WASTE HEAT TO WARM CITIES - USING MICRO-DATA CENTERS TO DECARBONIZE SEATTLE

Students: Tanner Rapp[1], Eliza Ballentine[1], Gavin Harris[1], Lina Tran[2], Mia Conner[2]

[1]UW Department of Mechanical Engineering

[2]UW Department of Electrical and Computer Engineering

McKinstry® For The Life Of Your Building

Project Genesis & Goals

Core Question: Can a micro-data center placed in vacant office space **decarbonize** building heating, help achieve **BEPS compliance**, and help address **downtown vacancy** while generating revenue for building owners?

Project Motivations:

- **High Vacancy - 35.6%** of commercial office space in downtown Seattle is vacant
- **Emissions** - Buildings are a top decarbonization target as large contributors to global greenhouse gas emissions
- **Seattle Building Emissions Performance Standards (BEPS)** - Requires GHG emission cuts by 2031 & 2036 & net zero emissions by 2041 for commercial buildings.
- Heating-Dominant Climate - Seattle's older buildings often use **fossil-fuel derived space heating**.
- Current Building Trends - The project's existing systems rely on district steam and **do not meet the BEPS targets**, making it a candidate for a low-carbon retrofit.
- **Decarbonization through electrification** - 75% of Washington state's electricity is from renewable sources, offering much 'cleaner' heating than district steam
- **Micro-data Center Opportunity** - Great quantities of waste heat may be recovered for central heating.

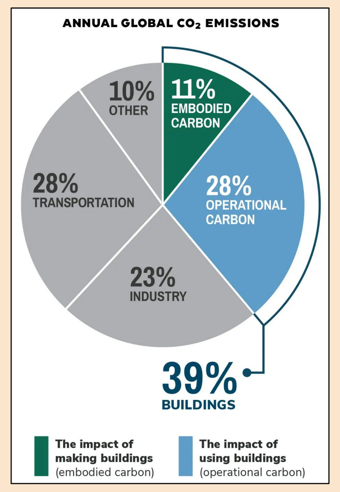
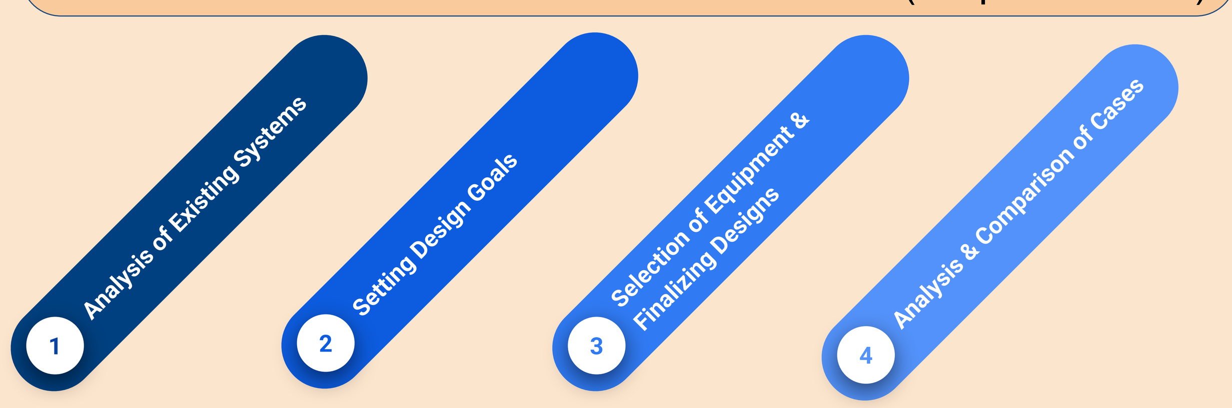


Figure 1: World Green Building Council - Global Status Report 2017

Project Scope: This study evaluates two pathways of replacing district steam with low carbon electricity based heating systems.

- **Typical electrification system** (Baseline Case)
- **Recoverable Heat from Micro-Data Center** (Proposed Case)



Initial Analyses

The building's **carbon emissions** are the primary **barrier to BEPS compliance**.

- **Current Emissions** - The building emits **well above BEPS limit**
- **Steam is the Issue** - Low energy intensity contribution, yet **largest contributor to building carbon emissions**

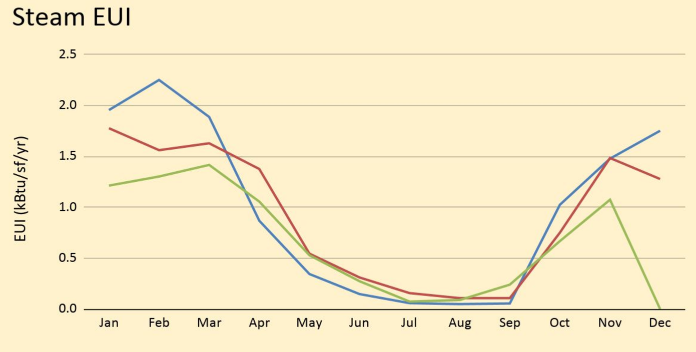


Figure 2: Building EUI From Steam Usage

Building Average Emissions

Note steam contribution disparity vs. in Figure 13

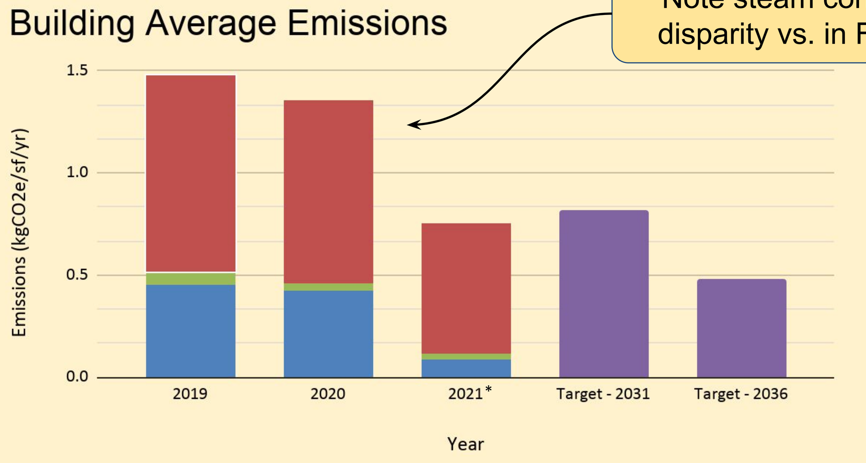


Figure 3: Total Building Emissions Graph From Building Utility Data

***Important Note:** Electrification is a great way to reduce emissions in Seattle since so much of the city's electricity comes from renewable sources*

*Note: Data from 2021 is not necessarily representative of actual building performance due to missing data and possibly COVID lockdowns

Existing Systems

Hydronic Loops: Building has 3 hydronic loops serving mechanical equipment which provide heating and cooling to the building.

Heating Hot Water (HHW)

- Primary heating provided by HRC
- Secondary heating provided by district steam through heat exchangers

Condensing Water (CW)

- Allows HRCs to reject heat from CHW loop to the atmosphere when the heating load is already satisfied

Chilled Water (CHW)

- Chilled primarily by HRCs
- Supply cooling to CRAH units

Building's Annual Cooling and Heating Load from Energy Model

Peak Loads — Existing Building Loads

- **Cooling** - 'Worst Day' 8000 kBtu
- **Heating** - 'Worst Day' 6500 kBtu

Potential data center —

- 24/7 cooling increases HRC primary heating capabilities

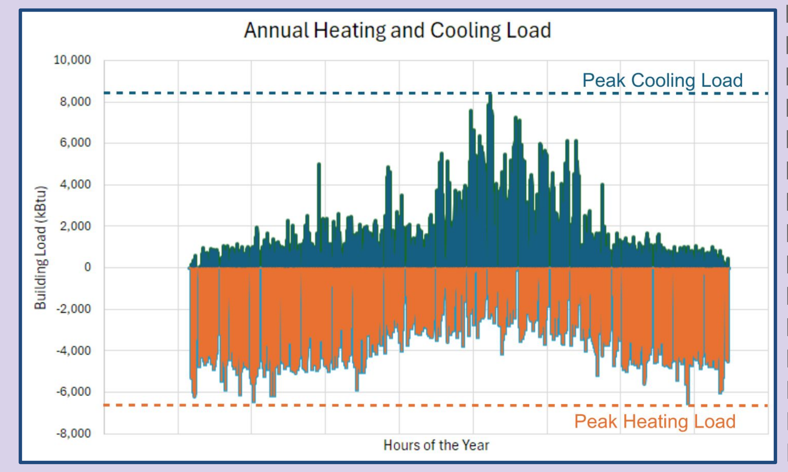


Figure 4: One Year of Energy Model Building Heating and Cooling Loads

Total HRC Cooling Capacity

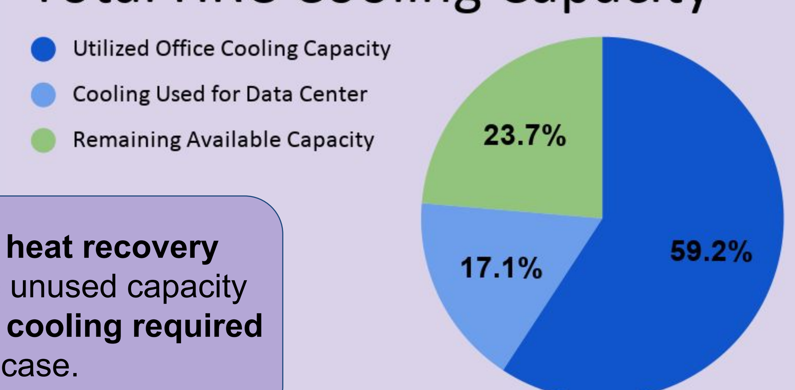


Figure 5: Heat Recovery Chiller Capacity Breakdown

The two high performance **heat recovery chillers (HRCs)** have ample unused capacity with room for the **200 tons of cooling required** by our proposed case.

Building Power Snapshot:

- Current Capacity: 13,302 kVA
- Peak Demand: 2,541 kVA is ~19% of capacity
- Remaining Service Capacity Available: 10,761 kVA

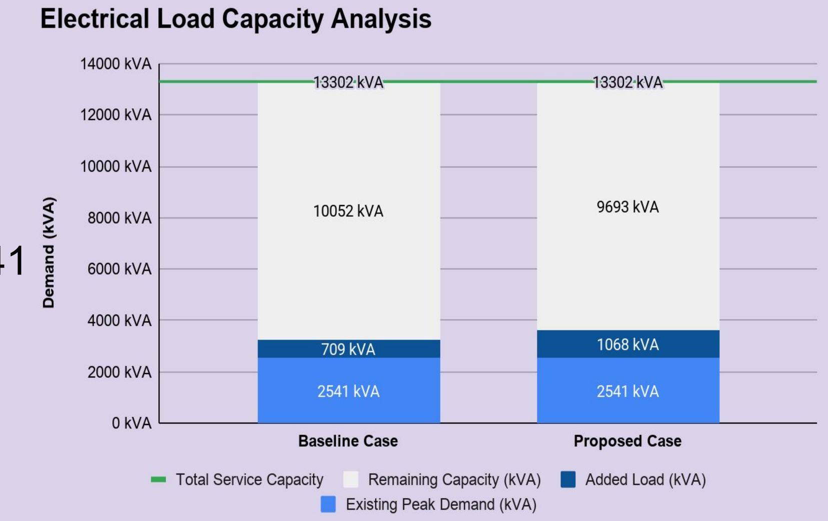


Figure 6: Electrical Capacity Analysis

Baseline Electrification Case

Primary	Air to Water Heat Pump (AWHP)	• Covers 73.1% of peak heating load • Covers full heating for most of the year • Supplemented by existing HRC heat • Year round efficiency in Seattle's mild climate
Secondary/ Backup	Condensing Fired Gas Boiler	• Up to 48% peak capacity - high redundancy • Reserved for cold weather peaks • Oversized to balance reduced AWHP performance at freezing air temperatures

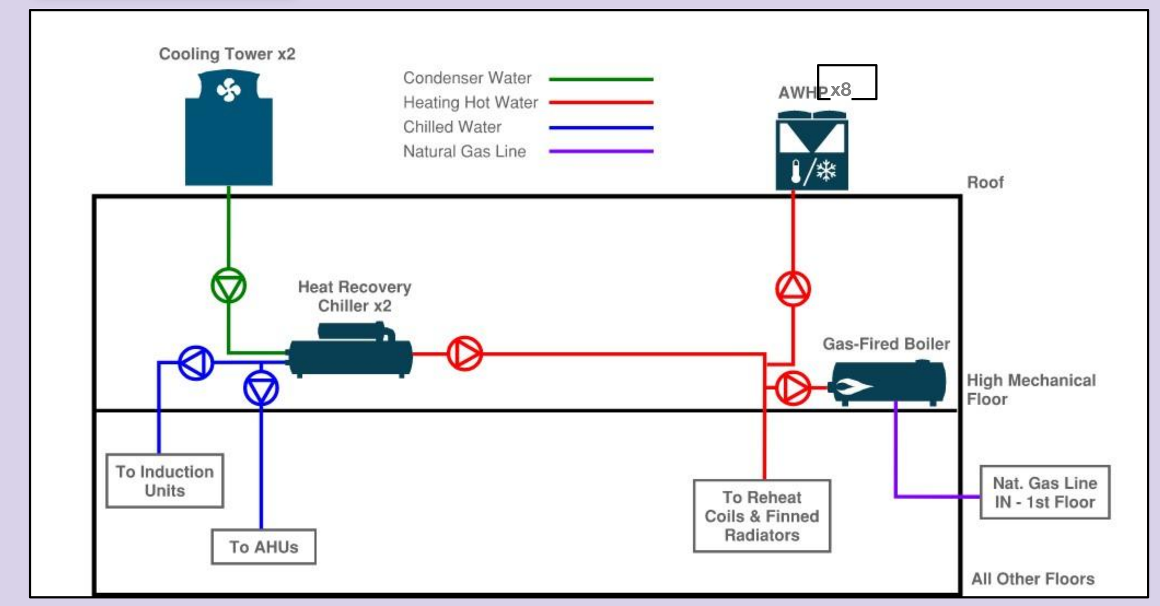


Figure 7: Simplified Diagram of Building Systems for Baseline Case

Baseline Maximum Heating Capacity Contribution by Component

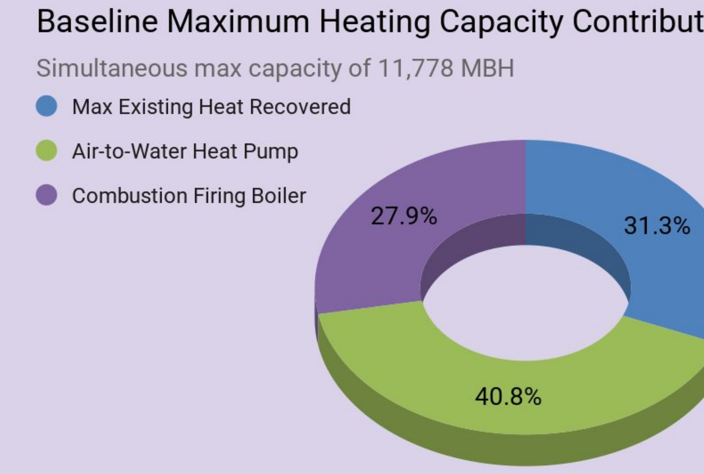


Figure 8: Baseline Case Heating Capacity Distribution

Electrical Capacity

- Building supports added **709 kVA** load without a requirement for service upgrades
- Existing distribution equipment insufficient to serve new mechanical loads
- Require a **new 480V/3, 1200 A panel** for AWHP equipment load

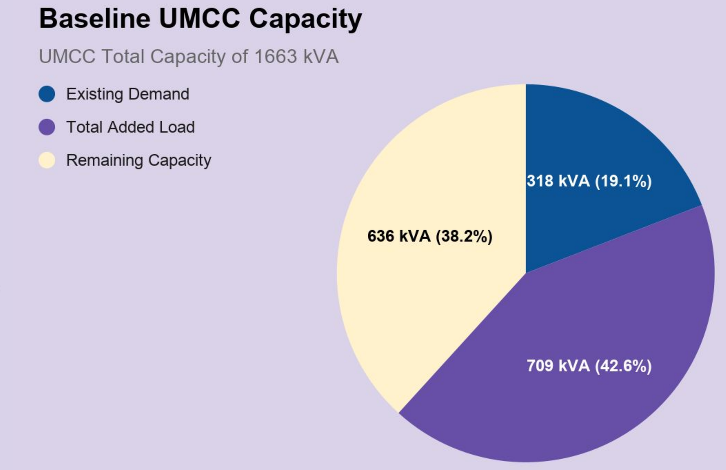


Figure 9: Baseline Case Panel Capacities

Proposed Data Center Case

Primary	Data Center Waste Heat	• HRCs can recover up to 46% of peak heating load or 250 tons 24/7 • Covers full heating for 78.9% of the year • Supplemented by existing HRC heat
Secondary	Air to Water Heat Pump (AWHP)	• Up to 27% peak heating load • Year round efficiency in Seattle's mild climate • Reduced performance at freezing air temperatures
Backup	Condensing Fired Gas Boiler	• Up to 22% peak capacity - medium redundancy • Reserved for cold weather peaks or equipment maintenance

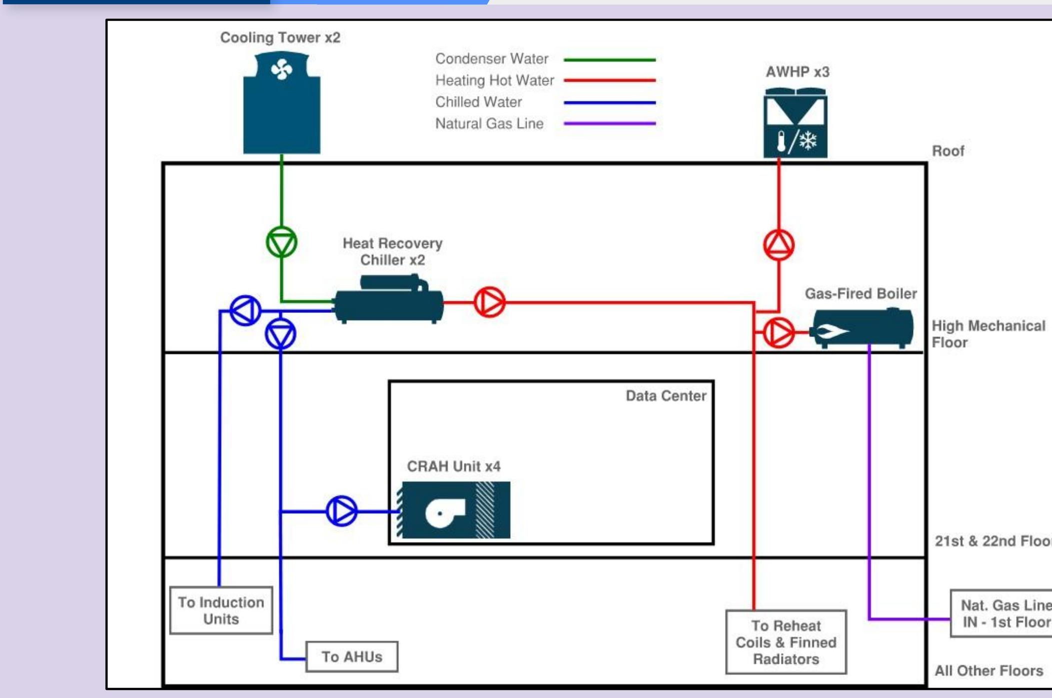


Figure 10: Simplified Diagram of Building Systems for Proposed Case

Proposed Maximum Heating Capacity Contribution by Component

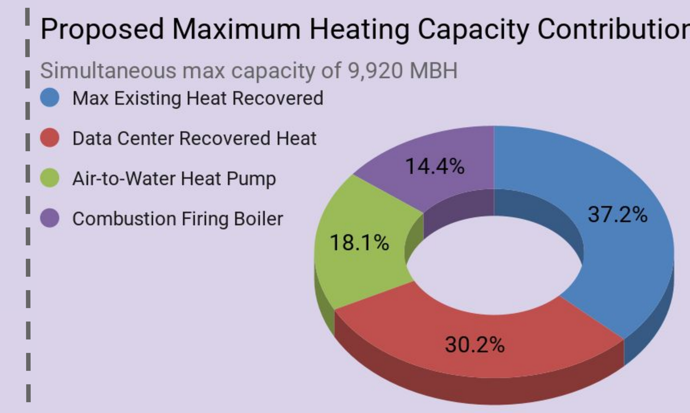


Figure 11: Proposed Case Heating Capacity Distribution

Proposed Panel Capacities

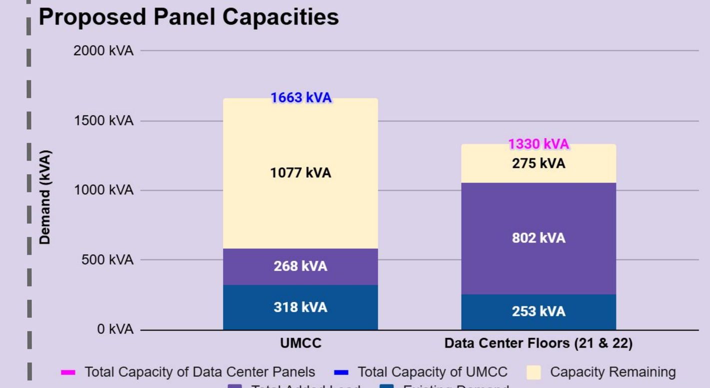


Figure 12: Proposed Case Panel Capacities

Electrical Capacity

- Building supports proposed added load without a requirement for service upgrades
- Existing distribution equipment insufficient to serve new data center and mechanical loads
- Require **four 225 A and two 800 A, 480V/3 new panels** for data center loads
- Require a **new 480V/3, 800 A panel** for AWHP equipment load
- Standby generator needed to backup data center and cooling equipment

Key Findings

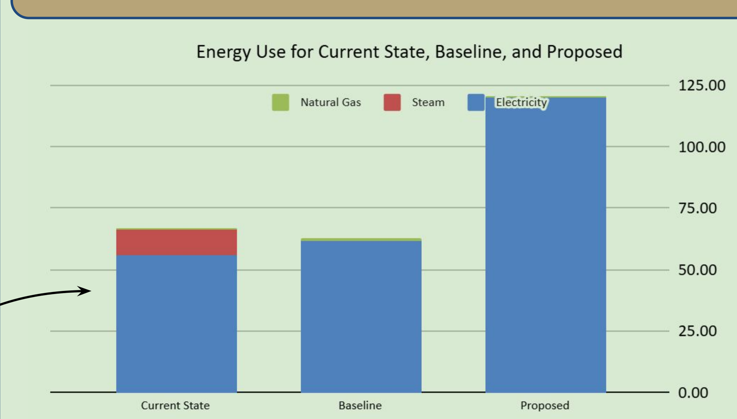


Figure 13: Projected EUIs for Each Case

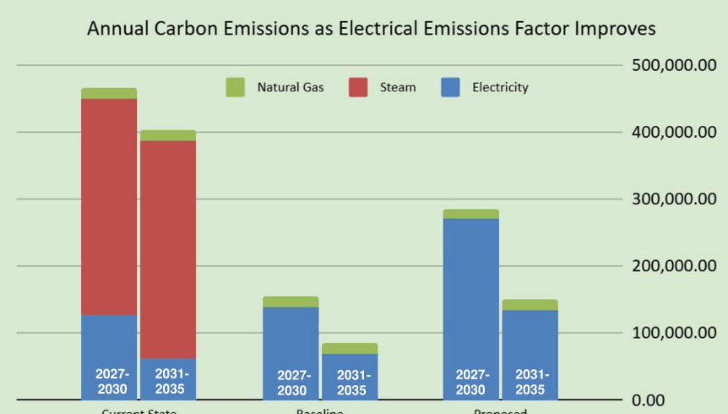


Figure 14: Projected Emissions for Each Case

CASE SELECTION CRITERIA	CURRENT STATE	BASELINE CASE	PROPOSED CASE
ADAPTABILITY	—	**HIGH** - Large equipment installations in the highest part of the building, housed in close proximity to central hydronic loops as to minimize additional piping.	**MEDIUM** - Large equipment installations throughout the building, with more complex data center design and installation ahead.
FIRST COST	—	$ $ $ $ $	$ $ $ $ $
15 YEAR LIFECYCLE COST	$ $ $ $ $	$ $ $ $ $	$ $ $ $ $
CARBON SAVINGS	CO_2 CO_2 CO_2 CO_2 CO_2	CO_2 CO_2 CO_2 CO_2 CO_2	CO_2 CO_2 CO_2 CO_2 CO_2
RESILIENCY / REDUNDANCY	🔧🔧🔧🔧🔧	🔧🔧🔧🔧🔧	🔧🔧🔧🔧🔧
BEPS COMPLIANCE	✗	✓	✓
ADVANTAGES	• No immediate expenditures or new construction	• Less equipment to install • Greatest GHG Emission Reduction • Lowest energy intensity	• Turns high vacancy rate into opportunity • Saves ~$8M over current state in 15 year life cycle
DISADVANTAGES	• Charged $3,876,550 non- compliance penalty every 5 years until BEPS targets are met. • Cheaper than baseline electrification	• Costs ~$1.5M more than the current state • Greater risk of structural issues with roof installation	• Highest energy intensity • Greatest initial investment • Slower to reduce emissions than baseline

RECOMMENDED

Recommendations and Next Steps

The **Proposed Data Center Heat Recovery case** appears the most viable

- **Financial viability** - Highest upfront investment, but total cost over the lifecycle is the lowest for the building owner.
- **Emissions reduction** - Moving away from gas-fired steam significantly cuts carbon emissions.
- **Energy savings** - Proposed system provides space-heating energy savings through added heat recovery, resulting in a much more efficient system than before.
- Vacancy issues in Seattle for property owners are remedied by providing new tenant revenue streams from data center operation.

Further Steps:

- Outside the scope of this project is a full design & study to validate performance, refine sizing, and confirm feasibility as a long-term decarbonization strategy.

Acknowledgements

The UW team gives special thanks to our clients from McKinstry: Claire Puryear, Mimi Petersen, Caroline Traube, and others at McKinstry that helped us with our project along the way.

We also give thanks to Scott Rushing and Sirine Maalej, our faculty advisors from the Mechanical Engineering Department at UW.