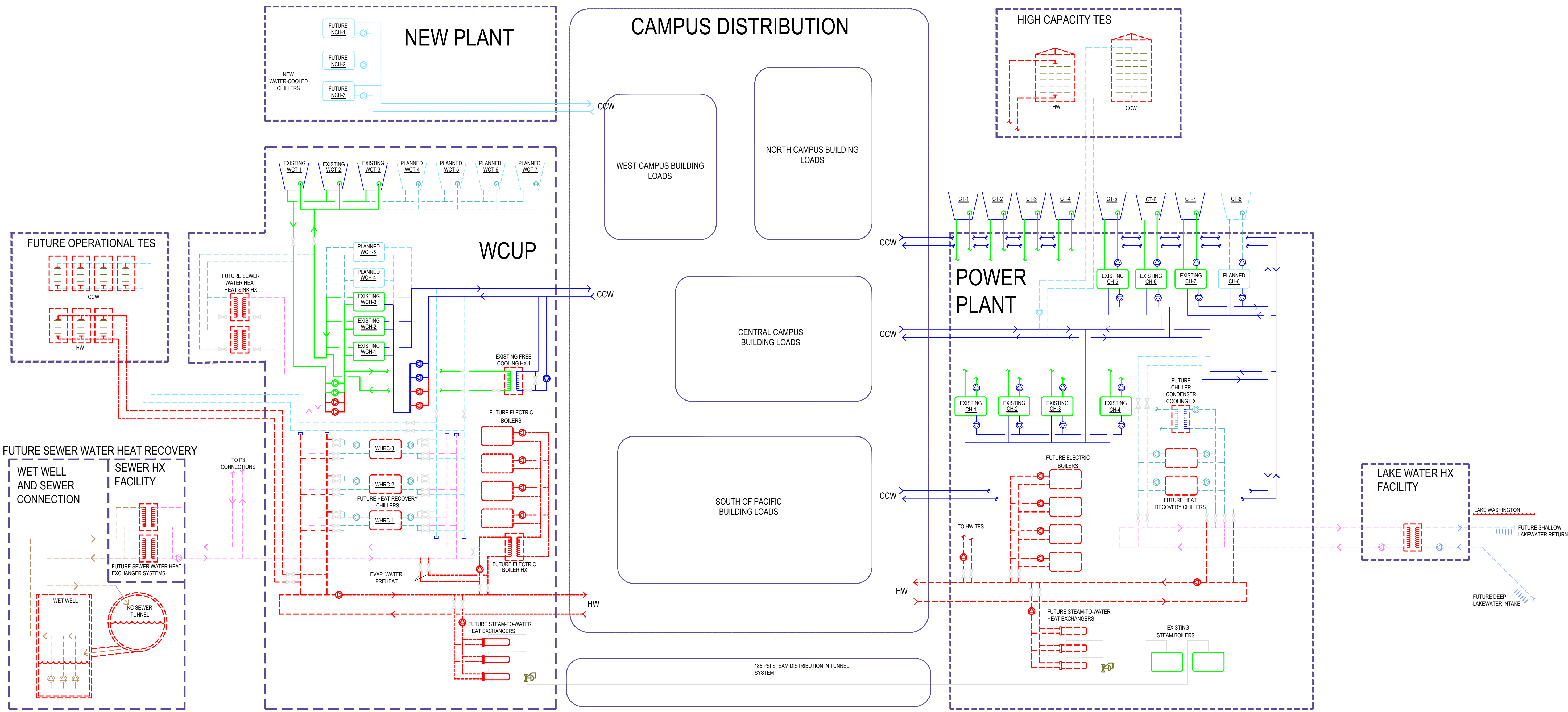
5.1.3: Overall System Schematic Diagram



OVERALL SYSTEM SCHEMATIC DIAGRAM

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5.2 Lake Interface Preliminary Permitting / Environmental Considerations Report

This report is superseded and removed to reduce file size - please see final report in Phase 3

5.3 Civil Engineering Technical Report

Section redacted for security reasons.

5.4 Potential Funding, Financing, and Incentive Programs

UNIVERSITY of WASHINGTON

Potential Funding, Financing, and Incentive Programs

February 16, 2024

Contents

1

Decarbonization Incentive Overview

Funding, Financing, and Incentive Analysis Workplan

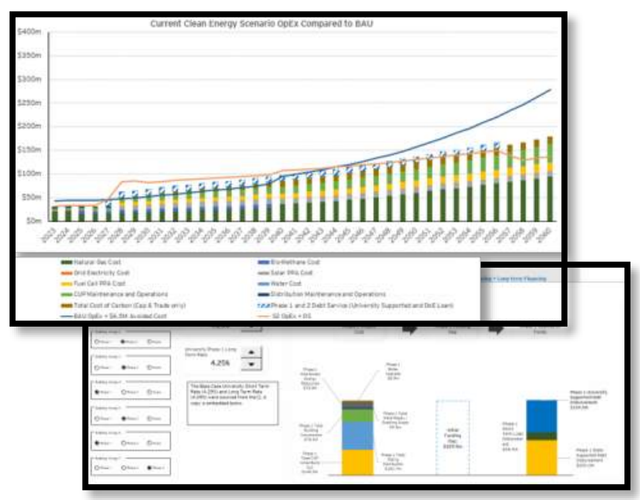
Phase 1: Assessment of Funding Opportunities

The Phase 1 funding/financing analysis is summarized within this report and is founded on the following set of actions:

- Discussions with University stakeholders and technical advisors to understand project scope, objectives, priorities, and constraints;
- Providing University stakeholders preliminary presentations outlining the anticipated analysis;
- Meeting with the University's financial working groups to understand key financial drivers and identified key metrics for future assessment;
- Informed by such discussions, developing the analysis in this report to identify Federal, State, and Local/Utility funding, financing, and/or incentives programs potentially relevant to the University's ERP and BRP initiatives; and
- Analyzing preliminary ERP and BRP technical approaches to "short-list" most relevant opportunities for the University to consider for pursuit based on eligibility, competitiveness, and evaluate the potential economic/financial benefit in future phases.

Future Phases of Funding / Financing Analysis

As the University and its technical advisors further define the ERP and BRP technical scope, capital cost estimates, and operating cost estimates, subsequent phases of the funding / financing workstream are expected to include:



- Development of a financial baseline for continued operation of existing systems ("business as usual");
- Development of long-term funding / financing cashflow models for the energy renewal program;
- Scenario analysis on potential / funding and financing sources and identify strategies that meet University objectives / constraints; and
- Analyze applicability of potential alternative delivery models (e.g., public-private partnerships) for certain project elements.

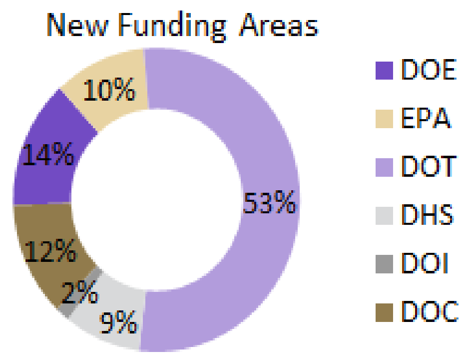
Overview of IIJA and IRA Programs

Infrastructure Investment and Jobs Act (IIJA)

The IIJA, also known as the Bipartisan Infrastructure Bill (BIL) will direct approximately $1.2t (~$550b new) over 5 federal fiscal years (FY 2022 – FY 2026) towards transportation, transit, energy security, electric vehicles, broadband, water, and cybersecurity primarily through federal grants. The IIJA is funded through multiple federal level fuel taxes, and other federal revenue sources.

~$73b of new funding, including:

- $550m - Energy Efficiency and Conservation Block grants
- $300m - Carbon Utilization Program
- $160m - DOE Loan Programs



Inflation Reduction Act (IRA)

The IRA will direct more than $400 billion over 10 federal fiscal years (FY 2023 – FY 2032) towards clean energy, electric vehicles, pollution reduction and energy security. The IRA is funded primarily by a 15% Corporate Alternative Minimum Tax and enhanced IRS Enforcement.

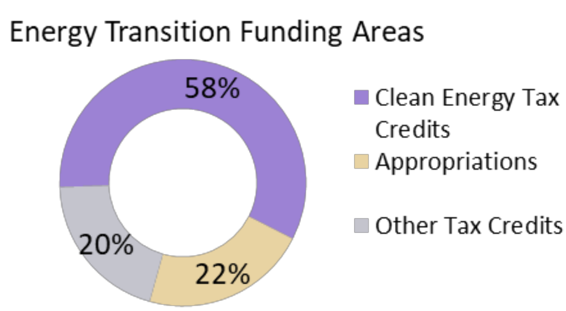
~$260b for Clean Energy Tax Credits

- Extension/expansion of current ITC/PTC
- New Technology Neutral Credits, Hydrogen and Nuclear Production Credits

~$98b in Appropriations (grants, loans and other programs)

~$90b for Other Tax Credits

- $10b - Clean Energy Manufacturing Tax Credits
- $80b - Clean Consumer Tax Credits



Common Types of Incentive Programs

Formula Funding

- Funding allocated **directly to states** through formula grants for eligible uses as defined by federal legislation.
- Amounts are pre-determined based on factors such as **population** or **state size**.
- Certain formula funds require States to directly apply to the program.

Competitive Grants

- Funding is allocated through a competitive application process.
- Multiple types of competitive grants, some may limit applicants to States, others may provide local governments and / or other not-for-profit or qualified entities to apply directly (e.g., cities, universities, utilities).

Federal Loans

- Loans that may be available to states and other organizations to finance all, or a portion of, capital projects what fit the eligible use of the loan program.
- Unlike grants and tax incentives, loan programs do require repayments; however, such programs typically offer more favorable terms to other debt funding.

Tax Credits

- Tax credits provide a direct reduction to an entity's tax liability, on a dollar-for-dollar basis; the tax credits cannot reduce the tax liability below zero and any credit that exceeds the current year tax liability would be rolled forward to future tax years.
- However, with the direct pay option offered through the IRA to non-profit / tax-exempt entities, tax credits can be taken as a lump sum cash payment for tax-exempt entities.

Tax

- Tax deductions reduces the taxable income of an entity, thereby reducing its ultimate tax liability by the product of the deduction amount and the entities' applicable, effective tax rate.
- Tax-exempt entities will need to assign tax deductions to a for-profit organization with sufficient taxable income in order to benefit from such potential deductions.

Rebates

- Rebates are an incentive program in which a purchaser of a product is able to claim a refund for some amount or percentage of the product's cost after specific requirements are met thus discounting the cost of the product.
- For energy products, rebates can typically be claimed once the product is installed and meeting certain performance requirements.

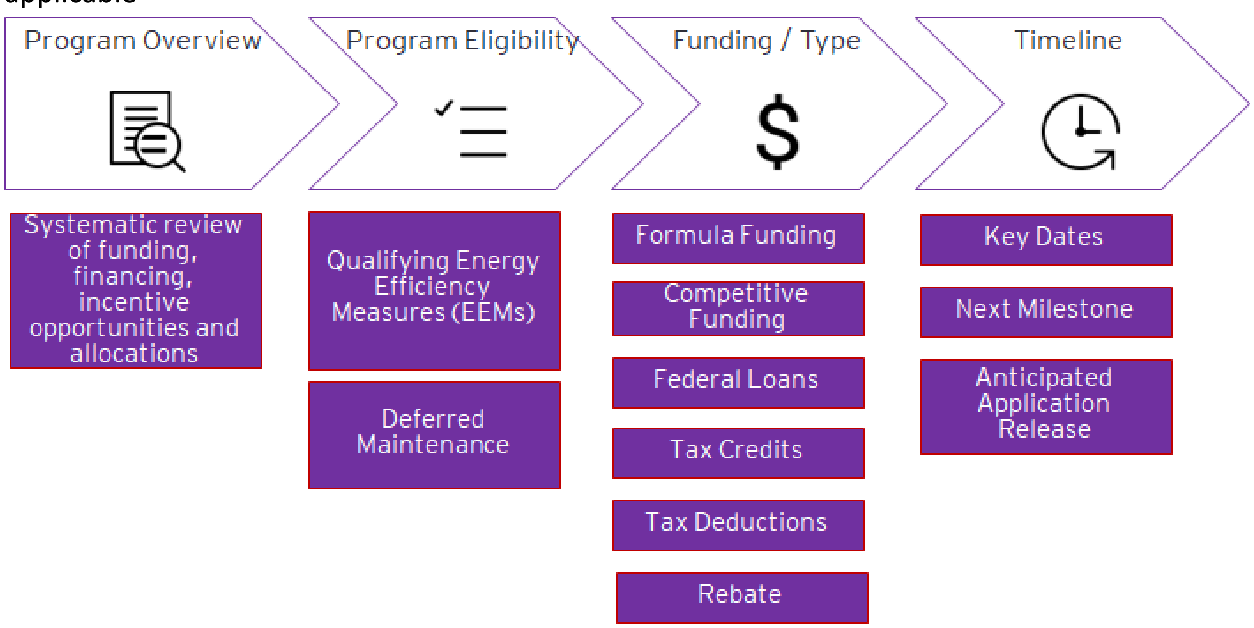
2

Federal, State and Utility Program Identification

Methodology to Incentive Program Analysis

A detailed approach was undertaken to analyze each federal, state, and utility program following the four steps:

1. Program Overview: Defining and understanding the key objectives of the federal program and addressing applicability to the University of Washington's Energy Renewal Program (ERP) and Building Renewal Program (BRP)
    - Programs identified as relevant to the ERP provide support for renewable power production and associated infrastructure;
    - Programs identified as relevant to the BRP provide support for facility modernization, energy efficiency and conservation measures at existing facilities, or the construction of new, energy efficient, facilities.
2. Program Eligibility: Defining the eligible uses and requirements for the program to evaluate the relevance of the program and the University's potential eligibility status
3. Funding / Program Type: Identifying funding availability and timing as well as program type (e.g., formula or competitive grant, tax credits or deductions, and loans)
4. Timeline: Establishing timelines of the funding distribution, key milestones and anticipated deadlines related to each program as of the writing of this report, when applicable



Key Identified Program Opportunities

- A detailed list of more than 25 potentially applicable federal, state, and local funding, financing, and incentives programs is outlined within this report.
- Please note that the IIJA and IRA do provide certain, limited, funding opportunities that directly support BRP focus areas, such as energy efficiency retrofits or facilities modernizations; rather, these legislative acts, and the IRA in particular, provides significant potential federal support for renewable power production initiatives, which may be of high relevance to the ERP. Nonetheless, there are additional programs beyond the IIJA and IRA, including US DOE and local utility incentives programs, that may also be of value for the BRP.
- This analysis has endeavored to identify key programs that provide the most meaningful opportunities for the University in the context of the ERP and BRP initiatives.
- Such identified key programs are highlighted in green throughout the summary tables provided in the subsequent pages and summarized in the table below:

IIJA	IRA	Other Federal Programs	State & Local
▸ Energy Efficiency Materials Pilot Program (Renew America's Nonprofits Grant Program) ▸ Energy Efficiency Revolving Loan Fund Capitalization Grant Program ▸ Grid Resiliency and Innovation Partnership Programs - Smart Grid Grants	▸ Investment Tax Credit (ITC) ▸ Energy Efficient Commercial Buildings Deduction (179D)	▸ Title XVII Loan Guarantee Program (US DOE)	▸ Climate Commitment Act ▸ Clean Energy Fund ▸ Utility Incentive Programs

IIJA Opportunities

IIJA programs were initially identified based on the University's eligibility to receive funding and alignment to the ERP and BRP initiative. **Further information on evaluated programs is available in the appendix.**

Program Name	ERP / BRP	Description	Funding Type	Application Type	Funding (22 - 26)	Applicability to Project
Energy Efficiency and Conservation Block Grant Program	BRP	To assist states, local governments, and tribes to reduce energy use, reduce fossil fuel emissions, and improve energy efficiency.	Formula / Competitive	Through State, (**Washington State Dept of Commerce**)	$550m (WA - $2m for 2023)	Project would qualify but limited available state funds to university (<$1m)
Energy Efficiency Materials Pilot Program *(Renew America's Nonprofits Grant Program)*	BRP	Grants to supply nonprofit buildings with energy-efficiency materials.	Competitive	Direct	$45m	Project would qualify under grant criteria
Energy Efficiency Revolving Loan Fund Capitalization Grant Program	BRP	Capitalization grants to States to establish a revolving loan fund under which the state will provide loans/grants for energy efficiency audits, upgrades, and retrofits to increase energy efficiency and building comfort.	Formula	Through State, (**Washington State Dept of Commerce**)	$250m	Project would qualify under grant criteria and could potentially utilize a loan through a non-profit lender
Energy Storage Demonstration and Pilot Grant Program	ERP	The Energy Storage Demonstration and Pilot Grant Program is designed to enter into agreements to carry out 3 energy storage system demonstration projects. The projects should have a focus on long-term energy storage to supply to the grid at peak points in demand.	Grant, Cooperative Agreement, or Other	Direct	$355m	No long-term energy storage and supply planned in current design
Extended Product System Rebates	ERP/BRP	Provides rebates for qualified extended product systems including air compressors, fans, and	Rebates	Direct	$10m	Products need to meet requirements to qualify

[redacted]

Program Name	ERP / BRP	Description	Funding Type	Application Type	Funding (22 - 26)	Applicability to Project
		pumps that meet qualifying criteria.				
Long-Duration Energy Storage Demonstration Initiative and Joint Program	ERP	A demonstration initiative composed of demonstration projects focused on the development of long-duration energy storage technologies.	Grant, Cooperative Agreement, or Other	Direct	$150m	No long-term energy storage planned in current design
Grid Resiliency and Innovation Partnership Programs (GRIP) - Smart Grid Grants	ERP	Designed to increase the flexibility, efficiency, and reliability of the electric power system, focusing on increasing transmission capacity, preventing faults, integrating renewable energy at transmission and distribution levels and facilitating integration of EV, buildings and other smart grid tech.	Competitive / Formula	Direct	$600m	Certain project elements may qualify under grant criteria, but may require coordination with local utility to pursue
Grid Resiliency and Innovation Partnership Programs (GRIP) - Grid Innovation Programs	ERP	Funds projects that use innovative approaches to transmission, storage, and distribution infrastructure to enhance grid resilience and reliability.	Competitive / Formula	Direct	$1,000m	Not an eligible entity or project for the program
Grid Resiliency and Innovation Partnership Programs (GRIP) – Utility and Industry Grants	ERP	Grid Resilience Utility and Industry Grants support activities that will modernize the electric grid to reduce impacts from extreme weather and natural disasters	Competitive / Formula	Direct	$100m	Not an eligible entity or project for the program

[redacted]

IRA Opportunities

IRA programs are primarily structured as tax credits / incentives for clean energy production and were evaluated based on the University's eligibility as well as align with the ERP and BRP initiatives. **Further information on evaluated programs is available in the appendix.**

Program Name	ERP / BRP	Description	Funding Type	Direct Pay?	Funding (23 - 32)	Applicability to Project
Investment Tax Credit (ITC) and Production Tax Credit (PTC)	ERP	Tax credits available to certain types of energy properties, including renewable electricity generators, energy storage systems, and geothermal heating and cooling systems.	Tax Credit	Yes	Unlimited; 6% - 40% of eligible project costs	ITC includes geothermal and HVAC thermal storage and could apply to any renewable electricity generation on-site
Energy Efficient Commercial Buildings Deduction (179D)	BRP	The 179D commercial buildings energy efficiency tax deduction primarily enables building owners to claim a tax deduction for installing qualifying systems in buildings.	Tax Deduction	No, may be allocated to designer	Lesser of the cost of installed property or (up to) $5 / sq ft	HVAC upgrade needs to meet the 25% savings requirement to qualify for the tax deduction
Pacific Coastal Salmon Recovery Fund	ERP	This competitive grants program provides funding to projects and activities that provide demonstrable and measurable benefits to Pacific anadromous salmonids and their habitat.	Competitive Grant (Through **Washington State Rec. & Conservation Office**)	N/A	$106m ($30m per request)	The lake cooling system could potentially provide some benefits to the salmonids and their habitat.
Climate Pollution Reduction Grants	ERP/BRP	The grant is intended to support the design of climate action plans that incorporate a variety of measures to reduce GHG emissions in six key sectors (this can include facility energy efficiency retrofits and clean power generation).	Competitive and Non-competitive Grants (Through **Washington State Dept of Commerce**)	N/A	$4.6b & $250m	Project would qualify for competitive grants with further assessment needed on the projects competitiveness

[redacted]

Program Name	ERP / BRP	Description	Funding Type	Direct Pay?	Funding (23 - 32)	Applicability to Project
Greenhouse Gas Reduction Fund	ERP	Provide competitive grants to mobilize financing and leverage private capital for clean energy and climate projects that reduce greenhouse gas emissions – with an emphasis on projects that benefit low-income and disadvantaged communities. The grants will fund three different non-profit green banks that will fund one of three programs: National Clean Investment Fund, Clean Communities Investment Accelerator, and Solar for All.	Loan	N/A	$27,000m	The grants go to the capital providers for clean projects which the University's project may qualify for, but the financial assistance programs will not be defined until 2025.
Wind Energy Technology Program	ERP	Grants for research, development, demonstration and commercialization activities to improve wind energy technologies	Competitive and Non-competitive Grants, Loans	N/A	$500k - $8M	The grants go to the capital providers for wind energy projects which is not in the current project scope
Clean Water State Revolving Fund	ERP	Federal government provides grants to capitalize State revolving loan funds for clean water treatment facilities and other green water projects.	Competitive and Non-competitive Grants, Loans	N/A	-	The grants go to the capital providers for water treatment projects is not in the current project scope

[redacted]

Additional Federal Opportunities

The US Department of Energy (US DOE) and IRS provide additional programs to support energy transition initiatives, which were analyzed for their applicability to the ERP and BRP. **Further information on evaluated programs is available in the appendix.**

Program Name	ERP / BRP	Description	Funding Type	Direct Pay?	Incentive Amount	Applicability to Project
Buildings Energy Efficiency Frontiers & Innovation Technologies "BENEFIT" (**Office of Energy and Renewable Energy**)	BRP	The BENEFIT program will invest up to $30 million across four topic areas including HVAC systems, roofing, building capacity / resilience, and lighting to further research, develop, and validate technologies with the potential to significantly advance building decarbonization	Grant	Direct	$30m (2024)	Project would qualify for the topic areas on HVAC systems and potentially for building resilience
Loan Guarantee Program (**US DOE**)	ERP	Direct loans from U.S. Treasury's Federal Financing Bank (FFB) backed by 100% "full faith and credit" DOE guarantees, OR DOE partial guarantees of commercial debt with a low interest rate.	Loan	N/A	-	Project would qualify under the Title 17: Energy Infrastructure Reinvestment
Modified Accelerated Cost-Recovery System, MACRS (**IRS**)	ERP	Under MACRS, businesses may recover investments in certain property through depreciation deductions. A number of renewable energy technologies are classified as five-year property (26 USC § 168(e)(3)(B)(vi)) under the MACRS, which refers to 26 USC § 48(a)(3)(A), often known as the energy investment tax credit or ITC to define eligible property	Tax Deduction	No	-	University likely does not have a tax liability

[redacted]

Additional State and Local Opportunities

In addition to the federal programs, there are also State & Local programs including that could provide further funding, rebates, and incentives.

Program Name	ERP / BRP	Description	Funding Type	Application Type	Incentive Amount	Applicability to Project
Renewable Energy Sales and Use Tax Exemption (State)	ERP	Sales tax exemption for equipment used to generate electricity using renewables. The tax exemption applies to labor and services related to the installation of the equipment, as well as to the sale of equipment and machinery. Eligible systems are those with a generating capacity of at least 1 kilowatt.	Sales Tax Incentive	Direct	50% of sales and use tax	Unlikely to apply – confirm University already has sales tax exemption.
Climate Commitment Act (State)	ERP/BRP	Washington's Climate Commitment Act (CCA) provides a Climate Investment Account (CIA) and Carbon Emission Reduction Account (CERA) that can provide funding to eligible projects that decrease emissions. Auction proceeds must be appropriated by the legislature.	Grant	**Washington Department of Ecology**	-	Emission reduction from the system upgrades could provide funding to the project
Clean Energy Fund (CEF)	ERP/BRP	Washington's CEF provides grants through various programs, including Building Electrification, Energy Efficiency Retrofits for Public Buildings, Electrification of Transportation Systems, Grid Modernization, Research, Development and Demonstration, and Solar.	Grant	**Washington Department of Commerce**	-	Various programs that could provide funding for project

Utility Energy Efficiency Programs

There are also several local utility energy efficiency programs that could provide further funding, rebates, and incentives.

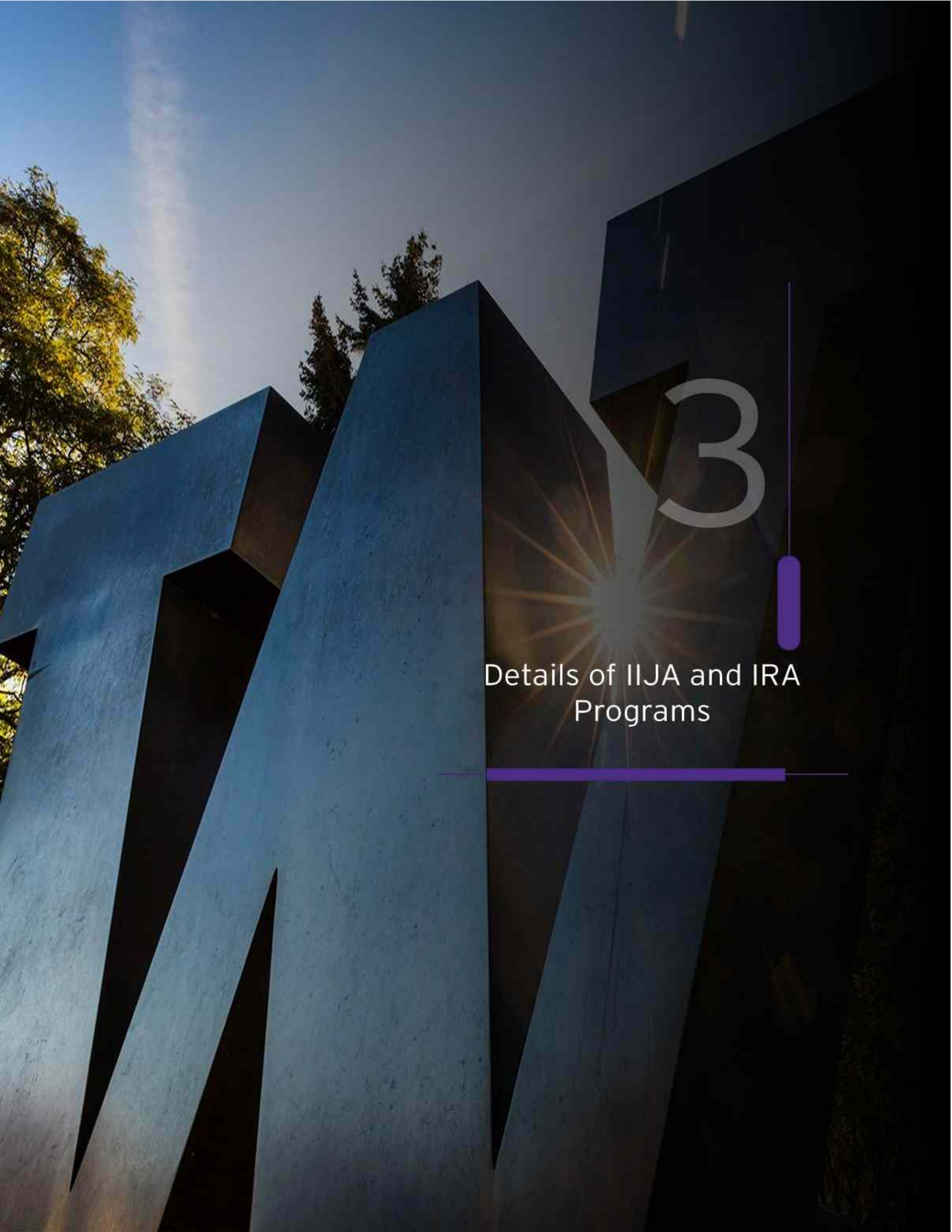
Program Name	ERP / BRP	Description	Funding Type	Application Type	Incentive amounts	Applicability to Project
Deep retrofit pay-for-performance	BRP	Pay for performance program that creates a baseline for expected electricity consumption and provides an incentive for reductions from that baseline. All measures are allowed for usage reductions.	Rebate	Through **Seattle City Light**	\$0.08 - \$0.18/kWh reduction, depending on program choice	Emission reduction from the system upgrades could provide funding to the project
Energy project manager / project development incentive	BRP	Additional funding available beyond other rebates to cover costs associated with applying for rebates	Rebate	Through **Seattle City Light**	\$0.025/kWh reduction	Potential coverage for project management costs
Existing building commissioning	BRP	Improvement of control systems programming to reduce energy consumption. Available as both a retro-commissioning and monitoring-based commissioning approach.	Rebate	Through **Seattle City Light**	Up to 100% of commissioning costs (\$0.25/ft2 plus \$0.05/kWh reduction)	Potential coverage for building control programming and other fixes
Early Adopter Incentive	BRP	WA Clean Building Standard require buildings to meet an energy use intensity (EUI) target by 2026-2028, depending on size. Early Adopter Incentives are available to retrofit buildings to meet these EUI targets early.	Rebate	State through **WA Dept of Commerce**, paid by **Seattle City Light**	\$0.85/ft2	If UW buildings are required to meet this standard, potentially available for buildings that are upgraded to meet WA Clean Building Standards early
Other incentives	BRP	Seattle City Light provides additional incentives in new construction and retrofit programs.	Rebate	Through **Seattle City Light**	Up to \$0.27/kWh for HVAC upgrades	Potentially available for building retrofits and central plant upgrades.

[redacted]

Key Stakeholder Identified

- As outlined in the preceding tables, and further detailed in the appendix, a number of the identified programs are not available to UW directly but would require coordination with additional State of Washington stakeholders to pursue and/or provide that UW's ERP and BRP projects are assessed as potential sub-grant recipients.
- As part of the analysis, such key stakeholders were identified, where applicable. The list below summarizes the key identified stakeholders as well as the applicable programs associated with each of the stakeholders:

Key Stakeholders	Incentive Programs
Washington State Department of Commerce	► Energy Efficiency Revolving Loan Fund Capitalization Grant Program ► Energy Efficiency and Conservation Block Grant Program ► Clean Energy Fund (CEF) ► Climate Pollution Reduction Grants ► Early Adopter Incentive Program
Washington State Recreation and Conservation Office	► Pacific Coastal Salmon Recovery Fund
Washington Department of Ecology	► Climate Commitment Act
Seattle City Light	► Incentive Programs



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Details of IIJA and IRA Programs

Energy Efficiency and Conservation Block Grant (EECBG) Program ☐

Program Description

The purpose of the Energy Efficiency and Conservation Block Grant Program (EECBG) Program is to assist eligible entities in implementing strategies to reduce fossil fuel emissions, to reduce total energy use, and to improve energy efficiency.

Funding Amount

$550 million

Availability

Available until expended.

Eligible Uses

(1) Development and implementation of energy efficiency and conservation strategy;

(2) retaining technical consultant services to assist the eligible entity in the development of such a strategy;

(3) conducting residential and commercial building energy audits;

(4) establishment of financial incentive programs for energy efficiency improvements;

(5) the provision of grants to nonprofit organizations and governmental agencies for the purpose of performing energy efficiency retrofits;

(6) development and implementation of energy efficiency and conservation programs for buildings and facilities within the jurisdiction of the eligible entity

(7) development and implementation of programs to conserve energy used in transportation

(8) development and implementation of building codes and inspection services to promote building energy efficiency;

(9) application and implementation of energy distribution technologies that significantly increase energy efficiency;

(10) activities to increase participation and efficiency rates for material conservation programs, including source reduction, recycling, and recycled content procurement programs that lead to increases in energy efficiency;

(11) the purchase and implementation of technologies to reduce, capture, and, to the maximum extent practicable, use methane and other greenhouse gases generated by landfills or similar sources;

(12) replacement of traffic signals and street lighting with energy efficient lighting technologies,

(13) development, implementation, and installation on or in any government building of the eligible entity of onsite renewable energy technology that generates electricity from renewable resources

(14) programs for financing energy efficiency, renewable energy, and zero-emission transportation (and associated infrastructure), capital investments, projects, and programs, which may include loan programs and performance contracting programs, for leveraging of additional public and private sector funds, and programs that allow rebates, grants, or other incentives for the purchase and installation of energy efficiency, renewable energy, and zero-emission transportation (and associated infrastructure) measures;

(15) any other appropriate activity, as determined by the Secretary5

IIJA Programs

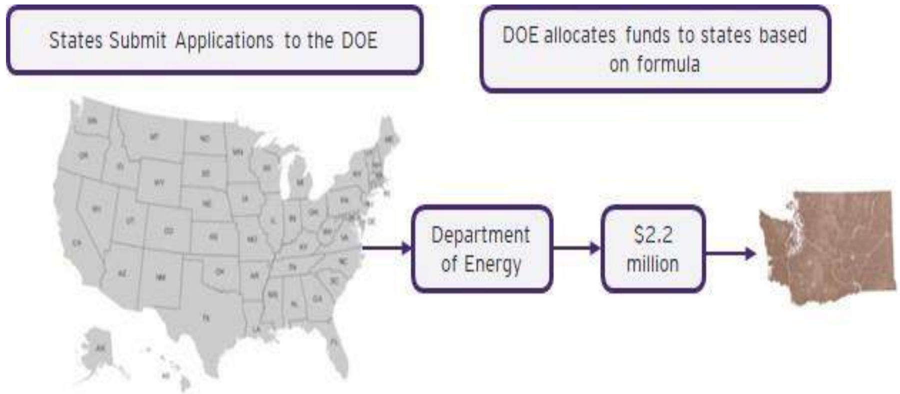
Energy Efficiency and Conservation Block Grant (EECBG) Program ☐

Formula Grant Overview

Of the amounts appropriated by IIJA, DOE will allocate funds as prescribed:

- $299,200,000 for formula grants to eligible units of local government
    - 34% to eligible units of local government-alternative 1 through formula grants
    - 34% to eligible units of local government-alternative 2 through formula grants
- 28% to states through formula grants - $123,200,000 for formula grants to states.
- 2% to Indian tribes through formula grants - $8,800,000 for formula grants to eligible Indian tribes.
- 2% for competitive grants to ineligible local governments and Indian tribes.

State Allocation



- EECBG Program Formula Grant Funding Allocation to Washington: $2.2 million

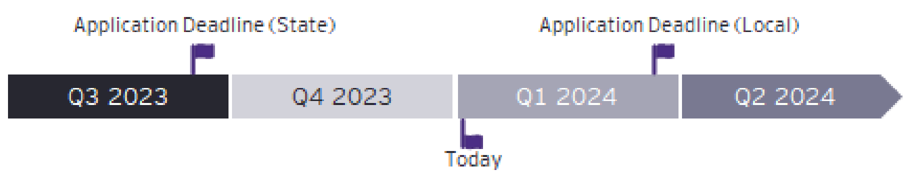
Local Government Allocation

- Larger cities, counties and tribes are being allocated funding directly from DOE.
- At least 60% of the State's funds will be redistributed by Washington State Department of Commerce to those ineligible for direct funding from the DOE.
- City & County Locations that are part of University of Washington system include:
    - Seattle
    - Tacoma
    - Bothell

Timelines and Next Steps

Next milestone (Please note, UW would not be anticipated to be a direct applicant for this program, but a sub-recipient and beneficiary of the State's program run by Washington State Department of Commerce):

- Pre-application Submission Deadline: ASAP
- Full Application Submission Deadline (State): ASAP
- Full Application Submission Deadline (Local): 01/31/2024



IIJA Programs

Energy Efficiency Materials Pilot Program (Renew America's Nonprofits Grant Program) ☐

Program Description

To fund a pilot program for materials (including products, equipment, or systems) that result in a reduction in use by a nonprofit organization of energy or fuel.

The following performance-based criteria determine the grant award and priority level:

- The energy savings achieved
- The cost-effectiveness of the use of energy-efficiency materials
- An effective plan for evaluation, measurement, and verification of energy savings
- The financial need of the applicant

Program Type

New Competitive Grants

Funding Amount

$45 million

Max Award Amount

$200,000 for individual building energy efficiency projects for Subrecipients

Availability

Available until expended

Eligible Uses

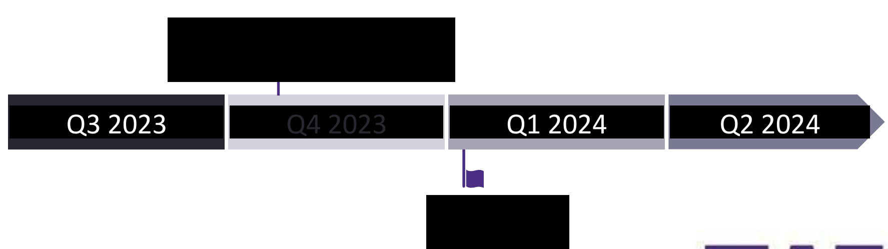
- To provide nonprofits with energy efficiency materials including:
  - Roof or lighting system of component of the system
  - Windows
  - Doors
- A heating, ventilation, or air conditioning system or component of the system (including insulation and wiring and plumbing improvements needed to serve a more efficient system)
- The term "energy-efficiency material" means a material (including a product, equipment, or system), the installation of which results in a reduction in use by a nonprofit organization of energy or fuel

Program Update

- The U.S. Department of Energy's (DOE) **Renew America's** Nonprofits program provides grants for energy efficiency projects in non-profit buildings. This revamped program originally defined as Energy Efficiency Materials Pilot Program in the IIJA. Primes will sub-award grants of up to $200,000 to non-profit 501(c)(3) subrecipients that own and operate their buildings, for building energy efficiency improvements.
- There are three types of role assigned for the program, in which Washington will be a Subrecipient:
  - Prime recipient: a 501(c)(3) non-profit organization interested in serving as a program lead and applying to this grant as a prospective Prime Recipient.
  - Subrecipient: a 501(c)(3) non-profit organization that owns and operates their building, needs energy efficiency upgrades, and is interested in engaging with prospective Prime Recipients as a prospective subrecipient.
  - Partner: an organization capable of partnering with/enhancing the services of a prospective Prime Recipient.

Timelines and Next Steps

- Prime recipients are expected to be announced October 2023 (Please note, UW would not be anticipated to be a direct applicant for this program, but a sub-recipient to one of the prime awardees)



Energy Efficiency Revolving Loan Fund Capitalization Grant Program ☐

Program Description

Provide capitalization grants to States to establish a revolving loan fund under which the State provides loans and grants for energy efficiency audits, upgrades, and retrofits to increase energy efficiency and improve the comfort of buildings.

Program Type

New Formula Grants

Funding Amount

$250 million

Max Award Amount

$15 million to State

Availability

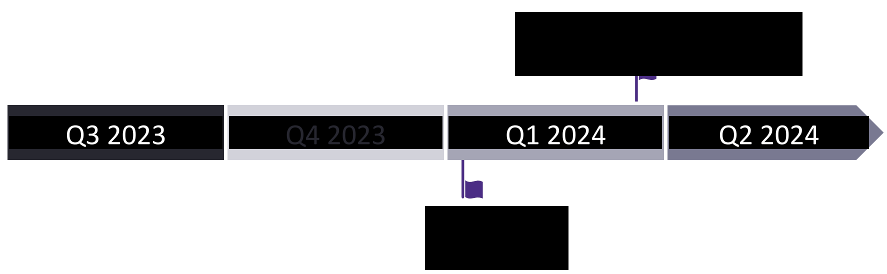
Available until expended

Eligible Uses

- Energy audits – Energy audits by sector
- Retrofits – Buildings retrofitted, building automation systems, streetlights, water conservation retrofits, wastewater treatment facilities retrofitted, process improvements, energy and water saved by sector
- Financial instruments – Financial incentives, existing/new financial programs utilized, energy savings performance contracts, energy investment partnerships
- Renewable energy market development – Geothermal systems installed, solar PV systems installed, renewable thermal systems installed, etc.
- Training/Education – Education and outreach conducted, technical assistance provided, workforce development
- Other – Energy storage systems, combined heat and power (CHP)

Timelines and Next Steps

- Awards to states and territories anticipated spring 2024 (Please note, UW would not be anticipated to be a direct applicant for this program, but a sub-recipient and beneficiary of the State's program run by Washington State Department of Commerce):



Energy Storage Demonstration and Pilot Grant Program ☐

Program Description

The Energy Storage Demonstration and Pilot Grant Program is designed to enter into agreements to carry out 3 energy storage system demonstration projects.

Program Type

Grant, Cooperative Agreement, or Other

Funding Amount

$355 million

Max Award Amount

NA

Availability

Available until expended

Eligible Uses

(i) To improve the security of critical infrastructure and emergency response systems.

(ii) To improve the reliability of transmission and distribution systems, particularly in rural areas, including high-energy cost rural areas.

(iii) To optimize transmission or distribution system operation and power quality to defer or avoid costs of replacing or upgrading electric grid infrastructure, including transformers and substations.

(iv) To supply energy at peak periods of demand on the electric grid or during periods of significant variation of electric grid supply.

(v) To reduce peak loads of homes and businesses.

(vi) To improve and advance power conversion systems.

(vii) To provide ancillary services for grid stability and management.

(viii) To integrate renewable energy resource production.

(ix) To increase the feasibility of microgrids (grid-connected or islanded mode).

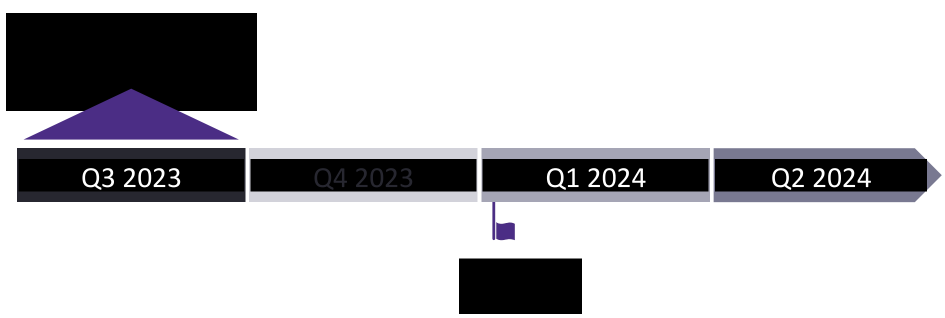
(x) To enable the use of stored energy in forms other than electricity to support the natural gas system and other industrial processes.

(xi) To integrate fast charging of electric vehicles.

(xii) To improve energy efficiency.

Timelines and Next Steps

- Await Notice of Funding Opportunity (NOFO) – formal announcement of the availability of Federal funding



Extended Product System Rebates ☐

Program Description

The Extended Product System Rebates Program is designed to provide rebates for qualified extended product systems, such as an electric motor, electronic control, and driven load.

Program Type

New – Rebate Grants

Funding Amount

$10 million

Max Award Amount

$25,000 per year

Availability

Available until expended

Eligible Uses

To qualify for a rebate payment, an eligible entity must demonstrate that its extended product system:

(1) includes an electric motor and an electronic control

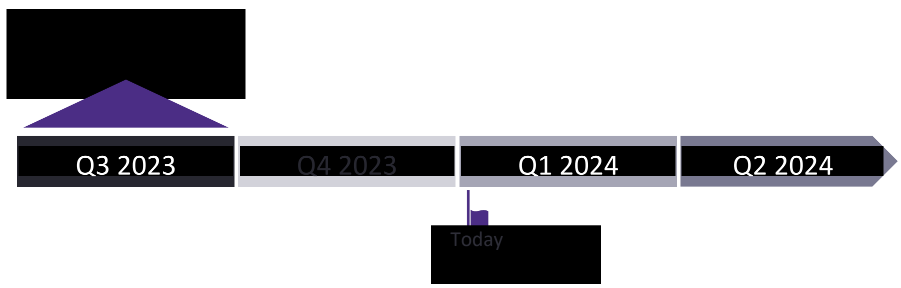
(2) reduces the input energy (as measured in kWh) required to operate the extended product system by not less than 5 percent, as compared to identified base levels set by the Secretary, and

(3) uses controls that automatically adjust the electric motor speed

An eligible entity must demonstrate that its extended product system meets the equipment-specific criteria for item (2) as described for pumps, air compressors, and fans.

Timelines and Next Steps

- Prepare application in accordance with relevant criteria



Long-Duration Energy Storage Demonstration Initiative and Joint Program ☐

Program Description

The Long-Duration Energy Storage Demonstration Initiative and Joint Program is designed to establish a demonstration initiative composed of demonstration projects focused on the development of long-duration energy storage technologies.

Program Type

Grant, Cooperative Agreement, or Other

Funding Amount

$159 million

Max Award Amount

NA

Availability

Available until expended

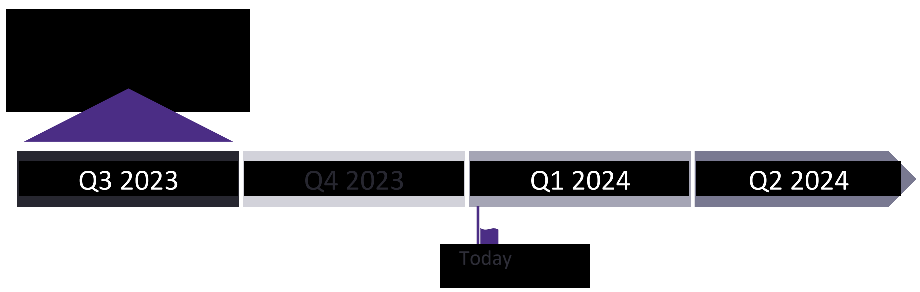
Eligible Uses

(i) demonstrate promising long-duration energy storage technologies at different scales; and

(ii) help new, innovative long-duration energy storage technologies become commercially viable.

Timelines and Next Steps

- Await Notice of Funding Opportunity (NOFO) – formal announcement of the availability of Federal funding
- Estimated application opening (Q4 2022) passed and NOFO yet to be released as of September 2023



Grid Resiliency and Innovation Partnership Programs - Smart Grid Grants

Program Description

Designed to increase the flexibility, efficiency and reliability of the electric power system, focusing on increasing transmission capacity, preventing faults, integrating renewable energy at transmission and distribution levels and facilitating integration of EV, buildings and other smart grid tech.

Funding Amount

$3 billion

Max Award Amount

$600 million annually FY22 – FY26

Specific Eligibility Requirements

None

Cost Matching

50% minimum

Eligible Entities

- Institutions of Higher Education
- For-profit entities
- Non-profit entities
- State and local government entities
- Tribal nations

Goals and Objectives

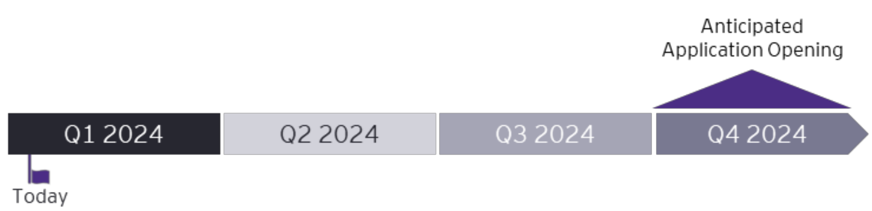
- Increase Transmission Capacity
    - Grid Enhancing Technologies
- Mitigate Wildfires
    - Asset Management Technologies
- Load Management/Electrification of “Edge Devices”
    - Managed Charging/Grid Infrastructure and Autonomous Control
- Incorporate Secure Communications/Cybersecurity

Example Project Type

- Dynamic line rating
- Flow control devices
- Advanced Conductors
- Network topology optimization
- Autonomous controls through data analytics, software and sensors
- Investments in optical ground wire, dark fiber, operational fiber and wireless broadband communications networks
- EV charging infrastructure, vehicle-to-grid technologies
- Investments to increase the ability to redirect or shut off power

Timeline and Next Steps

- Round 1 Funding (FY 22) was awarded in September 2023
- Round 2 Funding opened in December 2023, concept papers due in January 2024
- Would expect to target Round 3 Funding, NOFO is anticipated to be issued in Q4 2024 and would prepare application in accordance with relevant criteria.



IIJA Programs

Grid Resiliency and Innovation Partnership Programs - Grid Innovation Programs □

Program Description

Funds projects that use innovative approaches to transmission, storage and distribution infrastructure to enhance grid resilience and reliability.

Funding Amount

$5 billion

Max Award Amount

Up to $1B annually FY22 – FY26

Specific Eligibility Requirements

None

Cost Matching

50% minimum

Eligible Entities

- State
- Combination of 2 or more States
- Indian Tribe
- Unit of local government
- Public Utility Commission

Goals and Objectives

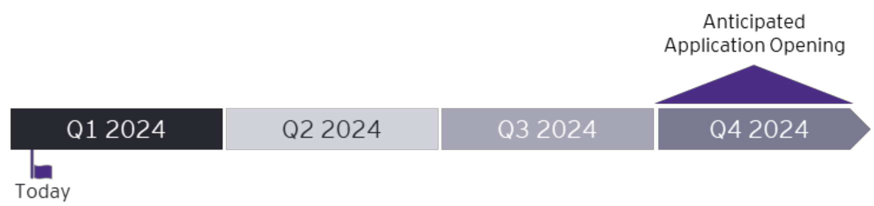
- Ensure reliable grid operations
- Improve overall grid resilience
- Enhance collaboration between and among eligible entities and private and public sector owners and operators on grid resilience
- Contribute to the decarbonization of the electricity and broader energy system

Example Project Type

- Capacity enhancements and renewable energy interconnection
- Advanced distribution grid assets and functionality
- Demonstration of innovative approaches for improved joint resilience

Timeline and Next Steps

- Round 1 Funding (FY 22) was awarded in September 2023
- Round 2 Funding opened in December 2023, concept papers due in January 2024
- Would expect to target Round 3 Funding, NOFO is anticipated to be issued in Q4 2024 and would prepare application in accordance with relevant criteria.



IIJA Programs

Grid Resiliency and Innovation Partnership Programs - Grid Resilience Utility and Industry Grants □

Program Description

Supports modernization of electric grid to reduce impacts due to extreme weather and natural disasters. Mitigate multiple hazards across a region or within a community.

Funding Amount

$2.5 billion

Max Award Amount

$600 million annually FY22 – FY26

Specific Eligibility Requirements

30% of program is for small utilities selling no more than 4 million MWh per year

Cost Matching

Small utilities 33% cost matching, otherwise 100%

Eligible Entities

- Electric grid operators
- Electricity storage operators
- Electricity generators
- Transmission owners or operators
- Distribution providers
- Fuel suppliers

Goals and Objectives

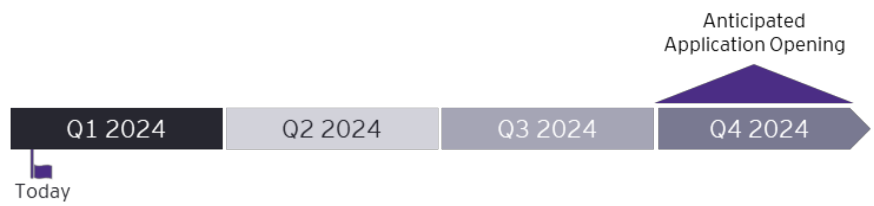
- Applications that address community transformation or ability to leverage capital investments
- Activities that reduce the likelihood and consequence of impacts to the grid from extreme weather and natural disasters
- Transformational, comprehensive approach to mitigating one or more hazards across a region or within a community
- NOT ALLOWED: construction of new electric generating facility that is not used for enhancing system adaptive capacity

Example Project Type

- Utility pole management
- Hardening of power lines, facilities, substations
- Undergrounding of electrical equipment
- Replacement of old overhead conductors
- Relocation of power lines
- Vegetation and fuel-load management
- Weatherization technologies
- Fire-resistant technologies
- Monitoring and control technologies
- Use or construction of distributed energy resources for enhancing system adaptive capacity
- Adaptive protection technologies
- Advanced modelling technologies

Timeline and Next Steps

- Round 1 Funding (FY 22) was awarded in September 2023
- Round 2 Funding opened in December 2023, concept papers due in January 2024
- Would expect to target Round 3 Funding, NOFO is anticipated to be issued in Q4 2024 and would prepare application in accordance with relevant criteria.



IRA Programs

Investment Tax Credit (ITC) and Production Tax Credit (PTC) ☐

Program Description

Emissions-based incentive that is neutral and flexible between clean electricity technologies. Taxpayers choose between a PTC (45Y) and an ITC (48E)

Funding Amount

Direct Pay Tax Credit

Max Award Amount

6% - 40%

Specific Eligibility Requirements

Prevailing wages and apprenticeship, domestic content requirements

Cost Matching

NA

Bonus Credit Highlights

- Prevailing wages and apprenticeship
  - If program requirements are not met, maximum credits are reduced by 80% for both credits
  - Only required during construction period
  - Wage requirement is required during the entire construction period and during the five-year ITC or ten-year PTC recapture period
- Domestic content and energy community
  - For domestic content, steel, iron, or manufactured product that is used in the project during the time of completion must be produced in the US
  - Energy community defined as a brownfield site; area with significant employment of extraction, processing, transport, or storage of coal, oil, or natural gas; a census tract, after 12/31/1999, with a coal mine closed or after 12/31/2009, where a coal-fired electric generating unit has been retired
  - Additional 10% for PTC and 10% of basis for ITC can be added for meeting these requirements

Solar ITC Example

- Project Size: 10MW
- Construction Start: December 2023
- Commercial Operation Date (COD): December 2024
- Project Cost: $10 million
- ITC Base credits: 6%
- Prevailing wages and apprenticeship requirement multiplier: 5

Total Tax Credit = $10 million x (6% x 5) = $3 million

With Direct Pay, tax-exempt entities can take the total credit value as cash payment

Timelines and Next Steps

- University of Washington to determine applicable technology sources to use throughout campus area for decarbonization
- Multiple financing methods can be used with direct pay method and using a project finance approach to energize a new project
- Although there is no immediate deadline, some features of the ITC and PTC credits change after 2024

IRA Programs

Clean Energy Investment Tax Credit (ITC) and Production Tax Credit (PTC) ☐

Program Description

- Extension of Production Tax Credit: production of energy from solar, wind, geothermal, biomass, hydropower, and other eligible projects
- Extension of Investment Tax Credit: production of energy from solar, geothermal, wind, and fuel cell technology, dynamic glass, thermal energy storage, standalone energy storage, and combined heat and power systems

Program Type

Existing Tax Credit with New Provisions

Funding Amount

NA

Max Award Amount

NA

Availability

Available until at least 2032, dependent on renewable technology and phasedown provisions.

Eligible Uses

- Pre-2025: Updates to previous laws
  - Full ITCs and PTCs are now available for projects that will be in service post 2021 and before 2025
  - PTC is available for solar projects that begin construction before 2025
  - ITC can be applied to wind projects
  - Standalone battery and thermal energy storage to qualify for ITC if placed in service before December 31, 2022
- 2025 – (2034): New laws
  - Technology-neutral tax credit applies to any project which begin construction from 2025 to at least 2032 allowing taxpayers to select either PTC or ITC for all clean power technologies
- The credits will be phased out in either latter of 2032 or when the US achieves 75% emissions reductions from 2022 levels
- New tax credit rate structure based on prevailing wage, apprenticeship, domestic production of components, and location requirements
- New Technology:
  - Standalone energy storage are also eligible for ITC, regardless of connected energy source
  - Other technologies eligible for ITC include fuel cells, biomass technology, electrical vehicle charging, and geothermal technology

Direct Pay and Transferability

- Tax-exempt entities such as non-profit organizations can convert tax credits into cash rebates directly paid from federal governments
- The projects must be in place post December 31, 2022
- Payment is not received until after commercial operations start
- If tax-exempt debt is used to fund the project, there is a 15% haircut on the credit (e.g., a 40% credit would be reduced to 34%)
- Entities eligible for direct pay are not permitted to transfer tax credits

Energy Efficient Commercial Buildings Deduction (179D) ☐

Program Description

Enables building owners to claim a tax deduction for installing qualifying energy efficiency systems in buildings. Tenants may be eligible if they make construction expenditures. If the system or building is installed on federal, state, or local government property, the 179D tax deduction may be transferred to the entity primarily responsible for the system's design.

Program Type

Existing Tax Deduction

Funding Amount

Ongoing

Max Award Amount

NA

Availability

NA

Eligible Uses

- Post-2023: Updates to previous laws
  - The maximum deduction for 179D is increased to $5.00 per sq. foot from $1.88 per sq. foot
  - Reduces qualifying amount by which building **must increase its energy efficiency** from **50% to 25%**
  - **Allows for 179D deductions to all tax-exempt entities including public universities, allowing for such organizations to assign the 179D deduction to the system designers**
- Eligible improvements for 179D deduction
  - Building envelope: energy efficient upgrades to walls, floors, fenestrations, or doors
  - HVAC systems: retrofits to high energy efficient HVAC equipment
  - Lights: retrofits to new energy efficient building lights
- Percentage reduction compared to a reference building that meets minimum requirements of ASHRAE Standard 90.1-2007

Maximizing Deductions

- With prevailing wage and apprenticeship requirements, starting deduction is $2.50 per square foot
  - The deduction increases by $0.10, up to maximum value of $5.00 per square foot, for each additional percentage of energy deduction
  - Without prevailing wage and apprenticeship requirement, the starting deduction is $.50 per square foot
  - The deduction increases by $.02, up to maximum value of $1.00 per square foot, for each additional percentage of energy deduction

Building SQ FT	Pre-IIJA Deduction	Post-IIJA Deduction	Value of Post-IIJA Tax Deduction (30% tax rate)
100,000	$188,000	$500,000	$150,000
500,000	$940,000	$2,500,000	$750,000
1,000,000	$1,880,000	$5,000,000	$1,500,000

IRA Programs

Climate Pollution Reduction Grants (CPRG)

Program Description

- This is a two-phased program designed to support the planning (phase 1) and implementation (phase 2) of Priority Climate Action Plans (PCAPs) to reduce greenhouse gas emissions and other harmful air pollution.
- Funding will be used to support the design and implementation of climate action plans that incorporate a variety of measures to reduce GHG emissions in six key sectors: electricity generation, industry, transportation, buildings, agriculture/natural and working lands, and waste management.

Program Type

Competitive and Non-Competitive Grants

Funding Amount

- $250m – Non-Competitive Grants (Phase 1)
- $4.6b – Competitive Grants (Phase 2)

Max Award Amount

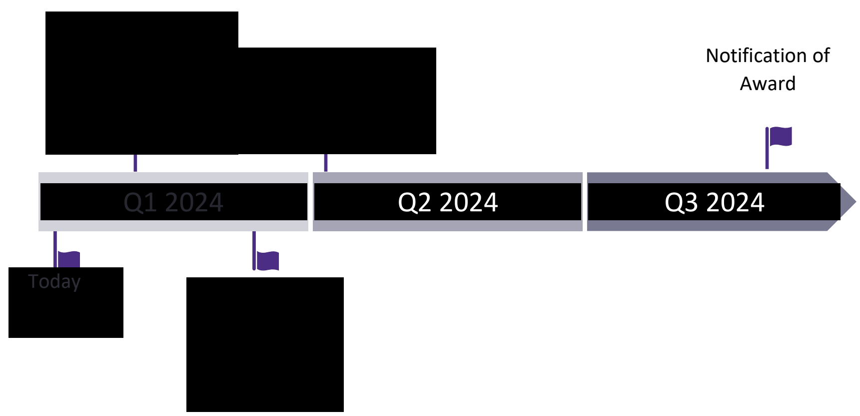
$500 million

Eligible Uses

- Planning grants:
  - $250 million for states, U.S. territories, municipalities, air pollution control agencies, tribes, and other similar groups to develop plans to reduce greenhouse gases (GHGs). The Priority Climate Action Plan (PCAP) is the first deliverable due under the CPRG planning grants.
- Implementation grants:
  - $4.6 billion for competitive grants to eligible applicants to implement GHG reduction programs, policies, projects, and measures identified in a PCAP developed under a CPRG planning grant.

Timeline and Next Steps

- Prepare application in accordance with relevant criteria in Notice of Funding Opportunity (Please note, UW would not be anticipated to be a direct applicant for this program, but a sub-recipient and beneficiary of the State's program run by Washington State Department of Commerce)



IRA Programs

Greenhouse Gas Reduction Fund Overview ☐

Program Description

This program will provide competitive grants to mobilize financing and leverage private capital for clean energy and climate projects that reduce greenhouse gas emissions – with an emphasis on projects that benefit low-income and disadvantaged communities.

Program Type

Competitive Grants

Funding Amount

$27,000 million

Max Award Amount

NA

Availability

Available until expended

Eligible Uses

- The Greenhouse Gas Reduction Fund (GGRF) is separated into three distinct funds:
  - **The National Clean Investment Fund ($14B) will fund 2-3 national non-profits that will partner with private capital provers to deliver financing at scale to businesses, communities, community lenders, and others, catalyzing tens of thousands of clean technology projects to accelerate our progress towards energy independence and a net-zero economic future.**
  - **The Clean Communities Investment Accelerator ($6B) will fund 2-7 hub non-profits with the plans and capabilities to rapidly build the clean financing capacity, primarily through sub-grants to local community lenders to ensure that households, small businesses, schools, and community institutions in low-income and disadvantaged communities have access to financing for cost-saving and pollution-reducing clean technology projects.**
  - **Solar for All ($7B) will provide up to 60 grants to expand the number of disadvantaged communities primed for solar through financing support to residential and community solar projects, with an emphasis on disadvantaged communities.**

Focus on National Clean Investment Fund

- Although Washington will not be eligible to directly apply for funding through the GGRF, the establishment of one, or more, national green banks under the GGRF will provide a potential new and attractive source of project financing for qualifying University projects. The National Clean Investment Fund, which is intended to capitalize two to three new national green banks must prioritize three project types – all of which align to Washington overall CAP goals and strategies:
  - Distributed Power & Generation
  - Decarbonization Retrofits of Existing Buildings
  - Transportation Pollution Reduction

Timeline

- The US EPA Issued NOFOs in Summer 2023, with grant applications due in October 2023. The US EPA anticipates Notices of Award to be announced in March 2024.
- However, it is anticipated that the establishment of new, national green banks may be time intensive, even after receipt of federal grants. Once awards are announced, funding will become available in July 2024, but It is likely that financing programs may not be available to lend until 2025, as grantees are provided a 12-month implementation phase to stand up the financial assistance programs with which UW would apply to.

Wind Energy Technology Program ☐

Program Description

Grants for research, development, demonstration and commercialization activities to improve wind energy technologies

Funding Amount

$1 billion

Max Award Amount

$500K - $8M per award

Specific Eligibility Requirements

None

Cost Matching

- 0% or 20% depending on topic area;
- No cost matching required for Institutes of Higher Education or Non-Profit Organizations

Eligible Entities

- Institutions of Higher Education
- For-profit and non-profit organizations
- State, local governments and Tribal Nations

Goals and Objectives

- Advance and accelerate the deployment of wind power
- Reduce the cost of electricity
- Maximize benefits of clean energy transition
- Develop curriculum for education and workforce training
- Understand community impacts of offshore wind development
- Connect communities with offshore wind development process
- Advance bat deterrent technology

Example Project Types

- Awarding grants and awards, on a competitive, merit-reviewed basis
- Performing precompetitive research and development
- Establishing or maintaining demonstration facilities and projects, including through stewardship of existing facilities such as the National Wind Test Center
- Providing technical assistance
- Entering into contracts and cooperative agreements
- Providing small business vouchers
- Establishing prize competitions
- Conducting education and outreach activities
- Conducting professional development activities
- Conducting analyses, studies, and reports

Clean Water State Revolving Fund ☐

Program Description

Federal government provides grants to capitalize State revolving loan funds.

Funding Amount

~$110 million in annual disbursements

Max Award Amount

Projects up to $35M

Specific Eligibility Requirements

None

Cost Matching

- State provides 20% matching funds

Eligible Entities

- Local government units

Goals and Objectives

- Provide funding for clean water infrastructure
- Advance the NCDEQ's mission to provide science-based environmental stewardship for the health and prosperity of North Carolinians
- Advance the water quality goals of CWA while targeting the most needy systems
- Provide low-cost financing for projects including:
    - Wastewater treatment facilities
    - Projects associated with estuary and nonpoint source programs

Example Project Types

- Wastewater treatment improvements
- Wastewater collection improvements
- Reclaimed water
- Stormwater BMPs
- Stream restoration
- Energy efficiency at treatment works or collection systems

Pacific Coastal Salmon Recovery Fund (PCSRF) ☐

Program Description

The objective of the FY 2024 PCSRF is to assist salmon restoration by allocating federal funding to projects and activities that provide demonstrable and measurable benefits to Pacific anadromous salmonids and their habitat.

Program Type

Competitive Grants

Funding Amount

$106 million

Max Award Amount

$30m per year

Availability

Available until expended

Eligible Entities

Eligible applicants include:

- State of Alaska
- State of Washington
- State of Oregon
- State of Idaho
- State of Nevada
- State of California
- Federally recognized tribes of the Columbia River and Pacific Coast (including Alaska), or their representative tribal commissions and consortia

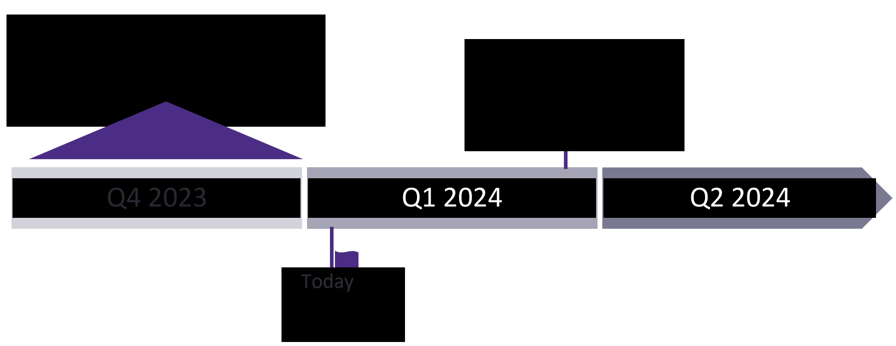
Goals and Objectives

Within the overall objectives of the PCSRF grant program, these funds will specifically provide federal financial assistance to states and tribes to support projects that:

- Protect, restore and conserve Pacific salmon and steelhead and their habitats, using approaches that enhance ecosystem resilience to climate hazards.
- Support tribes' role as fishery managers and stewards of tribal trust resources for cultural, spiritual, subsistence and recreational purposes before implementing conservation activities including outreach, research and monitoring.

Timeline and Next Steps

- Prepare application in accordance with relevant criteria. The precise timing of the FFO announcement varies from year to year, but generally occurs in January, with final applications due approximately two months later.



Additional Federal Programs

Buildings Energy Efficiency Frontiers & Innovation Technologies "BENEFIT" (Office of Energy and Renewable Energy) ☐

Program Description

The BENEFIT program will invest in four topic areas including HVAC systems, roofing, building capacity / resilience, and lighting to further research, develop, and validate technologies with the potential to significantly advance building decarbonization

Program Type

Grant

Funding Amount

$30m

Max Award Amount

$2m

Availability

Available until expended

Eligible Applicants

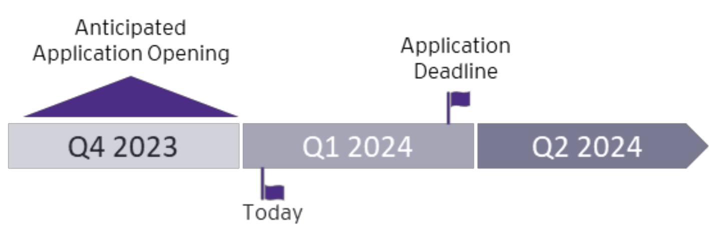
1. Institutions of higher education
2. For-profit entities
3. Nonprofit entities
4. State and local governmental entities and Indian tribes

Eligible Uses

- *Topic 1 - Heating, Ventilation, and Air Conditioning and Water Heating:* Technologies with improved materials, components, equipment design, and engineering, lower cost manufacturing processes, and easier installation.
- *Topic 2 - Innovative, Replicable, and Low-Cost Roof and Attic Retrofits:* Technologies for affordable and scalable roof and attic retrofits that improve energy efficiency and address air and water infiltration.
- *Topic 3 - Building Resilience and Capacity Constraints:* Novel approaches to maintain essential loads during blackouts and add power capacity to buildings without the need for major infrastructure upgrades; localized thermal management systems and thermally resilient building envelopes to provide cooling and overheating protection against extreme heat events.
- *Topic 4: Commercial Lighting Retrofit Advancements:* Low-cost, high-quality retrofit solutions for lagging sectors in energy-efficient lighting adoption (schools, certain commercial buildings).

Timeline and Next Steps

- *Prepare application in accordance with relevant criteria.*



Additional Federal Programs

Loan Guarantee Program (US DOE) ☐

Program Description

Under the Title 17 Clean Energy Financing Program, LPO can finance projects in the United States that support clean energy deployment and energy infrastructure reinvestment to reduce greenhouse gas emissions and air pollution. Title 17 was created by the Energy Policy Act of 2005 and has since been amended, most recently by the Infrastructure Investment and Jobs Act in 2021 and the Inflation Reduction Act in 2022.

Program Type

Loan

Funding Amount

$100bn

Max Award Amount

NA

Availability

Available until expended

Title 17 Clean Energy Finance Program: Project Categories

- Innovative Energy:
  - Financing for projects that deploy New or Significantly Improved Technology that is technically proven but not yet widely commercialized in the United States.
- Innovative Supply Chain:
  - Financing for projects that employ a New or Significantly Improved Technology in the manufacturing process for a qualifying clean energy technology or for projects that manufacture a New or Significantly Improved Technology.
- State Energy Financing Institution (SEFI)-Supported:
  - Financing for projects that support deployment of qualifying clean energy technology and receive meaningful financial support or credit enhancements from an entity within a state agency or financing authority.
- Energy Infrastructure Reinvestment (EIR):
  - Financing for projects that retool, repower, repurpose, or replace energy infrastructure that has ceased operations or upgrade operating energy infrastructure to avoid, reduce, utilize, or sequester air pollutants or greenhouse gas emissions.

Loan Structuring

- Through the Title 17 Clean Energy Financing Program, borrowers can access:
  - Direct loans from U.S. Treasury’s Federal Financing Bank (FFB) backed by 100% “full faith and credit” DOE guarantees, OR
  - DOE partial guarantees of commercial debt
- Interest Rate: For FFB loans backed by a DOE loan guarantee, the interest rate is: U.S. Treasury curve, plus a liquidity spread equal to “three-eighths” (0.375%), plus a risk-based charge:
  - The Treasury rate is fixed at the day or days the funds are drawn, according to loan tenor.
  - LPO may buy down the risk-based charge for certain projects.

Additional Federal Programs

Modified Accelerated Cost-Recovery System "MACRS" (IRS) ☐

Program Description

Under MACRS, businesses may recover investments in certain property through depreciation deductions. A number of renewable energy technologies are classified as five-year property (26 USC § 168(e)(3)(B)(vi)) under the MACRS, which refers to 26 USC § 48(a)(3)(A), often known as the energy investment tax credit or ITC to define eligible property

Program Type

Tax Deduction

Funding Amount

NA

Max Award Amount

NA

Availability

NA

Eligible Property

- a variety of solar-electric and solar-thermal technologies
- fuel cells and microturbines
- geothermal electric
- direct-use geothermal and geothermal heat pumps
- small wind (100 kW or less)
- combined heat and power (CHP)
- the provision which defines ITC technologies as eligible also adds the general term "wind" as an eligible technology, extending the five-year schedule to large wind facilities as well

Tax Refund Process

The University would depreciate the newly installed equipment using MACRS during the following years tax filings resulting in a lower taxable income. Under current law, the qualified equipment is allowed to be depreciated 20% each year until January 1, 2027.

*Program may be more relevant under a public private partnership where private developer is the tax owner of the underlying assets and may benefit from the associated tax depreciation.

Renewable Energy Sales and Use Tax Exemption

☐

Program Description

Sales tax exemption for equipment used to generate electricity using renewables. The tax exemption applies to labor and services related to the installation of the equipment, as well as to the sale of equipment and machinery. Eligible systems are those with a generating capacity of at least 1 kilowatt.

Program Type

Sales Tax Incentive

Funding Amount

50% of Sales and Use Tax

Max Award Amount

NA

Availability

Available until January 1, 2030

Eligible Machinery and Equipment

Category one (100% sales tax exemption):

- Renewable energy systems capable of generating at least 1kW of electricity using any of the following as the principal source of power:
  - Fuel cells.
  - Wind.
  - Biomass energy.
  - Tidal or wave energy.
  - Geothermal resources.
  - Technology that converts otherwise lost energy from exhaust.
- Solar energy systems capable of generating more than 500 kW AC of electricity.

Category two (50% sales tax exemption):

- Solar energy systems generating over 100 kW, up to 500 kW of electricity.

Tax Refund Process

In both categories, the buyer must pay sales tax to the contractor, and then apply for a refund directly from the Washington Department of Revenue.

The Washington Department of Revenue has an online application for category one and category two eligible equipment.

The applications are reviewed quarterly and refunds are disbursed following application approval. The applications need to be completed within 4 years of the sales and use tax payment.

Additional State & Local Programs

Climate Commitment Act (CCA) ☐

Program Description

Washington's Climate Commitment Act (CCA) created a cap-and-invest program that auctions off carbon allowances to covered businesses. The proceeds from these auctions are used to fund a Climate Investment Account (CIA) and Carbon Emission Reduction Account (CERA) that can provide funding to eligible projects that decrease emissions. Auction proceeds must be appropriated by the legislature.

Program Type

Grant

Funding Amount

NA

Max Award Amount

NA

Availability

NA

Accounts Funded by Cap-and-Invest Auctions

- Carbon Emissions Reduction Account (CERA) and its sub-accounts Climate Active Transportation Account (24% of CERA) and Climate Transit Programs Account (56% of CERA) focus on supporting projects that reduce emissions in the transportation sector.
- Climate Investment Account (CIA) and its sub-accounts Climate Commitment Account (75%) and Natural Climate Solutions Account (25%) provide for the administration of the CCA (max of 5%) and focus on supporting projects that support the energy transition.
- Air Quality & Health Disparities Improvement Account (AQHDIA) focuses on improving air quality in overburdened communities disproportionally impacted by air pollution.
- All accounts are subject to appropriations from the legislature
- A minimum of 35%, with a goal of 40%, of auction proceeds are to be used for projects that provide direct benefits to vulnerable populations within overburdened communities.
- Additionally, 10% of auction funds must be used of projects with Tribal support.

Clean Energy Fund (CEF)

☐

Program Description

Washington's CEF provides grants through various programs, including Building Electrification, Energy Retrofits for Public Buildings, Electrification of Transportation Systems, Grid Modernization, Research, Development and Demonstration, and Solar.

Program Type

Grant

Funding Amount

NA

Max Award Amount

NA

Availability

NA

CEF Programs

The CEF is run by the Washington State Department of Commerce and is overseen by the Energy and Climate Policy Advisory Committee (ECPAC) who reviews the historical structure and outcomes of CEF programs and developing recommendations for adjustments to the programs outlined below:

- **Building Electrification:** Funding for multifamily residential and commercial building owners and tenants to deploy and demonstrate grid-enabled, high-efficiency, all electric-buildings that reduce greenhouse gas emissions and accelerate the path to zero-energy.
- **Electrification of Transportation Systems:** This program provides grants to Washington State local governments and retail electric utilities for charging infrastructure.
- **Grants to Non-profit Lenders:** Revolving Loan Fund grants show that a modest public investment can promote private investment. This drives economic activity and jobs for Washingtonians and helps our state lead the nation in energy efficiency.
- **Grid Modernization:** Funding for public and private electrical utilities serving Washington customers. Utilities can partner with other public and private sector research organizations and businesses to apply for funding.
- **Research, Development and Demonstration:** This program is to provide match for federal and non-state funds for strategic research and development projects on new and emerging technologies.
- **Rural Clean Energy Innovation:** Support for a wide range of projects that enhance clean energy including, but not limited to; dairy digesters, renewable energy, energy efficiency and resilience.
- **Solar Deployment:** The Solar Deployment program supports the development of projects that deliver environmental and economic benefits to Washington communities.

Grant applications and funding timelines vary by program with additional program specific details available on the Washington State Department of Commerce's CEF webpage.

Deep Retrofit Pay-for-Performance ☐

Program Description

Pay for performance program that creates a baseline for expected electricity consumption and provides an incentive for reductions from that baseline. All measures are allowed for usage reductions.

Program Type

Rebate

Funding Amount

$0.08 - $0.18/kWh

Max Award Amount

NA

Availability

NA

Deep Retrofit Pay for Performance Program

- The Deep Retrofit Pay for Performance (P4P) program is for buildings >50,000 ft2 that have identified >15% electricity savings compared to baseline operation
- Program must be applied for before implementing electricity reduction projects
- Buildings must have stable electricity consumption to create a baseline and have an interval meter
- The program can provide incentives for capital and non-capital measures that decrease electricity consumption Incentives will not be paid for fuel switching

Incentive Payment Structures

- P4P participants are not eligible for other incentives if enrolled into P4P
- Three-Year Performance Period (Persistence Path) incentives will be paid at $0.08 per kWh saved compared to the baseline per year for 3 years
- Five-Year Performance Period (Tiered Path) pays $0.18 per kWh saved compared to the baseline; however, the baseline is reset every year, so only incremental savings are incentivized each year. The total period for this program is 5 years. If program savings are greater than 15% savings compared to baseline, the incentive increases up to $0.34 per kWh for savings greater than 50% of baseline.

Energy Project Manager/ Project Development Incentive ☐

Program Description

Additional funding available beyond other rebates to cover costs associated with applying for rebates

Program Type

Rebate

Funding Amount

$0.025/kWh reduction

Max Award Amount

NA

Availability

NA

Energy Project Manager Supplemental Incentive

- Site must designate an energy project manager and enroll in a comprehensive savings program, which must contain >200,000 kWh of identified savings and include one non-lighting project
- Energy reduction projects will receive an additional $0.025 per kWh, up to a cap of $150,000 per 2-year period
- Incentives can exceed the 70% limit of project costs otherwise in place, but cannot exceed 100%
- Program must be applied for before implementing electricity reduction projects

Project Development Incentive

- Energy reduction projects will receive an additional $0.025 per kWh for all projects implemented and all documents received by Seattle City Light by June 30, 2024
- Incentives can exceed the 70% limit of project costs otherwise in place, but cannot exceed 100%
- Incentive rates after June 30, 2024 will be determined in spring 2024

Existing building commissioning ☐

Program Description

Improvement of control systems programming to reduce energy consumption. Available as both a retro-commissioning and monitoring-based commissioning approach.

Program Type

Rebate

Funding Amount

Up to 100% of commissioning costs ($0.35/ft2 plus $0.05/kWh and $0.80/therm reduction)

Max Award Amount

NA

Availability

NA

Retro-Commissioning Program

- Buildings that are >50,000 ft2 and have a direct digital control (DDC) control system are eligible for this program
- There are 3 phases and incentives: up to $5,000 incentive for the assessment phase (up to 100% of assessment costs); $0.35/ft2 for implementation (up to 75% of commissioning provider costs); and $0.05/kWh and $0.80/therm first-year performance incentive (if savings >7% for electricity / >10% natural gas).
- One-time initiative to identify controls opportunities for energy reductions
- Program must be applied for before implementing electricity reduction projects

Monitoring-based Commissioning Program

- Same incentives and requirements as above
- Requires continuous fault detection and diagnostics (FDD) system to identify faults in the systems to reduce energy consumption

Utility Energy Efficiency Programs

Early Adopter Incentive

☐

Program Description

WA Clean Building Standard require buildings to meet an energy use intensity (EUI) target by June 2026-2028 deadlines for your respective building size, depending on size. Early Adopter Incentives are available to retrofit buildings to meet these EUI targets early.

Program Type

Rebate

Funding Amount

$0.85/ft2

Max Award Amount

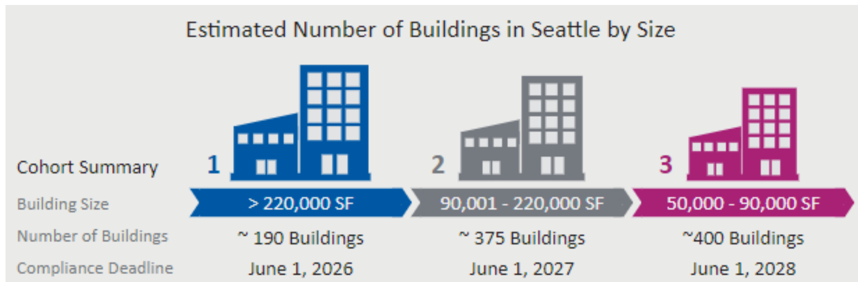
NA

Availability

$75m limit of funding

Early Adopter Incentive

- Requirements to be a Tier 1 building (commercial buildings > 50,000 ft2) and 15 points above EUI requirements
- Buildings must be brough into full compliance with the Clean Building Standard for a **minimum of 12 months before the compliance dates** proving the EUI reduction
- Program must be applied for through the Clean Buildings Portal to the Department of Commerce



Other Incentives ☐

Program Description

Seattle City Light provides additional incentives in new construction and retrofit programs.

Program Type

Rebate

Funding Amount

$0.27/kWh

Max Award Amount

NA

Availability

NA

Seattle City Light Incentive Program

- As of the 2022 Incentive Changes, Seattle City Light offers incentives for Heat Pump Water Heaters (HPWH) retrofits to existing commercial and industrial buildings.
- For hybrid heat pump water heaters ≤120 gallons, The HPWH incentives are for High COP and CO2 systems at $350 and $500, respectively.
- Additionally, hybrid heat pump water heaters ≤120 gallons, Seattle City Light provides instant rebates up to $600 per water heater through the wholesale distribution channel for NEEA Tier 1-4 qualifying products in commercial applications
- Any Heat Pump Water Heater greater than 120 gallons meeting NEEA's Advanced Water Heating Specification 8.0 is eligible for incentive funding at $0.24 per kWh.
- Chiller plant upgrades are also eligible for funding at $0.27 per kWh as a custom measure if the project includes controls, process load chillers, heat recovery, and/or reconfiguration.

5.5 Hot Water Testing Plan

Hot Water Testing Plan

Purpose

To establish the hot water supply temperature required at existing Hot Water heating loads within each building. Lower entering water temperatures enhance the efficiency of the central hot water generation equipment and impact the scope of hot water equipment conversion and replacement. The testing is intended to identify special spaces or equipment that may drive the hot water supply temperature, e.g. perimeter offices with little internal gain, etc. This operational test is intended to continue for an extended duration during cold weather, with the intent of identifying the lowest possible operating setpoint.

Scope

The scope of the testing plan is a selection of campus buildings end-use hot water heating loads. The Plan is intended to test each heating hot water hydronic loop within the building being considered. The end-use heating loads are considered as the following:

- Hot Water Heating Coils installed in Air Handling Units
- Hot Water Terminal Loads: These are small unitary loads distributed throughout the facility. Examples include but are not limited to: Variable Air Volume (VAV) terminal unit reheat coils, 4-pipe fan coil units, 4-pipe active chilled beams, unit heaters, cabinet unit heaters, etc.
- Hot Water Radiant Loads: Perimeter fin tube, radiant ceiling panels, radiant sails, etc.
- Hot Water Process Loads (if any)

Procedure for Buildings with full BAS

The following steps shall be implemented for testing in each building with Steam-to-Hot Water heat exchangers:

Step 1: Pre-Test Data Verification & User Interface Setup

1. Verify trend setup for all required points
2. Verify all BAS panels in affected buildings are
    a. operational and all systems normal
    b. all needed BAS graphics are visible and points active
3. Verify Outdoor air conditions:
    a. Outside Air Temperature (OAT) in degrees Fahrenheit
    b. Outside Air Relative Humidity (OARH) in percent relative humidity
4. Verify current operating hot water supply setpoint and supply temperature for each steam-to-hot water heat exchanger.
5. Verify the building Domestic Hot Water (DHW) supply temperature
6. Verify locations in the building that already have space temperature variances from setpoint (vestibules, stairwell and areas like this are common).

7. Notify Building Coordinators that testing will occur. Building Coordinators will log "cold calls" for review, although BAS trends will be the primary means of evaluation of the revised setpoints.

Step 2: Adjust Heat Exchanger Hot Water Supply Reset Schedule

1. For each steam-to-hot water heat exchanger:
    a. Adjust the Outside Air Temperature and/or Hot Water Supply Temperature Reset Schedule as determined between the UW and AEI team. The reset schedule shall be modified for one heat exchanger at a time; and the system shall be allowed to come to steady-state before the temperature for the next heat exchanger is altered.
    b. All buildings under DDC system control have had their maximum hot water supply temperature reduced to 160F or less. This test will attempt to reduce the temperature below 160F in two increments of 5F each (to 150F). The buildings listed in the table on page 6 are buildings whose original design temperature exceeded 160F. This list may be revised upon further discussion with UW.
    c. The BAS shall record the following Trend data:
        i. Time
        ii. OAT
        iii. OAH
        iv. Building Condensate Return Meter flow rate
        v. Steam Valve(s) position
        vi. Heat Exchanger Heating Hot Water Supply Temperature
        vii. Heat Exchanger Heating Hot Water Return Temperature
        viii. Pump Speed
        ix. Heating Hot water flow rate, if available
        x. Hydronic system differential pressure, if available
        xi. If the loop serves air handler heating hot water coils, the trend data shall include:
            1. Control Valve Position
            2. Heating Coil leaving air temperature
            3. Unit Discharge air temperature
            4. Coil Hot Water Supply Temperature, if available
            5. Coil Hot Water Return Temperature, if available
        xii. Sample of Terminal hot water control valve positions. Provide a representative number of VAV Reheat, Unit Heaters, fan coils and other terminal units.
        xiii. Provide space temperature of terminal unit control valves being monitored.
    d. The Building Operator shall monitor building conditions to determine if there are potential issues with the lower supply water temperature.
    e. Once all the steam-to-hot water heat exchanger reset schedules have been modified, the trend data will be reviewed. The UW and AEI team will assess the potential for

    additional modifications to the Steam-to-Hot Water heat exchanger supply temperature setpoint.
    f. If the end-use loads are not satisfied, the Building operator shall revert the supply water temperature reset schedule to the previous values.
    g. The testing and trending shall operate continuously, and the Building Operator shall adjust the hot water supply setpoint as needed to meet the building loads.
2. Trend Data
    a. The Trend Data for each heat exchanger and associated hot water loads shall be exported as a delimited text file for review and analysis.

<u>Procedure for Pneumatic Buildings or Limited (no terminal level) BAS</u>

The following steps shall be implemented for testing in each building with Steam-to-Hot Water heat exchangers:

Step 1: Pre-Test Data Verification & User Interface Setup

1. Select areas to be monitored including spaces to be monitored (favoring perimeter corner areas and high glazing areas) and AHU's to be monitored
    a. Locate IoT monitoring devices in spaces identified and in AHU heating coil discharge area (or unit discharge duct)
    b. Verify cloud communication with IoT devices
2. Verify Outdoor air conditions:
    a. Outside Air Temperature (OAT) in degrees Fahrenheit
    b. Outside Air Relative Humidity (OARH) in percent relative humidity
3. Verify current operating hot water supply setpoint and supply temperature for each steam-to-hot water heat exchanger.
4. Verify the building Domestic Hot Water (DHW) supply temperature
5. Verify locations in the building that already have space temperature variances from setpoint (vestibules, stairwell and areas like this are common).
6. Notify Building Coordinators that testing will occur. Building Coordinators will log "cold calls" for review, although BAS trends will be the primary means of evaluation of the revised setpoints.

Step 2: Adjust Heat Exchanger Hot Water Supply Reset Schedule

3. For each steam-to-hot water heat exchanger:
    a. Adjust the Outside Air Temperature and/or Hot Water Supply Temperature Reset Schedule as determined between the UW and AEI team. The reset schedule shall be modified for one heat exchanger at a time; and the system shall be allowed to come to steady-state before the temperature for the next heat exchanger is altered.
    b. Most buildings that still have terminal level pneumatic control have had their maximum hot water supply temperature reduced to 160F. This test will attempt to reduce the temperature below 160F in two increments of 5F each (to 150F). The buildings listed in

the table on page 6 are buildings whose original design temperature exceeded 160F. This list may be revised upon further discussion with UW. (Hutchinson and Anderson Halls are included in the list in order to attempt to highlight zones than are most sensitive to reduced supply temperature.)

   c. The IoT devices shall record the following Trend data:
      i. Time
      ii. OAT (if available)
      iii. Space temperature or AHU discharge temperature.
   d. The Building Operator shall monitor building conditions to determine if there are potential issues with the lower supply water temperature.
   e. Once all the steam-to-hot water heat exchanger reset schedules have been modified, the IoT data will be reviewed. The UW and AEI team will assess the potential for additional modifications to the Steam-to-Hot Water heat exchanger supply temperature setpoint.
   f. If the end-use loads are not satisfied, the Building operator shall revert the supply water temperature reset schedule to the previous values.
   g. The testing and trending shall operate continuously, and the Building Operator shall adjust the hot water supply setpoint as needed to meet the building loads.
4. Trend Data
   a. The Trend Data from each IoT device shall be downloaded from the cloud for review and analysis.
5. Possible IoT devices:
   a. https://www.amazon.com/Govee-Temperature-H5179-Thermometer-Notification/dp/B0C39TSV2W/ref=sr_1_4?crid=1EBQZWYZ2Q5Y4&amp=undefined&keywords=govee%2Btemperature%2Bsensor%2B6%2Bpack&qid=1701384067&sprefix=govee%2Btemp%2Caps%2C159&sr=8-4&th=1
   b. https://www.amazon.com/Thermometer-Hygrometer-Temperature-Notification-Greenhouse/dp/B0B4RXTFTG/ref=sr_1_55?crid=MM3MKX512HST&keywords=iot+thermometer+wifi&qid=1701384910&sprefix=iot+%2Caps%2C136&sr=8-55

Tier 1 Pneumatic (181 -212 design)	TIER 2 DDC (170 -180 design)	TIER 3 (150-169)
Bagley Hall	Allen Center for CSE (3991)	
Atmospheric Sciences (ATG)	EE (1008)	
Bloedel Hall	Foege (4057&4058)	
Hutchinson Hall	Suzzallo (1193)	
Hitchcock		

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