ATTACHMENT 1

Report on Alternatives for Heating and Cooling the CFJC

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King County

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SECTION 1 – EXECUTIVE SUMMARY

General

The purpose of this report is to discuss the options that have been considered for the heating and cooling systems of the new King County Child and Family Justice Center (CFJC). The report includes information about the different systems that have been considered and a summarized version of the analyses performed for some of these systems. This report is intended to meet the requirements of 2012 King County Ordinance 17304, Section 8 Energy Efficiency.

The various building heating and cooling systems discussed in this report are a combination of those required by the contract documents to be considered for this building, as well as some other alternatives that were suggested by the Design-Build team and additional systems that were requested for consideration at the CFJC Eco Charrette, held on April 23, 2015 and attended by both the Design-Build team and representatives from various departments at King County.

HVAC

There are 11 different mechanical system alternatives discussed in this report. After preliminary consideration by the design-build team, 7 of these systems were found to be feasible for analysis for this report. Each of those systems were modeled in a full year building energy simulation to evaluate the cost and energy use impacts for using these different alternatives in the CFJC, while meeting the energy efficiency requirements of the project to provide a system that requires 26% less energy than a LEED baseline building.

The 7 systems that were modeled for full analysis are:

1. Proposed System - Combination Central Plant with Geothermal Wells and Standard Capacity Chillers and Boilers for Peak Loads
2. High Efficiency Water Cooled Chillers
3. High Efficiency Boilers
4. Active Chilled Beam System
5. Passive Chilled Beam and Perimeter Radiant Heat
6. 100% Ground Source Capacity
7. Purchased Steam Peak Heating and DHW for Peak Loads

The 5 systems found not to be feasible for further analysis are:

1. Raised Underfloor Air Distribution
2. All Electric Heating - Variable Flow Refrigerant (VRF), Water Source Heat Pumps
3. Sewer Heat Recovery
4. Thermal Storage

These 5 systems were found to be not practical for the project due to non-energy and ELCCA reasons (unacceptable security impacts, catastrophic cost impacts, etc.), with the results of ELCCA analysis not being impactful to those conslusions.

Energy Use Intensity (EUI) and Energy Cost Index (ECI)

The Energy Use Intensity and Energy Cost Index (EUI and ECI) are measures of a building's annual energy use as a function of the building size. EUI indicates the annual kBtus of energy use for a building, divided by the square footage of that building, while ECI is the annual energy costs in dollars, divided by the square footage of the building. These numbers allow for a quick and high level comparison of building efficiency with other buildings of the same function. Based on the current square footage of the courthouse and detention of 208,000 sf, preliminary analysis shows that the building will have an EUI of 31.4 and an ECI of $0.84 when served by the proposed mechanical system. When served by the other alternative systems, the EUI would range between 28.8 – 33.2, while the ECI would range between $0.80 – $0.88.

Alternative Cost Summary

Each mechanical system alternative was evaluated based on a life cycle cost analysis that included first cost, mechanical operating costs, maintenance costs, and equipment replacement costs. Based on this life cycle cost analysis of the different mechanical systems, it is clear the proposed mechanical system will have the lowest overall cost over the life of the building.

The following table summarizes the life cycle cost analysis for a 15 year period.

Life Cycle Cost Comparison - 15 Year LCCA

	First Costs - Mechanical System Addition($)	Annual Mechanical Operating Costs - Difference($)	Annual Maintence Costs - Difference($)	Additional Replacement Costs 15 Year LCCA (Year)	Net Present Value (NPV - 15 Years)	Simple Payback Period
1. Proposed System	-	-	-	-	-	-
2. High Efficiency Chillers	$392,000	-$1,496	$27,000	N/A	-$636,251	N/A
3. High Efficiency Boilers	$133,500	-$492	$12,000	N/A	-$268,399	N/A
4. Active Chilled Beams	$2,943,000	$10,119	$6,000	N/A	-$2,869,976	>500 Yrs
5. Passive Chilled Beams	$3,875,000	$3,513	$6,000	N/A	-$3,736,520	>300 Yrs
6. 100% Ground Source	$1,905,000	-$7,163	$4,000	N/A	-$1,629,890	>80 Yrs
7. Purchased Steam Peak	$141,000	$3,159	$1,200	N/A	-$202,244	N/A

From the Net Present Value and Simple Payback Period values listed, it is clear that none of the system alternatives provide a positive return on investment when compared with the proposed system. Refer to Section 5 for additional discussion and evaluation of Life Cycle Cost findings.

Greenhouse Gas Emissions

The greenhouse gas emissions for all of the systems analyzed were far below the median emissions for comparable existing buildings. Using the proposed mechanical system, preliminary analysis shows that the building will release 97.5% less GHG emissions than a comparable existing building. Using the Energy Star Target Finder program, a comparable existing building generates 1,934 Metric Tons CO2e per year (see Appendix E). The proposed building is estimated to provide an annual reduction of 1,888 Metric Tons CO2e. This reduction is roughly equivalent to 397 passenger cars being removed from the road.

This reduction is due to two primary factors - emphasis on electricity as the source for the heating system over natural gas or other combustible fuel sources, and hydroelectric power from Seattle City Light.

While not included in the base price for the project, if the County is interested in reducing GHG more than what is currently proposed, the county could consider implementing alternatives identified in this report not currently planned for implementation. It should be noted that this would be at additional cost to the project.

Following is a summary of GHG emission estimates for the proposed system, the alternative systems, and for a comparable existing building:

System Type	MTCO2e
1. Proposed System	46
2. High Efficiency Chillers	46
3. High Efficiency Chillers	44
4. Active Chilled Beams	48
5. Passive Chilled Beams	47
6. 100% Thermal Wells	23
7. Purchased Steam	49
Comparable Existing Building (Energy Star)	1,934

Seattle 2030 District

The Seattle 2030 district is part of the 2030 Districts program, and is a plan to reduce environmental impacts from the new and existing buildings in Seattle. King County is a member of the Seattle 2030 District, and has committed to specific energy, emissions and water use goals as outlined by the program. The annual energy use in the new CFJC building, using the proposed mechanical system, falls within the thresholds of energy reduction goals, which is 70% less energy than the median comparable existing building.

Seattle District Energy Projects

District Energy Projects can be used to combine the heating and cooling needs of several buildings to implement waste heat recovery and efficiency improvements. Although there have been studies in the past to evaluate the benefits of implementing a District Energy Project in the First Hill Neighborhood, no such project currently exists. After considering the possible benefits of implementing a District Energy project, it was concluded that it is not practical to start a district energy project specifically for this facility. A district energy source will not be needed for heat recovery at this building because of the proposed heat recovery chiller with connection to ground wells and low additional thermal load. However, the proposed systems would be able to connect to a future District Energy Project, should one be implemented in the future, allowing it to take advantage of the benefits noted above.

Recommendations

The proposed mechanical system (combination central plant with geothermal wells and standard capacity chillers and boilers for peak loads) is the recommended system because it has the lowest life cycle cost of all the systems analyzed, it meets the project and Seattle 2030 District energy reduction goals, and has very low greenhouse gas emissions.

SECTION 2 – METHODOLOGY

Project Description

The new Children and Family Justice Center (CFJC) will be a unified facility that incorporates family and juvenile courts, community programs and services as well as a modern youth detention facility. The courts and supporting areas of the building comprise approximately 158,000 sf, while the detention and supporting areas of the building comprise approximately 50,000 sf.

Analysis and Design Approach

In order to develop the proposed mechanical systems for the CFJC project, the Design-Build team followed 5 steps in a process of consideration and analysis. This process is outlined below; and these steps are followed throughout the report

Step 1 – Reduce/Reuse/Recycle

The first part of the approach we used for this evaluation, and to develop a scope and approach that maximizes the efficiency of the building, is similar to the Reduce/Reuse/Recycle approach to minimizing the consumption of other natural resources.

- Reduce: This involves identifying opportunities for reducing the inherent need of the building to use energy at the outset.
    - Scope
        - Evaluate building characteristics impactful to HVAC system loads and required capacities.
        - Building envelope alternatives are evaluated, to find opportunities through building configuration/orientation, improvement of insulating values, and enhanced windows systems to reduce the building skin load in a cost and life-cycle effective manner.
        - Lighting systems were evaluated (high efficiency fluorescent, LED) for opportunities to not just reduce energy consumption of the lighting systems, but to reduce the need for the building HVAC systems to overcome heat generated by those lighting systems.
        - Occupant-generated loads (computers and other plug loads) were evaluated to establish targets for reduced power density through use of efficient end-use devices. Similar to lighting, this reduces both the direct consumption of the devices as well as the corresponding cooling load on the HVAC system.
    - Outcome
        - Building configuration is identified, and thermal performance targets for major building envelope components are established.
        - Lighting power density targets are established for all space types throughout the building.
        - Goals for occupant power usage reduction are established.
- Reuse: This involves making use of energy being rejected by one part or system of the building for another part or system in need of energy – essentially transferring energy from

place to place instead of working to extract energy from one part of the building while simultaneously working to provide energy to another part of the building.
  - Scope:
    - Coincident cooling and heating loads were quantified, identifying the scope of potential for re-use. For example, the courts portion of the building has significant year-round heat generation due to both person density and computer/plug loads. The detention area, however, has a more continuous heating load to accommodate outside air requirements during the majority of the year when the outside air temperature is colder than desired space temperature.
  - Outcome
    - Preliminary parameters for systems to support energy collection and reuse are established, including general capacities and configurations.
- Recycle: This involves recovering as much used energy as practical after use in the building for recycling into the building.
  - Scope:
    - Identify waste heat potential (primarily from building exhaust air), and the opportunity for second use.
  - Outcome
    - Identification of systems and portions of the building suitable for energy recovery, and establish preliminary sizing and operational parameters.

As a result of the reduce/reuse/recycle strategy, the energy needs were significantly reduced and parameters were defined for selecting systems.

Step 2 – Develop Mechanical Systems Alternatives for Consideration

This involves finding the best alternative for providing the remaining cooling and heating loads of the building, based on the reduce/reuse/recycle strategy.

- Developing an Initial List: An initial list of systems are developed from the following sources:
  - RFP Documents: Some systems were listed in the RFP documents to be considered for evaluation
  - Design-Build Team Eco-Charrette: The team held an internal eco-charrette, to identify additional systems for consideration.
  - Mechanical Team Brainstorming: The mechanical team developed additional refined alternatives through a brainstorming process.
  - Full Team Eco-Charrette, including Owner: After being selected for the project, we held an additional eco-charrette with the Owner to identify any additional options for consideration.
- Initial Vetting of Options: An initial process was executed, to determine viability of alternatives, prior to executing detailed modeling.

- Systems had to support incorporation of the system parameters from Step 1 for reuse and recovery. Systems that inherently did not support these load reductions were eliminated from consideration.
- Systems had to be capable of meeting all explicit requirements of the RFP documents.
- Impacts on other systems (electrical, structural, etc.) needed to not be so significant as to override any potential energy efficiency benefit quantified during modeling.

Step 3 – Model Alternative Systems

Systems determined to be viable for full-year building energy use simulation are then evaluated in a building energy model. This is further discussed in Section 3 – Building Energy Simulation

Step 4 – Develop Other Supporting Information, and life cycle summary information

Life cycle cost analyses were developed using first, operational and maintenance cost impacts for each of the system alternatives that were considered for building energy modeling. This information, along with the results of the energy models, are then combined into summary life cycle analysis.

Step 5 – Final Vetting

The results of this evaluation, and the proposed systems, are then re-vetted to ensure they fit within project budgetary parameters, and the confines of all other disciplines.

System Options – Mechanical Alternatives Considered

Below are a description of the Mechanical Alternatives Considered, with a description of both the heating and cooling plants and the connected HVAC systems for these alternatives.

In the narratives below, the Plants describe the equipment for generating heated or chilled water to distribute to equipment in the building. The HVAC systems describe the equipment that conditions and distributes air and/or water through the building and further conditions it to the requirements of individual spaces.

1. Proposed System - Combination Central Plant with Geothermal Wells and Standard Capacity Chillers and Boilers for Peak Loads

Plants:

In line with the Design Strategy, Reduce/Reuse/Recycle, the Design-Build team proposes the use of a Heat Recovery Chiller, which can be sized for half of the peak cooling load and will simultaneously meet half of the peak heating and hot water load of the building. When there is a cooling load in one part of the building due to internal load from people, equipment, etc, this chiller can utilize that waste heat to meet domestic hot water or building heating needs in other parts of the building. The heat recovery chiller uses electricity and can produce 3-6 times the amount of heat over the amount of electricity that it uses. This heat recovery chiller will also be tied to a ground loop of thermal wells to use as a heat source or heat sink and will eliminate the need for a cooling tower. The ground loop will allow the chiller to operate at its full capacity year round to meet the majority of heating or cooling needs for the building. Since the heat recovery chiller will be sized for half of peak heating and cooling loads, there will also be a standard efficiency boiler plant and air cooled chillers needed for the peak loads.

HVAC Systems:
The proposed HVAC systems consist of several large rooftop air handlers for the courts building, with fan powered VAV boxes and terminal reheat in the spaces. This type of system will allow for good temperature controllability and full air economizer capability in the building. The Detention pods will each have a smaller air handling unit with zone variable air boxes to control temperatures. Detention cells have a high exhaust requirements, but the exhausted air will be run through a heat exchanger to recover heat and preheat the outside air for these systems.

2. High Efficiency Water Cooled Chillers

Plants:
This alternative assumes that the project is utilizing the same heat recovery chiller as the proposed Plant, sized for half of peak capacity, but will use additional chillers comprised of high efficiency water cooled chillers and cooling towers for the additional required cooling capacity. This will reduce the annual cooling energy used to run the additional chillers during peak building loads. Water cooled chillers are typically tied to a cooling tower, which requires a higher first cost and additional maintenance costs.

HVAC Systems:
The HVAC Systems in this alternative are assumed to be the same as those described for the proposed HVAC Systems.

3. High Efficiency Boilers

Plants:
This alternative assumes that the project is utilizing the same heat recovery chiller as the proposed Plant, sized for half of peak capacity, but will use a boiler plant comprised of high efficiency condensing boilers for the additional required heating capacity. Condensing boilers are designed to allow for condensation of water vapor from the gas combustion process. Condensation from flue gases occurs when additional heat is extracted from the flue gases, and the gases are cooled to below their dew point. By allowing for this condensation, and providing improved heat exchangers that cool flue gases to below their dew point, additional heat is extracted from the combustion process and transferred to the water - providing greater efficiencies. This will reduce the annual heating energy needed for the gas boiler plant. However, condensing boilers are a higher first cost than standard boilers because they must be designed with heat exchangers that can handle acidic condensation.

HVAC Systems:
The HVAC Systems in this alternative are assumed to be the same as those described for the proposed HVAC Systems.

4. Active Chilled Beam System

Plants:
The Plants in this alternative are assumed to be the same as those described for the proposed Plants – heat recovery chillers/geo-thermal wells/standard efficiency chillers/standard efficiency boilers.

HVAC Systems:
This alternative uses active chilled beams as an HVAC system for the courts portion of the building. Active chilled beam systems involve a substantial reduction of the air distribution system in the building, with air distribution providing only a portion of the building's needed capacity. The remainder of the capacity is provided by active chilled beams. Chilled and heating water are piped to the beams, which effectively act like radiators in the occupied space, providing the remainder of the necessary capacity. In an active chilled beam system, the air distribution capacity is ducted to the active beam, and the beam uses the central system airflow to enhance beam capacity through induction of room air across the beam.

An active chilled beam system typically reduces fan energy in a building, buy reducing the volume of air that is distributed. Additionally, they can allow for chilled water temperatures to be elevated and heating water temperatures to be lowered, which allow for improved efficiencies at the central plant. Conversely, they can reduce the availability of airside economizer, requiring additional central cooling plant operation and energy use.

The high outside air needs for detention cells and security implications of chilled beams in a secure space would make chilled beams inappropriate for the detention areas of the building. As such, this alternative only implements chilled beams for the non-detention portions of the non-security/detention portions of the building. HVAC systems in security/detention areas of the building would remain the same as the proposed system – air handling units with zone variable air volume terminal units.

5. Passive Chilled Beam and Perimeter Radiant Heat

Plants:
The Plants in this alternative are assumed to be the same as those described for the proposed Plants – heat recovery chillers/geo-thermal wells/standard efficiency chillers/standard efficiency boilers.

HVAC Systems:
This alternative uses passive chilled beams as an HVAC system for the courts portion of the building. Passive chilled beams operate on a similar principal to active beams, with the

exception that the airside distribution is not directly coupled to the beam. Relative to active beams, passive beams can further reduce fan energy because the beams are able to provide capacity without requiring airflow in certain conditions. However, because the capacity of the beam is not enhanced by the active connection to the air distribution system, it requires additional beam infrastructure to achieve the same capacity needs – with correlating first cost impacts.

The high outside air needs for detention cells and security implications of chilled beams in a secure space would make chilled beams inappropriate for the detention areas of the building. As such, this alternative only implements chilled beams for the non-detention portions of the non-security/detention portions of the building. HVAC systems in security/detention areas of the building would remain the same as the proposed system – air handling units with zone variable air volume terminal units.

6. 100% Ground Source Capacity

Plants:

This alternative uses the same heat recovery chiller as the proposed Plant, sized for half of peak capacity, but with the addition of two more heat recovery chillers, each also sized for half of peak capacity. This excess in capacity allows for equipment redundancy. These heat recovery chillers would replace the peak air cooled chillers and the boiler energy use, although one boiler would be available, but not normally used, for added redundancy. All of the Plant equipment for this alternative ties into an expanded system of ground source thermal wells that are sized for full peak heating and cooling capacity. The benefits of this system are from the improvement in chiller and water heating efficiencies and the elimination of gas boilers. Expanding ground source thermal wells for full peak capacity would substantially increase the amount of wells needed and the first cost for the system.

HVAC Systems:

The HVAC Systems in this alternative are assumed to be the same as those described for the proposed HVAC Systems.

7. Purchased Steam Heating and DHW

Plants:

This alternative assumes that the project is utilizing the same heat recovery chiller as the proposed Plant, sized for half of peak capacity, but will use purchased steam from Enwave Seattle instead of a gas boiler plant for the peak heating and hot water load. This will eliminate the direct gas use onsite. Purchased steam is more expensive per unit of energy than gas, which will increase the annual energy costs for the building.

HVAC Systems:

The HVAC Systems in this alternative are assumed to be the same as those described for the proposed HVAC Systems.

8. Thermal Storage

Thermal storage, which involves storage of cooling or heating capacity generated at one time, for future consumption. It is not a system type by itself, but rather a feature that can be utilized in certain systems. The appropriate time for analysis of thermal storage is in the Design Development stage of the project, when more detailed decisions about the building and it's systems have been made and the appropriate level of detailed analysis can be performed.

Thermal storage will be evaluated in detail during Design Development, when the project design will be refined to a level necessary to adequately evaluate this option. It requires a more detailed understanding of intra-day load heating and cooling imbalances in the building than currently exists. During Design Development, when we are able to develop that deeper level of understanding, this refinement will be evaluated.

9. Raised Underfloor Air Distribution

Underfloor air distribution systems were considered, but were ultimately considered to be impractical for use in the building. Sound transfer and security requirements, specifically, were major points of consideration.

Ultimately, it was determined that required mitigation to meet all of the project's comprehensive needs was impractical in the context of how an underfloor air distribution system, and precluded efficient implementation of such a system.

10. All Electric Heating - Variable Refrigerant Flow (VRF), Water Source Heat Pumps

All electric heating isn't a specific system type, but rather a general approach. There are various system alternatives that can provide all electric forms of heating (electric resistance at VAV boxes, baseboard electric resistance, electric boilers, heat pump water heaters, etc.). As such, this isn't something that was identified as a specific system, but is addressed by multiple other system considerations. With that in mind, however, there are common impacts of all fully electric heating systems that we can address in this discussion.

A primary common benefit of fully electric heating systems is the opportunity to reduce greenhouse gas emission contributions to the environment. A primary common negative of fully electric heating systems is the additional capacity requirements placed on the back-up electrical system.

With the required emergency/back-up heating requirements in the RFP, a fully electric heating system would have substantial upsizing implications for the main electrical service, and the associated emergency/back-up generator system. While the extent of this impact would vary depending on the system alternative, the impact would be substantial for all fully electric systems. It was ultimately determined that any heating system fully reliant on an electric fuel source was cost prohibitive to the project, in large part because of the impact to the emergency/back-up generator system sizing. ROM would be $8 million for the increased back-up generator capacity and other mechanical equipment costs. This impact was determined early on to be more substantial than any incremental impact that could be achieved with any of the alternatives.

Systems that were determined to not be practical for implementation due to this limitation include water source heat pumps, variable refrigerant flow systems (air and water based), and point of use electric resistance heating. Systems that are electric based, but allow for gas and/or fuel oil back up, can remain under consideration.

11. Sewer Heat Recovery

Sewer heat recovery involves rejecting heat to or absorbing heat from the municipal sewer system. Such a system typically needs to be implemented on a municipal level, and needs to serve loads many times those that are associated with this project. It requires installation of a municipal level condenser water loop, connecting to a quantity of buildings, with a utility grade central plant serving it. While we are not a utility system developer, we have participated in discussions with developers on implementation of sewer heat recovery systems in Seattle. In those discussions, a required connected building load of 5,000,000 sf of occupied space was given as an approximation of the minimum requirement to make sewer heat recovery viable – making it well beyond the scope of this project.

SECTION 3 –BUILDING ENERGY SIMULATION

General Simulation Description

As discussed above, some of the system alternatives were considered viable for full year building energy use simulation in order to understand how the annual energy use and operating costs for the building would change with different mechanical systems options.

In order to estimate annual operating cost for the building, the Design-Build team utilized the energy analysis software Trane Trace 700. This software is one of the three programs approved by King County for use on this analysis, and it is the software that the Design Build Team has the most experience in using. This tool allows a designer to enter detailed information about the proposed building and its mechanical systems to get an output of estimated annual energy use broken out by specific equipment and type.

The information input into the program about the building itself can be highly detailed; it involves the following: building envelope and footprint, lighting power and schedules, occupancy densities, occupancy schedules, power use from computer and electronic equipment, required ventilation, water use and schedule, heating and cooling setpoints, and more. Many of these inputs can be estimated during early stages design, but they cannot all be verified until the building is occupied. The designer therefore must make assumptions about each building input based on the information provided by either the design team (for schematic design inputs) or by the contractual documents from the owner (for occupancy and use assumptions). For the purposes of this report, all of the assumptions about the building and its use were held the same across all analyses.

Building Inputs

The following subsection describes the assumptions made to represent the building in the energy modeling program. As explained above, these assumptions about this building's physical characteristics, schedule of operation, use, and occupancy were held constant across all alternatives considered in this report.

Ventilation Rates

Ventilation rates used in the simulated building were based on levels required in Seattle Mechanical Code 2012 dependent on space type categories defined in the tables of SMC 2012 Chapter 4, Ventilation.

Occupant Density

Occupant Density assumptions were taken from the CFJC Facility Performance Standards Section 6, Table B6.3 – Indoor HVAC Design Criteria. This table lists the peak assumed population density for each room type in the building.

Occupancy Schedule

The Occupancy Schedules used in building simulations were taken from the information provided in Addendum 1, Appendix F: Anticipated Facility Occupancy Schedule (Attached in Appendix B of this report). These schedules help establish occupied hours for air handling equipment and help to establish the peak hours of use for lighting and for receptacle equipment, such as computers.

Electrical Plug Loads

Assumptions about the peak electrical plug loads were taken from the CFJC Facility Performance Standards Section 6, Table B6.3 – Indoor HVAC Design Criteria (Attached in Appendix B of this report). This electrical and cooling load encompasses equipment that can be plugged into the building receptacles and are often controlled by occupants, such as computers and televisions. The table referenced above lists the peak assumed electrical plug load density for each room type in the building.

Lighting Power Density

Lighting throughout the building will be from LED fixtures, which have a lower power density than typical fluorescent fixtures used commercial buildings. Seattle Energy Code lists specific maximum lighting power densities for use in different space types. Although the lighting layout is still being developed at this stage of the building design, the Design-Build team has assumed a 30% reduction over code values for lighting power density – as a reasonable expectation for an LED-based lighting system.

Heating and Cooling Setpoints

Heating and cooling setpoints for each room type were taken from the CFJC Facility Performance Standards Section 6, Table B6.3 – Indoor HVAC Design Criteria. This document is attached in Appendix B of this report. In general, the building is heating setpoint is 72 degrees and cooling setpoint is 75 degrees.

Domestic Hot Water Use

The domestic hot water use for the building was estimated based on information about the anticipated staff and inmate occupancies combined with standard water use calculations as well as the kitchen and janitorial support requirements. According to these preliminary calculations, the building will require approximately 4,000 gallons of hot water per day. This load was applied to the building heating plant, spread throughout the day according to assumptions made based on the building occupancy schedule.

Utility Rates

Included in this section are the natural gas and electric rate schedules for this project. These rates were used in energy cost estimates included in this report.

PSE Gas Energy Rates

PSE Schedule 31 – Commercial General Service	
Basic Charge Per Month	$33.26
Total Per Therm Charge	$0.9709

Seattle City Light Electric Energy Rates

SCL Medium Network General Service	
Minimum Charge Per Month	$18.90
Per kWh	$0.0793
Monthly Per kW Peak	$4.52

Enwave Seattle (Purchased Steam) Rates

Rate structures from Enwave Seattle can vary depending on the connected capacity and monthly steam use. For the proposed heating and cooling plant, a heat recovery chiller covers the majority of the heating energy use, however the connected additional load will need to be sized for peak building heating and hot water capacity. The connected steam capacity would therefore need to be large, with small monthly steam use. The available rate schedule that most closely fits this steam use would be Schedule 23. The rate structure below is from 2013, and will be updated with a more current values if available.

Enwave Schedule 23		
	Consumption Levels	$/Mlbs
First	100 MLbs	13.8104
Next	300 MLbs	12.1646
Next	800 MLbs	10.6760
Next	1,800 MLbs	9.4793
Balance		8.7411
Additional Fuel Differential		13.1574
Total $/Therm Range	**$1.82- $2.24 (per Therm)**	

The basic rate is based on PSE gas rates, which Enwave Seattle uses as a fuel source for the majority of their steam boilers. Enwave also uses a biomass boiler for a portion of their steam generation, and the King County Auditor has estimated approximately 8.4% of the Enwave total fuel inputs are biomass [1]. The Fuel Differential rate is in addition to the base rate for steam, and it is based on Enwave efficiencies; this rate is unregulated. The King County Auditor's office has prepared reports of Enwave efficiencies in order to project anticipated billing rates [2]. Please see the appendices for this information.

Mechanical System Inputs

Once the building characteristics were entered into the full year building energy simulation, the designer entered information about the supporting mechanical systems. The software requires information about the cooling plant, heating plant, fans, heat recovery systems, pumps, and any miscellaneous mechanical accessories. These inputs related to mechanical systems were changed in different simulations in order to compare the alternative systems.

List of Systems Evaluated using Full Year Building Energy Simulation

After initial consideration of 12 alternative systems, 7 of these systems were analyzed further with a full year building energy model simulation. These systems include:

1. Proposed System - Combination Central Plant with Geothermal Wells and Standard Capacity Chillers and Boilers for Peak Loads
2. High Efficiency Water Cooled Chillers
3. High Efficiency Boilers
4. Active Chilled Beam System
5. Passive Chilled Beam and Perimeter Radiant Heat
6. 100% Ground Source Capacity
7. Purchased Steam Peak Heating and DHW for Peak Loads

System Simulation Description

After setting up the building in the simulation program, and entering all building inputs and assumptions, the various mechanical systems were input to the model. These system inputs follow the description of alternative systems in the Methodology section of this report. The mechanical inputs to the model are summarized below.

1. Proposed System: This Plant was generally described as a combination central plant with geothermal wells and standard capacity air cooled chillers and boilers for peak loads. The HVAC systems were modeled as proposed in the schematic mechanical design submittal, with rooftop air handlers connected to series fan powered VAV boxes in the courts building, separate air handlers for courts, and separate detention HVAC systems tied to an exhaust air energy recovery device.
2. High Efficiency Water Cooled Chillers: This mechanical system matches the proposed system description above, except the air cooled chillers were entered as high efficiency water cooled chillers with cooling towers.
3. High Efficiency Boilers: This mechanical system matches the proposed system description above, except the boilers were entered as high efficiency condensing boilers.

4. Active Chilled Beam System: This mechanical system was entered as rooftop air handlers sized only for ventilation air and connected active chilled beams in the courts buildings. All other plant and detention HVAC system inputs match the proposed system description above.
5. Passive Chilled Beam System: This mechanical system was entered as rooftop air handlers sized only for ventilation air and connected passive chilled beams in the courts buildings. All other plant and detention HVAC system inputs match the proposed system description above.
6. 100% Ground Source Capacity: This mechanical system matches the proposed system description above, except the air cooled chillers were entered as additional heat recovery chillers, also tied to the ground loop. The boiler plant was eliminated in this system alternative.
7. Purchased Steam for Peak Heating and DHW: This mechanical system matches the proposed system description above, except the boiler plant was replaced with a purchased steam utility.

SECTION 4 – SIMULATION FINDINGS

After modeling simulation of the mechanical system alternatives listed in Section 3, the results of the simulation are summarized in the tables below.

System Simulation Outputs

The tables in this section show the annual energy use and cost for each alternative system. Once again, the system alternative numbers are described below.

1. Proposed System
2. High Efficiency Water Cooled Chillers
3. High Efficiency Boilers
4. Active Chilled Beam System
5. Passive Chilled Beam and Perimeter Radiant Heat
6. 100% Ground Source Capacity
7. Purchased Steam Peak Heating and DHW for peak Loads

In Table 1, the energy use is broken out by end use for each of the systems. Although Lighting and Receptacle energy use are a function of the Building Inputs and do not change across this analysis, these values are displayed for informational purposes and will factor into the building Energy Use Intensity. Please note, the heat recovery chiller is classified as a Cooling Plant in this energy analysis and is used in all Alternative Systems. All energy use associated with the heat recovery chiller – whether it is used for heating or cooling – is listed under the Cooling Plant End Use.

Table 1: Annual Energy Use for Each System Alternative, by End Use

		System Number						
	End Use	1	2	3	4	5	6	7
Annual Energy Use (10^6 Btu/year)	Lighting	1,554	1,554	1,554	1,554	1,554	1,554	1,554
	Heating Plant (Non-Electric)	426	426	378	429	430	0	355
	Cooling Plant	1,135	1,108	1,135	1,542	1,487	1,171	1,135
	Pumps	374	354	373	657	577	240	373
	Heat Rejection	15	17	15	17	17	0	15
	Fans	1,119	1,119	1,119	803	698	1,119	1,119
	Receptacles	1,926	1,926	1,926	1,926	1,926	1,926	1,926
Energy Use	Total (10^6 Btu/yr)	6,549	6,504	6,500	6,928	6,689	6,010	6,477

Table 2 below shows that all of the estimated annual energy use and operating costs for the alternative systems are within 10% of the values for the proposed system.

Table 2: Annual Energy Use and Operating Costs for Each System Alternative, by Energy Source

	Annual Energy Use and Operating Costs		Electricity	Gas or Purchased Steam	Total
System Number	1. Proposed System	Energy Use (10^6 Btu/yr)	6,123	426	6,549
		Cost ($/yr)	$170,779	$4,195	$174,974
	2. High Efficiency Chillers	Energy Use (10^6 Btu/yr)	6,078	426	6,504
		Cost ($/yr)	$168,946	$4,195	$173,141
	3. High Efficiency Boilers	Energy Use (10^6 Btu/yr)	6,122	378	6,500
		Cost ($/yr)	$170,752	$3,725	$174,477
	4. Active Chilled Beams	Energy Use (10^6 Btu/yr)	6,499	429	6,928
		Cost ($/yr)	$180,514	$4,170	$184,684
	5. Passive Chilled Beams	Energy Use (10^6 Btu/yr)	6,259	430	6,689
		Cost ($/yr)	$173,982	$4,171	$178,153
	6. 100% Ground Source	Energy Use (10^6 Btu/yr)	6,010	0	6,010
		Cost ($/yr)	$168,050	$0	$168,050
	7. Purchased Steam Peak Loads	Energy Use (10^6 Btu/yr)	6,122	355	6,477
		Cost ($/yr)	$170,761	$7,372	$178,133

The greatest improvement on energy use and operating costs are from System #6: 100% Ground Source Capacity, which improved building energy use over the proposed system by 8% including a 17% improvement on energy use associated with the mechanical systems. This equates to a 4% reduction in building annual operating costs over the proposed system. The difference in energy vs. cost savings comes from the fact that Alternative #6 is primarily saving gas energy and gas costs much less per unit of energy than electricity.

Alternatives #2 and #3, High Efficiency Chillers or Boilers both save a small amount of energy compared to the proposed system; both reduce mechanical energy use by about 1.5%. The cost savings for the annual building operating cost is about 1% savings for the high efficiency chillers and about 0.3% savings for the high efficiency chillers over the proposed system.

Some of the alterative systems use more energy or have higher operating costs than the proposed system. Systems #4 and #5, Active or Passive Chilled Beams, both save fan energy, but use more chiller energy and have higher operating costs than the proposed system. The active chilled beams increase annual building operating costs over the proposed system by about 5% and passive chilled beams increase the cost by about 2%.

System #7, Purchased Steam for Heating and Domestic Hot Water Loads, reduces about 2.5% of the mechanical energy use over the proposed system, but increases the annual building operating cost by almost 2% because of the high cost of purchased steam compared with gas.

Validation of Outputs

Although every attempt has been made to model the actual building conditions that will exist when construction is complete, with the most accurate energy simulation program and calculation methods available, energy consumption, and operating cost outlined in this report should not be interpreted as a precise prediction of actual performance once the building is built and occupied. The modeling done in this report was based on Schematic Design Concepts for the building. Actual energy consumption and utility costs are likely to differ from results presented herein due to unpredictable variables. This occurs where the actual building varies from the modeled design and assumptions used in the modeling process. This may include changes in occupancy, schedules, equipment selection and installation, space temperature setpoints, building construction, commissioning, and weather variations from typical year data used, and other unforeseen circumstances.

EUI and ECI

Site Energy Use Intensity (EUI) is a measure of the amount of energy used in a year of building operation, divided by the area of the building, in units of annual kBtus per square foot of building area. Energy Cost Index (ECI) is a measure of the operating costs for a year of building operation, divided by the area of the building, in units of annual $ per square foot of building area. These metrics allow for a broad understand of predicted or actual building energy consumption and cost, that can allow for simple comparison with the energy use and costs on similar buildings.

After entering the individual space areas into the building simulation model, as measured from preliminary schematic design plans, the total building area was calculated to be 208,832 ft². This number was used for the preliminary EUI and ECI calculations, but should not be considered an accurate final building area. The EUI and ECI for each of the system alternatives are displayed in Table 3 below, using the energy and cost values from Table 2 in this report.

Table 3: EUI and ECI Calculated for the Alternative Systems

	EUI (kBtu/ft²/yr)	ECI ($/ft²/yr)
1. Proposed System	31.4	$0.84
2. High Efficiency Chillers	31.1	$0.83
3. High Efficiency Boilers	31.1	$0.84
4. Active Chilled Beams	33.2	$0.88
5. Passive Chilled Beams	32.0	$0.85
6. 100% Ground Source	28.8	$0.80
7. Purchased Steam Peak Loads	31.0	$0.85

The EUI and ECI values correspond directly with the energy and cost values, which were discussed and compared in the System Simulation Output subsection of this report.

From the Energy Star Target Finder website, a similar existing courthouse building in this area would have a site EUI of approximately 108. This means that the current Schematic Design estimate Site EUI for the building with the proposed mechanical system is 71% better than that of a comparable existing building.

Please note, that this Energy Star Target Finder baseline EUI has no relationship to the Performance Requirements for the building. The Energy Star Target Finder EUI is established as an average of existing building energy consumption, and the Performance Requirement baseline is a 2012 Seattle Energy Code compliant building.

SECTION 5 – LIFE CYCLE FINDINGS

In order to fully understand the economic impact of any particular mechanical system, it is essential to consider the life cycle costs of that system. Such cost evaluations should incorporate information about the annual energy cost savings or increase in conjunction with difference in first costs, the change in maintenance costs, and the difference in equipment replacement costs for that system.

First Costs

It is important to understand the first cost impact for budget considerations. See Table 4 below for a list of the estimated mechanical system first costs on all analyzed system alternatives. For each of the alternative systems, the estimated cost differences are broken out into mechanical equipment, material or labor cost increases in Table 5.

Table 4: Mechanical First Costs for each Alternative System

	First Costs - Mechanical System ($)	First Costs - Mechanical System (% Increase)
1. Proposed System	$13,635,000	-
2. High Efficiency Chillers	$14,027,000	3%
3. High Efficiency Boilers	$13,768,500	1%
4. Active Chilled Beams	$16,578,146	22%
5. Passive Chilled Beams	$17,509,646	28%
6. 100% Ground Source	$15,540,000	14%
7. Purchased Steam Peak	$13,776,000	1%

Table 5: Breakdown of Mechanical First Costs Addition for each Alternative System

	First Costs - Mechanical System Total Addition ($)	First Costs - Equipment Addition($)	First Costs - Materials Addition($)	First Costs - Labor Addition($)
1. Proposed System	Baseline	-	-	-
2. High Efficiency Chillers	$392,000	$294,000	$49,000	$49,000
3. High Efficiency Boilers	$133,500	$133,500	$0	$0
4. Active Chilled Beams	$2,943,146	$412,040	$1,012,442	$1,518,664
5. Passive Chilled Beams	$3,874,646	$581,196	$1,317,380	$1,976,070
6. 100% Ground Source	$1,905,000	$1,905,000	$0	$0
7. Purchased Steam Peak	$141,000	$56,000	$34,000	$51,000

Of each of the systems considered for analysis, the proposed mechanical system has the lowest first cost. Each of the other alternative systems are an increase of between 1% and almost 30% of the total mechanical first costs.

Systems #2 and #3, High efficiency Chillers or Boilers, would be a moderate cost increase to the project.

Systems #4 and #5, Active or Passive Chilled Beams, would be a significant increase to the mechanical first costs because of the increase in building-wide chilled water piping, as well as additional and more expensive zone equipment.

System #6, 100% Ground Source Capacity system, would be a noticeable increase in costs because it would require an additional field of thermal wells as well as additional plant-level expense.

System #7, Connection to Purchased Steam for Peak Loads, would add moderate first costs; while the boiler plant would be removed from the first cost, several new heat exchangers would be required in order to utilize the Purchased Steam and residual heat from Condensate.

Operating Costs

The difference in Operating Costs for the building are discussed in Section 4, Simulation Findings. In Table 6 below, the costs are separated out specifically by mechanical end-use energy costs. These costs are further separated to indicate the difference in annual operating cost, in comparison with the proposed mechanical system.

Table 6: Annual Mechanical Operating Costs for each Alternative System

	Annual Energy Use and Operating Costs		Electricity	Gas or Purchased Steam	Total	Operating Cost Difference From Proposed ($)
System Number	1. Proposed System	Annual Mechanical Energy Use (Btus x 10^6)	2,643	426	3,069	
		Annual Mechanical Energy Cost ($)	$73,711	$4,195	$77,906	-
	2. High Efficiency Chillers	Annual Mechanical Energy Use (Btus x 10^6)	2,598	426	3,024	
		Annual Mechanical Energy Cost ($)	$72,215	$4,195	$76,410	-$1,496
	3. High Efficiency Boilers	Annual Mechanical Energy Use (Btus x 10^6)	2,642	378	3,020	
		Annual Mechanical Energy Cost ($)	$73,689	$3,725	$77,414	-$491
	4. Active Chilled Beams	Annual Mechanical Energy Use (Btus x 10^6)	3,019	429	3,448	
		Annual Mechanical Energy Cost ($)	$83,855	$4,170	$88,025	$10,119
	5. Passive Chilled Beams	Annual Mechanical Energy Use (Btus x 10^6)	2,779	430	3,209	
		Annual Mechanical Energy Cost ($)	$77,248	$4,171	$81,419	$3,514
	6. 100% Ground Source	Annual Mechanical Energy Use (Btus x 10^6)	2,530	0	2,530	
		Annual Mechanical Energy Cost ($)	$70,743	$0	$70,743	-$7,162
	7. Purchased Steam Peak Loads	Annual Mechanical Energy Use (Btus x 10^6)	2,642	355	2,997	
		Annual Mechanical Energy Cost ($)	$73,693	$7,372	$81,065	$3,160

As discussed in Section 4, System Alternatives #2 and #3 provide modest energy cost reductions, Alternative #6 provides a noticeable energy cost reduction, and Systems #4, #5, and #7 increase the annual energy costs in comparison with the proposed system.

Maintenance Costs

Maintenance costs also contribute to the annual cost of a mechanical system. The maintenance costs discussed in this report are not intended to cover the absolute maintenance costs for the facility, nor do they represent an estimate of the facility staffing budget needed to support each mechanical alternative. Rather, these maintenance cost estimates represent the unique cost differential, in comparison with the proposed mechanical system, for maintainingthe equipment specific to that alternative. These unique costs and the specific source of the maintenance cost difference are displayed in Table 7 below.

Table 7: Differential Mechanical Maintenance Costs for each Alternative System

Differential Maintenance Costs by Maintenance Item - Comparison to Proposed System													
1. Proposed System		2. High Efficiency Chillers		3. High Efficiency Boilers		4. Active Chilled Beams		5. Passive Chilled Beams		6. 100% Ground Source		7. Purchased Steam Peak	
Baseline System	Annual Cost	Additional Maintenance	Annual Cost	Additional Maintenance	Annual Cost	Additional Maintenance	Annual Cost	Additional Maintenance	Annual Cost	Additional Maintenance	Annual Cost	Additional Maintenance	Annual Cost
N/A	Baseline	Cooling Tower Maintenance Contract	$27,000	Condensate Maintenance	$3,000	Chilled Water Piping and Valving to Zone Equipment	$6,000	Chilled Water Piping and Valving to Zone Equipment	$6,000	Additional Ground Loop Piping and Valving	$4,000	Heat Exchangers vs. Boilers Maintenance	-$1,200
				Increased Boiler Maintenance	$9,000							Steam Traps and Steam Devices	$2,400
Total	$0	Total	$27,000	Total	$12,000	Total	$6,000	Total	$6,000	Total	$4,000	Total	$1,200

There are only marginal differences in the maintenance costs for most alternative systems, however there is a noticeable increase in maintenance costs for System #2, high efficiency chillers, because of the added cooling tower in this alternative.

Equipment Replacement Costs

Equipment Replacement Costs are an important consideration for a life cycle system analysis, especially when considering a longer life-cycle of the building. Only the increase in system replacement costs are needed for comparison purposes, in addition to the period of equipment service life.

In a 15 year life cycle, none of the equipment replacement costs are considered to be different among the 7 System Alternatives. However, the chillers and boilers are assumed to reach end of service life within the period of a 30 year analysis. Table 8 below lists the equipment replacement year and differential in replacement costs over the proposed system.

Table 8: Equipment Replacement Cost Differential

	Replacement Costs - Addition($)	Equipment Replacement 30 Year LCCA (Year)
1. Proposed System	-	-
2. High Efficiency Chillers	$392,000	Year 22
3. High Efficiency Boilers	$133,500	Year 25
4. Active Chilled Beams	N/A	N/A
5. Passive Chilled Beams	N/A	N/A
6. 100% Ground Source	N/A	N/A
7. Purchased Steam Peak	N/A	N/A

Life Cycle Costs

Life cycle costs were analyzed for each of the alternative mechanical systems in comparison with the proposed system. King County provides a Life Cycle Cost Analysis (LCCA) calculator to evaluate the impact of a cost measure on the life cycle costs of a building [3]. This tool was used to evaluate the Return on Investment and the Benefit/Cost Ratio for each of the Alternative Mechanical Systems. This tool uses differential costs to evaluate the payback of an alternative system. Tables 9 and 10 below list the differential mechanical first, operating, maintenance, and replacement costs for each alternative system in comparison with the proposed mechanical system. In addition, these tables list the 15 and 30 year net present value and indicate the simple payback period for each system (if applicable). See the appendices for all inputs and outputs of the KC LCCA calculator for each system and timeframe.

Table 9: 15 Year Life Cycle Cost Inputs and Findings - Comparison to Proposed Mechanical System

Life Cycle Cost Comparison - 15 Year LCCA						
	First Costs - Mechanical System Addition($)	Annual Mechanical Operating Costs - Difference($)	Annual Maintence Costs - Difference($)	Additional Replacement Costs 15 Year LCCA (Year)	Net Present Value (NPV - 15 Years)	Simple Payback Period
1. Proposed System	-	-	-	-	-	-
2. High Efficiency Chillers	$392,000	-$1,496	$27,000	N/A	-$636,251	N/A
3. High Efficiency Boilers	$133,500	-$492	$12,000	N/A	-$268,399	N/A
4. Active Chilled Beams	$2,943,000	$10,119	$6,000	N/A	-$2,869,976	>500 Yrs
5. Passive Chilled Beams	$3,875,000	$3,513	$6,000	N/A	-$3,736,520	>300 Yrs
6. 100% Ground Source	$1,905,000	-$7,163	$4,000	N/A	-$1,629,890	>80 Yrs
7. Purchased Steam Peak	$141,000	$3,159	$1,200	N/A	-$202,244	N/A

Table 10: 30 Year Life Cycle Cost Inputs and Findings - Comparison to Proposed Mechanical System

Life Cycle Cost Comparison - 30 Year LCCA						
	First Costs - Mechanical System Addition($)	Annual Mechanical Operating Costs - Difference($)	Annual Maintence Costs - Difference($)	Additional Replacement Costs 30 Year LCCA (Year)	Net Present Value (NPV - 30 Years)	Simple Payback Period
1. Proposed System	-	-	-	-	-	-
2. High Efficiency Chillers	$392,000	-$1,496	$27,000	Year 22	-$1,022,765	N/A
3. High Efficiency Boilers	$133,500	-$492	$12,000	Year 19	-$422,658	N/A
4. Active Chilled Beams	$2,943,000	$10,119	$6,000	N/A	-$2,850,622	>500 Yrs
5. Passive Chilled Beams	$3,875,000	$3,513	$6,000	N/A	-$3,686,964	>300 Yrs
6. 100% Ground Source	$1,905,000	-$7,163	$4,000	N/A	-$1,440,219	>80 Yrs
7. Purchased Steam Peak	$141,000	$3,159	$1,200	N/A	-$252,036	N/A

Note that, in the above tables, the simple payback periods for some alternatives are labeled as N/A. This is because the payback is beyond the life cycle evaluation period, and would have additional costs beyond the life cycle evaluation period (ie equipment replacement for equipment with a life cycle greater than the evaluation period). Accurately determining the payback beyond the LCCA evaluation period is beyond this scope of this evaluation.

From the Net Present Values and Simple Payback values listed in Tables 9 and 10, it is clear that none of the system alternatives provide a positive return on investment when compared with the proposed system, in either a 15 or 30 year life cycle analysis.

Systems #4 and #5, Active or Passive Chilled Beams, and System # 7 have zero benefit in mechanical first, operating, maintenance, and replacement costs, and therefore have a negative payback. The net present value for these systems decreases between the 15 and 30 year life cycle analyses.

Systems #2, #3, and #6, High Efficiency Chillers or Boilers, or 100% Ground Source Capacity, have modest savings in mechanical operating costs that were far exceeded by their first costs and life cycle maintenance and replacement costs. The simple payback exceeds 80 years for all these alternatives and neither indicate a positive net present value on either a 15 or 30 year analysis.

System # 1, the Proposed Mechanical System, has the lowest life cycle cost of all the alternatives considered here, in either a 15 or 30 year analysis.

Greenhouse Gas Emissions

Reducing Greenhouse Gas Emissions is a King County policy, and is a specific directive in the 2012 King County Comprehensive Plan. King County is committed to a regional 80% reduction over 2007 levels in operational greenhouse gas emissions by 2050.

The CFJC will receive electricity from Seattle City Light (SCL). Because SCL produces electricity from primarily hydroelectric sources, electricity in this area is a utility with a very low carbon footprint. Carbon emissions per unit of energy are therefore much lower for SCL electricity than gas or steam [4] [5] [6], so it is beneficial to the CFJC to emphasize the use of electric energy over other sources.

Reference Table 11 below for information on emissions from each energy source considered.

Table 11: Emissions Factors for Different Energy Sources

Emissions factors:				References
Electricity	SCL	0.01315	$MTCO_2e/MWh$	[4]
Gas		0.05306	$MTCO_2e/MMBtu$	[5]
Purchsed Steam	Enwave	0.07075	$MTCO_2e/MMBtu$	[6]

The Proposed Design utilizes an electrically powered heat recovery chiller for the majority of the annual heating load of the building, which will allow for very low annual carbon emissions. Alternatively, we have evaluated System #6, which uses heat recovery chillers and additional ground source thermal wells to cover the entire annual heating load of the building, meaning that there would be no anticipated natural gas use. Finally, we have evaluated the emissions associated with System #7, using purchased steam for the peak heating source. See the set of tables below for a comparison of the greenhouse gas emissions on these three systems.

Table 12-14: Greenhouse Gas Emissions Comparison for Different HVAC System Types

Proposed System			
	Energy use		**GHG**
	MMBtu	% of total	$MTCO_2e$
Electricity	6,123	93%	24
Gas	426	7%	23
Total	**6,549**	**100%**	**46**

100% Thermal Wells			
	Energy use		**GHG**
	MMBtu	% of total	$MTCO_2e$
Electricity	6,010	100%	23
			-
Total	**6,010**	**100%**	**23**

Purchased Steam for Peak Loads			
	Energy use		**GHG**
	MMBtu	% of total	$MTCO_2e$
Electricity	6,122	95%	24
Steam	355	5%	25
Total	**6,477**	**100%**	**49**

Alternatives #2-5 have very similar estimated greenhouse gas emissions to the proposed system, all of these systems fall within 4% of each other for annual CO_2 equivalent production. According to a preliminary Energy Star Target Finder calculation (see Appendix E), the median existing building of this size and function would have an annual greenhouse gas emissions of 1,892 Metric Tons CO_2 equivalent ($MTCO_2e$). Table 15 below displays the calculated Greenhouse Gas emissions for all of the evaluated system types.

Table 13: Greenhouse Gas Emissions Comparison for Different HVAC System Types

System Type	MTCO2e
1. Proposed System	46
2. High Efficiency Chillers	46

3. High Efficiency Chillers	44
4. Active Chilled Beams	48
5. Passive Chilled Beams	47
6. 100% Thermal Wells	23
7. Purchased Steam	49
Comparable Existing Building (Energy Star)	1,934

From the Tables above, it is clear that all the systems evaluated have very low annual greenhouse gas emissions. In comparison with a similar existing building, the new building using the proposed mechanical system would have only 46 $\mathrm{MTCO_2e}$ in annual emissions, which is a 97.5% reduction. This is explained by the use of electricity for the majority of heating loads and by the use of Seattle City Light as a utility. Using 100% Thermal Well heating capacity would cut carbon emissions in half compared to the proposed system, however, greenhouse gas emissions in the proposed system is already very low. Using purchased steam for peak loads would cause a slight increase in the greenhouse gas emissions because Enwave Seattle produces 33% more emissions per unit of energy than natural gas [5] [6].

Seattle 2030 District

King County is a member of the Seattle 2030 District, and is committed to follow Seattle 2030 goals for the environmental impact of new and existing buildings. The Seattle 2030 District encompasses guidelines on the design and operation of new buildings such as the CFJC project that include goals for the reduction of Energy Use, Water Use, and CO2 Emissions of Auto and Freight.

For the Energy Use Goals, the District requires that buildings be designed to operate with 70% less energy use than the National median for similar existing buildings. This National median energy use is measured in Site Energy Use Intensity (EUI), which represents the amount of energy used to operate a building in one year divided by the total building area, in units of annual kBtus/square foot. Using preliminary data about a mixed Courthouse and Incarceration Building of this size, the Energy Star Target Finder baseline energy use for comparison to existing buildings is approximately 108 Site EUI. In order to have a 70% reduction in energy use, the CFJC will need to have an energy use intensity of approximately 32.4 Site EUI. From the schematic design level calculations done at this time and presented in this report on the proposed system, the site EUI for the CFJC project are estimated to be 31.4 EUI and will meet the goals of the Seattle 2030 District.

Please note, the EUI targets for the 2030 District has no relationship to the Performance Requirements for the building. The 2030 District EUI is established as an average of existing building energy consumption, and the Performance Requirement baseline is a 2012 Seattle Energy Code compliant building.

The final goal for the Seattle 2030 District is CO2 emissions savings related to Auto and Freight. This goal will be addressed in separate reporting to Seattle 2030 District, and will not be discussed further in this report, as it is unrelated to the Building Heating and Cooling Systems. For a discussion of Greenhouse Gas emissions related to the Building Heating and Cooling Systems, see the previous subsection of this report, titled “Greenhouse Gas Emissions”.

Seattle District Energy

District Energy Projects can be used to combine the heating and cooling needs of several buildings or even an entire neighborhood into one plant for the most effective use of waste heat recovery and efficiency improvements. In order to implement a District Energy Project, there needs to be a cluster of high demand buildings in one area that are able to tie into a plant for heat or waste recovery or else a large distribution network to serve the role of connecting buildings over larger distances.

City of Seattle prepared a study related to district energy in 2010, which has outlined the potential for partnership in the First Hill neighborhood. The report specifically mentions the potential for a district energy source tied to existing hospitals in the area, which have a high thermal density and from utilizing the existing Enwave Seattle infrastructure in that neighborhood. The CFJC project is located on the border of the First Hill neighborhood and could potentially tie into a district energy project if it were to become available.

As discussed in Section 2, related to Sewer Heat Recovery, district energy projects often relate to utilizing heat sources and heat sinks that would otherwise go unused. For reasons discussed in that section, Sewer Heat Recovery is not a viable option for this project, as would many systems that can be used to improve the efficiencies of building plants. The proposed design already makes use of the waste heat from the chilled water system for the majority of the utilized capacity of the building, and the ground loop will provide an efficient heat source or heat sink to the heat recovery chiller. As a result, the building does not stand to benefit from most district energy projects related to waste heat recovery. However, the nature of the proposed heat recovery chiller system does allow for the building to connect to a district energy project in the future if one is available. This connection to a district energy source would be in lieu of the connection to ground loop, and would be done if the district energy source were able to provide even greater efficiency improvements than ground source wells through the temperatures available.

Enwave Seattle (formerly Seattle Steam) is a historic District Energy Source for Seattle, and is a shared plant that has connected to buildings in Seattle for over 120 years. For further discussion about the use of purchased steam connection in place of the boiler plant, reference the system options under the methodology section of this report. After a building uses the purchased steam, condensate from the steam does not return to the Enwave steam plant. Rather, a building connected to Enwave can choose to use the high temperature condensate water as a further heat source for building heating and domestic hot water loads or discharge the condensate to the sewer if necessary. Separately, there is a possibility for a building with a large thermal load to reject high temperature condensate from purchased steam to a neighboring building with a smaller thermal load to use as a heat source. The CFJC building will be located within half a mile of several hospital buildings, where there would be a theoretical possibility to connect to these source buildings and utilize any high temperature condensate that they reject. There are several reasons why this would be impractical. First, the rejected condensate would not be a constant reliable source of heat, which would mean that a boiler plant or connected steam would still be required at the CFJC for when condensate is not available. Second, it would take a significant infrastructure effort to install this connection, which would not be practical for the small load from this facility alone, and the condensate temperatures would degrade in the distribution system. Finally, there is nothing about the thermal load of this facility that is unique to the CFJC, meaning that there would be no reason to distribute condensate out to this facility when the source building should benefit from utilizing the condensate instead.

While future District Energy projects in this neighborhood can provide some potential benefits to the CFJC if they are available in the future, it is not practical to implement a district energy project specifically for this facility. A district energy source is not needed for heat recovery at this building because of the proposed heat recovery chiller with connection to ground wells and low additional thermal load for this building.

SECTION 6 – SUMMARY OF FINDINGS

In general, it was found that the proposed building is already at a high efficiency and low operating cost point, reducing the energy and cost savings potential of further incremental impacts. See Table 16 below for a condensed table of findings, including the EUI/ECI values for each system, differential numbers for the 30 Year Net Present Value in comparison to the proposed system (negative numbers increased cost), and Greenhouse Gas emissions for all alternatives.

Table 16: Summary of Findings

	EUI (kBtu/ft²/yr)	ECI ($/ft²/yr)	Net Present Value Differential (NPV - 30 Years)	GHG Emissions (MTCO2e)
1. Proposed System	31.4	$0.84	-	46
2. High Efficiency Chillers	31.1	$0.83	-$1,022,765	46
3. High Efficiency Boilers	31.1	$0.84	-$422,658	44
4. Active Chilled Beams	33.2	$0.88	-$2,850,622	48
5. Passive Chilled Beams	32.0	$0.85	-$3,686,964	47
6. 100% Ground Source	28.8	$0.80	-$1,440,219	23
7. Purchased Steam Peak	31.0	$0.85	-$252,036	49

For central plant improvements (high efficiency chillers, high efficiency boilers, full capacity geothermal systems), incremental improvements in central plant efficiencies were small relative to first cost impacts. As such, life cycle costs are higher for these alternatives, with long-term operational cost reductions not offsetting initial investments. This was as-expected, as the development of the proposed system involved sizing of high efficiency central plant capacity to maximize efficiencies within established ROI/life cycle cost parameters.

For chilled beam systems (active and passive), they were found to result in an incremental increase in operating costs, along with an increase in first cost. This was also as expected. The operating characteristics of this building are such that the inherent loss of airside economizer associated with these systems caused more inefficiencies than the offsetting efficiencies could overcome.

Regarding energy districts, it was determined that the load of this building is just too inconsequential relative to the scale required to justify development of an energy district. While it could certainly be a customer of an energy district, it is nowhere significant of an energy user to assist in justification of development.

Finally, regarding consideration of the available steam utility, the available information from the steam utility indicates that connection to the utility would result in an increased first cost, increased operating cost, and increase in greenhouse gas emission contributions. The steam consumption of this building is both small enough in volume, and large enough in peak connected load requirements (resulting in substantial infrastructure costs, with limited ongoing revenue to the steam provider), that we suspect actual steam utility rates may be higher than the information currently available. However, given that it was already a negative cost impact, and such a change would just exacerbate the issue, it was determined this did not need to be pursued farther. Regarding greenhouse gas contributions, using the steam provider’s own information, it was shown that connection to steam resulted in an increase in greenhouse gas production. As such, it was determined this system alternative did not need to be pursued further.

SECTION 7 – RECOMMENDATIONS

System Recommendations

In keeping with the environmental and sustainability goals of the project, the Design-Build team has taken a mechanical design approach to Reduce, Reuse, and Recycle. In a mechanical context, this means that the team plans to reduce heating and cooling loads with architectural and electrical design considerations, reuse heat and cooling loads as heat sinks or heat sources with a heat recovery chiller, and recycle the heat from exhausted air in high ventilation spaces. The Proposed mechanical System is recommended for the heating and cooling of the new CFJC because it best follows the design approach while maintaining the lowest life cycle costs.

The recommended mechanical system uses a Heat Recovery Chiller sized for half of the peak cooling and heating load with air cooled chillers and standard efficiency boilers to meet the full peak cooling and heating loads. From the mechanical operating cost findings of this system, it is clear that most of the year the building heating and cooling load will be satisfied by the Heat Recovery Chiller, with only a small amount of energy used by the boilers and air cooled chillers. The recommended system uses large rooftop air handlers with full economizer capability for the courts building, and fan powered VAV boxes with terminal reheat in the spaces. The Detention pods each have a smaller air handling unit with zone variable air boxes, with exhausted air run through a heat exchanger to recover heat and preheat the outside air for these systems.

The recommended mechanical system has the lowest life cycle cost of all the systems analyzed for both a 15 year and 30 year analysis. This recommended system meets the project and Seattle 2030 District energy reduction goals, and contributes to process water savings. In addition, the recommended system has very low greenhouse gas emissions, with preliminary analysis indicating it will produce 97.5% less emissions than the median building of this size and function.

SECTION 8 – APPENDICES

Appendix A: References

[1] B. Thompson, "Record Analysis for CO2 Emission Calculations," King County Auditor's Office, Seattle, 2013.

[2] King County Auditor's Office , "Estimating SS Efficiency from Fuel Rate Escalation," 2013.

[3] King County Green Building, "King County LCCA Calculator," [Online]. Available: http://your.kingcounty.gov/solidwaste/greenbuilding/technical-resources.asp.

[4] California Climate Action Registry, "2008 Emission Factor," 2008. [Online]. Available: http://www.climateregistry.org/tools/member-resources/reporting-tips.html. [Accessed 2015].

[5] Environmental Protection Agency, "Clean Energy Calculations and References," 2013. [Online]. Available: http://www.epa.gov/cleanenergy/energy-resources/refs.html. [Accessed 2015].

[6] Enwave Seattle, "Climate Registry Reporting," 2014. [Online]. Available: http://www.enwaveseattle.com/climate-registry-reporting.htm. [Accessed 2015].

Appendix B: King County RFP Tables

Table B6.3 - Indoor HVAC Design Criteria

Room Type	Design Air Temperature Setpoint °F		Population Density ft2/person	Lighting Load W/ft2	Electrical Plug Load W/ft2
	Cooling	Heating			
Open and Closed Offices	75±2	72±2	100	0.88	1.2
Core Circulation	75±5	72±2	0 people	0.72	0.75
Storage	85±2	65±2	0 people	0.50	0.75
Judicial Chambers	75±2	72±2	15	0.90	1.5
Lobby	75±5	72±2	100	0.72	1.5
24/7 Tenant Cooling Loads	72±2	72±2	100	0.72	1.5
Holding Cells	75±2	72±2	40 people	0.88	0.9
Conference Rooms	75±2	72±2	15	0.98	1.2
Toilets /Janitor	75±2	72±2	0 people	0.78	0.75
Copy Rooms	75±2	72±2	200	0.78	1.1
Day Care	75±2	72±2	40	0.78	1.1
Public Toilet Rms.	75±2	72±2	200	0.78	1.1
Waiting Areas	75±2	72±2	33	0.72	1.4
Break Rooms	75±2	72±2	20	0.72	1.1
Hearing Rooms	75±2	72±2	26		1.1
Courtroom	75±2	72±2	18 (or #fixed seats)		1.6
Detention Cells	75±2	72±2	40	0.88	
Detention Dayrooms	75±2	72±2	33	0.75	
Secure Areas	75±2	72±2	66	0.72	

Notes:

- Lighting and plug load values are provided as allowances for preparation of load estimates not as an indication of the actual desired lighting and power density.
- Indoor setpoints for spaces that are proposed for natural ventilation may use the ASHRAE 55 Adaptive Thermal Comfort values as permitted by ASHRAE 55.

Children and Family Justice Center Project
Part B - Performance Standards
Appendix F: Anticipated Facility Occupancy Schedule

Court Program

ID	Component	Hours	Days	Comments
1.000	**Building Support**			
1.100	Entry Security Screening	0500-1200	M-S	
1.200	Public Lobby	0830-1630	M-F	These are open office hours
1.300	Public Child Care	0830-1630	M-F	These are open office hours
1.400	Shared Meeting Spaces	083-2100	M-S	This may vary depending on room and day
1.500	Staff Support	0800-1700	M-F	These are staff work times.
1.600	Information Technology/MIS	24hrs	7 Days	This may vary depending on room and day
1.700	Facilities & Building Support	24hrs	7 Days	This may vary depending on room and day
1.900	Mechanical & Electrical	24hrs	7 Days	
2.000	**Resource Center**	**0830-1630**	**M-F**	**These are open office hours**
2.100	Resource Center	0800-1700	M-F	These are staff work times.
3.000	**Juvenile Court**	**0830-1630**	**M-F**	**These are open office hours, which could vary at times.**
3.100	Chief Juvenile & Offender Courts	0830-1630	M-F	These are open office hours
3.200	Dependency Courts	0830-1630	M-F	These are open office hours
3.300	Becca and Treatment Courts	0830-1630	M-F	These are open office hours
3.400	Judicial Offices	0800-1700	M-F	These are staff work times.
4.000	**Juvenile Court Administration**	**0830-1630**	**M-F**	**These are open office hours**
4.100	Administration	0800-1700	M-F	These are staff work times.
4.200	Reform Initiatives, Analysts, Evaluators	0800-1700	M-F	These are staff work times.
4.300	Shared Space	0800-1700	M-F	These are staff work times.
5.000	**Juvenile Probation Services**	**0830-1630**	**M-F**	**These are open office hours**
5.100	Consolidated Intake Unit	0800-1700	M-F	These are staff work times.
5.200	City Unit/Supervision	0800-1700	M-F	These are staff work times.
5.300	Community Program/Restitution Monitor	0800-1700	M-F	These are staff work times.
5.400	Records Unit	0800-1700	M-F	These are staff work times.
5.500	Evidence Based Programs & Student Intern Unit	0800-1700	M-F	These are staff work times.
5.600	Warrants	0800-1700	M-F	These are staff work times.
5.700	Shared Space	0800-1700	M-F	These are staff work times.
6.000	**Treatment Services**	**0830-1630**	**M-F**	**These are open office hours**
6.100	Juvenile Drug Court	0830-1630	M-F	These are open office hours
6.200	Family Treatment Court	0830-1630	M-F	These are open office hours

ID	Component	Hours	Days	Comments
6.300	Juvenile Justice Assessment Team (JJAT)	0800-1700	M-F	These are staff work times.
7.000	**Juvenile Services Division**	**0830-1630**	**M-F**	**These are open office hours**
7.100	Partnership for Youth Justice	0830-1630	M-F	These are open office hours.
7.200	At-Risk Youth (Becca) Program	0830-1630	M-F	These are open office hours
7.300	Court Operations	0830-1630	M-F	These are open office hours
8.000	**Dependency CASA**	**0830-1630**	**M-F**	**These are open office hours**
8.100	Dependency CASA	0800-1700	M-F	These are staff work times.
9.000	**Judicial Administration/Clerk**	**0900-1630**	**M-F**	**These are open office hours**
9.100	Management	0700-1800	M-F	These are staff work times.
9.200	Cashiering	0900-1630	M-F	These are open office hours
9.300	Case Processing	0900-1630	M-F	These are open office hours
9.400	Records Services	0900-1630	M-F	These are open office hours
9.500	Court Services	0900-1630	M-F	These are open office hours
9.600	Step-Up Program	0900-1630	M-F	These are open office hours, has after hours conferencing needs.
9.700	Shared Spaces	0700-1800	M-F	These are staff work times.
10.000	**Prosecuting Attorney**	**0830-1630**	**M-F**	**These are open office hours**
10.100	Juvenile Offender Unit	0800-1700	M-F	These are staff work times.
11.000	Public Defense	0800-1700	M-F	These are staff work times.
11.100	Juvenile Offender Unit	0800-1700	M-F	These are staff work times.
12.000	**Children's Administration & Attorney General**	**0830-1630**	**M-F**	**These are open office hours**
12.100	Juvenile Court Office	0800-1700	M-F	These are staff work times.
13.000	**Security**			
13.100	Security Operations	0500-1200	M-S	
13.200	Central Juvenile Holding	0830-1630	M-F	
13.300	Central Adult Holding	0830-1630	M-F	

Detention Program

ID	Component	Hours	Days	Comments
1.000	**Administration**			
1.100	Public Entry	0600-2100	365/yr	
1.200	Visitation	0600-2100	365/yr	
1.300	Detention Administration (outside of detention)	0600-1800	365/yr	

Appendix F: Anticipated Facility Occupancy Schedule

ID	Component	Hours	Days	Comments
2.000	**Operations**			
2.100	Detention Administration (inside detention)	24/day	365/yr	
2.200	Central Control	24/day	365/yr	
2.300	Admissions Release	24/day	365/yr	
2.400	Staff Support	24/day	365/yr	
3.000	**Support Services**			
3.100	Food Service	0500-1900	365/yr	
3.200	Medical Services	24/day	365/yr	
3.300	General Services	0700-1700	M-F	
3.400	Detention IT services	0700-1700	M-F	
4.000	**Programs**			
4.100	Education	0700-2200	365/yr	
4.200	Recreation	0700-2200	365/yr	
4.300	Library Spiritual Center	0700-2200	365/yr	
5.000	**Housing**			
5.200	Pod "A" Orientation/General Housing	24/day	365/yr	
5.100	Pod "B" General Housing	24/day	365/yr	
5.400	Pod "C" Transitional Housing	24/day	365/yr	

Appendix C: Life Cycle Cost Analysis Calculations

Systems 2-5
15 year LCCA

Resource Life Cycle Cost Analysis (rLCCA) - Summary

	Strategy Option 2 - High Efficiency Chillers	**Strategy Option 3 - High Efficiency Boilers**	**Strategy Option 4- Active Chilled Beams**	**Strategy Option 5 - Passive Chilled Beams**
	Description	Description	Description	Description
Simple Payback Period (No Financing)	**-18.3**	**-11.6**	**599.2**	**392.1**
Net Present Value (NPV) ($)	**$ (636,251)**	**$ (268,399)**	**$ (2,869,976)**	**$ (3,736,520)**
Years Until Positive NPV (No Financing)	No Payback			
Savings to Investment Ratio	(0.62)	**(1.01)**	**0.02**	**0.04**
Internal Rate of Return (IRR) (%)	N/A	**N/A**	**N/A**	**N/A**
Project Incremental Cost Above Baseline ($)	$ 392,000	$ 133,500	$ 2,943,000	$ 3,875,000
Annual Equivalent Value ($)	$ (54,895)	$ (23,157)	$ (247,620)	$ (322,385)
First Year Resource Savings ($)	$ 5,593	$ 485	$ 10,912	$ 15,883
First Year Non-Resource Savings ($)	$ (27,000)	$ (12,000)	$ (6,000)	$ (6,000)
Net Present Value (NPV) ($)	$ (636,251)	$ (268,399)	$ (2,869,976)	$ (3,736,520)
Modified Internal Rate of Return (MIRR) (%)	-100.00%	-100.00%	N/A	N/A
Include financing?	**No**			

NPV Sensitivity Analysis	Real Discount Rate			Real Discount Rate Adjustment Factor			Real Discount Rate Adjustment Factor			Real Discount Rate Adjustment Factor		
	1.0%	3.0%	5.0%	1.0%	3.0%	5.0%	1.0%	3.0%	5.0%	1.0%	3.0%	5.0%
	$ (675,403)	$ (636,251)	$ (604,568)	$ (290,268)	$ (268,399)	$ (250,723)	$ (2,857,084)	$ (2,869,976)	$ (2,880,306)	$ (3,712,525)	$ (3,736,520)	$ (3,755,781)

First Year Costs	**Utilities**	Electricity Use (kWh)	(13,072)	(176)	110,317	39,977
		Electricity Cost ($)	$ 5,593	$ 14	$ 10,941	$ 15,922
		Natural Gas Use (Therm)	-	(485)	30	40
		Wastewater Cost ($)	$ -	$ -	$ -	$ -
	Fue	Vehicle Fuel Cost ($)	$ -	$ -	$ -	$ -
	GHG	Carbon Use (MTE)	(8.35)	(2.68)	70.59	25.73
		Carbon Cost ($)	$ -	$ -	$ -	$ -
First Year Savings	**Utilities**	Electricity Use Savings (kWh)	13,072	176	(110,317)	(39,977)
		Electricity Savings ($)	$ 5,593	$ 14	$ 10,941	$ 15,922
		Natural Gas Use Savings (Therm)	-	485	(30)	(40)
		Wastewater Savings ($)	$ -	$ -	$ -	$ -
	Fue	Vehicle Fuel Savings ($)	$ -	$ -	$ -	$ -
	GHG	Carbon Use Savings (MTE)	8.35	2.68	(70.59)	(25.73)
		Carbon Savings ($)	$ -	$ -	$ -	$ -

Resource Life Cycle Cost Analysis (rLCCA) - Summary

Systems 6-7
15 year LCCA

	Strategy Option 6 - 100% Ground Source	**Strategy Option 7 - Purchased Steam**
	Description	Purchased Steam accounted for under the Purchased Fuel Category.
Simple Payback Period (No Financing)	**82.5**	**-29.5**
Net Present Value (NPV) ($)	**$ (1,629,890)**	**$ (202,244)**
Years Until Positive NPV (No Financing)	No Payback	
Savings to Investment Ratio	0.14	**(0.43)**
Internal Rate of Return (IRR) (%)	-13.70%	**N/A**
Project Incremental Cost Above Baseline ($)	$ 1,905,000	$ 141,000
Annual Equivalent Value ($)	$ (140,626)	$ (17,450)
First Year Resource Savings ($)	$ 27,093	$ (3,577)
First Year Non-Resource Savings ($)	$ (4,000)	$ (1,200)
Net Present Value (NPV) ($)	$ (1,629,890)	$ (202,244)
Modified Internal Rate of Return (MIRR) (%)	-4.40%	-100.00%
Include financing?	**No**	

NPV Sensitivity Analysis	Real Discount Rate			Real Discount Rate Adjustment Factor		
	1.0%	3.0%	5.0%	1.0%	3.0%	5.0%
	$ (1,584,971)	$ (1,629,890)	$ (1,666,167)	$ (212,532)	$ (202,244)	$ (193,959)

			Strategy Option 6	Strategy Option 7
First Year Costs	Utilities	Electricity Use (kWh)	(33,001)	(176)
		Electricity Cost ($)	$ 22,957	$ 14
		Natural Gas Use (Therm)	-	-
		Natural Gas Cost ($)	$ 4,136	$ 4,136
		Water Use (CCF)	-	-
		Water Cost ($)	$ -	$ -
		Wastewater Use (CCF)	-	57
		Wastewater Cost ($)	$ -	$ (627)
		Total Utility Cost ($)	$ 27,093	$ 3,523
	Fuel	Vehicle Fuel Use (MMBTU)	Choose Fuel	355.0
		Vehicle Fuel Cost ($)	$ -	$ 7,100
	GHG	Carbon Use (MTE)	(21.07)	18.70
		Carbon Cost ($)	$ -	$ -
First Year Savings	Utilities	Electricity Use Savings (kWh)	33,001	176
		Electricity Savings ($)	$ 22,957	$ 14
		Natural Gas Use Savings (Therm)	4,260	4,260
		Natural Gas Savings ($)	$ 4,136	$ 4,136
		Water Use Savings (CCF)	-	-
		Water Savings ($)	$ -	$ -
		Wastewater Use Savings (CCF)	-	(57)
		Wastewater Savings ($)	$ -	$ (627)
		Total Utility Savings ($)	$ 27,093	$ 3,523
	Fuel	Vehicle Fuel Use Savings (MMBTU)	Choose Fuel	(355.0)
		Vehicle Fuel Savings ($)	$ -	$ (7,100)
	GHG	Carbon Use Savings (MTE)	43.65	3.88
		Carbon Savings ($)	$ -	$ -

Systems 2-5
30 year LCCA

Resource Life Cycle Cost Analysis (rLCCA) - Summary

	Strategy Option 2 - High Efficiency Chillers	**Strategy Option 3 - High Efficiency Boilers**	**Strategy Option 4- Active Chilled Beams**	**Strategy Option 5 - Passive Chilled Beams**
	Description	Description	Description	Description
Simple Payback Period (No Financing)	**-18.3**	**-11.6**	**599.2**	**392.1**
Net Present Value (NPV) ($)	**$ (1,022,765)**	**$ (422,658)**	**$ (2,850,662)**	**$ (3,686,964)**
Years Until Positive NPV (No Financing)	No Payback			
Savings to Investment Ratio	(1.61)	**(2.17)**	**0.03**	**0.05**
Internal Rate of Return (IRR) (%)	N/A	**N/A**	**N/A**	**N/A**
Project Incremental Cost Above Baseline ($)	$ 392,000	$ 133,500	$ 2,943,000	$ 3,875,000
Annual Equivalent Value ($)	$ (53,746)	$ (22,211)	$ (149,802)	$ (193,749)
First Year Resource Savings ($)	$ 5,593	$ 485	$ 10,912	$ 15,883
First Year Non-Resource Savings ($)	$ (27,000)	$ (12,000)	$ (6,000)	$ (6,000)
Net Present Value (NPV) ($)	$ (1,022,765)	$ (422,658)	$ (2,850,662)	$ (3,686,964)
Modified Internal Rate of Return (MIRR) (%)	-100.00%	-100.00%	N/A	N/A

Include financing?	**No**

NPV Sensitivity Analysis	Real Discount Rate			Real Discount Rate Adjustment Factor			Real Discount Rate Adjustment Factor			Real Discount Rate Adjustment Factor		
	1.0%	3.0%	5.0%	1.0%	3.0%	5.0%	1.0%	3.0%	5.0%	1.0%	3.0%	5.0%
	$ (1,271,313)	$ (1,022,765)	$ (858,440)	$ (535,618)	$ (422,658)	$ (349,027)	$ (2,821,601)	$ (2,850,662)	$ (2,870,480)	$ (3,627,428)	$ (3,686,964)	$ (3,727,518)

			Option 2	Option 3	Option 4	Option 5
First Year Costs	**Utilities**	Electricity Use (kWh)	(13,072)	(176)	110,317	39,977
		Electricity Cost ($)	$ 5,593	$ 14	$ 10,941	$ 15,922
		Natural Gas Use (Therm)	-	(485)	30	40
		Wastewater Cost ($)	$ -	$ -	$ -	$ -
	Fue	Vehicle Fuel Cost ($)	$ -	$ -	$ -	$ -
	GHG	Carbon Use (MTE)	(8.35)	(2.68)	70.59	25.73
		Carbon Cost ($)	$ -	$ -	$ -	$ -
First Year Savings	**Utilities**	Electricity Use Savings (kWh)	13,072	176	(110,317)	(39,977)
		Electricity Savings ($)	$ 5,593	$ 14	$ 10,941	$ 15,922
		Natural Gas Use Savings (Therm)	-	485	(30)	(40)
		Wastewater Savings ($)	$ -	$ -	$ -	$ -
	Fue	Vehicle Fuel Savings ($)	$ -	$ -	$ -	$ -
	GHG	Carbon Use Savings (MTE)	8.35	2.68	(70.59)	(25.73)
		Carbon Savings ($)	$ -	$ -	$ -	$ -

Resource Life Cycle Cost Analysis (rLCCA) - Summary

Systems 6-7
30 year LCCA

	Strategy Option 6 - 100% Ground Source	**Strategy Option 7 - Purchased Steam**
	Description	Purchased Steam accounted for under the Purchased Fuel Category.
Simple Payback Period (No Financing)	**82.5**	**-29.5**
Net Present Value (NPV) ($)	**$ (1,440,219)**	**$ (252,036)**
Years Until Positive NPV (No Financing)	No Payback	
Savings to Investment Ratio	0.24	**(0.79)**
Internal Rate of Return (IRR) (%)	-2.47%	**N/A**
Project Incremental Cost Above Baseline ($)	$ 1,905,000	$ 141,000
Annual Equivalent Value ($)	$ (75,683)	$ (13,244)
First Year Resource Savings ($)	$ 27,093	$ (3,577)
First Year Non-Resource Savings ($)	$ (4,000)	$ (1,200)
Net Present Value (NPV) ($)	$ (1,440,219)	$ (252,036)
Modified Internal Rate of Return (MIRR) (%)	-1.37%	-100.00%

Include financing?	**No**

NPV Sensitivity Analysis	Real Discount Rate			Real Discount Rate Adjustment Factor		
	1.0%	3.0%	5.0%	1.0%	3.0%	5.0%
	$ (1,288,788)	$ (1,440,219)	$ (1,542,808)	$ (290,595)	$ (252,036)	$ (226,218)

			Option 6	Option 7
First Year Costs	**Utilities**	Electricity Use (kWh)	(33,001)	(176)
		Electricity Cost ($)	$ 22,957	$ 14
		Natural Gas Use (Therm)	-	-
		Natural Gas Cost ($)	$ 4,136	$ 4,136
		Water Use (CCF)	-	-
		Water Cost ($)	$ -	$ -
		Wastewater Use (CCF)	-	57
		Wastewater Cost ($)	$ -	$ (627)
		Total Utility Cost ($)	$ 27,093	$ 3,523
	Fuel	Vehicle Fuel Use (MMBTU)	Choose Fuel	355.0
		Vehicle Fuel Cost ($)	$ -	$ 7,100
	GHG	Carbon Use (MTE)	(21.07)	18.70
		Carbon Cost ($)	$ -	$ -
First Year Savings	**Utilities**	Electricity Use Savings (kWh)	33,001	176
		Electricity Savings ($)	$ 22,957	$ 14
		Natural Gas Use Savings (Therm)	4,260	4,260
		Natural Gas Savings ($)	$ 4,136	$ 4,136
		Water Use Savings (CCF)	-	-
		Water Savings ($)	$ -	$ -
		Wastewater Use Savings (CCF)	-	(57)
		Wastewater Savings ($)	$ -	$ (627)
		Total Utility Savings ($)	$ 27,093	$ 3,523
	Fuel	Vehicle Fuel Use Savings (MMBTU)	Choose Fuel	(355.0)
		Vehicle Fuel Savings ($)	$ -	$ (7,100)
	GHG	Carbon Use Savings (MTE)	43.65	3.88
		Carbon Savings ($)	$ -	$ -

Appendix D: King County Reports

BTU's per mlb of steam delivered by SS	1,194,000
BTU's per mlb of steam (usable)	1,105,600
Change in PSE Rate/mm BTU	0.0056
Change in SS Fuel Charge/ mlb	0.01
Change in SS Fuel Charge/mm delivered BTU	0.008375
Change in SS Fuel Charge/mm usable BTU	0.009045
Implied Seattle Steam Efficiency Factor	67%
Implied Usable Steam Efficiency Factor	62%

Seattle Steam Rate Sheet Language:
"One-cent ($0.01) per thousand pounds of steam (Mlb) per month for each increase or decrease of fifty-six hundredths of a cent ($0.0056) of the weighted average of the delivered cost of one million BTUs of the Cost of Gas"

Record of Analysis for CO_2 Emission Calculation

Ben Thompson

2/27/13

Link to analysis: Greenhouse Gas Calculation for Post Conversion.xlsx

One of the objectives of our engagement is to calculate the greenhouse gas (GHG) emission impact of converting the King County Courthouse and King County Jail from Seattle Steam to on-site natural gas boilers. There were two basic steps to conduct this analysis:

1. Determine the current GHG emissions of the on-site boilers
2. Determine how much GHG emissions there would have been if King County had stayed on Seattle Steam

In preparation for this analysis, I spoke to Neil Caudill from WA State Department of Ecology about the best way to do these calculations. Mr. Caudill provided the following information via email:

Email from Neil Caudill about Greenhouse Gas Calculation

Included in this email was a link to the Electronic Code of Federal Regulations (CFR), section 98.33 "Calculating Greenhouse Gas (GHG) Emissions" (see page 2 for applicable formulas). This section included several formulas that the owners and operators of certain facilities that directly emit GHGs are required to use to calculate emissions due to their activities. Each entity selects the appropriate formula based on how the fuel input is measured.

Current CO_2 Emissions

To determine the current CO_2 emissions for operations in the Courthouse and Jail, I used equation C-1a, as the natural gas bills we have are expressed in therms. This analysis is the Greenhouse Gas Calculation for Post Conversion worksheet "On-Site Boilers". The steps I took to conduct this analysis are:

1. Took the therms used for each building from the analysis Larry did of the utility bills post-conversion, this document is linked in cell B6. I copied this data into columns B and C.
2. Added columns B and C together to find total therms for each month, in column D
3. In column E, I used the formula from the CFR, that is in cell B1, to calculate the CO_2 emissions based on the total therms per month.
4. The other component of this formula, beside amount of gas measured in therms, is the emission factor of the fuel. To determine the emission factor of the fuel (in this case, natural gas) I went to PDF page 36 of the CFR, which includes a table of various fuel types and used the factor for gas, which is 53.02, this is in cell B3.

In addition to the CFR method, a very common way entities report GHG emissions is documented in the Climate Registry Protocol. To check that these methods produced consistent answers, I used the appropriate formula from the protocol, outlined on PDF page 83 of the linked document. To use this method, you convert fuel usage, in this case therms of natural gas to MMBTU and then multiply by the default emission factor for that fuel, which is found 2013-Climate-Registry-Default-Emissions-Factors

I went through those steps and confirmed the values that I calculated using the CFR methodology. This is in column M. (Note: I just used March 2010 and onward as according to FMD this was the first month that King County was fully using the on-site boilers and off Seattle Steam. The months prior were hybrid in that energy consumption was a mix of both on-site and off-site sources).

Seattle Steam Emissions

The calculation to determine what the GHG emissions would have been if King County had stayed on Seattle Steam are slightly more complicated, as there are several ways to calculate emissions from district energy, conversions must be made between energy used on-site versus what would have been steam consumption, and Seattle Steam did not make available some of the data necessary to use the most accurate means of calculating CO_2 emissions.

To determine the emissions from Seattle Steam I used the steps outlined in chapter 15 of the Climate Registry Protocol "Indirect Emission from Imported Steam, District, Heating, Cooling, and Electricity from a CHP Plant". The protocol outlines three main ways to determine CO_2 emissions on PDF page 118, highlighted and labeled 1-3. We used all three methods and compared the results we found.

In order to use method 1, we had to obtain emission factors from Seattle Steam (this analysis is in worksheet "Seattle Steam Factors"). They provided these on their website, however, it was unclear to us how current these factors were, therefore, in our meeting with Seattle Steam, ROI Seattle Steam, 4-8-13, we requested updated factors. These were provided via email by Stan Gent, Emails from Stan Gent\Inbox, see highlighted factors on page 1 (these factors are 171 lbs of CO_2 per MMBTU for the Jail and 176 for the Courthouse, which are in cells B2 and B3).

In order to determine what, I converted the amount of natural gas purchased into an equivalent amount of steam. To do this, I took the following steps:

1. In columns B and C, I took the total therms from the utility bills. This is the same source as was used for the calculation of emissions under the current system.
2. Translated the total therms by facility to MMBTUs. This conversion was straight forward as 1 therm equals .1 MMBTU, see highlighted text in EIA Therm to MMBTU Conversion factor for this factor, also in cell B4. This conversion is in columns E and F. The reason we did this conversion, was to put the energy that would have been consumed in the same units that Seattle Steam supplied its emission factor in.
3. In order to more accurately calculate the amount of energy that would have been purchased from Seattle Steam, we had to make allowances for the fact that there are efficiency differences between how the County used natural gas and steam. Namely, when we purchased steam, this steam was converted via heat exchangers to hot water that was used for heating and hot water. In the case of natural gas, the natural gas is burned to heat water. There are differences in the efficiency of these two methods. In order to accurately estimate the amount of steam that

would be needed, we had to account for these differences. In the pro forma analysis that was done prior to this project being implemented, FMD and McKinstry estimated that the efficiency differences for the Jail would be 9.7% less and for the Courthouse 2.4%. Therefore, in order to determine the amount of MMBTUs that would be needed, I multiplied the estimates in columns E and F by the respective factors to determine total MMBTUs in columns H and I.

4. Once I had the MMBTUs for each building, I calculated the pounds of CO_2 just by multiplying by the respective factors for each building. These calculations are in columns K and L.
5. To convert from pounds to metric tonnes, I divided pounds by 2,200. This is in columns N and O and then the total for both buildings is in column P.

In order to calculate the CO_2 from Seattle Steam using the second method, which relies on actual boiler efficiency and transport loss number, we asked Seattle Steam for this information. However, they choose not to provide these factors, see ROI Seattle Steam, 4-8-13. Therefore, we had to estimate these two numbers. We had done work trying to reverse engineer these factors using the Seattle Steam rate sheet. The way we did this is explained in Estimating SS Efficiency from Fuel Rate Escalation

Based on this estimate of Seattle Steam having approximately 50% losses associated with transport and other factors, I set the total efficiency factor of the system at 50%, in cell F1 of worksheet “Seattle Steam Estimates.” Then I took the following steps:

1. Calculated the EF/TE factor according to the protocol by dividing the Natural Gas emission factor of 53.02 by the total efficiency factor to get a EF/TE 107.1111
2. In addition to understanding the total efficiency factor we had to take into consideration the amount of biomass, specifically wood, that Seattle Steam burns. The reason for this is that under the protocol biomass is reported separately from other fuels in calculating emissions. Therefore, we requested and Mr. Gent provided an estimate of the total carbon dioxide emitted from Seattle Steam for 2012 (see sticky note).
3. Cells A42 to G44 show the calculations I did to determine the percentage of wood burned. The complicating issue in this calculation is that natural gas and biomass have different emission factors, therefore, the relative percentages of inputs are not just each input’s respective percentage of CO_2. The emission factor for each input is shown in cells C46 and C47. Basically, natural gas produces about 57% less carbon than biomass, therefore, once I converted metric tonnes (mtons) to kilograms (kgs), I multiplied the amount of biogenic CO_2 by 57% to determine what percentage of the total CO_2 was from each input. These calculations are in cells G42 and G43. Thus we estimate that Seattle Steam used 8.4% of the total inputs as biogenic.
4. In order to remove the steam generated from biogenic sources, I multiplied the total MMBTUs for each building by the percentage of natural gas (91.6%), which is in cell F42. These calculations are in columns E and F.
5. To calculate emissions, I used the same formula as the previous method, MMBTUs * Emission Factor, except in this case, I used emission factor divided by the total system efficiency, as is described in the protocol. This value is 107.11 and is in cell J1. Lastly, I multiplied the product by .0001 to go from kilograms to metric tonnes. These calculations are in columns H and I and the totals are in column J.

The third way to calculate CO_2 described in the protocol is to use a default efficiency factor of 75%. This is somewhat problematic, as it is just a default number with no indication as to whether the steam is delivered in an open or closed system, size of the system, whether it is high or low pressure, etc. In order to use this method, I took the following steps:

1. In worksheet “Seattle Steam Estimate” I calculated the EF/TE by dividing the natural gas emission factor (53.02) by the total efficiency factor (75%) in cell T1 to get an EF/TE value of 70.693.
2. Multiplied this EF/TE value by the MMBTUs in columns E and F. These were the MMBTUs that already controlled for the amount of biogenic fuel, therefore, this estimate accounts for that issue. These calculations are in columns N and O. Also converted KGs to metric tonnes.
3. Added these calculations together in column P to get total estimated emissions for both buildings.

Comparison

After calculating emissions for the current on-site boilers and also calculating estimated emissions if King County had stayed on Seattle Steam, I summarized these figures in the worksheet “Comparison”. Columns B-E are the calculations described above. There is also an average of these methods in column F. Columns H-K compare these estimated emissions with the on-site values and show the following differences:

Method	Difference from On-Site
SS Factors	40%
SS Estimate	74%
75% Default Factor	15%
Average of 3 SS Methods	43%

So using all of the different methods, we come to the conclusion that under current operating conditions staying on Seattle Steam would have resulted in greater emissions of CO_2 than has occurred after the transition to on-site natural gas boilers.

Average Annual Decrease

In order to attempt to quantify the average annual decrease of CO_2 that has occurred because of King County’s transition to on-site boilers, I took the following steps:

1. Calculated the total amount of CO_2 from on-site, SS Factors and SS Estimates for 2011 and 2012. I did not use the 75% efficiency factor, as it is just a default value and is not representative of the local conditions. These calculations are in the “Comparison” worksheet in column M-O.
2. Calculated the difference between on-site and the two factors in column O.

3. I averaged these differences in cell O11 to find that the average annual decrease was about 2000 metric tonnes of CO_2.

Appendix E: Preliminary Energy Star Target Finder Tool Values

The following sheet is a preliminary calculation using the Energy Star Target Finder tool to estimate the energy and greenhouse gas emissions for a comparable existing building.

LEARN MORE AT
energystar.gov

ENERGY STAR® Statement of Energy Design Intent (SEDI)[1]

N/A

ENERGY STAR®
Design Score[2]

Primary Property Function: Courthouse
Gross Floor Area (ft^2): 205,000
Estimated Date of Certification of Occupancy: ________

Date Generated: June 05, 2015

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[1] This form may be used to apply for the ENERGY STAR Designed to Earn. This form was generated from Portfolio Manager's target finder: http://www.portfoliomanager.energystar.gov/targetfinder.

[2] The ENERGY STAR Score is based on total source energy. The scale is 1-100. A score of 75 is the minimum to be eligible for the ENERGY STAR.

Property & Contact Information for Design Project

Property Address	**Project Architect**	**Owner Contact**
________	____ ________	____ ________
________, Washington 98122	,	,
	(___)___-_____	(___)___-_____
	______________	______________
Property ID: 4444227	**Architect Of Record**	**Property Owner**
	______________	______________
	______________	,
	__________, ____ _____	(___)___-_____
	(___)___-_____	

Estimated Design Energy

No estimated energy information provided.

Estimated Design Use Details

Courthouse		**Prison/Incarceration**	
Gross Floor Area	155,000 Sq. Ft.	Gross Floor Area	50,000 Sq. Ft.
Percent That Can Be Cooled	50 % or more ← default value	Number of Computers	40
Percent That Can Be Heated	50 % or more ← default value	Number of Workers on Main Shift	150
Number of Computers	310 ← default value	Weekly Operating Hours	168
Number of Workers on Main Shift	356.5 ← default value		
Weekly Operating Hours	75		

Design Energy and Emission Results

Metric	Design Project	Median Property	Estimated Savings
ENERGY STAR Score (1-100)	N/A	50	N/A
Energy Reduction (from Median)(%)	N/A	0	N/A
Source Energy Use Intensity (kBtu/ft²/yr)	0	243	243
Site Energy Use Intensity (kBtu/ft²/yr)	0	108	108
Source Energy Use (kBtu/yr)	0	49,814,069	49,814,069
Site Energy Use (kBtu/yr)	0	22,240,230	22,240,230
Energy Costs ($)	0	377,973	377,973
Total GHG Emissions (Metric Tons CO2e)	0	1,934	1,934