# WASHINGTON CAPITOL CAMPUS

# DECARBONIZATION REPORT

DES
Washington State
DEPARTMENT OF
ENTERPRISE SERVICES

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# **WASHINGTON STATE CAPITOL CAMPUS** DECARBONIZATION REPORT

## ACKNOWLEDGEMENTS

The authors would like to thank the Washington State Department of Enterprise Services, and specifically the Facility Professional Services and Facility Steering Committee, as well as the Washington State Capitol Campus Buildings & Grounds Department. Numerous individuals supported this effort and provided the feedback that helped shape this plan. Thank you!

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# 1: EXECUTIVE SUMMARY

# Building a Resilient, Low-Carbon Future for Washington State's Capitol Campus

Washington State is taking decisive action to modernize its infrastructure and prepare for a decarbonized future. The Capitol Campus in Olympia, home to the core of state government operations, currently relies on a 100-year-old steam system that is inefficient, outdated, and increasingly at risk of failure. Recognizing the urgency of both infrastructure renewal and carbon emissions reduction, the Washington State Department of Enterprise Services (DES) partnered with Millig Design Build to create a comprehensive Decarbonization Master Plan for the Capitol Campus.

This plan responds directly to two critical pieces of state legislation: the Clean Buildings Performance Standard (CBPS) (House Bill 1257 and Senate Bill 5277) and the State District Energy System Decarbonization requirement (House Bill 1390). These laws mandate the reduction of energy use and greenhouse gas emissions from public buildings and campus-scale heating systems, commonly referred to as district energy systems.

The result is a forward-looking roadmap to phase out fossil fuel use, improve energy efficiency, and ensure continued reliable operations of critical government facilities.

## Why This Plan Matters

The Capitol Campus's central plant equipment is located in the 100-year-old Powerhouse building which serves nearly two million square feet of state facilities and plays a central role in Washington's democratic process. This energy infrastructure is:

- **Aging and vulnerable:** Some components date back to 1920, with growing risk of failure.
- **Inefficient:** The current steam-based heating system is highly inefficient with only a fraction of the energy consumed at the Powerhouse going to heating and cooling campus buildings.
- **Non-compliant:** Without action, the campus faces over $1.17 million in fines by 2027 for failing to meet required energy performance targets.
- **At risk:** The Powerhouse houses critical boilers and chillers and is located in a landslide/flood hazard zone.

This moment presents a rare opportunity: Washington can both solve these infrastructure challenges and lead by example in complying with statutory requirements.

## The Vision: A Modern, All-Electric Energy System

The project team evaluated four possible strategies for replacing the existing system. After extensive modeling, stakeholder engagement, and cost-benefit analysis, the preferred path forward is a district energy system based on highly efficient electric heat pumps. This fifth-generation design will:

- Replace fossil fuels with electric-powered heating and cooling
- Reuse energy by capturing and redistributing waste heat between buildings
- Phase construction to minimize disruption and allow for maximum flexibility in budgeting
- Improve reliability with built-in system redundancy
- Avoid the need for a costly new electrical substation

### The Process: Bottom-Up Modeling & Rigorous Engineering

Rather than start with top-down assumptions, the project team began with detailed building assessments, creating highly accurate energy models for each of the major buildings on campus. These models simulate energy performance during every hour of the year (8,760-hourly load profiles) and reflect:

- Construction types and characteristics
- Equipment age, condition, and efficiency
- Real-time occupancy patterns
- Actual utility data from newly installed submeters

Building models were then aggregated into a full "digital clone" of the Capitol Campus, allowing for iterative scenario testing. This process revealed the potential for significant heat recovery due to simultaneous heating and cooling loads within and across buildings.

***Key findings from this phase:***

- Much of the campus heating needs could be met using heat recovered from cooling processes elsewhere on the campus.
- Energy efficiency measures can reduce electrical load enough to avoid a new substation.
- A heat pump-based option is the optimal solution for maximizing operational cost savings and minimizing first costs.

### The Solution: A Hybrid Heat Pump-Based District Energy System

The team studied four strategy alternatives:

1. Central electric boilers
2. Central four-pipe hydronic heat pump plant
3. Two-pipe ambient temperature loop with distributed hydronic heat pump plants
4. Eliminate district energy system with decentralized HVAC systems

Each was modeled for energy use, emissions, constructability, cost, llife cycle value, compliance, and risk. The resulting analysis showed that the optimal solution is a hybrid strategy that combines the best elements of strategies two and three:

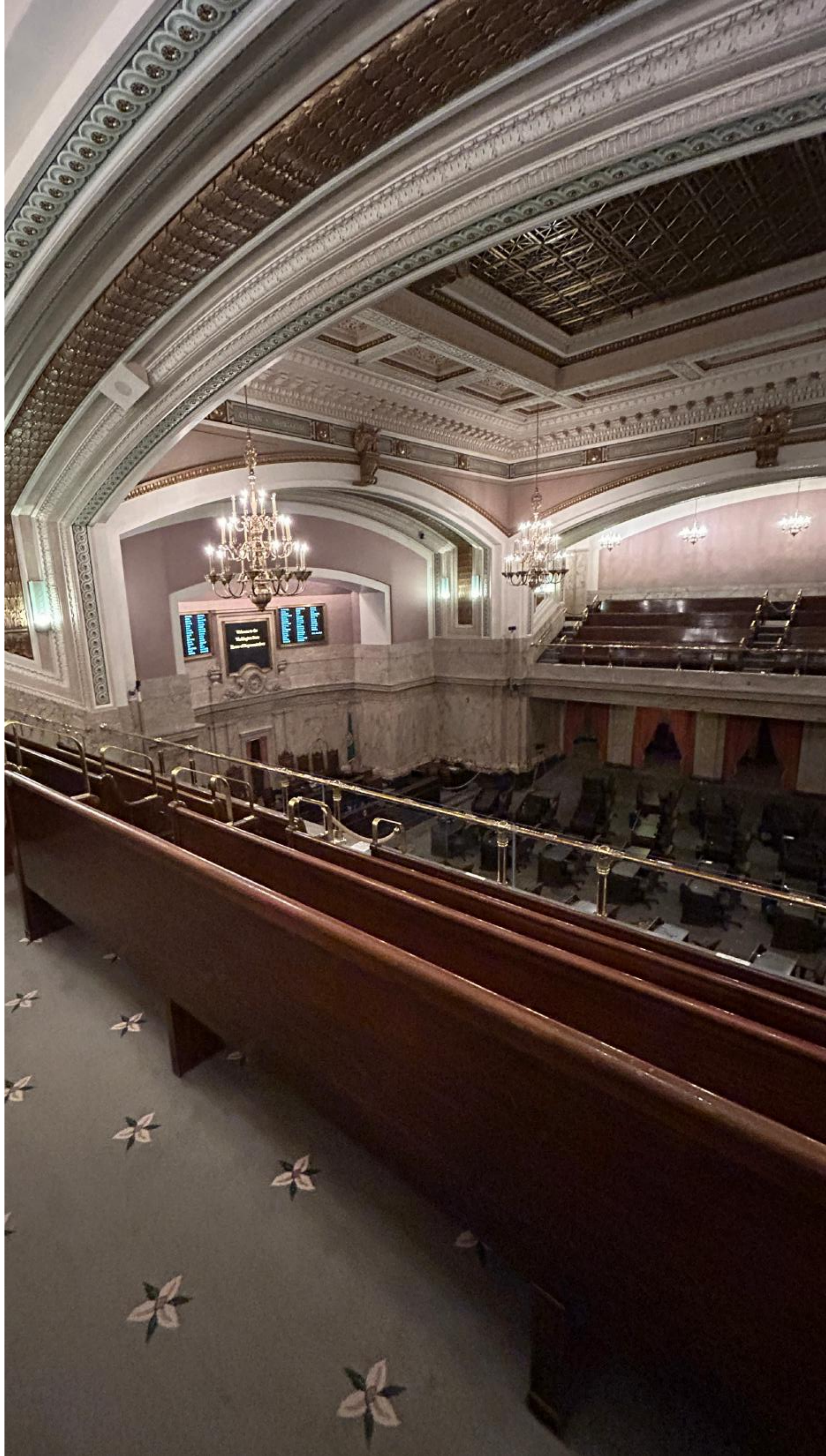
- **East Campus:** A new two-pipe Ambient Temperature Loop (ATL) connected to building-level heat pump plants in Office Building 2, Highways-Licenses Building, Employment Security Building, and State Archives.
- **West Campus:** A centralized four-pipe hydronic heat pump plant providing hot and chilled water to the historic buildings with limited mechanical space located on West Campus.
- **Campus-wide interconnection:** The systems will be tied together to share excess heat, boosting energy efficiency and resilience.

### Financial Analysis

The Lifecycle Cost Analysis (LCCA) showed that the Two-Pipe Ambient Temperature Loop (ATL) with Distributed Hydronic Heat Pump is the lowest life-cycle cost solution. Ultimately, the ATL option is not feasible in West Campus buildings due to insufficient mechanical room space within these buildings. For this reason, a hybrid of the ATL with Distributed Heat Pumps for East Campus and a Central Hydronic Heat Pump Plant for West Campus yields the feasible solution with the lowest life cycle cost. This LCCA analysis includes:

- Capital costs of $130 million to $180 million total for the hybrid solution
- Minimized or avoided costs of an electrical substation expansion, $1.17 million in penalties, and $759,314 per year in operating costs
- Maintenance and component replacement cycles over 30 years

Compared with the $155 million to $220 million cost of decentralized or electric boiler options, the hybrid solution provides the best balance of upfront investment,



## Key Benefits & Impact of Implementation

### 1. Improved Resilience and Reliability

- Eliminates systems that are well past end-of-life and reduces operational risks
- Modular, phased approach supports ongoing state operations
- New system components are distributed and redundant
- Allows future integration of new technologies like geothermal wells and additional building connections

### 2. Energy and Cost Savings

- Reduces energy use intensity (EUI) by 53% to meet Clean Buildings Performance Standards (CBPS)
- Lowers operating costs by approximately $759,314 annually
- Avoids more than $1.17 million in fines for not meeting CBPS

### 3. Carbon Emissions Reduction

- Eliminates on-site fossil fuel use (Scope 1 emissions)
- Reduces energy demand and improves overall efficiency
- Aligns with PSE's plans to decarbonize the electrical grid serving the Capitol Campus by 2030

### 4. Leadership by Example

- Establishes Washington as a national model for campus-scale decarbonization
- Creates a replicable process that other agencies and institutions can follow

## Implementation Timeline

The project will be implemented over multiple biennia, with full construction expected to begin in **2027** and final completion targeted for **2034**. The plan is designed to:

- Begin with energy efficiency upgrades and heat pump installations on the East Campus
- Transition to constructing the new West Campus plant and connecting remaining buildings
- Maintain continuous heating and cooling service during construction

## The Result: A Blueprint for Operational Resilience & Climate Leadership

This Capitol Campus Decarbonization Plan is more than an infrastructure project. It is:

- A legally compliant response to mandates from HB 1257 and HB 1390
- A technically rigorous solution rooted in real-world modeling
- A fiscally responsible investment with the lowest llife cycle cost
- A blueprint for how state campuses across the country can decarbonize while improving reliability

DES and the project team have developed not just a plan, but a flexible implementation framework. With phased deployment, stakeholder alignment, and a validated path to compliance, this strategy ensures the Capitol Campus will continue to serve Washington State for decades in a manner that is resilient, efficient, and sustainable.

# 2: INTRODUCTION

# Project Background

The Washington State Department of Enterprise Services (DES) owns and operates nearly all of the facilities on the State Capitol Campus, and is responsible for managing its carbon emissions and making long-term investments in its facilities.

Ten major buildings on campus are currently served by a central steam system, and six buildings on the west side of campus are served by a central chilled water system. The cooling plant and natural gas-fired boilers that provide chilled water and steam to the campus-wide distribution network are located in a building on the far western edge of campus called the Powerhouse.

Major changes are required to improve the central utility systems on the Capitol Campus for three primary reasons:

- **Systems age and increasing risk of failure:** Some components of the existing system are over a century old, and others are well past their expected life span. This puts the campus at an increased risk for a catastrophic failure, which would impede critical government operations.
- **Powerhouse flood & landslide risk:** The campus boilers and chillers cannot remain in their current location because of the risk of landslide and flood at the existing Powerhouse location.
- **Decarbonization and energy efficiency requirements:** The State is a national leader in climate action and the environment. In May 2023, Washington passed House Bill 1390, which requires state-owned district energy systems, including the Capitol Campus, to develop a decarbonization plan to:
    - ○ Replace fossil fuels in the existing heating plant
    - ○ Identify opportunities to expand access to the district energy system after decarbonization
    - ○ Identify sources and uses of waste heat and cooling
    - ○ Implement conservation measures at buildings across the campus to meet facility energy use intensity targets.

In the Fall of 2023, DES engaged with Millig Design Build on a nearly two year effort to produce a Decarbonization Master Plan to identify the preferred strategy and overall costs to end the use of fossil fuels for heating the Capitol Campus.

### Key Analysis Criteria

DES and the project team used the following desired outcomes as the framework for this analysis:

- Eliminate site Scope 1 fossil fuel carbon emissions
- Minimize site Scope 2 electrical carbon emissions
- Eliminate central plant equipment from the Powerhouse
- Minimize the impact of implementation on the operation of campus facilities
- Minimize the need to expand or build an additional electrical substation
- The solution must be practical, cost-effective, & maintainable by DES campus staff

**SCOPE 1 EMISSIONS**
Greenhouse gases that an organization emits from sources it owns or controls directly. For the Washington State Capitol Campus, the primary source of Scope 1 emissions is natural gas burned to generate heat at the Powerhouse.

**SCOPE 2 EMISSIONS**
Greenhouse gases that an organization indirectly causes to be emitted from off-site sources that the organization does not control. For the Washington State Capitol Campus, the primary source of Scope 2 emissions is electricity supplied by the local utility generated by fossil fuels.

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# District Energy System Master Planning Process

The project team's approach to this decarbonization planning process included the following major phases:

1. Pre-Plan
2. Building-Level Modeling & Analysis
3. District Energy Balancing
4. Decarbonization Plan Development
5. Decarbonization Report

A unique aspect of the engineering approach was the rigorous analysis performed during **Building-Level Modeling & Analysis** and **District Energy Balancing** phases before the development of the central system decarbonization plan.

Traditional master planning approaches omit these two foundational steps altogether, skipping straight to plan development for central systems, while ignoring vital building-level energy and load-reduction strategies. This, unfortunately, requires using rule-of-thumb assumptions for building cooling and heating loads, leaving the plan inaccurate and limiting its usefulness in the future as it cannot easily be updated to evolve with inevitable changes in program needs or available technologies.

For this decarbonization planning effort, however, DES's engineering partner, Millig Design Build, designed a process with the understanding that things will inevitably change in the coming years during plan implementation.

Conducting this rigorous analysis at the building-level, in addition to the district energy system-level, is the foundation of a comprehensive and adaptable plan that can adapt to future changes through future updates to the energy models with new scenarios.

The result is a living set of computer models and documents that can be updated over the next 15 years throughout implementation and continue to provide valuable information for future decision making.

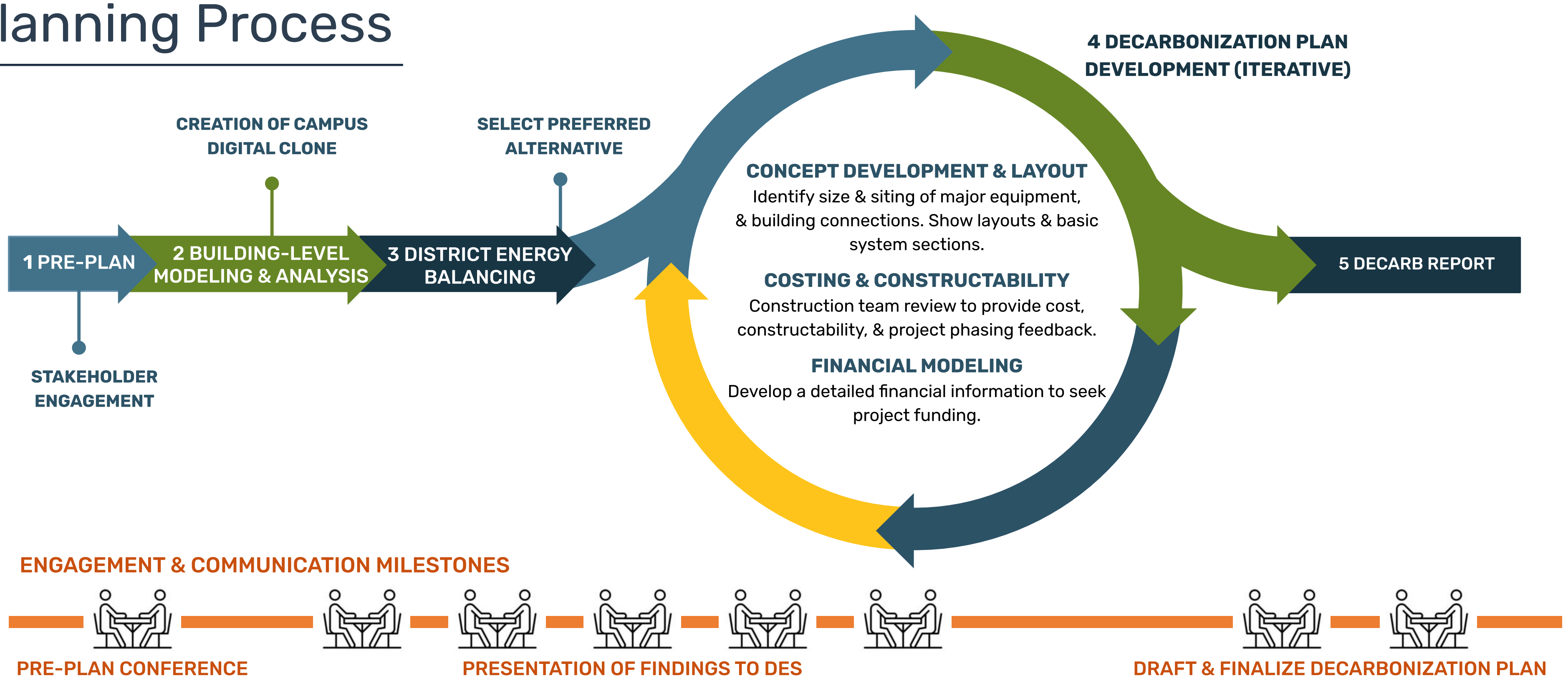


**Diagram 2.1:** An overview of the development process of this Decarbonization Report, discussed further on following pages.

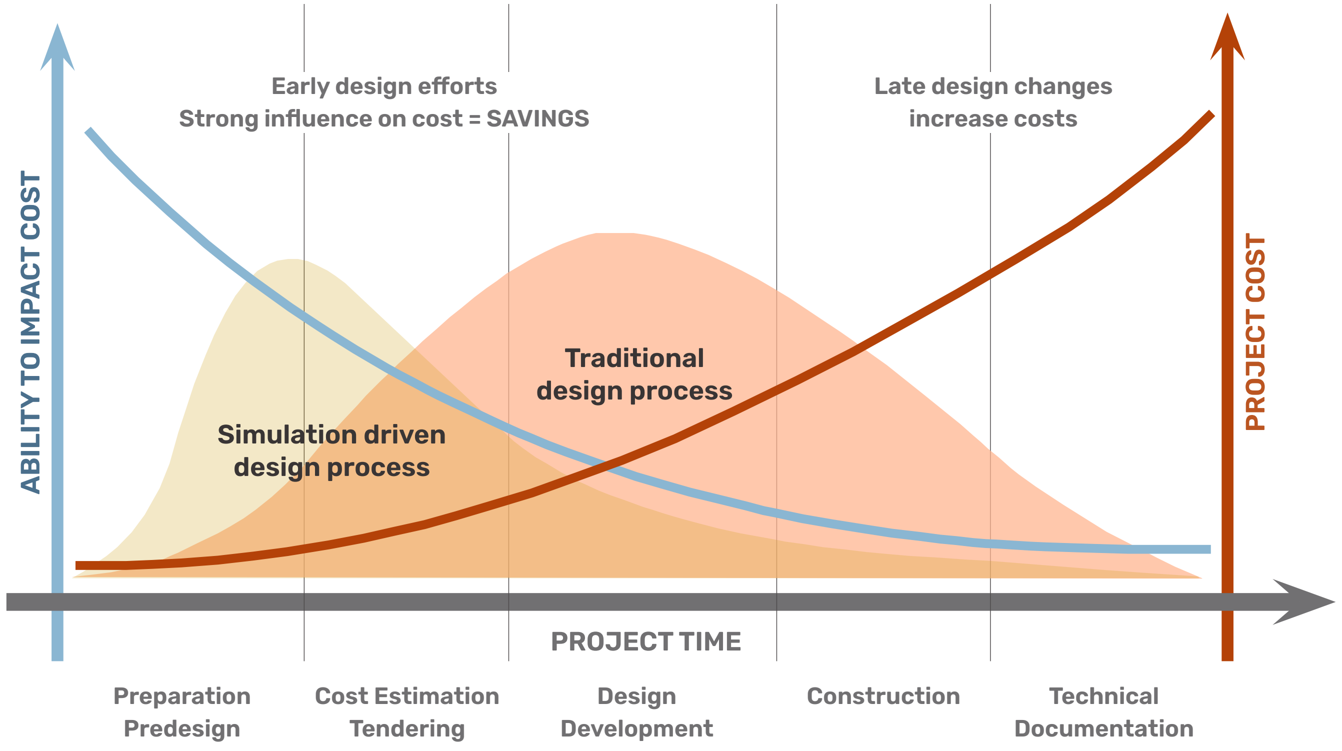


**Diagram 2.2:** The National Renewable Energy Laboratory found that a modeling-driven early design process leads to a drastic reduction in overall project implementation costs.

# 1 Pre-Plan Phase

## Pre-Plan Conference

Before beginning any engineering, DES and Millig Design Build had to establish:

- The project team and stakeholders, and their role in the process
- The scope, requirements, & goals
- Major milestones in the development process

To this end, Millig Design Build held a Pre-Plan Conference, which was attended by a wide array of stakeholders, including the DES planning group, Buildings & Grounds (the department that maintains the facilities on the Capitol Campus), policy advisors, marketing and public relations staff, and building managers.

During this all-day event, the project requirements, legislative mandate, the scope, and process of the study were discussed, as well as lessons learned from past similar efforts. Each stakeholder had the opportunity to communicate their top priorities for the project and their biggest concerns.

The group also walked the campus and inspected the Powerhouse and systems that serve other key facilities. The team used this workshop to generate a Team Charter and a Responsibility Matrix.

The result was a framework for decision-making organized around an existing DES body called the Capitol Campus Facilities Steering Committee (FSC), focused on deep engagement with key stakeholders.

## Building and District Energy System Assessment

The first technical effort was for Millig Design Build's team to physically walk through all the buildings and gather data for each facility. That included assessing the mechanical and electrical infrastructure for its type, age, condition, and operating characteristics. It also included amassing thousands of pages of building plans from over a century of construction and a detailed review of the campus' existing digital controls system.

> The Facilities Steering Committee (FSC) aligns direction and decisions across divisions that support facility work. Members include leaders and experts in buildings and grounds, security, risk management, facility planning and project delivery, real estate, communications, legislative affairs, finance, and more.

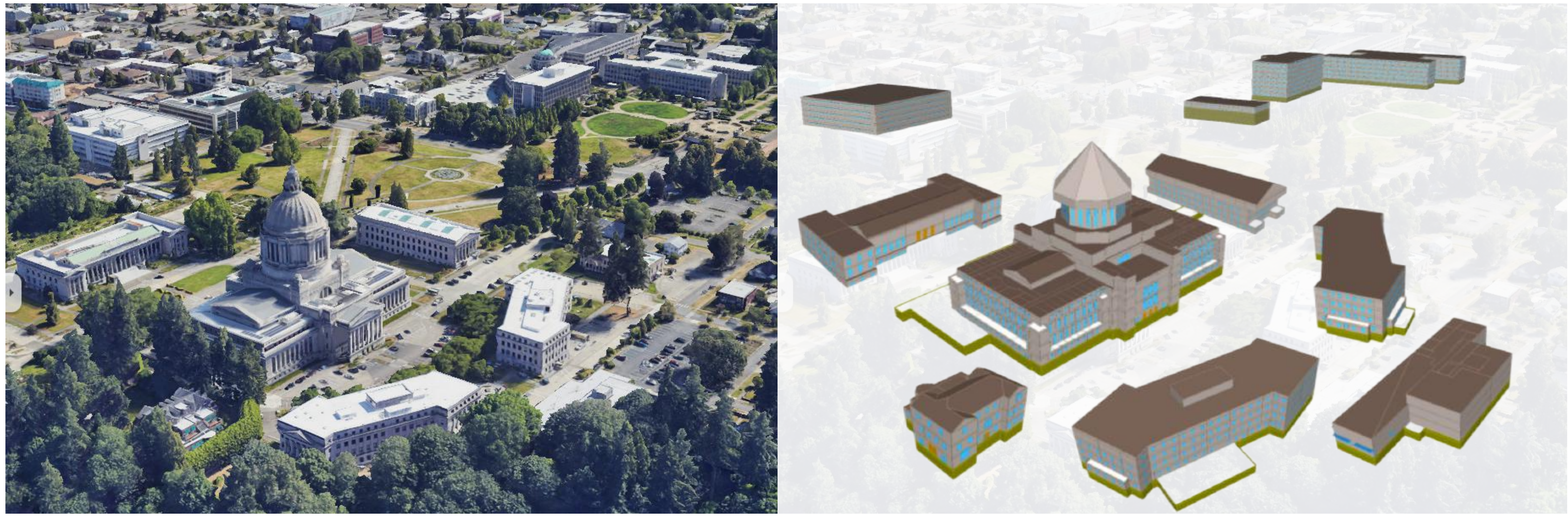


**Diagram 2.3:** Aerial and 3D rendering

# 2 Building-Level Modeling & Analysis

## Creating a Digital Clone of the Campus

Using detailed information obtained during the system assessment, Millig's team built an 8,760-hour computer simulation of each building, incorporating each building's physical characteristics and construction type, HVAC systems and operational data, occupancy data, and average annual local weather data. Each model was closely calibrated to the building's actual utility data, obtained from newly installed campus-wide submeters, to confirm its accuracy.

These detailed models could then be mined for information about the heating, cooling, and electrical loads of the existing buildings, and also serve as the basis for accurately quantifying the impact of load reduction and heat recovery strategies.

## Building-Level Upgrade Analysis

With the baseline building models complete, Millig's team documented all potential energy conservation, load reduction, and heat recovery strategies for each building. These measures were analyzed to minimize heating and electrical loads while maximizing the heat recovery potential through simultaneous heating and cooling, and for cost-effectiveness.

Each cost-effective measure was modeled to quantify its energy-saving potential. This produced new, optimized hourly load profiles for each building to be used in the District Energy Balancing analysis phase.

# 3 District Energy Balancing

## District-Level Analysis

District Energy Balancing uses the diversity of energy load profiles and building types to cost-effectively optimize district energy use by balancing energy consumption and production, mainly through sharing heat between facilities.

In this exercise, Millig Design Build analyzed the thermal needs of individual buildings and then consolidated all the individual building loads to establish the hour-by-hour thermal requirements of the district system as a whole.

The computer models were used to refine design concepts and determine the impact and outcomes of several different strategies for decarbonization. Cost estimates were developed for each strategy to comparatively analyze the financials of the different options.

## FSC Presentations

The project team scheduled a series of meetings with the Facilities Steering Committee to inform, discuss, and receive feedback about each step of the engineering analysis.

The FSC presentations were designed to build upon each other to ensure a strong understanding of the existing systems, the benefits and drawbacks of all potential decarbonization strategies, the results of district energy balancing, and the recommended alternative.

# 4 Decarbonization Plan Development

## Conceptual Development & Layout of the Preferred Alternative

With the Preferred Alternative selected, the Millig team then set about determining and showing how to implement the decarbonization solution in each building and at the district energy level. We considered cost, constructability, preliminary equipment sizing, system selection, redundancy, and resiliency to develop the scope of work and how each system will be implemented in each building.

## Adjustments to the Preferred Alternative

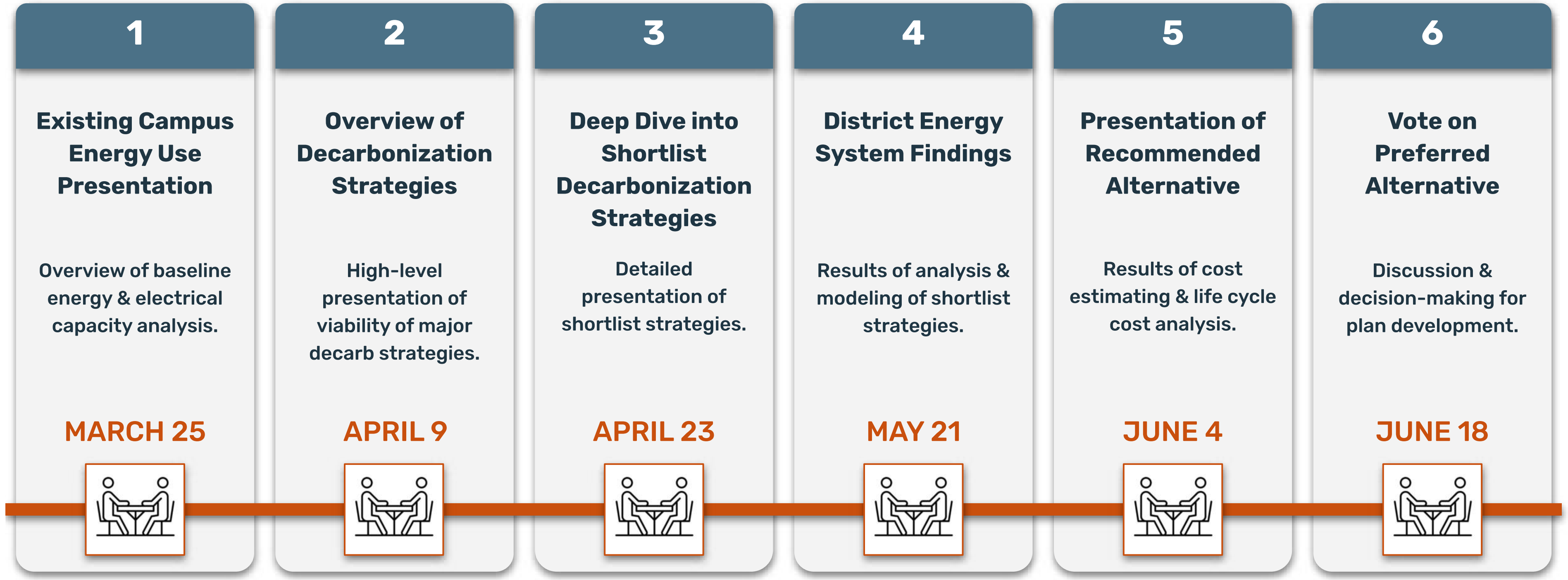
During this process, the project team found that the Preferred Alternative selected by the FSC, while conceptually optimal across the entire campus, was not practically feasible in several buildings on the West Campus. The specific physical characteristics of the West Campus meant that elements of the second-place strategy would need to be incorporated into the final solution. See Sections 8, 9, and 10 for complete details.

The team completed the Decarbonization Plan Development process by finalizing the energy and carbon emissions performance and cost estimates for the details of the final solution. The computer energy model was updated, and equipment sizing was revised. Finally, the team developed the phased implementation plan and finalized all project financials.

# 5 Decarbonization Report

## Drafting the Report

A comprehensive planning effort is only as valuable as its ability to successfully communicate the details of the project to all stakeholders with varying degrees of technical expertise. The following report sets out to achieve this goal by systematically building the knowledge base of the reader, to demonstrate both the need and the opportunity of making this plan a reality over the next decade.



| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| **Existing Campus Energy Use Presentation** | **Overview of Decarbonization Strategies** | **Deep Dive into Shortlist Decarbonization Strategies** | **District Energy System Findings** | **Presentation of Recommended Alternative** | **Vote on Preferred Alternative** |
| Overview of baseline energy & electrical capacity analysis. | High-level presentation of viability of major decarb strategies. | Detailed presentation of shortlist strategies. | Results of analysis & modeling of shortlist strategies. | Results of cost estimating & life cycle cost analysis. | Discussion & decision-making for plan development. |
| MARCH 25 | APRIL 9 | APRIL 23 | MAY 21 | JUNE 4 | JUNE 18 |

**Diagram 2.4:** Overview of the five presentations given to the FSC in the spring and summer of 2024, which led to a vote on the Preferred Alternative.

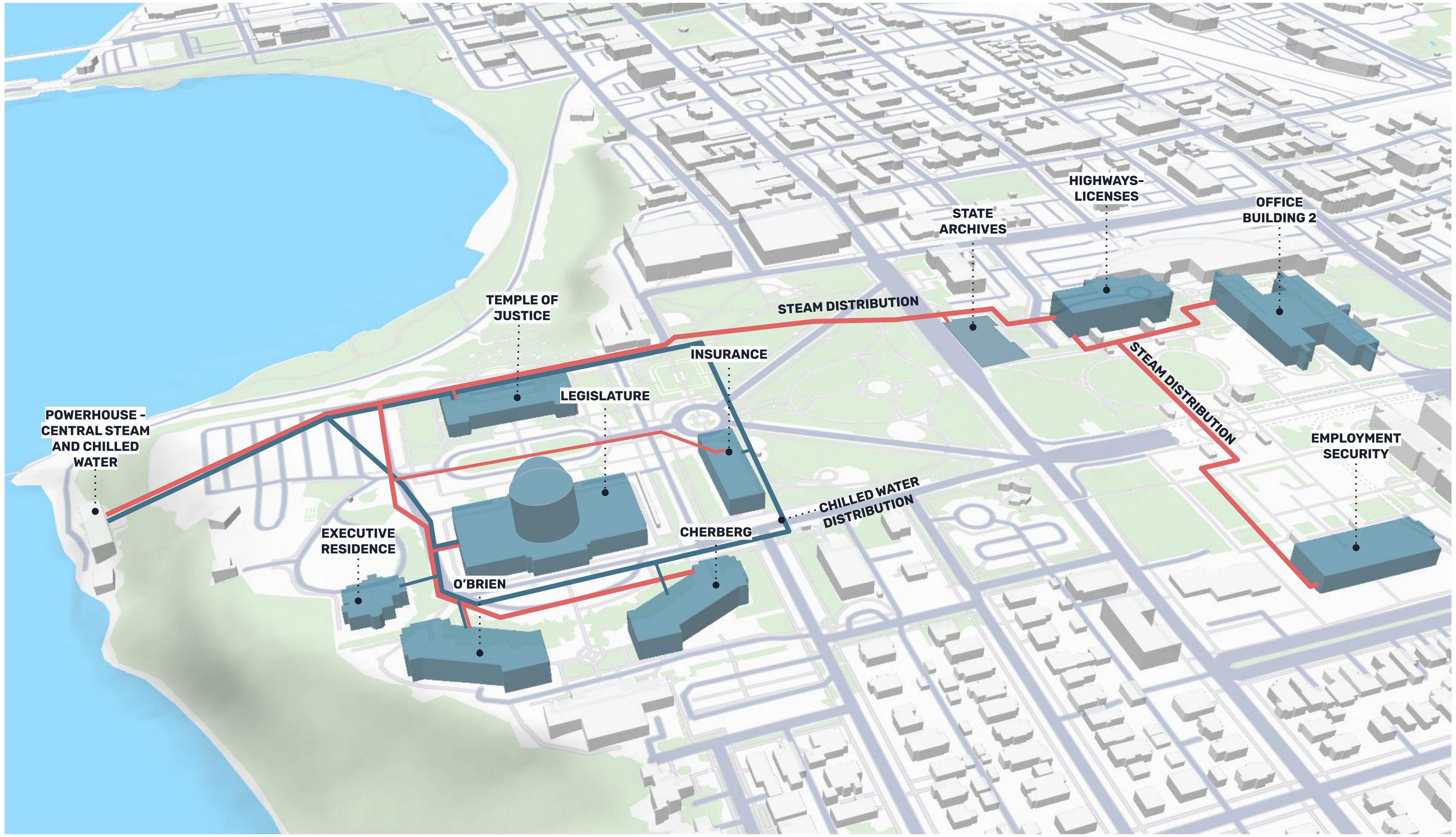
# 3: PROJECT BACKGROUND & OVERVIEW

# Problem Statement

**The aging central heating and cooling infrastructure serving the Washington State Capitol Campus is well past its expected service life and is increasingly experiencing failures. The current building that houses the central plant is at high risk of landslide and flooding. Energy consumption levels across campus exceed State energy use requirements and are subject to hefty monetary fines. A new central system is needed; however, Washington State law prevents the replacement with any new system that directly consumes fossil fuels.**

## Inefficiencies & Risks of the Existing District Energy System

Originally constructed in 1920, the Powerhouse building on has been providing steam for heating the Washington State Capitol campus for over a century. Central chilled water production was added for building cooling in 1994.



**Map 3.1:** Shows the existing steam and chilled water infrastructure across the campus.

A **District Energy System** is where a central energy plant provides thermal energy (heat & cooling) to multiple buildings through a network of insulated pipes, eliminating the need for individual boilers/chillers in each building.

## Steam System

The central plant in the Powerhouse generates medium-pressure steam at 100 psi (temperatures exceeding 300°F), which is delivered to ten buildings across the campus, totaling 1,733,222 square feet. The campus steam distribution consists of approximately two miles of steam and condensate return piping, which is located in steam tunnels, the underground parking garage, or directly buried in the ground. Much of this piping infrastructure serving the west side of campus was installed in 1994. Steam distribution on the East Campus buildings was installed when these buildings were constructed in the 1960s and 1970s.

Steam is generated by three natural gas-fired, water-tube steam boilers, one installed in 1960 and two installed in 1970. Thanks to the diligent efforts of the operations and facilities management staff, the life span of this equipment has been extended to the maximum extent possible. However, due to the system's age:

- Plant equipment failures have become more frequent.
- Technicians capable of working on medium-pressure steam systems are limited.
- The steam network suffers from frequent parts failures (pressure reducing stations, condensate pumps, and steam traps).
- It is becoming increasingly difficult to source parts for the existing equipment.
- Distribution and combustion losses mean that approximately 51% of the steam energy generated at the central plant never reaches campus buildings.
- A lack of isolation valves makes it difficult to correct issues locally, requiring the total shutdown of the plant for emergency repairs.
- The condensate return systems have suffered numerous recent failures, leading to excessive consumption of water and the requirement for more thermal energy to heat that water.

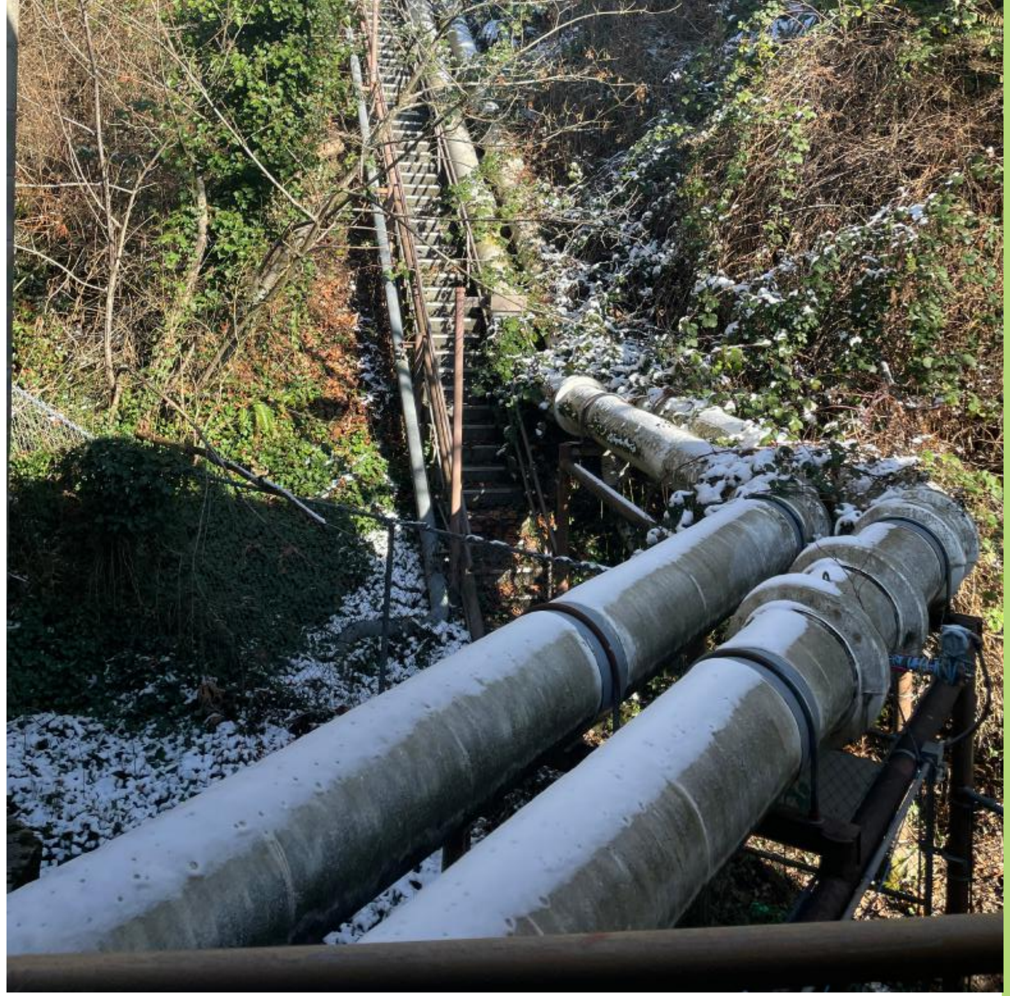


**Image 3.2 (above):** Powerhouse Building.
**Image 3.3 (top right):** Steam piping from Powerhouse to main campus.
**Image 3.4 (bottom right):** Powerhouse Boilers.

## Chilled Water System

The Powerhouse is also the source of much of the campus cooling. The chilled water systems consist of two water-cooled chillers installed in 1994 and 2015, pumps, cooling towers, and a network of approximately a mile of hydronic piping, which serves six buildings on the west side of campus. Each building on the east side of the campus has an independent chiller or cooling system. While the chillers are in adequate condition, the distribution infrastructure has seen growing failures in recent years; failed joints and leaking underground piping have required numerous shutdowns and expensive repairs.

**Image 3.5:** Chiller for West Campus chilled water loop, located in the Powerhouse.

## Electrical Infrastructure

A Puget Sound Energy electrical substation located in the southeast corner of campus serves the campus' electrical needs. The Capitol Campus has a contract capacity of 13 MegaVolt-Amperes (MVA), of which the campus uses approximately 51%, and the substation cannot be expanded without significant capital investment. All medium-voltage distribution circuits and transformers downstream of the substation are owned and maintained by DES.

**Image 3.6:** Puget Sound Energy's Cherry Street Electrical Substation.

## The Powerhouse's Unsuitable Location

The Powerhouse is located at the bottom of a steep hillside just feet from the edge of Capitol Lake on the far west side of campus. The hillside is at a significant risk of landslide, as noted in past geological studies of the campus, including Moffatt & Nichol (2008) and Golder Associates (2010).

A significant seismic event could destroy the Powerhouse, leaving most of the campus with no heating or cooling on the West Campus. The following image from the Golder Associates Report (2010) shows the high risk of slope failure.

Additionally, the State of Washington is considering restoring Capitol Lake to estuary conditions; after implementation, this will allow the waterline of Capitol Lake to vary significantly which is incompatible with the Powerhouse's current location.

**Map 3.7:** Landslide Risk for Powerhouse from Golder Associates report: Hillside Evaluation and Preliminary Design (2010).

### Campus Facilities Included in the Scope of this Study

The Capitol Campus facilities included in the scope of this study consist of (19) occupied buildings and the Plaza Garage, a large underground parking structure.

The following buildings get electricity from the Puget Sound Energy campus substation and are connected to the campus district energy system:

- Office Building 2
- Legislative Building
- Highways-Licenses Building
- John L. O'Brien Building
- John A. Cherberg Building
- Employment Security Building
- Temple of Justice
- Insurance Building
- State Archives
- Executive Residence (Governor's Mansion) (receives district chilled water only)
- Natural Resources Building (receives district energy hydronic heat via OB2)

The following buildings are supplied with electricity via the Puget Sound Energy campus substation, but are not currently connected to the district energy system. These buildings were analyzed for electrical capacity, demand, and thermal loads to decide whether they could or should be added to a future heat pump-based district energy system.

- Capitol Court Building
- Transportation Building
- Helen Sommers Building
- Capitol Child Care Center
- Legislative Modular Building (temporary building)
- Plaza Garage

The following buildings were under construction during the writing of this report. These buildings are connected to the campus substation but will not be connected to the district energy system:

- Irving R. Newhouse Building (newly replaced)
- Joel M. Pritchard State Library (newly expanded and remodeled)

The following buildings are currently unoccupied and slated for demolition. They represent locations where future central plant equipment could be located:

- Opportunity Site 1: General Administration Building
- Opportunity Site 2: Conservatory Building

| Building Name | Square Footage |
|---|---|
| Temple of Justice | 85,900 |
| Office Building 2 | 379,204 |
| Legislative Building | 255,564 |
| Insurance | 65,502 |
| Powerhouse | 11,186 |
| Pritchard Library | 76,000 |
| Highway-Licenses | 193,900 |
| State Archives | 51,317 |
| O'Brien | 100,700 |
| Executive Residence | 20,000 |
| Cherberg | 100,377 |
| Employment Security | 93,200 |
| Natural Resources | 387,558 |
| Capitol Court | 45,142 |
| Transportation | 204,053 |
| Helen Sommers | 233,833 |
| Child Care | 12,066 |
| Plaza Garage | 846,100 |
| Newhouse | 59,000 |
| Legislative Modular | 15,090 |

**Table 3.8:** Buildings List with Square Footages.

## Legislative Mandate

The Washington State Capitol Campus must meet the Clean Buildings Performance Standard (CBPS) requirements as defined in House Bill 1257 and expanded in Senate Bill 5722 (discussed more later in Appendix 1). CBPS requires the buildings on the Capitol Campus to meet energy use requirements depending on their building type. Failure to meet these requirements will result in significant monetary fines.

### Clean Buildings Performance Standard (HB 1257)

CBPS energy use is measured in Energy Use Intensity (EUI), or the total energy consumed (kBtu) per square foot (ft$^2$) of building area per year.

The overall campus EUI is currently 101.8 kBtu/ft$^2$/year. The EUI target (EUIt) set by CPBS requires a 25% decrease in overall energy use to achieve an EUI of 58.0 kBtu/ft$^2$/year.

On an individual basis, eight of the existing ten buildings connected to the district energy system currently do not meet the EUI target required by the CBPS.

### Decarbonization Plan & Implementation (HB 1390)

In 2023, the legislature approved a new bill, HB 1390, which established a definition of State District Energy Systems and provided an alternative compliance pathway for CBPS on these state-owned campuses with central plants. The alternative compliance pathway includes developing and implementing a Campus Decarbonization Plan over the next 15 years instead of meeting building target EUI compliance in 2026, 2027, and 2028.

In its role as stewards of the Capitol Campus, the Department of Enterprise Services studied both requirements and what it would take to meet them and found that there was no viable path to upgrade the individual campus buildings within the timeline provided by the CBPS requirements. Instead, DES chose to pursue the Decarbonization Plan requirements from HB 1390 to meet legal requirements and avoid fines.

> If Capitol Campus energy use is not reduced to meet the Clean Buildings Performance Standard, **the fines for non-compliance will exceed $1.17M by 2027.** Executing this Campus Decarbonization Plan over the next 15 years will satisfy the legislative requirements and avoid these hefty fines.

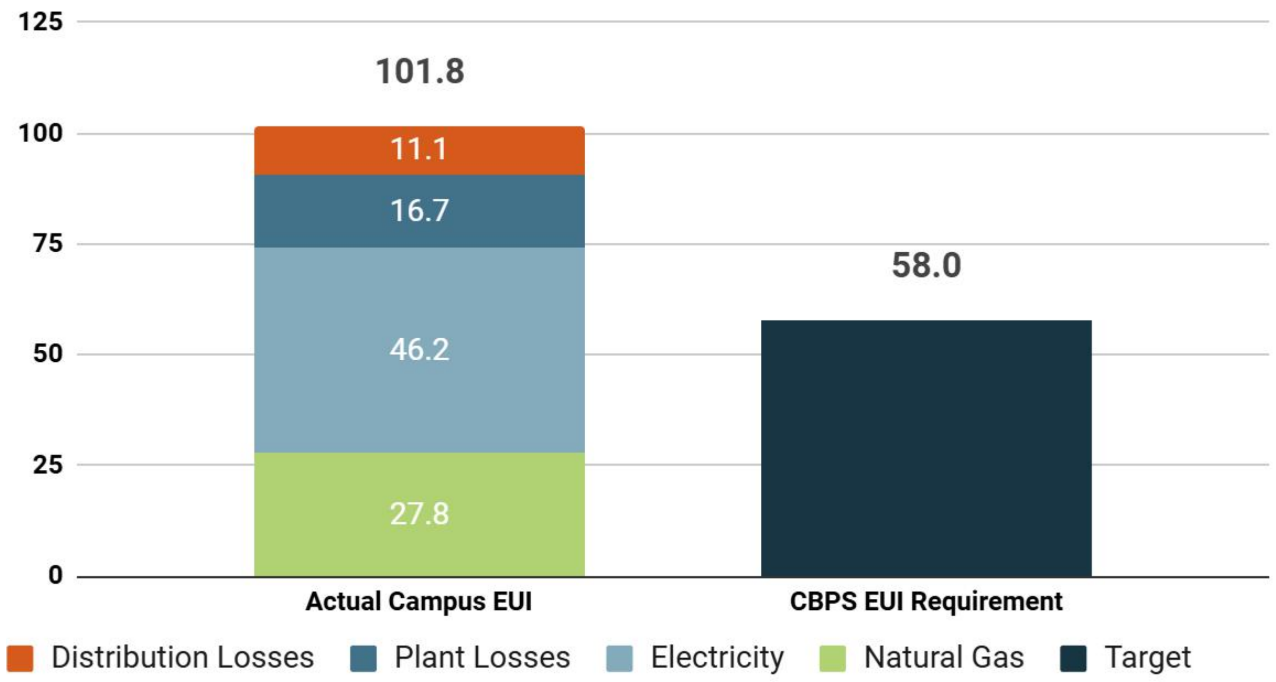


**Chart 3.9:** Campus EUI and CBPS Target EUI.

**WHAT IS "DECARBONIZATION" FOR THE CAPITOL CAMPUS?**

In this context, "decarbonization" means electrifying heating systems to replace the use of on-site natural gas in favor of cleaner utility-provided electricity.

The key components of Capitol Campus decarbonization are:

- Reduce electrical and heating loads within each building
- Recover waste heat from on-site sources
- Generate remaining needed heat with electrically-powered equipment

After eliminating natural gas as a source for on-site heating, the sole source of energy on the Capitol Campus will be electricity generated from the local utility's mix of hydroelectric, solar, wind, natural gas, and coal. This will effectively decarbonize the campus as:

- DES already purchases green power offsets for all the carbon emissions associated with the electricity supplied to the campus.
- The local utility, Puget Sound Energy, is committed to fully decarbonizing the electricity it supplies by 2030.

# Opportunity Statement

**The dire need for comprehensive replacement of the campus' central systems provides the Washington State Capitol Campus with the opportunity to design and install a new system that will reduce operational and maintenance costs while dramatically increasing resiliency and reliability. Washington State also has the opportunity to be recognized as a national leader in decarbonization and energy efficiency.**

Modern district energy system designs deploy heat pumps to move heat from one place to another using electricity. This is far more efficient than generating heat directly through a conventional furnace or boiler.

### Key Benefits of Heat Pumps

Heat pumps are highly efficient at generating heat, compared to earlier technologies:

| TECHNOLOGY | PERFORMANCE |
|---|---|
| **Electric resistance heating** | 1 unit of energy in = 1 unit of heat out |
| **Natural gas boiler & furnace** | 1 unit of energy in = .8 to .9 units of heat out |
| **Heat pump** | 1 unit of energy in = 2.5 to 5 units of energy out |

Heat pumps operate best in moderate climates, such as Olympia, where annual outdoor air temperatures range from 20°F to 90°F. Further, heat pumps are widely available in a variety of sizes and configurations to suit all potential applications across the Capitol Campus, and system-, building-, and central-plant-level heat pump equipment is available and has a long history of success in the market.

> The technologies supporting the existing systems are more than a century old. Modern technologies now available at large scale can provide the same services, but at a fraction of the energy use and ongoing operating costs.

## WATER-TO-WATER OR HYDRONIC HEAT PUMPS

The Capitol Campus would specifically use **hydronic** heat pumps, a type of heat pump that generates tempered hot or chilled water from a separate heat source and sink. Hydronic heat pumps can be configured as air-to-water or water-to-water.

When applied at the Capitol Campus vs In Application at the Capitol Campus at the Capitol Campus, hydronic heat pumps would move heat between the buildings' hot- and chilled-water loops to a central Ambient Temperature Loop acting as the heat source and sink. This Ambient Temperature Loop would connect all buildings to enable heat recovery between buildings.

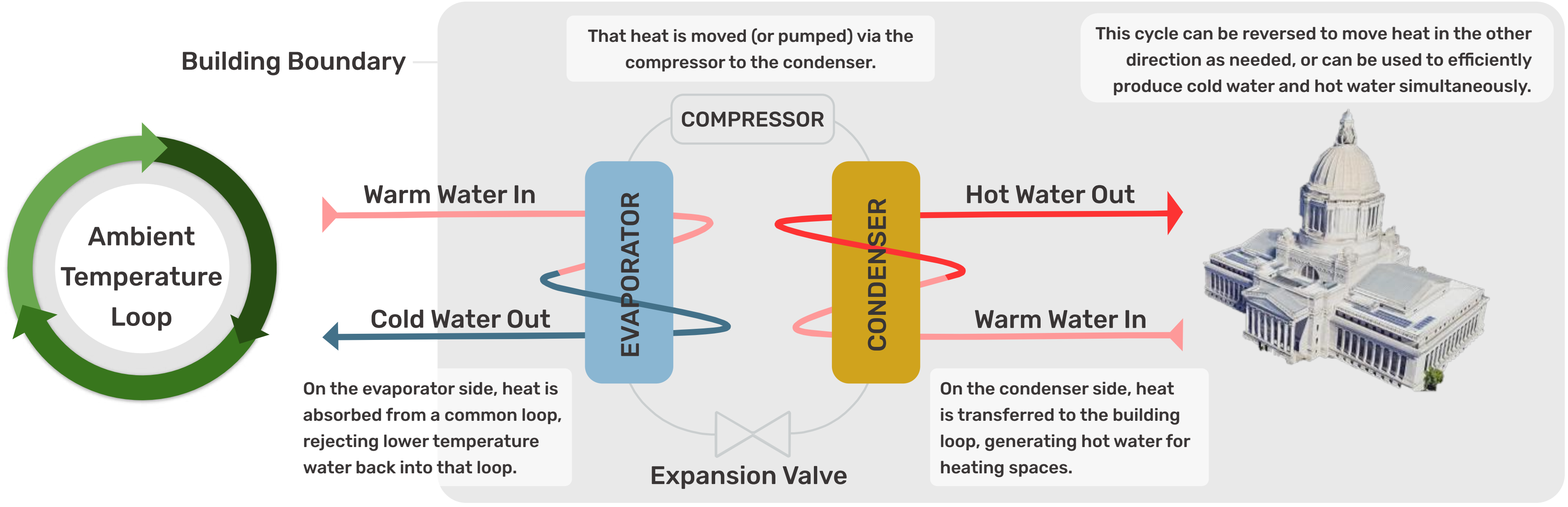
Hydronic heat pumps are key for the Capitol Campus, as most building-level air handling systems use hydronic (water-based) systems for space heating and cooling.

## KEY BENEFITS OF A HYDRONIC HEAT PUMP-BASED DISTRICT ENERGY SYSTEM

Industry leaders consider hydronic heat-pump based systems the best practice for modern district energy systems, including the Federal Department of Energy (DOE), National Renewable Energy Lab (NREL), the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE), and the State of Washington.

Beyond increased energy efficiency and reduced operating costs, a new heat pump-based system will improve the reliability and resilience of the central heating and cooling services of the Capitol Campus by adding redundancy and distributed generation. Compared to other options, such as electric boilers, hydronic heat pumps will add the least amount of additional strain on the campus' single electrical substation.

**Diagram 3.10:** Schematic of Building-Level Hydronic Heat Pump Connection to Campus Loop.



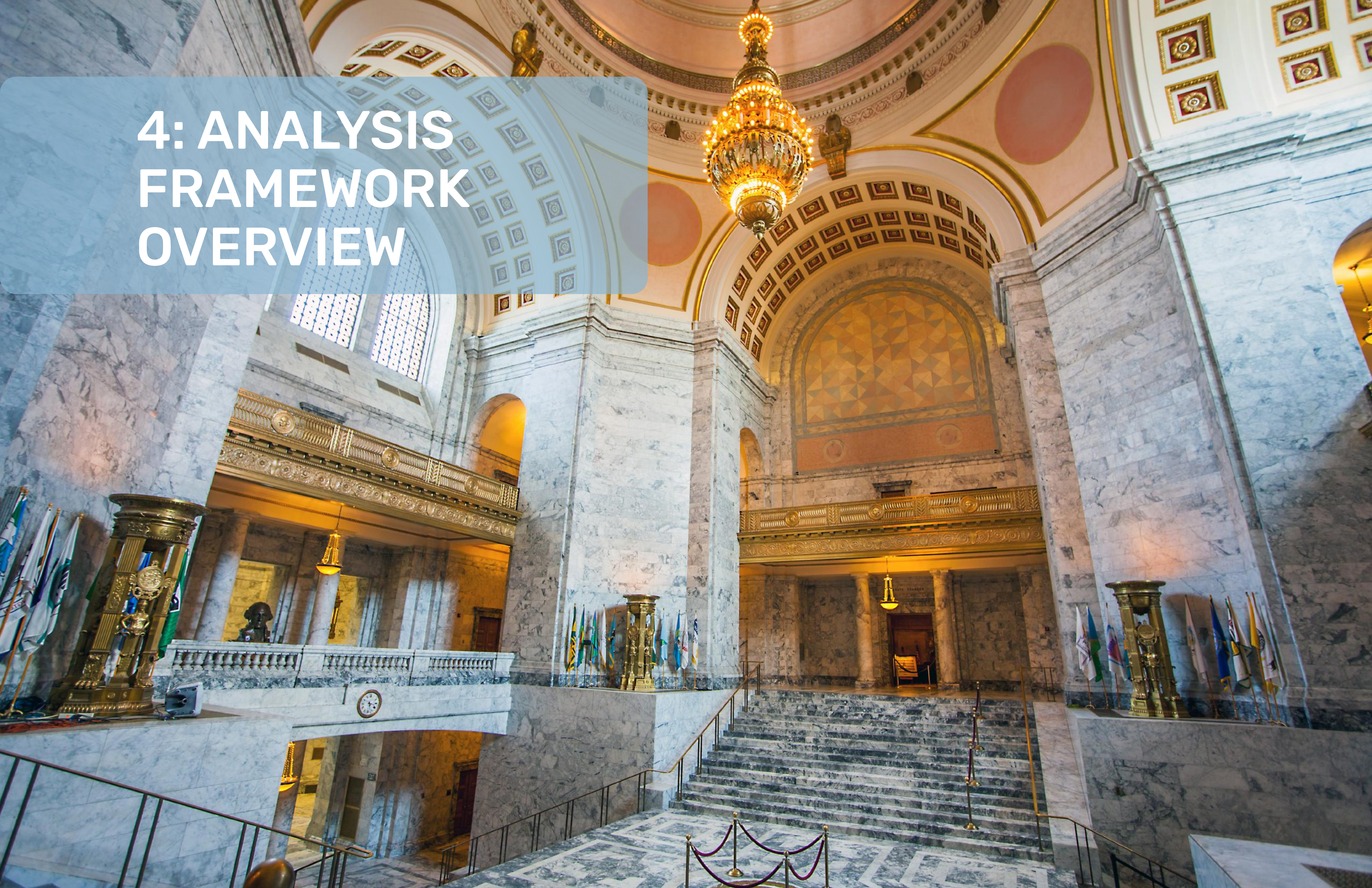
That heat is moved (or pumped) via the compressor to the condenser.

This cycle can be reversed to move heat in the other direction as needed, or can be used to efficiently produce cold water and hot water simultaneously.

On the evaporator side, heat is absorbed from a common loop, rejecting lower temperature water back into that loop.

On the condenser side, heat is transferred to the building loop, generating hot water for heating spaces.

# 4: ANALYSIS FRAMEWORK OVERVIEW



# District Energy Balancing

There are unique opportunities for energy use reduction when multiple buildings are connected to a central system. A diversity of building types and thermal load profiles (heating and cooling needs) allows for the sharing of heat between buildings via heat pumps, saving energy and reducing overall load on the central systems.

The Washington State Capitol Campus' existing district energy system generates heating and cooling using **two separate systems**: natural gas-fired boilers generate steam for heating, while chillers and cooling towers reject heat from the buildings to the atmosphere via a chilled water system. The boilers run year-round to provide heat to the buildings and the chillers operate eight months out of the year to provide cooling to the same buildings.

This system design simultaneously pulls heat out of the buildings, and rejects it to the atmosphere via the chilled water system while also providing heat to those same buildings or other buildings on campus by combusting natural gas in the campus steam boilers. Below are examples of what drives this coincidental need for heating and cooling.

- In a single large building, this simultaneous heating and cooling can occur when the internal loads drive a need for cooling on the interior of the building while heating is also needed in perimeter areas due to building envelope losses (through windows, roofs, walls, and doors).
- Across a campus, this simultaneous heating and cooling can occur when one building may be mostly in heating mode because of its function and occupancy, while a neighboring building may be mostly in cooling mode because it houses a data center or has other high internal heat-generating loads.

The following charts show two load profiles from buildings on the Capitol Campus. The first load profile shows a building (Employment Security) with simultaneous heating and cooling, while the second image shows a building (Temple of Justice) with minimal simultaneous heating and cooling.

The following section introduces concepts and common terminology for the Capitol Campus district energy system analysis.

**Employment Security Building – Daily Heating & Cooling Loads**

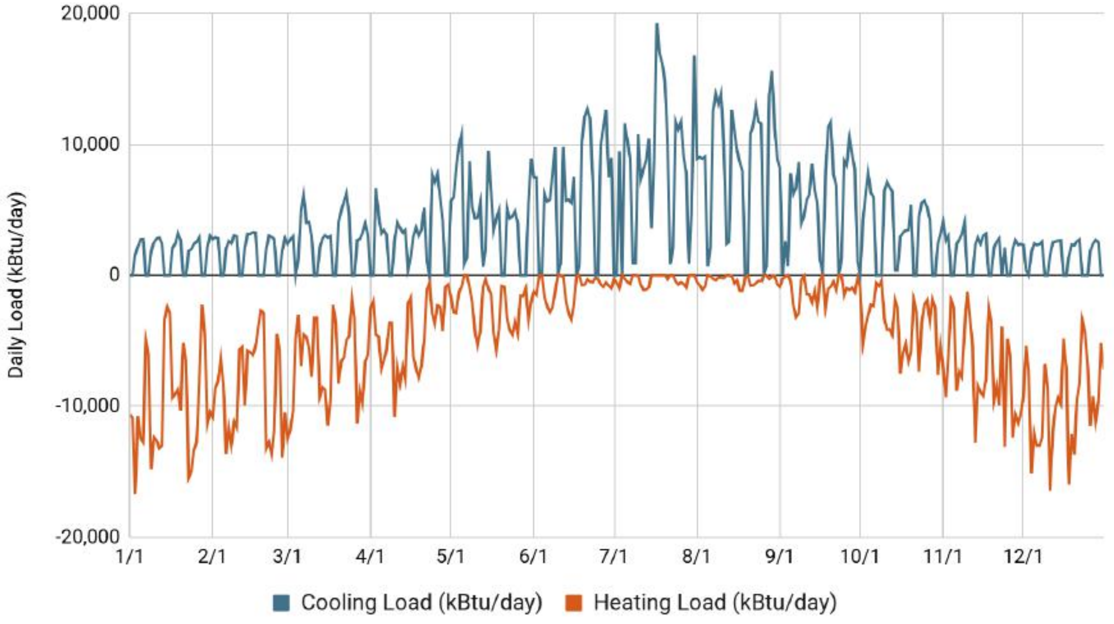


**Chart 4.1:** Example of a campus building with simultaneous heating and cooling.

**Temple of Justice Building – Daily Heating & Cooling Loads**

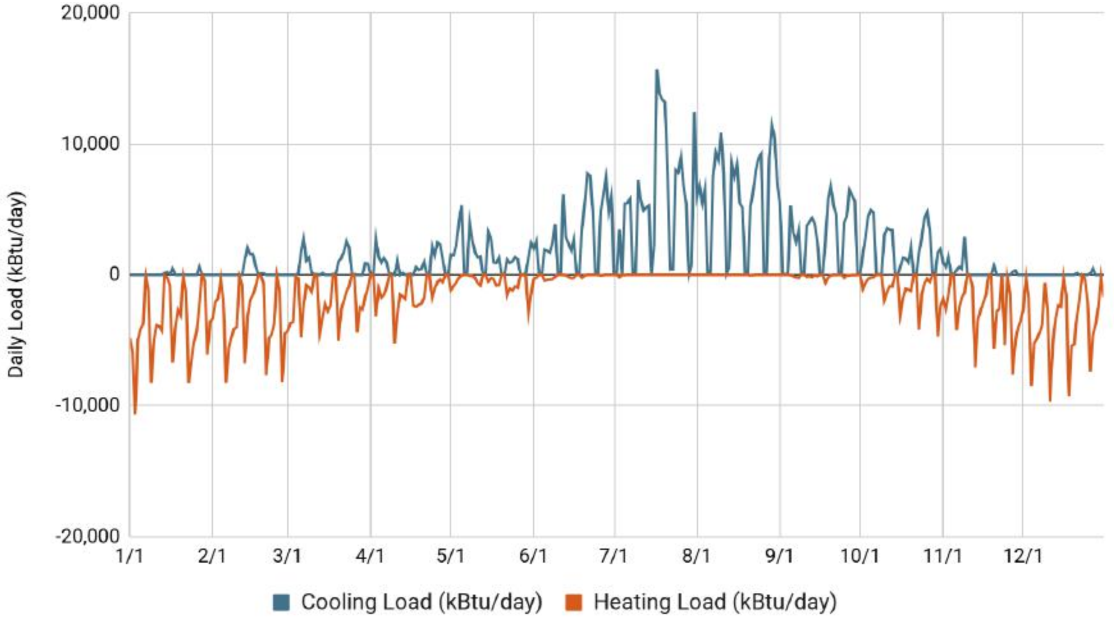


**Chart 4.2:** Example of a campus building that has very little simultaneous heating and cooling.

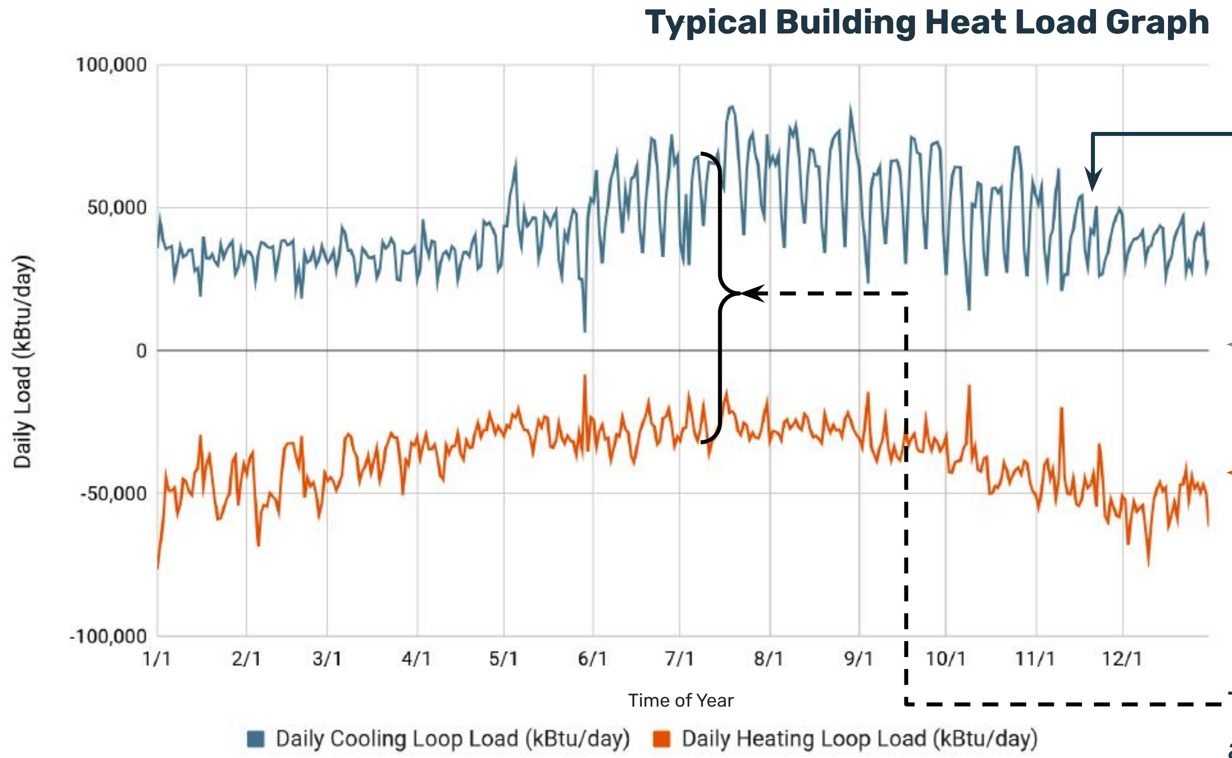
*See the next page for an explanation of how to read load profile graphs.*

## HOW TO READ A LOAD PROFILE

A load profile is a graph that shows heating and cooling needs over time. These graphs demonstrate the extent of one building's simultaneous heating and cooling demand by overlaying the heating and cooling load profiles on one graph.

This same concept can be utilized to show the campus' simultaneous heating and cooling demands by combining all of the buildings' heating and cooling load profiles together.

A heat pump-based district energy system can take excess heat away from areas that need to be cooled and use it in other areas or buildings that need it, instead of wasting the energy by discharging it.



The **Blue line** is the cooling load. This is extra heat that needs to be removed.

The center line represents stasis, where no heating or cooling is needed.

The **Red line** is the heating load. This is the amount of heat that needs to be added.

The difference between the **Blue** and **Red** lines is the magnitude of heat recovery potential at that instance in time.

Simultaneous heating & cooling loads represent an opportunity to satisfy thermal requirements by *moving* heat from one place to another, instead of simultaneously *creating* heat with boilers & *rejecting* heat with chillers & cooling towers.

**Diagram 4.3:** Guidance for how to read a load profile.

## Ambient Temperature Loop

An Ambient Temperature Loop (ATL) is a hydronic distribution network (piping loop) that provides 65-85°F water to multiple buildings and facilitates heat recovery between buildings.

Buildings take or reject heat into the loop via water-to-water or water-to-air heat pumps located in each building. Much of the campus' heating and cooling needs are satisfied by moving heat from one area to another through the Ambient Temperature Loop.

Supplemental heat is added to or removed from the loop, as needed, to maintain a relatively constant temperature inside the piping system. This is accomplished through heating equipment such as air-to-water heat pumps, electric boilers, and heat rejection equipment such as cooling towers.

The strength of this concept is that it takes advantage of **Energy Load Diversity**. Energy Load Diversity refers to the fact that individual buildings have different thermal heating and cooling needs at different times, such that combination of the profiles across multiple buildings results in significantly lower overall heating and cooling demands than the sum of each of the individual building peaks.

The following page highlights case studies of campuses where Ambient Temperature Loop systems have been implemented and have been successfully operating for a number of years.

> **This type of system is not new to the Washington State Capitol Campus.** A water-source heat pump system has been serving the State Archives Building since the mid-1970's. It uses the same technology, only it serves one building instead of a network of buildings.

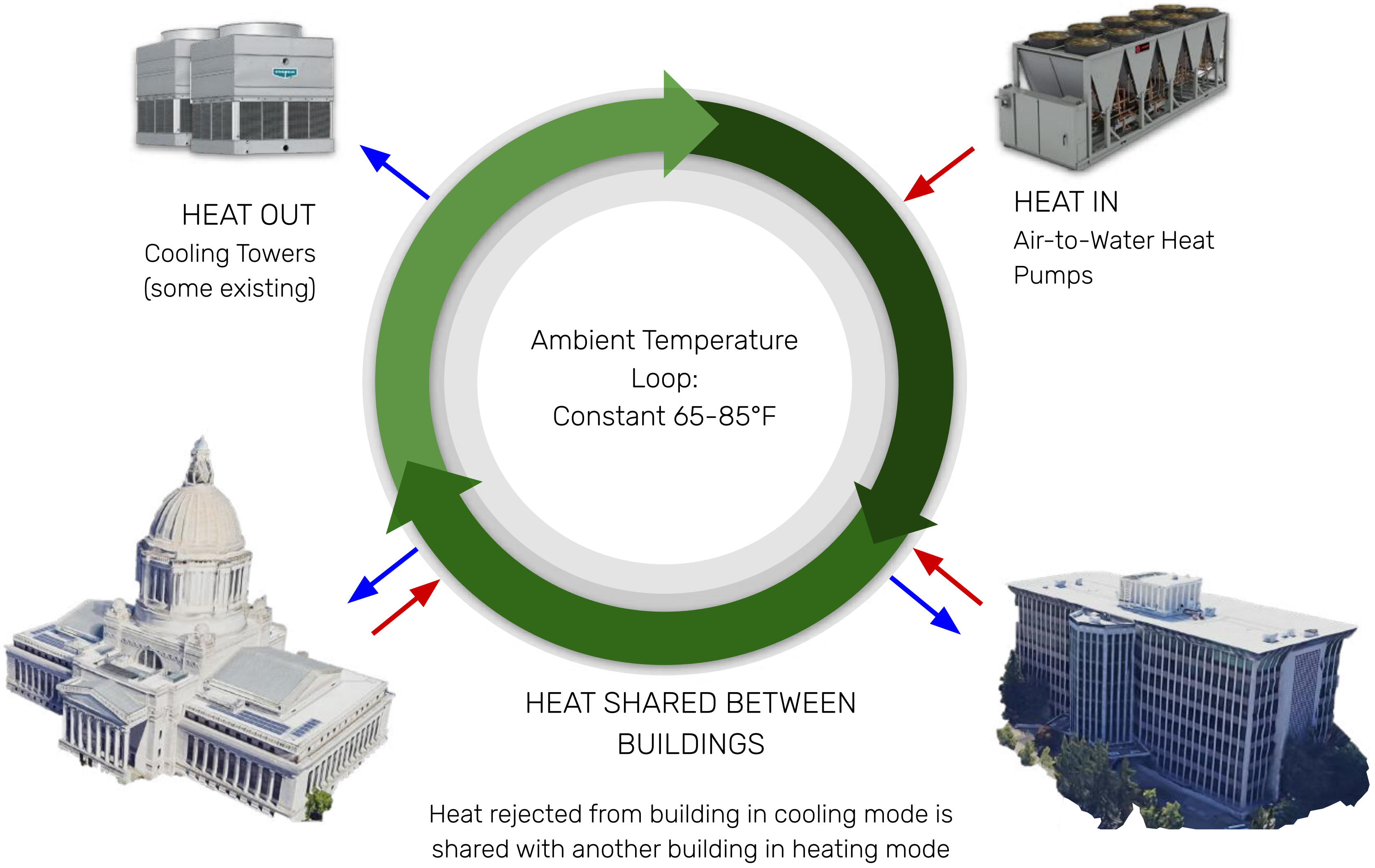


**Diagram 4.4:** Ambient Temperature Loop Conceptual Diagram.

## AMBIENT TEMPERATURE LOOP CASE STUDIES

### Amazon Headquarters - Seattle, WA

Constructed between 2012 and 2015, Amazon's Doppler Tower in downtown Seattle is heated and cooled by heat pumps connected to an ambient temperature loop similar to the system envisioned for the Capitol Campus.

Heat is rejected into the ambient temperature loop by heat pumps in the nearby 34-story Westin Building Exchange. The Westin Building Exchange is a massive data center which has a year-round cooling load. The heat from that building is moved into the ambient temperature loop, and that thermal energy is then used to heat the Amazon Headquarters.

The ambient temperature loop is maintained between 65-75°F and is connected to five large heat pumps in the basement of Amazon's Headquarters. These heat pumps heat and cool approximately three million square feet of office space and multi-use spaces.

*Image citation: Columbia Green Technologies*

### Colorado Mesa University - Grand Junction, CO

Beginning in 2008, Colorado Mesa University (CMU) began building out a system of two and a half miles of ambient temperature loop piping to serve hydronic heat pumps located in 16 buildings on campus. This system is connected to a geoexchange system *(explained on page 28)* which allows it to use the ground as a source of heat and a place for heat rejection.

The system takes advantage of the diversity in the thermal loads of the connected buildings and 471 bore holes in the geoexchange system to balance the campus district energy use to save $1.2 million in energy each year.

This system serves 1.2 million square feet of academic buildings and has been successfully operating for more than 15 years. In 2023 and 2024, CMU invested an additional $9 million in expanding the system to connect it to several more buildings.

*Image citation: Colorado Mesa University*

### City of Denver's National Western Center - Denver, CO

In 2015, the National Western Center Master Plan set ambitious sustainability goals for their campus. By 2018, construction was underway on a new utility infrastructure project to create a district energy system to serve over one million square feet of educational, research, and conference spaces.

Today, the campus sources 90% of its heating and cooling from recovered waste heat and distributes that heat to the campus via an ambient temperature loop. Each building on the campus houses water-to-water heat pumps which provide the heating and cooling needed for the HVAC equipment in that building.

The campus has partnered with the City of Denver's sewer system to recover heat from the main city wastewater pipeline, providing the additional benefit of cooling the effluent before it is cleaned and returned to the South Platte River.

*Image citation: AECOM*

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# Two-Pipe & Four-Pipe System Configurations

## Four Pipes

The most common type of district energy system today is a central **four-pipe** distribution system. It has heating supply and return, and cooling supply and return, for a total of four pipes, as shown in the diagram to the right. The Capitol Campus currently has this system configuration, served by natural gas-fired boilers and water-cooled chillers.

In a decarbonized four-pipe hydronic system, instead of natural gas fired-boilers and chillers, the heating and cooling water is generated by a central heat pump plant. This concept is explored in detail on page 50 in *Decarbonization Strategy 2: Central Four Pipe Hydronic Heat Pump Plant*.

## Two Pipes

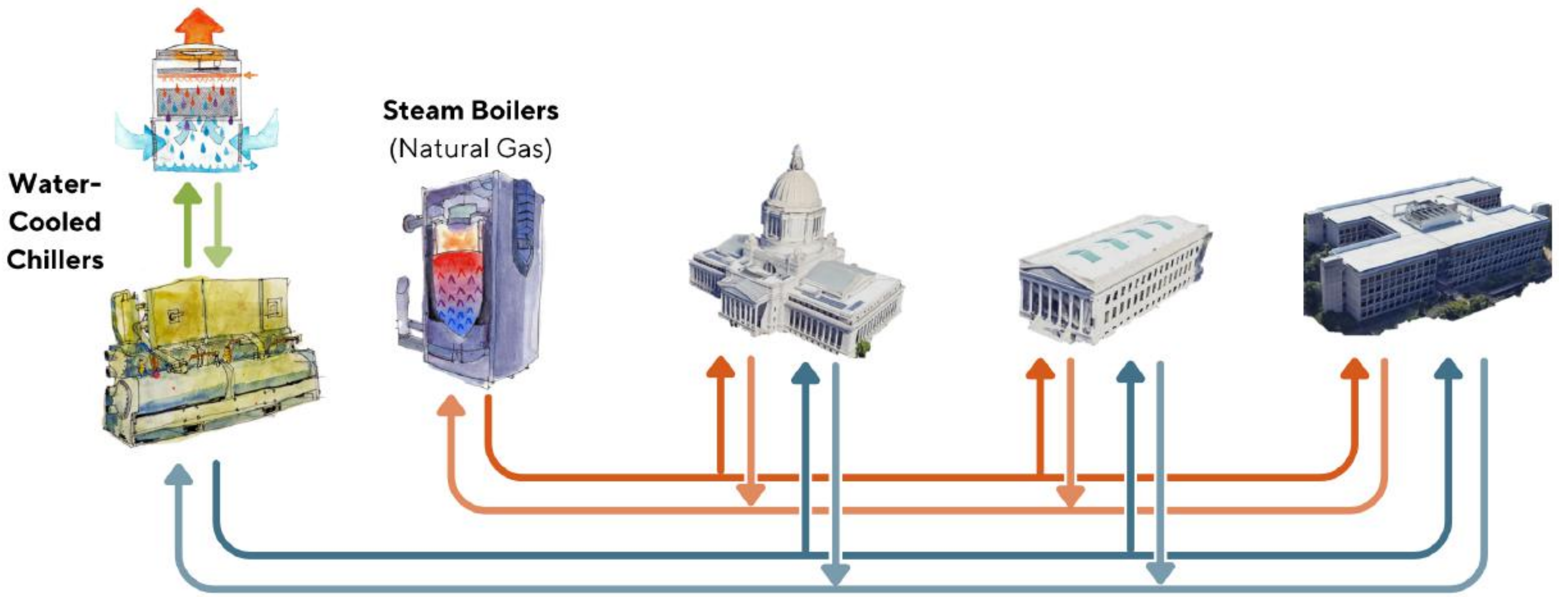
A **two-pipe** hydronic distribution system uses ambient (moderate) temperature water as a heat transfer medium and only has one set of supply and return piping, as shown in the diagram to the right. This concept is explored in detail later in the sections that discuss *Decarbonization Strategy 3: Two-Pipe Ambient Temperature Loop with Distributed Hydronic Heat Pumps*.

## Comparing Two- & Four-Pipe Systems

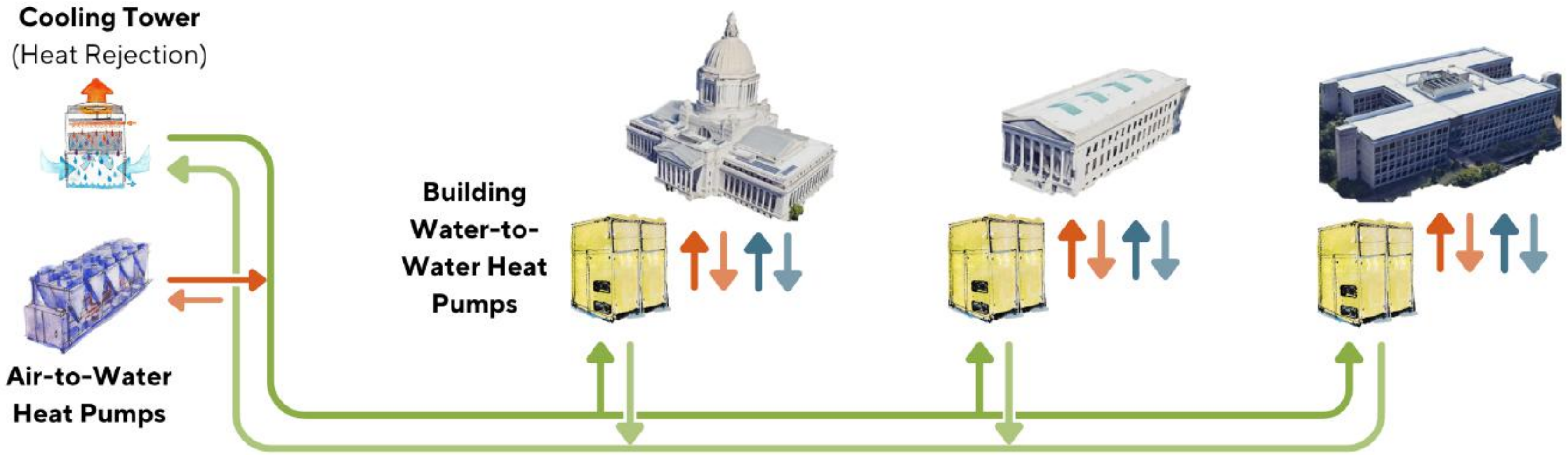
When designing and constructing a new system, a two-pipe ATL system has some distinct advantages over a traditional central four-pipe distribution system:

- **Lower distribution losses:** Circulating high-temperature heating water or steam through a large distribution piping network means more heat is lost to its surroundings than occurs with neutral-temperature loop systems. The same is true for chilled water versus a ambient temperature loop.
- **Lower first cost:** The cost of the distribution system (piping, insulation, earthwork, and installation) of four-pipe systems is significantly more costly than the cost of a two-pipe ATL system.

**Four-Pipe System Diagram (Central Stream and Chilled Water)**



**Two-Pipe System Diagram (Central Ambient Temperature Loop & Water-to-Water Pumps)**



**Diagrams 4.5 and 4.6:** System Diagrams.

## Factoring in Existing Piping Conditions

If an existing district energy system has hydronic heating and cooling piping networks that are in good condition, staying with a four-pipe system is likely to be the lowest cost option. However, at the Capitol Campus, the existing steam piping and much of the chilled water piping is in poor condition and in need of replacement. It cannot be repurposed for distribution in a decarbonized centralized hydronic heat pump plant system design.

# Energy Efficiency & Load Reduction

Any major system replacement project should first consider reducing wasted energy and maximizing heat recovery to minimize the size and cost of new central equipment and electrical infrastructure upgrades.

The project team explored all opportunities for energy and load reduction within all buildings on the Capitol Campus to:

1. Improve building efficiency and reduce the overall energy demands of the buildings, especially in heating mode.
2. Reduce the electrical consumption of existing systems on campus.
3. Align upgrades with needed capital improvements in facilities with end-of-life equipment.

## Energy Efficiency

Building-level energy efficiency will directly reduce the needed equipment size and power requirements of the central distribution systems. Standards such as Washington's Energy Code and ASHRAE 90.1 were referenced in exploring various opportunities to improve energy efficiency across the campus. Low-cost, high-yield opportunities include scheduling, setpoint optimization, and LED lighting retrofits throughout many of the facilities. Repairs to existing infrastructure have benefits beyond energy savings, as they can also reduce maintenance costs and increase occupant comfort.

Larger capital improvement projects should be implemented to upgrade infrastructure that is beyond its end-of-life or inadequate and to address a few key components that need to be modified to accommodate the new district energy system.

Examples, discussed in detail in later sections of the report, include:

- Upgrading from fluorescent to LED lighting.
- Replacing high-temperature hydronic heating coils with low-temperature coils.
- Installing new controls equipment and tuning controls sequences and schedules.

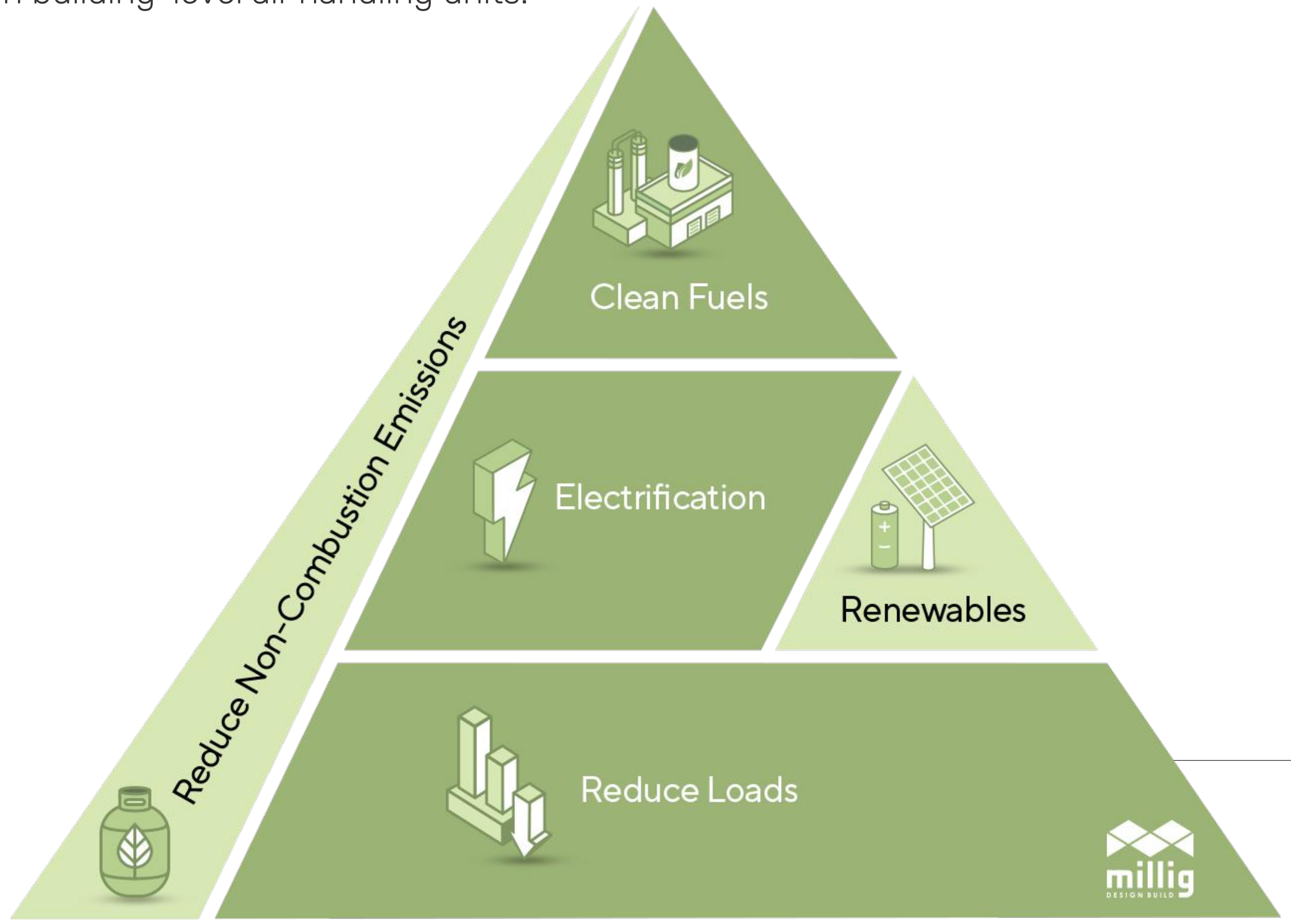
## Load Reduction

Load reduction strategies are similar to energy efficiency but specifically target heat recovery and reducing heating loads.

One critical part of load reduction identified for the Capitol Campus is the disabling of air-side economizer function on building-level air handling units.

Economizers are used for "free cooling" of buildings by bringing in cold outdoor air to cool the building down whenever outdoor temperatures allow, rather than using the mechanical chilled water system. This is typically a powerful energy efficiency strategy because when operating in economizer mode, there is no mechanical rejection of heat into the energy-intensive chilled water loop.

However, within the context of district energy balancing, it is more beneficial to use chilled water for cooling so that heat that needs to be removed can be recovered and used for heating in other areas. This can be either within the same building or carried by the district energy system to other buildings with heating needs.



**BUILDING-LEVEL LOAD REDUCTION IS THE FOUNDATIONAL STEP OF ANY DECARBONIZATION EFFORT**

Identify measures to reduce energy consumed at the building level to:

- Minimize the size and cost of electrification and renewables needed to offset energy consumed on site.
- Free up electrical capacity (which is especially critical at the WA Capitol Campus to avoid or minimize required electrical substation upgrades).

**Diagram 4.7:** Millig's Decarbonization Pyramid.

## Geoexchange System

Whenever a heat pump is operating, it must have a heat source and a heat sink. The heat source is where the heat comes from, while the heat sink is where the heat goes.

For example, in the case of a refrigerator, the heat source is the air in the interior of the refrigerator, and the heat sink is the air outside of the refrigerator into which the heat is rejected.

In the winter, the ground is a heat source for the heat pump system because the temperature under the ground (50-60°F) is warm compared to the outdoor air temperature. Conversely, in the summer, the ground is a heat sink for the heat pump system because the temperature under the ground is cool compared to the outdoor air temperature.

As heat is consistently rejected underground throughout the summer, the local soil temperature is increased. That heat can then be accessed by the geoexchange system in the winter. This effectively turns the ground into a thermal battery that stores heat for later use by the district energy system.

### Major System Components

Geoexchange systems require an underground heat collector system. This is a system of connected vertical pipes that are buried in the ground. Typically placed about 20 feet apart, deep bore holes are drilled and then vertical piping is installed.

After the piping is connected and pumps are installed, water is circulated through these pipes to either absorb or reject heat to the surrounding soil.

> At about 30 feet below ground, temperatures remain relatively constant year-round, between 50-60°F. A geoexchange system takes advantage of the constant underground temperature by using the ground as a heat source and heat sink.

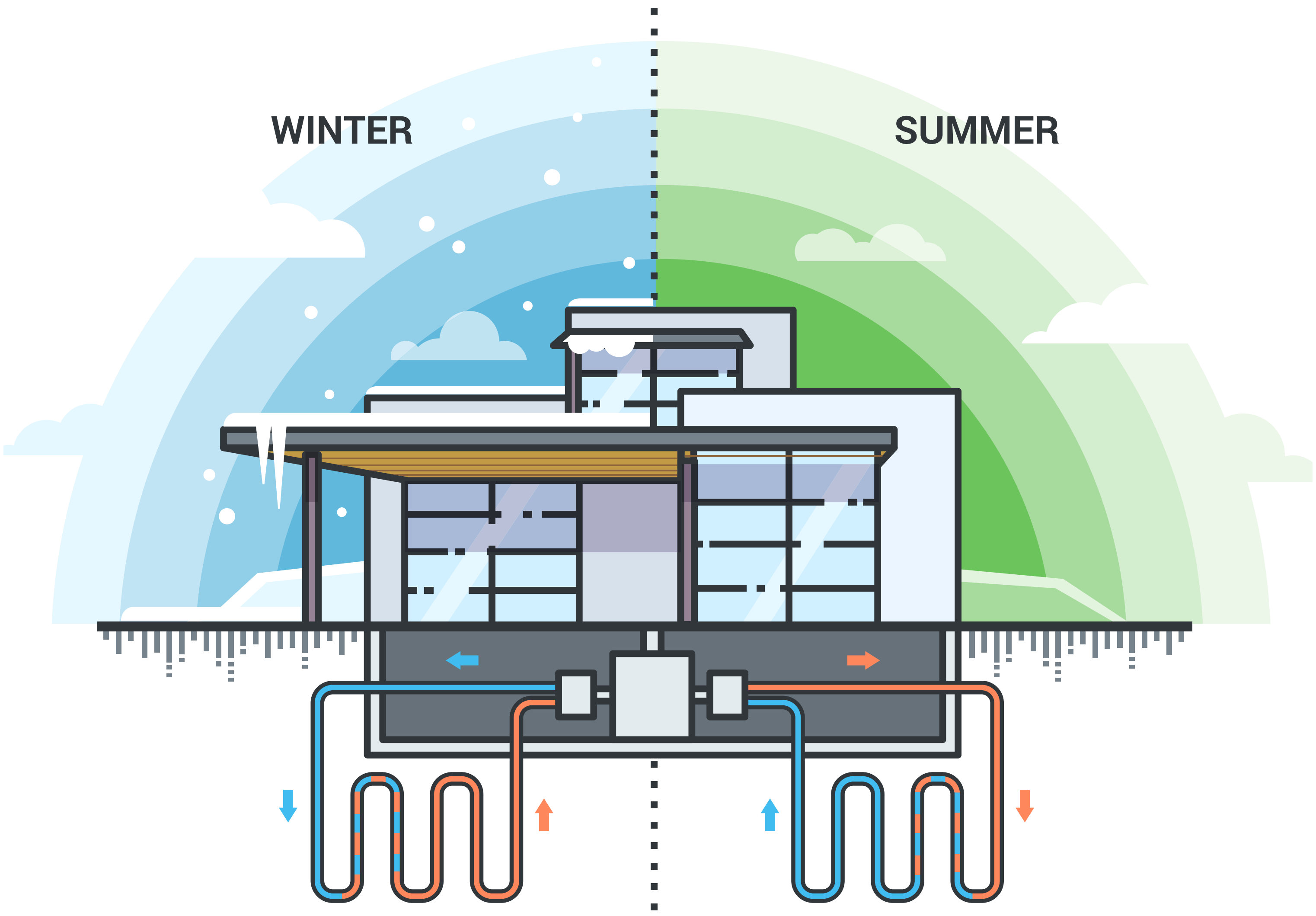


**Diagram 4.8:** Geothermal summer vs. winter operation.

**EXISTING GEOEXCHANGE SYSTEM ON THE CAPITOL CAMPUS**

A geoexchange system with heat recovery chillers was installed at the Helen Sommers building when it was constructed in 2017. The Helen Sommers building's system consists of 30 wells drilled to a depth of 300 feet under the building.

According to *High Performance Buildings* magazine, in the year after the building was constructed, the wells provided 67% of the annual heating load in Year 1 for this 225,000 square foot building.

# Overview of Four Potential Strategies for Decarbonization

### 1 Central Electric Boilers

- Decarbonization of the district energy system would be achieved by using electric hot water boilers for district heating.
- The existing Powerhouse would be demolished and replaced with a new plant located on the main campus. Electric hot water boilers and hot water distribution piping would be installed, as would new chillers and chilled water piping. The campus electric service and distribution would require service would require significant expansion.
- After central installation, although the campus would be decarbonized, the campus would not comply with Washington State Energy Code, which prohibits the use of electric resistance boilers in this application.

### 2 Central Four-Pipe Hydronic Heat Pump Plant

- Decarbonization would be achieved by using a central hydronic heat pump plant to generate low-temperature hot water and chilled water.
- The existing Powerhouse would be demolished and replaced with a new plant on the main campus. New hot water and chilled water piping would distribute low-temperature hot water (LTHW) and chilled water to the campus.
- Complementary building energy efficiency measures would be installed, likely avoiding major electrical service expansion.
- Significant building HVAC upgrades in numerous buildings would be required to accommodate low-temperature hot water.

### 3 Two-Pipe Ambient Temperature Loop (ATL) with Distributed Hydronic Heat Pump Plants

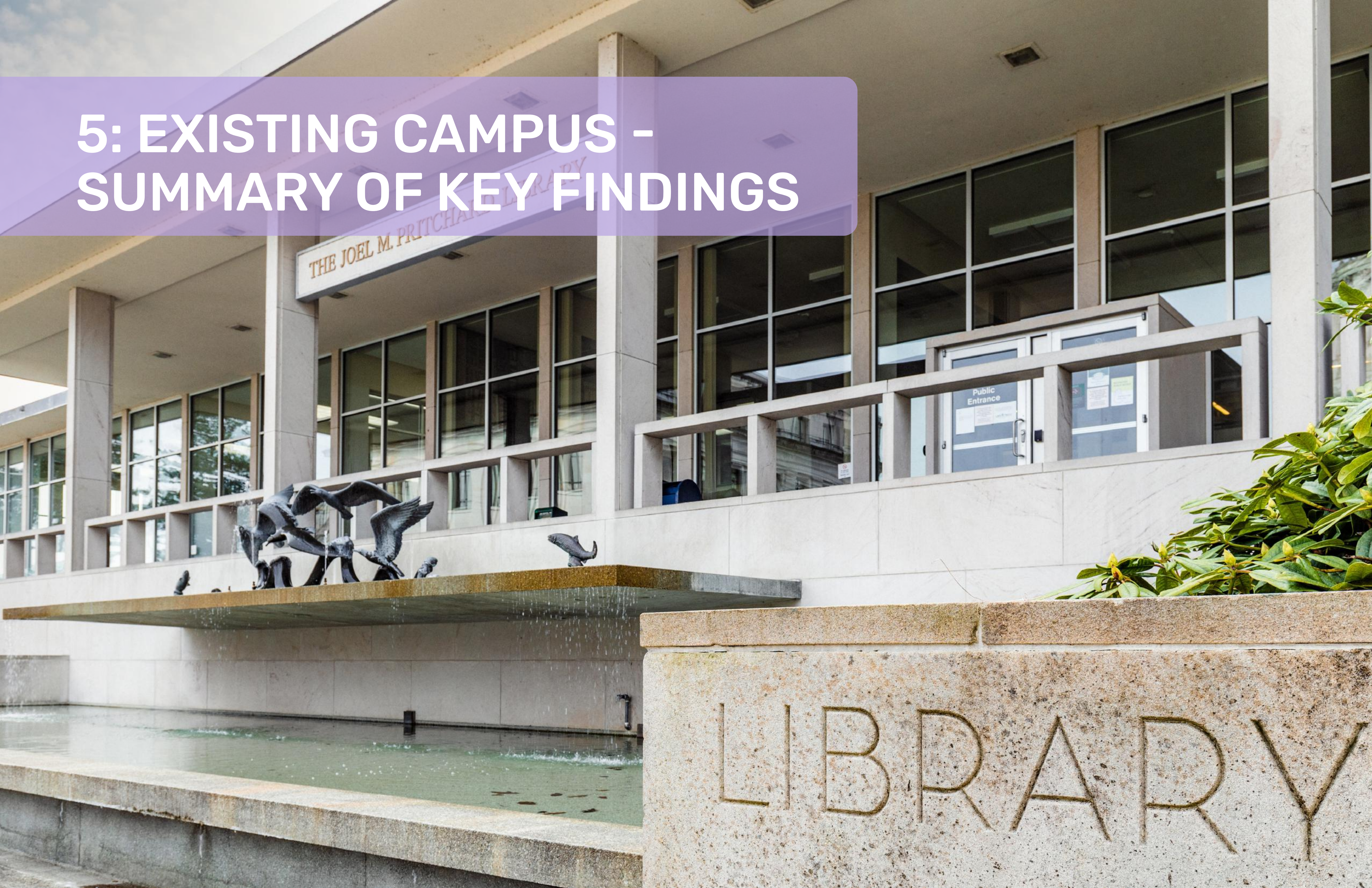
- Decarbonization would be achieved by using a new Ambient Temperature Loop (ATL) throughout campus to serve distributed heat pump plants in each building.
- The existing Powerhouse would be demolished. New ATL piping will be run throughout campus and hydronic heat pumps will be installed in most major buildings.
- Complementary building energy efficiency measures would be installed, likely avoiding major electrical service expansion.

### 4 Eliminate District Energy System with Distributed Unitary HVAC Systems

- Decarbonization would be achieved by eliminating the district energy system and utilizing individual electric hot water boilers and chillers, or heat pumps, in each building for heating and cooling.
- The campus electrical substation would require significant expansion, as would the electrical feeder system.
- Significant building HVAC upgrades would be necessary.

> Four strategies to decarbonize the heating system of the Capitol Campus were explored in this study. Each strategy will be explained fully in Section 7: Analysis of Alternatives.

# 5: EXISTING CAMPUS - SUMMARY OF KEY FINDINGS



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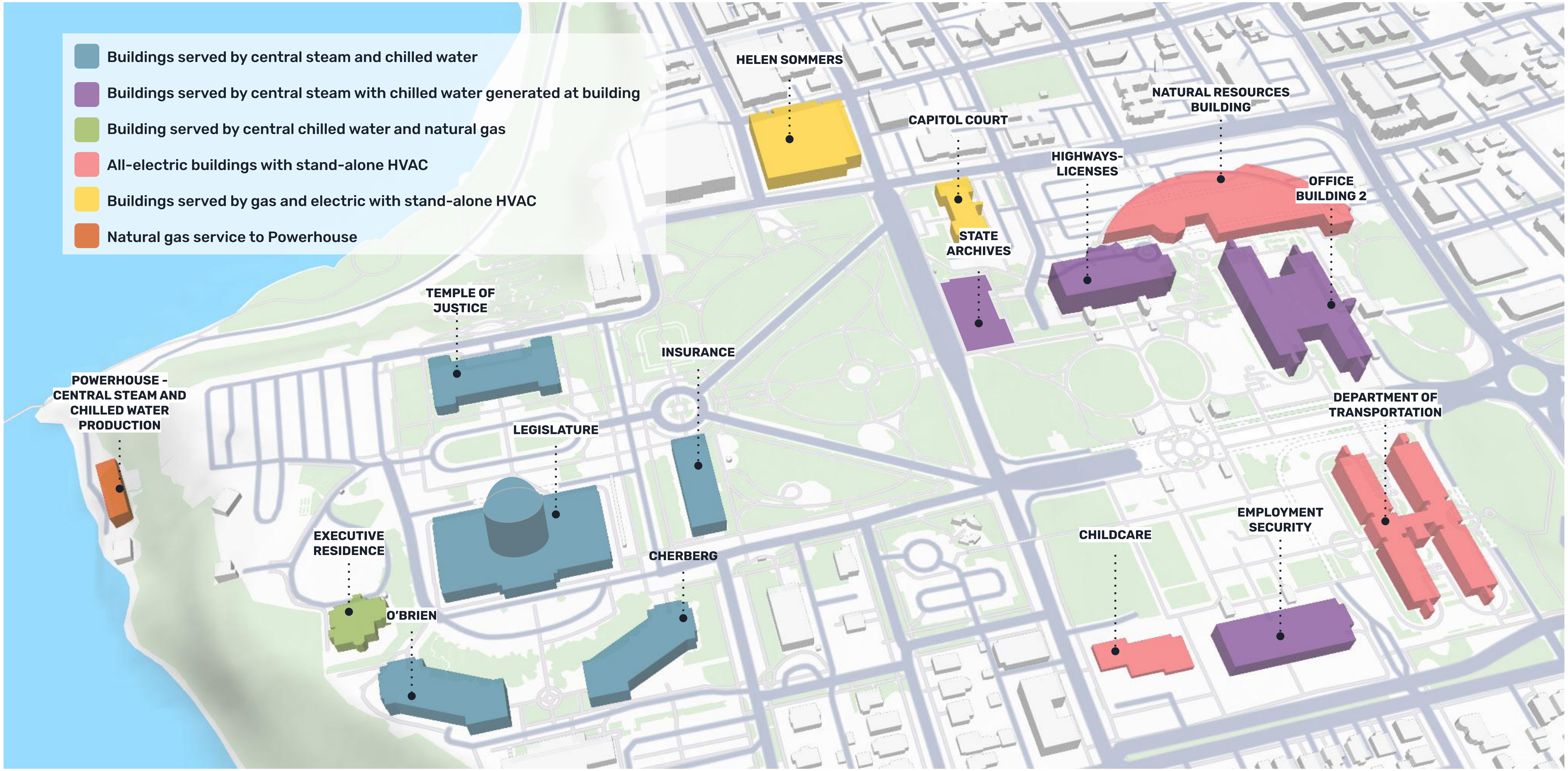
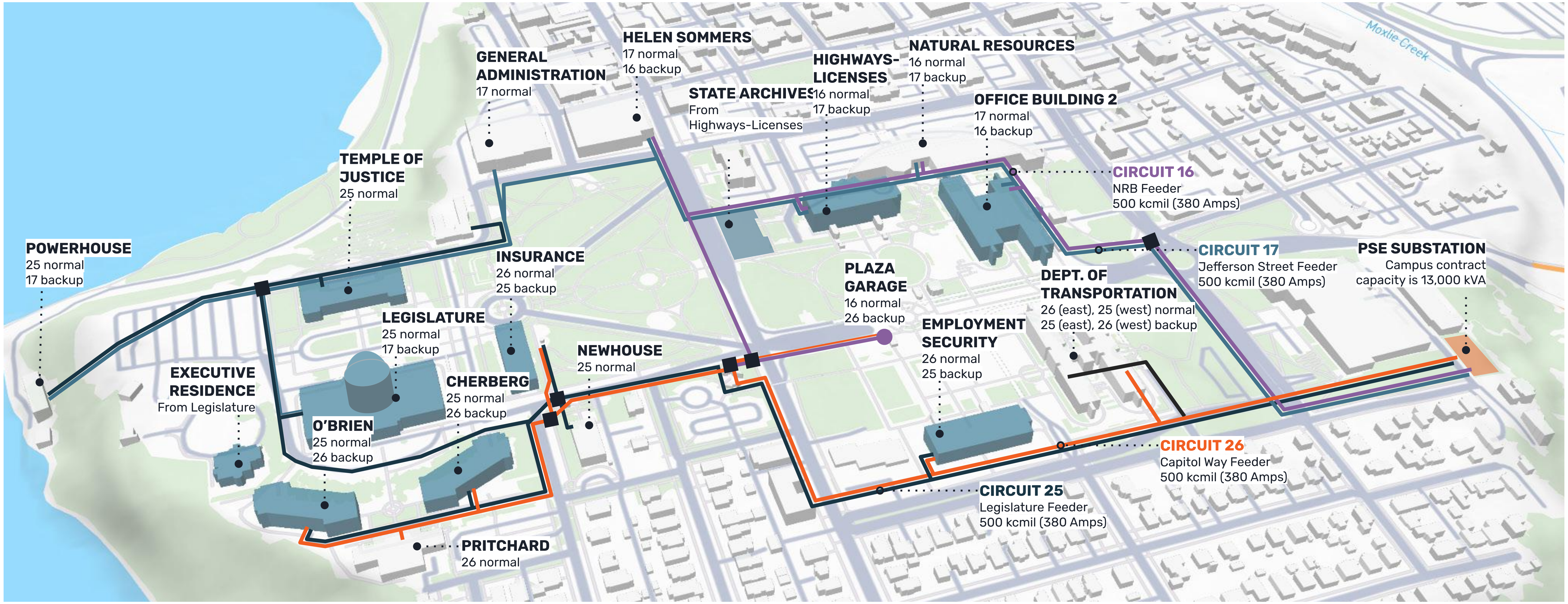
# Utility Infrastructure Overview

A key component of the analysis for this study is understanding the energy demands of each major building on campus, including those that are served by the district energy system and those that are not.



**Map 5.1:** Illustrates how each building is served by the campus utilities. All buildings shown are served by campus electrical substation.



**Map 5.2:** Electrical distribution map showing the current layout of the circuits serving the campus. The name of the distribution feeder(s) for each building is shown below the building name.

# Primary Electrical Infrastructure

The Puget Sound Energy (PSE) substation is located on the eastern edge of campus on Cherry Street and supplies electricity to four separate feeder circuits serving the buildings on campus.

The maximum contract capacity allowed by the existing substation for the Capitol Campus is 13,000 kilo-Volt Amps (kVA).

Electricity is provided to the campus buildings at 12,470 volts, and each of the feeder circuits has a wire size of 500 KCMIL and a 380 amp capacity.

Each building is fed by two circuits for redundancy, one for 'normal operation' and one for 'backup' if the normal circuit is down due to maintenance or emergency.

**THE FOUR DISTRIBUTION SYSTEM CIRCUITS ARE:**

- 17 - Jefferson Street Feeder
- 25 - Legislature Feeder
- 26 - Capitol Way Feeder
- 16 - NRB Feeder

# Evaluating the Electrical System Capacity

## Feeder Capacity

Feeder capacity refers to the maximum amount of current a feeder line can carry. This capacity is dictated by building codes and is determined by factors like the feeder's conductor size and conductor material. The campus feeder system is owned and maintained by the State of Washington.

Under 'normal operation', the current peak load on each circuit is about 8% - 42% of each circuit's rated capacity of 380 Amps. Normal operation load by circuit is shown in the four left-most bars on Chart 5.3 below.

Worst-case loading occurs when any one circuit is taken out of service, and buildings connected to that circuit for 'normal operation' must be served by the 'backup' circuit. This analysis shows that the backup operation peak load is 15% - 56% of each circuit's rated capacity. The four right-most bars on Chart 5.3 below show the worst-case backup operation load by circuit.

***Note:*** *All potential district energy system projects includes keeping the current convention of a normal and backup circuit connection to each building.*

## Substation Capacity

Substation capacity refers to the maximum amount of electrical power a substation can handle. The total Cherry Street substation capacity is 20,000 kVA, provided by two 10,000 kVA transformers. However, the substation serves not only the Capitol Campus but also a portion of the adjacent neighborhood and the 1500 Jefferson Building (not owned by DES). The portion of the substation's capacity that PSE allocates for use by the Capitol Campus is 13,000 kVA.

Detailed analysis showed that the current campus electrical peak load of 6,692 kVA, or approximately 51% of the PSE contract capacity (13,000 kVA). That leaves approximately 6,308 kVA of capacity available for any expansion of the electrical demand on campus.

The area chart below shows that the daily peak load throughout the year remains relatively constant and is well below the Capitol Campus' contract capacity.

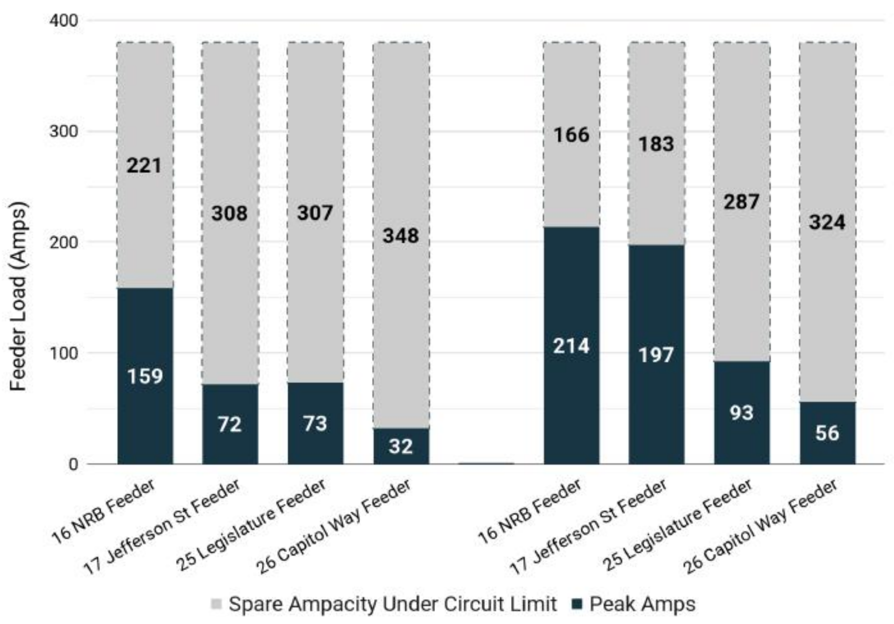
Two primary aspects of the electrical system must be evaluated to understand the available electrical capacity: feeder capacity and substation capacity.

**ADDITIONAL FACTORS IMPACTING SUBSTATION CAPACITY**

As previously noted, energy efficiency measures would free up more electrical capacity at the substation. The estimated impact of the shortlisted energy efficiency measures would be to increase the available capacity by approximately 1,000 kVA.

On the other hand, future campus construction projects and initiatives need to be carefully planned to manage the amount of additional electrical demand they add to the existing campus substation, including:

- New load from any new buildings or building additions
- New load from electric vehicle charging stations



**Far left: Chart 5.3:** Baseline Capitol Campus Peak Feeder Loads.

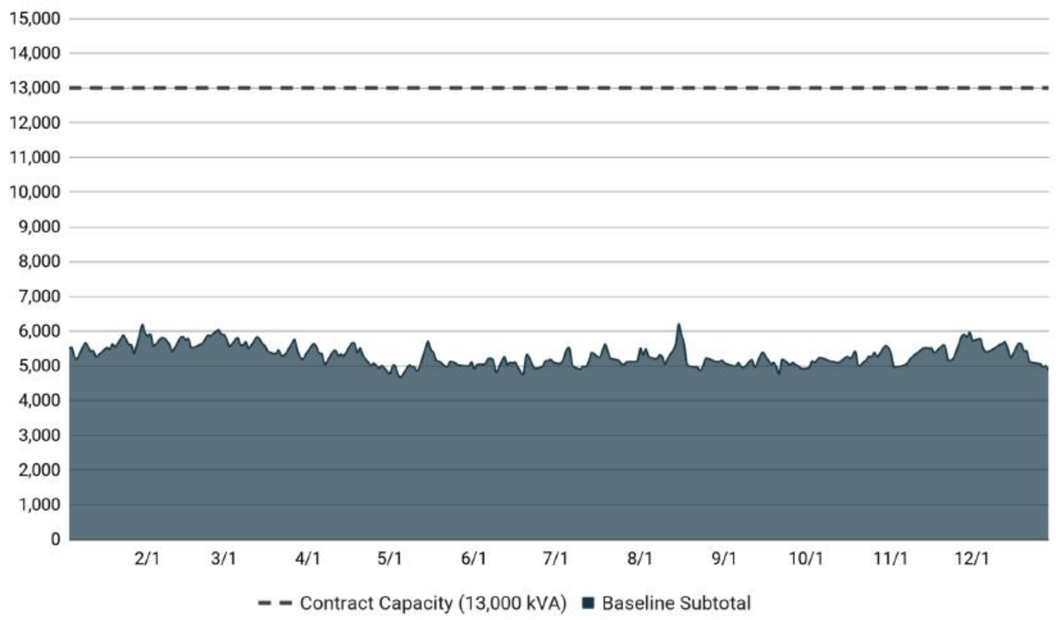


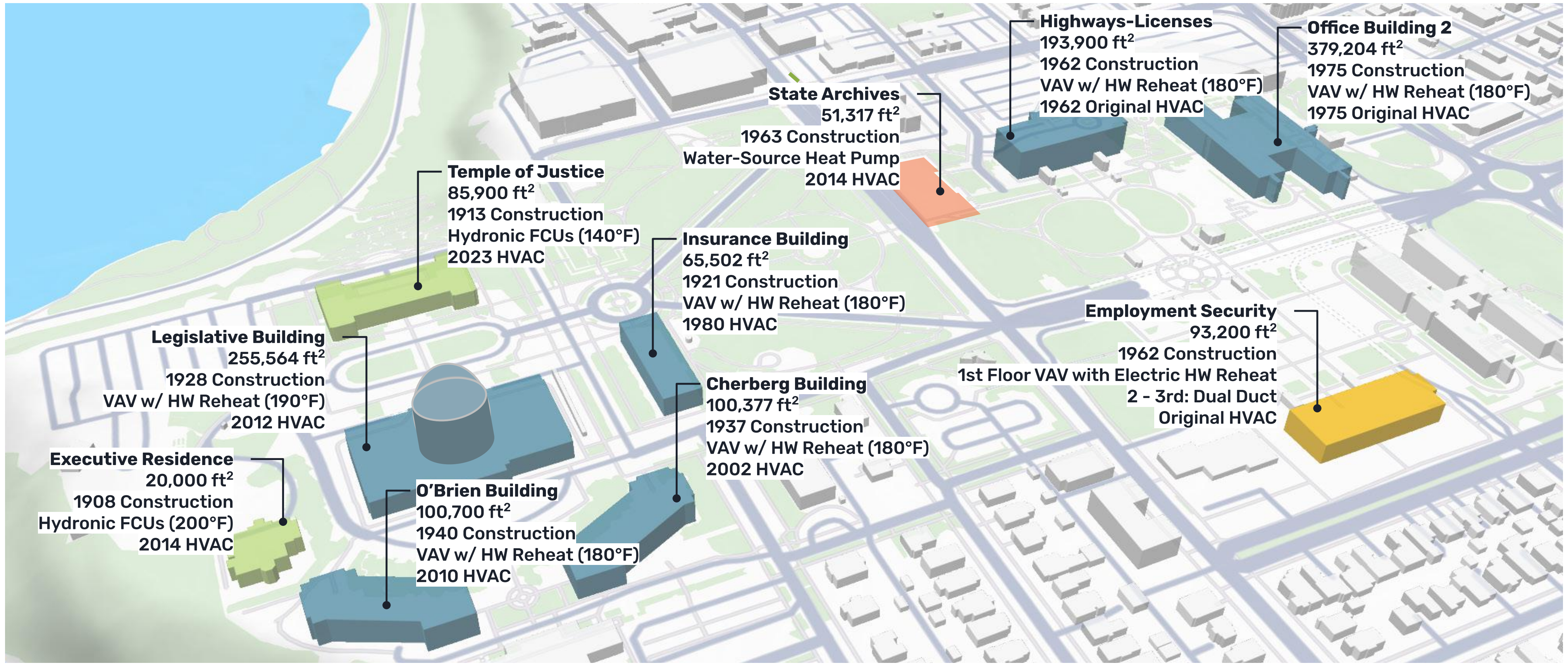
**Chart 5.4:** Baseline Capital Campus Peak Daily Substation Load.

# Building-Level Energy Systems Infrastructure

Facilities across the campus employ a wide range of systems to provide heating, ventilation, and air conditioning (HVAC). Buildings served by the existing district energy system are conditioned primarily by hydronic equipment, which uses the steam and chilled water networks.

As discussed on the following page, some buildings not currently served by the district energy system are candidates for future inclusion in the network since they already have systems that could easily be incorporated into a central heat pump-based district energy system.

Meanwhile, other buildings have systems that could not easily benefit from a district heating or cooling system. For the buildings that cannot be easily added to the system, independent compliance with the CBPS program will be required. Fortunately, these buildings (Prichard, Newhouse, and Child Care) were recently renovated or constructed and already have high-efficiency systems.



**Map 5.5:** Illustrates the variety of HVAC systems on campus.

## CAPITOL CAMPUS BUILDING HVAC SYSTEMS OVERVIEW

**Variable Air Volume (VAV):** This system consists of a central air handling unit which provides cool primary air to terminal units (VAV boxes) throughout the building. The temperature of the primary air is set by the zone that requires the most cooling and is often approximately 55°F. Each zone has a VAV box with a reheat coil (either hot water or electric), which modulates the airflow and warms up the supply air to the temperature required to maintain that space's temperature set point. The reheat coil in a VAV unit can be designed for high-temperature hot water (180-200°F) or low-temperature hot water (less than 140°F).

**Fan Coil Units (FCU):** FCUs are small air handling units that typically serve single zones or small areas. Each FCU has its own supply air, return air, and outside air.

**Water-source Heat Pump:** This system consists of small heat pump fan coil units that take or reject heat into a central condenser water loop. Heat is moved between spaces within the building via this loop. Supplemental heat is added by a boiler or steam heat exchanger, and excess heat is rejected through a fluid cooler, as needed.

**Dual Duct:** A dual duct system consists of a large central air handler with a heating coil that produces hot air in the hot deck, and a cooling coil that simultaneously produces cold air in the cold deck. Two sets of ducts leave the central air handling unit, one carrying hot air and one carrying cold air. At each zone, varying amounts of hot air is mixed with cold air to supply the zone with the appropriate temperature air to maintain space temperature set points.

# District Energy System Expansion

### Additional Building to be Included in the District Energy System

The following building is not currently on the existing district energy system (it does not receive steam heating or chilled water from the central plant). However, is it a good candidate for inclusion in the proposed heat pump-based district energy system.

***Note:*** *The solutions proposed in later sections of this report include the cost and energy impacts of adding this building to the district energy system.*

#### Natural Resources Building

Cooling for this building is provided by chilled water, and heat is rejected via cooling towers. The heat energy that is currently rejected from this building will positively benefit the district energy balancing.

Its proximity to Office Building 2 (OB2), where the East Campus heat pump plant will be located, makes this an ideal building to add to the new system.

### Other Candidates for Inclusion

The following buildings are not currently on the existing district energy system, but they could be considered as part of a future plan to expand the proposed hydronic heat pump-based district energy system.

***Note:*** *The solutions proposed in later sections of this report do not currently include the cost and energy impacts of adding these systems to the district energy system.*

#### Department of Transportation Building

This building also uses chilled water and rejects heat via a cooling tower. The future district energy system could be phased to include this building in the future.

#### Helen Sommers Building

This building has a ground-source heat exchange system with highly efficient and modern condensing boilers, which still have close to twenty years of usable life left. However, this building could be integrated into a future district energy system.

#### Capitol Court Building

This building is served by water-source heat pumps, which could directly exchange energy with the Ambient Temperature Loop, eliminating its current dependence on an existing natural gas boiler which is nearing the end of its life. Its proximity to the proposed routing of the Ambient Temperature Loop piping also makes it a good candidate.

### Buildings Not Optimal for Inclusion

The following buildings use fully electric Variable Refrigerant Flow (VRF) equipment for their HVAC needs. VRF is a highly efficient stand-alone air-source heat pump system that cannot tie into and would not benefit from a future connection to the hydronic heat-pump-based district heating system.

- **Joel M. Pritchard Building**
- **Irving R. Newhouse Building**
- **Child Care Center**

**Image 5.6 (top):** Natural Resources Building.
**Image 5.7 (middle):** Helen Sommers Building.
**Image 5.8 (bottom):** Department of Transportation Building.

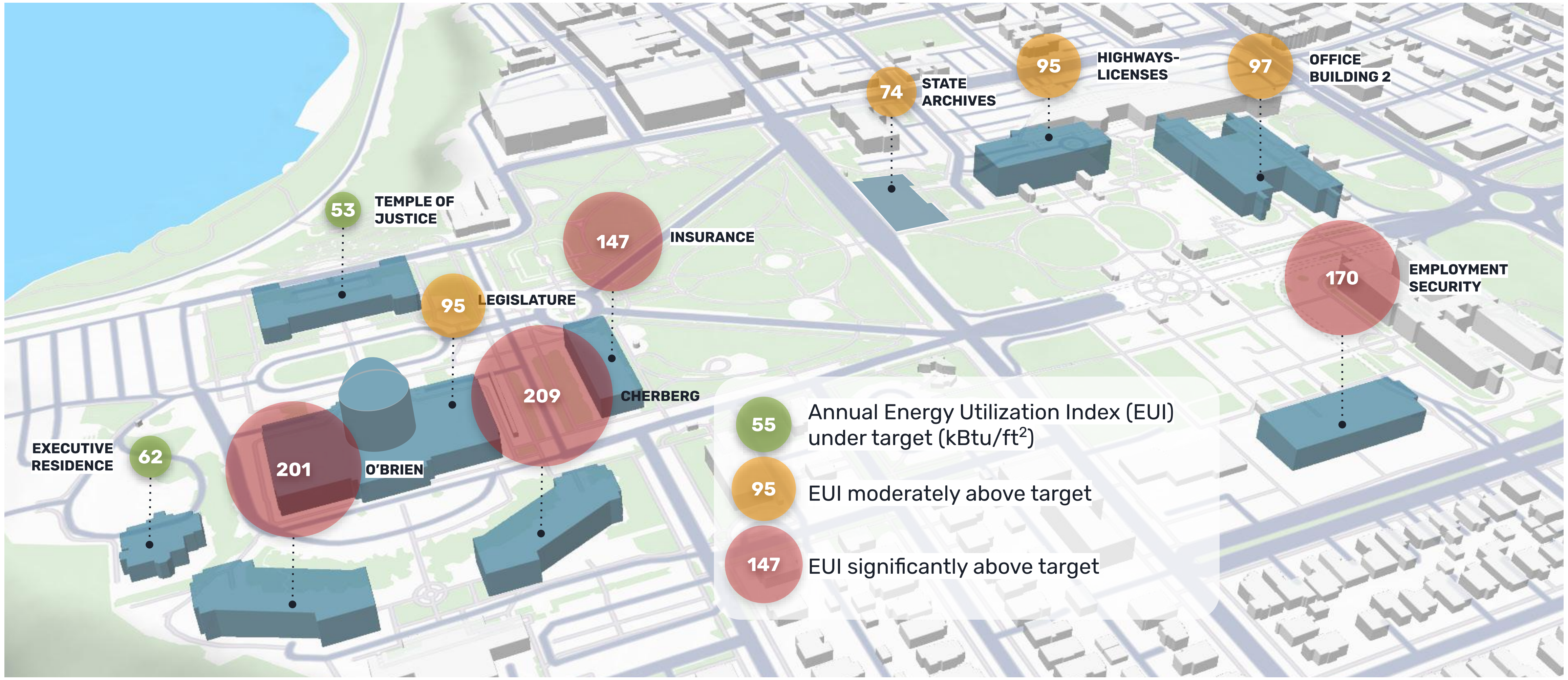


**Diagram 5.9:** Displays the energy use intensity (EUI) of each facility on campus.

# Campus Baseline Energy & Carbon Analysis

The Washington State Capitol Campus has one electricity and one main natural gas meter for over three million square feet of facilities. The single electric substation serves all the buildings on campus, and the natural gas consumed at the Powerhouse provides nearly all of the campus' heating energy. Outside of the boilers in the Powerhouse, small amounts of natural gas are used only in some kitchens and cafeterias, and small hot water boilers like the one serving the Executive Residence.

Detailed building-level modeling was needed to separate the energy consumption and carbon emissions associated with each facility on campus. This modeling effort was combined with and validated by actual metered data from submeters that DES installed across the campus throughout 2024. The meters now record steam, hot water, chilled water, and electrical consumption of each building.

For buildings currently connected to the district heating and cooling systems, the relative impact of the consumed energy and carbon of the Powerhouse was distributed to those buildings based on their modeled and documented heating and cooling loads.

### ENERGY USE INTENSITY PER BUILDING

Energy use intensity (EUI) is a metric used to express the normalized energy use of buildings as energy consumed per square foot per year. A lower EUI indicates better energy efficiency, and it is used as a metric to compare buildings of a similar type but different sizes.

## Carbon Emission Intensity per Building

Carbon Emission Intensity is a way to compare the relative carbon emissions per square foot of different buildings. The buildings served by the existing district heating and cooling system have some of the highest energy and carbon intensities. This is due to the highly inefficient steam distribution system, which experiences high energy losses across the nearly two miles of distribution steam and condensate piping throughout campus. EUIs are particularly high at Cherberg, O'Brien, Employment Security, and Insurance Buildings, which are all due for much-needed renovation and optimization to their HVAC systems and infrastructure.

***Note:*** *The campus is enrolled in PSE's Green Direct Energy Program. According to PSE, this program provides customers the ability to purchase 100% of their energy from a dedicated, local, renewable energy resource. However, for illustrative purposes, the carbon intensity of the buildings was calculated using the state average emissions factor for 2023 to understand their carbon emission intensity compared to other buildings.*

## Carbon End Use Analysis

Carbon end use analysis tracks the site emissions associated with the campus natural gas and electricity meters to the facilities responsible for those emissions.

Carbon dioxide emissions associated with natural gas are easily quantified. The combustion of natural gas generates 116.65 pounds of carbon dioxide per million British Thermal Units (lbs of $CO_2$ per million BTUs). Natural gas is billed in units of Therms and this converts to approximately 11.7 lbs of $CO_2$ per Therm.

Carbon dioxide emission rates per unit of electricity depend on the local utility's generation methods. Washington has one of the lowest emissions factors in the country, thanks to significant hydroelectric electrical generation in the region, at 266.585 lbs of $CO_2e$ per megawatt hour (MWh).

**Building Carbon Intensity (Tonnes $CO_2$ per Thousand Square Feet)**

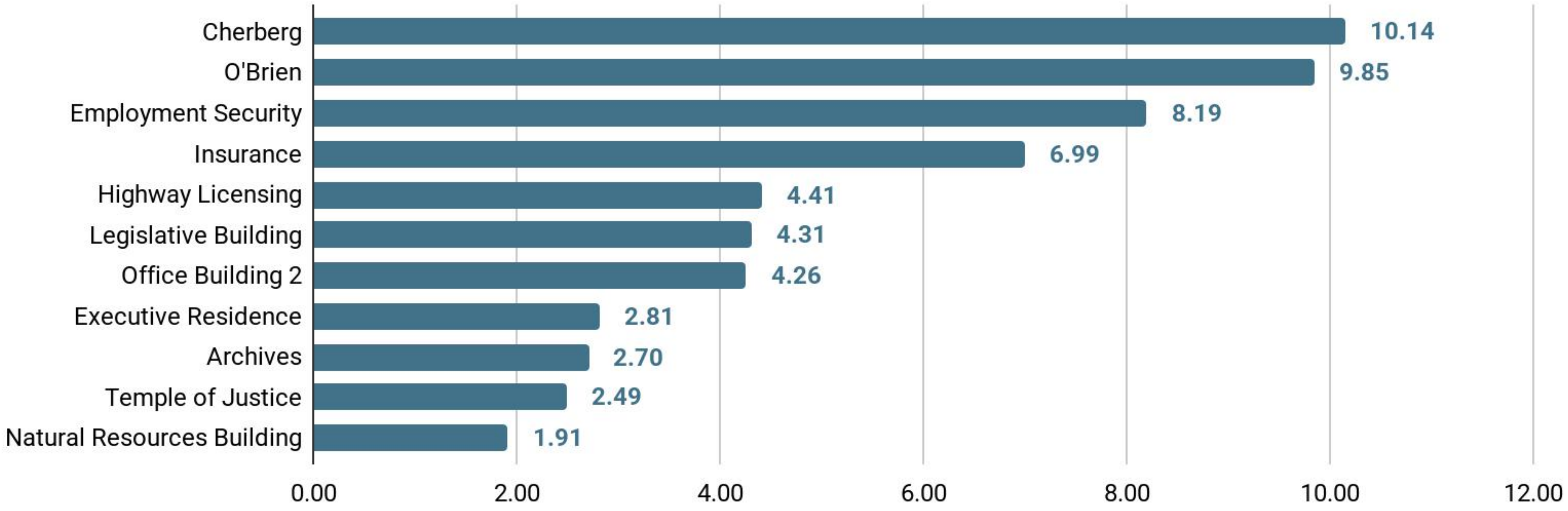


**Chart 5.10:** Shows the carbon intensities of each building to identify facilities with the largest contribution to carbon emissions per square foot. ***Note:*** *The Powerhouse's gas and electric consumption was allocated to each building served proportional to their relative steam and chilled water consumption.*

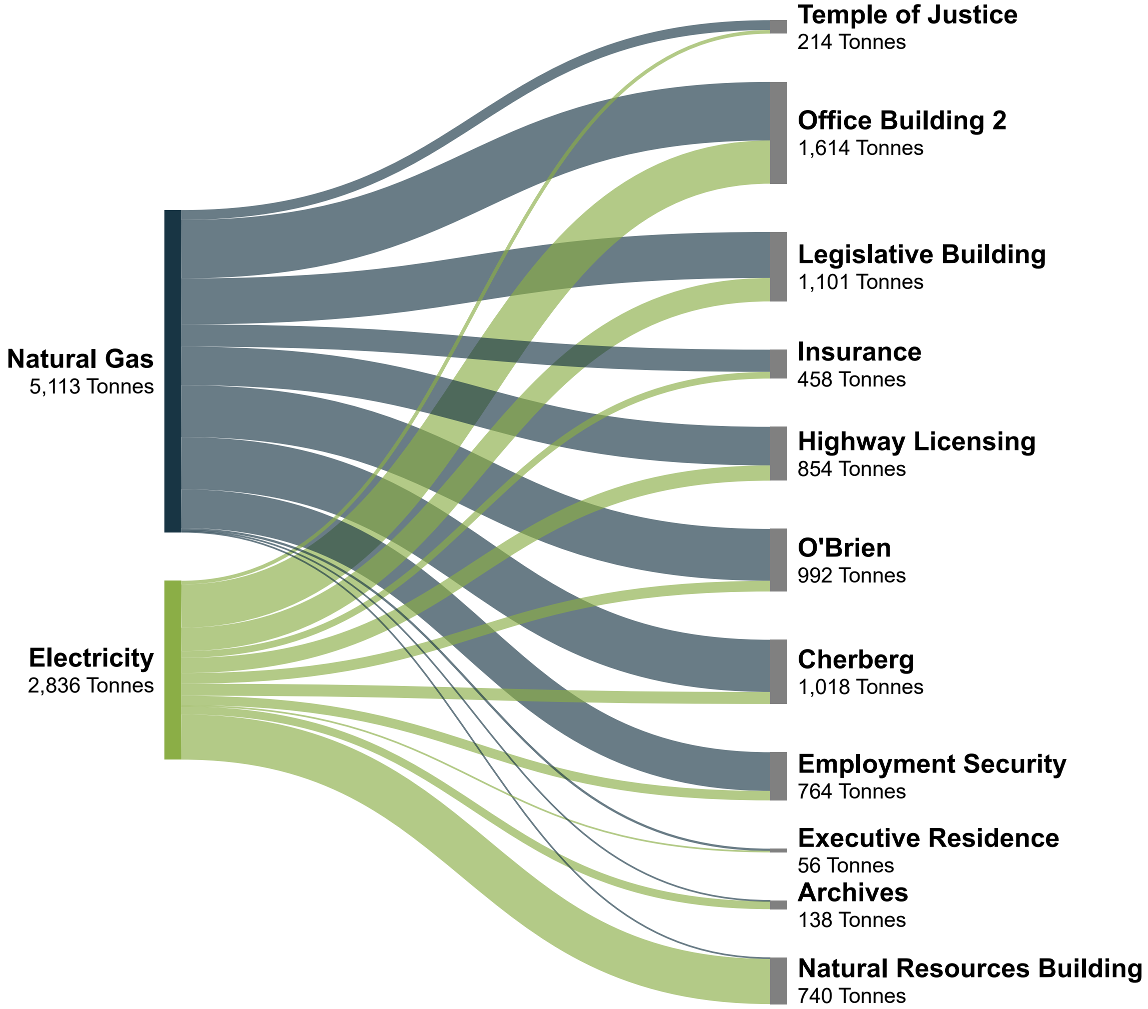


**Chart 5.11:** A diagram showing the annual carbon emissions of the campus. On the left side, the emissions from each fuel source, electricity and natural gas, are shown. Those emissions are then attributed to each building on the district energy system on the right side of the diagram.

# 6: DISTRICT ENERGY BALANCING & STRATEGY DEVELOPMENT

# Digital Simulation & Baseline Analysis

**Any change made to the district energy system will affect the performance of all buildings connected to it. Similarly, any changes to the building-level operation or efficiency will affect the load and performance of the central heating and cooling equipment.**

To understand these interdependent relationships, the project team developed a ‘digital clone’ of the entire Capitol Campus. Detailed energy models were developed for each major building on campus. This allowed engineers to:

- Mine the digital clone for data about existing facility energy use and heating and cooling loads
- Iteratively model and analyze the impacts of district energy system replacement options and building-level efficiency improvements.

## Digital Simulation & Baseline Analysis

Beginning in the fall of 2023, project engineers collected critical data about the buildings, systems, utility consumption, and operation of facilities across the Capitol Campus.

- The team studied and photographed building plans at the State Archives Building to develop a timeline of architectural, mechanical, electrical, and plumbing installations, improvements, and renovations. Some of the oldest plans were nearly a century old, dating back to the original construction of buildings on the campus, while some of the newest were from buildings currently under construction.
- Each campus building was physically inspected and audited to determine the actual equipment and systems currently serving each facility. This information was used to develop a database of all major equipment.
- The building automation systems were evaluated and documented to obtain operational data.
- Natural gas, electricity, and water consumption information were collected and analyzed.
- All previous reports and studies conducted on campus buildings were collected and reviewed.

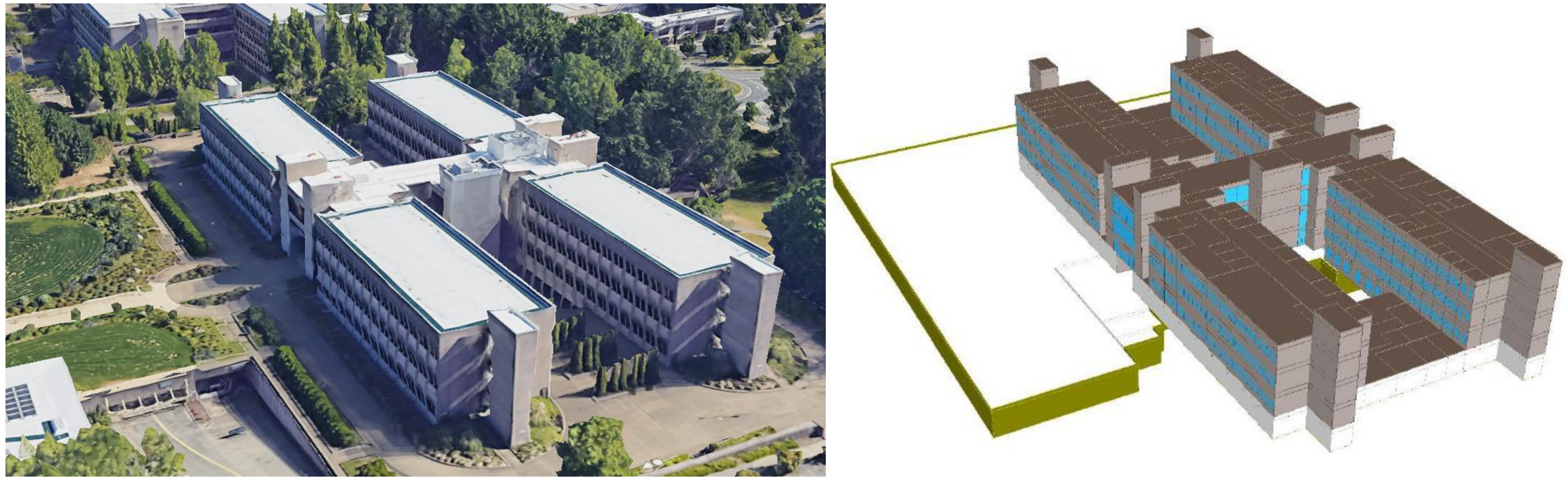


**Diagram 6.1:** Example eQUEST model of the Department of Transportation building.

Building models were created using this extensive data in the software program eQUEST. Information for each building, including accurate physical characteristics and construction types, as well as actual equipment and operational data, was entered into the program.

This information is used to calculate operational information for each hour of the year using Typical Meteorological Year (TMY) weather data for Olympia, WA. The central plant was also modeled, and all buildings/systems were calibrated to actual historic utility bills and campus submetering data. Models were calibrated based on the total annual consumption and the monthly consumption and submetering data to fine-tune seasonal operation.

To be considered accurate, the difference between the actual energy usage and the modeled usage for the simulation must be calculated. We use the mean bias error and *coefficient of variation* to determine the accuracy and precision of the model, as follows:

- The mean bias error is the percentage difference between the modeled energy usage and the baseline.
  - A model with a mean bias error of less than +5% is considered accurately calibrated.
- A coefficient of variation demonstrates how precisely the simulation represents actual conditions
  - A model with a coefficient of variation of less than 15% demonstrates precision in the energy model.

**eQUEST** is a widely-used, industry standard building energy simulation tool, developed by Lawrence Berkeley National Laboratory with funding from the U.S. Department of Energy.

## Energy End Use

Chart 6.2 is an end-use breakdown of the electrical and natural gas energy use of buildings across the campus.

***Note:*** *Nearly all of the space heating usage represents indirect consumption for most buildings, as the heating-related natural gas for these services is actually consumed at the Powerhouse by the central steam boilers.*

## Distribution & Operational Losses

After comparing the heating and cooling loads of all the buildings served by the central plant versus the actual energy consumed at the central plant, we found that the Powerhouse consumes far more energy than needed to heat the buildings on campus, indicating that there is significant energy lost in distributing stream to buildings.

### Steam System Heat Loss Analysis

The losses were calculated using a combination of utility data, submetering data, and feedback from the boiler operators and systems.

Operational losses are high because the boiler system operates 24 hours a day, 365 days a year. Losses associated with the deaerator and blowdown cannot be avoided in this system type, because they are required for the safe and continuous operation of the steam boilers.

Thermal losses result from the heat transfer that occurs anytime there is a temperature differential. The greater that difference, the greater the thermal loss. The Capitol Campus has over two miles of underground pipes, with steam at 340°F and condensate anywhere from 130°F to 200°F. Pipe insulation is intended to reduce thermal losses; however, not all insulation is in good condition. Fundamentally, when steam flows through two miles of piping, 24 hours per day, at a large temperature differential to its surroundings, thermal losses cannot be avoided.

Approximately 20% of the steam energy leaving the Powerhouse does not reach the buildings it serves.

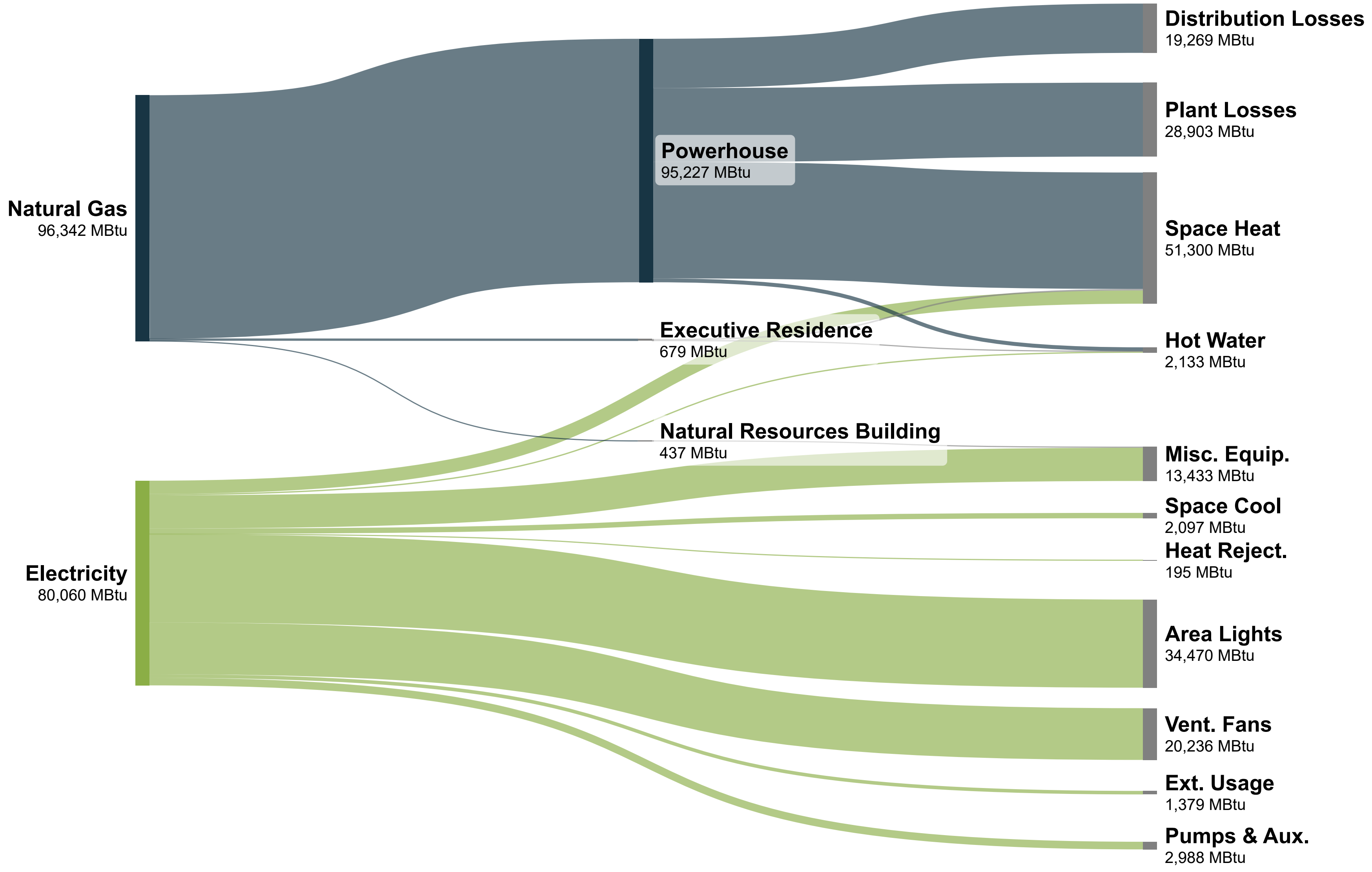


**Chart 6.2:** Energy end use breakdown of the electrical and natural gas energy use of buildings across the campus.

### STEAM DISTRIBUTION LOSSES PRIMARILY RESULT FROM:

- Heat escaping from steam pipes and components via radiative and convective losses to the surroundings.
- Steam leaks and condensate not being recovered.

These losses reduce the efficiency of steam systems and increase operating costs.

# Heat Recovery Potential

## Simultaneous Heating & Cooling within a Building

Diagram 6.3 illustrates heating and cooling loads within commercial buildings, with Office Building 2 used as the example.

Heat is lost through the building envelope to the outside on a cold day, putting those zones in heating mode. However, near the center of the building, the internal loads from occupants, computers, lighting, and other equipment result in a need for cooling in those areas.

Office Building 2 provides a good example of the concept of simultaneous heating and cooling. The existing HVAC systems serving OB2 use the cooling system to reject heat from the warmer zones to the atmosphere (outside the building) on the interior of the building, while the steam boilers burn natural gas to generate 100% of the heat needed to heat the perimeter where the building experiences high heat losses through exterior windows, doors, and walls.

## Simultaneous Heating & Cooling Across Campus

Rigorous building-level modeling of the Capitol Campus was conducted to determine the load profile of the buildings connected to the central systems to assess the magnitude of potential heat recovery with a heat pump-based district energy system. (This is described in detail in later sections of this report.)

Chart 6.4 illustrates the district heating and cooling energy balance of the buildings currently served by the existing district energy system.

The filled-in portion of the graph represents the opportunity for heat recovery from chilled water systems to serve the campus' heating load. As shown, the campus has simultaneous heating and cooling needs throughout the year, and recovered heat from building cooling demand alone could potentially serve 46% of the overall campus heating needs.

**Office Building 2 Heat Map**

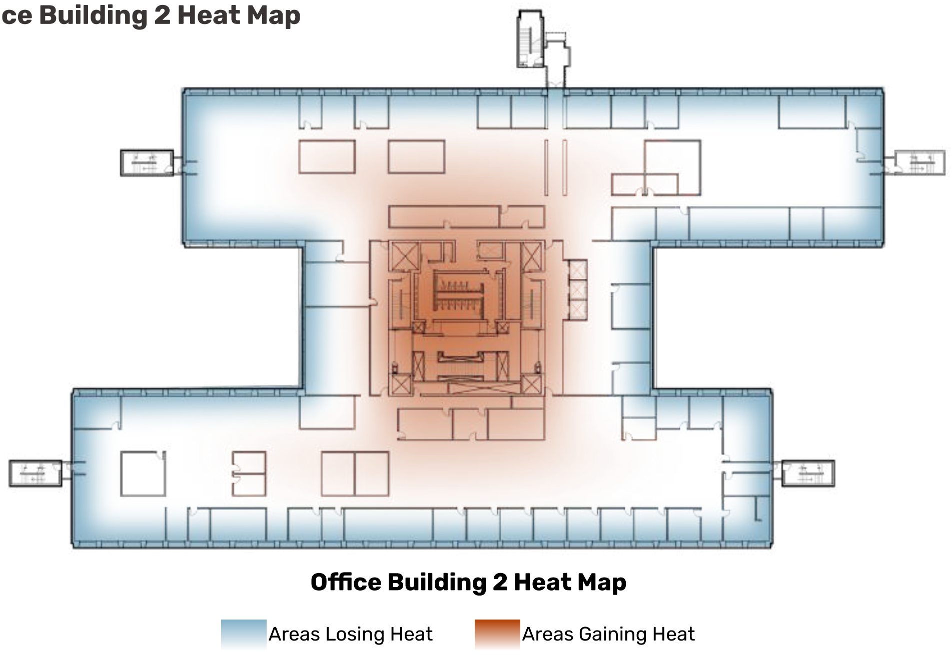


**Diagram 6.3:** Heat map of Office Building 2 on a 30°F day.

**Annual District Energy Balance with Heat Recovery**

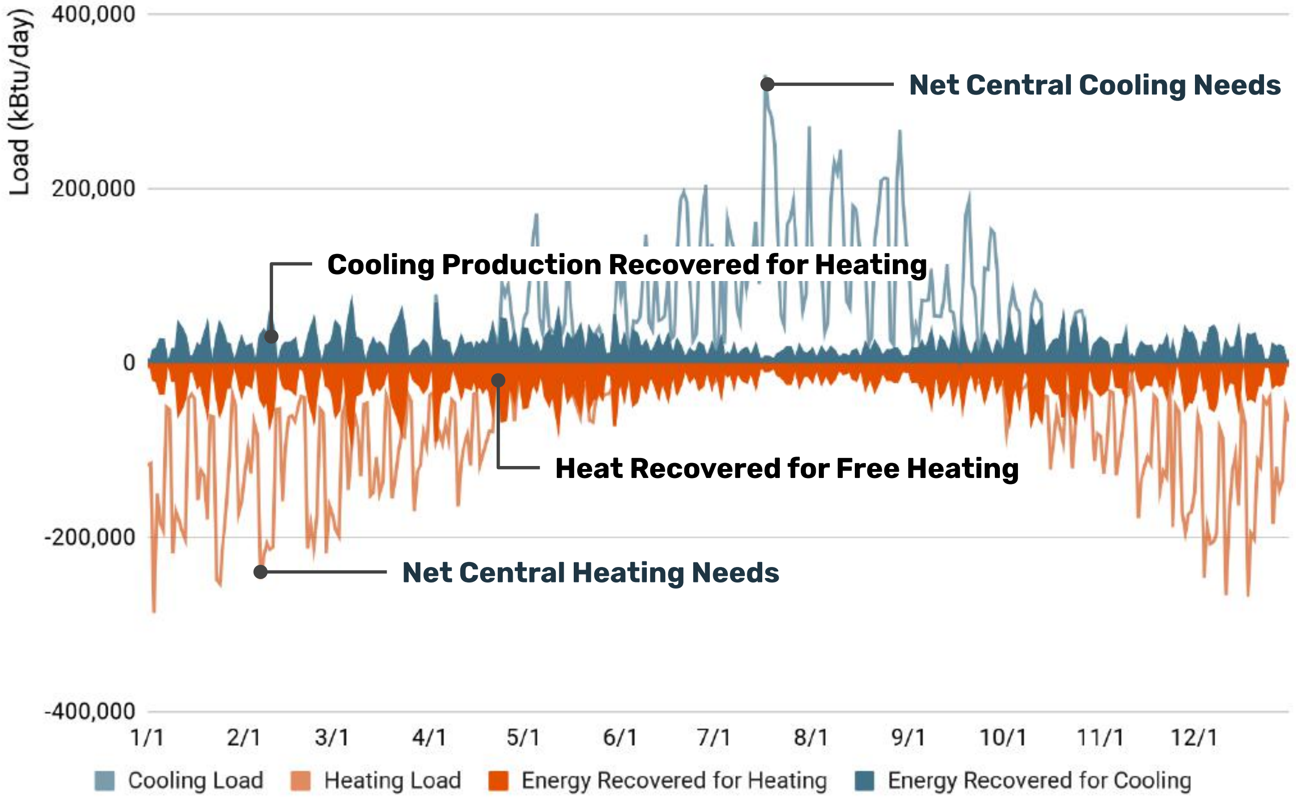


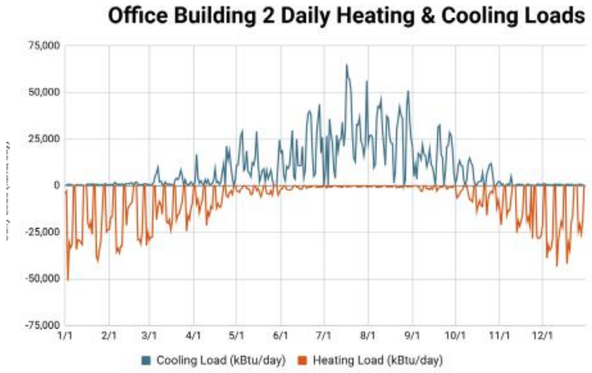
**Chart 6.4:** Illustrates the district heating and cooling energy balance of the buildings currently served by the existing district energy system.

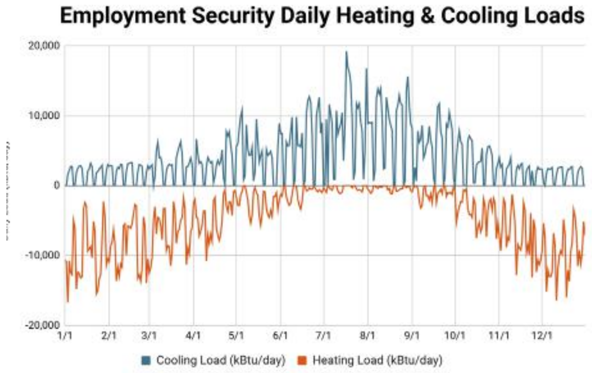
## Building Annual Load Profiles

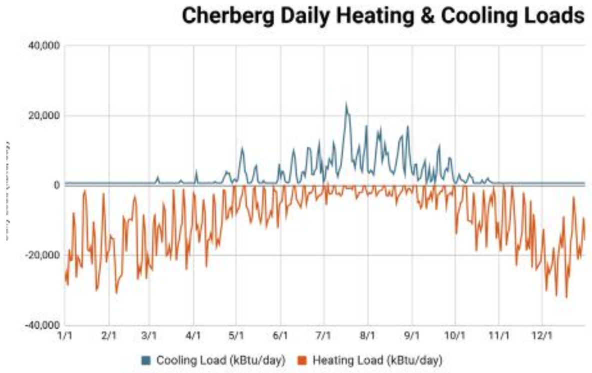
These charts illustrate daily heating and cooling loads throughout the year for each building served by the district energy system. This analysis provides data on the simultaneous heating and cooling opportunity throughout the year on a building-by-building basis.

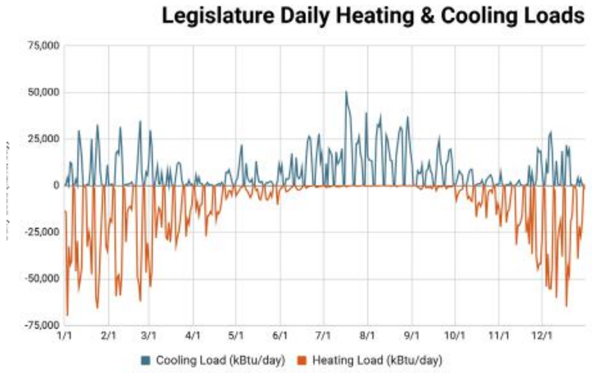
Below, it is easy to see that there is significant simultaneous, year-round heating and cooling demand at the Highways-Licenses, Employment Security, Cherberg, O'Brien, Legislature, and Insurance buildings.

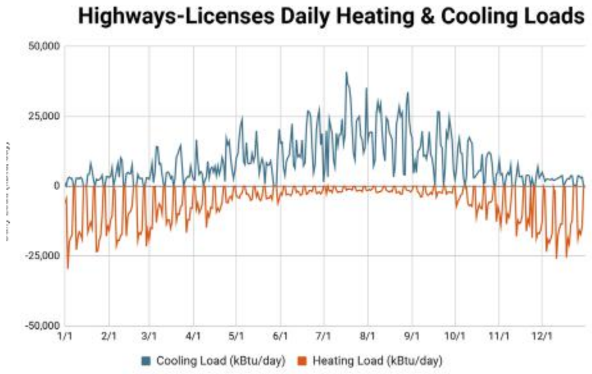
These buildings' loads provide a good opportunity to recover heat from the cooling process for free heating through water-to-water heat pumps.

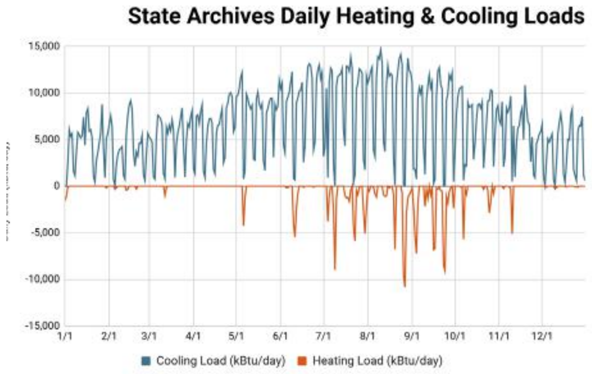

Office Building 2 Daily Heating & Cooling Loads

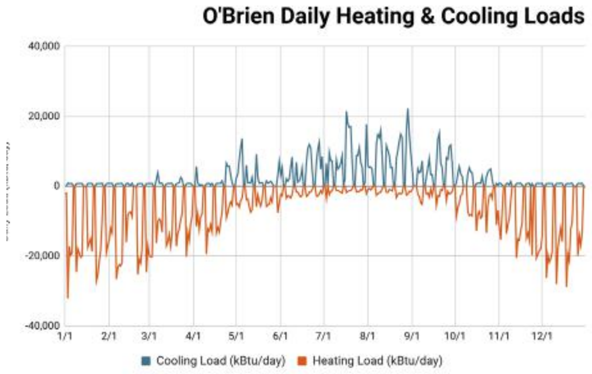

Employment Security Daily Heating & Cooling Loads

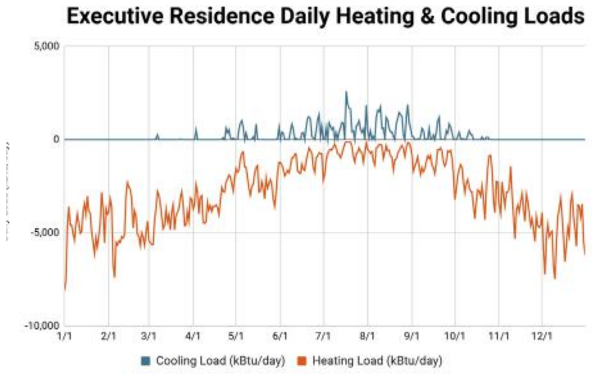

Cherberg Daily Heating & Cooling Loads

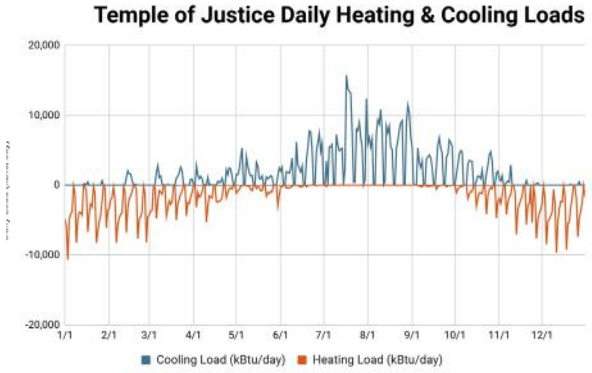

Legislature Daily Heating & Cooling Loads

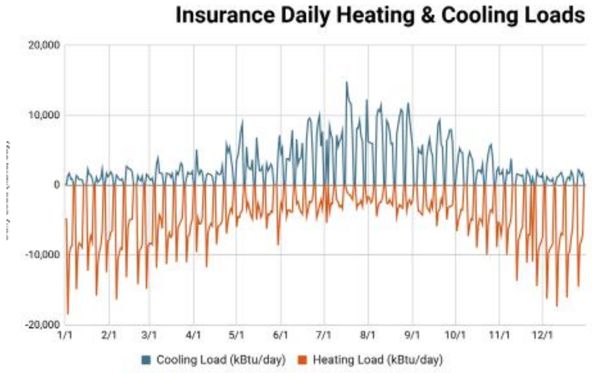

Highways-Licenses Daily Heating & Cooling Loads


State Archives Daily Heating & Cooling Loads


O'Brien Daily Heating & Cooling Loads


Executive Residence Daily Heating & Cooling Loads


Temple of Justice Daily Heating & Cooling Loads


Insurance Daily Heating & Cooling Loads

**Charts 6.5-6.14:** Annual heating and cooling load profiles for each building (in kBtu/day) served by the district energy system. Blue and red indicates cooling and heating load, respectively.

## Campus Electrical System's Capacity to Support All Electric Heat

After implementing energy and load reduction strategies, maximizing heat recovery, and eliminating heating distribution losses, the campus electrical system must support the significant electrical requirements of a new electrified heating system. The capacity of the existing PSE substation and campus distribution circuits represents a critical system consideration, as any required expansion will significantly impact the cost and implementation timeline of the new district energy system.

To understand the impact of each district energy system replacement alternative on the existing electrical distribution infrastructure, a detailed model of the campus' electrical system was developed using metered 15-minute interval data for each of the four distribution feeders, submetering data from the campus metering system, and hourly building energy models to quantify the effects of energy and load reduction strategies.

Each building is served by two circuits, one for normal operation and one for backup if the normal circuit is down due to maintenance or an emergency. To understand the worst-case circuit loading, analysis was performed for normal operation and four backup scenarios. The backup scenarios evaluated the impact of each of the four circuits taken out of service separately, leaving the remaining three circuits to carry the campus load.

Chart 6.15 shows the potential for the current campus substation to support additional electrical load, including a new all-electric district heating system. The chart details the peak annual campus load on the PSE substation (5,739 kVA) after electrical and load reduction measures are implemented, but before any new district energy system is implemented. The grey pie represents the additional electric load the current substation can support (7,261 kVA), or 56% of the Capitol Campus' contract capacity with PSE.

**Capitol Campus Baseline Load on Substation after Energy & Load Reduction Measures**

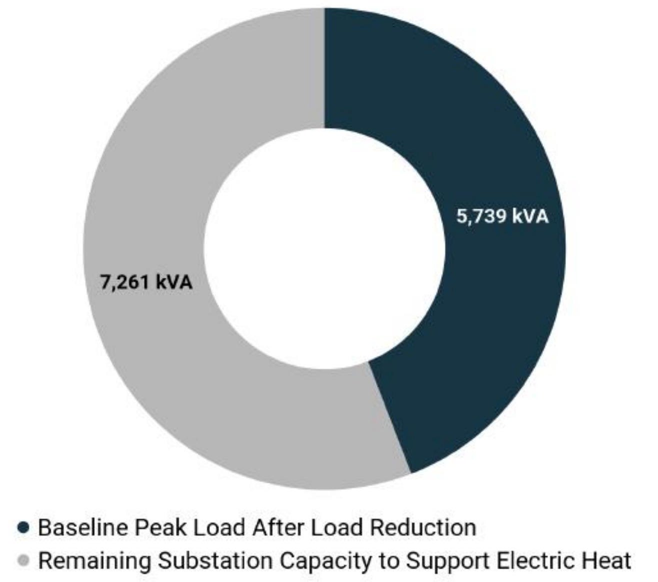


**Chart 6.15:** Projected campus substation electrical capacity after implementation of energy efficiency measures.

## Electrical System Impacts of Direct Replacement with Electric Boiler Versus Heat Pump-Based Solution

### Electric Boiler-Based District Energy Solution

Chart 6.16 (top) shows the electrical load impacts of performing significant energy efficiency and load reduction strategies within the buildings and systems on campus, along with replacing the existing natural gas-fired steam boilers with electric boilers. The required electrical capacity would exceed the Capitol Campus' contract capacity with PSE of 13,000 kVA during peak heating season. Further, a central electric boiler heating plant would require 13,624 kVA of power, drawing an additional 391 amps on one of the four campus feeders. Without even accounting for the existing building loads of the circuit, this extra load alone significantly exceeds any circuit's ampacity of 380 amps, requiring the installation of new distribution feeders.

### Hydronic Heat Pump-Based District Energy Solution

Chart 6.17 (bottom) shows the electrical load impacts of performing significant energy efficiency and load reduction strategies within the buildings and systems on campus and replacing the existing natural gas-fired steam boilers with hydronic heat pumps. During peak heating season, the required electrical capacity would be 9,523 kVA, or 3,477 kVA below the 13,000 kVA contract capacity.

### Conclusion

This analysis unequivocally showed that even with the implementation of load reduction and energy efficiency strategies within building-level HVAC systems, an electric boiler-based solution would exceed the available electrical capacity of the substation and feeders. This option would trigger the need for a cost expansion of the existing electrical substation and additional distribution feeders to the campus.

A heat pump-based solution, in combination with load reduction and energy efficiency strategies, will enable the campus to continue utilizing the existing substation. It is important to note that reconfiguring the loads across the campus feeders may be required as part of any proposed hydronic heat pump solution.

**Capitol Campus Substation Load after Electric Boiler Alternative**

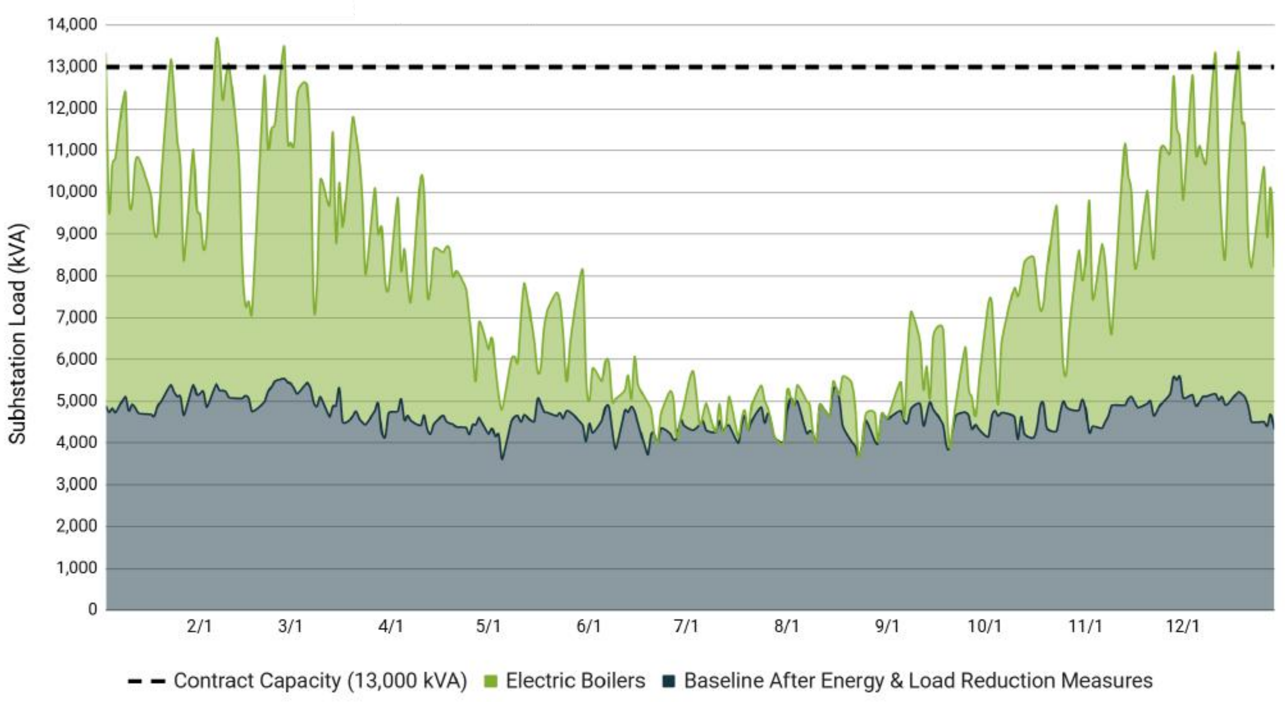


**Chart 6.16:** Electrical Load Impact of Electric Boilers.

**Capitol Campus Substation Load after Hydronic Heat Pump Alternative**

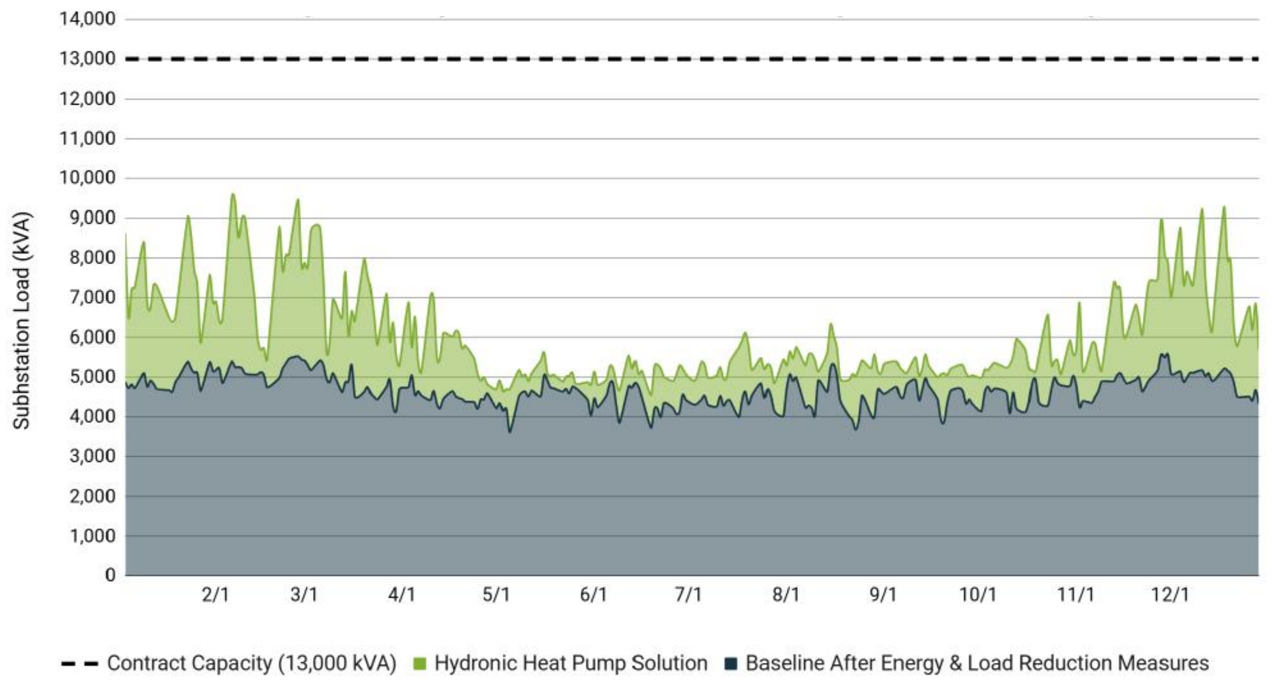


**Chart 6.17:** Electrical Load Impact of Hydronic Heat Pump Alternative.

# 7: ANALYSIS OF ALTERNATIVES

# Comparison of Alternative Strategies for Decarbonization

The following section describes the four broad strategies of non-fossil fuel replacement options for the campus' district energy system.

**Strategy 1.** Central Electric Boilers

**Strategy 2.** Central Four-Pipe Hydronic Heat Pump Plant

**Strategy 3.** Two-Pipe Ambient Temperature Loop with Distributed Hydronic Heat Pump Plants

**Strategy 4.** Decentralized HVAC Systems

Within each of these high-level strategies there are a multitude of options for the specific system configuration; equipment size, type, and manufacturer; distribution piping and equipment locations; and construction phasing.

The scope, estimated cost, energy impact, advantages, and disadvantages of the competing alternatives are described on the following page; however, a comparison of each alternative is shown in the table below.

> During a four-month process, these strategies were presented to the Capitol Campus Facilities Steering Committee (FSC) and discussed in a series of meetings. At the end of this process, the FSC selected Strategy 3 (Ambient Temperature Loop) as the Preferred Alternative.

### Advantages & Disadvantages Common to All Strategies

Any advantages or disadvantages common to all options are listed here, but omitted in each strategy discussion below to avoid redundancy:

**ADVANTAGES OF ALL STRATEGIES**

- Decarbonization and elimination of on-site natural gas usage.
- New equipment and distribution piping will solve issues related to the age of existing equipment and ongoing failures and risk.
- All systems would be designed to modern safety and redundancy standards, as well as all current codes, increasing safety, reliability, and resilience.

**DISADVANTAGES OF ALL STRATEGIES**

- Disruption of the Capitol Campus during construction and implementation.
- A significant capital investment is required for all options.
- Increased load on electrical distribution system and campus substation.
- New system types for campus staff to learn to operate and maintain

**Table 7.1:** Comparison of Each Replacement Alternative.

| | **PROJECT CRITERIA**<br>**Green = Good**<br>*All scoring is relative to other options* | **Installed Cost** | **Energy Cost** | **Maint Cost & Labor** | **Campus Energy Usage After Install** | **Disruption to Operations During Install** | **Phase Construction Over Time** | **Achieves Multiple Other Benefits** | **Extent of Electrical System Upgrades** | **Amount of Large, Noisy Equipment on Campus** | **Resilience & Reliability** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | **Central Electric Boilers** | | | 🟩 | | ▨ | | | | ░ | ▨ |
| **2** | **Central Hydronic Heat Pump Plant** | ░ | 🟩 | ▨ | 🟩 | ▨ | | 🟩 | ▨ | ░ | ▨ |
| **3** | **Ambient Temperature Loop w/ Distributed Hydronic Heat Pumps** | 🟩 | 🟩 | ▨ | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | ▨ | ▨ |
| **4** | **Eliminate District Energy System; Distributed Unitary Equipment** | ░ | | | | | 🟩 | 🟩 | | ▨ | 🟩 |

# Strategy 1:
# Central Electric Boilers

***Note:*** *This option was explored but found not to be feasible based on Washington Energy Code requirements and the timeline for CBPS compliance.*

This option is a one-for-one replacement of natural gas-fired boilers with hydronic electric boilers in a new Powerhouse location and conversion from a steam to a hot-water system.

### Scope of Work Summary:

- Construct a new boiler plant on the main campus with industrial electric boilers, chillers, cooling towers, and pumps.
- Site and construct a major expansion of the PSE electrical substation; upgrade campus electrical distribution system.
- Install approximately two miles of hot water supply and return piping.
- Replace the campus chilled water distribution piping.
- Remove building-level steam infrastructure, including eliminating steam-to-hot water heat exchangers and steam heating coils.

**Implementation Cost:** $182 to $222 million

**Annual Energy Cost Impact:** $373,000 cost savings below current

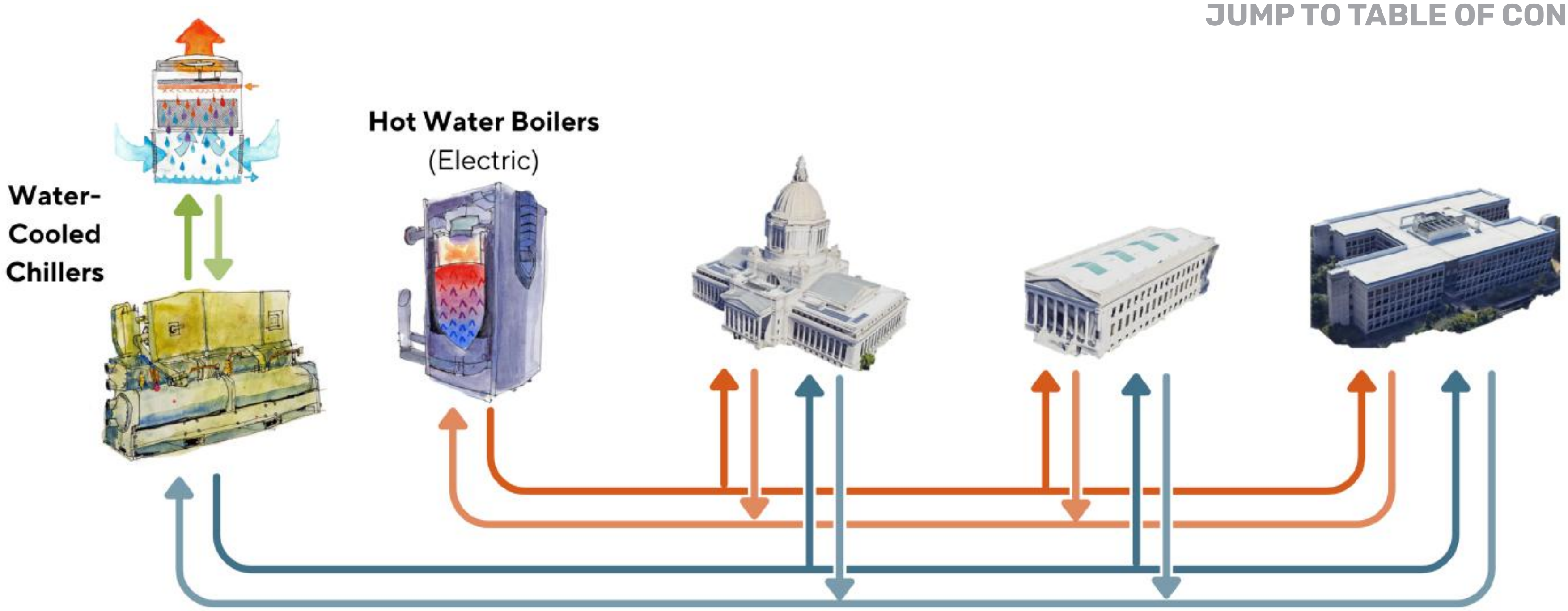


**Diagram 7.2:** Central electric hot water boiler simplified diagram.

**Image 7.3:** Example image of an industrial-scale electric boiler

### ADVANTAGES OF CENTRAL ELECTRIC BOILERS

**Simplicity**

- This one-for-one replacement strategy maintains a four-pipe configuration on campus, with separate hot and chilled water systems similar to the current system, except hot water is distributed in the place of steam. This approach closely resembles the existing system, requiring the least operational changes for maintenance and building staff.

**Least number of pieces of equipment**

- Ongoing maintenance costs will be lowest.

***Disadvantages are shown on the following page.***

## DISADVANTAGES OF CENTRAL ELECTRIC BOILERS

### Not compliant with Washington State Energy Code

- Electric boilers in this application are not permitted under WAC 51-11C-40314. The Washington code favors heat pump solutions over electric resistance heat due to their higher efficiency.
- This strategy maintains two separate systems for heating and cooling, with no opportunity for heat recovery.

### Requires new electrical substation

- An additional electrical substation or major expansion would need to be sited and constructed before becoming operational. The planning, permitting, and construction process would take several years and add significant additional cost to the project.

### Highest implementation cost

- At $182 to $222M and a higher energy cost than the other systems, this option has the highest first cost and llife cycle cost of all options.

### Limited potential for construction phasing

Some implementation phasing is possible, but due to the nature of this system, the vast majority of the investment and construction would need to be executed within a single biennium.

### Resilience similar to current system

- The resilience of this system design would not be significantly improved from the current system.

### Requires new central plant facility

- A new central plant building would need to be constructed on campus to house the new boilers, chillers and cooling towers.

### Extensive distribution piping infrastructure

- New four-pipe hot water and chilled water distribution piping would be laid throughout the campus.

### High ongoing energy costs

- Poorest energy performance of all systems analyzed.

### Limited future system expansion

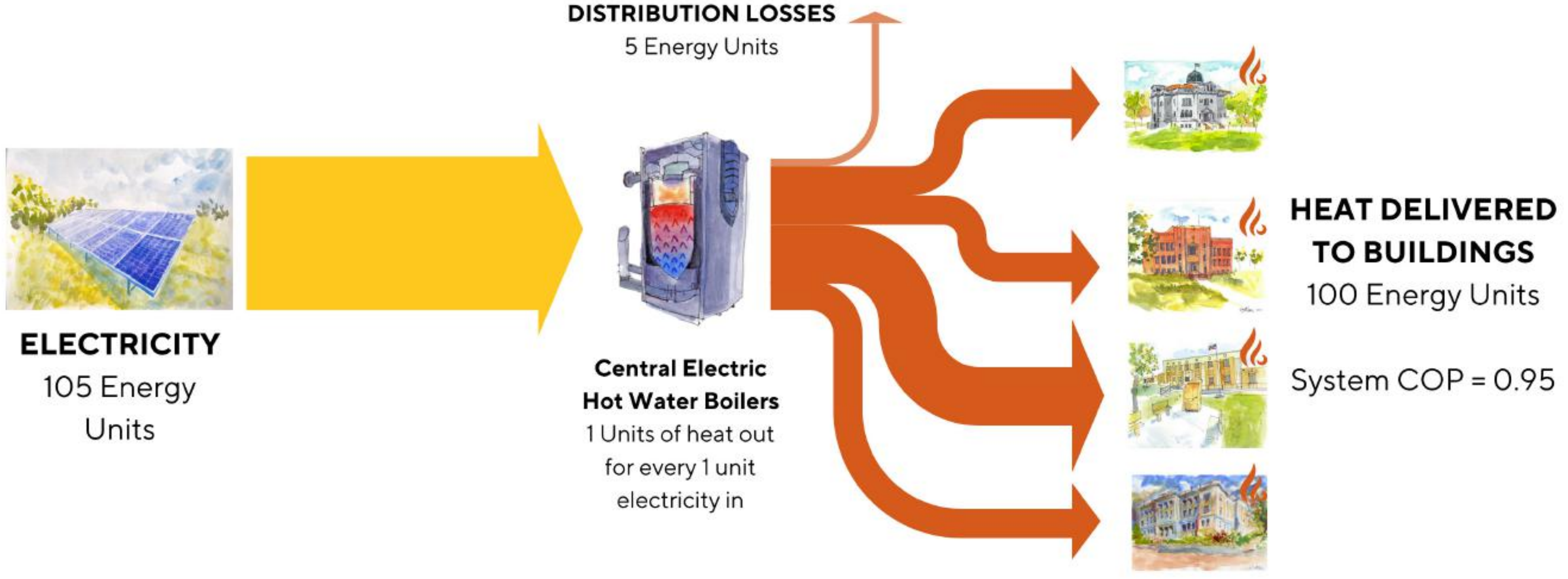
- This system has the most limitations in accommodating future growth.

## Energy Flow Through System

Diagram 7.4 visually demonstrates the flow of energy required by the system for heating.

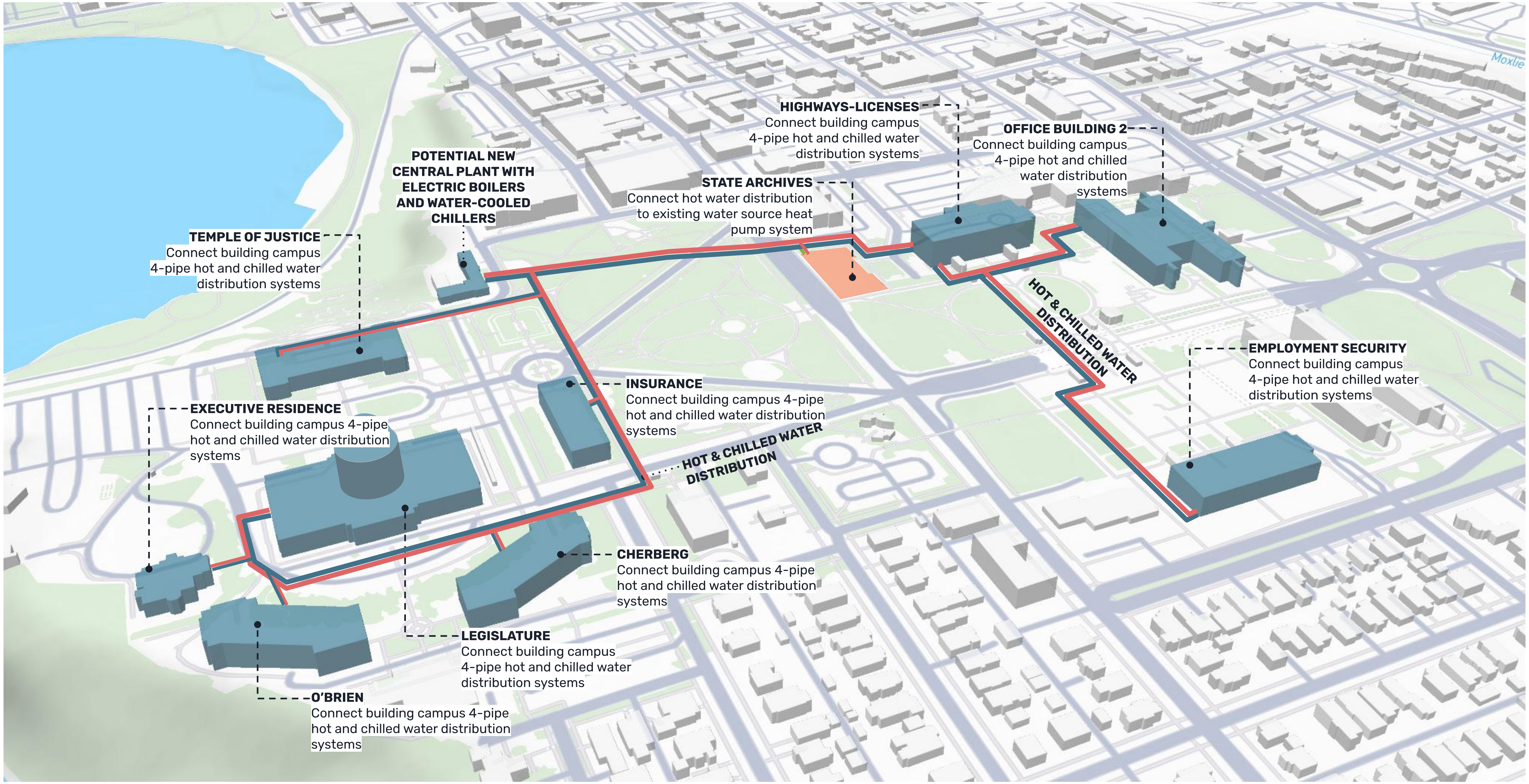
- Starting on the left, electrical energy is converted into heat energy by the boilers and distributed to the buildings with some distribution losses.
- The system coefficient of performance (COP) is 0.95, meaning that for every unit of energy in, 0.95 energy units are delivered to buildings.
    - This is the lowest COP of all options considered and the only option that does not include using recovered waste heat to offset heating needs.
- A separate system is required for cooling, and no heat recovery occurs.

**Diagram 7.4:** Electric boilers energy performance flow diagram.



***Map of the campus system layout for Central Electric Boiler implementation appears on the following page.***

## Strategy 1: Implementation Map



**POTENTIAL NEW CENTRAL PLANT WITH ELECTRIC BOILERS AND WATER-COOLED CHILLERS**

**HIGHWAYS-LICENSES**
Connect building campus 4-pipe hot and chilled water distribution systems

**OFFICE BUILDING 2**
Connect building campus 4-pipe hot and chilled water distribution systems

**STATE ARCHIVES**
Connect hot water distribution to existing water source heat pump system

**TEMPLE OF JUSTICE**
Connect building campus 4-pipe hot and chilled water distribution systems

**EMPLOYMENT SECURITY**
Connect building campus 4-pipe hot and chilled water distribution systems

**INSURANCE**
Connect building campus 4-pipe hot and chilled water distribution systems

**EXECUTIVE RESIDENCE**
Connect building campus 4-pipe hot and chilled water distribution systems

**CHERBERG**
Connect building campus 4-pipe hot and chilled water distribution systems

**LEGISLATURE**
Connect building campus 4-pipe hot and chilled water distribution systems

**O'BRIEN**
Connect building campus 4-pipe hot and chilled water distribution systems

**Map 7.5:** Central Electric Boiler Implementation.

# Strategy 2: Central Four-Pipe Hydronic Heat Pump Plant

This strategy is commonly referred to as a fourth-generation district energy system. Functionally, it is similar to the existing system, using a four-pipe hydronic distribution network to deliver hot and chilled water to each building served on campus. The key differences are the method of generating hot and chilled water, and that low-temperature hot water will be delivered to each facility rather than steam.

In this system, the heating and chilled water systems would no longer be disconnected. A central hydronic heat pump plant would simultaneously produce hot and chilled water from campus return water, allowing for heat to be recovered from buildings across campus.

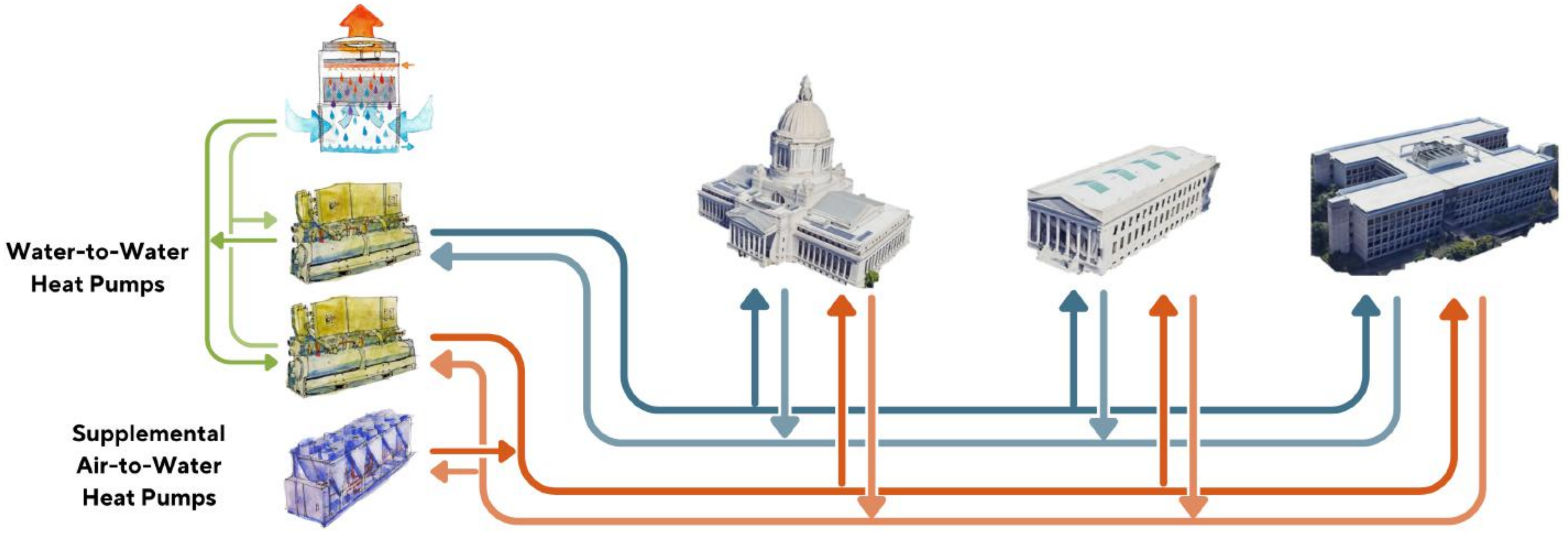


**Diagram 7.6:** Central hydronic heat pump plant simplified diagram.

## Scope of Work Summary:

- Construct a new central plant on the main campus with industrial hydronic heat pumps designed to recover heat from the chilled water loop to produce low-temperature hot water.
- Optimize building controls to maximize heat recovered from the cooling process.
- Install hot water piping and replace some or all chilled water piping.
- Upgrade building air handling systems to use low-temperature hot water (120-140°F) and remove steam equipment.
- For times of low cooling loads, install air-to-water heat pumps, a geoexchange system (ground wells), or supplemental electric boilers.
- Implement complementary energy efficiency measures in buildings to reduce heating loads, maximize recovered heat, and free up additional electrical capacity.
- Modifications to the electrical substation and additional electrical distribution circuits are required.

**Implementation Cost:** $170 to $207 million

**Annual Energy Cost Impact:** $744,000 cost savings below current

**Meets CBPS & HB 1390**

### ADVANTAGES OF CENTRAL FOUR-PIPE HYDRONIC HEAT PUMP PLANT

**Compliant with HB1257 and HB1390**

- Heat pump efficiencies and heat recovery potential result in a significant reduction in campus energy use.

**Minimizes need for new electrical substation**

- Efficiencies minimize the additional demand on the substation and electrical infrastructure.

**Potential for interconnection with geothermal ground loop system**

- This system is well-suited for use with a geoexchange system (geothermal well field). While geoexchange will act as a traditional heat sink and heat source, more importantly for the Capitol Campus, the wellfield would become a thermal storage battery, allowing heat to be stored underground in the summer, and allowing the district energy system to access that stored heat in the winter.

*Advantages continued on the following page.*

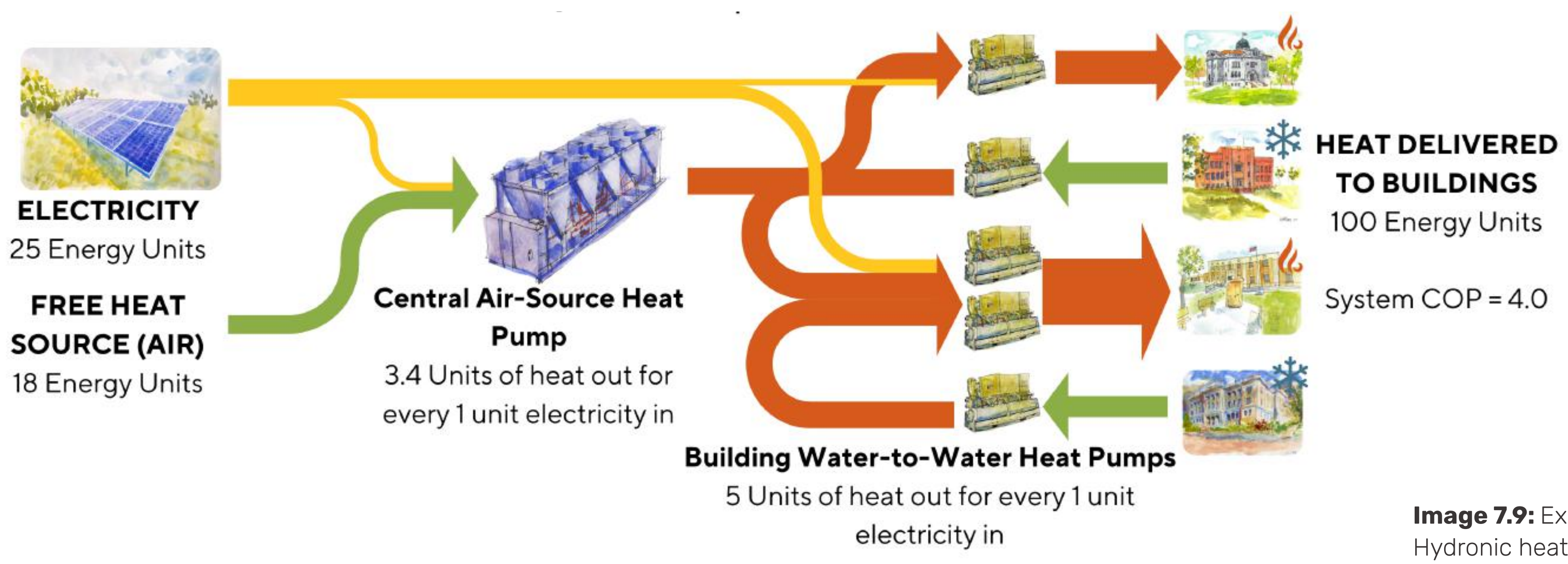


**Image 7.8:** Central four-pipe hydronic Heat Pump Plant energy performance flow diagram.

**Image 7.9:** Example: Hydronic heat pump plant at Stanford University.

## Energy Flow Through System

Diagram 7.8 illustrates the energy use of the central heat pump plant, demonstrating how this approach greatly improves the efficiency of the heating process.

During the heating season, this system's expected COP will average approximately 4.0, which results from the combined performance of the water-to-water heat pumps and the efficiency of air-to-water heat pumps required to supplement the campus' heating load. This is over four times as efficient as the electric boiler option.

***Note:*** *The actual COP will vary depending on the outside air temperature and the amount of the heating load met by recovered heat or produced by air source heat pumps. This variability is accounted for within the campus digital clone energy models, which simulated how the system would perform during each hour of an average year.*

### ADVANTAGES CONTINUED

- The installation of the geothermal well field is disruptive, as it requires heavy machinery to drill deep bore holes. However, once installed, there is little visible or functional impact above ground.

**Low ongoing energy costs**

- Same as the Ambient Temperature Loop, this strategy has the best energy performance of all systems analyzed.
- This approach would result in annual energy cost savings of approximately $744,000.

**Eliminates the need to drain the chilled water system annually**

- Since the system is designed to operate both the heating and cooling loops year-round, the inefficiencies and costs associated with shutting down and draining the chilled water loop are eliminated.

**Potential for future system expansion**

- This option can accommodate the future addition of newly constructed buildings or buildings not currently on the district energy system.

### DISADVANTAGES OF CENTRAL FOUR-PIPE HYDRONIC HEAT PUMP PLANT

**Resilience similar to current system**

- The resilience of this system design would be similar to the existing system but not improved.

**Requires new building**

- A new central plant building would need to be constructed on campus to house four to eight heat recovery chillers, supplemental air-to-water heat pumps, and significant pumping infrastructure.

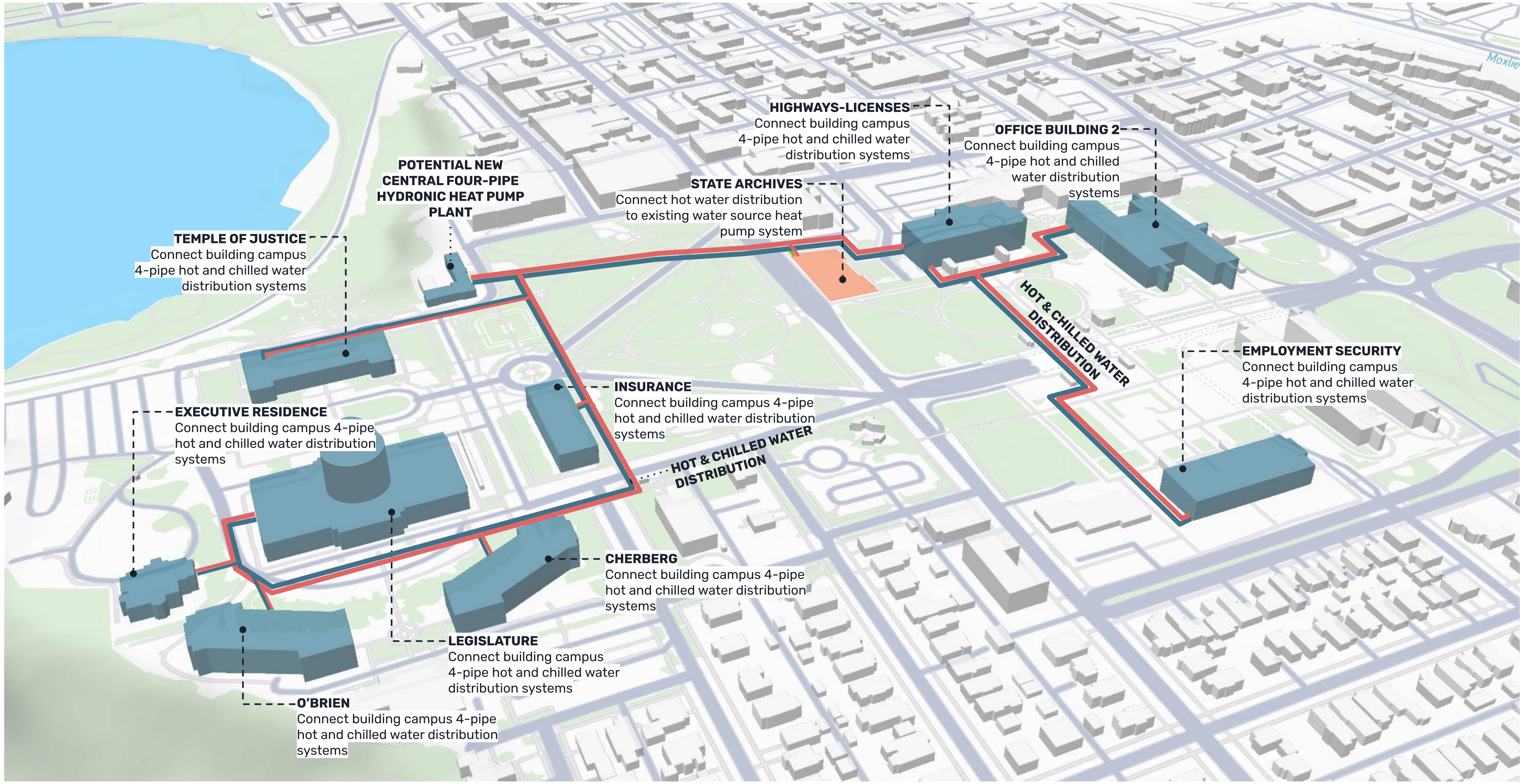
**Limited potential for construction phasing**

- Like the Central Electric Boiler strategy, most of this upgrade would need to occur in a single biennium.

**Extensive distribution piping infrastructure**

- New four-pipe hot water and chilled water distribution piping would be laid throughout the campus.

## Strategy 2: Implementation Map



**Map 7.10:** Central Four-Pipe Hydronic Heat Pump Plant Implementation.

## Other Factors to Consider

### Building-Level HVAC Modifications

This strategy would involve more modifications to the HVAC systems within the buildings themselves to accommodate the performance of the central hydronic heat pumps. Currently, most buildings convert steam into hot water, and the heating coils that serve the buildings are designed to operate at 180°F and above.

The central heat recovery chillers operate more efficiently and have higher capacities at lower hot water temperatures (140°F and below). The hot water coils in most buildings would need to be replaced with low-temperature coils.

This conversion to low-temperature hot water coils is not a new concept for the campus. It is already the campus' design standard and a code requirement to design all new buildings and hydronic system retrofits to include low-temperature hot water coils. Specifically, the Temple of Justice has already been upgraded.

These low-temperature coil replacements are required to increase the efficiency of central systems to minimize or eliminate the need for modifications to the electrical substation.

# Strategy 3: Two-Pipe Ambient Temperature Loop with Distributed Hydronic Heat Pump Plants

This strategy is commonly referred to as a fifth-generation district energy system, and it is based around a Ambient Temperature Loop (ATL). Instead of delivering hot and chilled water to each building via two separate loops, this strategy connects each building to one hydronic ATL loop maintained at a moderate temperature. This ATL serves as a common heat sink and source for hydronic heat pumps located within each building that locally generate hot and chilled water for use by the HVAC systems in that building.

The building-level hydronic heat pumps draw from or reject heat into the central Ambient Temperature Loop. This allows for heat recovery and transfer across campus, while reducing the cost and maintenance of piping infrastructure, eliminating the need for a central plant building, and increasing resilience.

**Implementation Cost:** $138 to $168 million

**Annual Energy Cost Impact:** $770,000 cost savings below current

**Meets CBPS & HB 1390**

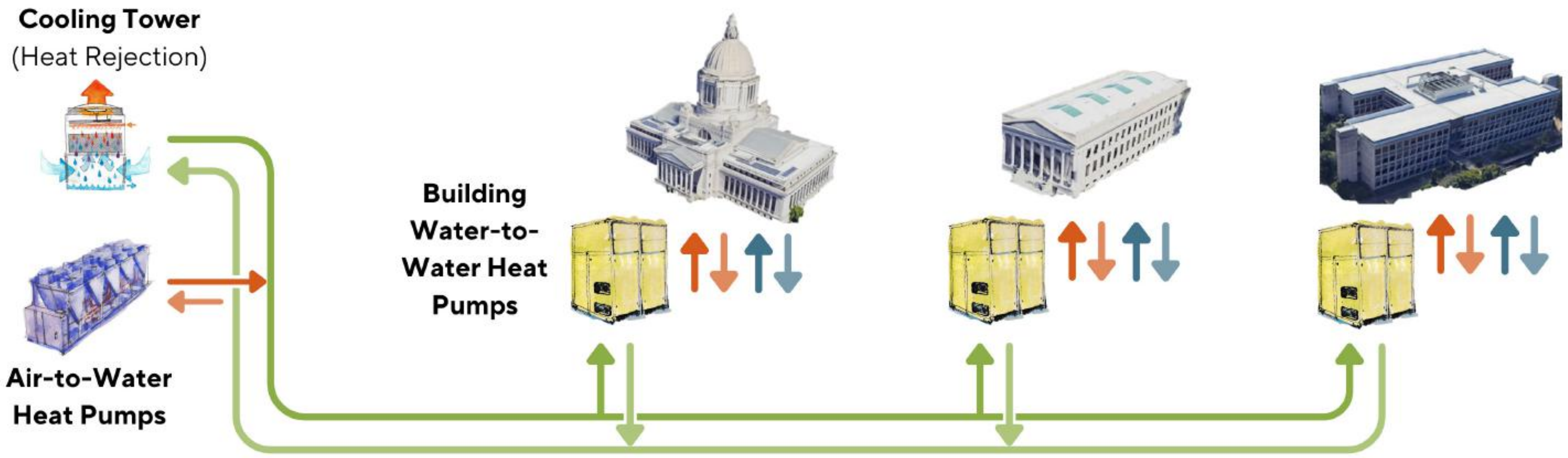


**Diagram 7.11:** Two-Pipe Ambient Temperature Loop performance flow diagram.

## Scope of Work Summary:

- Install Ambient Temperature Loop piping.
    - This can be done in parallel with existing steam and chilled water systems so that they continue to operate during the phased construction period, and buildings can be added to the system over time.
- Install water-to-water heat pumps in each major building to take or reject heat to the ATL.
- Optimize building controls for heat rejection to recover as much heat as possible.
- Install modular central plant equipment, such as air-to-water heat pumps (AWHPs), cooling towers (CTs), small electric boilers, or a geoexchange system for times of low cooling loads, as needed over time.
- Implement complementary energy efficiency measures in buildings to reduce heating loads, maximize recovered heat, and free up additional electrical capacity.
- Minor electrical infrastructure upgrades will be required.

### ADVANTAGES OF TWO-PIPE AMBIENT TEMPERATURE LOOP WITH DISTRIBUTED HYDRONIC HEAT PUMP PLANTS

**Compliant with HB1257 and HB1390**

**Minimizes need for new electrical substation**

**Lowest ongoing energy costs**

**Potential for interconnection with geoexchange system (geothermal wells)**

**Low ongoing energy costs**

- This strategy has the best energy performance of all systems analyzed.
- This approach would result in annual energy cost savings of approximately $770,000.

**Flexible construction phasing & expansion**

- This system can be built out over time and has a high degree of flexibility for phased installation.
- Highly flexible to add additional buildings to the system in the future.

*Advantages continued on the following page.*

**ADVANTAGES *continued***

**Maximum resiliency improvement of central systems**

- Resilience would be improved beyond existing and other central systems analyzed.

**No large new building required**

- All the new equipment would be located within the mechanical spaces of existing facilities.

**Reduced piping distribution costs**

- The installation cost of piping would be approximately half the cost of the previous two strategies.
- While the distribution pipes are physically larger in an ATL system than in a central four-pipe hot and chilled water system, the ATL pipes benefit from being directly buried and do not need to be insulated.

**Reduced thermal distribution losses**

- Thermal losses from a traditional high-temperature hot water system, even a new system with proper insulation, represent a significant portion of the energy consumed at the central plant. The ambient temperature of the Ambient Temperature Loop eliminates distribution losses.

**Eliminates the need to drain the chilled water system annually**

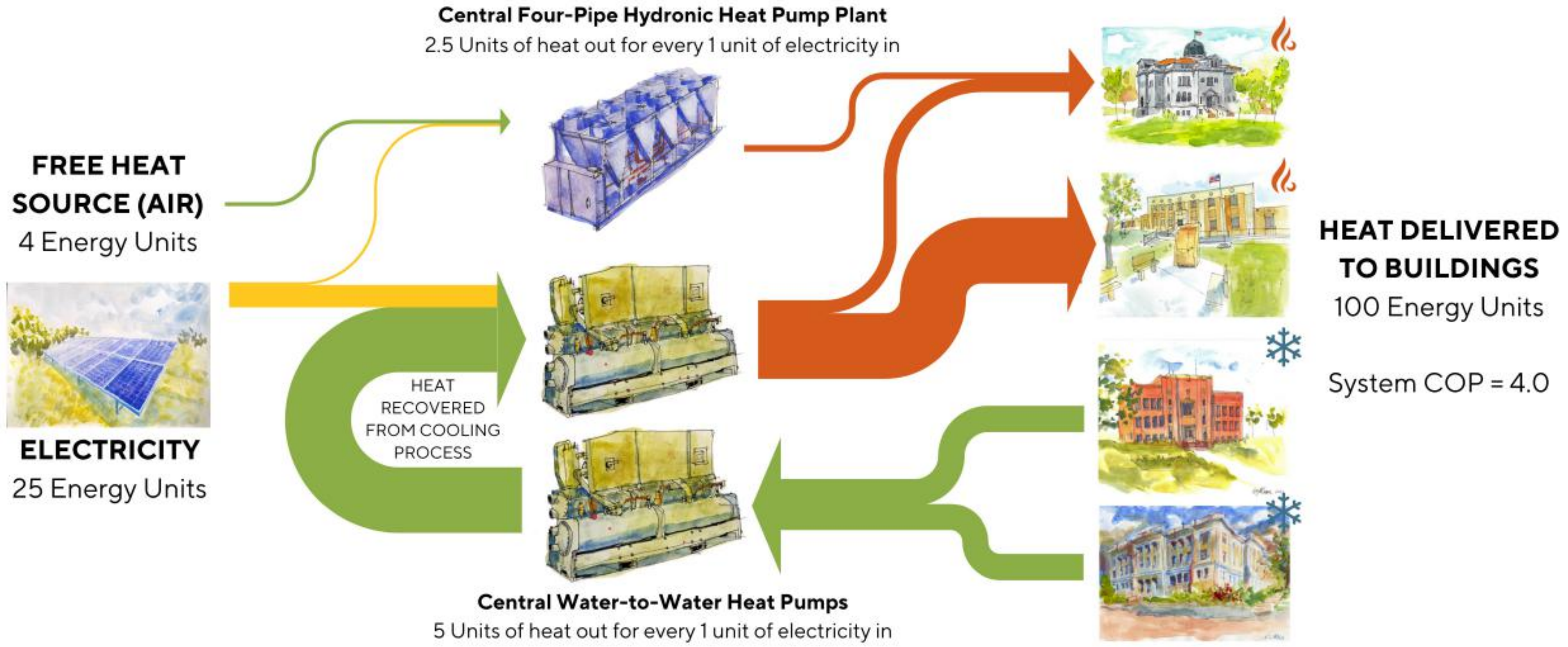


**Diagram 7.12:** Ambient Temperature Loop energy performance flow diagram.

**DISADVANTAGES OF TWO-PIPE AMBIENT TEMPERATURE LOOP WITH DISTRIBUTED HYDRONIC HEAT PUMP PLANTS**

**Requires mechanical room space in each building, in which West Campus buildings are limited.**

**More individual pieces of equipment to maintain**

- Whereas electric boilers and chillers or central hydronic heat pump systems will have around five large pieces of equipment, an ATL with distributed heat pumps may have 10 large pieces of equipment to service and maintain.

### Energy Flow Through System

During the heating season, this system's expected COP will average approximately 4.0, which results from the combined performance of the water-to-water heat pumps and the efficiency of air-to-water heat pumps required to supplement the campus' heating load. This is over four times as efficient as the electric boiler option.

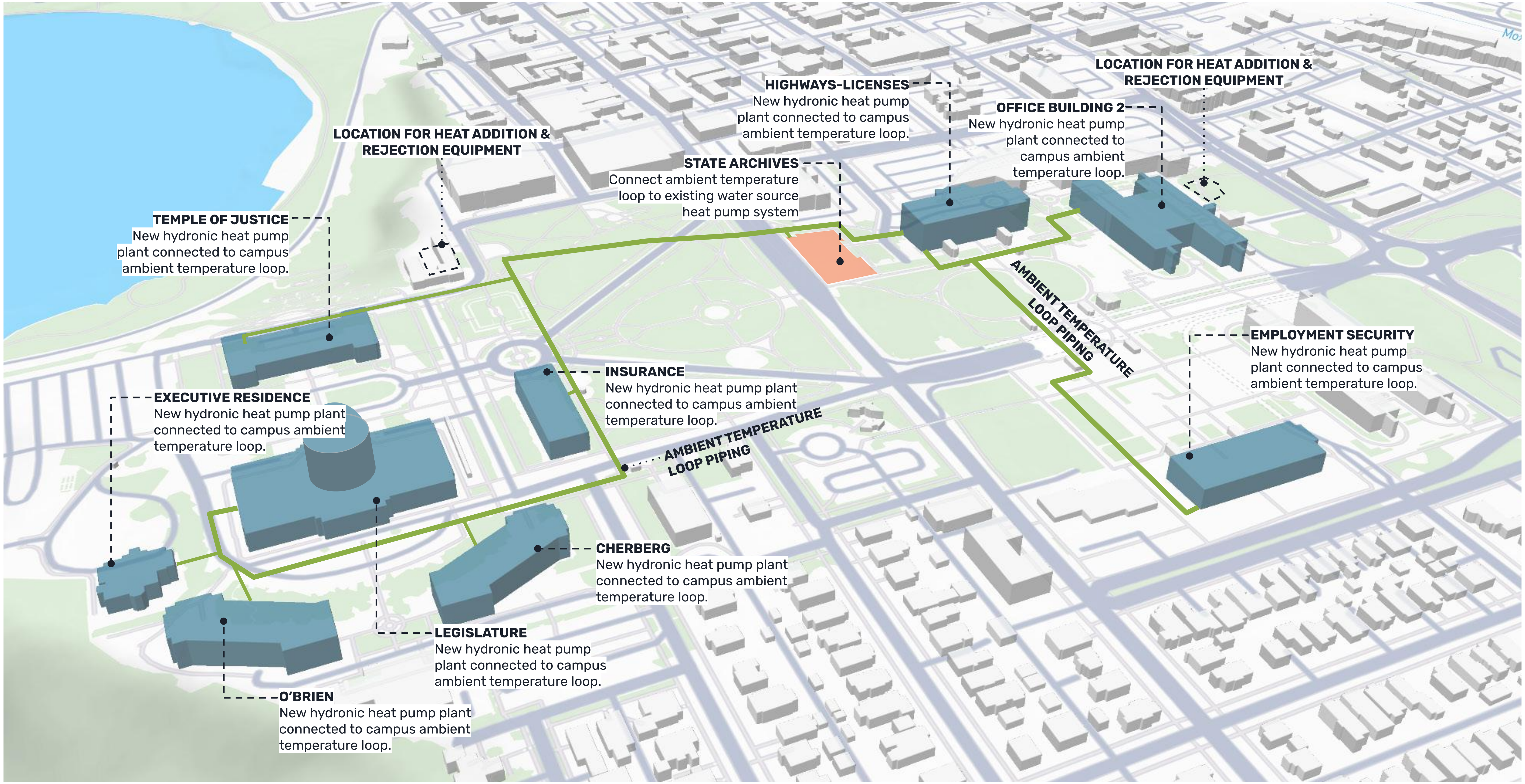
***Note:*** *The actual COP will vary depending on the outside air temperature and the amount of the heating load met by recovered heat or produced by air-to-water heat pumps. This variability is accounted for within the campus digital clone energy models, which modeled how the system would perform during each hour of an average year.*

### Other Factors to Consider

#### Building-Level HVAC Modifications

Like the Central Heat Pump Plant strategy, this strategy would involve modifications to the HVAC systems within the buildings to accommodate low-temperature hot water coils.

## Strategy 3: Implementation Map



**Map 7.13:** Two-Pipe Ambient Temperature Loop with Distributed Hydronic Heat Pump Plants Implementation.

# Strategy 4: Decentralized HVAC Systems

***Note:*** *This option was explored but found not to be feasible based on Washington Energy Code requirements and the timeline for CBPS compliance.*

This strategy entirely abandons the centralized district heating and cooling system concept. The campus would be decarbonized by eliminating the district energy system and using stand-alone, electric hot water boilers and chillers, or unitary heat pump technology in each building for heating and cooling.

**The elimination of the district energy system means that HB 1390 will no longer apply to the Capitol Campus, and each building would be subject to Clean Buildings Performance Standard requirements and timelines.**

DES will be required to implement a variety of aggressive energy conservation measures across campus to meet energy use (EUI) requirements. If EUI compliance is not met by energy reduction deadlines in 2026, 2027, and 2028, DES will face financial penalties.

### Scope of Work Summary:

- Site and install new boilers, chillers, cooling towers, and pumps, or replace HVAC systems with unitary air-source heat pump systems, in nine large buildings across campus.
- Site and construct a major expansion of the PSE electrical substation; upgrade campus electrical distribution system.
- Remove heat exchangers previously used to convert steam to hot water for building-level HVAC systems.
- Replace several building-level steam coils with hot water coils.

### DISADVANTAGES OF DECENTRALIZED HVAC SYSTEMS

**Not compliant with Washington State Energy Code**

- Electric boilers in this application are not permitted under WAC 51-11C-40314.

**Short design & implementation time**

- To avoid CBPS fines of up to $1.3M, each building would need a custom solution designed and implemented in the next one to three years.

**Noise & aesthetics of new equipment**

- Large, noisy equipment must be located either inside or outside of each building.

**Significantly more individual pieces of equipment to maintain**

- This option would require a large number of new boilers, chillers, cooling towers, and pumps for buildings that stay on hydronic systems
- Numerous new air-to-air heat pumps with indoor units and outdoor compressors would need to be maintained for buildings that are converted to Variable Refrigerant Flow (VRF) systems.

**New Electrical Substation & Electrical Infrastructure**

- A new substation or major expansion would be required.
- Electrical feeders across campus would require reconfiguration and upgrades.
- To handle significantly larger electrical loads, the main switchboards and distribution panels within the buildings would need to be expanded or replaced.

### ADVANTAGES OF DECENTRALIZED HVAC SYSTEMS

**Flexible phasing**

- No centralized infrastructure means this strategy can be installed building-by-building in any order and at any pace.

**Maximum resiliency improvement**

- Resilience would be improved beyond existing and all other systems analyzed. Any failure would be localized to one building or system.

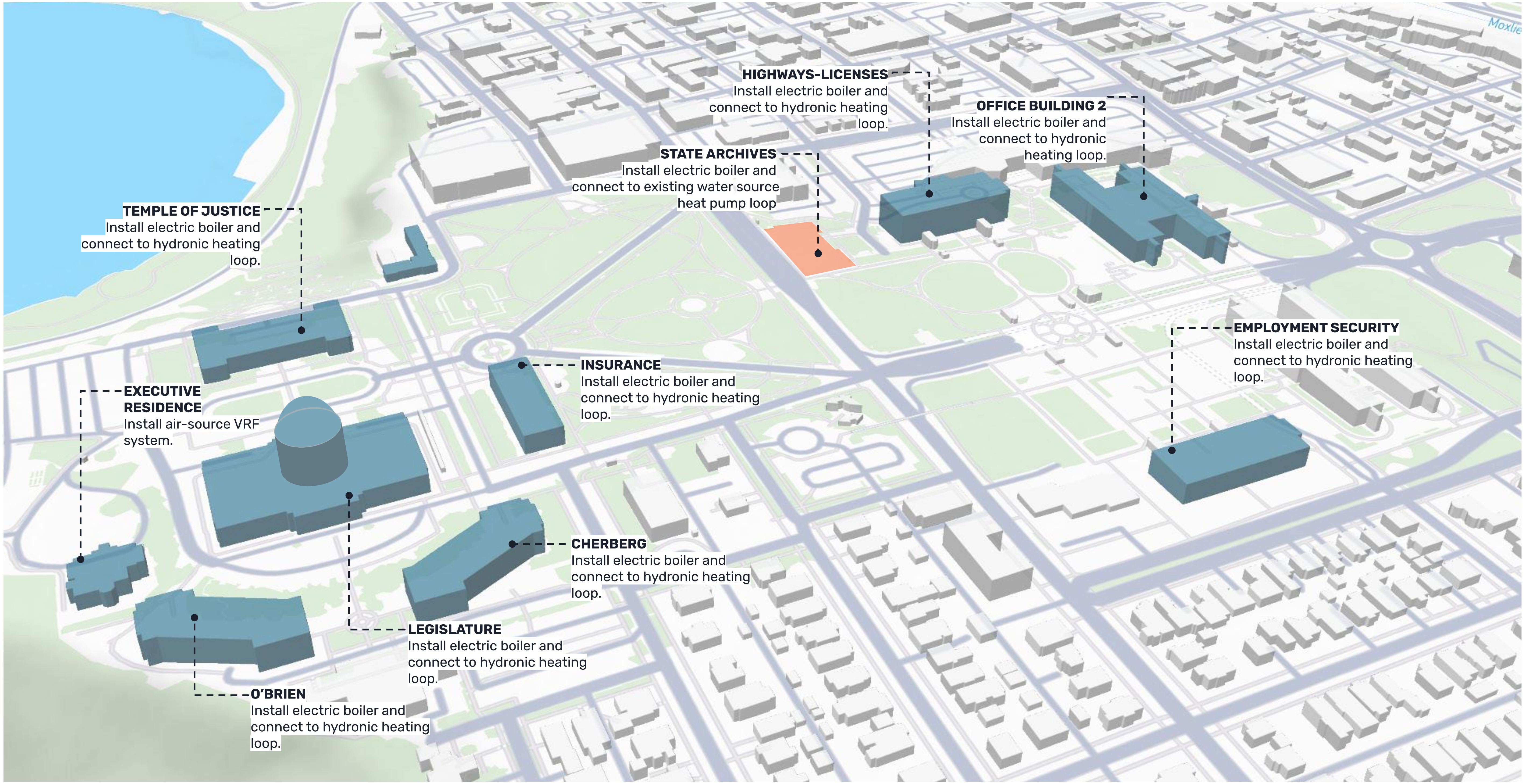
**Implementation Cost:** $175 to $214 million

**Annual Energy Cost Impact:** $381,000 cost savings below current

**Image 7.14:** Daikin VRF outdoor units.

*The map on following page shows the proposed decentralized system in each building.*

## Strategy 4: Implementation Map



**Map 7.15:** Decentralized System in Each Building Implementation.

# Life Cycle Cost Analysis

A Life Cycle Cost Analysis (LCCA) provides the best way to make an informed decision about which decarbonization strategy is optimal for the Washington State Capitol Campus for the long term.

The LCCA takes into account all financial implications of the project, including:

- All-in capital costs (first cost)
- Ongoing energy costs
- Ongoing maintenance costs
- Future capital costs and component replacements

**The 30-year LCCA shows that the Two-Pipe Ambient Temperature Loop with Distributed Heat Pumps is the lowest llife cycle cost option, with the Central Four-Pipe Ambient Temperature Loop Plant as the next best option.** These strategies are constructible, practical, and achieve the goals identified for the district energy system replacement project.

Central Electric Boilers and Decentralized HVAC Systems are not feasible because electric boilers are limited to specific applications under the Washington State Energy Code and would not be compliant for buildings in this scope.

## LCCA Assumptions

- 2.929% general inflation applied to all costs 2026 and beyond per the Office of Financial Management's 2025 Life Cycle Cost Model.
- 3.809% nominal discount rate per the Office of Financial Management's 2025 Life Cycle Cost Model.

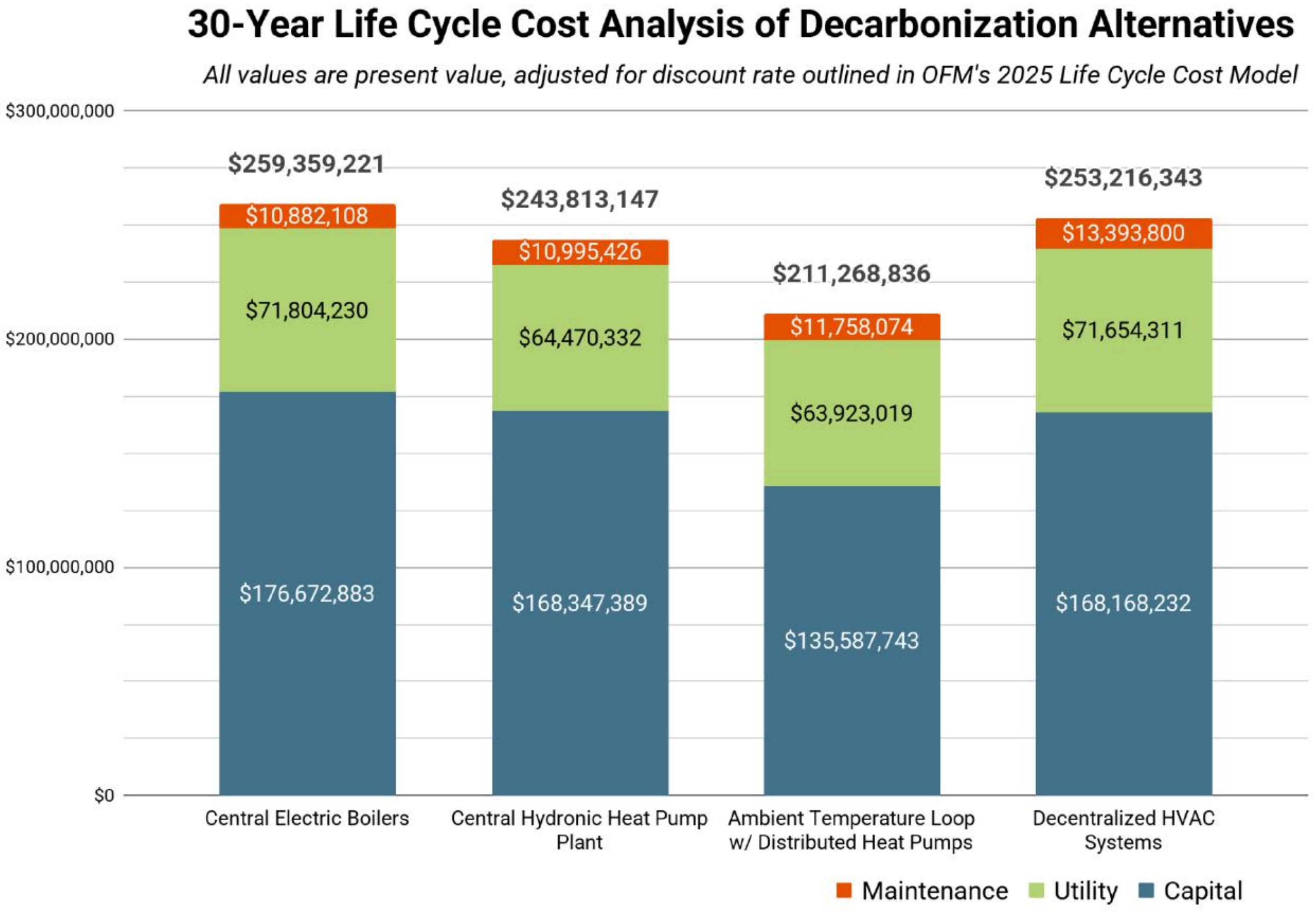


**Chart 7.16:** 30-Year Life Cycle Cost Analysis of Decarbonization Alternatives.

**UTILITY COSTS ARE INCLUSIVE OF ALL THE ENERGY USES FOR THE FOLLOWING BUILDINGS:**

- Office Building Two
- Highways-Licenses
- Employment Security
- Natural Resources Building
- State Archives
- Cherberg
- O'Brien
- Executive Residence
- Legislature
- Temple of Justice
- Insurance

# Implementation Cost Comparison

First cost is always an important consideration for any project, especially one of this magnitude. According to a conceptual budgeting exercise, the two heat pump-based options for the Capitol Campus (Central Four-Pipe Hydronic Heat Pump Plant and Two-Pipe Ambient Temperature Loop with Distributed Hydronic Heat Pump Plants) are the lowest feasible capital cost options for the Washington State Capitol Campus.

***Note:*** *The Capital cost from the LCCA table on the previous page is the net present value over the implementation period.*

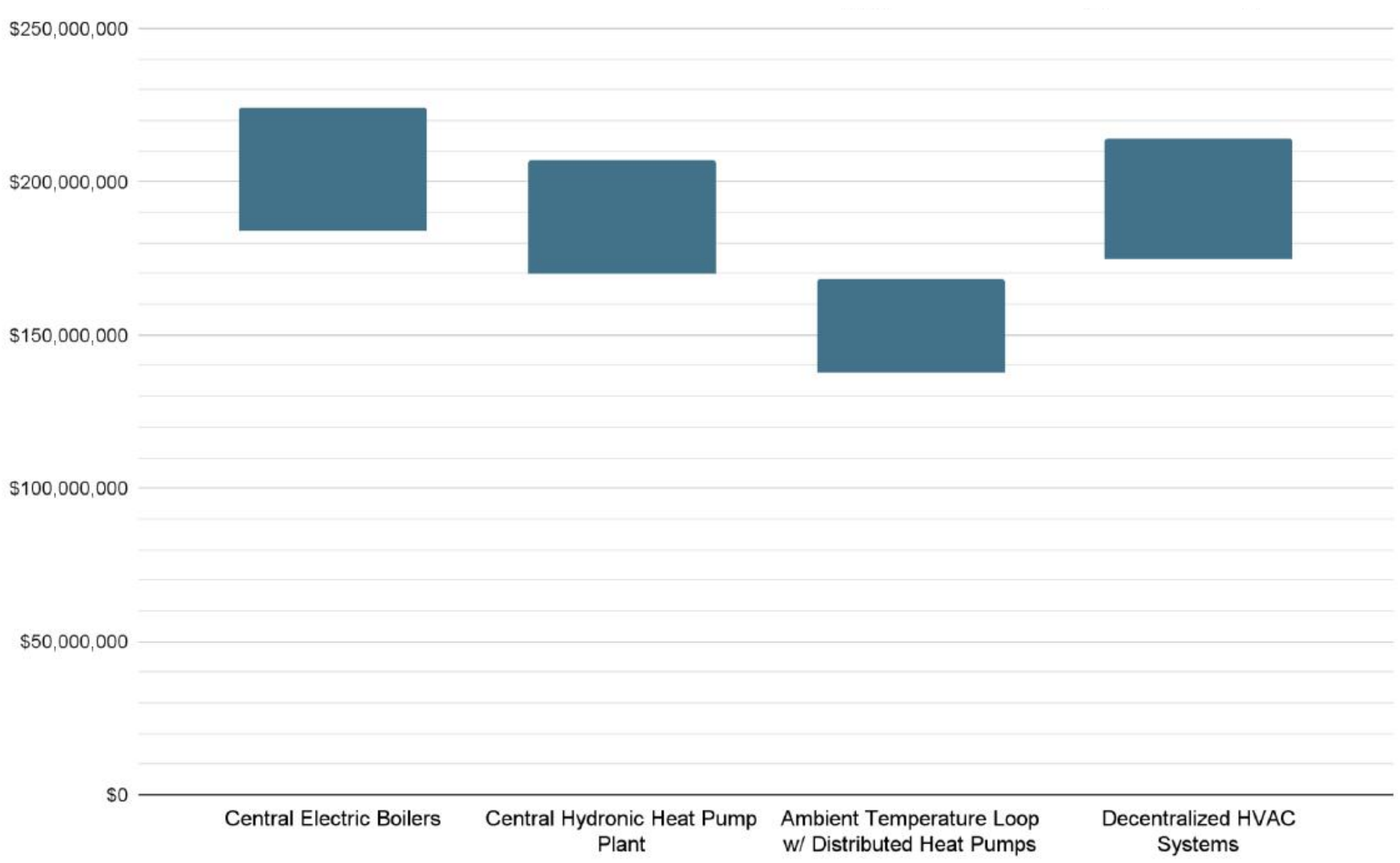


**Chart 7.17:** Decarbonization Strategy Cost Budget Comparison.

# Selection of Preferred Decarbonization Strategy

The process by which the preferred strategy was selected was highly collaborative and required engagement from a wide array of campus partners.

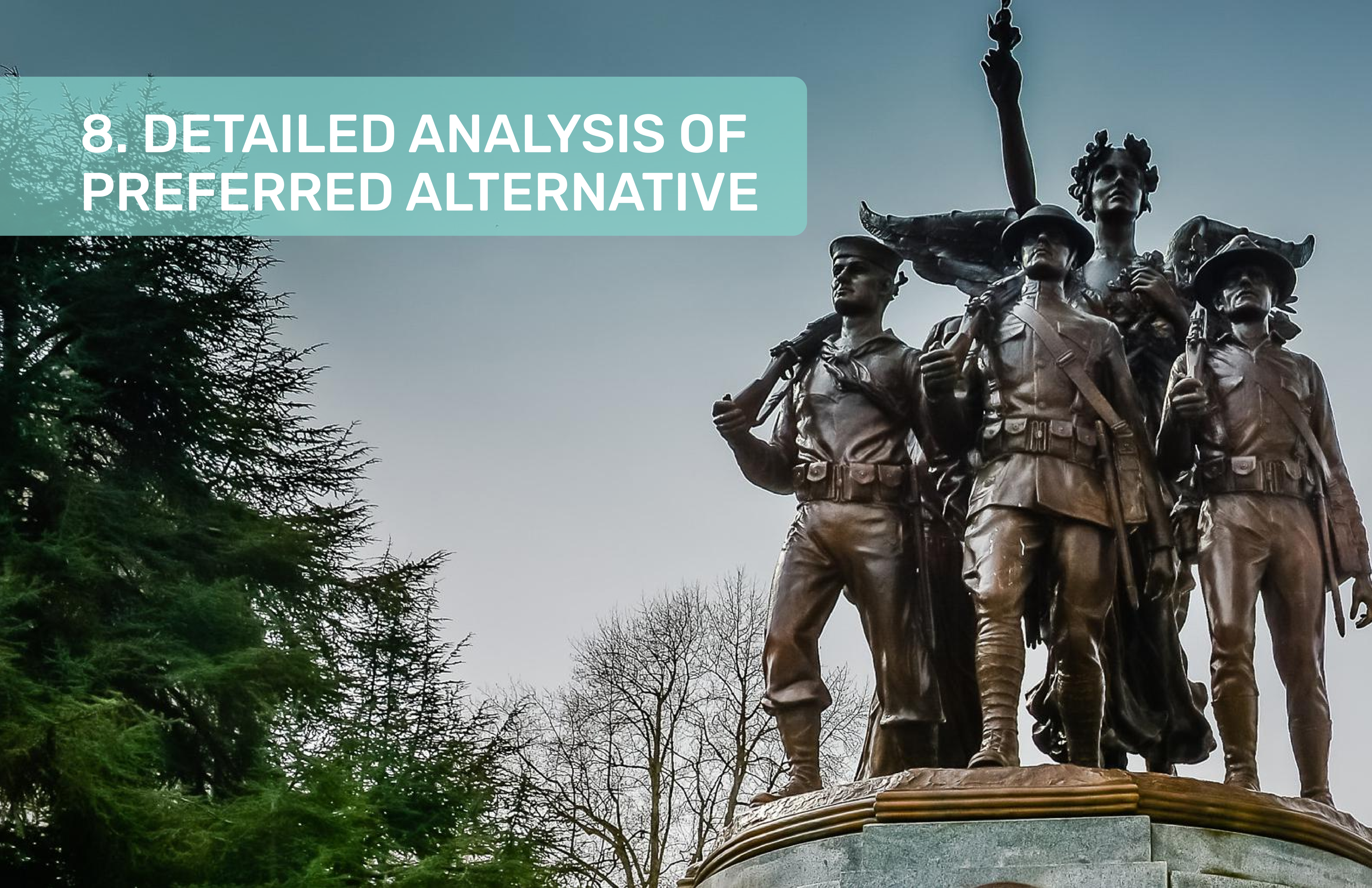
The goal of this interactive process was to provide decision makers with all the information necessary to make an informed decision about the Preferred Alternative to move forward with for detailed planning.

Ultimately, the Two-Pipe Ambient Temperature Loop with Distributed Heat Pump Plants strategy was selected as the Preferred Alternative because of the cost, feasibility, and energy efficiency.

**ADAPTING THE SELECTED STRATEGY FOR THE REAL WORLD**

During the detailed implementation planning process, it was determined that the Ambient Temperature Loop with Distributed Heat Pumps is not feasible in the West Campus buildings due to space limitations for installing heat pumps. Consequently, the Preferred Alternative recommendation combines the Ambient Temperature Loop on East Campus and the Central Hydronic Heat Pump Plant on West Campus.

# 8. DETAILED ANALYSIS OF PREFERRED ALTERNATIVE



# Summary & Key Findings

After selection of the Two-Pipe Ambient Temperature Loop with Distributed Hydronic Heat Pump Plants option as the Preferred Alternative, a detailed planning effort began to determine the details of implementation. This included preliminary equipment sizing and selection, equipment siting and layout, distribution pipe sizing, updating energy and electrical models, and detailed cost estimating.

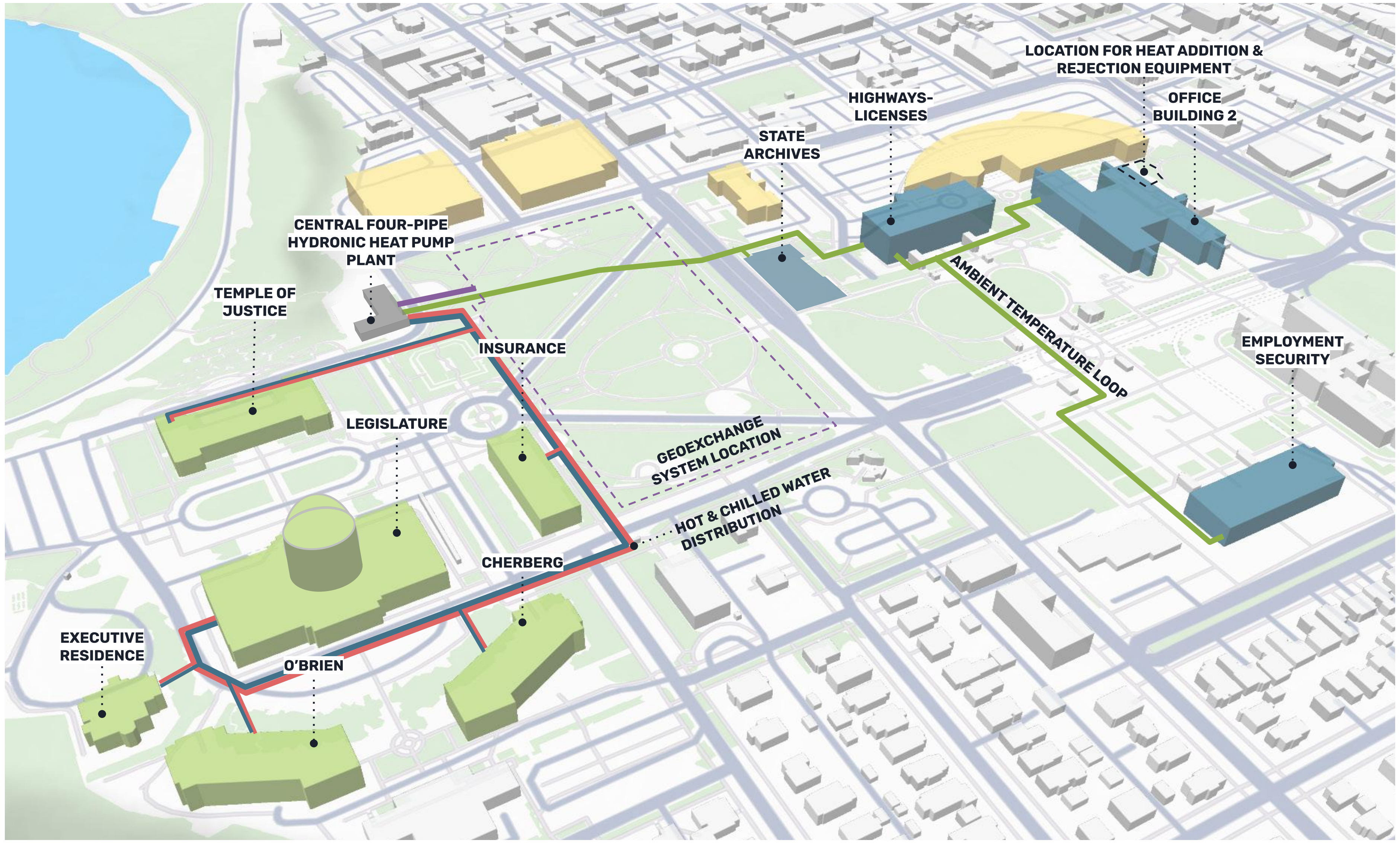
**During this process, it was determined, for reasons explained below, that the optimal solution for the specific circumstances of the Washington Capitol Campus is to utilize a hybrid of the two heat pump-based solutions.**

A combination of a Two-Pipe Ambient Temperature Loop (ATL) with Distributed Hydronic Heat Pump Plants in each building on the East Campus and a new central four-pipe hydronic heat pump plant (central heat pump plant) serving the buildings on the West Campus yields the lowest life-cycle cost while being best suited to integrate with the existing campus buildings.

The ATL with distributed heat pump plants is recommended for East Campus because there is ample space in those buildings to install heat pump plants, and a simple two-pipe ATL system minimizes the cost of the district energy infrastructure between buildings.

Conversely, West Campus buildings have very limited physical space for additional mechanical rooms to house distributed hydronic heat pumps. On this side of campus, a central heat pump plant that produces hot and chilled water for direct use in each West Campus building is optimal.

For reliability and to maximize free energy recovery across campus, the West Campus heat pump plant would be connected to the East Campus ATL.



**Map 8.1:** Preferred Alternative Implementation.

- 🟩 **Buildings served by central heat pump plant**
- 🟦 **Buildings directly connected to ambient temperature loop**
- 🟨 **Buildings for future connection to ambient temperature loop**
- **2-Pipe Ambient Temperature Loop Piping**
- **4-Pipe Hot & Chilled Water Distribution**
- **Geoexchange Wellfield Piping**

# East Campus District Energy Concept

The East Campus buildings account for 61% of the occupied square footage connected to the district energy system, totaling over 1.1 million square feet. Decarbonizing this side of the campus would be achieved through a Two-Pipe Ambient Temperature Loop with Distributed Hydronic Heat Pump Plants (ATL).

## Building Scope Overview

Water-to-water heat pump plants would be installed in Office Building 2 (OB2), Highways-Licenses, and Employment Security. These plants would generate hot and chilled water to satisfy their respective buildings' space heating and cooling needs. Minimal work is required at State Archives because it already has a water-source heat pump system, making it suited for direct connection to the ATL.

Although almost entirely electrically heated, the Natural Resources Building (NRB) would be connected to the heating water from the new heat pump plant at OB2 through existing hot water piping currently connecting these buildings. This would provide preheat for NRB's central air handling unit. Electric resistance heating already provides space heating through VAV boxes within each space; therefore, this building will be fully electrified, requiring no more work to decarbonize.

## District Energy Overview

Heat pumps local to Office Building 2, Highway-Licenses, Employment Security, and State Archives will be interconnected by Ambient Temperature Loop piping, which would draw and/or reject heat, depending on the building's heating and cooling needs. This will allow any building needing heat to receive that heat directly from a building needing cooling.

The piping system will consist of a supply and return pipe that carries moderate temperature water (60°F to 85°F) between buildings. Most of this piping will be run through the existing Plaza Garage to connect Office Building 2, Highways-Licenses, and Employment Security. The ATL leaving Highways-Licenses to the west will be directly buried underground.

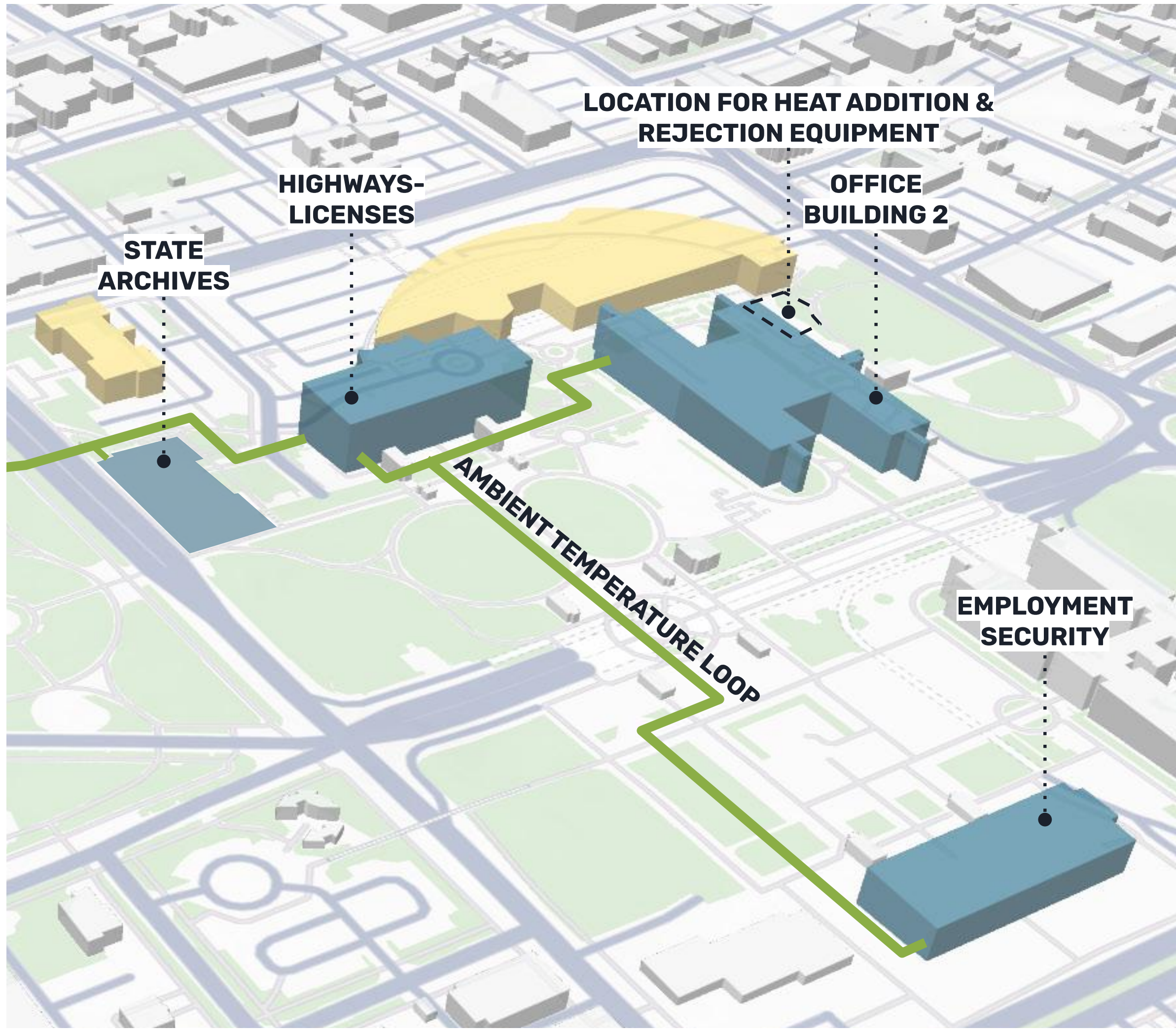
Heat addition and rejection equipment will be installed outdoors and connected to the ATL to supplement the loop's heating or cooling needs when the thermal requirements across the connected buildings are not balanced. This equipment would consist of cooling towers for heat rejection and air-to-water heat pumps (AWHP) for heat addition.

### SPECIFICATIONS

**Cooling Tower Specifications:** 25,000 MBH, 90°F EWT, 80°F LWT @ 65.7°F WBT

**AWHP Specifications:** N + 1 Redundancy, 8,500 MBH Heating @ 60°F EWT, 20°F OAT

Serviceability, aesthetics, and noise must be considered when siting outdoor equipment. For the east side of campus, the area just to the northeast of Office Building 2 is ideal. This area already contains a generator and cooling towers for the Natural Resources Building and is out of the way of normal campus circulation. Further, this equipment would be hidden by architectural screening, making it blend in with the surrounding buildings.



**Map 8.2:** East Campus Concept

**Image 8.3:** Air-to-Water Heat Pump.

# East Campus Building Concepts

### Office Building 2, Highway-Licenses & Employment Security

Each building on the East Campus will have water-source heat pump equipment installed to provide heating and cooling for that building's existing HVAC equipment.

Where Office Building 2, Highway-Licenses, and Employment Security have water-cooled chilled water plants and steam-to-hot water heat exchangers located within each building, new water-to-water heat pump plants will be installed to replace the current hot- and chilled-water services.

These plants will provide hot and chilled water, identical to the current services, to central air handling units and VAV terminal boxes throughout each building. Most of the HVAC infrastructure in these buildings is suitable for use with this concept; however, upgrades are needed to address end-of-life equipment and improve heat recovery potential and heating performance of lower temperature hot water generated by the water-to-water heat pumps (WWHPs).

The new heat pump plants in each building should be designed so that if any one heat pump is taken out of service, the remaining unit has enough capacity to heat and cool the building (N+1 redundancy). This is also needed to allow one machine to operate as an off-season machine (to generate hot water during the summer) to satisfy each building's simultaneous heating and cooling needs.

The new WWHPs will be connected to the ATL as a heat source and heat sink, depending on the mode of the heat pumps. Further, the heat pumps shall be piped in parallel with changeover valves so that any machine can generate hot water while another generates chilled water, satisfying the building's heating and cooling needs.

**Map 8.4:** OB2 East Outdoor Plant.

**Image 8.5:** 3D rendering of OB2 Indoor Heat Pump Plant.

## Simplified Schematic Diagram for Office Building 2, Highway-Licenses & Employment Security

The following illustration demonstrates how this concept provides simultaneous heating and cooling for a building. This diagram represents the plant concept for these three buildings.

In this example for a typical summer day, the heat pump on the left moves heat from the ATL to the building's heating water loop. The two heat pumps on the right generate chilled water or move heat from the building's chilled water loop to the ATL.

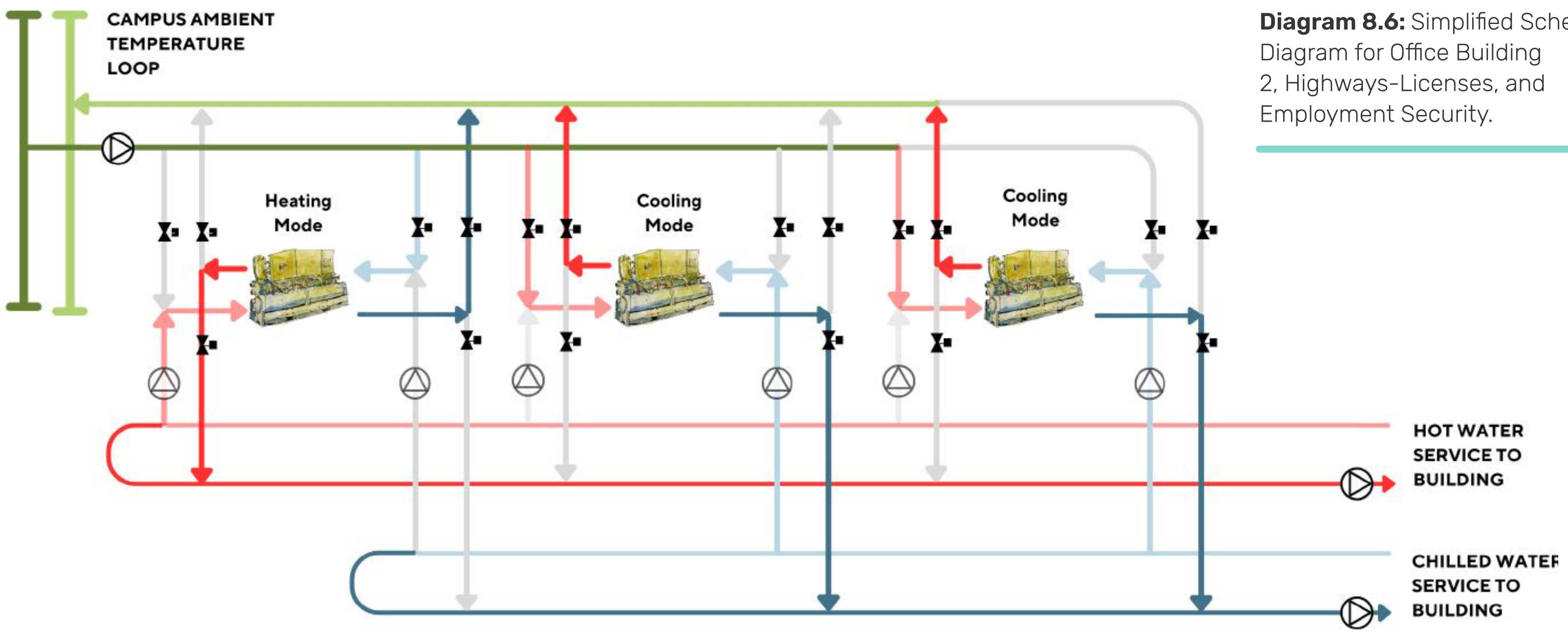


**Diagram 8.6:** Simplified Schematic Diagram for Office Building 2, Highways-Licenses, and Employment Security.

## State Archives Building

The State Archives Building is already suitable for connecting to the ATL. It currently has a water-source heat pump system, where fan-coil units (shown in Image 8.7 photo) generate cooling directly by drawing and rejecting heat to a glycol condenser water loop local to the building. A steam heat exchanger and fluid cooler regulate the temperature of this condenser water loop local to the building.

To connect Archives to the ATL, the fluid coolers would simply be removed, and the existing condenser water loop would be connected to the campus ATL. A new pump would be required within the Archives to promote flow to the building from the ATL.

The current system uses glycol, an anti-freezing agent which is often needed to provide freeze protection in hydronic systems where the water piping is exposed to the outdoors. After connecting to the district energy system, glycol should be removed from the building condenser loop as the piping will no longer be exposed to the outdoors at the fluid cooler. This will improve the performance of the existing heat pumps and reduce the energy usage of the system.

**Image 8.7 (left):** Heat pump fan coil unit in Archives Building.

**Image 8.8 (above):** Archives Building.

# West Campus District Energy Concept

The West Campus buildings account for 39% of the occupied square footage connected to the district energy system, totaling over 683,000 square feet. Decarbonizing this side of the campus would be achieved through a Central Four-Pipe Hydronic Heat Pump Plant (central heat pump plant).

## District Energy Overview

The buildings on the West Campus that receive steam and/or chilled water from the existing district energy system include the Temple of Justice, Legislature, O'Brien, Cherburg, Insurance, and the Executive Residence.

After a thorough review of the building plans for these facilities, as well as site walks and discussions with campus planning experts, it became clear that the options for electrifying these facilities are limited by the lack of mechanical room space needed to house water-to-water heat pumps. Additionally, due to the historic and aesthetic characteristics of the West Campus, the siting of large, noisy equipment outside of the buildings or the construction of new mechanical sheds or penthouses were not feasible.

Consequently, the strategy of a Ambient Temperature Loop with distributed heat pumps was determined to be unsuitable for West Campus.

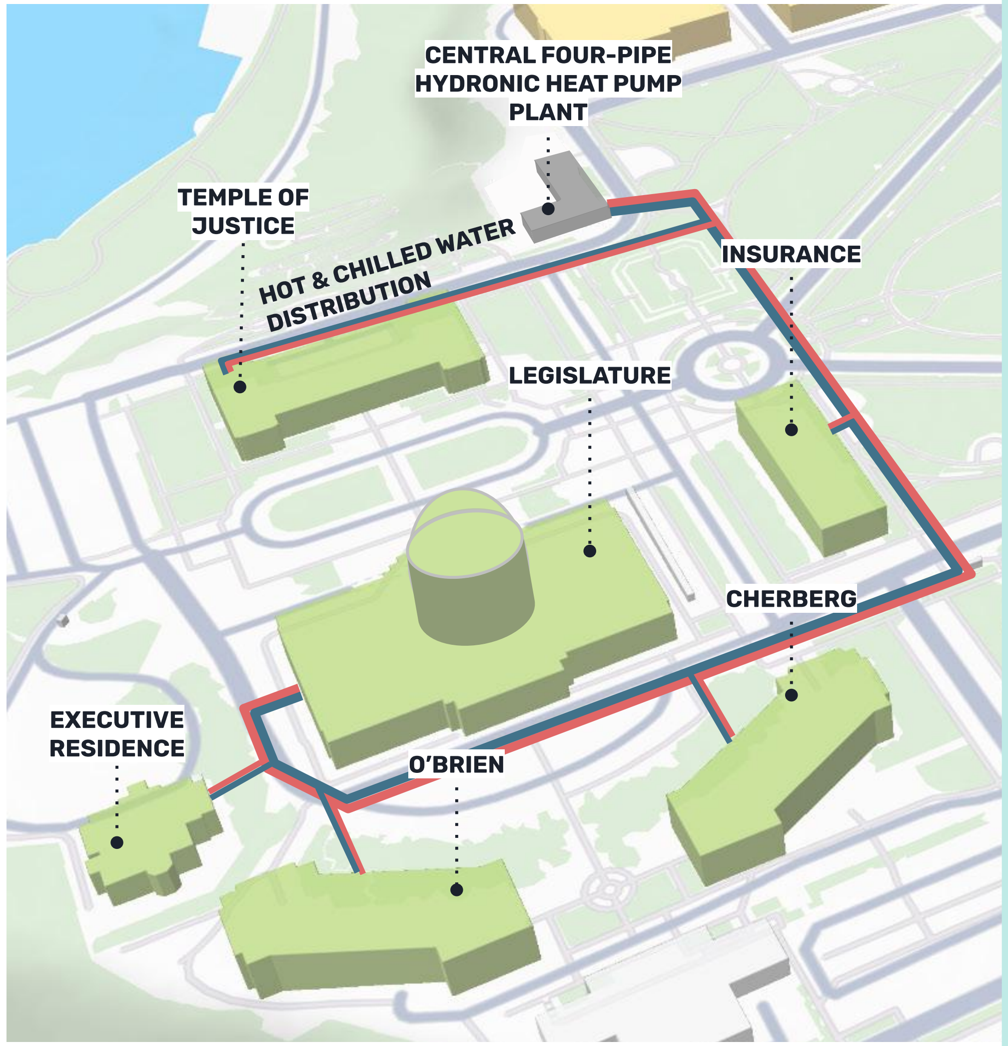
A hybrid approach, with a central hydronic heat pump plant on West Campus has the benefit of sharing heat between all the buildings on the district energy system; however, it generates hot and chilled water centrally in a new facility. Like the current system, this hot and chilled water is distributed to the West Campus buildings.

The new West Thermal Energy Plant (West TEP) must generate hot water that is hot enough for the heating coils in the West Campus buildings. These buildings have coils designed for 180°F to 200°F water, except for the Temple of Justice, which has recently undergone an upgrade and has new heating coils designed for 140°F water.

As previously discussed, although heat pumps are available to generate these high (>140°F) temperatures, they are expensive and inefficient. Considering the need for HVAC remodel work in most of these buildings, new systems or system retrofits, designed for 140°F water, will be needed to ensure cost-effective and reliable plant operation.

Four-pipe hot and chilled water distribution piping will be distributed from the West TEP to each West Campus building (see illustration for proposed routing). This piping can be installed in the existing steam tunnels after the steam and condensate piping is removed. Further, hydronic piping is flexible, as it can be directly buried if needed, and it has no serviceable components.

Connecting the West TEP to the East Campus ATL will significantly improve resiliency, redundancy, and heat recovery potential. This will provide a path to import or export excess heat from one side of the Capitol Campus to the other, minimizing the need to supplement the ATL with energy from the central heat addition and heat rejection equipment. Also, this will allow for the central heat addition and heat rejection equipment on one side of campus to be used for the entire campus, providing needed redundancy.



**Map 8.9:** West Campus Concept Schematic.

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# New West Thermal Energy Plant

### Site Selection

A new central heat pump plant will be needed for West Campus and this will require either a new facility or mechanical space to be created in an existing building to house the central heat pumps, pumps, and an operator's office.

Siting this equipment on the compact Capitol Campus represents a design challenge. When considering the location for the new four-pipe central heat pump plant, referred to as the West Thermal Energy Plant (West TEP), the following were considered:

- The West TEP needs to be located as close as possible to the West Campus building cluster to minimize hot-and-chilled water distribution piping costs.
- The facility will also be connected to the ATL on the East Campus, so its proximity to the East Campus should also be considered.

Despite the limited development space, two sites were identified in collaboration with DES campus planning staff as potential future locations for this facility:

1. **Opportunity Site 1:** The site of the former General Administration building.
2. **Opportunity Site 2:** The site of the Conservatory on Water Street.

Both sites are in an ideal location, being close to the buildings served on West Campus while having good access to East Campus.

**Image 8.10:** 3D rendering of potential West TEP at Opportunity Site 2.

**Image 8.11:** Currently unused Conservatory at Opportunity Site 2.

## Plant Design

The new West Thermal Energy Plant should be designed for function and performance, while maintaining an aesthetic style suited for the West Capitol Campus. Architectural panels can be used to screen rooftop equipment or ventilation intakes and exhaust grilles. Future design discussions should also consider providing access and educational opportunities for the public to learn about the innovative and sustainable district energy system serving the Capitol Campus.

Respecting the building height requirements on the Capitol Campus, future designs should consider that two stories may be required to accommodate all the new mechanical equipment. The large water-to-water heat pumps and office spaces are best located on the ground floor, while the pump and electrical rooms are well-suited for the second floor.

## West TEP Features

The new plant would require approximately 9,000 - 12,000 square feet of interior spaces for:

- Central plant equipment (water-to-water heat pumps and pumps)
- Electrical equipment
- Shop/service space
- Operator office
- Services and restrooms
- Potentially an area for visitor viewing and district energy education

Exterior space will be needed for:

- Parking and service vehicle access
- Cooling towers
- Air-to-water heat pumps
- 12,470V to 480V Electrical transformer

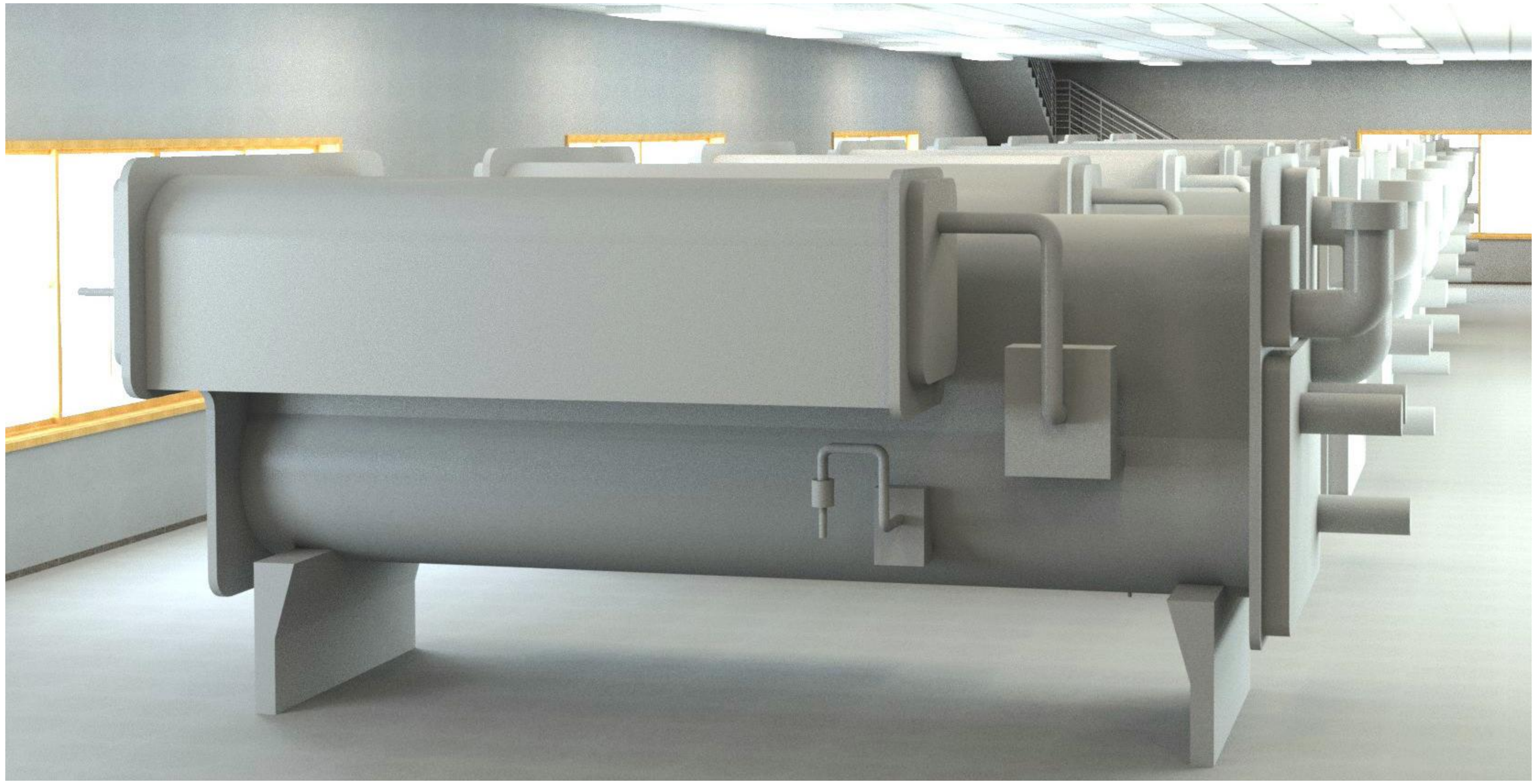


**Image 8.12:** 3D rendering of water-to-water heat pumps (WWHP) in West TEP.

## System Capacity & Layout

The main machine room, housing the water-to-water heat pumps, will consist of parallel machines capable of generating 14,900 MBH heating and 11,500 MBH cooling while having an N+1 redundancy. Three 1,000-ton machines efficiently achieve this. Additional floor space shall accommodate two additional 1,000-ton machines for future campus expansion.

### WWHP SPECIFICATIONS

- N + 1 Redundancy, 14,900 MBH Heating @ 180°F/65°F leaving water temperatures
- 11,500 MBH Cooling @ 45°F/92°F leaving water temperatures

### Plant's Integration with Geoexchange System

The district energy system would benefit from the energy storage aspect of a geoexchange system (or geothermal wellfield). This would allow for the storage of excess heat in the district energy system to the earth while the campus is predominantly in the cooling mode. This stored heat is then available later as the campus net demand shifts to the heating mode. Essentially, the ground acts as a thermal battery that is charged and discharged at different times, limiting the amount of mechanical generation of heat addition or rejection required to temper the loop.

For example, the campus may be primarily in cooling mode in the afternoon, storing excess heat in the ground. The next morning, during cool weather, the campus would demand heating. In this case, the heat pumps would pull stored heat from the ground, thus eliminating the need to provide heat to the heat pumps through supplemental heating equipment.

The same principle applies seasonally. The ground stores heat all summer, thus raising its temperature, and then is used as a heat source months later in the winter when the campus needs heating.

A water-to-water heat pump installed in the West TEP between the district energy system and the geoexchange piping is the mechanism for adding and extracting heat from the geoexchange system or ground. This machine would operate anytime the Ambient Temperature Loop needs to add or reject heat. The local piping and automated valves local to this heat pump can be designed to manage the direction of heat flow to and from the geoexchange system per the diagram below.

**GEOEXCHANGE WWHP SPECIFICATIONS**

- 4,300 MBH Heating @ 65°F/34°F leaving water temperatures
- 5,500 MBH Cooling @ 60°F/92°F leaving water temperatures

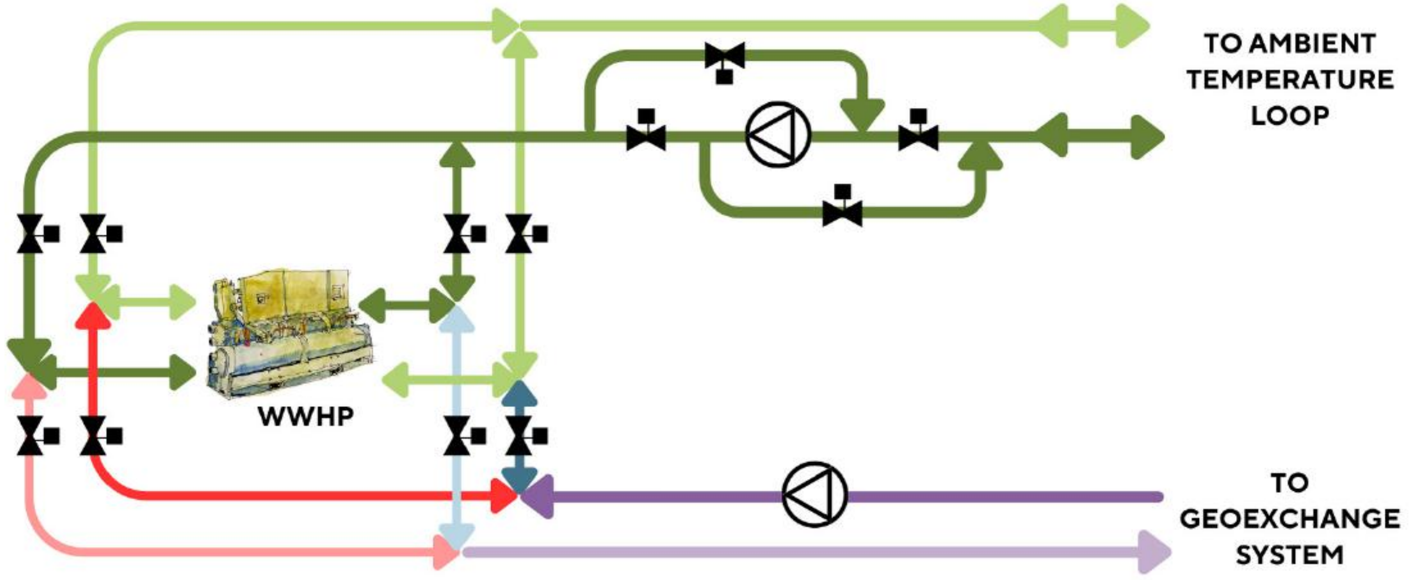


**Diagram 8.13:** Connection schematic for geoexchange system and ATL.

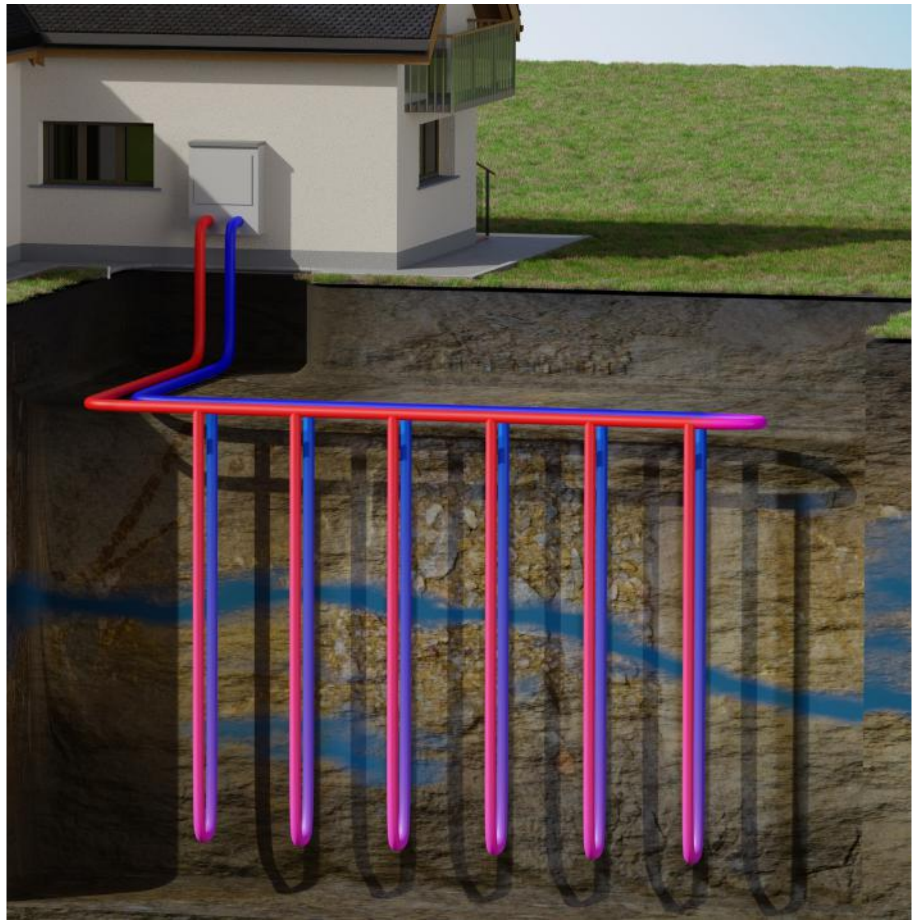


**Diagram 8.14:** Rendering of a typical vertical well field for geoexchange system.

**Diagram 8.15:** Example water-to-water heat pump.

## West Thermal Energy Plant Diagrammatic Layout

The diagram below illustrates the diagrammatic layout of all equipment within the West TEP. The heart of the system is a 1,000 ton water-to-water heat pumps.

These machines will distribute the chilled and hot water to the West Campus. The 100 ton water-to-water heat pump manages the heat exchange between the district energy system and the geoexchange system.

Lastly, the equipment shown above the dotted grey line (shown in the diagram as roof line), which includes cooling towers and air-to-water heat pumps, is used to manage the temperature of the ATL when the campus heating and cooling loads are not evenly balanced, and the geoexchange system alone cannot manage the ATL's temperature.

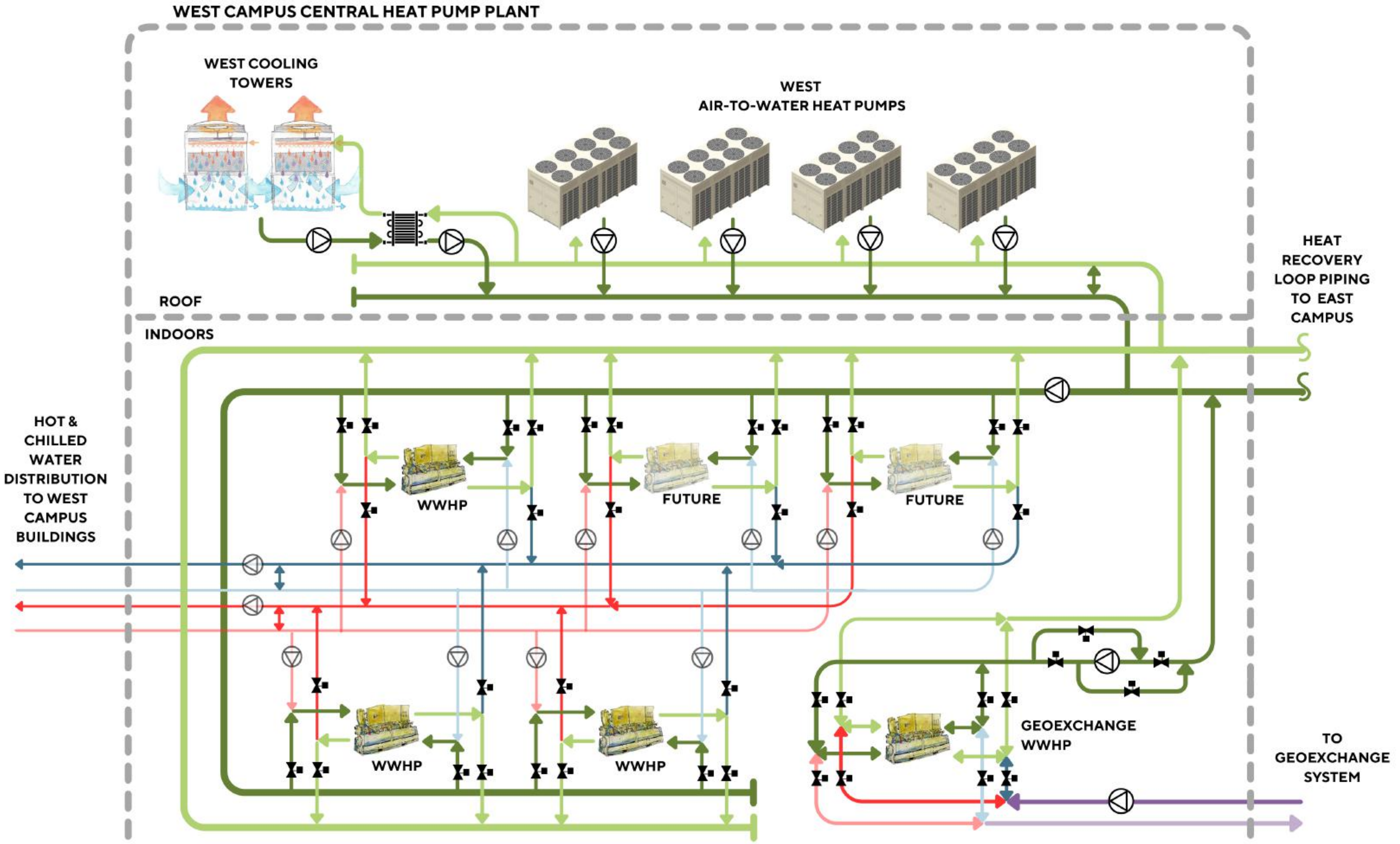


**Diagram 8.16:** Schematic for West TEP.

# West Campus Building Concepts

### Legislature, Temple of Justice, Insurance, Cheberg & O'Brien

All five buildings will be supplied with hot and chilled water from the West TEP, requiring minimal work to be connected to the new 4-pipe hot- and chilled-water distribution system on West Campus.

Chilled Water Connection: Since these buildings are all on central chilled water from the Powerhouse, the existing building-level chilled water connection and associated pumps can be directly connected to the new chilled water distribution system.

Hot Water Connection: Since these buildings are all on central steam from the Powerhouse, these connections are more involved. Fortunately, all the buildings immediately convert steam to heating hot water through heat exchangers located in each building. Therefore, the building's heating medium is hot water, matching what will be produced by the West TEP.

The heat exchangers can be removed and the buildings can be directly connected to the new hot water system. This new arrangement will reuse the existing buildings' heating water pumps.

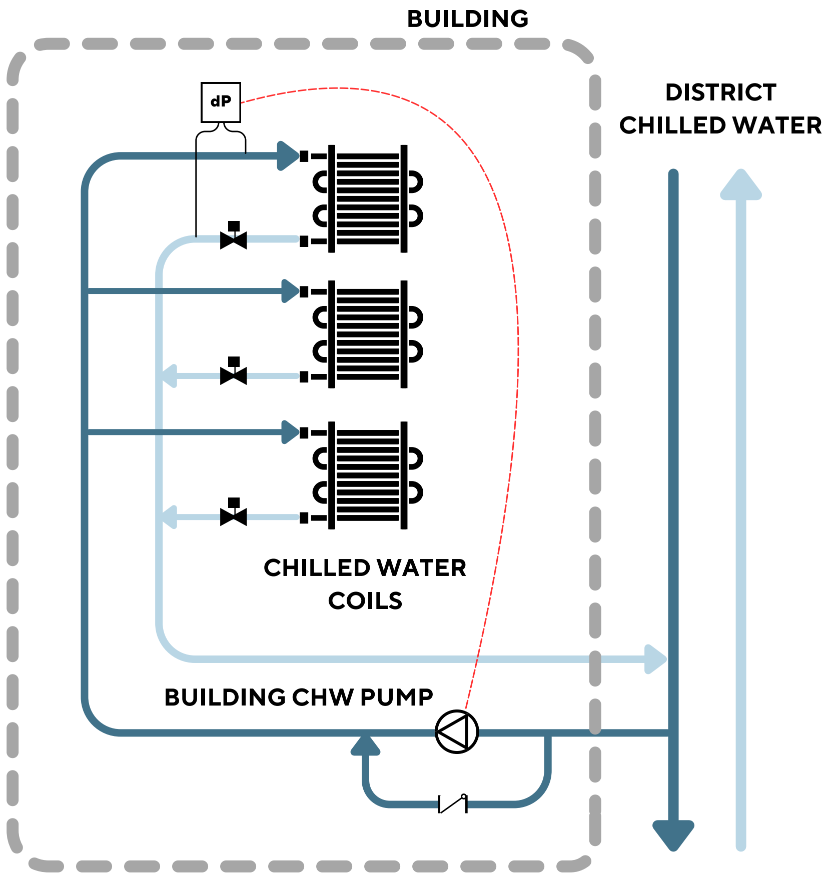
### Executive Residence

Like the other West Campus buildings, the Executive Residence's current chilled water service connection will be replaced and connected to the new chilled water distribution system. This building has hydronic boilers for heating, which will be removed and replaced with hot water from the campus heating water distribution system. The current chilled and hot water pumps will be reused.

### Building & District Hydronic System Interconnection

The interconnection between the building and the district hydronic distribution systems is essential to properly decouple the buildings from the distribution system and independently regulate the hot and chilled water temperatures at each building. Further, system pressures must be considered to provide positive venting of coils located at the top of the tallest building; fortunately, in the case of the West Campus, there is not a wide variation in the heights of the highest coils; each building is almost the same height.

The following piping interconnection and control scheme is recommended for each building connection to the hot and chilled water district. These allow for decoupled pressure control within each building, and the hot water scheme allows the building to receive a lower heating water temperature, as needed, to satisfy its needs while returning lower return water temperatures to the plant.



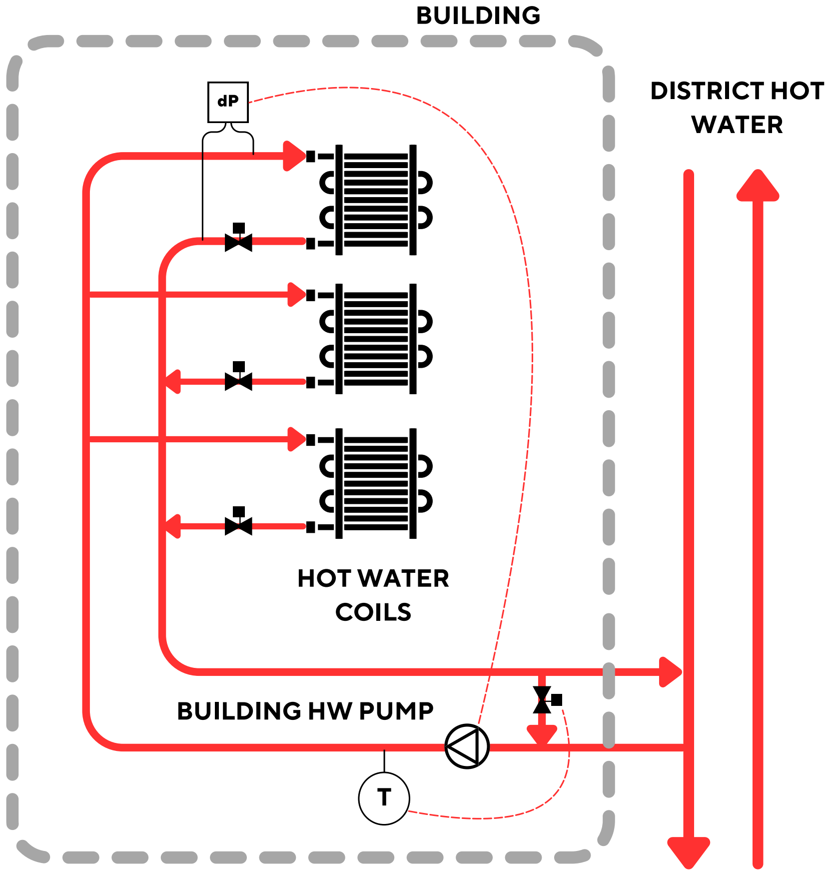


**Diagram 8.17:** Top right: Chilled Water Connection.
**Diagram 8.18:** Bottom right: Hot Water Connection.

## Campus Concept Summary

A diagram of all the necessary equipment and piping was developed to illustrate the technical concepts, accurately estimate the cost, and establish a phasing plan for the project.

The diagram below is a hydronic schematic of the ambient temperature loop, distributed heat pumps, central heat pump plant on the West Campus, and other major equipment.

As mentioned in the analysis section for this solution, the ambient temperature loop provides limitless expansion opportunities. Including ground heat exchangers or waste heat recovery streams could further enhance the system.

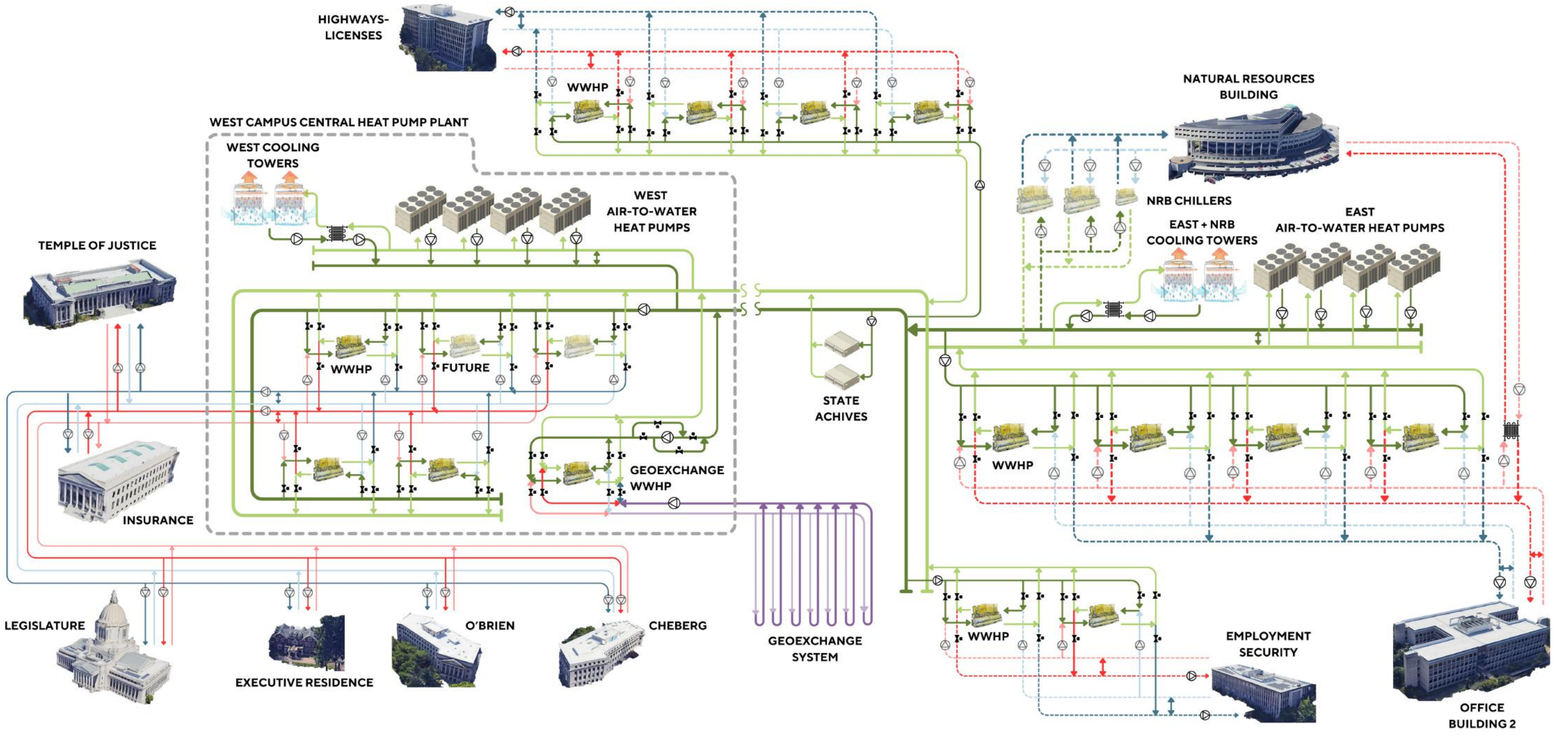


**Diagram 8.19:** Washington State Capital Campus: Campus District Energy Concept Diagram.

# Impact on Campus Electrical System

After thermal loads are reduced by eliminating distribution losses and maximizing heat recovery within and between buildings, the campus electrical system will need to serve the proposed hydronic heat pump solution. This represents a critical system consideration, as expanding the campus' electrical distribution system will significantly impact the cost and implementation timeline of the new district energy system.

A detailed model of the campus' electrical infrastructure, building energy models, and the hydronic heat pump solution model was used to develop an hourly predicted electrical load on the electrical substation and each of the four campus distribution feeders.

Each building is served by two circuits, one for normal operation and one for backup if the normal circuit is down due to maintenance or an emergency. To understand the worst-case circuit loading after implementing the proposed hydronic heat pump solution, analysis was performed for normal operation and four backup scenarios. The backup scenarios evaluated the impact of each of the four circuits taken out of service separately, leaving the remaining three circuits to carry the campus load.

Annual peak feeder loads are summarized in **Chart 8.20**.

**Chart 8.21** shows normal operation of the four campus feeder circuits throughout the year after the implementation of energy and load reduction measures and the proposed hydronic heat pump solution. The dotted lines at the top show the feeders' rated ampacity and their National Electrical Code limit. Under normal conditions, these feeders are between 25% and 59% loaded relative to feeder ampacity.

**Chart 8.22** shows the Backup Operation of each campus feeder. This is a worst-case loading scenario that shows the consequences on the other feeders of any circuit taken out of service. Under backup conditions, these feeders are loaded between 45% and 83% of their ampacity.

The impact on the load on the campus substation is shown in **Chart 8.23**. After the implementation of the proposed hydronic heat pump solution, the Capitol Campus' load on the PSE substation is estimated to be 8,856 kVA, or 68% of the contract capacity (13,000 kVA). This is a net increase of 2,164 kVA from the baseline campus load of 6,692 kVA.

The result of this electrical load analysis is that the Preferred Alternative, in conjunction with the energy and load reduction measures recommended for each building, can be implemented by the campus' existing electrical distribution circuits without requiring major upgrades.

**Chart 8.20:** Capitol Campus Peak Feeder Loads After Proposed Solution.

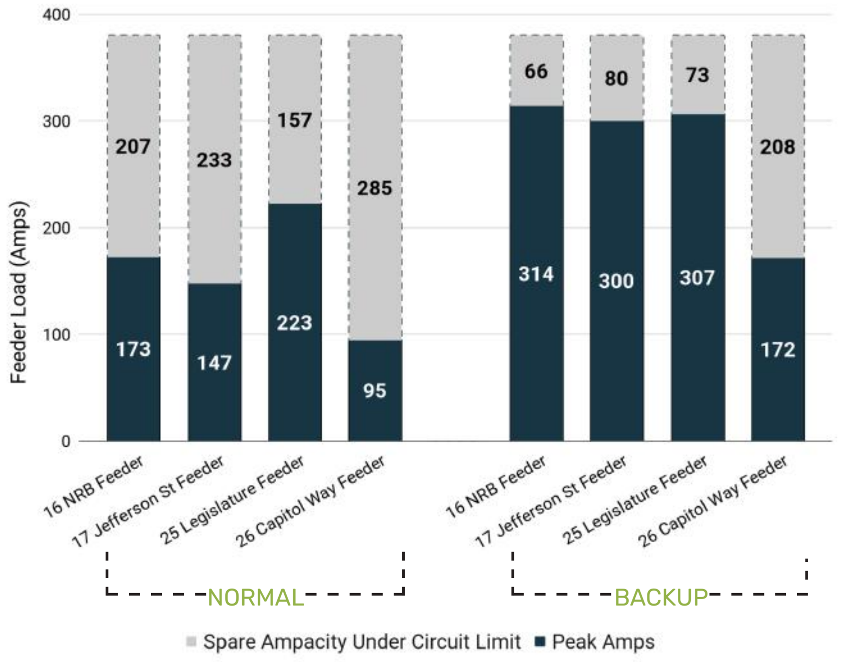


**Chart 8.21:** Normal Operation: Daily Peak Electrical Load by Circuit.

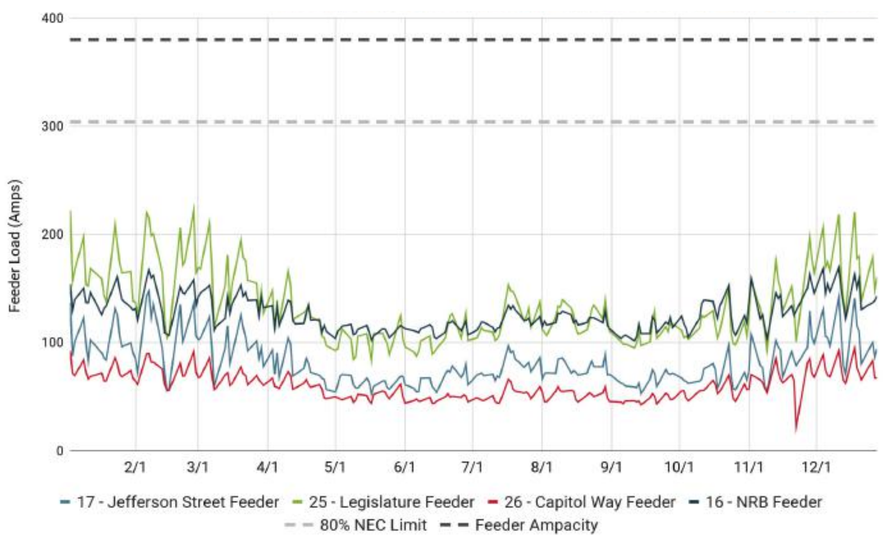


**Chart 8.22:** Backup Operation: Daily Peak Electrical Load by Circuit.

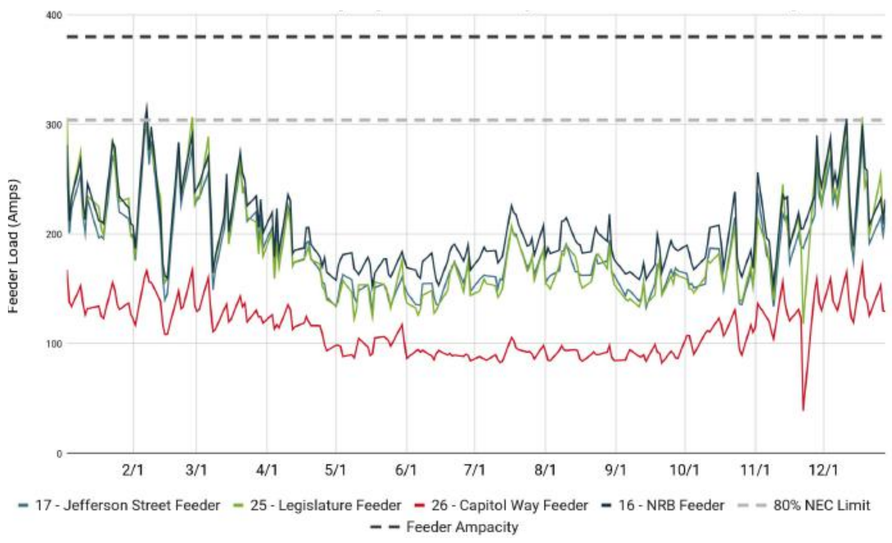
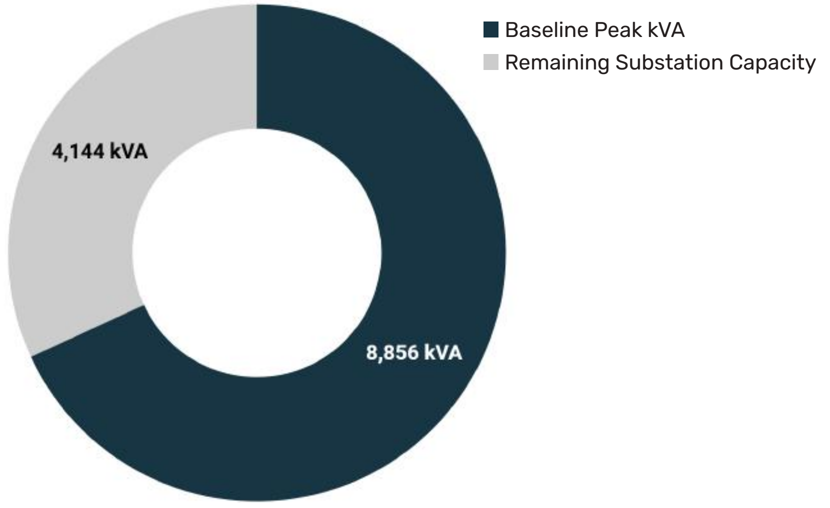


**Chart 8.23:** Capitol Campus Substation Load After Proposed Solution.



# Energy & Environmental Impact

## CBPS Compliance

House Bill (HB) 1257 and 1390 set the requirements for decarbonization planning for campus district energy systems to meet the state's Energy Performance Standard and established an alternative compliance pathway.

The district energy solution is 18% below the CBPS requirements of 58 kBtu/ft²/year. The chart below demonstrates the recommended solution's relative impact at the district level over the implementation period (2025 to 2034). The EUI value beginning in year 2035 reflects full implementation of the hybrid Central Heat Pump Plant and Ambient Temperature Loop solution, and this level of performance is expected from 2035 and beyond.

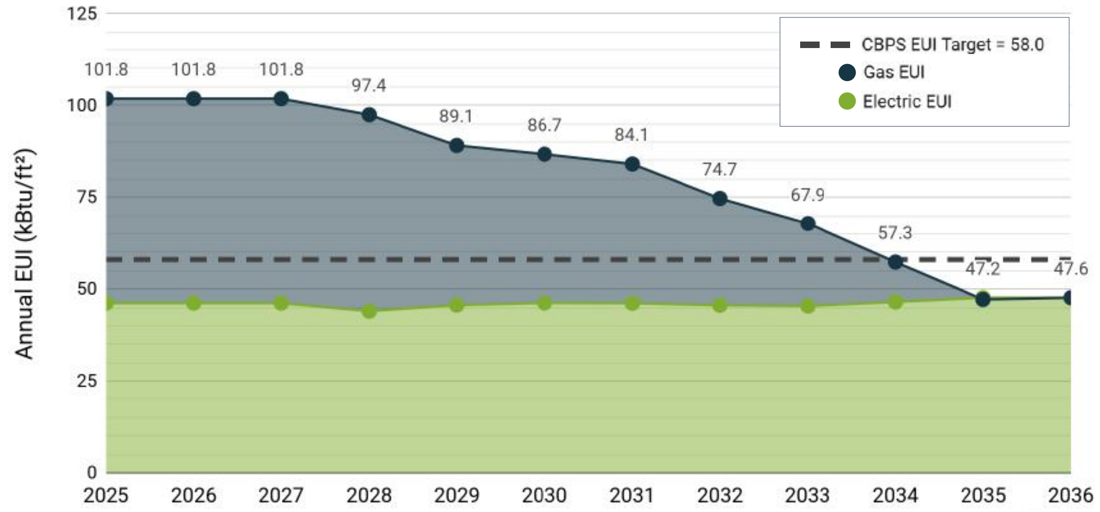
## Carbon Emissions Reduction

The building- and district energy-level improvements outlined in this plan put the Capitol Campus on the path to decarbonization. The solution lowers each building's demand for heating, cooling, and electrical loads while transitioning 100% of the buildings from natural gas (Scope 1 emission) to high-efficiency electric heating (Scope 2 emission) through large-scale heat pumps. This strategy utilizes a lower amount of cleaner electricity and exploits the buildings' load diversity and corresponding potential for heat recovery.

This carbon emissions analysis assumes a carbon emissions factor of 266.585 lb $CO_2e$/MWh of electricity consumed on campus in 2025, matching Washington's state-wide emissions as reported on the Environmental Protection Agency's Emissions & Generation Resource Integrated Database (eGRID) reported for 2023. A linear reduction in the carbon emissions factor to zero was used between 2025 and 2030 to reflect PSE's commitment to decarbonizing its electrical generation.

The natural gas carbon emissions factor used is 11.70 lb $CO_2e$/Therm of gas consumed on campus.

Capitol Campus Energy Utilization Index Projection



Capitol Campus Carbon Emissions Projection

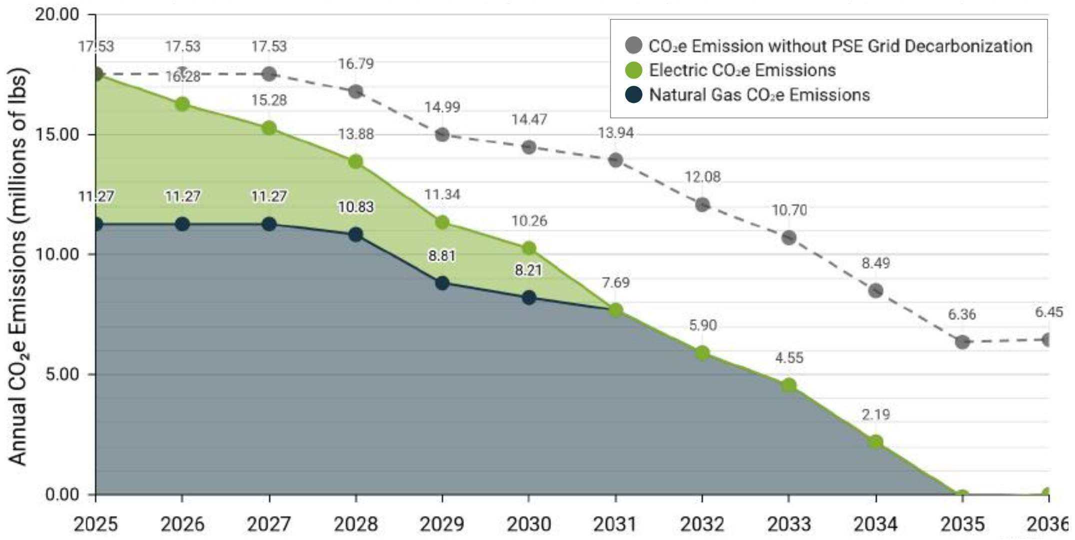


**Chart 8.25 (bottom):** Capitol Campus Energy Utilization Index Projection.

**Chart 8.24 (top):** Capitol Campus Carbon Emissions Projection.

> This plan will reduce the campus' carbon footprint by 64%. PSE's planned decarbonization of the electric grid will yield further reductions, resulting in the full elimination of Scope 1 and 2 emissions from the Capitol Campus.

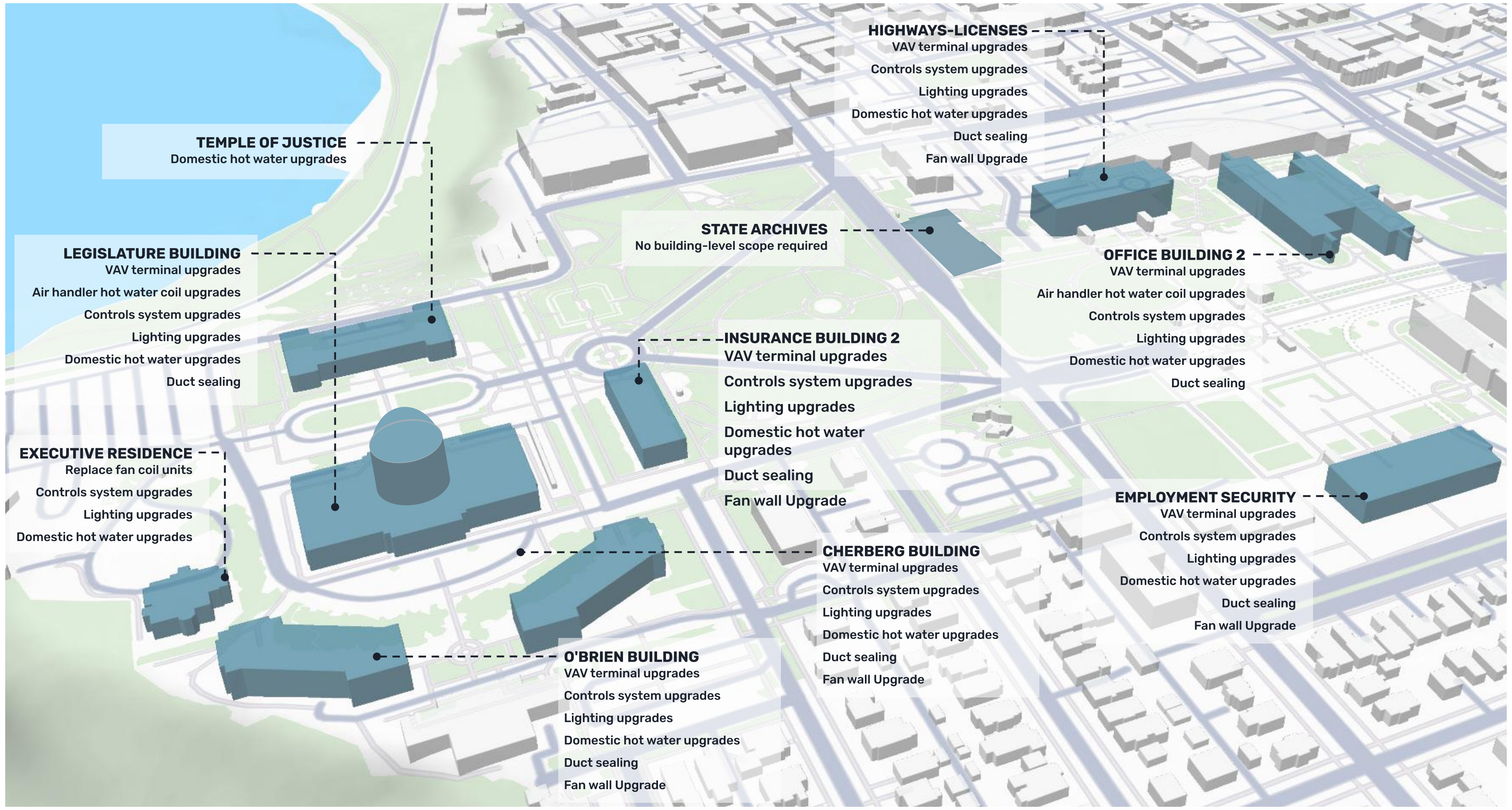
# 9: BUILDING-LEVEL STRATEGIES FOR DISTRICT ENERGY ADOPTION

# Required Building-Level Upgrades

The previous section outlined the work required to generate thermal energy, distribute that energy throughout campus, and connect each building to the district energy system. This work, however, requires some building-level improvements to be successful.

The major driver for these building-level improvements is reducing the current heating and electrical loads to free up the needed capacity for electrifying the campus' heating systems.

Other drivers include maximizing heat recovery potential through new control strategies and enabling the use of the hydronic heat pumps by replacing hydronic heating coils in the building's airside equipment to utilize lower-temperature hot water.



**Map 9.1:** Upgrade measures by building.

## BUILDING UPGRADE MEASURES

To be successfully connected to the district energy system, each building on campus needs to be addressed with a combination of the following upgrades. *See the following pages for a high-level summary of each building's existing systems and the required upgrades.*

**VAV Terminal Unit Hot Water Coil Upgrades:** Retrofit the existing terminal unit reheat coils with new hot water coils designed for 140°F heating hot water.

**Air Handling Unit Hot Water Coil Upgrades:** Retrofit the existing air handling units with new hot water coils designed for 140°F heating hot water.

**Controls System Upgrades:** Install new DDC controls on all HVAC equipment. Implement optimized controls sequences to reduce VAV reheat demand and maximize heat recovery potential. This will include disabling airside economizer operation.

**Lighting Systems Upgrades:** Retrofit existing fluorescent lighting with LED lighting.

**Domestic Hot Water Heating Upgrades:** Replace the existing natural gas water heater with an electric heat pump water heater.

**Duct Sealing and Sheet Metal Duct Repair:** Seal existing ductwork and repair existing damage to minimize air leakage and reduce thermal demands. This upgrade will extend the life of the existing ductwork, allowing it to be reused while also improving air flow and energy efficiency.

**Fan Wall Upgrade:** Replace the existing single supply fan with several fans in a fan wall configuration. This allows for improved operation and control, reliability, and energy efficiency.

## OFFICE BUILDING TWO

**Construction Date:** 1975 | **Square Footage:** 379,204

**Renovation Summary:** In 2005 and 2006, the primary mechanical systems, including three chillers, cooling towers, pumps, and the main air handling unit, were retrofitted.

**Lighting Type:** Primarily linear fluorescent tubes

**Existing District Energy Connection:**

- Connected to the Powerhouse's central steam system.
- Steam is converted to hot water in the building through a heat exchanger for space heating.
- Three water-cooled chillers, with a total tonnage capacity of 840 tons, and two cooling towers supply this building with chilled water.

**Existing HVAC System:**

- Four-pipe hydronic variable air volume (VAV) air handling systems with VAV terminals for hot water reheat.
- The heating coils were designed for 180°F water.

**Existing Domestic Hot Water System:**

- Electric resistance and steam-to-hot water heat exchanger

### Building-Level Scope of Work

- VAV Terminal Unit Hot Water Coil Upgrades
- Air Handling Unit Hot Water Coil Upgrades
- Controls System Upgrades
- Lighting Systems Upgrades
- Domestic Hot Water Heating Upgrades
- Duct Sealing and Sheet Metal Duct Repair

## HIGHWAYS-LICENSES BUILDING

**Construction Date: 1962** | **Square Footage:** 193,900

**Renovation Summary:** In 2009, primary mechanical systems, including chiller, cooling tower, pumps, and air handler, were retrofitted.

**Lighting Type:** Primarily linear fluorescent tubes

**Existing District Energy Connection:**

- Connected to the Powerhouse's central steam system.
- Steam is converted to hot water in the building through a heat exchanger for space heating.
- Two water-cooled centrifugal chillers and one cooling tower supply chilled water to this building.

**Existing HVAC System:**

- Four-pipe hydronic variable air volume (VAV) air handling systems with VAV terminals for hot water reheat.
- The heating coils were designed for 180°F water.

**Existing Domestic Hot Water System:**

- Steam-to-hot water heat exchanger

### Building-Level Scope of Work

- VAV Terminal Unit Upgrades
- Controls System Upgrades
- Lighting Systems Upgrades
- Domestic Hot Water Heating Upgrades
- Duct Sealing and Sheet Metal Duct Repair
- Fan Wall Upgrade




## EMPLOYMENT SECURITY BUILDING

**Construction Date:** 1961 | **Square Footage:** 93,200

**Renovation Summary:** 1985 and 2010 chiller replacements

**Lighting Type:** Primarily linear fluorescent tubes

**Existing District Energy Connection:**

- Connected to the Powerhouse's central steam system.
- Steam is converted to hot water in the building through a heat exchanger for space heating.
- Three water-cooled chillers supply chilled water with a total tonnage capacity of 430 tons.

**Existing HVAC System:**

- First Floor is served by a four-pipe hydronic variable air volume (VAV) air handling system with VAV terminals for hot water reheat.
- The second and third floors are served by a dual duct system, which was original to the building's construction.
- Air handler pre-heat coils are steam; all reheat coils were designed for 180°F water.

**Existing Domestic Hot Water System:**

- Steam-to-hot water heat exchanger

### Building-Level Scope of Work

- Replace VAV terminals on the first floor with ones designed for 140°F water.
- Controls System Upgrades
- Lighting Systems Upgrades
- Domestic Hot Water Heating Upgrades
- Duct Sealing and Sheet Metal Duct Repair

## STATE ARCHIVES BUILDING

**Construction Date:** 1963

**Square Footage:** 51,317

**Renovation Summary:** 2014 new HVAC system and electrical upgrades.

**Lighting Type:** Primarily LEDs

**Existing District Energy Connection:**

- Connected to the Powerhouse's central steam system.

**Existing HVAC System:**

- A water-source heat pump system provides heating and cooling throughout the building via a common condenser water loop and fan coil units.
- A closed-circuit evaporative fluid cooler with 30% glycol rejects excess heat from the system.

**Existing Domestic Hot Water System:**

- Steam-to-hot water heat exchanger and electric point-of-use

### Building-Level Scope of Work

- No building-level scope required

## JOHN A. CHERBERG BUILDING

**Construction Date:** 1937

**Square Footage:** 100,377

**Renovation Summary:** Has undergone several major renovations, including a major HVAC renovation in 2002.

**Lighting Type:** Primarily linear fluorescent tubes

**Existing District Energy Connection:**
- Connected to the Powerhouse's central steam system.
- Steam is converted to hot water in the building through a heat exchanger for space heating.
- Connected to the Powerhouse's central chilled water system.

**Existing HVAC System:**
- Four-pipe hydronic variable air volume (VAV) air handling systems with VAV terminals for hot water reheat.
- The heating coils were installed in 2002 and are designed for 180°F water.

**Existing Domestic Hot Water System:**
- Steam-to-hot water heat exchanger

### Building-Level Scope of Work

- VAV Terminal Unit Hot Water Coil Upgrades
- Controls System Upgrades
- Lighting Systems Upgrades
- Domestic Hot Water Heating Upgrades
- Duct Sealing and Sheet Metal Duct Repair
- Fan Wall Upgrade

## JOHN L. O'BRIEN BUILDING

**Construction Date:** 1947

**Square Footage:** 100,700

**Renovation Summary:** Has undergone several major renovations, including a major HVAC renovation in 2010.

**Lighting Type:** Primarily linear fluorescent tubes

**Existing District Energy Connection:**
- Connected to the Powerhouse's central steam system.
- Steam is converted to hot water in the building through a heat exchanger for space heating.
- Connected to the Powerhouse's central chilled water system.

**Existing HVAC System:**
- Four-pipe hydronic variable air volume (VAV) air handling systems with VAV terminals for hot water reheat.
- The heating coils were installed in 2010 and are designed for 180°F water.

**Existing Domestic Hot Water System:**
- Steam-to-hot water heat exchanger

### Building-Level Scope of Work

- VAV Terminal Unit Hot Water Coil Upgrades
- Controls System Upgrades
- Lighting Systems Upgrades
- Domestic Hot Water Heating Upgrades
- Duct Sealing and Sheet Metal Duct Repair
- Fan Wall Upgrade

## LEGISLATIVE BUILDING

**Construction Date:** 1928

**Square Footage:** 255,564

**Renovation Summary:** Has undergone several major renovations, including major HVAC renovations in 2003 and 2012.

**Lighting Type:** Primarily linear fluorescent tubes

**Existing District Energy Connection:**
- Connected to the Powerhouse's central steam system.
- Steam is converted to hot water in the building through a heat exchanger for space heating.
- Connected to the Powerhouse's central chilled water system.

**Existing HVAC System:**
- Four-pipe hydronic variable air volume (VAV) air handling systems with VAV terminals for hot water reheat.
- The heating coils were designed for 190°F water.

**Existing Domestic Hot Water System:**
- Steam-to-hot water heat exchanger

### Building-Level Scope of Work

- VAV Terminal Unit Hot Water Coil Upgrades
- Air Handling Unit Hot Water Coil Upgrades
- Controls System Upgrades
- Lighting Systems Upgrades
- Domestic Hot Water Heating Upgrades
- Duct Sealing and Sheet Metal Duct Repair

## TEMPLE OF JUSTICE

**Construction Date:** 1913

**Square Footage:** 85,900

**Renovation Summary:** Has undergone several major renovations, including a major HVAC and electrical renovation in 2023-2024.

**Lighting Type:** Primarily LED

**Existing District Energy Connection:**
- Connected to the Powerhouse's central steam system.
- Steam is converted to hot water in the building through a heat exchanger for space heating.
- Connected to the Powerhouse's central chilled water system.

**Existing HVAC System:**
- The HVAC system was upgraded in 2023-2024 with new fan coil units.
- The heating coils are designed for 140°F water.

### Building-Level Scope of Work

- Domestic Hot Water Heating Upgrades


## EXECUTIVE RESIDENCE

**Construction Date:** 1908

**Square Footage:** 20,000

**Renovation Summary:** Has undergone several major renovations, including major HVAC renovations in 2000 and 2014.

**Lighting Type:** Mix of incandescent, fluorescent, and LED technology.

**Existing District Energy Connection:**
- Has a stand-alone boiler for hot water heating.
- Connected to the Powerhouse's central chilled water system.

**Existing HVAC System:**
- The HVAC system was upgraded in 2014 with new fan coil units.
- The heating coils are designed for 200°F water.

**Existing Domestic Hot Water System:**
- Three 199 MBH gas-fired instantaneous water heaters

### Building-Level Scope of Work

- Replace high-temperature heating water fan coil units with units designed for 140°F heating water.
- Lighting System Upgrades
- Replace the water heater with a heat pump water heater.
- Controls System Upgrades


## INSURANCE BUILDING

**Construction Date:** 1921

**Square Footage:** 65,502

**Renovation Summary:** Has undergone several major renovations, including a major HVAC renovation in 1980.

**Lighting Type:** Primarily linear fluorescent tubes

**Existing District Energy Connection:**
- Connected to the Powerhouse's central steam system.
- Steam is converted to hot water in the building through a heat exchanger for space heating.
- Connected to the Powerhouse's central chilled water system.

**Existing HVAC System:**
- Four-pipe hydronic variable air volume (VAV) air handling systems with VAV terminals for hot water reheat.
- The heating coils are designed for 180°F water.

**Existing Domestic Hot Water System:**
- Steam-to-hot water heat exchanger

### Building-Level Scope of Work

- VAV Terminal Unit Hot Water Coil Upgrades
- Controls System Upgrades
- Lighting Systems Upgrades
- Domestic Hot Water Heating Upgrades
- Duct Sealing and Sheet Metal Duct Repair
- Fan Wall Upgrade

# 10: DECARBONIZATION PLAN IMPLEMENTATION

# Practical Roadmap to a Phased Implementation

One major advantage of the recommended decarbonization solution is that its implementation can be phased over multiple biennia, allowing incremental progress and flexibility in capital budgeting. The design of all the project's components will take approximately three years to complete. However, construction on some aspects of the system can begin before the completion of the full design.

| BUILDING ABBREVIATION LIST | |
|---|---|
| OB2 | Office Building Two |
| HWY | Highways-Licenses Building |
| ESB | Employment Security Building |
| NRB | Natural Resources Building |
| ACH | Archives and Records Center |
| CHB | John A. Cherberg Building |
| OBN | John L. O'Brien Building |
| LEG | Legislative Building |
| TOJ | Temple of Justice |
| EXR | Executive Residence (Governor's Mansion) |
| INS | Insurance Building |

**Table 10.1:** Building Abbreviation List.

> The following pages describe the major steps and phases of work in the general order in which they will occur. After each primary grouping of work, a time-by-activity schedule graphically displays how the work will progress.

## Design Scope

**3 years (mid-2025 to mid-2028)**

Design phase activities shall progress according to the following:

### Energy Efficiency & Load Reduction Development

- Facility audits and scope development for load reduction measures and terminal unit replacements.
- These load reduction measures are critical to reducing electrical loads and maximizing heat recovery, ensuring the right size of central equipment.
- The East Campus facilities include Office Building Two, Highways-Licenses, Employment Security, and Natural Resources buildings.
- West Campus Facilities include O'Brien, Cherberg, Insurance, and Legislative buildings.

### Low-Temperature Hot Water Coils Design

- Design replacements of high-temperature terminal reheat coil and steam air handler preheat coils in OB2, HWY, ESB, INS, CHB, OBN.
- New coils shall be selected for 140°F or lower heating water temperature.

### East Building-Level Heat Pump Plant

- Design of the distributed heat pump plants, which will be located in each building to take or reject heat from the Ambient Temperature Loop.
- The facilities included are OB2, HWY, ACH, ESB, and NRB.

### Medium Voltage Electrical Design

- Site utilities design of modifications to the 12,470V medium-voltage electrical distribution circuits owned by DES, which distributed electricity to each building.

### West Thermal Energy Plant Design

- Architectural, civil, and engineering design of the central heat pump plant, which will serve the four-pipe distribution system on the West Campus.

### Geoexchange Design (Optional)

- Testing, sizing, and locating wells for maximum geothermal exchange and designing the piping, pumping, and geoexchange heat pump system.

### Campus-wide Piping Design

- Design of Ambient Temperature Loop distribution system for the East Campus.
- Design of the four-pipe hot and chilled water distribution system for the West Campus.

# Design Schedule

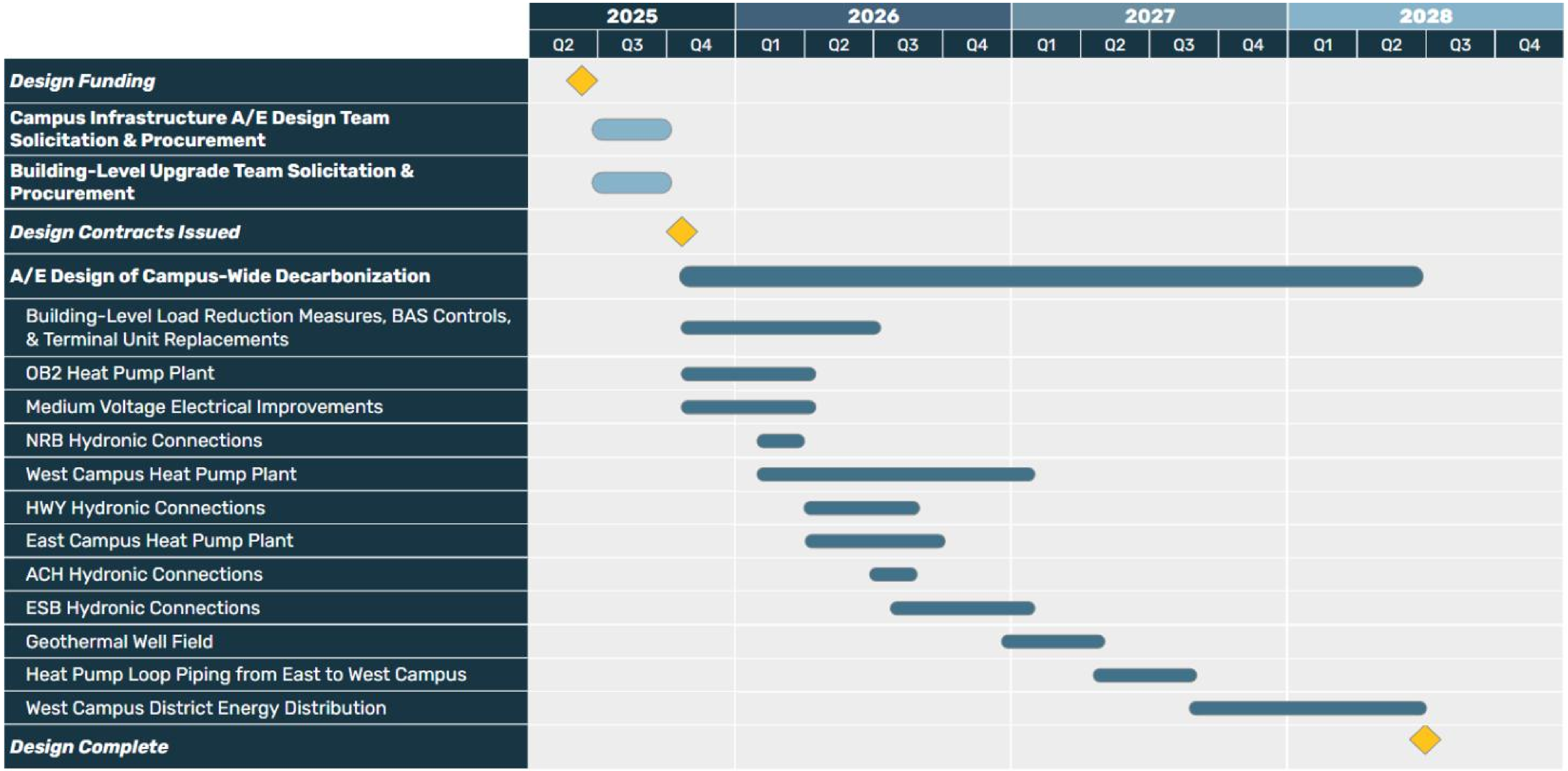


**Table 10.2:** Design Phase Schedule.

JUMP TO TABLE OF CONTENTS

# Phased Construction Implementation Summary

> Working in two phases will allow the buildings that are furthest from the Powerhouse to be disconnected from the campus steam distribution system while maintaining steam service for buildings addressed in later phases.

The new Capitol Campus district energy system is expected to be constructed over seven years, from mid-2027 to mid-2034. **The work will be performed in two phases, working from east to west.**

### Phase 1: East Campus

Phase 1 will address Office Building 2, Highways-Licenses, Employment Security, and Archives and Records Center, eliminating steam service to the East Campus, east of Capitol Way. This allows for the decommissioning and removal of a significant amount of antiquated steam distribution while facilitating the independent operation of the East Campus from the Powerhouse.

Phase 1 will also include energy conservation and load reduction measures within each East Campus building. This work is needed to reduce loads on the current electrical distribution system to avoid costly site electrical infrastructure upgrades.

### Phase 2: West Campus Central Heat Pump Plant & Thermal Energy Distribution

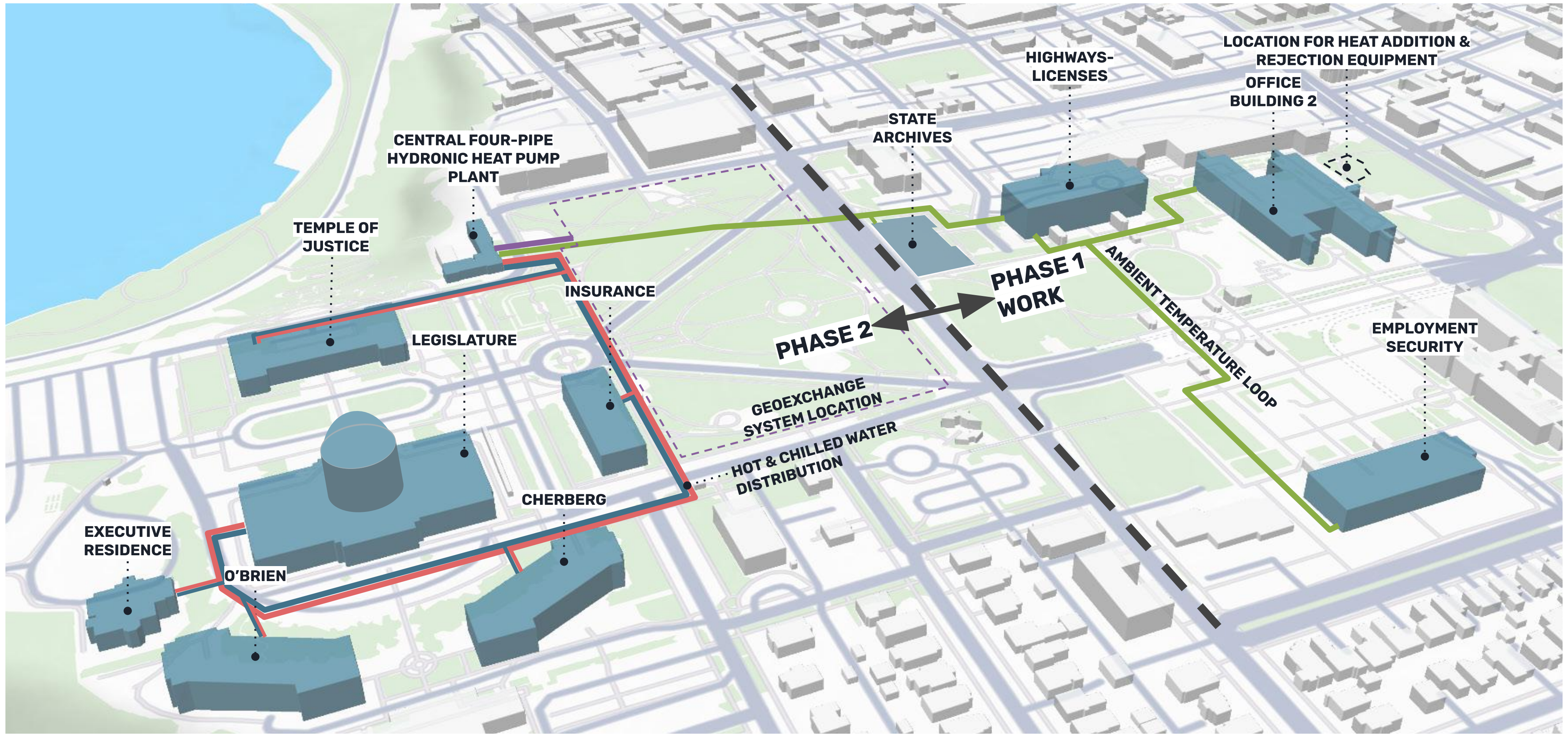
This phase will eliminate the need for the Powerhouse's central chilled water and steam by building a new central plant that produces hot and chilled water using large-scale, all-electric water-to-water heat pumps. This plant will ultimately service the Temple of Justice, the Legislature Building, the Executive Residence, O'Brien, Cherberg, and Insurance.

This phase will also include the installation of the West Campus hot- and chilled-water distribution piping from the new Central Heat Pump Plant to the buildings on West Campus. It will also connect the new central heat pump plant on West Campus to the Ambient Temperature Loop on East Campus. This significantly increases the redundancy and resilience of the district energy system while enabling the energy and economic benefits of recovering heat from buildings to be used in other buildings across the campus.

Lastly, this presents the option to implement a geothermal exchange system in the lawn between the Insurance Building and Capitol Way. The geoexchange system would exchange heat energy with the ATL through a water-to-water heat pump located in the new central heat pump plant on West Campus.

### Phase 2: West Campus Buildings & Connections

This phase will include all work within the West Campus buildings to connect them to the hot- and chilled-water distribution piping already installed. This will include interconnection between the building and the West Campus hydronic distribution system, replacing high-temperature (180F°+) hydronic heating coils with low-temperature coils (140°F and below), and implementation of energy conservation and load reduction measures within each West Campus building. This work is needed to reduce the current electrical distribution load to avoid costly site electrical infrastructure upgrades. It also reduces the capacity and cost of the new central heat pump plant.



**Map 10.3:** Phase 1 and 2 Implementation.

# Phase 1 Construction Implementation

**2.5 years (mid 2027 - late 2029)**

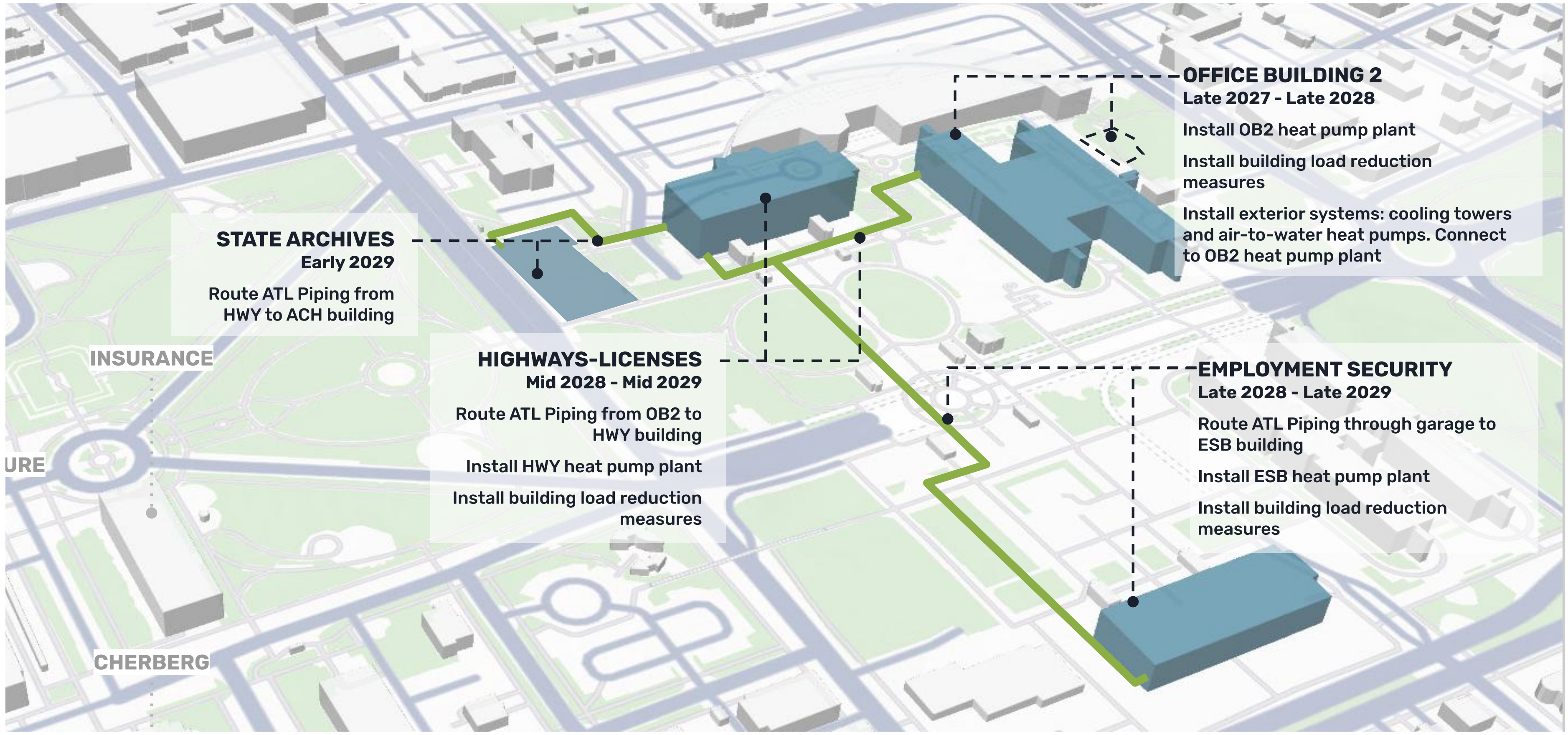
This work is focused on the East Campus and includes installing hydronic heat pump equipment in each building and implementing load reduction and energy efficiency measures. This work can overlap with the completion of the final stages of design of the West Campus central heat pump plant and the connection between the ATL and the West Campus four-pipe loop.

Phase 1 Construction activities shall progress according to the following:

## Office Building 2

*Mid 2027 - Mid 2028*

- Install new heat pump plant in Office Building 2
- Install new exterior air-to-water heat pumps and cooling towers east of OB2 and route Ambient Temperature Loop piping to OB2's heat pump plant.
- Tie the chiller condensers at the Natural Resources Building to the new ATL
- Perform energy and load reduction measures within OB2.
- Install new heating water coils throughout OB2, designed for 140°F water.



**Map 10.4:** Phase 1 Construction Scope of Work

## Highways-Licenses & State Archives

*Mid 2028 - Mid 2029*

- Install new heat pump plant in the Highways-Licenses Building
- Route ATL piping from OB2's heat pump plant to Highways-Licenses' plant.
- Route ATL piping from Highways-Licenses' heat pumps plant to the State Archives Building. Connect the existing water-source heat pump loop within Archives to the ATL.
- Perform energy and load reduction measures within Highways-Licenses.
- Install new heating water coils throughout Highways-Licenses, designed for 140°F water.

## Employment Security Building

*Mid 2028 - End 2029*

- Install new heat pump plant in the Employment Security Building
- Route ATL piping from Highways-Licenses to Employment Security's plant.
- Perform energy and load reduction measures within Highways-Licenses.
- Convert dual-duct terminals to single-duct VAV with hydronic reheat coils designed for 140°F water.

# Phase 1 Schedule

| | 2027 | | | 2028 | | | | 2029 | | | | 2030 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| ***Phase 1 Funding for East Campus Construction*** | ◆ | | | | | | | | | | | | | | |
| **East Campus Infrastructure Construction Team Solicitation & Procurement** | | 🟩 | | | | | | | | | | | | | |
| **Building-Level HVAC & Controls Construction Team Solicitation & Procurement** | | 🟩 | | | | | | | | | | | | | |
| ***East Campus Construction Begins*** | | | ◆ | | | | | | | | | | | | |
| **East Outdoor Plant Project** | | | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | | | | | | | | |
| **OB2 & NRB Projects** | | | 🟩 | 🟩 | 🟩 | 🟩 | | | | | | | | | |
| Heat Pump Plant & Heat Pump Loop Connection | | | 🟩 | 🟩 | 🟩 | 🟩 | | | | | | | | | |
| Building-Level Load Reduction, BAS, TU Upgrades | | | 🟩 | 🟩 | 🟩 | 🟩 | | | | | | | | | |
| ***OB2 Heat Pump Plant Operational*** | | | | | | ◆ | | | | | | | | | |
| **HWY Projects** | | | | | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | | | | | | |
| Heat Pump Plant & Heat Pump Loop Connection | | | | | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | | | | | | |
| Building-Level Load Reduction, BAS, TU Upgrades | | | | | | 🟩 | 🟩 | 🟩 | 🟩 | | | | | | |
| ***HWY Connected to Heat Pump Loop*** | | | | | | | | | ◆ | | | | | | |
| **ACH Heat Pump Loop Connection** | | | | | | | | 🟩 | 🟩 | | | | | | |
| ***ACH Connected to Heat Pump Loop*** | | | | | | | | | ◆ | | | | | | |
| **ESB Construction** | | | | | | | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | | | |
| Heat Pump Plant & Heat Pump Loop Connection | | | | | | | 🟩 | 🟩 | 🟩 | 🟩 | | | | | |
| Building-Level Load Reduction, BAS, TU Upgrades | | | | | | | | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | | | |
| ***ESB Connected to Heat Pump Loop*** | | | | | | | | | | | | ◆ | | | |

**Table 10.5:** Phase 1 Schedule.

# Phase 2: West Campus Heat Pump Plant & Thermal Energy Distribution Construction

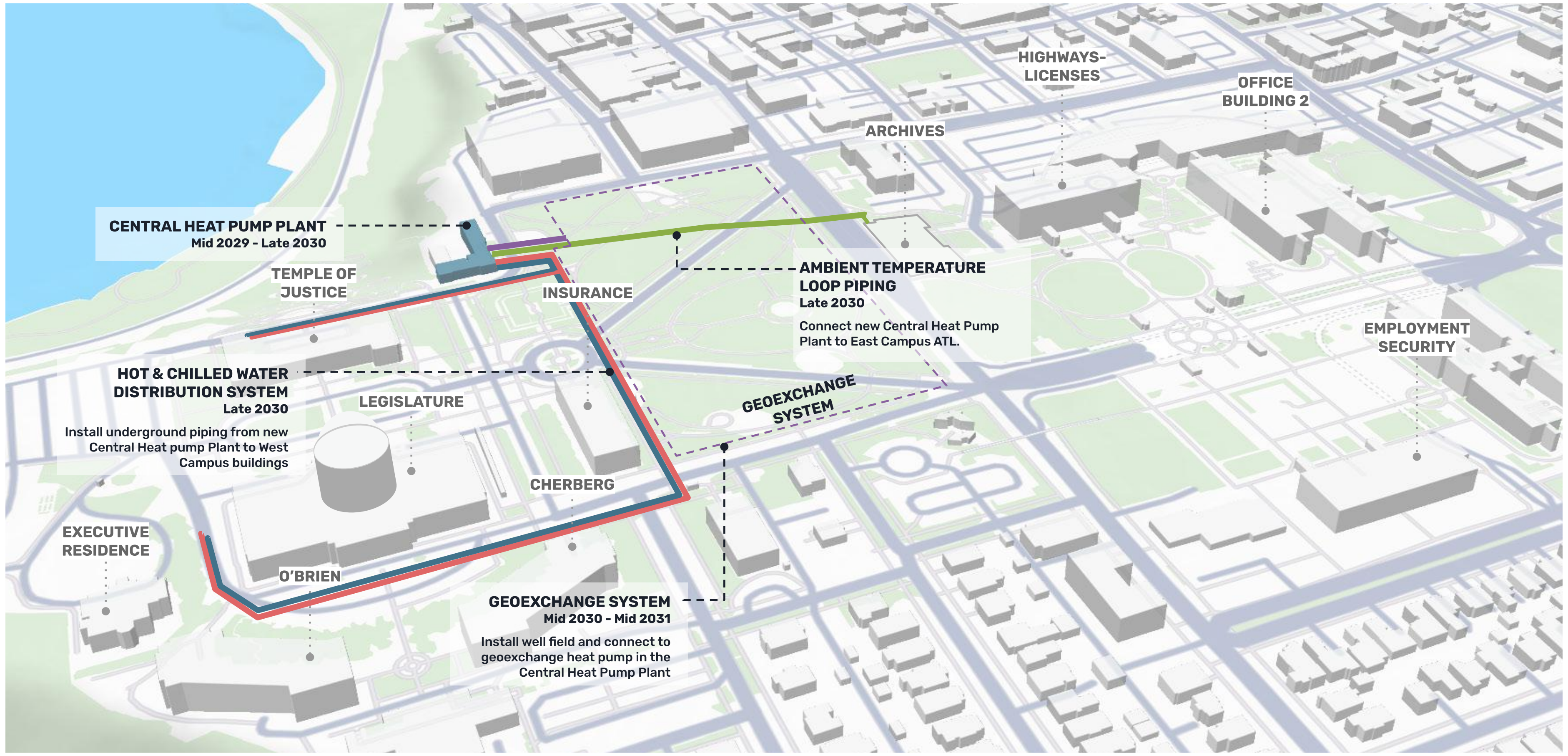
**3 years (mid 2029 - mid 2032)**
This work is focused on the West Campus and includes the construction of a new Central Heat Pump Plant that produces hot and chilled water to serve the HVAC needs of the West Campus. This phase also includes the installation of the West Campus hot and chilled water distribution system.

Construction activities shall progress according to the following:

## Central Heat Pump Plant

*Mid 2029 - Early 2031*

- Construct a new central Heat Pump Plant facility (Possible location is the Old Conservatory).
- Route the ATL distribution from East Campus (at State Archives) to the new Central Heat Pump Plant.
- Route hot and chilled water distribution from the new Central Heat Pump Plant to the Temple of Justice. Connect to TOJ's hydronic heating and cooling distribution piping.



**Map 10.6:** Phase 2 Scope of Work.

## West Campus Thermal Energy Distribution Piping

*Early 2030 - Early 2031*

- Route the ATL distribution from East Campus (at State Archives) to the new Central Heat Pump Plant.
- Route hot and chilled water distribution piping throughout West Campus.

## Install Geoexchange System

*Mid 2030 - Mid 2031*

- Install a geoexchange well field and connect to ATL through a geoexchange heat pump in the new Central Heat Pump Plant.

# Phase 2: West Campus Heat Pump Plant & Thermal Energy Distribution Schedule

| | 2029 | | | 2030 | | | | 2031 | | | | 2032 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| ***Phase 2A Funding for West Campus Heat Pump Plant and Distribution Construction*** | ◆ | | | | | | | | | | | | | | |
| **West Campus Infrastructure Construction Team Solicitation & Procurement** | | ■ | | | | | | | | | | | | | |
| ***West Campus Construction Begins*** | | | ◆ | | | | | | | | | | | | |
| **West Campus Heat Pump Plant Construction** | | | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | |
| **West Campus HW & CHW Piping - Connect East & West Loops** | | | | ■ | ■ | ■ | ■ | ■ | | | | | | | |
| ***West Campus Heat Pump Plant Complete*** | | | | | | | | | ◆ | | | | | | |
| **Geothermal Well-Field & Connect to Heat Pump Loop** | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | |
| ***West Heat Pump Loop Complete*** | | | | | | | | | | | ◆ | | | | |
| **Campus Medium Voltage Electrical Upgrades** | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |

**Table 10.7:** Phase 2: Schedule.

# Phase 2: West Campus Buildings & Connections Construction

**4.5 years (early 2030 - mid 2034)**

This work is focused on the West Campus and includes the connection of all West Campus buildings to the West Campus hot and chilled water distribution piping. This phase also includes implementing load reduction and energy efficiency measures and replacing high-temperature hot water air coils throughout the buildings with coils designed for 140°F water.

Construction activities shall progress according to the following:

## Cherberg Building

*Early 2030 - Mid 2031*

- Connect building to West Campus hot and chilled water distribution system.
- Perform energy and load reduction measures within Cherberg.
- Install new heating water coils throughout Cherberg, designed for 140°F water.

## O'Brien Building

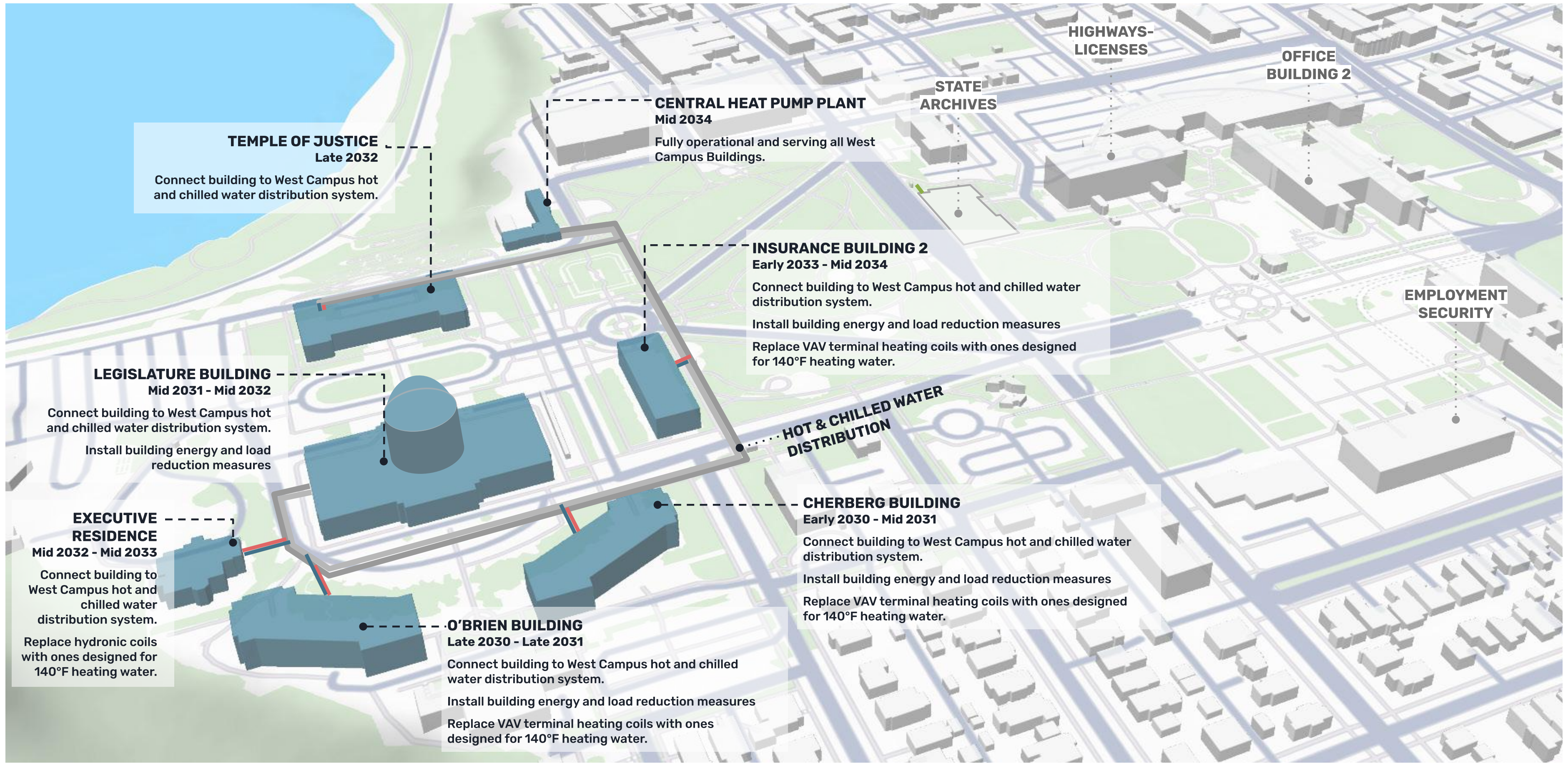
*Late 2030 - Early 2032*

- Connect building to West Campus hot and chilled water distribution system.
- Perform energy and load reduction measures within O'Brien.
- Install new heating water coils throughout O'Brien, designed for 140°F water.

## The Legislative Building

*Mid 2031 - Mid 2032*

- Connect building to West Campus hot and chilled water distribution system.
- Perform energy and load reduction measures within the Legislature Building.



**Map 10.8:** Phase 2 Scope of Work.

## Executive Residence

*Mid 2032 - Mid 2033*

- Connect building to West Campus hot and chilled water distribution system.
- Install new heating water coils throughout the Executive Residence, designed for 140°F water.

## Temple of Justice

*Mid 2032 - Early 2033*

- Connect building to West Campus hot and chilled water distribution system.

## Insurance Building

*Early 2033 - Mid 2034*

- Connect building to West Campus hot and chilled water distribution system.
- Perform energy and load reduction measures within Insurance.
- Install new heating water coils throughout the Insurance Building, designed for 140°F water.

# Phase 2: West Campus Buildings & Connections Schedule

**Table 10.9:** Phase 2 Schedule.

*Continued on next page.*

# Phase 2: West Campus Buildings & Connections Schedule Continued

**Table 10.10:** 2 Schedule continued.

# Project Economics

## Financial Pro Forma

**Chart 10.11** (top right) demonstrates the cash flow over the design and implementation period corresponding to the project schedule. This includes the capital required to fund the plan's implementation and the predicted utility and maintenance cost savings expected throughout the period. The utility savings reflect the annual utility cost reduction compared to the baseline period, before project implementation.

A cashflow model can be found in Appendix 2. The cashflow model shows that 2025 and 2026 have only design costs, with construction beginning in 2027. When the central heat pump systems and West Campus hydronic heat pump plants are constructed, high construction costs are incurred from 2028 to 2032.

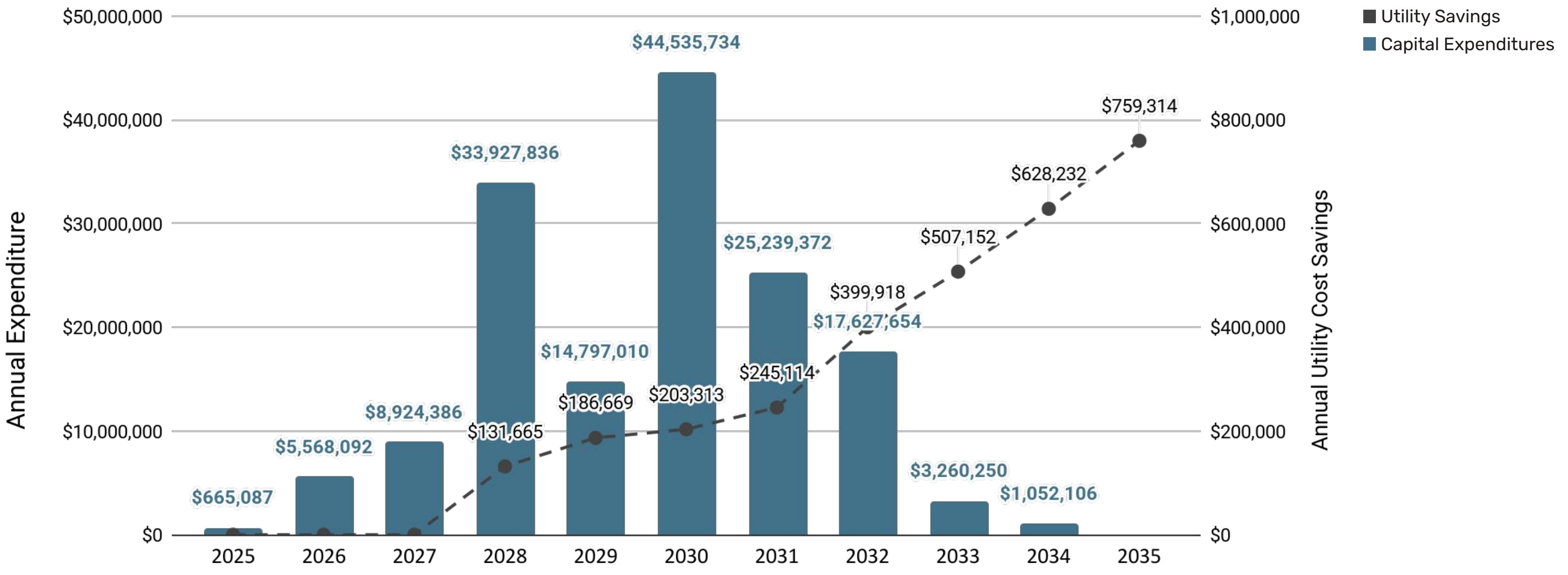


**Chart 10.11:** Annual Implementation Cashflow of Preferred Alternative.

## Life Cycle Cost Analysis

**Chart 10.12** shows the net present value of all cashflows (Life Cycle Cost) associated with the implementation of this plan illustrated in the chart below. The capital, utility, and maintenance costs are considered over the next 30 years. ***Note:*** *Maintenance and utility costs of maintaining the existing district energy system are included.*

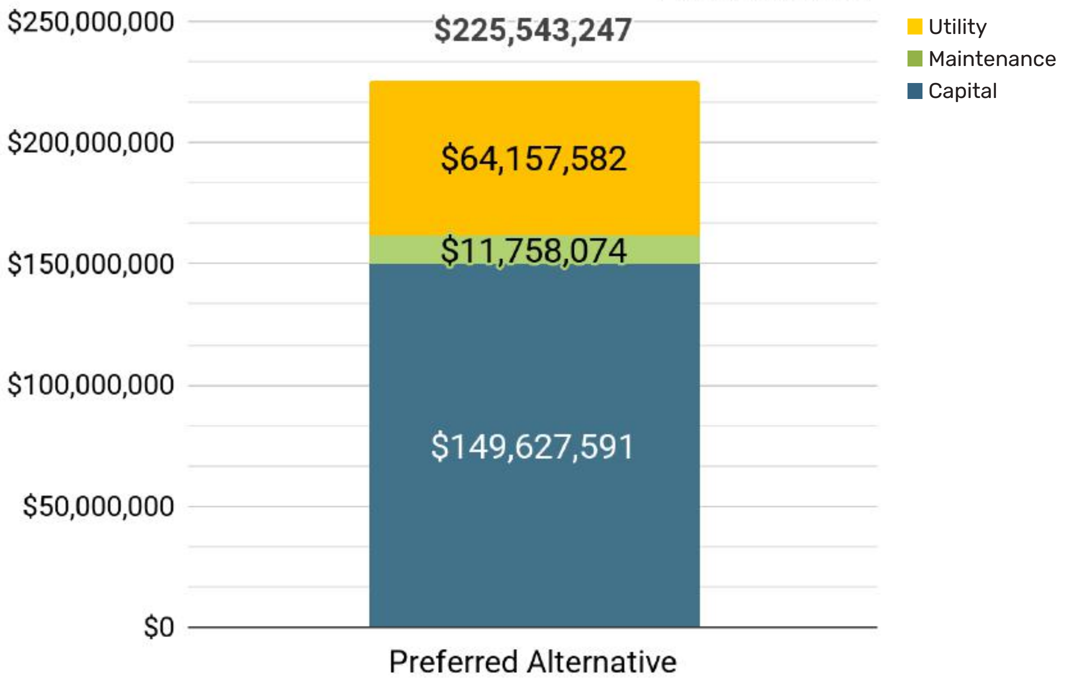


**Chart 10.12:** 30-Year Life Cycle Cost Analysis of Preferred Alternative.

# Existing System Risk Assessment During Implementation

| RISK TITLE | RISK CATEGORY | LIKELIHOOD | SEVERITY OF ISSUE | DESCRIPTION OF RISK | RISK MITIGATION STRATEGY |
|---|---|---|---|---|---|
| **Steam or CHW Main Distribution Piping Failure** | **Steam & CHW Distribution** | **Possible** | **Major** | Rupture of high pressure steam piping or main chilled water pipes leaving the central plant could leave all of West Campus and some of East Campus with no heating or cooling. All buildings served downstream of the piping failure would be affected. Most buildings have no provision for local heat generation, requiring shutdown until repairs could be completed. | Perform inspections of all accessible piping to check for signs of leaks or imminent failure. Design and construct provision to connect temporary heating and cooling equipment to critical buildings in the event of central CHW or steam shutdown. |
| **Steam or CHW Branch/ Local Piping or Valve Failure** | **Steam & CHW Distribution** | **Likely** | **Minor** | Hundreds of isolation and control valves are present throughout miles of steam and CHW distribution piping, which could fail or malfunction and prevent buildings from receiving the heating or cooling they require. CHW piping near Cherberg and O'Brien has recently failed, requiring emergency repairs and leaving nearby buildings without cooling until repairs are completed. | Perform inspections of all CHW and Steam valves and traps to check for signs of leaks or imminent failure. Design and construct provision to connect temporary heating and cooling equipment to critical buildings in the event of central CHW or steam shutdown. |
| **Central Chiller Failure** | **Central Heating & Cooling Equipment** | **Possible** | **Moderate** | Two chillers generate chilled water for nearly all buildings on West Campus, with limited redundancy given their varying sizes. One chiller is approximately twice the size of the other, and is the older of the two units. If this unit critically failed or required extensive maintenance, West Campus would have greatly limited cooling capacity. | Perform routine maintenance and diagnostics of all chiller performance metrics, and analysis of trend data from Building Automation Systems to identify degrading performance. Identify methods for temporary cooling in critical spaces and consider removal from central CHW to be served by independent systems. |
| **Central Steam Boiler Failure** | **Central Heating & Cooling Equipment** | **Likely** | **Major** | Two of three steam boilers at the Powerhouse were built in 1970 and the third was built in 1960. Replacement components for this old equipment are not readily available, and require specialty technical knowledge to perform repairs. Equipment is at end of life and is prone to failure as a result. All buildings connected to the steam loop on West Campus could be affected if multiple boilers failure simultaneously. | Regular maintenance and inspection of boiler inventory and ancillary systems like deaerator and feedwater system help proactively identify and fix small issues before they result in complete system failure. The overall plant capacity has significant redundancy built in, meaning one boiler failure still allows for full design output. |
| **Electrical System Overload** | **Electrical Infrastructure** | **Unlikely** | **Catastrophic** | As buildings continue to be constructed, additional EV chargers are installed, and building electrical demand increases, strain on the already burdened electrical distribution infrastructure will increase. | Review monthly peak demand data for all buildings and infrastructure connected to primary substation, forecast future connected load from new buildings and chargers, and ensure resulting estimated load can be accommodated. |
| **Natural Gas Moratorium or Interruption before Implementation** | **Regulatory** | **Possible** | **Major** | Changing legislators and legislation could place restrictions or bans on natural gas, which would cripple the Capitol Campus' ability to provide heating to nearly all facilities. More temporary natural gas outages or service interruptions yield a similar, but much smaller, challenge. | There is a diesel storage tank that can operate the steam plant for a short period, but long delays in service would require consistent refilling of the tank. The campus could investigate procuring uninterruptible natural gas supply from the utility. |
| **Permitting and Regulatory/ Administrative Delays** | **Regulatory** | **Possible** | **Minor** | Challenges in receiving construction funding, approval, and permitting may delay the anticipated implementation timeline, which could make compliance with certain CBPS requirements difficult and result in fines. | In the event of a funding gap or shortage, prioritize implementation of project components that most dramatically affect building energy consumption. |
| **Supply Chain Delays** | **Implementation & Constructability** | **Likely** | **Moderate** | Implementation of the Preferred Alternative system relies heavily on large air-to-water heat pumps, water-to-water heat pumps, and cooling towers to add and reject heat from the loop. Delays in this equipment require continued reliance on the failing existing steam infrastructure. | Careful design to accommodate multiple manufacturers' equipment would limit a single manufacturer's delay. Construction planning to ensure current systems remain operational until new equipment is on site and functioning will be necessary to promote uninterrupted facility usage. |
| **New Buildings Constructed w/o Provision for ATL Connection** | **Implementation & Constructability** | **Unlikely** | **Moderate** | The benefit of an ATL continues to improve the more buildings are connected, as this represents more potential for load diversity and energy sharing across the campus. New buildings designed without the ability to connect to this loop represent additional maintenance burden as well as increasing overall campus systems' complexity. | Development of clear design standards for new construction or renovations to existing facilities could ensure interconnection with the Preferred Alternative's distribution network, while still leaving flexibility for building-specific system needs. |
| **Landslide Damage to Powerhouse** | **Natural Disaster** | **Possible** | **Catastrophic** | Geologic studies in 2008 and 2010 identified high risk of slope failure near the Powerhouse that could cause catastrophic damage, causing nearly all of West Campus to lose heating and cooling service. | Secure funding to design and rectify geological deficiencies near the Powerhouse to reduce likelihood of landslide. |
| **Capitol Lake Flood Damage to Powerhouse** | **Natural Disaster** | **Unlikely** | **Catastrophic** | Current discussions and plans to return Lake Washington to estuary conditions would result in variable waterline that could in turn flood the Powerhouse or contribute to slope failure identified above. | In the event formal action to return Lake Washington to estuary conditions is approved, additional design, study, and survey would be required to identify necessary modifications. Until that time, no action is recommended. |
| **Earthquake** | **Natural Disaster** | **Unlikely** | **Catastrophic** | The Capitol Campus resides within a high risk earthquake zone. Damage caused to buildings, piping infrastructure, and central heating and cooling systems could range from minor to catastrophic. | Design new facilities and implement bracing as needed in accordance with American Society of Civil Engineers' guidance. codes, and standards. |
| **Building HVAC System Critical Failure Prior to ATL Integration** | **Central Heating & Cooling Equipment** | **Unlikely** | **Major** | Certain buildings on the East Campus contain their own CHW generating equipment that could fail prior to connection to the ATL. Direct replacement of this equipment would be costly and provide limited value (backup operation only) after ATL connection. Campus-wide, older hot water coils ar rated for high entering water temperature, and direct replacement would require re-work following ATL integration. | Perform regular preventative maintenance to all existing systems to maximize remaining operating life. Evaluate repair options rather than whole replacement of equipment on a case by case basis to minimize capital expense prior to ATL Integration. |

**Map 10.13:** Existing System Risk Assessment.

# APPENDIX 1: STATUTORY REQUIREMENTS

# Statutory Requirements & Decarb Plan Alignment

**Several layers of legislative requirements were considered for this analysis. Specifically, any new system design must enable the campus to meet Washington's Clean Buildings Performance Standards and decarbonization plan requirements of House Bill 1257 2019, Senate Bill 5722 2022, and House Bill 1390 2023.**

## House Bill 1257 (2019)

http://www.commerce.wa.gov/wp-content/uploads/2019/06/HB1257.pdf

### Summary:

In 2019, the Clean Building bill was signed into law, establishing a Clean Buildings Performance Standard (CBPS). This bill required the Department of Commerce to establish rules for energy performance standards, to collect data on compliance, and to report on outcomes to the state.

The Clean Buildings Performance Standard adopted the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 100-2018 as a base, and established energy use intensity targets (EUIt) specific to Washington state for different building occupancy types.

The law required investments in energy efficiency with fines for non-compliance. The original law applied to all covered buildings larger than 50,000 square feet and was later expanded by SB 5722 and HB 1390.

The primary requirements of HB 1257 CBPS include:

- Benchmark each covered building by measuring and tracking energy use over time.
- Applicable buildings must meet EUI Targets or implement all cost-effective energy efficiency measures to reduce energy consumption.
- An Energy Management Plan and an Operations & Maintenance Plan must be developed for each building to maintain the energy savings over time.

### EUI Target for the Capitol Campus

The primary space usage type on the Capitol Campus is Government Office which has an EUI target of 66. Because of a mix of additional space types, the overall EUI target for the Capitol Campus is 58.

## Senate Bill 5722 (2022)

https://lawfilesext.leg.wa.gov/biennium/2021-22/Pdf/Bills/Senate%20Passed%20Legislature/5722-S.PL.pdf?q=20231228075402

### Summary:

In 2022, this Clean Buildings expansion bill was signed into law. It extended the bill to include smaller buildings so that it would now apply to all buildings over 20,000 square feet. This created a second "Tier" of buildings with a longer timeframe for compliance.

## House Bill 1390 (2023)

https://lawfilesext.leg.wa.gov/biennium/2023-24/Pdf/Bills/House%20Passed%20Legislature/1390-S2.PL.pdf?q=20230511075520

### Summary:

In 2023, the Clean Buildings law was amended to add a new section addressing facilities connected to district energy systems. The bill identified "state-owned district energy systems" and recognized that compliance with the CBPS for these larger systems presents unique opportunities and requires a longer timeline for implementation.

The bill requires owners of publicly-owned district energy systems to develop a decarbonization plan to be implemented over a maximum of 15 years. The decarbonization plan must include:

- Mechanisms to replace fossil fuels in the heating plants, including a schedule for replacement.
- Assessment of options to share nearby waste heat and cooling.
- A strategy to incentivize growth to a decarbonized system and requirements for facilities joining the system.
- Evaluation, prioritization, and scheduled plan for reducing energy use through conservation efforts that meet the campus energy use intensity target.
- Result in a campus that will meet EUI target when fully implemented.

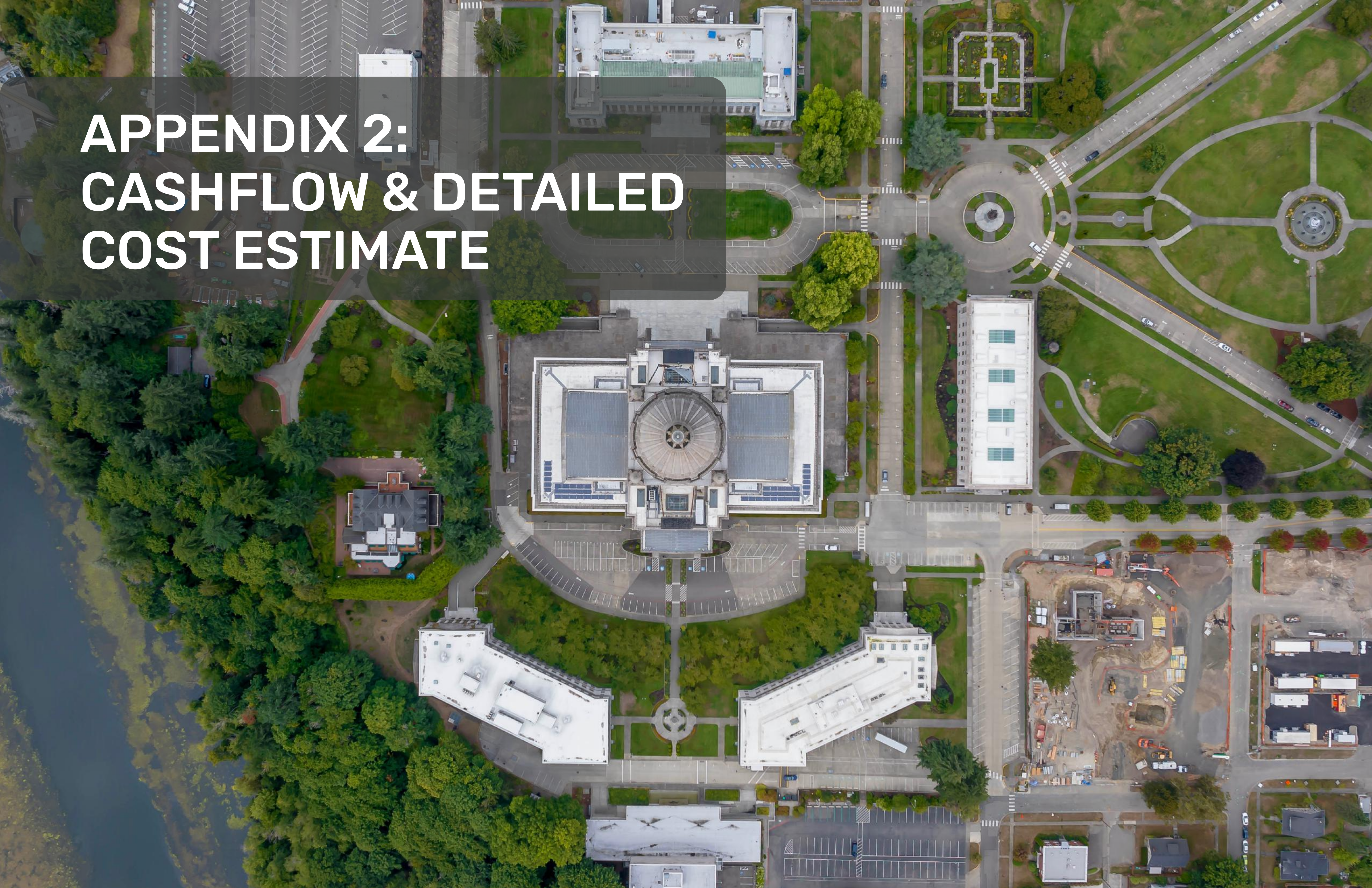
In addition, the plan is encouraged to address:

- Distribution network upgrades.
- On-site energy storage facilities.
- Incorporation of industrial symbiosis projects or networks.

HB 1390 also provided more detail and process around how state-owned district energy systems can comply with the Clean Buildings Performance Standard (HB 1257).

The owner of a state campus district energy system is not required to meet the energy use intensity target for the system or for any of the buildings connected to the system, or conduct an investment-grade audit, to otherwise comply with the state energy performance standard, if the owner of the system:

1. Is implementing, or has fully implemented, an approved decarbonization plan that, when fully implemented, meets the energy use intensity target established for the campus.
2. Meets the other CBPS requirements for benchmarking, energy management, and O&M planning.
3. Submits a request to Commerce once every five years and Commerce approves the request.



# APPENDIX 2: CASHFLOW & DETAILED COST ESTIMATE

# Project Implementation & Utility Cost Savings Cashflow

The following table details the projected capital costs for the design and implementation of each year during the implementation period for the Hybrid Hydronic Heat Pump Plant (Preferred Alternative). This cash flow model corresponds to the design and implementation schedule outlined in Section 10: Decarbonization Plan Implementation.

These values include direct construction costs, indirect costs, and design costs.

The indirect construction costs include:

- Builder's risk contingency
- Builder's fee
- Preconstruction services
- Commissioning
- Sales tax

These costs do not include:

- DES Construction Contingency
- Sales Tax for Owner Construction Contingency
- Agency Project Management
- Historic & Archeological Mitigation
- B&G Support
- Finance
- Signage
- Advertisements
- Badging

The C-100 that follows this Appendix includes all costs listed as excluded above.

| | EXPENDITURES | | | SAVINGS | CASHFLOW | | |
|---|---|---|---|---|---|---|---|
| Year | Design | Construction | Total | Annual Utility Savings | Annual | Present Value[1] | Cumulative Present Value |
| 2025 | $665,087 | $0 | $665,087 | $0 | -$665,087 | -$665,087 | - |
| 2026 | $5,568,092 | $0 | $5,568,092 | $0 | -$5,568,092 | -$5,520,920 | -$6,186,007 |
| 2027 | $1,171,131 | $7,753,255 | $8,924,386 | $0 | -$8,924,386 | -$8,773,815 | -$14,959,822 |
| 2028 | $514,077 | $33,413,759 | $33,927,836 | $131,665 | -$33,796,171 | -$32,944,486 | -$47,904,308 |
| 2029 | $0 | $14,797,010 | $14,797,010 | $186,669 | -$14,610,341 | -$14,121,495 | -$62,025,803 |
| 2030 | $0 | $44,535,734 | $44,535,734 | $203,313 | -$44,332,422 | -$42,486,098 | -$104,511,901 |
| 2031 | $0 | $25,239,372 | $25,239,372 | $245,114 | -$24,994,258 | -$23,750,388 | -$128,262,289 |
| 2032 | $0 | $17,627,654 | $17,627,654 | $399,918 | -$17,227,736 | -$16,231,691 | -$144,493,980 |
| 2033 | $0 | $3,260,250 | $3,260,250 | $507,152 | -$2,753,098 | -$2,571,948 | -$147,065,928 |
| 2034 | $0 | $1,052,106 | $1,052,106 | $628,232 | -$423,875 | -$392,630 | -$147,458,558 |
| 2035 | | | | $759,314 | $759,314 | $697,384 | -$146,761,174 |
| 2036 | | | | $759,314 | $759,314 | $691,476 | -$146,069,698 |
| 2037 | | | | $759,314 | $759,314 | $685,618 | -$145,384,080 |
| 2038 | | | | $759,314 | $759,314 | $679,810 | -$144,704,271 |
| 2039 | | | | $759,314 | $759,314 | $674,050 | -$144,030,220 |
| 2040 | | | | $759,314 | $759,314 | $668,340 | -$143,361,880 |
| | $7,918,386 | $147,679,141 | $155,597,527 | $6,857,945 | -$148,739,582 | -$143,361,880 | |

***Notes:***

[1] Present Value calculations assume a 2.929% inflation and a nominal discount rate of 3.809% per the State of Washington Office of Financial Management's 2025 Life Cycle Cost Model.

**Table A1.1:** Cashflow model.

# Detailed Cost Estimate

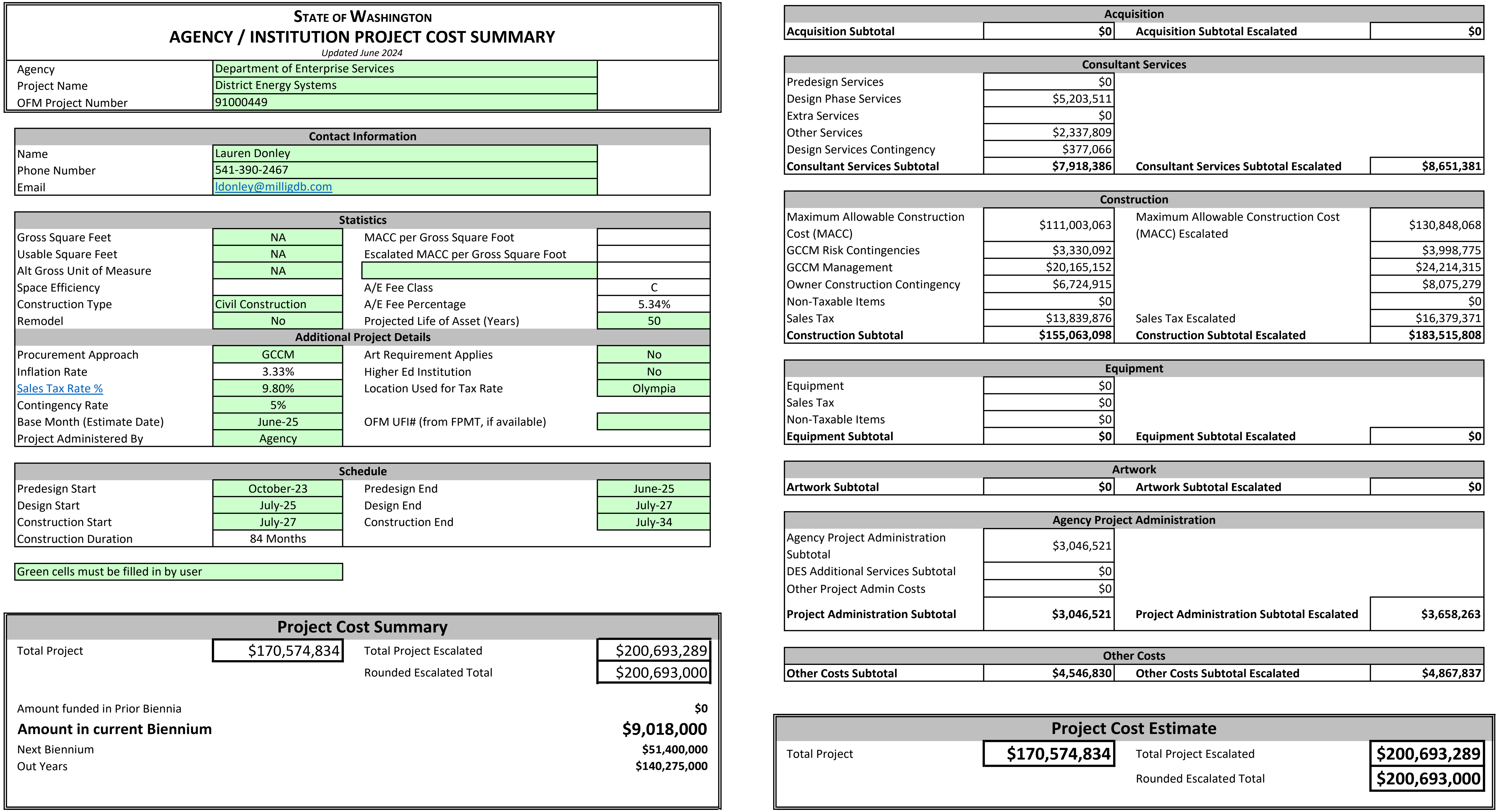
This section details the cost estimate of the Hybrid Hydronic Heat Pump Plant (Preferred Alternative). The first table is an overview of direct construction costs by building, followed by indirect cost totals across all buildings.

The Total Project Cost subtotal of $155,597,526 corresponds to the cost estimates presented in all previous sections of this report. The additional costs unique to the C-100 are itemized at the bottom of this table, with the complete C-100 on the following pages.

**Table A2.1:** Detailed cost estimate.

| Direct Construction Costs | |
|---|---|
| West Campus Central Heat Pump Plant Building | $26,971,752 |
| Geothermal Well Field | $7,461,924 |
| HWY Licensing Building | $8,679,434 |
| East Campus Plant | $6,413,353 |
| Office Building 2 | $12,478,839 |
| Employment Security Building | $4,754,660 |
| Archives Building | $265,826 |
| Temple of Justice | $2,191,705 |
| Legislature | $9,708,406 |
| O'Brien | $3,914,308 |
| Cherberg | $4,116,690 |
| Insurance | $2,881,552 |
| Executive Residence | $330,788 |
| Campus Electrical Infrastructure Upgrades | $11,052,816 |
| General Conditions: | $9,023,637 |
| Permitting | $757,370 |
| **Maximum Allowable Construction Costs:** | **$111,003,062** |
| | |
| **Indirect Construction Costs** | |
| GCCM Risk Contingency | $3,330,092 |
| GCCM Fee | $16,977,350 |
| GCCM Preconstruction Services | $2,008,819 |
| Commissioning | $1,178,983 |
| Sales Tax | $13,180,834 |
| **Subtotal of Indirect Construction Costs:** | **$36,676,078** |
| | |
| **Design Costs** | |
| A/E Basic Design Services | $5,203,511 |
| Bid/Construction/Closeout | $2,337,809 |
| Design Services Contingency | $377,066 |
| **Design Costs Subtotal:** | **$7,918,386** |
| | |
| **Total Project Cost:** | **$155,597,526** |
| | |
| **Costs Excluded in Above Estimate but Included in C-100 Estimate** | |
| The costs above exclude the following: | |
| Owner Construction Contingency | $6,724,915 |
| Sales Tax for Owner Construction Contingency | $659,042 |
| Agency Project Management | $3,046,521 |
| Historic & Archeological Mitigation | $50,000 |
| B&G Support | $1,938,289 |
| Finance | $1,938,289 |
| Signage | $155,063 |
| Advertisements | $310,126 |
| Badging | $155,063 |
| | |
| **C100 Project Total:** | **$170,574,834** |
| **C100 Project Total with Escalation:** | **$200,693,289** |

# C-100 Estimate



STATE OF WASHINGTON
**AGENCY / INSTITUTION PROJECT COST SUMMARY**
*Updated June 2024*

| | |
|---|---|
| Agency | Department of Enterprise Services |
| Project Name | District Energy Systems |
| OFM Project Number | 91000449 |

**Contact Information**

| | |
|---|---|
| Name | Lauren Donley |
| Phone Number | 541-390-2467 |
| Email | ldonley@milligdb.com |

**Statistics**

| | | | |
|---|---|---|---|
| Gross Square Feet | NA | MACC per Gross Square Foot | |
| Usable Square Feet | NA | Escalated MACC per Gross Square Foot | |
| Alt Gross Unit of Measure | NA | | |
| Space Efficiency | | A/E Fee Class | C |
| Construction Type | Civil Construction | A/E Fee Percentage | 5.34% |
| Remodel | No | Projected Life of Asset (Years) | 50 |

**Additional Project Details**

| | | | |
|---|---|---|---|
| Procurement Approach | GCCM | Art Requirement Applies | No |
| Inflation Rate | 3.33% | Higher Ed Institution | No |
| Sales Tax Rate % | 9.80% | Location Used for Tax Rate | Olympia |
| Contingency Rate | 5% | | |
| Base Month (Estimate Date) | June-25 | OFM UFI# (from FPMT, if available) | |
| Project Administered By | Agency | | |

**Schedule**

| | | | |
|---|---|---|---|
| Predesign Start | October-23 | Predesign End | June-25 |
| Design Start | July-25 | Design End | July-27 |
| Construction Start | July-27 | Construction End | July-34 |
| Construction Duration | 84 Months | | |

Green cells must be filled in by user

**Project Cost Summary**

| | | | |
|---|---|---|---|
| Total Project | $170,574,834 | Total Project Escalated | $200,693,289 |
| | | Rounded Escalated Total | $200,693,000 |

| | |
|---|---|
| Amount funded in Prior Biennia | $0 |
| **Amount in current Biennium** | **$9,018,000** |
| Next Biennium | $51,400,000 |
| Out Years | $140,275,000 |

**Acquisition**

| | | | |
|---|---|---|---|
| **Acquisition Subtotal** | **$0** | **Acquisition Subtotal Escalated** | **$0** |

**Consultant Services**

| | | | |
|---|---|---|---|
| Predesign Services | $0 | | |
| Design Phase Services | $5,203,511 | | |
| Extra Services | $0 | | |
| Other Services | $2,337,809 | | |
| Design Services Contingency | $377,066 | | |
| **Consultant Services Subtotal** | **$7,918,386** | **Consultant Services Subtotal Escalated** | **$8,651,381** |

**Construction**

| | | | |
|---|---|---|---|
| Maximum Allowable Construction Cost (MACC) | $111,003,063 | Maximum Allowable Construction Cost (MACC) Escalated | $130,848,068 |
| GCCM Risk Contingencies | $3,330,092 | | $3,998,775 |
| GCCM Management | $20,165,152 | | $24,214,315 |
| Owner Construction Contingency | $6,724,915 | | $8,075,279 |
| Non-Taxable Items | $0 | | $0 |
| Sales Tax | $13,839,876 | Sales Tax Escalated | $16,379,371 |
| **Construction Subtotal** | **$155,063,098** | **Construction Subtotal Escalated** | **$183,515,808** |

**Equipment**

| | | | |
|---|---|---|---|
| Equipment | $0 | | |
| Sales Tax | $0 | | |
| Non-Taxable Items | $0 | | |
| **Equipment Subtotal** | **$0** | **Equipment Subtotal Escalated** | **$0** |

**Artwork**

| | | | |
|---|---|---|---|
| **Artwork Subtotal** | **$0** | **Artwork Subtotal Escalated** | **$0** |

**Agency Project Administration**

| | | | |
|---|---|---|---|
| Agency Project Administration Subtotal | $3,046,521 | | |
| DES Additional Services Subtotal | $0 | | |
| Other Project Admin Costs | $0 | | |
| **Project Administration Subtotal** | **$3,046,521** | **Project Administration Subtotal Escalated** | **$3,658,263** |

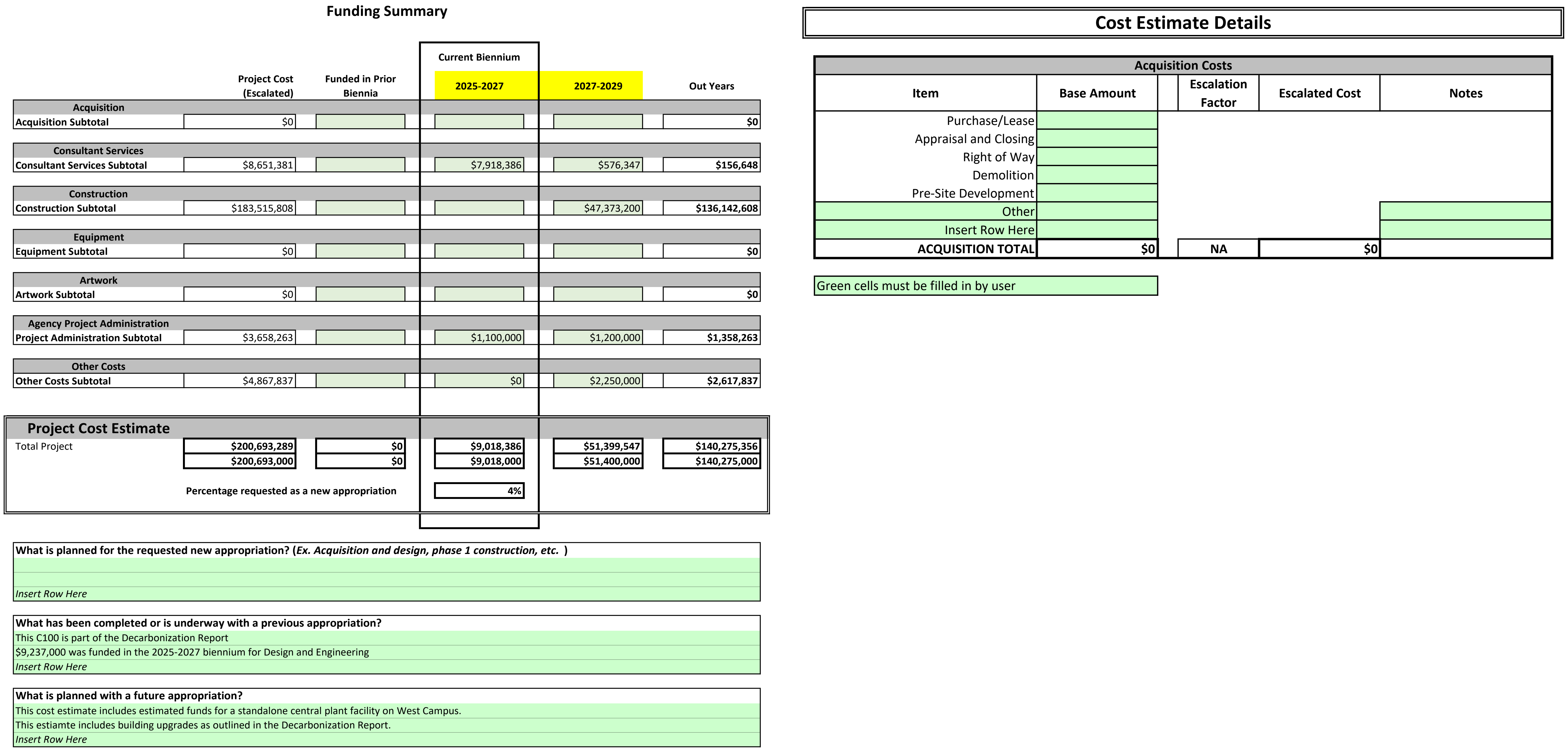
**Other Costs**

| | | | |
|---|---|---|---|
| **Other Costs Subtotal** | **$4,546,830** | **Other Costs Subtotal Escalated** | **$4,867,837** |

**Project Cost Estimate**

| | | | |
|---|---|---|---|
| Total Project | $170,574,834 | Total Project Escalated | $200,693,289 |
| | | Rounded Escalated Total | $200,693,000 |

**Table A2.2:** Project cost summary.



## Funding Summary

| | Project Cost (Escalated) | Funded in Prior Biennia | Current Biennium 2025-2027 | 2027-2029 | Out Years |
|---|---|---|---|---|---|
| **Acquisition** | | | | | |
| Acquisition Subtotal | $0 | | | | $0 |
| **Consultant Services** | | | | | |
| Consultant Services Subtotal | $8,651,381 | | $7,918,386 | $576,347 | $156,648 |
| **Construction** | | | | | |
| Construction Subtotal | $183,515,808 | | | $47,373,200 | $136,142,608 |
| **Equipment** | | | | | |
| Equipment Subtotal | $0 | | | | $0 |
| **Artwork** | | | | | |
| Artwork Subtotal | $0 | | | | $0 |
| **Agency Project Administration** | | | | | |
| Project Administration Subtotal | $3,658,263 | | $1,100,000 | $1,200,000 | $1,358,263 |
| **Other Costs** | | | | | |
| Other Costs Subtotal | $4,867,837 | | $0 | $2,250,000 | $2,617,837 |
| **Project Cost Estimate** | | | | | |
| Total Project | $200,693,289 | $0 | $9,018,386 | $51,399,547 | $140,275,356 |
| | $200,693,000 | $0 | $9,018,000 | $51,400,000 | $140,275,000 |
| | Percentage requested as a new appropriation | | 4% | | |

**What is planned for the requested new appropriation? (*Ex. Acquisition and design, phase 1 construction, etc.* )**

*Insert Row Here*

**What has been completed or is underway with a previous appropriation?**

This C100 is part of the Decarbonization Report

$9,237,000 was funded in the 2025-2027 biennium for Design and Engineering

*Insert Row Here*

**What is planned with a future appropriation?**

This cost estimate includes estimated funds for a standalone central plant facility on West Campus.

This estiamte includes building upgrades as outlined in the Decarbonization Report.

*Insert Row Here*

## Cost Estimate Details

| Acquisition Costs | | | | |
|---|---|---|---|---|
| **Item** | **Base Amount** | **Escalation Factor** | **Escalated Cost** | **Notes** |
| Purchase/Lease | | | | |
| Appraisal and Closing | | | | |
| Right of Way | | | | |
| Demolition | | | | |
| Pre-Site Development | | | | |
| Other | | | | |
| Insert Row Here | | | | |
| **ACQUISITION TOTAL** | **$0** | **NA** | **$0** | |

Green cells must be filled in by user

**Table A2.2:** Project cost summary (continued).

JUMP TO TABLE OF CONTENTS

## Cost Estimate Details

| Item | Base Amount | | Escalation Factor | Escalated Cost | Notes |
|---|---|---|---|---|---|
| **Consultant Services** | | | | | |
| **1) Pre-Schematic Design Services** | | | | | |
| Programming/Site Analysis | | | | | |
| Environmental Analysis | | | | | |
| Predesign Study | | | | | |
| Other | | | | | |
| Insert Row Here | | | | | |
| **Sub TOTAL** | **$0** | | **1.0027** | **$0** | Escalated to Design Start |
| **2) Construction Documents** | | | | | |
| **A/E Basic Design Services** | $5,203,511 | | | | 69% of A/E Basic Services |
| Other | | | | | |
| Insert Row Here | | | | | |
| **Sub TOTAL** | **$5,203,511** | | **1.0361** | **$5,391,358** | Escalated to Mid-Design |
| **3) Extra Services** | | | | | |
| Civil Design (Above Basic Svcs) | | | | | |
| Geotechnical Investigation | | | | | |
| Commissioning | | | | | |
| Site Survey | | | | | |
| Testing | | | | | |
| LEED Services | | | | | |
| Voice/Data Consultant | | | | | |
| Value Engineering | | | | | |
| Constructability Review | | | | | |
| Environmental Mitigation (EIS) | | | | | |
| Landscape Consultant | | | | | |
| Other | | | | | |
| Insert Row Here | | | | | |
| **Sub TOTAL** | **$0** | | **1.0361** | **$0** | Escalated to Mid-Design |
| **4) Other Services** | | | | | |
| **Bid/Construction/Closeout** | $2,337,809 | | | | 31% of A/E Basic Services |
| HVAC Balancing | | | | | |
| Staffing | | | | | |
| Other | | | | | |
| Insert Row Here | | | | | |
| **Sub TOTAL** | **$2,337,809** | | **1.2008** | **$2,807,242** | Escalated to Mid-Const. |
| **5) Design Services Contingency** | | | | | |
| Design Services Contingency | $377,066 | | | | |
| Other | | | | | |
| Insert Row Here | | | | | |
| **Sub TOTAL** | **$377,066** | | **1.2008** | **$452,781** | Escalated to Mid-Const. |
| **CONSULTANT SERVICES TOTAL** | **$7,918,386** | | | **$8,651,381** | |

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## Cost Estimate Details

| Item | Base Amount | | Escalation Factor | Escalated Cost | Notes |
|---|---|---|---|---|---|
| **Construction Contracts** | | | | | |
| **1) Site Work** | | | | | |
| G10 - Site Preparation | $259,533 | | | | |
| G20 - Site Improvements | $370,268 | | | | |
| G30 - Site Mechanical Utilities | $7,091,658 | | | | |
| G40 - Site Electrical Utilities | $11,052,817 | | | | |
| G60 - Other Site Construction | | | | | |
| Other | | | | | |
| Insert Row Here | | | | | |
| **Sub TOTAL** | **$18,774,276** | | **1.0706** | **$20,099,740** | |
| **2) Related Project Costs** | | | | | |
| Offsite Improvements | | | | | |
| City Utilities Relocation | | | | | |
| Parking Mitigation | | | | | |
| Stormwater Retention/Detention | | | | | |
| Other | | | | | |
| Insert Row Here | | | | | |
| **Sub TOTAL** | **$0** | | **1.0706** | **$0** | |
| **3) Facility Construction** | | | | | |
| A10 - Foundations | $782,655 | | | | |
| A20 - Basement Construction | | | | | |
| B10 - Superstructure | $5,869,913 | | | | |
| B20 - Exterior Closure | $143,548 | | | | |
| B30 - Roofing | $586,991 | | | | |
| C10 - Interior Construction | $5,087,258 | | | | |
| C20 - Stairs | | | | | |
| C30 - Interior Finishes | $415,786 | | | | |
| D10 - Conveying | $489,159 | | | | |
| D20 - Plumbing Systems | $1,643,895 | | | | |
| D30 - HVAC Systems | $55,949,689 | | | | |
| D40 - Fire Protection Systems | $586,991 | | | | |
| D50 - Electrical Systems | $10,891,895 | | | | |
| F10 - Special Construction | | | | | |
| F20 - Selective Demolition | | | | | |
| General Conditions | $9,023,637 | | | | |
| Permits | $757,370 | | | | |
| Insert Row Here | | | | | |
| **Sub TOTAL** | **$92,228,787** | | **1.2008** | **$110,748,328** | |
| **4) Maximum Allowable Construction Cost** | | | | | |
| **MACC Sub TOTAL** | **$111,003,063** | | | **$130,848,068** | |
| | *NA* | | | *NA* | *per GSF* |

**Table A2.2:** Project cost summary (continued).

| | | | | |
|---|---|---|---|---|
| **5a) GCCM Risk Contingency** | | | | |
| GCCM Risk Contingency | $3,330,092 | | | |
| Other | | | | |
| Insert Row Here | | | | |
| **Sub TOTAL** | **$3,330,092** | **1.2008** | **$3,998,775** | |
| **5b) GCCM Costs** | | | | |
| GCCM Fee | $16,977,350 | | | |
| Bid General Conditions | | | | |
| GCCM Preconstruction Services | $2,008,819 | | | |
| Commissioning | $1,178,983 | | | |
| Insert Row Here | | | | |
| **Sub TOTAL** | **$20,165,152** | **1.2008** | **$24,214,315** | |
| **6) Total Cost of Construction (TCC)** | | | | |
| **TCC Sub TOTAL** | **$134,498,307** | | **$159,061,158** | |
| | *NA* | | *NA per 0* | |
| **7) Owner Construction Contingency** | | | | |
| Allowance for Change Orders | $6,724,915 | | | |
| Other | | | | |
| Insert Row Here | | | | |
| **Sub TOTAL** | **$6,724,915** | **1.2008** | **$8,075,279** | |
| **8) Non-Taxable Items** | | | | |
| Other | | | | |
| Insert Row Here | | | | |
| **Sub TOTAL** | **$0** | **1.2008** | **$0** | |
| **9) Sales Tax** | | | | |
| **Sub TOTAL** | **$13,839,876** | | **$16,379,371** | |
| **CONSTRUCTION CONTRACTS TOTAL** | **$155,063,098** | | **$183,515,808** | |

Green cells must be filled in by user

**Table A2.2:** Project cost summary (continued).

## Cost Estimate Details

| **Equipment** | | | | |
|---|---|---|---|---|
| **Item** | **Base Amount** | **Escalation Factor** | **Escalated Cost** | **Notes** |
| **1) Equipment** | | | | |
| E10 - Equipment | | | | |
| E20 - Furnishings | | | | |
| F10 - Special Construction | | | | |
| Other | | | | |
| Insert Row Here | | | | |
| **Sub TOTAL** | **$0** | **1.1431** | **$0** | |
| **2) Non Taxable Items** | | | | |
| Other | | | | |
| Insert Row Here | | | | |
| **Sub TOTAL** | **$0** | **1.1431** | **$0** | |
| **3) Sales Tax** | | | | |
| **Sub TOTAL** | **$0** | | **$0** | |
| **EQUIPMENT TOTAL** | **$0** | | **$0** | |

Green cells must be filled in by user

## Cost Estimate Details

| **Artwork** | | | | |
|---|---|---|---|---|
| **Item** | **Base Amount** | **Escalation Factor** | **Escalated Cost** | **Notes** |
| **1) Artwork** | | | | |
| Project Artwork | $0 | | | 0.5% of total project cost for new construction |
| Higher Ed Artwork | $0 | | | 0.5% of total project cost for new and renewal construction |
| Other | | | | |
| Insert Row Here | | | | |
| **ARTWORK TOTAL** | **$0** | **NA** | **$0** | |

Green cells must be filled in by user

## Cost Estimate Details

| Project Management | | | | | |
|---|---|---|---|---|---|
| **Item** | **Base Amount** | | **Escalation Factor** | **Escalated Cost** | **Notes** |
| **1) Agency Project Management** | | | | | |
| Agency Project Management | $3,046,521 | | | | |
| Additional Services | | | | | |
| Other | | | | | |
| Insert Row Here | | | | | |
| *Subtotal of Other* | *$0* | | | | |
| **PROJECT MANAGEMENT TOTAL** | **$3,046,521** | | **1.2008** | **$3,658,263** | |

Green cells must be filled in by user

## Cost Estimate Details

| Other Costs | | | | | |
|---|---|---|---|---|---|
| **Item** | **Base Amount** | | **Escalation Factor** | **Escalated Cost** | **Notes** |
| Mitigation Costs | | | | | |
| Hazardous Material Remediation/Removal | | | | | |
| Historic and Archeological Mitigation | $50,000 | | | | |
| Other | | | | | |
| B&G Support | $1,938,289 | | | | |
| Finance | $1,938,289 | | | | |
| Signange | $155,063 | | | | |
| Advertisments | $310,126 | | | | |
| Badging | $155,063 | | | | |
| **OTHER COSTS TOTAL** | **$4,546,830** | | **1.0706** | **$4,867,837** | |

Green cells must be filled in by user

**Table A2.2:** Project cost summary (continued).

## C-100(2024)
## Additional Notes

**Tab A. Acquisition**

*Insert Row Here*

**Tab B. Consultant Services**

$9,237,000 was funded in the 2025-2027 biennium for Design and Engineering.

*Insert Row Here*

**Tab C. Construction Contracts**

*Insert Row Here*

**Tab D. Equipment**

*Insert Row Here*

**Tab E. Artwork**

*Insert Row Here*

**Tab F. Project Management**

*Insert Row Here*

**Tab G. Other Costs**

*Insert Row Here*

Attributions
Hold for names

DES
Washington State
DEPARTMENT OF
ENTERPRISE SERVICES

millig
DESIGN BUILD