Feasibility Study of Using Ground Source Heat Pumps in Two Buildings at Whidbey Island Naval Air Station

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I. EXECUTIVE SUMMARY

Simulation models were developed for two buildings at Whidbey Island Naval Air Station (the McCormick Center BOQ and Mt. Olympus BOQ) presently heated by steam from the central steam plant. Ground source heat pump (GSHP) systems were designed for the buildings, and the simulations were re-run to determine the energy and energy cost savings associated with the GSHPs. Costs for the GSHPs were estimated as well, allowing calculation of simple payback.

Since neither building presently uses air conditioning, costs and savings were modeled for a heating-only GSHP system, and for a system that includes both heating and cooling. For the McCormick BOQ, the simple payback of a heating only GSHP is estimated at 9.97 years. Since ground source heat pumps provide both heating and cooling, there would essentially be no cost increase to provide cooling for the building. The simple payback of a GSHP system to provide heating and cooling for the McCormick BOQ was estimated at 10.03 years. The slight increase is due to the extra electricity required to provide the small amount of cooling the building requires.

The Mt. Olympus BOQ has lower heating requirements due to better insulation, better windows and presumed lower infiltration. The simple payback of a heating only GSHP for this building is estimated at 18.99 years. With a system designed to provide both heating and cooling, the simple payback rises to 20.08 years.

Given the cost of bringing a drill rig to the site to install vertical bore heat exchangers, it may be advantageous to retrofit both buildings with GSHPs as part of the same project. For a heating-only system, the simple payback of converting both buildings to GSHP is estimated at 12.46 years. For a system to provide both heating and cooling for the buildings, the simple payback is estimated at 12.99 years.

In all simulations, it was assumed that natural gas-fired water heaters would replace the steam converters that presently provide hot water for the buildings. It would also be possible to use dedicated water-to-water ground source heat pumps to provide hot water.

II. BACKGROUND AND BASE CASE

A. Background on McCormick Center/BOQ

Building and System Description of McCormick Center

The McCormick Center / BOQ building 973 is a 65,569 square foot three story building constructed in 1965. Figure 1 shows an aerial view of the building. The facility contains 130 guest rooms (see Figure 2 for a typical guest room) and operates as a hotel providing temporary berthing and as the primary lodging facility for VIP Naval personnel visiting NAS Whidbey Island.

The building is located near the end of the central steam distribution system. Steam from the central steam plant is converted to heating hot water (HHW) to meet the facility's heating needs. A two-pipe hydronic piping system delivers 180 ºF HHW to cabinet convectors and fin-tube radiation units throughout the facility. Ventilation air is provided to corridor and common areas by four heating ventilation units. Heating is controlled at the room level by pneumatic thermostats and three-way control valves. Currently, the building has no cooling system.

The facility averages a 75% nightly occupancy for a minimum 100 people per night. Occupants have no independent control over the heating in the room without requesting management assistance. Due to the condition, age, location and operability of the pneumatic stats, they tend to be set to provide comfort heat by occupant complaint. This limited room temperature control often leads to room overheating and occupants controlling the room temperature by opening the operable windows. Energy Management Control System (EMCS) to the building is limited to optimum start and stop of the HHW circulation pumps by two room temperature sensors.

Domestic hot water (DHW) is supplied by two semi-instant hot water heaters or steam converters with steam from the central plant. The hot water heaters are rated to supply up 150 gpm of 120 ºF water.

B. Baseline Simulation Model for McCormick Center/BOQ

In order to assess the feasibility of GSHP system applications for the candidate building, a building simulation model was developed using an hourly building energy simulation program, eQuest version 3.6. As the initial step, a baseline simulation model was developed using as-built drawings, site notes, and pictures. Figure 3 is a representation of the baseline building model produced using eQuest's graphical output. Most of the unidentified simulation inputs were defined as the default values for the lodging building type. The simulation assumes that the fuel of the central steam boiler is natural gas with a combined overall efficiency (i.e., system efficiency + transmission loss) of 50%. The simulation used the TMY2 weather file for Seattle, WA, which is about 25 miles from the site.

After the initial model was developed, the simulation result was calibrated to match with the 831 MBtu/hr of peak heating load which was provided by site personnel. Calibration was achieved by manipulating the building infiltration rate and building envelope insulation level.

Figure 4 presents the baseline building simulation results. The annual electricity and natural gas consumption for the building is 613 MWh (kWh x000) and 15,860 MMBtu (Btu x 000,000), respectively. This level of energy consumption corresponds to an annual utility bill of approximately $175,540 based on the utility rates of $0.04939/kWh, and $0.916/therm.

C. Background on Mt Olympus/BOQ Building 2527

Mt Olympus / BOQ building 2527 is a 58,751 square foot, three and a half story building constructed in 1970. The facility contains 83 guest rooms, a conference area and housing staff offices. This building also operates as a hotel, providing temporary lodging to new arrivals, short term and visiting naval Personnel. An aerial view of the building is shown in Figure 5.

The building has a built up roof system with 4” rigid insulation, and 3” minimum concrete on steel deck (6” max). There is 18” of plenum space with a suspended gypsum board ceiling. The exterior walls consist of 8” filled block with 1” rigid insulation. The floor is constructed of a 4” concrete slab with vapor barrier above 6” rock and 3’ compacted fill. The window systems of the building were retrofitted in 2000. The new windows systems have aluminum frames with thermal break and tinted double pane glazing (1/4” with 1/2” air gap).

Occupancy in the building averages 80%. Office space and conference room use is Monday through Friday. Room temperatures are set to 70 ºF controlled by room stat. The heater is rarely turned down when unoccupied by lodger or housekeeping.

Building 2527 is located at the end of the central steam distribution system. Steam from the central steam plant is converted to heating hot water (HHW) to meet the facilities heating needs. A two-pipe hydronic piping system delivers HHW to cabinet convectors, fin-tube radiation units in guest room and lobby areas temperature is controlled at the room level by electric thermostats and two-way control valves. Additionally, fan coil units serve some corridor and office spaces. Ventilation air is provided to corridor, meeting and office spaces by three heating ventilation units. The building has no cooling.

D. Baseline Simulation Model for Mt Olympus/BOQ Building 2527

Similar to what was done for the McCormick Center, an as-built simulation model was developed using eQuest version 3.6. The initial input file was developed using the original drawings and the communication with site personnel. Information not provided (such as lighting

and plug loads, and building occupancy schedule) was defined based on the recommended defaults from the simulation program.

Figure 6 shows a representation of the modeled building using eQuest's graphical output. With the information provided, the initial simulation was performed using the TMY-2 weather file for Seattle, Washington. The monthly simulation results are presented in Figure 7. As shown, the annual electricity consumption is about 357 MWh (kWh x 000). The annual space heating and DHW use is about 6,638 MMBtu (Btu x 000,000). The calculated annual energy cost is $85,495.

E. Validation of Simulation Results

Since the peak heating load for the McCormick Center Building was the only information available for the calibration, the simulation results of the two buildings were compared with the average building energy consumption from two sources for validation purpose.

1) EIA's 2003 Commercial Building Energy Consumption Survey (CBECS) provides the average building energy consumption by building type and geographical location of the building. The survey shows that the average EUI (kBtu/sqft-hr) for lodging buildings in U.S. in 2003 was about 100 kBtu/sqft-hr. Of these, the electricity use and natural gas use account for 42 and 46 kBtu/sqft-yr, respectively.
2) U.S. DOE EERE's Commercial Building Benchmark Models also provide the average building energy consumption by building type and location. From this source, the energy use for the average hotel in Seattle, WA was modeled as 131 kBtu/sqft-yr. According to the Benchmark model, the electricity and natural gas use intensity was 46.9 (Without cooling, the electricity use intensity decreases to 39 kBtu/sqft-yr) and 84.31 kBtu/sqft-yr, respectively. Of the natural gas use, the space heating and DHW was 16.2 and 54.2 kBtu/sqft-yr, respectively.

Table 1 shows the summary of the comparison. Since the CBECS data represents the national average value, and the benchmark model represents for the average hotel building close to the Whidbey Island, the latter was chosen for the validation.

<u>McCormick Center</u>

The total electricity use without cooling was 32 kBtu/sqft-yr which was close to the benchmark model's number (i.e., 39 kBtu/hr). However, the space heating and DHW energy use for the building (i.e., 151.7 kBtu/hr-sqft) was almost two times higher than the benchmark model's use (i.e., 84.3 kBtu/sqft-yr) even not considering the steam loss during the transmission. This could be caused by a high infiltration rate, single pane windows, overheating, etc.

Mt Olympus Building

The total electricity use without cooling was 21 kBtu/sqft-yr which was little lower than the benchmark model's number (i.e., 39 kBtu/hr). The space heating and DHW energy use for the building was 64 kBtu/sqft-yr which is also lower than the benchmark model natural gas energy use (i.e., 84.3 kBtu/sqft-yr).

III. USE OF GROUND SOURCE HEAT PUMPS

A. Application of a GSHP System for McCormick Center

In order to assess the feasibility of GSHP application for the candidate building, a typical vertical borehole system was chosen and designed for the building. Two software packages were used for the design and the assessment. First, Ground Loop Design (GLD) version 5.3 was used to size the ground loop. Then, eQuest with Climate Master add-on feature version 1.0 plug-in was used to estimate the energy consumption with the previously designed ground loop.

Ground Loop Design

GLD requires two types of inputs. The first set involves average block loads for the building. The design day loads for heating and cooling were calculated from the baseline eQuest simulation. The estimated peak cooling load of 1,184.4 kBtu/hr and the peak heating load of 817.0 kBtu/hr were input in this procedure. The next set of inputs involves the characteristics of soil, borehole, and pipe. While deep earth temperature can be read from a map, soil formation thermal conductivity would have to be measured on site in an in situ test. Maximum drilling depth would also have to be established at the site. For this study, representative values were used for the unknown parameters. A summary of the inputs is provided in Table 2. The final result shows that ninety (90) 250 ft boreholes would be needed to meet the building design load. The possible layout of the 90 boreholes can be found in Figure 8. As shown, the land area around the building can be used for the installation of the 90 boreholes. Boreholes are assumed to be spaced 20ft apart.

Energy Simulation with GSHP System

The baseline simulation model was modified with the previously designed GSHP system. The original system in the baseline model was replaced with the GSHP system using Climate Master Add-on Feature V-1.0. Since the current add-on program cannot simulate a heating-only GSHP system, the model was developed for a system that would provide both cooling and heating. The simulation assumes console water-to-air GSHP units are installed in rooms, with water-to-water

heat pumps providing heated and chilled water for the large air handlers that supply ventilation air.

Since the eQuest program cannot simulate a DHW with GSHP system, the DHW is assumed to be provided by onsite natural gas water heaters. The simulation results are shown in Figure 9. As shown, the annual electrical energy consumption increased from 613 MWh to 1,056.4 MWh (i.e., a 172% increase). The annul natural gas use decreased to 4,220 MMBtu. The final analysis shows that the annual energy savings would be 7,826 MMBtu/yr (i.e., 56.4% savings), and the energy cost savings would be $84,707 annually (i.e., 48.3 % savings based on average utility rate of $0.04939/kWh, $0.916/Therm)

Since this building has no cooling system, the simulation was modified to eliminate the cooling capacity for a valid comparison. To do this, the cooling set point was set to 99 ºF so that the cooling system would not operate even during summer months. Figure 10 shows the simulation results. As shown, the cooling energy consumption has been removed from Figure 2, and the pump and ventilation fan energy associated with the cooling system was reduced as well. The final analysis shows that the annual energy savings would be 7,608 MMBtu/yr (i.e., 57.63% savings), and the energy cost savings would be $ 87,799 annually (i.e., 50.0% savings based on average utility rate of $0.04939/kWh, $0.916/Therm).

B. Estimate of Simple Payback

The initial installation cost for the selected GSHP system was estimated based on the survey results from the existing GSHP systems at Department of Defense facilities. This survey estimated a commercial project cost per ton installed capacity from more than 50 systems installed. The estimation shows that the project cost per ton installed capacity is about $6,951.5/ton. In addition, there is an additional initial cost for the installation of new natural gas water heaters. In order to estimate the required storage size of water heaters for the building, the method from the ASHRAE Application Handbook was used. For about 150 quest rooms, the estimated storage size of the water heater would be about 2,600 gal. Considering other spaces in the building, the final estimated water heater storage size was assumed to be 3,000 gal. The installation cost for 100 gallon commercial water heater was assumed to be $6,000 based on the data from 2008 RS Means and other web sources. Therefore, the simple payback can be estimated as follows:

a. With cooling capacity

Initial installation cost for GSHP: 6,951.5 x 100 (ton) = $695,150

Initial installation cost for natural gas Water Heaters: 6,000 ($/100 gal) x 30 = $180,000

Total initial cost: $875,150

Baseline annual energy cost: $175,540
GSHP with cooling: $90,834
Annual savings: $84,707/yr
Estimated simple payback: $875,150/90,834 = 10.33 yrs

b. Without cooling capacity

Initial installation cost for GSHP: 6,951.5 x 100 (ton) = $695,150
Initial installation cost for natural gas Water Heaters: 6,000 x 30 = $180,000
Total initial cost: $713,150

Baseline annual energy cost: $175,540
GSHP with cooling: $87,741
Annual savings: $87,799/yr
Estimated simple payback: $875,150/87,799 = 9.97 yrs

C. Application of a GSHP System for Mt Olympus/BOQ Building 2527

Using a similar procedure, a typical GSHP system was designed and simulated for Mt Olympus building in order to assess the feasibility of GSHP installation for this building.

Ground Loop Design

The estimated the peak cooling load of 849kBtu/hr and the peak heating load of 698kBtu/hr were input in the GLD tool. The same specification of the borehole, soil, and pipe used for the McCormick Center was applied for this building. The final result shows that forty-five (45) 250 ft boreholes would be needed to meet the building design load. The possible layout of the 45 boreholes can be found in Figure 11. Boreholes are assumed to be spaced 20ft apart. As shown, 45 boreholes could be located at the back of the west wing of the building.

GSHP simulation

The energy savings potential of a GSHP system was also evaluated. The original system in the model was replaced with a GSHP system using Climate Master Add-on Feature V-1.0. Since the current add-on program cannot simulate a heating-only GSHP system, the model was first developed for both cooling and heating. The simulation assumes console water-to-air GSHP units are installed in rooms, with water-to-water heat pumps providing heated and chilled water for the large air handlers that supply ventilation air.

The simulation results are shown on Figure 12. As shown, the annual electrical energy consumption increased from 357 MWh to 744 MWh. The annul natural gas use decreased to 1,092 MMBtu/hr for DHW heating. The final analysis shows that the annual energy savings will

be 4,226 MMBtu/yr (i.e., 53.8% savings), and the energy cost savings would be annually $31,698 (i.e., 40.4% savings based on average utility rate of $0.04939/kWh, $0.916/Therm)

D. Estimate of Simple Payback

Again, the initial installation cost for the selected GSHP system was estimated based the survey results from the existing GSHP systems at Department of Defense facilities. The initial cost for the new water heaters was estimated as described above. For about 120 guest rooms, the estimated storage size of the water heater would be about 2,100 gal. Considering other spaces in the building, the final estimated water heater storage size was assumed to be 2,500 gal. The installation cost for 100 gallon commercial water heater was assumed to be $6,000 based on the data from 2008 RS Means and other web sources. Therefore, the simple payback can be estimated as follows:

a. With cooling capacity

Initial installation cost for GSHP: 6,951.5 x 70 (ton) = $486,605
Initial installation cost for natural gas Water Heaters: 6,000 ($/100 gal) x 25 = $150,000
Total initial cost: $636,605

Baseline annual energy cost: $78,439
GSHP with cooling: $46,741
Annual savings: $31,698/yr
Estimated simple payback: $636,605/31,698 = 20.08 yrs

b. Without cooling capacity

Initial installation cost for GSHP: 6,951.5 x 70 (ton) = $486,605
Initial installation cost for natural gas Water Heaters: 6,000 ($/100 gal) x 25 = $150,000
Total initial cost: $636,605

Baseline annual energy cost: $78,439
GSHP with cooling: $44,910
Annual savings: $33,529/yr
Estimated simple payback: $713,150/33,529 = 18.99 yrs

E. Combined Energy and Cost Savings, and Simple Payback

Results for the two buildings were combined to calculate the simple payback of installing GSHPs in both buildings. These figures are also estimated based on the two installation cost rates (i.e., installation cost/ton). Table 3 presents the final calculation for energy and cost savings, and simple payback. In summary, the combined (i.e., McCormick Center + Mt Olympus building) total simple payback for GSHP with cooling system is estimated at 12.99 years, and at 12.46 years without the cooling system.

Figure 1: Aerial View of the McCormick Center

Figure 2: Typical Guest Room with a Unit Heater

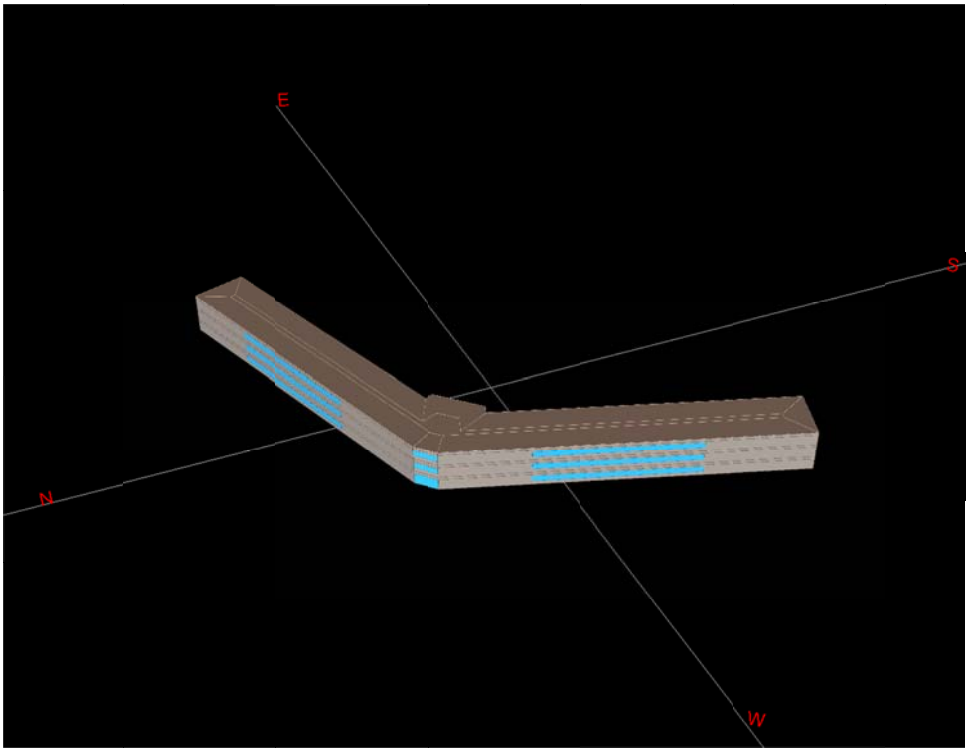
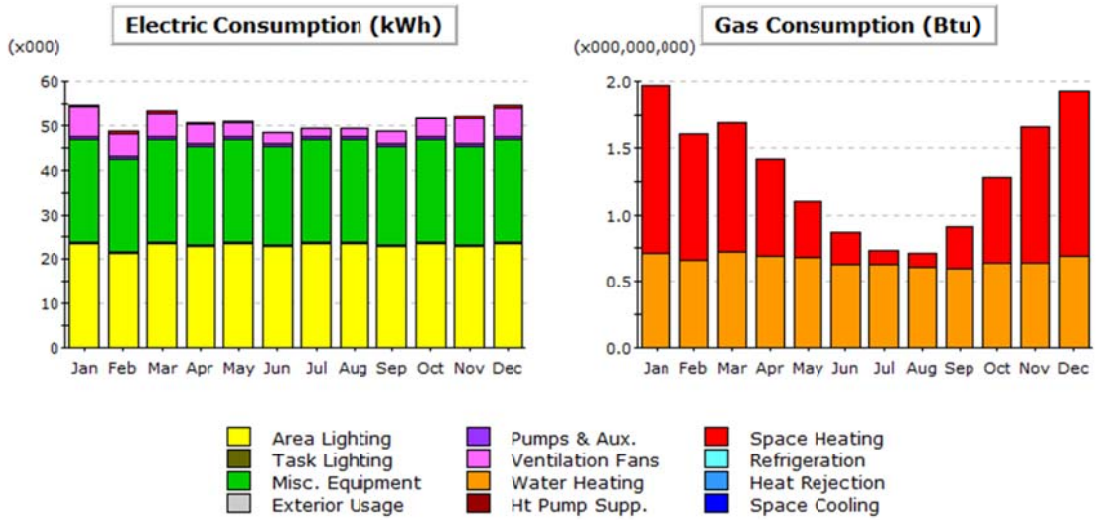


Figure 3: eQuest Model for McCormick Center



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.55	0.44	0.44	0.34	0.20	0.11	0.06	0.05	0.15	0.31	0.46	0.54	3.65
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	6.72	5.30	5.43	4.39	3.11	2.27	1.80	1.75	2.64	4.14	5.66	6.64	49.84
Pumps & Aux.	0.70	0.63	0.70	0.67	0.70	0.67	0.70	0.70	0.67	0.70	0.67	0.70	8.21
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	22.78	20.57	22.78	22.04	22.78	22.04	22.78	22.78	22.04	22.78	22.04	22.78	268.18
Task Lights	0.39	0.35	0.39	0.38	0.39	0.38	0.39	0.39	0.38	0.39	0.38	0.39	4.58
Area Lights	23.63	21.35	23.63	22.87	23.63	22.87	23.63	23.63	22.87	23.63	22.87	23.63	278.26
Total	54.76	48.64	53.37	50.70	50.81	48.34	49.36	49.29	48.75	51.94	52.09	54.68	612.73

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	1.26	0.95	0.96	0.72	0.42	0.23	0.11	0.10	0.31	0.64	1.01	1.24	7.95
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.71	0.66	0.73	0.69	0.68	0.63	0.62	0.61	0.60	0.64	0.64	0.69	7.91
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.97	1.60	1.68	1.41	1.10	0.86	0.74	0.71	0.91	1.28	1.65	1.93	15.86

Figure 4: McCormick Center Baseline eQuest Monthly Energy Usage

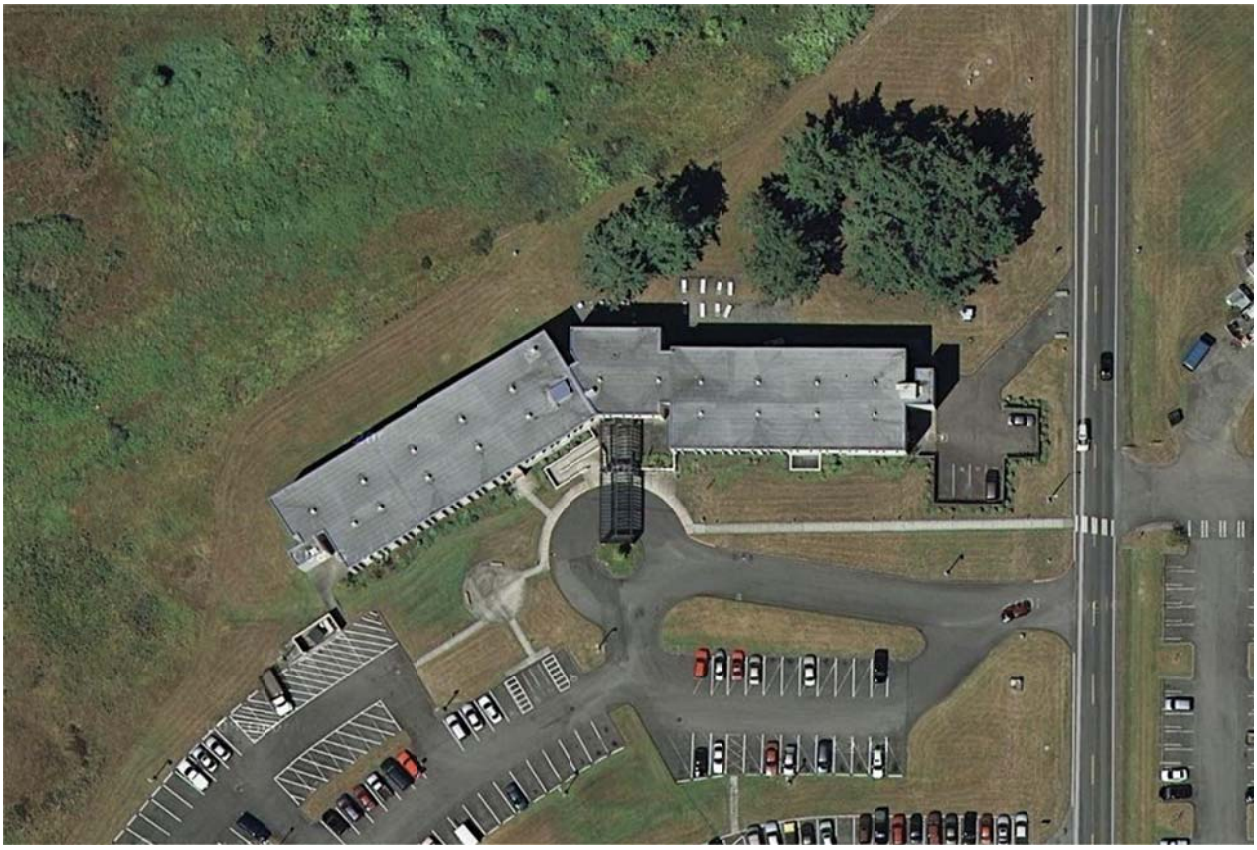


Figure 5: Aerial View of the Mt Olympus Building

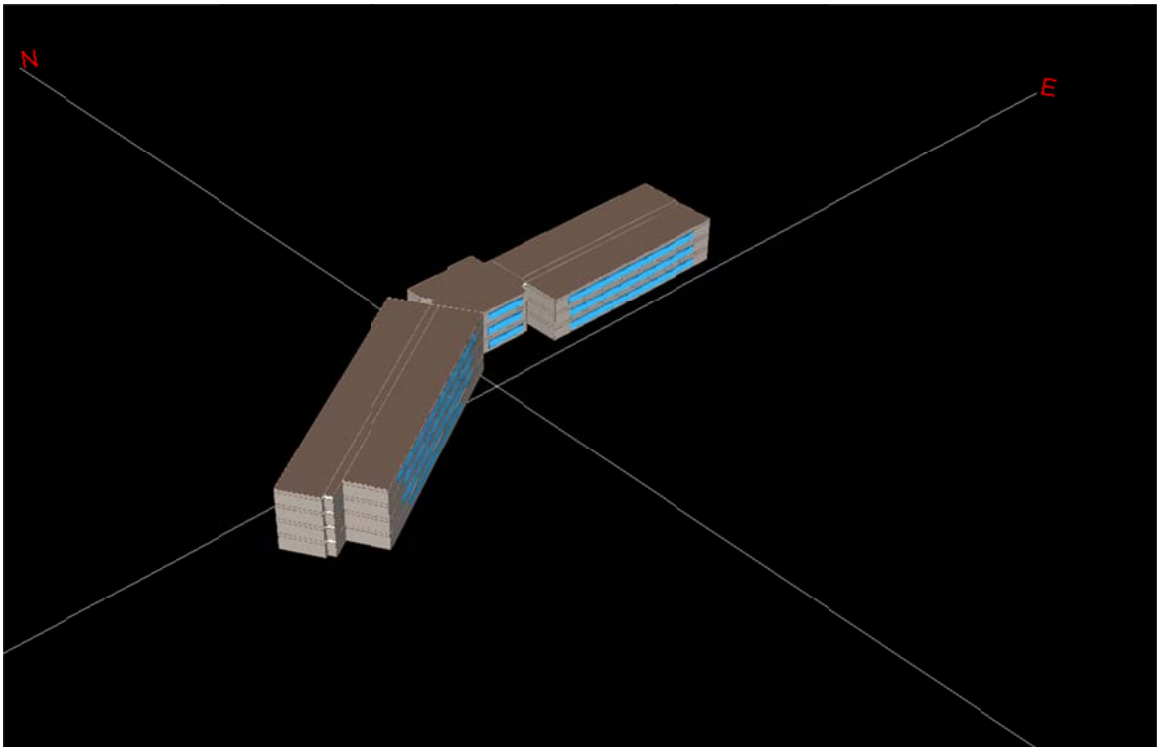
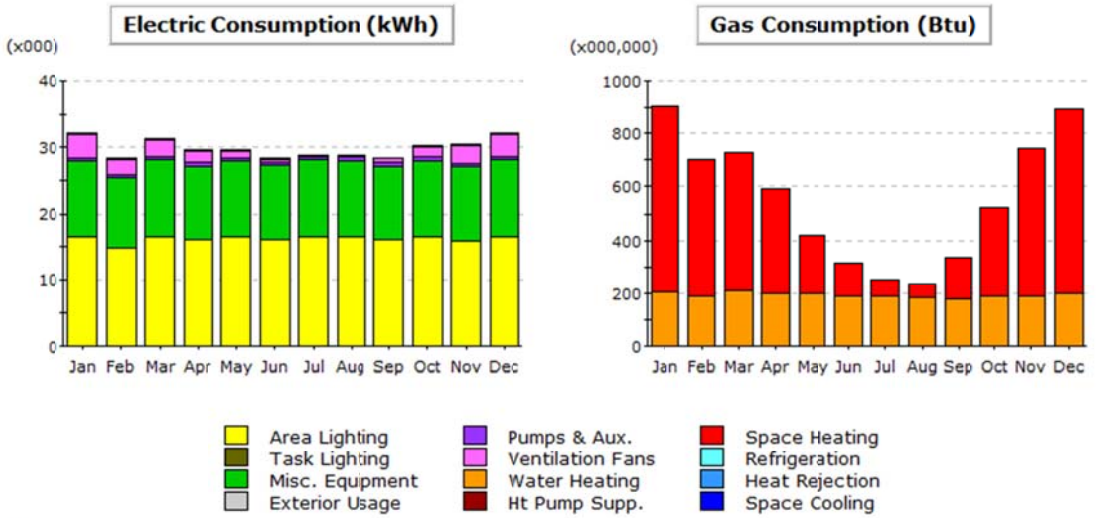


Figure 6: eQuest Model for Mt Olympus Building



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.24	0.20	0.20	0.16	0.10	0.06	0.03	0.03	0.07	0.15	0.21	0.24	1.69
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	3.40	2.47	2.48	1.84	0.99	0.54	0.23	0.18	0.69	1.56	2.69	3.37	20.43
Pumps & Aux.	0.47	0.43	0.47	0.46	0.47	0.46	0.47	0.47	0.46	0.47	0.46	0.47	5.57
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	11.39	10.31	11.43	11.07	11.39	11.07	11.43	11.41	11.06	11.41	11.03	11.43	134.42
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	16.50	14.94	16.58	16.04	16.50	16.05	16.58	16.52	16.03	16.53	16.00	16.58	194.85
Total	32.01	28.34	31.16	29.58	29.46	28.17	28.74	28.61	28.31	30.12	30.38	32.09	356.98

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	701.2	511.2	516.2	387.7	217.7	125.5	62.0	52.6	155.9	332.8	556.8	694.5	4,314.2
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	205.8	189.1	209.7	201.4	201.1	188.4	188.6	185.1	179.1	188.2	187.2	200.2	2,323.9
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	907.0	700.2	725.9	589.2	418.8	314.0	250.6	237.7	334.9	521.0	744.0	894.7	6,638.1

Figure 7: Mt Olympus Building Baseline eQuest Monthly Energy Usage

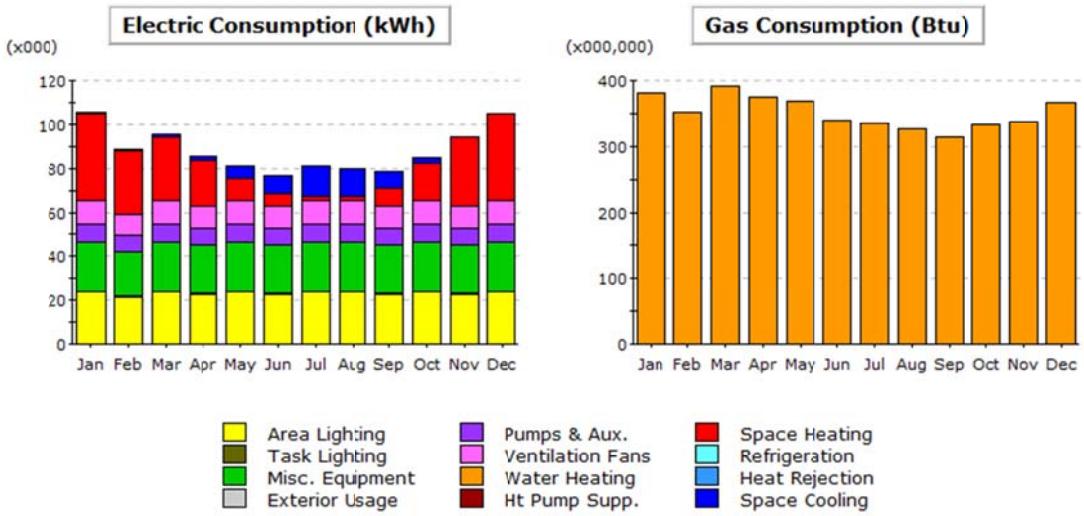
Table 1: Validation for the EUIs of Two Buildings in Whidbey Island.

Building	Elec. Use (kBtu/sqft-yr)	N.G. Use (kBtu/sqft-yr)
CBECS (National average for Logding)	42	46
Benchmark Model (Hotel in Seattle, WA)	39 (withoug cooling)	84.3
McCormick Center	32 (Without cooling)	151.7 (Without steam transmission loss)
Mt Olympus Bldg.	21 (withoug cooling)	64 (Without steam transmission loss)

Table 2: Ground Loop Design Input

Category	Input	Value
Fluid	Design Heat Pump Inlet Fluid Temperature: Cooling	95.0F
	Design Heat Pump Inlet Fluid Temperature: Heating	35.0F
	Design System Flow Rate	3.0 gpm/ton
Soil	Ground Temperature	51.0F
	Soil Thermal Conductivity	1.2 Btu/(h*ft*F)
	Thermal Diffusivity	0.75 ft^2/day
U-Tube	Borehole Thermal Resistance	0.241 h*ft*F/Btu
	Borehole Diameter	6.00 in
	Pipe Size	1 1/2 in.
	Pipe Type	SDR11

Figure 8: Borehole layout for McCormick Center



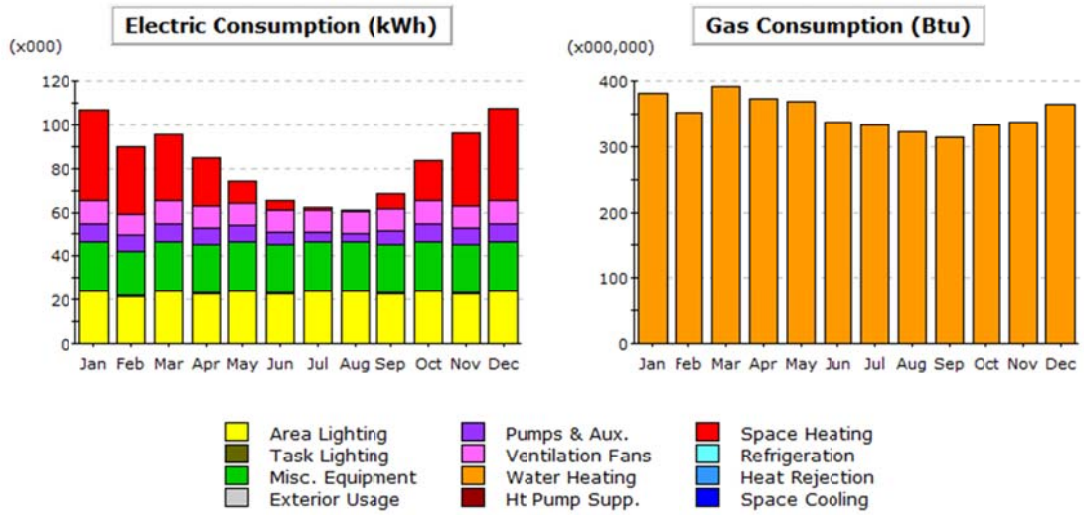
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.1	0.3	1.1	1.9	5.6	8.6	13.4	12.8	8.0	2.0	0.3	0.0	54.3
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	40.1	29.1	29.0	20.6	10.5	5.2	2.3	2.0	7.7	17.4	31.0	39.9	234.8
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	10.3	9.3	10.3	10.0	10.3	10.0	10.3	10.3	10.0	10.3	10.0	10.3	121.8
Pumps & Aux.	8.0	7.3	8.0	7.8	8.0	7.8	8.0	8.0	7.8	8.0	7.8	8.0	94.5
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	22.8	20.6	22.8	22.0	22.8	22.0	22.8	22.8	22.0	22.8	22.0	22.8	268.2
Task Lights	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	4.6
Area Lights	23.6	21.3	23.6	22.9	23.6	22.9	23.6	23.6	22.9	23.6	22.9	23.6	278.3
Total	105.3	88.3	95.4	85.6	81.3	76.9	80.8	80.0	78.8	84.5	94.3	105.1	1,056.4

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	381.3	352.6	391.1	374.0	368.7	339.6	335.6	326.0	314.9	333.5	337.3	365.7	4,220.3
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	381.3	352.6	391.1	374.0	368.7	339.6	335.6	326.0	314.9	333.5	337.3	365.7	4,220.3

Figure 9: McCormick Center with GSHP System (with Cooling) eQuest Monthly Energy Usage



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.00	-	0.00	0.01	-	0.01	0.10	0.05	0.10	0.00	-	-	0.28
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	41.94	30.71	30.39	21.60	10.15	4.20	1.10	0.70	7.14	18.54	33.20	42.36	242.04
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	10.34	9.34	10.34	10.01	10.34	10.01	10.34	10.34	10.01	10.34	10.01	10.34	121.75
Pumps & Aux.	8.03	7.25	8.00	7.70	7.08	5.69	3.96	3.33	6.10	8.01	7.77	8.03	80.94
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	22.78	20.57	22.78	22.04	22.78	22.04	22.78	22.78	22.04	22.78	22.04	22.78	268.18
Task Lights	0.39	0.35	0.39	0.38	0.39	0.38	0.39	0.39	0.38	0.39	0.38	0.39	4.58
Area Lights	23.63	21.35	23.63	22.87	23.63	22.87	23.63	23.63	22.87	23.63	22.87	23.63	278.26
Total	107.11	89.57	95.53	84.61	74.37	65.19	62.30	61.23	68.63	83.69	96.27	107.53	996.03

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	380.9	352.3	390.7	373.6	367.6	338.0	332.9	323.3	313.5	333.0	337.0	365.4	4,208.2
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	380.9	352.3	390.7	373.6	367.6	338.0	332.9	323.3	313.5	333.0	337.0	365.4	4,208.2

Figure 10: McCormick Center with GSHP System (without Cooling) eQuest Monthly Energy Usage

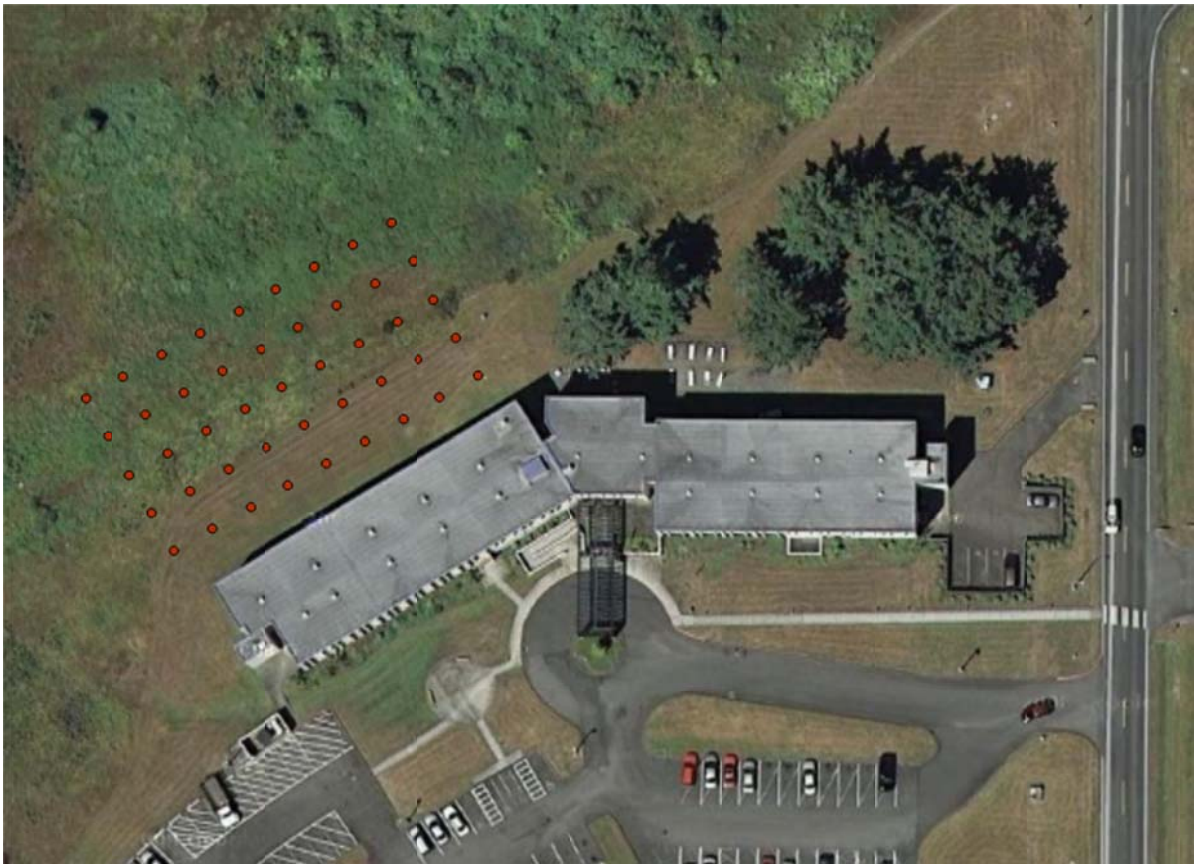
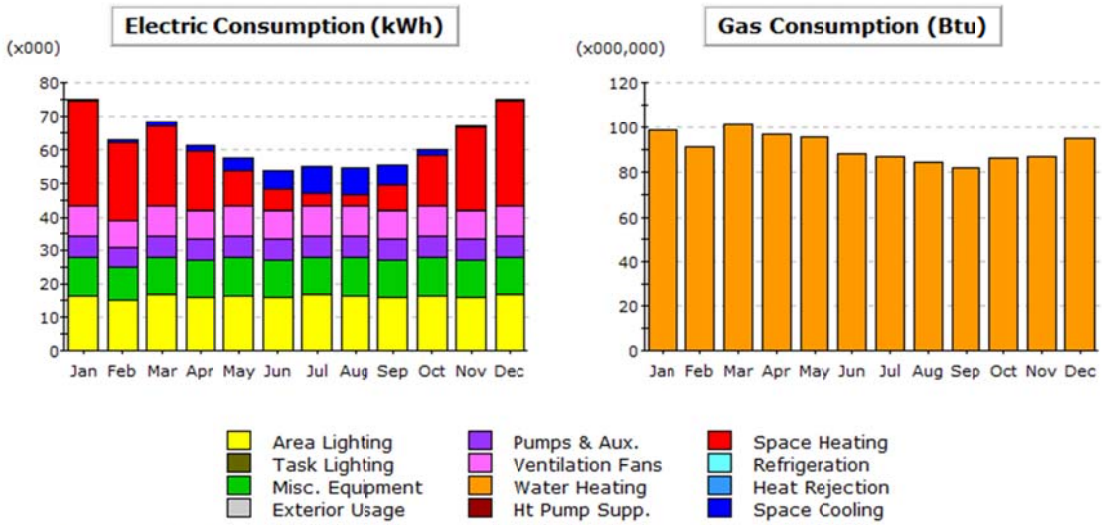


Figure 11: Borehole layout for Mt Olympus Building



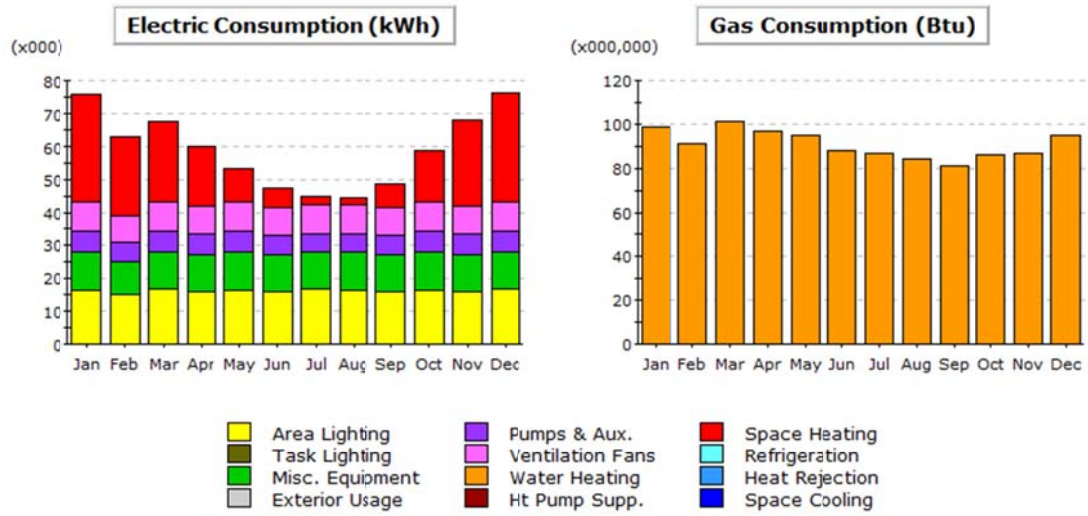
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.38	0.68	1.32	1.58	3.77	5.22	7.69	7.71	5.54	1.84	0.45	0.22	36.40
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	31.29	23.09	23.64	17.62	10.39	6.31	3.80	3.37	7.68	14.91	24.70	31.35	198.15
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	8.81	7.96	8.81	8.52	8.81	8.52	8.81	8.81	8.52	8.81	8.52	8.81	103.71
Pumps & Aux.	6.48	5.86	6.48	6.27	6.48	6.27	6.48	6.48	6.27	6.48	6.27	6.48	76.33
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	11.39	10.31	11.43	11.07	11.39	11.07	11.43	11.41	11.06	11.41	11.03	11.43	134.42
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	16.50	14.94	16.58	16.04	16.50	16.05	16.58	16.52	16.03	16.53	16.00	16.58	194.85
Total	74.86	62.83	68.26	61.11	57.35	53.44	54.79	54.30	55.10	59.98	66.97	74.87	743.87

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	98.5	91.2	101.3	97.0	95.3	88.0	86.9	84.3	81.4	86.2	87.0	94.6	1,091.8
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	98.5	91.2	101.3	97.0	95.3	88.0	86.9	84.3	81.4	86.2	87.0	94.6	1,091.8

Figure 12: Mt Olympus Building with GSHP System (with Cooling) eQuest Monthly Energy Usage



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.00	0.00	0.01	0.00	-	-	0.01	0.01	0.13	0.02	0.00	0.00	0.21
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	32.44	23.88	24.26	18.15	9.98	5.55	2.53	2.06	6.92	15.29	26.11	32.91	200.08
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	8.81	7.96	8.81	8.52	8.81	8.52	8.81	8.81	8.52	8.81	8.52	8.81	103.71
Pumps & Aux.	6.48	5.86	6.48	6.27	6.46	5.94	5.55	5.72	5.87	6.48	6.27	6.48	73.88
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	11.39	10.31	11.43	11.07	11.39	11.07	11.43	11.41	11.06	11.41	11.03	11.43	134.42
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	16.50	14.94	16.58	16.04	16.50	16.05	16.58	16.52	16.03	16.53	16.00	16.58	194.85
Total	75.62	62.95	67.56	60.06	53.14	47.14	44.92	44.54	48.53	58.54	67.94	76.21	707.15

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	98.5	91.2	101.2	96.9	95.2	87.8	86.5	83.9	81.2	86.2	86.9	94.6	1,089.9
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	98.5	91.2	101.2	96.9	95.2	87.8	86.5	83.9	81.2	86.2	86.9	94.6	1,089.9

Figure 13: Mt Olympus Building with GSHP System (without Cooling) eQuest Monthly Energy Usage

Table 3: Energy and Cost Savings, Simple Payback from Two Buildings in Whidbey Island (Using Survey Data (i.e., using $6,951.5/ton)

Scenario	Annual Elec. Use (MWh)	Annual N.G. Use (MMBtu)	Total Annual Energy Use (MMBtu)	Annual Energy Cost	Cost Savings	Initial Cost	Simple Payback (yr)
Baseline	613	15,860	17,951	$175,540	-	$875,150	-
GSHP with Cooling	1,056	4,220	7,826	$90,834	$84,707	-	10.33
GSHP without Cooling	996	4,208	7,608	$87,741	$87,799	-	9.97
Baseline	357	6,638	7,857	$78,439	-	$636,605	-
GSHP with Cooling	744	1,092	3,631	$46,741	$31,698	-	20.08
GSHP without Cooling	707	1,090	3,503	$44,910	$33,529	-	18.99
Baseline	970	22,498	25,808	$253,979	-	$1,511,755	-
GSHP with Cooling	1,800	5,312	11,456	$137,574	$116,405	-	12.99
GSHP without Cooling	1,703	5,298	11,111	$132,651	$121,329	-	12.46