Technical Analysis Study

For

PSU Fourth Avenue Building

1900 SW 4th Ave

Portland, OR 97204

Project

#1527488429

Sponsored by:

Energy Trust of Oregon

Existing Buildings Program

Submitted by:

Interface Engineering

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NEXT STEPS FOR PARTICIPANT

APPLY FOR ENERGY TRUST INCENTIVES

Make an implementation decision: Please evaluate the information contained in this report and any potential measures and incentives listed in the Form 110C – Project Detail and Incentive Estimates (produced by PMC). Have your contractors bid for the measure(s) you wish to implement and send the PMC a copy of the final bid. PMC will review your contractor's proposed scope to determine compliance with Energy Trust's program requirements and the energy efficiency measures as described in this report. After we determine that the project bid specifications match the studied measure, Form 120C – Incentive Application will be provided for you to review. If you apply for Energy Trust incentives for your project, your signed Form 120 C - Incentive Application must be provided to the PMC BEFORE you issue purchase orders or make other financial commitments to begin the project work.

Upon Completion of the Project: The PMC must be notified once the project is completed in order to arrange a post-installation inspection for projects that receive incentives greater than $5,000. The program must receive all required documentation and perform any required post installation inspections before incentives can be issued.

APPLY FOR ENERGY TRUST SOLAR INCENTIVES

Make a solar implementation decision: Please evaluate the solar site evaluation (SSE), if included in this report. Your PMC will arrange a meeting to discuss the results of the evaluation. Or, if you wish to move forward, your PMC will provide you with a list of qualified Trade Ally contractors. Obtain bids on the solar measures you want to implement. When you've selected a solar Trade Ally contractor for the installation, the Trade Ally will provide and submit the necessary incentive application paperwork to Energy Trust on your behalf. The PMC and Energy Trust's solar staff are available to answer all your solar questions.

Upon Completion of the Solar Project: The solar Trade Ally will arrange for the final Energy Trust inspections, and within 30 days of a successful inspection you'll receive your solar incentive check from Energy Trust.

EXECUTIVE SUMMARY:

This report documents a technical analysis performed for future energy efficiency improvements to the HVAC systems at the Fourth Avenue Building (FAB) located at 1900 SW Fourth Avenue in Portland, OR. The facility was built in 1962, is one story below ground, two above, and also contains two parking levels beneath part of the lower level. Total floor area is 200,000 square feet. The FAB is interconnected with two adjacent buildings: the 156,000 ft^2 City Tower and the 130,000 ft^2 Engineering Building. These interconnected buildings receive their main electrical service through the FAB and also share some building services.

The EEMs in this analysis affect the FAB and adjacent City Tower which currently shares a chilled water loop with FAB. FAB, City Tower and Engineering Building are on a single utility account. Using data from the last three years, the average annual energy use for the three buildings was 16,500 therms, and 12.4 million kWh. This translates to an Energy Use Index of 90 kBtu/sqft/yr. Table 1 below lists the energy efficiency recommendation for this facility. Combined, these recommendations are expected to reduce the building's gas usage by 64% and reduce the electricity consumption by 3%.

ENERGY EFFICIENCY MEASURE (EEM) SUMMARY

- **EEM 1: Chiller Plant Upgrade:** Replace existing chiller with a high efficiency chiller and a heat recovery chiller. Upgrade to variable speed pumping.
- **EEM 2: Well-Water Connection:** Install a plate and frame heat exchanger to take engineering building reinjection well water and make FAB chilled water
- **EEM 3: Heat Recovery to City Tower:** Provide heat to the city tower from FAB heat recovery and ground sources
- **EEM4: Chilled Water to City Tower:** Remove the city tower chiller and provide chilled water from FAB
- **EEM 5: OIT Datacenter Improvements:** Install heat aisle curtains in server room and add VFD to existing Liebert CRAC units
- **EEM 6: Add UPS Fan Coils to Heat Recovery Loop:** Re-configure CHW piping so that UPS room is served by dedicated heat recovery chiller

Table 1: EEM summary Table

Measure Number	Estimated Annual kWh Savings	Estimated Annual Therm Savings	Total Annual Energy Cost Savings	Annual *Non-Energy Cost Savings	Installation Cost	** Simple Payback
EEM #1	824,694	14,249	$ 73,627	$ 7,800	$ 679,841	8.3
EEM #2	n/a	n/a	n/a	n/a	n/a	n/a
EEM #3	75,469	0	$ 5,434	$ 0	$ 41,262	7.6
EEM #4	n/a	n/a	n/a	n/a	n/a	n/a
EEM #5	151,436	0	$ 10,903	$ 0	$ 100,335	9.2
EEM #6	23,589	1,657	$ 3,355	$ 0	$ 17,390	5.2

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*Non-energy cost benefits are from items such as avoided maintenance or water costs.

** Cost savings are based on Energy Trust average utility rates of $0.072/kWh and $1.00/therm for payback calculation. Actual participant rate may be different.

PROJECT DESCRIPTION

- Location: 1900 SW 4th Ave. Portland, OR
- Year built: 1962
- Building Square Footage: 200,000 ft^2 plus 166,000 ft^2 below grade parking
- Type of Facility: University Offices, University Classroom/Research, Datacenter, PacifiCorp Offices & Datacenter, Parking
- Operating Hours: Primary occupancy is 7:30 AM – 5:30 PM weekdays with reduced occupancy weekends, holidays and school breaks. Areas occupied by PacifiCorp and the PSU data center are used 24/7.

Table 2: Historical Building Energy Use

	Electric Use (kWh)				Natural Gas Use (Therms)			
	Ending 6/2011	Ending 6/2012	Ending 6/2013	Average	Ending 6/2011	Ending 6/2012	Ending 6/2013	Average
Jun	953,386	1,002,697	1,051,028	1,002,370	19	0	0	6
Jul	1,059,667	1,079,564	974,267	1,037,833	0	0	0	0
Aug	978,965	1,035,708	1,042,546	1,019,073	0	0	0	0
Sep	928,692	1,069,343	1,026,778	1,008,271	9	9	34	17
Oct	966,569	966,603	970,852	968,008	216	403	296	305
Nov	2,107,855	1,909,437	998,280	1,671,857	1,391	1,721	2,264	1,792
Dec	327,662	309,613	1,073,832	570,369	3,930	3,923	2,264	3,372
Jan	1,064,885	1,068,993	978,754	1,037,544	5,482	2,699	5,695	4,625
Feb	1,114,703	1,138,549	923,140	1,058,797	4,875	2,699	4,415	3,996
Mar	1,038,781	1,034,604	943,918	1,005,768	1,575	1,007	1,221	1,268
Apr	1,080,594	981,294	949,553	1,003,814	1,640	322	319	760
May	1,021,091	1,025,660	933,230	993,327	988	61	0	350
Total	12,642,850	12,622,065	11,866,178	12,377,031	20,125	12,844	16,508	16,492
Total Energy use in kBtu					43,879,663			
Energy Use Index Kbtu/sf/yr					90			

Energy use and EUI shown for combination of FAB, Engineering Building and City Tower, which all share a utility account.

Building Shell

- Number of stories: 3
- Square footage and height of each story
    - Parking 1: 83,000 ft^2.
    - Parking 2: 83,000 ft^2.
    - Lower Level (below grade): 125,000 ft^2. 12.5' floor-floor ht.
    - Plaza Level (ground floor): 40,000 ft^2. 12.5' floor-floor ht.
    - Second Level: 40,000 ft^2. 12.5' floor-floor ht.
- Total volume of the building: 2,562,500 ft^3 (excludes parking)
- Tightness of the building: Average or better due to significant below grade square footage

Internal Loads

- Occupancy
    - Typical of a University building
- Lighting
    - Typical office/classroom lighting. Installed LPD estimated at 1.1 W/sqft.
- Equipment
    - Office computers, computer labs, datacenters (see details below)

Water Side HVAC System

- Chilled water loop system
    - Chiller – type, IPLV, COP
        - Two chillers currently in service: WCU-4, WCU-5
        - 550 and 510 tons respectively
        - Trane CVHE 050 model
        - Full load efficiency is 0.53 kW/ton (6.6 COP)
        - Installed in 1985 (approx.)
        - Controlled in a lead/lag arrangement
    - Pumps
        - Condenser Pumps
            - CWP-4, CWP-5
            - Constant speed
            - Scheduled to run as needed for WCU-4/5 operation or in support of DHRC chilled water system.
        - Evaporator pumps
            - Primary
                - CHWP-4, CHWP-5
                - Constant Speed
            - Secondary
                - P-18-1, P-18-2, P-18-3.
                - Lead/lag controls
                - Recently replaced with premium efficiency motor

            - Variable speed drive
            - Each is 25 HP
    - Cooling Tower
        - Fan – type, power, schedule
    - Details of operations
        - 24/7 operation to serve data-center, UPS, Telecom and other year-round loads
        - CHW temperature reset between 44 and 55F based on maximum AHU cooling demand
- Dedicated Heat Recovery Chiller (DHRC) system
    - Chiller
        - DHRC-1, DHRC-2, DHRC-3 Heat Recovery Modular Chillers
            - 50 Tons each. Designed for n+1 redundancy
            - Variable flow valving
            - Model: Multistack M550X6H1W
            - NPLV efficiency 0.664 kW/ton, Full load efficiency 1.443 kW/ton
            - Full load heating COP = 3.43
    - Pumps
        - CHWP-1A, CHWP-1B Chilled water pumps
            - Variable flow
            - 285 GPM
            - 10 HP
        - CWP-1A, CWP-1B Condenser Water Pumps
            - Variable flow
            - 390 GPM
            - 7.5 HP
        - CWP-2A, CWP-2B Condenser Water Bypass Pumps
            - Variable flow
            - 390 GPM
            - 3 HP
    - Heat Exchangers
        - HX-1, HX-2
        - Located between DHRC and cooling tower
        - Plate and frame
- Hot Water Loop System
    - Boiler
        - GB-1 Gas Boiler
            - 84% eff
            - 1,209 kBtu/h Capacity, 80 GPM
        - EB-1 Electric Boiler
            - Backup boiler
    - Pumps

- HWP-1
  - 80 GPM, constant flow boiler circulation pump
  - 2 HP
- P-19-1, P-19-2 Heating Water pumps
  - Premium efficiency motors
  - Variable speed
  - 5 HP

Air Side HVAC System

- The FAB is currently served by the following main air handling systems:

System Tag	Description	CFM	Area Served
SF-GA	VAV	36,760	Lower Level
SF-1A	VAV	23,390	Plaza level interior
SF-1B	VAV Dual Duct	7,970	Plaza level perimeter
SF-2A	VAV	43,490	2nd floor interior
SF-2B	VAV	14,000	2nd floor perimeter
ASU-9	CV. Abandoned	6,130	Lower level
ASU-12	VAV	9,600	Lower level
ASU-14	VAV	21,000	Lower level
ASU-15	VAV	21,000	Lower Level

- In addition to the main air handling units, there are multiple cooling only constant volume fan coils and computer room AC units serving labs and data center zones
- Controls – Cooling setpoints are typically kept at 72-75F, and heating setpoints vary from 50 to 73F. Night setbacks are 65 for heating, 82 for cooling. HVAC fans run daily from 6am to 10pm, with reduced hours on weekends.
- Other Building Energy Equipment
  - Datacenters
    - There are three datacenters in the FAB: MAIN, ENG and COLO. The table below reports as-operated loads, which were calculated by the installed UPS and PDU equipment.

Datacenter	Room #	Load	HVAC Equipment
MAIN	090-07	72 kW	CRU-3 (17 tons), CRU-4 (17 tons)
ENG	090-06	24 kW	
COLO	090-04	37 kW	CRU-1 (17 tons), CRU-2 (17 tons), CRU-5 (XX tons)
Total		133 kW	

  - UPS
    - The building has an uninterruptible power supply, which is served by two fan coil units, FCU-6A and FCU-6B. Each FCU is approximately 6 tons running at 3,000 CFM.
  - Transformer Room – served by small fan coil
  - Switchgear – served by small fan coil

DETAILED DESCRIPTION OF THE PROPOSED MEASURES

EEM1 – CHILLER PLANT UPGRADE

Baseline Condition

In the building's current configuration two chillers (WCU-4 and WCU-5) provide cooling for all of the air handlers in the FAB, with the exception of the data center which is served by dedicated heat recovery chillers. WCU-4 and WCU-5 are both Trane CVHE 050 model chillers, with capacities of 550 and 510 tons respectively. Only one chiller operates at a given time, with the second chiller serving as a backup unit. While the chiller's nameplate full load efficiency is 0.53 kW/ton, they are often operated at a very low load. Facilities personnel have measured the as-operated low load efficiency to be 2.5 kW/ton. Both chillers were installed in approximately 1985, and rebuilt in 2008 and 2011.

Pumping is currently constant speed on the primary CHW loop and condenser water loop, with variable speed secondary.

Proposed Condition

The proposed EEM would install two new chillers to replace one of the existing chillers. One chiller would be designed to meet peak summer cooling demand using a highly efficient magnetic bearing compressor. The second chiller would be a heat recovery unit sized to meet the building's base cooling load while simultaneously providing heat to the hot water loop. An existing 500 ton chiller will remain installed as a backup unit.

Pumping will be upgraded to a variable speed primary CHW loop and variable speed CW loop.

The following will be required to implement this measure:

- 500 ton high efficiency magnetic bearing centrifugal chiller
- 100 ton heat recovery chiller (1700 MBH heating capacity)
- Controls
- Piping modification to tie new heat recovery chiller into hot water loop
- VFD on CHW and CW pumps

Table 3: Summary of EEM 1

	kWh Savings	Therm Savings
Estimated energy savings	824,694	14,249
Age of equipment being replaced	28 yr	
Past major rebuild or main component replacement? What and when?	Existing chillers were rebuilt in 2008 & 2011	
Early retrofit or end-of-life replacement	Early Retrofit	
Measure Cost	$ 679,841	
Notes	Maintenance savings of approximately $7,800 per year are also expected	

Table 4: EEM 1 Conditions

Item	Baseline Condition	Proposed Condition
Chiller full load kW/ton	0.65	0.487
Heat recovery chiller	No	Yes
Chilled Water Primary pumping	Constant Speed	Variable Speed
Condenser Water pumping	Constant Speed	Variable Speed

EEM2 – WELL-WATER CONNECTION

Baseline Condition
The FAB currently has no connection to the ground-well which provides water to heat pumps serving the adjacent Engineering Building (EB).

Proposed Condition
This measure investigated the feasibility of using EB well water to generate chilled water for FAB. A full year of temperature trend data from the building automation system (BAS) revealed that average well water temperatures are 55°F or higher, which will not generate cold enough chilled water for the FAB.

A possible use of the well water would be to cool the condenser on a new Liebert computer room air conditioning (CRAC) unit being considered for the data center as a redundant unit. Since this unit's intent is to add redundancy to the system, energy savings are not accounted for in the current study.

Table 5: Summary of EEM 2

	kWh Savings	Therm Savings
Estimated energy savings	n/a	n/a
Age of equipment being replaced	n/a	
Past major rebuild or main component replacement? What and when?	n/a	
Early retrofit or end-of-life replacement	n/a	
Incremental Cost	n/a	
Notes	n/a	

EEM3 – HEAT RECOVERY TO CITY TOWER

Baseline Condition

The City Tower is located directly above the FAB, and FAB chilled water is used for cooling in the City Tower. Heating in the tower is currently provided by electric resistance terminal reheat units, as well as heating coils in ASU-11, 12 and 13 served by the FAB hot water loop. City Tower AHU-1 currently serves floors 3-7 and does not contain a heating coil.

Proposed Condition

This measure proposes modifying the hydronic piping to AHU-1 so that the existing cooling coil can also be used as a heating coil during cold weather. Energy savings assume that EEM1 will be implemented before (or in combination with) this measure so that additional heat recovery capacity is available.

Piping will be added to connect the existing chilled water coil to the FAB HW loop (the HW loop is served by the FAB heat recovery chillers). Controls will be installed to isolate this coil from the chilled water loop and run the coil as a heating coil during cold weather. Adding the option for a changeover to heating at the coil in AHU-1 will displace electric resistance heating during morning warm-up, and should also allow a supply air temperature reset which will reduce reheat energy on cold days (some zones will always require cooling, so reheat cannot be fully eliminated). Additional energy savings would be possible by switching to hot water terminal units; however, the initial cost of retrofitting all terminal units does not make this a viable option.

The following will be required to implement this measure:

- HW piping from HW loop to CHW branch serving AHU-1
- 2 way control valves
- Isolation valves
- Additional control points and sequence programming

Non-Energy Savings Description

This measure will eliminate the need to drain the cooling coil, which is currently done annually. Estimated labor cost savings of $800/year.

Table 6: Summary of EEM 3

	kWh Savings	Therm Savings
Estimated energy savings	75,469	0
Age of equipment being replaced	n/a	
Past major rebuild or main component replacement? What and when?	n/a	
Early retrofit or end-of-life replacement	n/a	
Incremental Cost	$ 41,262	
Notes	Calculation assumes EEM1 is also implemented	

Table 7: EEM 3 Conditions

Item	Baseline Condition	Proposed Condition
AHU-1 Heating Coil	None	Changeover from CHW to HW
City tower heat source, floors 3-7	Electric reheat coils	Preheat at AHU, electric reheat

EEM4 – CHILLED WATER TO CITY TOWER

Baseline Condition

The city tower currently has a 100 ton water-cooled chiller (CH-1) that serves ASU-11 and ASU-13. Instead of a traditional cooling tower configuration, the condenser on CH-1 is cooled by the FAB chilled water loop.

Proposed Condition

It has been proposed that CH-1 might be removed from the city tower, and chilled water could be provided directly from the FAB chillers.

Further investigation has determined that the current City Tower chiller (CH-1) is required. This chiller produces chilled water at a temperature of 34°F, and serves air handlers ASU-11 and ASU-13. Both air handlers were part of the original City Tower construction, but were undersized to meet the cooling load with a typical chilled water temperature of 45°F. In order to achieve the required level of cooling a colder CHW supply temperature is required. Since ASU-11 and 13 are still in good working order - replacement is not expected to be cost effective.

Table 8: Summary of EEM 4

	kWh Savings	Therm Savings
Estimated energy savings	n/a	n/a
Age of equipment being replaced	n/a	
Past major rebuild or main component replacement? What and when?	n/a	
Early retrofit or end-of-life replacement	n/a	
Incremental Cost	n/a	
Notes	This measure is not recommended at this time.	

EEM5 – OIT DATACENTER IMPROVEMENTS

Baseline Condition

The Portland State University Office of Information Technology (OIT) currently maintains 3 datacenters as shown in the table below. ENG and COLO are jointly served by 3 air handling units, and share an under-floor air distribution system. MAIN also has under-floor distribution and is served by two units. CRU's 1 through 4 are Liebert FH376C models from 2006, and CRU-5 is a newer Liebert CW060 unit from 2009. All units have constant speed fans.

<table>
<tr><th>Datacenter</th><th>Room #</th><th>Load</th><th>HVAC Equipment</th></tr>
<tr><td>MAIN</td><td>090-07</td><td>72 kW</td><td>CRU-3 (17 tons), CRU-4 (17 tons)</td></tr>
<tr><td>ENG</td><td>090-06</td><td>24 kW</td><td rowspan="2">CRU-1 (17 tons), CRU-2 (17 tons), CRU-5 (17 tons)</td></tr>
<tr><td>COLO</td><td>090-04</td><td>37 kW</td></tr>
<tr><td colspan="2">Total</td><td>133 kW</td><td>85 tons</td></tr>
</table>

Proposed Condition

Hot aisle containment: Modern datacenter design uses a hot-aisle / cold-aisle configuration to avoid air mixing and increase energy efficiency. A retrofit is proposed that will modernize the existing facility by adding containment panels to isolate the existing hot aisle. This will result in reduced mixing between the cold supply air and warm return air, and allows a higher supply air temperature to be used.

Variable air volume: Variable speed drives and associated controls will be added to all CRAC units. This will allow a reduction in fan speed and therefore fan energy use.

Air Sealing: Ensure raised floor is well sealed at all non-essential opening. This will help maintain static pressure in the under-floor plenum, enabling greater energy savings from the variable speed fan retrofit. Supply and return air diffusers that serve un-used regions of the datacenter should be sealed.

Temperature Control: A walk-through of the datacenter revealed room temperatures as low as 53°F. If equipment requirements allow, the temperature setpoints should be adjusted so that server racks are exposed to air temperatures of 72°F or higher. This could result in an increased discharge air temperature from the CRAC units, reduced airflow, and possibly a reduction in chilled water supply temperature. A comprehensive review of current control sequences will be conducted and adjustments made to bring the system up to current best-practice for supply air rate, temperature and CHW temperature control.

Table 9: Summary of EEM 5

	kWh Savings	Therm Savings
Estimated energy savings	151,436	0
Age of equipment being replaced		
Past major rebuild or main component replacement? What and when?		
Early retrofit or end-of-life replacement		
Incremental Cost	$ 100,335	
Notes		

Table 10: EEM 5 Conditions

Item	**Baseline Condition**	**Proposed Condition**
Datacenter hot aisle contained?	No	Yes
Fan control	Constant Speed	Variable Speed
Room setpoint	65	80
Supply air temperature	55	65

EEM6 – ADD UPS FAN COILS TO HEAT RECOVERY LOOP

Baseline Condition

The uninterruptible power supply room (UPS) is currently served by fan coils units FCU-6A and FCU-6B. Each unit is 3,000 CFM and provides 6 tons of cooling for a total capacity of 12 tons. The fan coils are served by the chillers, WCU-4 and WCU-5.

Proposed Condition

Reconfigure the UPS fan coil units to be served by the dedicated heat recovery chillers (DHRC 1, 2, 3). Recovered heat can be used for space heating. Excess heat is rejected to cooling tower CT-1.

The following will be required to implement this measure:

- Piping modifications to tie FCU-6A/6B into the DHRCs chilled water and heating water loops.
- Control system updates to serve and monitor new load on DHRC

Non-Energy Savings Description

The UPS will be served by the newer and more reliable DHRC modular chiller. This change will also consolidate all of the university's datacenter loads, thereby facilitating better metering and benchmarking of IT energy use.

Table 11: Summary of EEM 6

	kWh Savings	Therm Savings
Estimated energy savings	23,589	1,657
Age of equipment being replaced	n/a	
Past major rebuild or main component replacement? What and when?	n/a	
Early retrofit or end-of-life replacement	n/a	
Incremental Cost	$ 17,390	
Notes		

Table 12: EEM 6 Conditions

Item	Baseline Condition	Proposed Condition
FCU-6A/6B CHW System	Central chillers WCU-4/5	Heat recovery chiller (DHRC)

Appendix

EEM 1: Detailed Calculations

Calculation Methodology

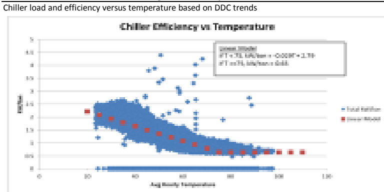
Existing cooling load is calculated by using BAS trend data to estimate chiller loading and efficiency as a function of temperature. This curve fit was validated by comparing the bin temperature calculation to measured chiller energy use over the past year. The existing gas boiler usage versus temperature is also analyzed to calculate the building's heating demand.

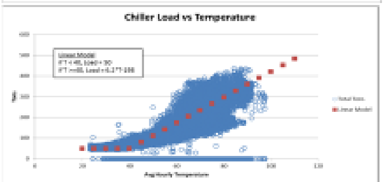
For the proposed ECM, a new heat recovery chiller is added to handle periods of low cooling load but high heat load. When the heat load is small (warmer weather), a second, larger chiller will be used to to efficiently produce chilled water up to 500 tons.

Baseline (existing Condition)

WCU-4, WCU-5 Trend Data from Building Automation System

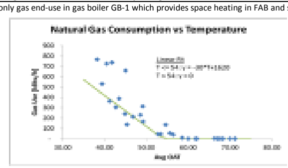
Chiller load and efficiency versus temperature based on DDC trends





Gas Usage Data from NW Natural Utility Billing

The only gas end-use in gas boiler GB-1 which provides space heating in FAB and some areas of City Tower



Baseline Chiller Energy Consumption

Portland, OR

Temp Bin	Frequency [hrs]	Chiller Load [tons]	Percent Loading	Code Baseline Chiller: Efficiency [kW/ton]	Code Baseline Chiller: Power [kW]	Code Baseline Chiller: Energy [kWh]	Existing Chillers: Efficiency [kW/ton]	Existing Chillers: Power [kW]	Existing Chillers: Energy [kWh]	CHW Primary Pump [kWh]	CW Pump [kWh]
0	0	50	10%				2.79	139.50	-	-	-
5	0	50	10%				2.65	132.25	-	-	-
10	0	50	10%				2.50	125.00	-	-	-
15	6	50	10%				2.36	117.75	559	90	198
20	37	50	10%				2.21	110.50	3,237	555	1,221
25	79	50	10%				2.07	103.25	6,457	1,185	2,607
30	319	50	10%				1.92	96.00	24,244	4,785	10,527
35	639	50	10%				1.78	88.75	44,896	9,585	21,087
40	1096	50	10%				1.63	81.50	70,715	16,440	36,168
45	1300	81	16%				1.49	120.29	123,793	19,500	42,900
50	1249	112	22%				1.34	150.08	148,398	18,735	41,217
55	1173	143	29%		Not Used		1.20	170.89	158,688	17,595	38,709
60	981	174	35%				1.05	182.70	141,889	14,715	32,373
65	584	205	41%				0.91	185.53	85,774	8,760	19,272
70	393	236	47%				0.76	179.36	55,803	5,895	12,969
75	311	267	53%				0.65	173.55	42,729	4,665	10,263
80	238	298	60%				0.65	193.70	36,496	3,570	7,854
85	144	329	66%				0.65	213.85	24,379	2,160	4,752
90	118	360	72%				0.65	234.00	21,860	1,770	3,894
95	56	391	78%				0.65	254.15	11,267	840	1,848
100	16	422	84%				0.65	274.30	3,474	240	528
105	17	453	91%				0.65	294.45	3,963	255	561
110	4	484	97%	0.58	278.78	883	0.65	314.60	996	60	132
					Total	560,490			1,009,620	131,400	289,080
								Total	1,430,100	pump total	420,480

Proposed

Chiller Performance Parameters

Heat Recovery Chiller Curve

Cooling MBH	Cooling Tons	Cooling EER	Cooling kW/ton	Heating COP
1230.7	103	8.9	1.35	3.6
1116.2	93	9.1	1.32	3.7
1001.7	83	9.4	1.28	3.8
884.1	74	9.8	1.22	3.9
763.5	64	10	1.20	3.9
642.9	54	10.5	1.14	4.1
516.8	43	10.7	1.12	4.1
390.7	33	11	1.09	4.2
264.6	22	11.8	1.02	4.5

High Efficiency Chiller Curve

Cooling Tons	Cooling kW/ton
500	0.487
375	0.365
250	0.267
125	0.294

High Efficiency Chiller Energy Use and coincident gas use

Monthly gas bills are used to determine how much heat load is served by GB-1 (gas boiler).
Any load currently served by GB-1 could potentially be served by a heat recovery chiller
Portland, OR

Temp Bin	Frequency [hrs]	Chiller Load [tons]	Percent Loading	Ht Recov?	Efficiency [kW/ton]	Power [kW]	Energy [kWh]	Heat Recovery COP	Heat recovery possible kWh	Pre ht Recovery: kWh gas used	Post Ht Recovery: kWh gas	Excess heat?	CHW Primary Pump [kWh]	CW Pump [kWh]
0	0	50	10%	Ht Recov	1.14	57.00	-	3.69	-	-	-	-	-	-
5	0	50.00	10%	Ht Recov	1.14	57.00	-	3.69	-	-	-	-	-	-
10	0	50.00	10%	Ht Recov	1.14	57.00	-	3.69	-	-	-	-	-	-
15	6	50.00	10%	Ht Recov	1.14	57.00	271	3.69	999	2,057	1,058	-	38	84
20	37	50.00	10%	Ht Recov	1.14	57.00	1,670	3.69	6,161	11,061	4,900	-	234	515
25	79	50.00	10%	Ht Recov	1.14	57.00	3,565	3.69	13,154	20,144	6,989	-	500	1,100
30	319	50.00	10%	Ht Recov	1.14	57.00	14,395	3.69	53,117	67,315	14,198	-	2,019	4,441
35	639	50.00	10%	Ht Recov	1.14	57.00	28,835	3.69	106,401	106,750	349	-	4,044	8,896
40	1096	50.00	10%	Ht Recov	1.14	57.00	49,457	3.69	182,496	134,912	-	47,584	6,936	15,258
45	1300	81.00	16%	Ht Recov	1.28	103.68	106,704	3.42	364,928	102,872	-	262,055	8,227	18,098
50	1249	112.00	22%	Std	0.29	32.93	32,559	0	-	43,927	43,927	-	7,904	17,388
55	1173	143.00	29%	Std	0.29	40.76	37,846	0	-	-	-	-	7,423	16,330
60	981	174.00	35%	Std	0.28	47.85	37,162	0	-	-	-	-	6,208	13,657

65	584	205.00	41%	Std	0.27	54.74	25,306	0	-		-	-	-	3,696	8,130
70	393	236.00	47%	Std	0.27	63.01	19,605	0	-		-	-	-	2,487	5,471
75	311	267.00	53%	Std	0.27	71.29	17,552	0	-		-	-	-	1,968	4,330
80	238	298.00	60%	Std	0.29	84.93	16,002	0	-		-	-	-	1,506	3,313
85	144	329.00	66%	Std	0.33	108.57	12,377	0	-		-	-	-	911	2,005
90	118	360.00	72%	Std	0.36	127.80	11,939	0	-		-	-	-	747	1,643
95	56	391.00	78%	Std	0.38	146.63	6,500	0	-		-	-	-	402	884
100	16	422.00	84%	Std	0.40	168.80	2,138	0	-		-	-	-	144	317
105	17	453.00	91%	Std	0.45	203.85	2,743	0	-		-	-	-	190	417
110	4	484.00	97%	Std	0.49	235.71	746	0	-		-	-	-	54	120
					Total		**427,371**			total	489,039	71,422		**55,636**	**122,399**
										kBtu	1,668,600	243,693		**pump Total**	**178,035**
										therms	16,686	2,437		**kWh Total**	**605,406**
										therms saved -->	**14,249**				

Boiler Gas Use

Referenced in above chiller calculation to determine when heat recovery is beneficial

Portland, OR

		Pre UPS	
Temp Bin	**Frequency [hrs]**	**Gas Use [kBtu]**	**Gas Use [kWh]**
0	0	-	-
5	0	-	-
10	0	-	-
15	6	7,020	2,057
20	37	37,740	11,061
25	79	68,730	20,144
30	319	229,680	67,315
35	639	364,230	106,750
40	1096	460,320	134,912
45	1300	351,000	102,872
50	1249	149,880	43,927
55	1173	-	-
60	981	-	-
65	584	-	-
70	393	-	-
75	311	-	-
80	238	-	-
85	144	-	-
90	118	-	-
95	56	-	-
100	16	-	-
105	17	-	-
110	4	-	-
		1,668,600	**489,039**
	Total Therms	16,686	
	Gas $/year	$ 16,686	

Summary

	Pre	Post	Savings
Chiller [kWh]	1,430,100	605,406	824,694
Total	1,430,100	605,406	**824,694**
GB-1 Gas [therms]	16,686	2,437	14,249

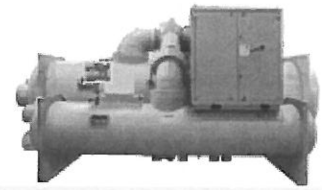
HEAT RECOVERY CHILLER

JOB NAME	**Heating**	**REP. OFFICE**	Oregon Air Reps
JOB	[redacted]	**SALESMAN**	Mike Wilson
		CUSTOMER	
MODEL NUMBER	TGZ190AXXX		
UNIT TAGGING	CH-1	**VERSION**	SPECIAL FACTORY RATING

DESIGN PERFORMANCE												
Heating MBH	Cooling MBH	Power (kW)	Heating COP	NPLV	Evaporator with 100% Water				4 Pass Condenser with 100% Water			
					Flow	PD	EWT	LWT	Flow	PD	EWT	LWT
1704.7	1230.7	138.9	3.6	10.2	307.7	11.0	54.0	46.0	170.5	12.8	110.0	130.0

DESIGN PERFORMANCE													
% Load	Heating MBH	Cooling MBH	Power (kW)	Heating COP	Cooling EER	Evaporator with 100% Water				4 Pass Condenser with 100% Water			
						Flow	PD	EWT	LWT	Flow	PD	EWT	LWT
100	1704.7	1230.7	138.9	3.6	8.9	307.7	11.0	54.0	46.0	170.5	12.8	110.0	130.0
90	1534.2	1116.2	122.5	3.7	9.1	307.7	11.0	54.0	46.7	170.5	12.8	112.0	130.0
80	1363.7	1001.7	106.1	3.8	9.4	307.7	11.0	54.0	47.5	170.5	12.8	114.0	130.0
70	1193.3	884.1	90.6	3.9	9.8	307.7	11.0	54.0	48.3	170.5	12.8	116.0	130.0
60	1022.8	763.5	76.0	3.9	10.0	307.7	11.0	54.0	49.0	170.5	12.8	118.0	130.0
50	852.3	642.9	61.4	4.1	10.5	307.7	11.0	54.0	49.8	170.5	12.8	120.0	130.0
40	681.9	516.8	48.4	4.1	10.7	307.7	11.0	54.0	50.6	170.5	12.8	122.0	130.0
30	511.4	390.7	35.4	4.2	11.0	307.7	11.0	54.0	51.5	170.5	12.8	124.0	130.0
20	340.9	264.6	22.4	4.5	11.8	307.7	11.0	54.0	52.3	170.5	12.8	126.0	130.0
10 (HGBP)	170.5	138.5	22.4	5.3	6.2	307.7	11.0	54.0	53.1	170.5	12.8	128.0	130.0

Job Information	Technical Data Sheet
Job Name	PSU Chiller Project
Date	12/5/2013
Submitted By	Mike Wilson
Software Version	08.90
Unit Tag	CH-1



Unit Overview

Model Number	Capacity ton	NPLV kW/ton	Voltage	Drive Type	ASHRAE 90.1	LEED EA Credit 4
WME0500S	500.0	0.306	460 v / 60 Hz	VFD/UM	'04, '07 & '10	Pass

Unit

Model Number: WME0500SSM2R/E3012-JU-2**/C2612-FAYY-2*****/R134-BAAAPAB-U

Approval: AHRI and ETL / cETL

Vessel Code: ASME

Compressor Quantity	Capacity Control	Refrigerant Type	Refrigerant Weight
1	VFD / Inlet Guide Vanes	R134a	1092 lb

Evaporator

Entering Fluid Temperature	Leaving Fluid Temperature	Fluid Type	Actual Fluid Flow	Minimum Fluid Flow
55.99 °F	45.00 °F	Water	1090.95 gpm	321.0 gpm

Length	Diameter	Number of Passes	Tube Material	Tube Wall Thickness	Fouling Factor
12 ft	30 in	2	Copper	0.025 in	0.00010 °F.ft².h/Btu

Condenser

Entering Fluid Temperature	Leaving Fluid Temperature	Fluid Type	Fluid Flow
80.00 °F	89.11 °F	Water	1500.00 gpm

Length	Diameter	Number of Passes	Tube Material	Tube Wall Thickness	Fouling Factor
12 ft	26 in	2	Copper	0.025 in	0.00025 °F.ft².h/Btu

Unit Performance

Design

Capacity ton	Input kW	Efficiency kW/ton	RLA A	NPLV kW/ton	Part Load Efficiency 75% kW/ton	50% kW/ton	25% kW/ton	Evaporator Fluid Pressure Drop ft H_2O	Evaporator Fluid Entering Temperature °F	Condenser Fluid Pressure Drop ft H_2O	Condenser Fluid Leaving Temperature °F
500.0	243.6	0.487	343	0.306	0.365	0.267	0.294	17.1	55.99	14.6	89.11

Performance Points Rated at AHRI Condenser Relief

Point #	% of Design Load	Capacity ton	Input kW	Efficiency kW/ton	RLA A	Evap. Flow gpm	Evap. Entering Temperature °F	Evap. Leaving Temperature °F	Evap. Pressure Drop ft H_2O	Cond. Flow gpm	Cond. Entering Temperature °F	Cond. Leaving Temperature °F	Cond. Pressure Drop ft H_2O
1	100.0	500.0	243.6	0.487	343	1,090.95	55.99	45.00	17.1	1,500.00	80.00	89.11	14.6
2	75.0	375.0	136.9	0.365	206	1,090.95	53.24	45.00	17.1	1,500.00	72.50	79.12	14.7
3	50.0	250.0	66.7	0.267	108	1,090.95	50.50	45.00	17.1	1,500.00	65.00	69.34	14.7
4	25.0	125.0	36.7	0.294	62	1,090.95	47.75	45.00	17.1	1,500.00	65.00	67.21	14.7

EEM 3

Cost Estimate

Item	Equip. Cost	Labor Hrs	Labor	Bare Total	Total O&P	Qty	Unit	Total
4" HW pipe (from 2nd floor to penthouse)	$ 22	0.3	$ 30	$ 52	$ 60	200	ea	$ 11,960
2 way valves	$ 2,500	4	$ 400	$ 2,900	$ 3,335	2	ea	$ 6,670
Isolation valves	$ 2,500	4	$ 400	$ 2,900	$ 3,335	2	ea	$ 6,670
Controls, Supply air temp reset program and test	$ 4,000	16	$ 1,600	$ 5,600	$ 6,440	1	ea	$ 6,440
Subtotal								$ 31,740
Contingency								$ 9,522
Total								$ 41,262

Payback Calculation

Electric	
Baseline kWh	635,434
Proposed kWh	559,965
kWh Savings	75,469
pct Savings Electric	12%
Gas	
Baseline Therms	-
Proposed Therms	-
Therm Savings	-
pct Savings Gas	#DIV/0!
Total	
Energy Cost Savings/year	$ 5,434
Measure Cost	$ 41,262
Simple Payback, Years	7.6
Estimated Incentive	$ 18,867
Payback w/ Incentive	4.1

EEM 3: Detailed Calculations

Calculation Methodology

This measure calculates energy savings from using FAB heat recovery to provide heat to the City Tower AHU-1. This air handler serves floors 3-7 with a VAV electric reheat system. In the baseline (existing) configuration there is no heating coil in the air handler. Proposed EEM would add a heating coil and provide controls to minimize use of reheat boxes.

An eQUEST energy model is used to model heating demand in the City Tower. A simple geometry was created to match the building's floor area. Utility billing information was reviewed to verify the modeled energy use is reasonable. In the baseline model, AHU-1 is modeled without a central heating coil. For the poposed model, a heating coil is added with the HEAT-CONTROL = WARMEST control setting. This will allow the sytem to reset the supply air temperature until the warmest zone is satisfied (further reset above this point would cause overheating in other zones). Reheat at the zone level will serve the zones that require additional heat.

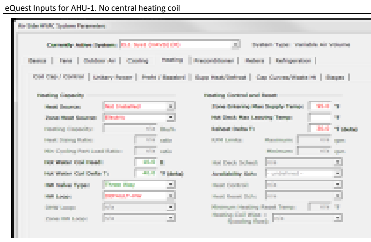
The difference in electrical energy (inclusive of pumps) between baseline and proposed models represents the energy savings for this measure.

Baseline (existing Condition)

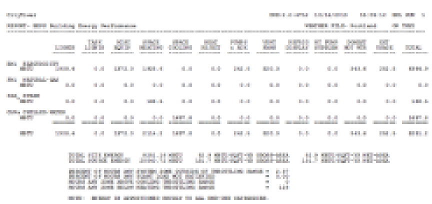
Utility Bills for City Tower

Start Date	End Date	kWh				
1/1/2012	1/31/2012	196109.8407				
3/1/2012	3/31/2012	179494.718				
4/1/2012	4/30/2012	205664.6697				
5/1/2012	5/31/2012	175816.5995				
6/1/2012	6/30/2012	201137.1961				
7/1/2012	7/31/2012	211572.4936				
8/1/2012	8/30/2012	249257.5974				
9/1/2012	9/30/2012	226108.0371				
10/1/2012	10/31/2012	185855.2638				
11/1/2012	11/30/2012	166330.5882				
12/1/2012	12/31/2012	236354.237	kWh/year	kBtu/yr		**Elec EUI**
4/1/2013	4/30/2013	150812.2391	2,384,513	8135959.995		**52.2**

eQuest Inputs for AHU-1. No central heating coil



eQUEST Outputs

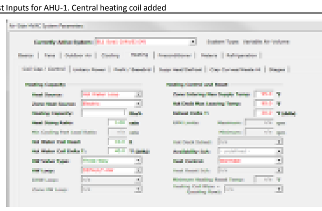


Note: FAB_STEAM in the report above, refers to a "purchased heat meter" in eQUEST. This was used to account for heat that is supplied by FAB to AHU's at City Tower

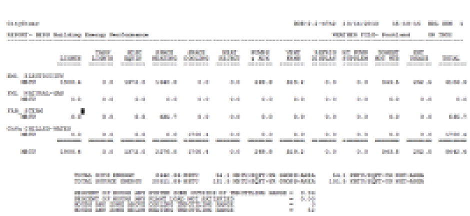
	Space Heating	Pumps & Aux	Total
Electric MMBtu	1925.6	242.5	2168.1
HW from FAB MMBtu	188.5	0	188.5

Proposed

eQuest Inputs for AHU-1. Central heating coil added



eQUEST Outputs



Savings from heat recovery

	Baseline			Proposed					
	Space Heating	Pumps & Aux	Total	Space Heating	Pumps & Aux	Total	Electric Savings (MMBtu)	kWh	Heat (MMBtu)
Electric MMBtu	1925.6	242.5	2168.1	1640.8	269.8	1910.6	257.5	75,469	
HW from FAB MMBtu	188.5	0	188.5	635.7	0	635.7			447.2

Summary

	Pre	Post	**Savings**
City Tower Electric Heating [kWh]	635,434	559,965	**75,469**

EEM 5

Cost Estimate

Item	Equip. Cost	Labor Hrs	labor rate	Labor	Bare Total	Total O&P	Qty	Unit	Total
Hot Aisle Containment	$ 15,000	100	100	$ 10,000	$ 25,000	$ 25,000	2.5	ea	$ 62,500
VFD conversion for Liebert Units (includes new inverter duty motors for Liebert FH376 units (4))	$ 4,500	8	100	$ 800	$ 5,300	$ 6,095	5	ea	$ 30,475
Air sealing	$ -	16	100	$ 1,600	$ 1,600	$ 1,840	3	ea	$ 5,520
Review and adjust Sequence of Operations	$ -	16	100	$ 1,600	$ 1,600	$ 1,840	1	ea	$ 1,840
Subtotal									$ 100,335
Contingency									$ -
Total									$ 100,335

Payback Calculation

Electric	
Baseline kWh	511,606
Proposed kWh	360,170
kWh Savings	151,436
pct Savings Electric	30%
Gas	
Baseline Therms	0
Proposed Therms	0
Therm Savings	-
pct Savings Gas	0%
Total	
Energy Cost Savings/year	$ 10,903
Measure Cost	$ 100,335
Simple Payback, Years	9.2
Estimated Incentive	$ 37,859
Payback w/ Incentive	5.7

EEM 5: Detailed Calculations

Calculation Methodology

An eQUEST energy model is used to calculate savings for this measure. The baseline model is set up to closely replicate current datacenter operation as follows:

Datacenter Room Setpoint - 65
Supply air temperature - 55
Fans - constant volume

The proposed model makes the following changes:

Datacenter Room Setpoint - 80
Supply air temperature - 65
Fans - variable volume. Min flow = 60%.

Baseline (existing Condition)

```
Baseline Datacenter                                        DOE-2.2-47h2  10/16/2013    11:20:27  BDL RUN  1
REPORT- BEPS Building Energy Performance                               WEATHER FILE- Portland     OR TMY2
```

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY MBTU	63.1	0.0	3976.4	0.0	739.2	23.0	303.9	679.5	0.0	0.0	0.0	0.0	5785.0
FM1 NATURAL-GAS MBTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MBTU	63.1	0.0	3976.4	0.0	739.2	23.0	303.9	679.5	0.0	0.0	0.0	0.0	5785.0

```
TOTAL SITE ENERGY      5785.04 MBTU   1205.2 KBTU/SQFT-YR GROSS-AREA   1205.2 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY   17356.14 MBTU   3615.7 KBTU/SQFT-YR GROSS-AREA   3615.7 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE =  0.00
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED                =  0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE                =     0
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE                =     0

NOTE:  ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.
```

Proposed

```
Baseline Datacenter                                        DOE-2.2-47h2  10/22/2013    11:16:41  BDL RUN  1
REPORT- BEPS Building Energy Performance                               WEATHER FILE- Portland     OR TMY2
```

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY MBTU	63.1	0.0	3976.4	0.0	632.7	19.7	303.9	272.6	0.0	0.0	0.0	0.0	5268.4
FM1 NATURAL-GAS MBTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MBTU	63.1	0.0	3976.4	0.0	632.7	19.7	303.9	272.6	0.0	0.0	0.0	0.0	5268.4

```
TOTAL SITE ENERGY      5268.37 MBTU   1097.6 KBTU/SQFT-YR GROSS-AREA   1097.6 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY   15806.13 MBTU   3292.7 KBTU/SQFT-YR GROSS-AREA   3292.7 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE =  0.00
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED                =  0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE                =     0
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE                =     0

NOTE:  ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.
```

Summary

	Pre	Post	Savings
Cooling	739.20	632.70	107
Pumps	303.90	303.90	-
Heat Rejectio	23.00	19.70	3
Fans	679.50	272.60	407
Total			
MMBtu	1745.60	1228.90	517
Total kWh	**511,606**	**360,170**	151,436

Enterprise Control Systems
15 South Grady Way
Suite 631
Renton, WA 98057
USA
t. 800-570-5755 f. 425-460-8485

QUOTE

Number ECSQ2961

Date May 7, 2013

Customer:	**Ship To:**
Portland State University Tudor Hison 1930 S.W. 4th Ave., Ste 90 Portland, OR 97201 **Phone** (503)725-3284 **Fax** (503)725-6487	**Portland State University** Tudor Hison 1930 S.W. 4th Ave., Ste 90 Portland, OR 97201 **Phone** (503)725-3284 **Fax** (503)725-6487

Account Executive	Ship Via	Terms
Steve Karlson	Per Customer PO	Net 30

Line	Qty	ECS Part Number	Description	Unit Price	Ext. Price
1			**Below BOM is for Doors & Over Rack Clear Panels**		
2	2	4.1.401.10010	I-40 Dual Sliding Door - _"W x _"H Clear Anodized Aluminum Finish, Door Dims: 78" High x 89" Wide- E/O 42"	$2,995.00	$5,990.00
3	1	4.1.251.30010	I-25 Floor Panel Clear Anodized - (9"-25") Floor Panel Dims: 78" High x 12" Wide	$440.00	$440.00
4	2	4.1.251.31010	I-25 Over Rack Panel Clear Anodized - (9"-25") O/R Panel Dims: 23" High x 72" long	$440.00	$880.00
5	2	4.1.251.31010	I-25 Over Rack Panel Clear Anodized - (9"-25") O/R Dims: 23" High x 60" Wide	$440.00	$880.00
6	1	4.1.251.31010	I-25 Over Rack Panel Clear Anodized - (9"-25") O/R Dims: 23" High x 54.5" Wide	$440.00	$440.00
7	7	4.1.251.31010	I-25 Over Rack Panel Clear Anodized - (9"-25") O/R Dims: 23" High x 82.5" Wide	$440.00	$3,080.00
8	8	3.4.000.10440	Fire Proof Cube - 4"x40"	$84.00	$672.00
9	1	Shipping	Shipping & Handling	$2,337.23	$2,337.23
10	1	9.0.000.00000	Site Services: Installation of Products Includes (2) year warranty on all products & installation services.	$10,260.00	$10,260.00

SubTotal	$24,979.23
Tax	$0.00
Total	**$24,979.23**

SubZero Terms and Conditions Attached and are part of this proposal.

QUOTE IS VALID FOR 30 DAYS - PRICES SUBJECT TO CHANGE - PRICES BASED UPON TOTAL PURCHASE -
PRICING DOES NOT INCLUDE SALES AND/OR USE TAX UNLESS OTHERWISE STATED
PRICING DOES NOT INCLUDE SHIPPING SHIPPING TERMS SHALL BE FOB ORIGIN AND ALL SHIPPING CHARGES SHALL BE PREPAID AND ADDED TO INVOICE.
WE SHALL NOT BE LIABLE FOR ANY LOSS OF PROFITS, BUSINESS, GOODWILL, DATA, INTERRUPTION OF BUSINESS, NOR FOR INCIDENTIAL OR CONSEQUENTIAL MERCHANTABILITY OR FITNESS OF PURPOSE, DAMAGES RELATED TO THIS AGREEEMENT.
MINIMUM 15% RESTOCKING FEE WITH ORIGINAL PACKAGING.
CREDIT CARD PAYMENTS MUST BE SUBMITTED AT TIME OF ORDER, OTHERWISE PAYMENT TERMS ARE NET 30 UPON APPROVED CREDIT

Precision Cooling
For *Business-Critical Continuity*™

Liebert® Variable Speed Upgrade Kits

Save Money Through Energy Efficient Operation

Save from $1,700 to $5,100/year per unit

Get more efficient operation from your existing Chilled Water CRAC systems and quick payback through lower electricity costs and utility rebates.

The Variable Speed Drive (VSD/VFD) Upgrade is easily installed on your Liebert Deluxe System/3 Chilled Water systems, providing immediate results with lower electrical bills.

Typically, CRAC fans run at a constant speed and deliver a constant volume of air flow. Adding a Variable Speed Drive to the fan motor allows fan speed and power draw to be reduced as load decreases. A 20 percent reduction in fan speed provides almost 50 percent savings in fan power consumption.

Liebert Deluxe System/3 Chilled Water systems are easily field retrofitted with the VSD/VFD motor kit to maximize energy efficiency

VSD Features

Lowest Total Cost of Ownership

- Average payback on electricity costs is less than two years
- Utility rebates available in some regions, providing even faster payback

Flexibility

- Easy field installation by a factory trained technician

Higher Availability

- Variable fan speed increases the life of the fan and motor

The VSD/VFD Motor Upgrade Kit is Ideally Suited For Chilled Water Models of Liebert Deluxe System/3:

- In IT operations looking for fast, easy methods of cutting costs long term
- In IT operations looking for fast ROI on cost saving initiatives

...a 20% reduction in fan speed provides almost 50% savings in power consumption

EMERSON
Network Power

Non Standard Assessment/1-Time Services

Tag #	Description	Model #	Coverage Type	Coverage Amount
	VSD Upgrade on (1) (kit with ring) CW060DCSAT6463A (S# C09C1403002) and on (4) (replacement motor) FH376C-AA0I (S#'s 745661-001 & 002, 832754-001 & 002). Work to be performed by Liebert FDO (8x5). All parts and labor included for VSD upgrades.	VSDUPGRADEHVAC		$30,754

Total price not including tax: $30,754
any tax required must be included in customer purchase order

EEM 6

Cost Estimate

Item	Equip. Cost	Labor Hrs	Labor	Bare Total	Total O&P	Qty	Unit	Total
1 1/4" CHW piping to/from FCU-6A (branch from existing DHRC piping)	$ 14	0.1	$ 10	$ 24	$ 27	180	ft	$ 4,906
1 1/4" CHW piping to/from FCU-6B (branch from existing DHRC piping)	$ 14	0.1	$ 10	$ 24	$ 27	180	ft	$ 4,906
Controls	$ 1,500	16	$ 1,600	$ 3,100	$ 3,565	1	ea	$ 3,565
	$ -	0	$ -	$ -	$ -	1	ea	$ -
	$ -	0	$ -	$ -	$ -	1	ea	$ -
	$ -	0	$ -	$ -	$ -	1	ea	$ -
	$ -	0	$ -	$ -	$ -	1	ea	$ -
Subtotal								$ 13,377
Contingency								$ 4,013
Total								$ 17,390

Payback Calculation

Electric	
Baseline kWh	1,185,118
Proposed kWh	1,161,529
kWh Savings	23,589
pct Savings Electric	2%
Gas	
Baseline Therms	16,686
Proposed Therms	15,029
Therm Savings	1,657
pct Savings Gas	10%
Total	
Energy Cost Savings/year	$ 3,355
Measure Cost	$ 17,390
Simple Payback, Years	5.2
Estimated Incentive	$ 7,554
Payback w/ Incentive	2.9

EEM 6: Detailed Calculations

Calculation Methodology

Existing UPS cooling load is calculated by measuring airflow and temperature provided by the fan-coils that serve the zone. In the existing configuration, energy is used by the fans for air distribution, and by the central chiller plant to produce and distribute chilled water to the fan coils.

In the proposed EEM, an existing dedicated heat recovery chiller (DHRC) will be used to serve the same two fan-coil units. Airflow and chilled water distribution are expected to have similar energy use to the existing condition, therefore they are not included in this calculation.

Energy savings will be provided in two areas:
1. Increased efficiency of the DHRC compared to the efficiency of the central chillers which often operate at low efficiency part load conditions.
2. The added load of the UPS room creates the potential for additional heat recovery. When there is a demand for the recovered heat it will offset the use of a gas boiler.

Baseline (existing Condition)

Measurement of fan coil load using DDC points

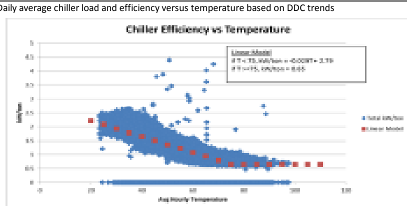
Unit	CFM	EAT	LAT	GPM	EWT	Calc'd sensible btu/hr
FCU-6A	2500	57.6	70.5	n/A	50	34,830
FCU-6B	2446	57	69	n/A	50	31,700
					Total Btu/h	66,530
					Total Tons	5.54

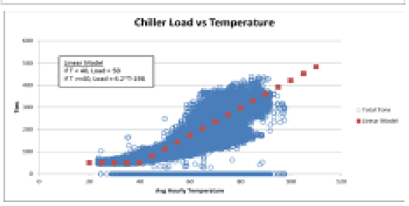
Schedule

UPS is located in a core zone with negligible shell losses
UPS load is constant 24/7/365.

WCU-4, WCU-5 Trend Data from Building Automation System

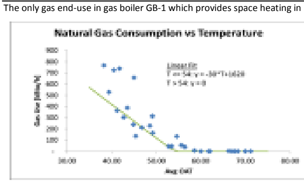
Daily average chiller load and efficiency versus temperature based on DDC trends





Gas Usage Data from NW Natural Utility Billing

The only gas end-use in gas boiler GB-1 which provides space heating in FAB and some areas of City Tower



WCU-4/5 Chiller Energy Consumption

Portland, OR

Temp Bin	Frequency [hrs]	Chiller Load [tons]	Efficiency [kW/ton]	Power [kW]	Energy [kWh]
0	0	50.00	2.79	139.50	-
5	0	50.00	2.65	132.25	-
10	0	50.00	2.50	125.00	-
15	6	50.00	2.36	117.75	559
20	37	50.00	2.21	110.50	3,237
25	79	50.00	2.07	103.25	6,457
30	319	50.00	1.92	96.00	24,244
35	639	50.00	1.78	88.75	44,896
40	1096	50.00	1.63	81.50	70,715
45	1300	81.00	1.49	120.29	123,793
50	1249	112.00	1.34	150.08	148,398
55	1173	143.00	1.20	170.89	158,688
60	981	174.00	1.05	182.70	141,889
65	584	205.00	0.91	185.53	85,774
70	393	236.00	0.76	179.36	55,803
75	311	267.00	0.65	173.55	42,729
80	238	298.00	0.65	193.70	36,496
85	144	329.00	0.65	213.85	24,379
90	118	360.00	0.65	234.00	21,860
95	56	391.00	0.65	254.15	11,267
100	16	422.00	0.65	274.30	3,474
105	17	453.00	0.65	294.45	3,963
110	4	484.00	0.65	314.60	996
			Total		1,009,620

Proposed

WCU-4/5 Chiller energy use (same as above except load is reduced by 5.54 tons)

Portland, OR

Temp Bin	Frequency [hrs]	Chiller Load [tons]	Efficiency [kW/ton]	Power [kW]	Energy [kWh]
0	0	44.46	2.79	124.04	-
5	0	44.46	2.65	117.60	-
10	0	44.46	2.50	111.15	-
15	6	44.46	2.36	104.70	497
20	37	44.46	2.21	98.26	2,878
25	79	44.46	2.07	91.81	5,742
30	319	44.46	1.92	85.36	21,558
35	639	44.46	1.78	78.92	39,922
40	1096	44.46	1.63	72.47	62,880
45	1300	75.46	1.49	112.06	115,326
50	1249	106.46	1.34	142.66	141,057
55	1173	137.46	1.20	164.26	152,540
60	981	168.46	1.05	176.88	137,372
65	584	199.46	0.91	180.51	83,456
70	393	230.46	0.76	175.15	54,493
75	311	261.46	0.65	169.95	41,843

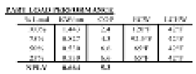
80	238	292.46	0.65	190.10	35,818
85	144	323.46	0.65	210.25	23,968
90	118	354.46	0.65	230.40	21,523
95	56	385.46	0.65	250.55	11,108
100	16	416.46	0.65	270.70	3,429
105	17	447.46	0.65	290.85	3,914
110	4	478.46	0.65	311.00	985
				Total	**960,310**

Heat Recovery Chiller Energy Use & Useful Recovered Heat

Monthly gas bills are used to determine how much heat load is served by GB-1 (gas boiler).
Any load currently served by GB-1 could potentially be served by the DHRC.

Multistack Heat Recovery Chiller Performance Parameters

Load	kW/ton	COP
100%	1.443	2.4
75%	0.827	4.3
50%	0.53	6.6
25%	0.53	6.6



Portland, OR

Temp Bin	Frequency [hrs]	Chiller Load w/o UPS [tons]	Efficiency [kW/ton]	Power [kW]	Energy [kWh]	Heat Output [kWh]	Chiller Load w/ UPS [tons]	Efficiency [kW/ton]	Power [kW]	Energy [kWh]	Heat Output [kWh]	Add'l heat recovered post UPS [kWh]	Pre UPS Gas Use [kBtu]	Pre UPS Gas Use [kWh]	Post UPS Gas Use [kWh]	Post UPS Gas Use [kBtu]
0	0	37.8	0.53	20.034	-	-	43.34	0.53	22.9702	-	-	-	-	-	-	-
5	0	37.8	0.53	20.034	-	-	43.34	0.53	22.9702	-	-	-	-	-	-	-
10	0	37.8	0.53	20.034	-	-	43.34	0.53	22.9702	-	-	-	-	-	-	-
15	6	37.8	0.53	20.034	120	421	43.34	0.53	22.9702	138	482	62	7,020	2,057	1,996	6,810
20	37	37.8	0.53	20.034	741	2,594	43.34	0.53	22.9702	850	2,975	380	37,740	11,061	10,681	36,443
25	79	37.8	0.53	20.034	1,583	5,539	43.34	0.53	22.9702	1,815	6,351	812	68,730	20,144	19,332	65,960
30	319	37.8	0.53	20.034	6,391	22,368	43.34	0.53	22.9702	7,327	25,646	3,278	229,680	67,315	64,037	218,495
35	639	37.8	0.53	20.034	12,802	44,806	43.34	0.53	22.9702	14,678	51,373	6,567	364,230	106,750	100,183	341,824
40	1096	37.8	0.53	20.034	21,957	76,850	43.34	0.53	22.9702	25,175	88,114	11,263	460,320	134,912	123,649	421,890
45	1300	37.8	0.53	20.034	26,044	91,155	43.34	0.53	22.9702	29,861	104,514	13,360	351,000	102,872	89,513	305,417
50	1249	37.8	0.53	20.034	25,022	87,579	43.34	0.53	22.9702	28,690	100,414	12,836	149,880	43,927	31,092	106,085
55	1173	37.8	0.53	20.034	23,500	82,250	43.34	0.53	22.9702	26,944	94,304	12,055	-	-	-	-
60	981	37.8	0.53	20.034	19,653	68,787	43.34	0.53	22.9702	22,534	78,868	10,081	-	-	-	-
65	584	37.8	0.53	20.034	11,700	40,949	43.34	0.53	22.9702	13,415	46,951	6,002	-	-	-	-
70	393	37.8	0.53	20.034	7,873	27,557	43.34	0.53	22.9702	9,027	31,596	4,039	-	-	-	-
75	311	37.8	0.53	20.034	6,231	21,807	43.34	0.53	22.9702	7,144	25,003	3,196	-	-	-	-
80	238	37.8	0.53	20.034	4,768	16,688	43.34	0.53	22.9702	5,467	19,134	2,446	-	-	-	-
85	144	37.8	0.53	20.034	2,885	10,097	43.34	0.53	22.9702	3,308	11,577	1,480	-	-	-	-
90	118	37.8	0.53	20.034	2,364	8,274	43.34	0.53	22.9702	2,710	9,487	1,213	-	-	-	-
95	56	37.8	0.53	20.034	1,122	3,927	43.34	0.53	22.9702	1,286	4,502	575	-	-	-	-
100	16	37.8	0.53	20.034	321	1,122	43.34	0.53	22.9702	368	1,286	164	-	-	-	-
105	17	37.8	0.53	20.034	341	1,192	43.34	0.53	22.9702	390	1,367	175	-	-	-	-
110	4	37.8	0.53	20.034	80	280	43.34	0.53	22.9702	92	322	41	-	-	-	-
				Total	**175,498**				**Total**	**201,219**			**1,668,600**	**489,039**	**440,481**	**1,502,922**
									Add'l kWh used	25,721		**Total Therms**	16,686			15,029
															Therms Saved	1,657
												Gas $/year	$ 16,686		Cost Svgs	$ 1,657

Summary

	Pre	Post	Savings
WCU 4/5 [kWh]	1,009,620	960,310	49,310
DHRC [kWh]	175,498	201,219	(25,721)
Total	1,185,118	1,161,529	**23,589**
GB-1 Gas [therms]	16,686	15,029	1,657

III MULTISTACK

Submittal Information Monday, January 19, 2009

JOB NAME: PSU Data Center
LOCATION:
CUSTOMER:

ENGINEER:
ARCHITECT:
CONTRACTOR

Multistack Order Number:
Customer P.O. Number:
Sales Representative: Steve Welch

Submitted by: Steve Welch / EW
Quote #: QEW011420094
Approved by: **Date:**

GENERAL INFORMATION

Chiller I.D. (3) MS50X6H1W

Dimensions (inches):
- **Length:** 98
- **Width:** 56
- **Height:** 67

CHILLED WATER DESIGN

Entering Temperature:	52.0	°F
Leaving Temperature:	42.0	°F
Evaporator Flow Rate:	185.1	GPM
Evaporator Pressure Drop:	4.9	Feet

CONDENSER WATER DESIGN

Entering Temperature:	120.0	°F
Leaving Temperature:	130.0	°F
Condenser Flow Rate:	261.0	GPM
Condenser Pressure Drop:	6.3	Feet

CHILLER PERFORMANCE (AT FULL LOAD)

(2 Modules Operating, 1 Redundant)

Cooling Capacity:	77.2	Tons
Power Input:	111.4	KW
EER:	8.3	

PART LOAD PERFORMANCE

% Load	KW/ton	COP	ECW	LCHW
100%	1.443	2.4	120°F	42°F
75%	0.827	4.3	92.5°F	42°F
50%	0.530	6.6	65°F	42°F
25%	0.530	6.6	65°F	42°F
NPLV	**0.664**	**5.3**		

WATER-COOLED CHILLER FEATURES

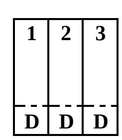
- Stainless steel evaporator and condenser
- Lead compressor sequencing every 24 hours
- Automatic internal rescheduling if fault occurs
- Multiple, independent refrigeration systems
- Automatic logging of any fault conditions
- Electronic chilled water control
- Modules fit through single width doors and into passenger elevators
- Filters in condenser and evaporator supply headers
- Stainless steel evaporator & condenser inlet headers
- Quick interconnect modular design
- R-410A Refrigerant
- Warranty: Compressor (5 Year)
- Total Access Design w/ Var. Flow (Evap. & Cond.) (2" C-Steel Valves)
- FRM (No Glycol Protection, includes PPM & ΔP Switch)
- Interoperability Web Portal (BACnet or Modbus)

ELECTRICAL DATA

MAIN POWER SUPPLY 460 / 60 / 3

ELECTRICAL CIRCUIT(S) CAPACITY	SINGLE MODULE CIRCUIT	SINGLE MODULE CIRCUIT	SINGLE MODULE CIRCUIT
Minimum Circuit Ampacity (amps)	104	104	104
Maximum Over Current Protection (MOP)	175	175	175

CHILLER BUSBAR SCHEMATIC
- SINGLE MODULE DIRECT CONNECT = **D**
- ROUTING OF BUSBARS: _ _ _



PLAN VIEW

IMPORTANT: To assure full equipment design performance, life and reliability, the MULTISTACK chiller must be piped in accordance with Installation Manual unless specifically authorized otherwise by MULTISTACK in writing.