APPENDIX B: ENERGY ANALYSIS

Executive Summary

Portico Architects is designing the Mary Lowell Center in Seward, Alaska for the National Park Service. The purpose of the energy analysis is to assess the potential energy savings for the conceptual building design and highlight measures that are the most appropriate for this project.

The table below summarizes the results for the analysis. Four cases were analyzed:

- Case 1 – ASHRAE 90.1-2001 code-compliant building with packaged variable air volume system and wood chip boiler.
- Case 2 - proposed design with wood chip boiler. Energy efficiency measures include R-30 roof insulation, U=0.4 windows, daylighting controls, natural ventilation, radiant slab heating and demand controlled ventilation.
- Case 3 – low cost proposed design. Replace wood chip boilers with propane boilers (85% efficient) and radiant floors with fin-tube convection heaters
- Case 4 – high cost proposed design. Add energy recovery ventilation to Case 2.

The table gives annual electricity and heating costs for the four cases. In all four cases, the domestic water heating costs $666 annually and is included in the heating costs. The wood chip boilers are modeled in Case 1 and Case 2. The cost savings with the proposed design are primarily due to the demand controlled ventilation. The wood chip boilers in the proposed design save $21,000 as compared to the 85%-efficient fuel oil boilers (Case 3). The energy recovery ventilation (ERV) saves a net $1,400 per year; the heating energy savings are somewhat offset by the increase in fan energy use.

	Electricity $/yr	Heating $/yr	Total	$ Savings
Case 1 ASHRAE 90.1-01	$28,201	$17,568	$45,769	
Case 2 Proposed	$23,411	$8,469	$31,880	$13,889
Case 3 Fuel Oil Boilers	$23,487	$29,781	$53,268	-$7,499
Case 4 Add ERV to Case 2	$25,763	$4,695	$30,458	$15,311

Please refer to the original analysis for recommendations on insulation, including basement insulation. Additional savings are anticipated with a more efficient lighting design and controls. Occupant loads need to be revisited to ensure they have been characterized accurately in order to optimize natural ventilation for cooling. The large variations in occupant loads make demand controlled ventilation very cost effective. Variable frequency drives for the fans may also be cost effective.

Peak demand charges account for nearly 40% of the electricity costs. Lighting is the largest end use at over 50% of the peak demand each month. It will be important to control this load as well as equipment and exhibit loads to keeps these costs down.

Energy Analysis

Introduction

Portico Architects is designing the Mary Lowell Center in Seward, Alaska for the National Park Service. The purpose of the energy analysis is to assess the potential energy savings for the conceptual building design and highlight measures that are the most appropriate for this project.

The energy analysis is based on the energy cost budget method in the ASHRAE 90.1 - 2001 energy standard. This requires that a budget building be modeled that meets ASHRAE 90.1-2001 and that the proposed design be modeled and compared to the budget building.

Climate

For the hourly weather data, the TMY weather file for Juneau, Alaska was used. Table 2 summarizes the weather data. ASHRAE 90.1-01 (IECC 2003) prescriptive requirements for this climate (B-22) have been followed in the budget building (case 1).

Table 2. Climatic Conditions

Climatic Conditions	Seward, AK	Juneau, AK
Latitude	60.12	58.4
Longitude	149.95	134.6
Elevation ft	59	
Summer Design Conditions (Tdb/Twb)	70/56.8 F	69/59 F
Winter Design Conditions (Tdb)	3 F	-1
Cooling Degree Days (base 60° F)	29	0
Heating Degree Days (base 65° F)	9007	9334

Utility Structure

The electricity and fuel oil rates were provided by the City of Seward. The utility rates used in the analysis are as follows:

Electric Rates

Energy Charge, first 200 kWh	$0.1056/kWh
Energy Charge, above 200 kWh	$0.0758/kWh
Peak Demand Charge	$13/kW

Fuel Oil Rate

Fuel Oil per gallon	$2/gal

Wood Chip Cost

Wood Chip	$0.3/therm

Simulation Model Assumptions

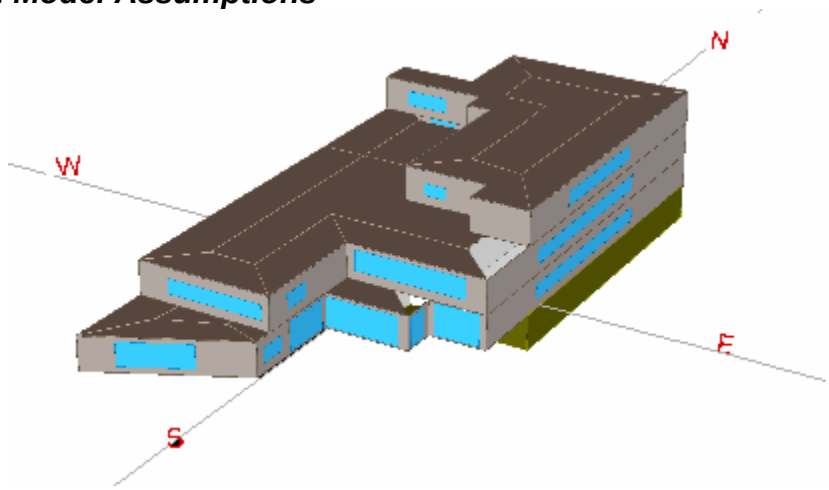


Figure 1 EQUEST model of building.

The EQUEST building energy simulation program was used to model the energy use in the building. EQUEST uses the DOE-2.2 simulation engine for the calculations. Figure 1 depicts the building as modeled in EQUEST. The architectural form for this building is nearly impossible to mimic in EQUEST. The most important issue is to develop a model that accurately reflects the thermal performance of the building. EQUEST cannot simulate use of the tower as a ventilation stack; this will be done separately.

The envelope assumptions for the proposed design and the ASHRAE 90.1-01 budget building are given in Table 3. Table 4 lists the assumptions for lighting power densities (LPD) as required by ASHRAE 90.1-01. The proposed case is assumed to have daylighting controls. The equipment power density is the electricity load from anything that is plugged in, except for heating, ventilation and air conditioning equipment. We have assumed 0.75 W/sf in the offices and exhibit areas, 0.5 W/sf in the auditoriums, 0.2 W/sf in the lobby, and 0.1 W/sf in the restrooms and corridors.

The building HVAC assumptions are given in Table 5.

Table 3. Building Envelope Assumptions

Element	Budget (ASHRAE 90.1-2001)	Proposed
Floor Area (ft^2)	54,200	54,200
Number of Stories	2 VC/ 4 Offices	2 VC/ 4 Offices
Average Floor-to-Ceiling Height		0
Floor-to-Floor Height	16' VC / 12' Offices	16' VC / 12' Offices
Window Area (ft^2)		0
North	517	517
East	1268	1268
Southeast	358	358
South	821	821
West	797	797
Window to Wall Ratio	21%	21%
Windows / Glazing		0
NFRC Window U-Value Solar Heat Gain Coefficient	U=0.57 SHGCall=0.49	U=0.40 SHGCall=0.49
Frame Type	T/B Metal	T/B Metal
Shading	None	None
Envelope Constructions		
Exterior Wall Construction	Steel Framed	Steel Framed
Insulation	R-13 + R-7.5 c.i.	R-13 + R-7.5 c.i.
Total U-Value	0.064	0.064
Roof Construction		
Insulation	R-15	R-33
Total U-Value	0.063	0.03
Slab Construction		
Insulation	NR	NR
Underground Walls		
Insulation	NR	NR

Table 4. Lighting Power Densities

Space Function	Budget LPD A90.1-2001 (W/ft2)	Proposed LPD (W/ft2)	EPD (W/ft2)
Mechanical/Electrical	1.5		0.10
Storage (active)	0.8		0.10
Lobby/Shared	1.1		0.20
Office	1.1		0.75
Restroom	0.9		0.10
Conference	1.3		0.25
Corridor	0.5		0.10
Visitors (General Exhibits)	1.0		0.75
Total Building	**0.98**		

Table 5. Building HVAC Assumptions

	Budget	**Proposed**
HVAC System	Packaged VAV with reheat	Radiant floor with dedicated outdoor air system
Cooling System	Direct Expansion (DX)	Natural ventilation
Cooling Efficiency	9.5 EER	N/A
Heating System	2 Wood Chip Boilers	2 Wood Chip Boilers
Heating Efficiency	65%	65%
Supply Air Flow		
Supply Fan Control	No VSD	No VSD
Supply Fan Static Pressure	2"	1"
Minimum outdoor air requirements	20 cfm/person	20 cfm/person
Economizer	Yes	Yes
Demand Control Ventilation	No	Yes
Energy Recovery Ventilation	No	No
Thermostat Cooling Setpoints/Setback	78/86 F	78/86 F
Thermostat Heating Setpoint/Setup	68/62 F	68/62 F
Humidity Control	No	No
Water Heater	Electric	Electric
Hot Water Demand (gpm)	.30 gpm	.30 gpm
Pumps	No VFD	No VFD
Motors	High Efficiency	High Efficiency

Table 7 gives the operating hours for the different areas of the building. Note that the visitor center and conference center are only open Tuesday and Thursday from October 1 to May 1.

Table 7. Schedules and Occupancy

	Occupancy			Fans
	Winter	Summer	Peak Occupants	
Offices	8am-6pm M-F	8am-6pm M-F	Offices: 100 sf/occ, Storage: 300 sf/occ	On one hour before and one hour after occupancy
Exhibit and conference	8am-6pm Tues&Thurs	8am-6pm M-F	15 sf/occ	On one hour before and one hour after occupancy

Results

For the schematic design phase, four cases were analyzed:

- Case 1 – ASHRAE 90.1-2001 code-compliant building with wood chip boiler.
- Case 2 - proposed design with wood chip boiler. Energy efficiency measures include R-30 roof insulation, U=0.4 windows, daylighting controls, natural ventilation, radiant slab heating and demand controlled ventilation.
- Case 3 – low cost proposed design. Replace wood chip boilers with propane boilers (85% efficient) and radiant floors with fin-tube convection heaters
- Case 4 – high cost proposed design. Add energy recovery ventilation to Case 2.

To determine the most appropriate strategies for reducing energy use it is important to consider energy use by end use and the individual load components. Figure 2 compares the annual energy costs for the regulated end uses for each case. As expected, space heating and lights are the largest end uses. The wood chip boilers in Case 2 have the potential to reducing heating costs by $21,000 as compared to the proposed design with fuel oil boilers (Case 3). Note that Case 2 and Case 3 were modeled with demand controlled ventilation, so the predicted savings are conservative.

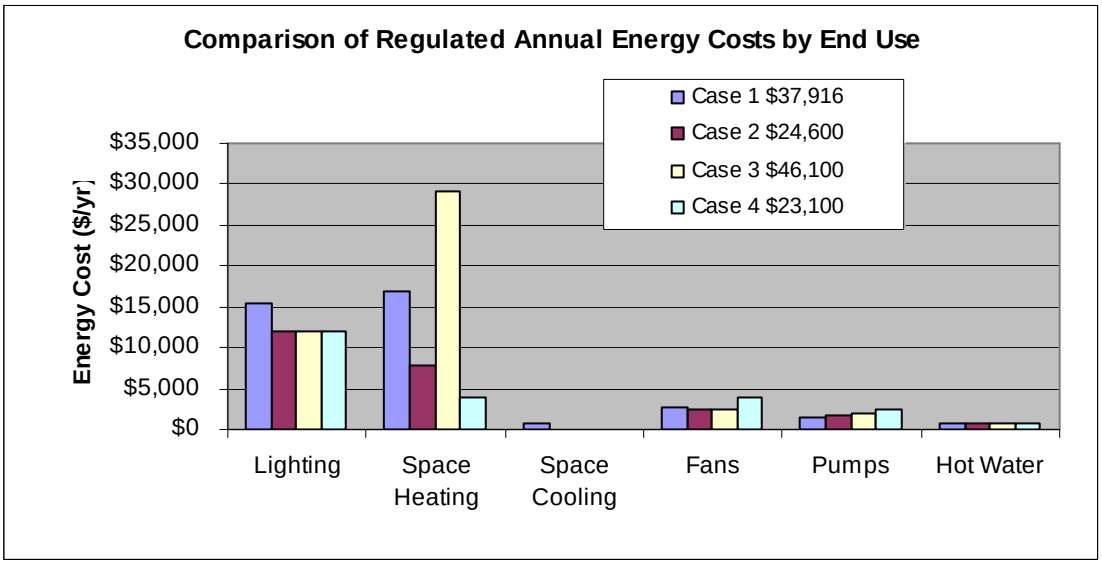
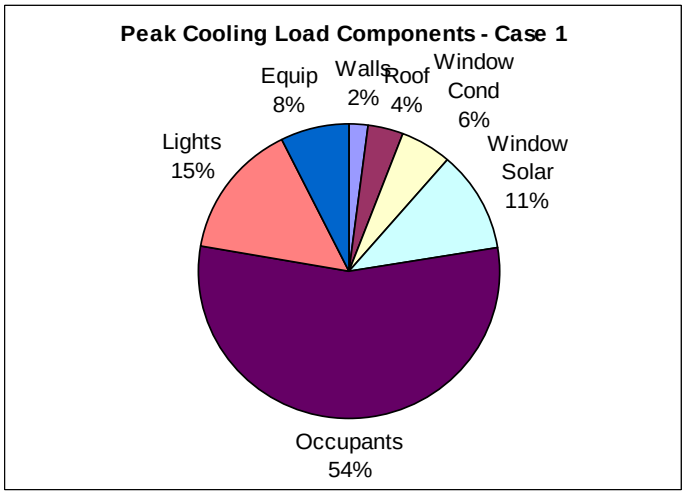


Figure 2 Comparison of annual energy costs by regulated end use.

Next, consider the load components for cooling and heating. Even though cooling energy costs are minimal, it is important to minimize the cooling loads in order to avoid having to mechanically cool the building. Occupants account for more than half the cooling

load, followed by lights and the window solar heat gain (Figure 3a). There is no ventilation load because the outside air temperature is about the same as the indoor air temperature, or lower, during cooling times. From the end-use cost comparison and the cooling loads, there are clearly significant benefits from minimizing lighting energy use through a more efficient design, daylighting and occupancy sensors.



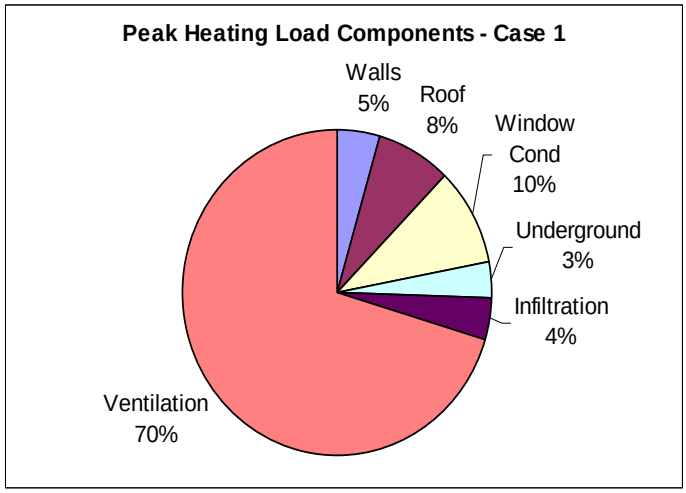


Figure 3a and 3b. Peak cooling and heating load components.

On the heating side, the outside air ventilation load is by far the largest heating load (Figure 3b). The envelope components account for the rest of the load, along with infiltration.

Figure 4 compares the monthly space heating energy use for the four cases. The energy use with the fuel oil boilers is less than the wood chip boilers because the fuel oil boilers are more efficient. However, the fuel costs for the wood chip boilers is much less than that for fuel oil. Energy recovery ventilation reduces the space heating energy use, although the savings are somewhat offset by the increase in fan energy. The cost effectiveness of this measure needs to be considered more fully.

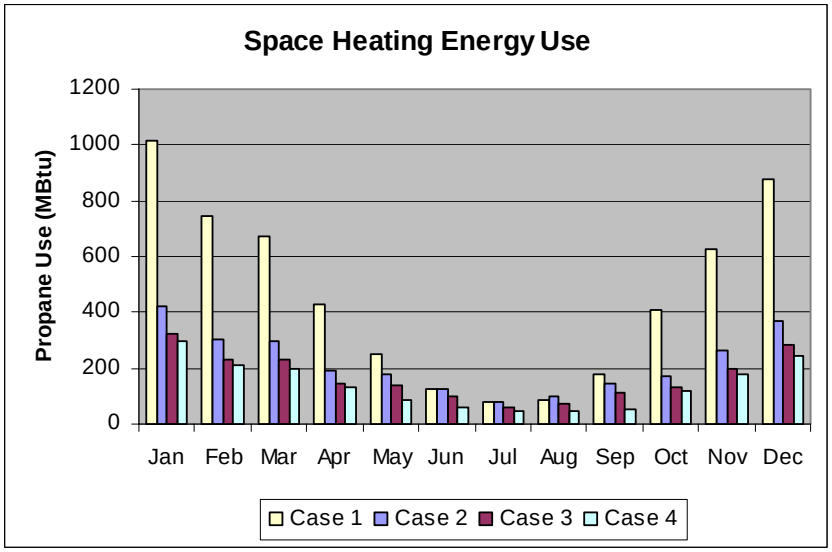


Figure 4 Monthly space heating energy use.

On the electric side, lighting dominates the energy use. Figure 5 shows the electricity end uses by percentage for the proposed design. Daylighting controls have been modeled, although they have not been optimized. Lighting energy use could be further reduced through occupancy sensors and a more energy efficient design. Variable frequency drives may also be cost effective; as the design progresses, these can be easily analyzed.

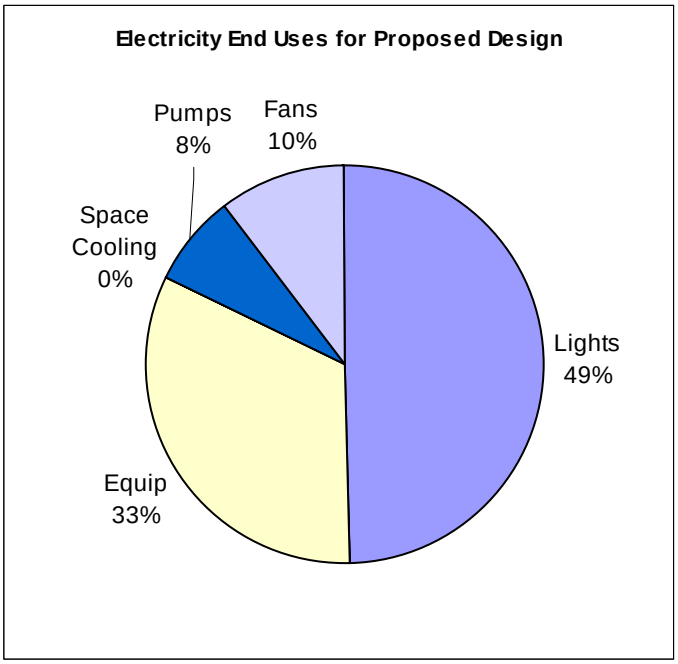


Figure 5 Electricity end uses for proposed design.

Peak demand charges account for nearly 40% of the electricity costs. Lighting is the largest end use at over 50% of the peak demand each month. It will be important to control this load as well as equipment and exhibit loads to keeps these costs down.