McCall, Idaho Biomass Options:
Analysis and Building Readiness

May 2013

Prepared by:
WSU Extension Energy Program

P.O. Box 43165 • Olympia, WA 98504-3165
(360) 956-2004 • Fax (360) 236-2004 • TDD (360) 956-2218

WSUEEP13-019

WASHINGTON STATE UNIVERSITY
EXTENSION ENERGY PROGRAM

Cooperating agencies: Washington State University Extension Energy Program, Idaho Department of Agriculture, McCall Memorial Hospital, McCall-Donnelly High School

Acknowledgements

This material is funded by the U.S. Department of Energy under Title IV of the American Recovery and Reinvestment Act of 2009 (“ARRA”), (Public Law 111-5), through its Renewable Energy Enterprise Zone Program Award No. DE-EE0000141 to the Idaho Office of Energy Resources (IOER). WSU gratefully acknowledges the help of Matt Wiggs of the Idaho Office of Energy Resources and the support of St. Luke’s McCall Memorial Hospital, McCall-Donnelly High School, the U.S. Forest Service, and Rick Brenneman and the Idaho Woody Biomass Utilization Partnership.

Disclaimer

Authors

The Washington State University Energy Program had a team of experts with specific skill sets author this report. The authors are David Sjoding (Principal Investigator), Ken Eklund, Carolyn Roos Ph.D., Marcia Karr, PE, and Luke Howard. Carolyn Roos and Marcia Karr are mechanical engineers and Luke Howard is a Building Science Specialist.

Executive Summary

St. Luke's McCall Memorial Hospital, McCall-Donnelly High School, and the U.S. Forest Service (USFS) requested the Washington State University (WSU) Energy Program to perform a feasibility study to assess the potential for using biomass as an energy source for space heating, water heating and electricity for ten existing buildings and one proposed building located in McCall, Idaho. This preliminary feasibility study explores several options at a conceptual level with the expectation that a more detailed study of recommended options will follow[1]. A life cycle cost analysis was performed for converting to biomass-heating at the hospital and high school[2]. There is a sharp cost of energy differential between the relatively cheaper electricity and fuel oil/propane. This differential has impacted the results of the analysis. An Action Plan has been developed (see below).

All but one of these eleven buildings uses electricity for space heating. McCall Memorial Hospital -- a 38,000 square foot, 15 bed hospital – uses fuel oil for space heating and propane for potable water heating. The high school's 90,189 square foot main building used about 520,000 kWh per year for heating and has annual demand charges of about 400 kW per year. The proposed Payette Supervisors Office 12,438 square feet will be heated very efficiently with a geothermal variable refrigerant heat pump system. An analysis of this building's envelope energy efficiency was also included. Other buildings were small and not included in this analysis.

Energy efficiency improvements are an important first step in any energy project and should be implemented regardless. A number of energy efficiency measures and actions are recommended for the high school and hospital campuses that we estimate could achieve energy savings of at least 20%. Many are operation and maintenance (O&M) measures, which can be implemented at low or no cost. We recommend implementation of O&M measures immediately. A few specific energy efficiency measures were found cost effective for the new McCall Forest Headquarters. Measures requiring capital expenditures may require further analysis to determine costs and savings and possibly obtain incentive funding. A few specific energy efficiency measures were found cost effective for the new Payette Supervisors Office.

Two options were examined for replacing the fuel oil boilers at the hospital and the electric boilers at the high school's main building: 1) A wood pellet boiler; and 2) A semi-automated wood chip boiler, as summarized in Tables 1 and 2. Wood pellet systems have lower capital investment but greater fuel costs, compared to wood chip

---

[1] This study is based primarily on utility and fuel billing data, a comparison of energy use with average energy utilization indices (EUIs) for similar buildings in the U.S with similar climate, information gathered in a meeting of interested parties, by email with building personnel, and a brief tour of the site. We were not provided with architectural drawings of any of the buildings and did not perform in-depth site assessments of the buildings.

[2] The life cycle cost analysis was performed in RELCOST Financial, available at http://www.chpcenternw.org/ResourcesSoftwareLinks/Software.aspx, developed by the Washington State University Energy Program.

systems. A properly designed wood pellet system is easier to maintain and operate. Energy cost savings at the hospital are due to the lower cost of biomass compared to fuel oil. Cost savings at the high school are due to both reductions in electricity demand charges and using less electricity.   At the hospital, a wood pellet system is estimated to have an internal rate of return of 17% and discounted payback of 7.1 years, assuming 10% energy efficiency is first achieved. A 25% grant – the maximum of the USDA's REAP program or similar program offerings – would improve the internal rate of return to 24% and reduce the discounted payback to 5.0 years.

As a third option for heating the hospital, there is a possibility of a small industrial biomass processing facility being located near the medical campus. Waste heat might be recovered from this facility and used to heat the hospital and two other buildings that have forced air electric heating. The discounted payback for this option is 2.3 years for the hospital only and 7.5 years if all three buildings are included in the project.

District heating is not recommended because most of the buildings are small and are electrically heated. District heating is practical when the better efficiency of a larger central plant outweighs the greater installation and operation costs of the hot water distribution system. This is not the case here due to costs associated with excavation in rocky soil for miles of distribution.

Combined heat and power (CHP) also is not cost effective because cooling and water heating needs during the summer are comparatively very small. CHP is only cost effective if the heat recovered from electricity generation can be put to good use year round, which in this case results in a CHP system that is too small to be practical. In addition, the low price of electricity from Idaho Power further negates the cost effectiveness of CHP.

Action Plan

We recommend further investigation of energy efficiency at all existing buildings and, if incentive funding is available, of biomass heating at McCall Memorial Hospital.   We recommend the following steps to investigate this opportunity further.

1. Implement energy efficiency improvements at all buildings.
    - Focus first on O&M measures at the high school main building and hospital and measures at the hospital that would enable reducing the size of a wood-fired boiler, if installed.
    - Contact Idaho Power for information on efficiency incentives available and requirements for obtaining them.
    - Perform energy analysis of capital measures to determine cost effectiveness and prioritize measures for the existing buildings and new McCall Forest Headquarters.

2. Proceed with further analysis of biomass-heating at McCall Memorial Hospital
    - Investigate coordinating with a possible biomass processing facility and district heating project.

- Investigate long term biomass availability, reliability and costs, including exploration of agreements with forest managers and long term Stewardship Contracts.
  Contact US Forest Service Biomass Coordinator for your area.
  http://www.fs.fed.us/woodybiomass/aboutus.shtml
- Investigate possible incentives from USDA, the State of Idaho and Idaho Power, summarized in Table 3. For example, USFS funding of up to $250,000 for system engineering design under the Woody Biomass Utilization Grant requires a comprehensive feasibility study and a woody biomass resource supply assessment. Preparation for a 2014 proposal should begin this summer.
- If incentives and assistance are available, hire a design engineering firm with experience in bioenergy to perform a “Level 3” engineering and design study and proceed with the design, if feasible.

Table 1. Two options for conversion to biomass heating at McCall Memorial Hospital, which is currently heated with a 3.2 MMBtu/h fuel oil boiler.

Building Floor Area (square feet)	38,000	
Existing Fuel Oil Boiler Size[2] (MMBtu/h)	3.2	
Assumed Size of New Biomass Boiler[2] (MMBtu/h)	2.9	
Current Fuel Oil Use for Heating & Emergency Back Up Generation (gallons)	~52,000	
Diesel Savings (gallons), Not Including Energy Conservation Savings[2]	42,400	
Fuel Oil Cost	$3.40	
Biomass Fuel Required (tons)	380 bone dry tons, 760 green tons[3]	
Biomass Fuel	Wood Pellets	Wood Chips
Assumed Biomass Cost, Delivered in Bulk	$185	$50/green ton $100/bone dry ton
Installed Project Cost[2]	$620,000	$830,000
First Year Energy Cost Savings ($/yr)	$73,000	$106,000
Operation & Maintenance Labor (hrs/yr)	44	260
Internal Rate of Return After 10% Energy Efficiency Achieved	17.4%	14.7%
Discounted Payback Before (years) After 10% Energy Efficiency Achieved[2]	7.1	8.5

1. Heating degree days in McCall ID averaged 8,698 over years 2010 to 2012, http://www.wrcc.dri.edu/cgi-bin/cliMONthdd.pl?id5708

2. Energy efficiency measures discussed in Section “Energy Efficiency Improvements” below would reduce biomass use and fuel oil savings attributed to the biomass heating project. Biomass boiler size may also be reduced, reducing project cost. A preliminary estimate assumes energy efficiency measures would reduce fuel uses by 10% and enable downsizing the boiler by 10%.

3. Green wood chips are assumed to have a moisture content of 50% on a wet basis.

Table 2. Incentives your project may be eligible to receive

Incentive Source	Assistance of Interest	Website
USDA REAP Grant	Project costs including design and construction	http://www.rurdev.usda.gov/BCP_ReapResEei.html
U.S. Forest Service Woody Biomass Utilization Program	Design and analysis costs	http://www.fpl.fs.fed.us/research/units/tmu/tmugrants.shtml
State of Idaho Low Interest Energy Loan Program	Low interest loan on biomass-heating system at hospital	http://www.energy.idaho.gov/financialassistance/energyloans.htm
Idaho Power “Easy Upgrades Efficiency Incentive”	Prescriptive measures for lighting	http://www.idahopower.com/EnergyEfficiency/Business/Programs/EasyUpgrades/
Idaho Power “Custom Efficiency Program”	Custom measures for electric heating, fans, pumps, controls, lighting	http://www.idahopower.com/pdfs/printPDF.cfm

Introduction

The use of biomass to generate heat and power is crucial in achieving energy independence and increasing our use of renewable energy sources, especially in rural America. Using forest thinnings and trimmings from forest lands as an energy resource can also improve forest health and resiliency and prevent wildfires when implemented as part of a sustainable forest management program. Using a local product as an energy source keeps dollars in the local economy. At the same time, facilities can save on energy bills when switching from expensive fuels like diesel and propane, if biomass is readily available over the long term. They can also improve system reliability.

Located in the middle of federal and state forest land, McCall has good availability of biomass. The National Forest System in particular provides a great biomass resource for this location with approximately 650,000 acres of overstocked land having accessible slopes in a non-reserved category within 40 miles of McCall.[3]

Good candidate facilities for biomass energy systems include those that have high heating bills, those that have either steam or hot water heating distribution systems and those that have ready access to reasonably priced biomass fuel. Of the 11 buildings in this study, McCall Memorial Hospital is ideal. The fact that it operates 24 hours a day, 7 days a week also improves cost effectiveness.

Both wood chip and pellet biomass systems are proven technologies, providing heat to millions of homes and commercial buildings throughout the world. Biomass boilers can be semi-or fully-automatic. They can be purchased with a de-ashing system, automatic fire tube cleaning, and more. Maintenance and operation is easy to learn, especially when staff is already familiar with diesel boilers. Training will need to be part of the project specifications because the biomass boiler is different than a diesel boiler, but, hospital staff has demonstrated the aptitude.

Study Objectives

We were requested to examine biomass heating, district heating, combined heat and power, and energy efficiency improvements. The tasks addressed in this report are:

- Conduct a billing analysis of each building to identify the Energy Use index (EUI), the overall load shapes for heating and cooling, and the energy footprint of each building;
- Evaluate the current and potential systems that fit the loads and the district heating and CHP potential;
- Select systems to compare while identifying the pros and cons of each system including an estimated capital cost;
- Generate system line drawings and model specifications of direction selected by the Facilities based on above deliverables.

---

[3] "Preliminary Biomass Feasibility Study, Payette National Forest – Krassel Yeard, McCall, Idaho", prepared by Craig Hustwit, James Baker, Dean Graham, National Energy Technology Laboratory, prepared for William L. Perry, Supervising Civil Engineer, Payette National Forest, March 2011

Site Descriptions

The buildings included in this study are summarized in Table 4. A satellite image of the hospital complex and high school is shown in Figure 1.

Hospital Complex

The St. Luke's McCall Memorial Hospital complex is comprised of 5 buildings – a hospital, three medical clinic buildings and a chapel.

The main hospital building is 50 years old with an addition added 15 years ago. It is heated by two 3.2 MMBtu/h fuel oil boilers, which are alternated. The boilers generate steam with converters for hot water distribution to serve space heating needs. A 100 ton chiller provides air conditioning. The hospital has a 250 kW diesel generator for life/safety systems. A propane boiler provides hot water to serve the laundry, physical therapy and cooking needs. We estimate the hospital uses approximately 600 gallons of hot water per day, based on propane billing records.

As shown in utility billing data in Figure A-5, the electricity demand during winter months averages 200kW. In summer months, space cooling adds approximately 95kW. From billing data, it is estimated the cooling is required approximately 1,300 hours per year.

McCall-Donnelly High School Campus

The McCall-Donnelly High School serves approximately 282 students. The campus has a 90,000 square foot main building and four smaller buildings: an annex, a roughly 3,000 square foot IT building and two 1,100 square foot portable buildings. Facilities are occupied from 6:00 am to 3:30 pm during the school year.

The main building is heated by a 2.94 MMBtu/h electric hot water boiler. There is no mechanical cooling. The smaller buildings all have electric forced air furnaces.

The school campus uses an estimated 850,000 kWh/yr for space heating and 600,000 kWh/yr for lighting and other electric uses. Electricity costs average $104,000 per year based on utility bills from 2010 and 2011, including demand charges.

U.S. Forest Service Payette Supervisor Office Building

The Payette Supervisor's Office building has not been built yet. It is to be about 12,000 square foot office building. The heating and cooling loads are modeled by the Case, Lowe & Hart firm.

The current design is to use a mechanical HVAC system that is the most efficient technology available today - A water source VRF. We also recommend the 2-pipe VRF to allow for more flexibility of future tenant improvements. The design is for about 21-ton capacity on the condensing units. The peak heating load is modeled to be 170,000 BTU/hr.

The design currently has about $75,000 budgeted for the vertical bores. This first cost may be eliminated if biomass is provided. The maintenance cost of pumps and controls for the ground source system may also be eliminated. However, biomass capital costs and maintenance cost would be added.

Table 2. Floor areas, energy utilization utilities and national median energy use of buildings of same type

Facility	Floor Area (square feet)	Energy Utilization Index (EUI) (kWh/ft^2)	National Median Energy Use[1] (kWh/ft^2)
HIGH SCHOOL CAMPUS			
Main Building	90,189	15.4	8.4
Two Portable Class Rooms	1,100 each	21.6	
Annex	Unknown		
Information Tech Building	3,000		
U.S. FOREST SERVICE			
Payette Supervisors Office (planned)	12,438	N/A	
HOSPITAL COMPLEX			
St. Luke's McCall Memorial Hospital	38,000	337	26.5
Nokes Medical Office	4,000	29	
Lake Street Therapy	5,995	37	
Integrative Medical Clinic	1,480	69	
St Luke's Clinic	14,219	18	
Our Savior Chapel	5,479	6	--
TOTAL	**~177,000**		

1. U.S. Energy Information Administration, U.S. Commercial Buildings Energy Intensity, website: http://www.eia.gov/emeu/efficiency/cbecstrends/cbi_html/cbecs_trends_6b.html

Figure 1. Satellite image of high school campus, outlined in red, and the medical campus, outlined in purple. An open area that can be used for biomass storage or other purposes is outlined in green.

Energy Efficiency Opportunities

There have been some great advances in technology in the last decade to help reduce energy consumption in buildings. Measures to reduce energy consumption by roughly 20% are outlined for the high school and hospital complex.

O&M measures and other low-cost/no-cost measures should be considered first because they are the lowest-cost opportunities. Quite often they can be performed by the owner. O&M measures, when performed regularly, can maintain energy efficiency over the life of the equipment and often save additional costs by extending equipment life.

Energy efficiency measures requiring significant capital investments should be prioritized after low-cost/no-cost O&M measures have been implemented. While these measures may be expensive, their energy cost savings will often pay for the initial investment within a reasonable time frame.

We caution that drawings for the hospital have not yet been made available. Also, a complete energy assessment of the buildings was not part of the scope of this work. Therefore, we would likely have additional recommendations with more complete drawing and specifications.

Energy Efficiency Measures for the High School Campus

Based on a review of the drawings for the high school, there is the potential to save at least 20% on energy consumption at the high school campus. We recommend the following Operation and Maintenance, and Capital measures and actions to achieve energy efficiency improvements:

Operations and Maintenance Measures, High School

1. Retro commission and verify operation of the variable speed drive controls on the two Gym fans and the cafeteria fan. This type of system typically requires recalibration every few years to maintain operation at the most efficient level.
2. Verify calibration of the carbon dioxide sensors in the gym and café, and that they are controlling the position of the outside air dampers. This typically needs to be recalibrated every few years to maintain operation at the most efficient level.
3. Verify calibration of motorized dampers on hot water to air terminal units for minimum outside air supply. These dampers typically need to be recalibrated every few years to assure we are not over ventilating spaces. Air brought into the building needs to be heated. If the amount of air brought into the building can be reduced without compromising barometric, odor, or moisture control, then energy can be saved.
4. Verify calibration of thermostats. Thermostats typically require recalibration every few years to maintain a comfortable and energy efficient operation.
5. Verify and calibrate controls on kitchen make up air unit variable speed drive. Proper operation of the Type 1 hood is a safety concern as well as an energy efficient feature. This type of system typically requires recalibration every few years to maintain operation at the most efficient level.

6. Verify insulation thickness and insulation condition on potable and hydronic hot water piping. Current energy codes require 1.5” thick insulation of piping up to and including 1.5” diameter, and 2” insulation on pipe that is over 1.5” diameter.
7. Verify hot water reset on hydronic system to modulate boiler operation based on outside air temperature. As the outside air temperature rises, the hydronic system can operate at a cooler temperature saving energy without compromising comfort.
8. Operate variable speed controls for hydronic pumps to maintain 15 degree delta between supply and return loops. This method of control maximizes the energy saving capability of the pump VSD.
9. Re-pipe expansion tank to be just ahead of pumps. Currently shown connected ahead of boilers which are ahead of pumps which can cause cavitation. Cavitation negatively impacts pump capacity, and therefore, efficiency. Cavitation also reduces the life of the pump.
10. Re-pipe pot feeder to be connected across the pumps, providing a differential pressure so chemical treatment can be introduced
11. Verify variable speed control operation on supply fan SF-1. This typically needs to be recalibrated every few years to assure energy efficient operation.

Capital Measures, High School

1. Providing all Energy Star appliances, computer, copiers, refrigeration, etc, can save, on average, 30% over 10 year old equipment.
2. Add air side economizers to the gym and café air handlers. Air side economizers provide free cooling when the outside air temperature is cool enough to meet the load.
3. Add heat recovery ventilators to the Gym, shop and Café spaces. These are high occupancy spaces, requiring a lot of outside air to be heated. Modulating the outside air dampers based on actual occupancy and CO2 levels, removes the prescriptive ventilation requirement and can save a lot of energy.
4. Add variable speed blower motors on the 10’ Kitchen Captive Air hood and make up air systems. Captive air is the brand of hood specified on your plans, and Captive air has a plug in controller called the EMS for this feature making it an easy retrofit. Please verify motor compatibility with the EMS.
5. If biomass is not installed, replace the electric hot water boiler (840 kW, 2,866 MBH) with heat pump and storage tank. Air source heat pump water heaters with CO_2 refrigerants are available that can produce hot water up to 195 degrees and can save on average 40% of water heating cost. The existing boiler can be used as the storage tank if it is large enough to meet the peak load.
6. Verify which terminal units[4] have 3-way valves and if not needed, replace with 2-way valves. A three way valve is needed on the most remote coil to prevent dead-

---

[4] In the high school’s heating system, air is delivered to conditioned spaces through terminal units, which are located at the end of a branch ducts. In a hydronic heating system, such as this, terminal units contain control valves that regulate the flow of hot water through a coil (heat exchanger) to heat air passing through the coil to a setpoint temperature. Three-way control valves generally indicate that the flow of hot water through the coil is reduced by bypassing it around the coil, rather than reducing the total flow rate to the unit, as two-way control valves do when used in a system with a variable speed drives. Removing bypasses reduces pumping energy by taking advantage of the variable speed drive already installed on this system.

heading the pump. But, 3-way valves prevent maximizing the pump VSD capability.

7. Replace the backdraft damper on supply fan SF-1 with a motorized damper interlocked on a schedule and if possible, on carbon dioxide sensors. A backdraft damper on an intake penetration does not provide any infiltration protection since prevailing winds will open it. Intake applications require a motorized damper interlocked with the fan operation.
8. Replace propane unit heaters with radiant heaters, use 0-2 hour timers where heaters are not used for freeze protection. Radiant heat typically saves 20% to 60% heating costs, depending on how leaky the space is. A space with overhead doors will allow the heated air to escape, making unit heaters an inappropriate choice. Radiant heat, on the other hand, heats surfaces, not the air, so the heat tends to stay in the building even if the building is leaky. Reducing leakage is also recommended.
9. Upgrade lighting systems with energy efficient fixtures and controls. Proper controls will limit the operation of lighting to meet the requirements only. Controls include motion sensor, timer, daylight, and combination.

Energy Efficiency Measures for the Hospital Complex

Based on the current energy use index (EUI) and the age of the buildings, there is the potential to save at least 20% on energy consumption at the hospital complex. Without benefit of drawings, we recommend the following non-site specific capital improvement measures to achieve energy efficiency improvements:

Capital Measures, Hospital

1. Reduce lighting power densities by replacing current lighting with more energy efficient lighting. Lighting is a significant percentage of energy budgets, typically between 20% and 40%. Reducing the lighting by 50% will result is about 15% reduction in the overall bill.
2. Provide motion, daylighting and occupancy sensors to reduce the time that lights are on.
3. Foam, caulk and seal envelope to reduce infiltration of air and moisture. Adding an air curtain at the main entrance, if one doesn't already exist, will reduce heating costs.
4. Replace current hot water system with CO_2 refrigerant heat pump water heaters, both potable and hydronic. The biomass system proposed will support most of the load and will use the existing boilers as supplemental to the biomass. The existing boilers can actually be replaced with air source heat pump boilers using about 40% less energy
5. Provide demand control ventilation to reduce the amount of outside air being heated, thereby saving on the heating cost. This can be done only with consideration to barometric and odor control requirements.
6. Provide more efficient pumps for the hydronic and potable circulation systems. Premium efficient motors typically save about 5% over standard efficient motors.

Building Envelope Energy Efficiency Measures for the Proposed U.S. Forest Service Payette Supervisor Office Building

Evaluation of improvements to the proposed Forest Service Office Building thermal enclosure was performed to identify cost effective measures for reducing the buildings space conditioning consumption relative to a 2009 International Energy Conservation Code (IECC) baseline. This evaluation was performed using TREAT® energy simulation software.

Building Model Description

A complete set of building plans were not available for the modeling of this structure. The models were developed from net building envelope component areas obtained from the space conditioning system design performed by Case, Lowe and Hart, AE. This model represents a one story commercial building with typical office occupancy and use patterns and a total conditioned floor area of 12,435 square feet.

Typical meteorological data for Soda Springs, Idaho (8847 HDD and 116 CDD) was used to represent long term averaged site conditions for this site in McCall. An average commercial block and seasonal utility rate from Idaho Power of $.048343 was used in all savings calculations. Improvement cost data was acquired from RS Means Light Commercial Cost Data 2013, King County Housing Authority and research performed for the EPA's Energy Star Homes program.

Three baseline building envelope models were built based upon the 2009 IECC requirements for commercial construction in Climate Zone 6. These three models varied only in the description of the above grade wall assembly. These models represent the building built with wood framed above grade walls (AGW), Concrete block (mass) AGW's or steel stud AGW's. The roof structure in all baseline models represents a pitched attic roof assembly and the floors are molded as unheated slab on grade.

There were two different ground source heat pump (GSHP) space conditioning systems evaluated for each of the three baseline models. One model represents the minimum efficiency requirements for a GSHP and one represents typical efficiencies seen with a GSHP VRF system.

Table 3 provides a detailed description of all baseline model assumptions.

Table 3. Baseline Model Assumptions

	Construction Type		
	Wood Framed AGW	**MASS Wall**	**Metal Framed AGW**
Climate Data	TMY 3 Soda Springs, Idaho		
Utility Rate	$0.048383/kWh		
Conditioned Floor Area	12,435 Square Feet		
Envelope Measures			
Attic	R-38		
Above Grade Walls (AGW)	R-13 + R-7.5	R-13.3 ci	R-13 + R-7.5
Unheated Slab	R-10 from top of slab down 24”		
Opaque Exterior Doors	U-0.07		
Vinyl Windows	U-0.35		
Air Infiltration Rate	0.35 ACH_n		
Space Conditioning			
Heating and Cooling 1	3.1 COP, 13.4 EER GSHP		
Heating and Cooling 1	4.1 COP, 17.7 EER GSHP (VRF)		
Thermostat	Heating Season Schedule = 68°F occupied, 60°F unoccupied		
Ventilation	ASHRAE 62.1 - 2007		

AGW = Above Grade Wall
TMY = Typical Meteorological Year
ci = Continuous Insulation
ACHn = Air Changes Per Hour under average conditions
GSHP = Ground Source Heat Pump
VRF = Variable Refrigerant Flow

Building Envelope Analysis

Seven different improvement measures and six different packages of improvement measures were analyzed for all three building types with both GSHP efficiency options. Software analysis provided total space conditioning energy consumption for the baseline model and estimated space conditioning savings for each measure or package of measure analyzed.

From these modeled savings, benefit to cost ratios were calculated. These cost to benefit ratios were derived using present value of the individual measure or package over the life of the individual measure or package at a discount rate of 3% and an assumed fuel escalation rate of 1%. The life of all measures and packages is assumed to be 30 years for this calculation. Benefit to cost ratios greater than one are assumed to be cost effective.

Table 4 summarizes the benefit cost ratios for all individual improvement measures and packaged measures analyzed for both code minimum GSHP and high efficiency GSHP. Despite McCall’s significant heating season only the window improvement has a benefit ratio of greater than one at the parameters detailed above for all building types with both heating system efficiencies. The increased slab insulation has a ratio greater than one for the inefficient heating system. None of the packages for any of the configurations has a benefit to cost ratio of greater than one.

It is important to note however, calculations are based on estimates of improvement costs. Measure 7 in particular estimates costs and savings for reducing air leakage rates from 0.35 ACH_{50} to 0.20 ACH_{50}. In this case, the cost estimate of the improvement was taken from rate schedules for existing construction air sealing improvement which is likely an overestimate for new construction. Additionally, these estimates are based upon a 30 year life of measure and only a 1% fuel escalation rate. If any improvement measure is pursued it is advised that local estimates be evaluated.

A complete and more detailed table of all modeled improvement measures and packages can be found in an attached spreadsheet using TREAT.

In addition to building envelope improvements, both interior and exterior lighting and control efficiencies should be considered. LED lighting may be a cost effective lighting option for exterior and parking. The best interior lighting option is the most efficient T8 available. Controls should include occupancy sensors and daylight dimming. Because the building fenestration and occupancy layout was not known, an analysis of these options was not done.

Table 4. Benefit to Cost Ratios of Beyond Code Improvements for Three Wall Types

2009 IECC Baseline with Minimum Efficiency GSHP (3.1 COP)				
Individual Improvement Measure		Wood Framed AGW	Mass Wall	Metal Framed AGW
		Benefit to Cost Ratio	Benefit to Cost Ratio	Benefit to Cost Ratio
2	R-49 attic	0.26	0.26	0.27
3	R-20 ci roof deck with R-38 full cavity fill	0.13	0.13	0.14
4	R-21 +R-7 ci AGW	0.49	0.17	0.30
5	U-0.30 windows	2.40	2.40	2.44
6	R-15, 2' slab	0.89	1.24	0.86
7	Air infiltration reduction to 0.2 ACH_N	0.54	0.54	0.54
Improvement Package				
A	2+4+5+6+7	0.52	0.53	0.49
B	3+4+5+6+7	0.36	0.37	0.35
C	4+5+6+7	0.62	0.63	0.55
D	2+4+6	0.37	0.39	0.32
E	3+4+6	0.20	0.21	0.19
F	4+6	0.56	0.63	0.37
2009 IECC Baseline with High Efficiency VRF GSHP (4.1 COP)				
Individual Improvement Measure				
2	R-49 attic	0.20	0.20	0.20
3	R-20 ci roof deck with R-38 full cavity fill	0.10	0.10	0.10
4	R-21 +R-7ci AGW	0.37	0.13	0.23
5	U-0.30 windows	1.81	1.82	1.84
6	R-15, 2' slab	0.63	0.90	0.60
7	Air infiltration reduction to 0.2 ACH_N	0.41	0.41	0.41
Improvement Package				
A	2+4+5+6+7	0.40	0.40	0.37
B	3+4+5+6+7	0.27	0.28	0.26
C	4+5+6+7	0.47	0.48	0.42
D	2+4+6	0..28	0.30	0.24
E	3+4+6	0..15	0.16	0.14
F	4+6	0..41	0.47	0.28

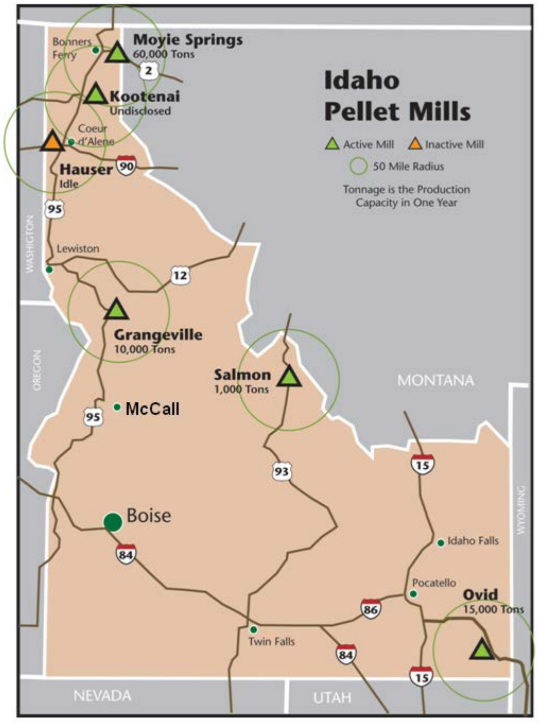
Biomass Availability and Costs

A preliminary review of biomass availability within a 40 mile radius of this location was conducted as part of the 2011 study "Preliminary Biomass Feasibility Study, Payette National Forest – Krassel Yeard, McCall, Idaho".[5] Available biomass is primarily from public lands owned by the national forest system, state of Idaho and the Bureau of Land Management, as shown in Table 5. The authors of this study concluded that "there is unlikely to be significant competition for wood fuel for a medium sized thermal biomass system at one or more of the proposed facilities at McCall, Idaho."

The authors found that the cost of forest biomass recovered from logging operations in western Montana ranged from $23 to $68 per *green* ton[6] in 2010. (This corresponds to approximately $46 to $136 on a dry basis in 2010 dollars.) They also surveyed pellet manufacturers in 2011 and found the cost of wood pellets delivered to McCall in bulk, Idaho ranged from $85 to $150 per ton.

McCall is approximately 90 miles south of a pellet mill[7] in Grangeville, Idaho, as shown in Figure 2.

Figure 2. Locations of active and inactive pellet mills in Idaho (2012)



---

[5] Hustwit et al

[6] Green wood typically has a moisture content of 40% to 60% on a wet basis (Hai Yang 2012). To convert from green to bone-dry mass, the basis (wet or dry) of the moisture content is important. For wet basis, $M_w = (W-D)/W$ where M_w is the percentage moisture in the sample based on wet weight, W is the weight of the initial sample (moisture and solids) and D is the oven dry weight. For 50% moisture content, D=0.5W. (This may seem obvious, but on a dry basis the correct equation is D=W/1.5.)
http://nobel.scas.bcit.ca/chem2204/expt1/expt1.htm
Hai Yang 2012
http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/30673/YangHai2012.pdf?sequence=1

[7] Rocky Mountain Pellet Company, www.rockycanyonpellet.com

Table 5. Total mass of woody biomass in bone dry tons available from several sources within a 40 mile radius of the site (Hustwit et al)

Woody Biomass Source	Estimated Total (1000 BDT)	Comment
Fuel Treatment Activities[1], Private Lands	3.0 to 9.1	Most of this material is not profitable at this time and would require subsidy to encourage residue removal.
Fuel Treatment Activities[1], Public Lands	46.0 to 138.1	--
Available Logging Slash Private Lands	36.0	--
Available Logging Slash Public Lands	103.8	--
Forest Products Manufacturing Residue	~13 [2]	8 wood products manufacturers within 50 miles of McCall. The largest uses a significant portion in a 6 MW plant[3]
Land-filled Urban Wood Waste	~0	Relatively little, cost of collection would be too high. Currently being hauled to regional landfill.
Agricultural Byproducts	~0	Very little available and high cost of collection

1. Includes forest management activities to reduce fire potential, such as biomass thinning and collection of timber harvest residues

2. Industrial wood products residue within 50 miles of McCall totals approximately 25,750 green tons or approximately half this at 50% moisture content wet basis.

3. Tamarack Mills LLC

Biomass Heating at McCall Memorial Hospital

We recommend installing a dedicated biomass-fired boiler to serve the heating needs of the McCall Memorial Hospital building. The existing fuel oil boilers would remain to provide backup and supplemental heating. Estimated internal rate of return and discounted payback for a pellet system and a wood chip system are shown in Table 6. Cash flow tables from the life cycle cost analyses are included in Appendix B.

The pellet system option is more cost effective than the wood-chip system, based on the assumptions discussed above, as shown in Table 6. The wood chip boiler system has greater capital cost and operation and maintenance costs but lower fuel cost, compared to the pellet system and these balance out to a certain extent. Even if paybacks were similar or favored the wood-chip system somewhat, a fully automatic pellet system might still be preferred due to its convenience. A wood-chip system would be preferred if the supply or cost of pellets, for example, is less reliable than wood chips.

These results are subject to uncertainty in the inputs of the analysis. The impact on project viability of differences from the assumptions used is illustrated in Figures 4 and 5 in the Section “Sensitivity Analysis”. These diagrams show that capital cost of the system and the cost of fuel have a greater impact on viability than other factors examined. A better estimate of capital costs will be provided in a Level 3 analysis because it will be based on a more complete design and estimates from manufacturers. The uncertainty in cost of fuel should also be reduced by investigating long term fuel purchase agreements.

Table 6. Project internal rate of return and discounted payback for McCall Memorial Hospital for two system types with and without a 25% grant, based on a preliminary assumptions

System	Case	Project IRR[2]	Discounted Payback[2] (years)
Pellet System	No Grant, No Efficiency	14.1%	8.8
	No Grant, 10% Efficiency Gains[1]	17.1%	7.1
	25% Grant, 10% Efficiency Gain[1]	24.3%	5.0
Wood Chip System	No Grant, No Efficiency	13.0%	9.6
	No Grant, 10% Efficiency Gains[1]	14.7%	8.5
	25% Grant, 10 % Efficiency Gain[1]	20.6%	6.0

1. It is assumed energy efficiency enables reducing boiler size by 10%.
2. Results are strongly impacted by capital cost and fuel costs assumed in the analysis.
3. A U.S. Forest Service Woody Biomass Utilization Grant for design and engineering costs would further reduce costs and improve project economics.

Scenario Descriptions

A general schematic of the system is shown in Figure 3.

System Size

In cost estimates and results shown in Table 1 it was assumed the biomass boiler is the same as the existing boiler, 3.2 MMbtu/h. In the "efficiency" scenarios, it is assumed the boiler can be downsized by approximately 10%.

Wood Chip System

Wood chips may be a more readily available fuel source than pellets. A wood chip system should be included as part of the backup power system to help ensure system reliability. A wood chip system typically requires more operator involvement than the fully automated pellet systems. Depending on the source of wood chips, conveying augers can get blocked by bridging or oversized chips, shutting down the system.

This option includes a wood-chip boiler with emission controls, a new building with a fuel storage pit, automated wood-chip handling and screening equipment, and pollution controls. A new pipe loop will be required between the new building and the existing system. The system also requires a large hot water tank as thermal storage. Capital costs assumed also include a loader to handle fuel on site.

A semi-automated system with a covered wood storage is assumed in cost estimates. However, for greater automation a storage pit might be installed. A pit would enable live-bottom delivery trucks to enter the building and unload directly into the pit from above. Fuel would then be fed from the pit into the boiler using conveyors and augers. Fuel handling also includes a screening system. The feedstock handling area includes an unloading area, storage area, and area for screening and fuel handling equipment.

Pellet System

Pellet systems are fully automatic, metering the fuel to meet the load and have improved air quality. A pellet system should be included as part of the backup power system to help ensure system reliability. Operations and maintenance costs of a pellet system are lower than for a wood chip system. Pellets are easier to store than wood chips.

This option includes a pellet boiler, pellet storage silo, thermal storage tank, fuel handling equipment, a pipe loop between the new building and existing system, and integration of controls.

Analysis Assumptions

Fuel Use

It is assumed with both the wood chip and pellet systems, the existing fuel oil boilers will still be used for 15% of the heating requirements. Institutions with wood-fired boilers tend to still use their fossil fuel boilers in spring and fall months because they are easier to start up and turn down.

We estimate 380 bone dry tons (760 green tons at 50% moisture) of biomass would be required to serve the space heating needs of the hospital, if energy efficiency measures discussed above are not implemented. In this analysis, it is assumed 10% energy efficiency savings have been achieved, bringing the biomass use to 340 bone dry tons. This offsets approximately 37,000 gallons of heating oil, which has also been reduced by 10% to account for prior conservation. Approximately 13,000 gallons of fuel oil will still be used for heating in the fall and spring and for diesel power. The quantity of biomass required to replace this quantity of heating oil was calculated assuming roughly similar overall efficiencies of the existing and new systems.

Biomass requirements for space heating were estimated from utility and fuel billing data, shown in Appendix A. Annual diesel use at the hospital was 48,000 in 2010 and 57,000 in 2011[8]. There is some uncertainty about how much was used for heating and how much for the diesel-powered back-up generator. We estimate that about 95% of the fuel oil was used for heating, based on conversations with site personnel about use of the diesel generators for routine start-up and to provide electricity for power outages. Power outages in McCall have become uncommon.

The hospital also uses 1,500 gallons of potable hot water for laundry and physical therapy. Propane use during winter months could be offset by the biomass boiler. This option was not included in this analysis because it is relatively small compared to other uncertainties and not including it is more conservative.

Energy content of both wood chips and pellets is approximately 8,000 Btu per bone dry pound.

Biomass Fuel Cost

We estimate costs of wood chips obtained locally at $50 per green ton, which corresponds to about $100 per bone dry ton. The cost of wood pellets is assumed to be $150 per ton[9]. These assumptions are based on the study by Hustwit, which is discussed above in the Section “Biomass Availability”.

Capital Expenditures

Capital expenditures for the pellet and wood chip systems are shown in Table 7. Capital costs include equipment and installation costs for the boiler, stack, pollution control equipment, boiler house, chip or pellet storage, plumbing modifications, thermal storage tank, interconnection to existing boiler room, and fuel handling equipment (e.g. skid-steer loader). Capital costs also include 10% contingency, 10% contractor mark up and 15% design and engineering costs.

---

[8] While 2011 was a colder year, weather does not account for all the difference between fuel use in the two years.

[9] Hustwit et al surveyed pellet manufacturers in 2011 and found bulk delivery of wood pellets delivered to McCall, Idaho ranged from $85 to $150 per ton.

Capital costs for boilers are related to size, while costs of other system components are fairly independent of size. A capital cost of $90,000 per MMBtu/h was assumed for the boiler.

Table 7. Preliminary Estimate of Capital Expenditures

	Pellet System	Wood Chip System
Boiler (3.2 MMBtu/h)	$300,000	$300,000
Stack (for pollution dispersion)	--	30,000
Pollution control equipment	--	$50,000
Boiler House and Fuel Storage/silo	$80,000	$110,000
Thermal Storage Tank	$20,000	$20,000
Interconnection to Existing Boiler System	$50,000	$50,000
Controls	$10,000	$10,000
Fuel handling and screening equipment	Included in silo cost	$25,000
Bucket loader for fuel loading and handling on site	--	$20,000
10% General Contractor Markup	$46,000	$61,000
10% Construction Contingency	$46,000	$61,000
15% Design & Engineering	$69,000	$92,000
TOTAL	**$621,000**	**$829,000**

* A boiler cost of $270,000 is assumed in the “10% efficiency gains” scenario shown in Table 1, assuming efficiency enables a smaller boiler size.

Operation and Maintenance Assumptions

A semi-automated wood chip heating system of this size may require up to one hour per day to load fuel, clean ashes and check on pumps, motors and controls during the heating season. In this analysis it is assumed maintenance personnel will spend one hour per day for 240 days per year and an additional 20 hours for annual routine maintenance.

Pellet boilers require less maintenance than wood chip boilers. It is assumed a pellet boiler will require one hour per week over 34 weeks in addition to their current maintenance and an additional 10 hours for annual routine maintenance.

It is assumed the wood chip system will require $15,000 of scheduled maintenance is required every 5 years for repair and replacement of major items such as the furnace refractory. This cost is assumed to be $10,000 every 5 years for the pellet system.

Fully loaded labor costs are assumed to be $75 per hour for maintenance staff.

Table 8. Maintenance Labor, McCall Memorial Hospital

	Pellet System	Wood Chip System
Scheduled annual maintenance (hours per year)	10	20
Routine maintenance (hours per year)	34	240
TOTAL	**44**	**260**

Escalation

Escalation of fuel oil prices is assumed to follow that of crude oil. The U.S. Energy Information Agency projects a growth rate of 3.6% of crude oil over the period from 2010-2040 (http://www.eia.gov/oiaf/aeo/tablebrowser/.)

We have assumed an escalation rate of pellet and wood chip prices of 4%. Pellet prices fluctuate more dramatically than wood chip prices but less than for fossil fuels. Because they are a manufactured product, pellet prices track more closely to fossil fuels than other biomass fuels.

A general inflation rate of 2.7% was assumed.

Discount Rate and Project Life

A discount rate of 5% and project life of 20 years were assumed for the hospital. A low discount rate was assumed because this is a non-profit organization, which does not have a profit component in their cost of capital.

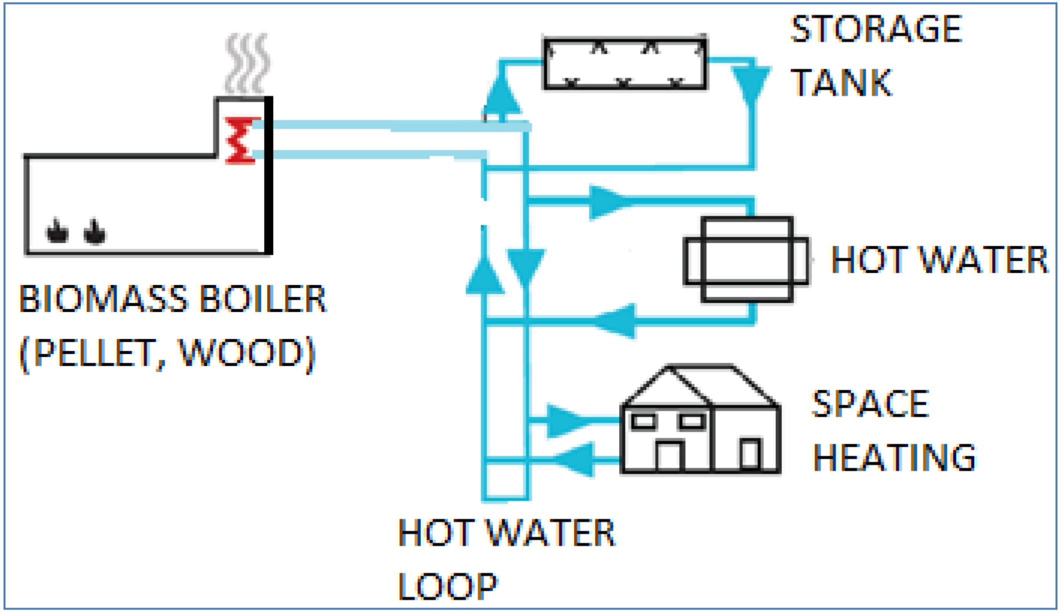
Financing and Incentives

The life cycle cost analysis assumes a low interest loan at 4% over a period of five years for the first $100,000, which may be available as an Idaho State incentive. A USDA REAP grant of up to 25% of the total cost was analyzed in the sensitivity analysis but is not included in the base case. Results with and without this grant were calculated.

Taxes

St. Luke’s is a 501c3 federally recognized non-profit organization and so is tax exempt.

Figure 3: Schematic of biomass system for space heating and potable water heating



Sensitivity Analysis

The sensitivity of project viability to variation in certain parameters is shown in the spider diagrams in Figures 4 and 5 for the pellet system and wood-chip system, respectively.[10] Parameters investigated were capital expenditures, biomass cost, fuel oil savings, grant amount, and O&M expenses.

Project viability is most sensitive to capital expenditures, biomass cost and fuel oil savings. The uncertainty in these three factors should be pinned down in the design, engineering, equipment specifics and final cost estimates stage of project development. Nevertheless, all but one scenario examined is at least break even[11] and most have good IRRs (varying only one parameter at a time).

If capital expenses and wood pellet costs are lower than we have assumed, the IRR improves significantly. But it also declines rapidly as these costs increase. These two issues must be carefully examined in the design and engineering stage of project development.

We have included fuel oil savings in the sensitivity analysis because fuel oil is used both for heating and emergency back-up power. One reason for concern is that the difference in energy use between 2011 and 2012 is greater than can be explained by weather alone[12]. There may be, for example, back-up power usage in 2012 that was not reported to us, which would result in an overestimation of fuel oil attributed to heating. If fuel oil use for heating is significantly less than assumed the IRR worsens, as shown by the green line in Figures 4 and 5.[13] A better accounting of fuel oil use should therefore be part of the Level 3 study.

O&M costs impacts project viability much less and so less effort can be devoted to them in the Level 3 study (provided the assumptions in this study and the range of uncertainty used in the sensitivity analysis are reasonable.)

Notice the baseline (center of the spider diagram at 0% variation) is modelled as having

---

[10] Sensitivity analysis, also referred to as "What If" analysis, provides information on what effect changes in factors such as cost, revenues, incentives and sources of funding will have on project viability. By indentifying the relative importance of risky variables, the decision-maker can adjust projects to reduce the risks and consider responses should the outcome risks occur.

In a spider diagram, the base case is located at the center of the diagram at 0% variation in all parameters. The base case uses the most likely values for each parameter. Then parameters are varied one by one, while holding others constant. The corresponding change in some measure of performance, such as the IRR, NPV or levelized costs, is plotted on the horizontal axis for each change in input.

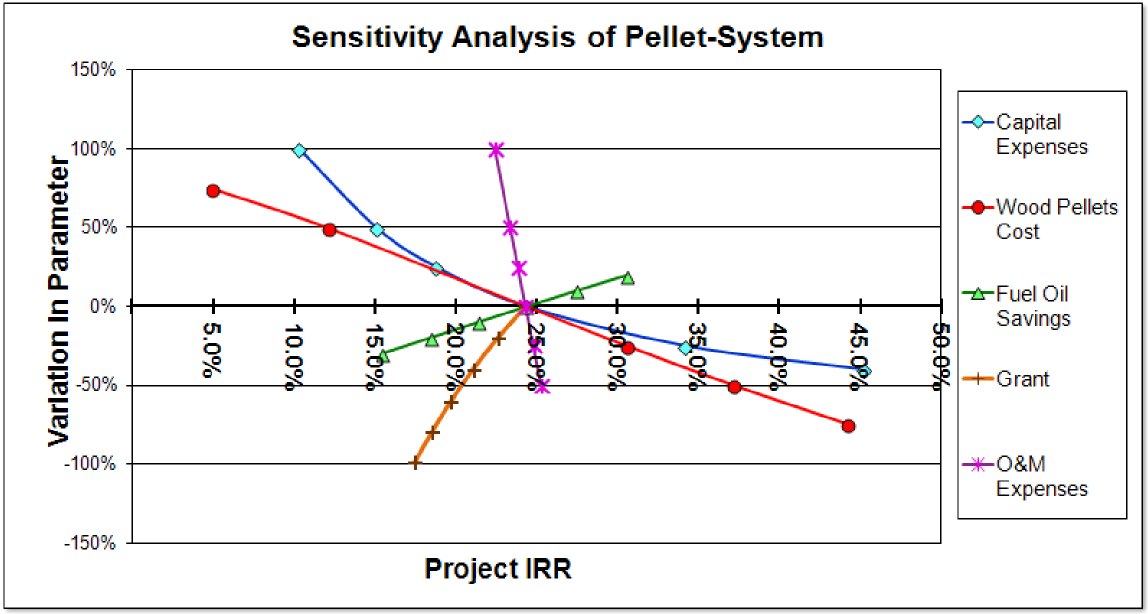
[11] If the IRR equals the discount rate – assumed to be 5% in this analysis – the project has a zero net worth at the end of its life and the discounted payback equals the project life (i.e. it just pays for itself.) So all scenarios with an IRR of 5% or greater do better than breaking even.

[12] The average of these two records were used in the analysis as fuel oil savings.

[13] The interaction between fuel oil use and biomass requirements have been accounted for in the analysis. Lower fuel oil use means the heating load is less than assumed in the analysis. A lower heating load means less biomass is required to offset the fuel oil use.

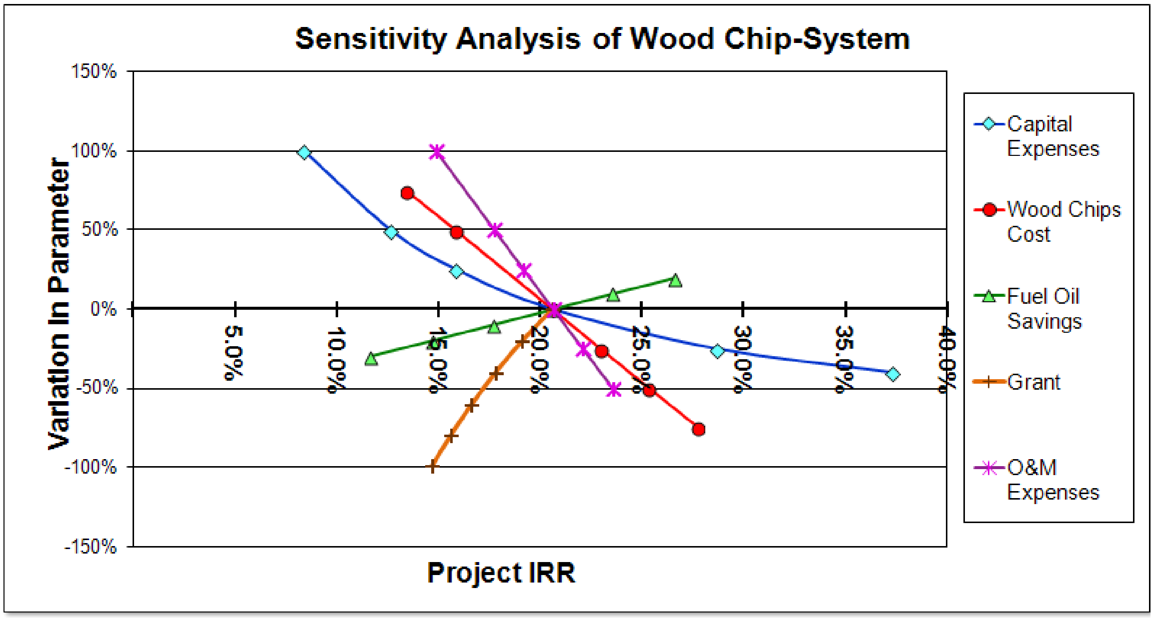
received a grant of 25%. The impact of lower grant amounts is shown by the orange line in Figures 4 and 5, where -100% variation means no grant is obtained.

Figure 4. Spider diagram showing sensitivity of project viability of pellet system to several parameters, assuming energy efficiency measures are implemented first[1,2]



1. The *less* steep the slope, the *greater* the impact of the parameter on project viability
2. The base case at the center of the diagram is with a 25% grant. Negative 100% variation means no grant was received.

Figure 5. Spider diagram showing sensitivity of project viability of wood-chip system to several parameters, assuming energy efficiency measures are implemented first[1,2]



1. The *less* steep the slope, the *greater* the impact of the parameter on project viability
2. The base case at the center of the diagram is with a 25% grant.

Heat Recovery at Industrial Facility to Heat Medical Campus

There is a possibility of a small industrial biomass processing facility being located near the medical campus. Waste heat might be recovered from this facility and used to heat the hospital, Nokes Medical Offices and Lake Street Therapy Building. In Nokes Medical Offices and Lake Street Therapy are currently heated by electric furnaces. In these buildings, hot water coils would be installed in the air handlers to transfer heat from the pipe loop to the buildings HVAC system.

Two scenarios are examined: heating the hospital only and heating all three buildings. As shown in Table 9, waste heat recovery to heat the hospital only is 2.7 years -- the best return of all scenarios examined in this study. The discounted payback for including all three buildings is greater, but still good, at 6.7 years, due to the cost of heating system modifications required in these buildings and their lower cost of electricity compared to diesel.

Either of these options – waste heat recovery for the hospital only or for district heating of the hospital, Nokes Medical Offices and Lake Street Therapy Building -- is recommended over biomass heating-only at the hospital, if such an industrial facility is likely in the near future and coordination with that facility to provide district heating is a possibility.

Table 9. Project internal rate of return and discounted payback for waste heat recovery from industrial facility and district heating at medical campus

Scenario	Project IRR	Discounted Payback (years)
Hospital Only	43.9%	2.7
Hospital, Nokes Offices and Lake Street Therapy	19.1%	6.7

Assumptions

A preliminary cost estimate is shown in Table 10. Distribution losses were assumed to be 10%. Coil effectiveness is assumed to be 70%. Energy savings and heat purchases shown in Table 11 were estimated from billing histories shown in Appendix A.

Recovered heat from industrial facilities is frequently sold at 50% the price of natural gas. In this case, with natural gas unavailable, we have assumed a price of 50% that of propane. The price of propane in McCall is estimated at $2.50 per gallon.

Propane unit cost, and therefore the cost of recovered heat, is assumed to escalate at the same rate as diesel. Electricity is assumed to escalate at the rate of general inflation.

Sensitivity Analysis

The sensitivity of the viability of this heat recovery project to variation in certain parameters is shown in the spider diagrams in Figures 6 and 7 for the two options: 1) heating the hospital only and 2) heating the hospital, Nokes Medical Offices and Lake Street Therapy. Parameters investigated were capital expenses, heat oil cost, fuel oil savings, and electricity savings.

Project viability is most sensitive to the cost of recovered heat and diesel cost savings and least sensitive to electricity cost. Essentially, the excellent return on using heat recovery for space heating at the hospital covers the poor return on heat recovery for the other two electrically heated buildings. For all three buildings, the payback is still good because of the large savings at the hospital.

Table 10. Preliminary cost estimate for waste heat recovery from proposed industrial facility and district heating at the medical campus

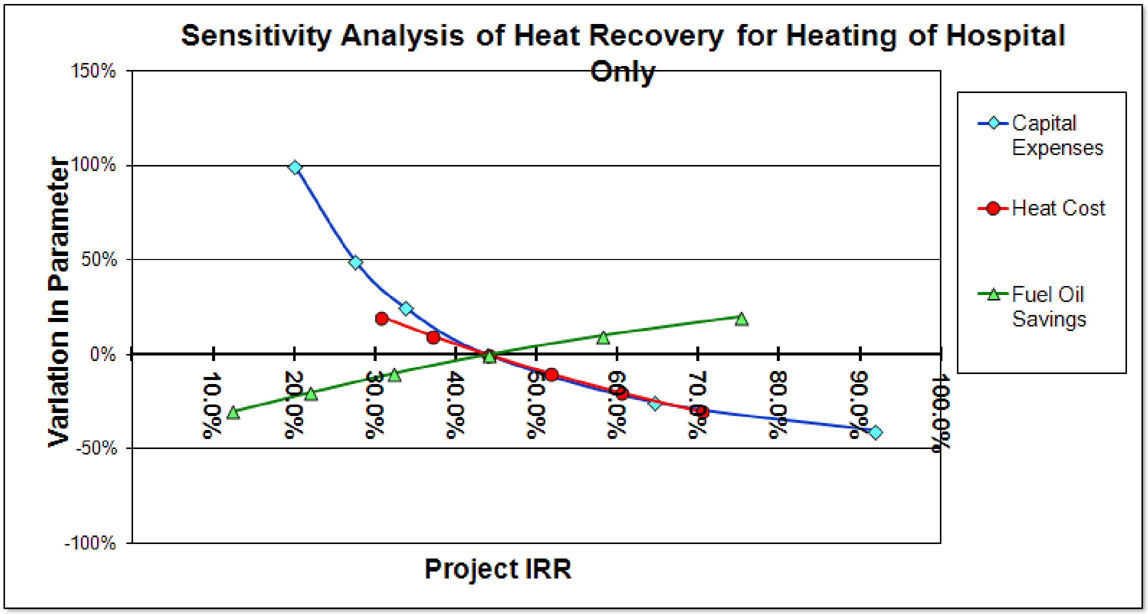
	Hospital Only	Hospital, Nokes Offices and Lake Street Offices
Building HVAC modifications	$50,000	$100,000 per building for 2 buildings
Piping to site from industrial facility (assume ¼ mile at $30/ft)	$40,000	$40,000
Equipment at industrial facility (coils, pumps, metering)	$50,000	$50,000
Easements and permitting	$30,000	$30,000
Engineering (15%)	$21,000	$51,000
Contingency (10%)	$14,000	$34,000
Contractor Profit (10%)	$14,000	$34,000
TOTAL	**$219,000**	**$489,000**

* A boiler cost of $270,000 is assumed in the "10% efficiency gains" scenario shown in Table 1, assuming efficiency enables a smaller boiler size.

Table 11. Estimated energy savings and heat purchases for waste heat recovery project

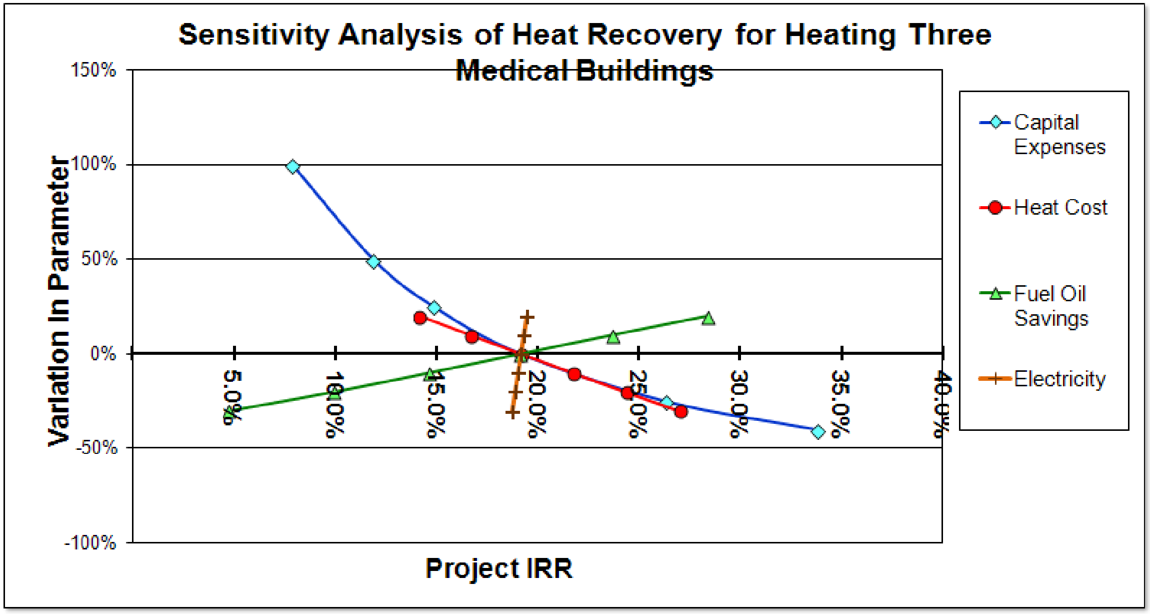
	Estimated Annual Heating Energy Savings	Estimated Heat Purchase (MMBtu/yr)
Hospital	42,400 gallons diesel	6,400
Medical Office Nokes	60,000 kWh/yr	290
Lake Street Therapy	57,000 kWh/yr	280

Figure 6. Spider diagram showing sensitivity of project viability of heat recovery for space heating of the McCall Memorial Hospital to several parameters[1]



1. The *less* steep the slope, the *greater* the impact of the parameter on project viability

Figure 7. Spider diagram showing sensitivity of project viability of heat recovery for district heating of the McCall Memorial Hospital, Nokes Medical Offices and Lake Street Therapy Building to several parameters[1,2]



1. The *less* steep the slope, the *greater* the impact of the parameter on project viability

Biomass Heating at the High School

Replacing the electric boilers at the main building of the high school with either a pellet system or a wood chip system was not cost effective, even considering avoided demand charges. The IRR is negative for all scenarios, even with energy efficiency measures installed first.

Assumptions

Biomass costs, escalation, capital costs, O&M costs, financing and available incentives are assumed to be similar for the high school as for the hospital. The electricity energy rate used was $0.040963 per kWh for monthly energy use over 2,000 kWh.[14] The demand rate is $6 per kW above 20 kW.

Estimated fuel requirements were 94 bone dry tons of wood. Total heating electricity use, including auxiliary equipment, was estimated as the electricity use above the average of the months of May and June, shown in Figures A-1 and A-2 in Appendix A, and assuming auxiliary use for pumps and fans consumes 15% of this. Energy use during summer months cannot be used to estimate base load, as would usually be done in billing analysis, because of low summer occupancy.

Demand charges that would be offset by biomass heating is estimated approximately $10,500 per year, by attributing all demand over 200 kW to heating. Demand below 200 kW accounts for base loads and auxiliary heating equipment. This was estimated based on Figure A-2 in a similar manner as for energy use.

---

[14] Idaho Power and Light, Rate Schedule 9.

Biomass Combined Heat and Power

Combined heat and power was not found to be cost effective at any of the buildings, primarily because there is not sufficient need for the waste heat of electricity generation during the summer and the small size of the project. The hospital does use potable hot water year round for laundry and physical therapy, but the volume required is too small to justify electricity generation. Hot water use would need to be at least an order of magnitude greater at the hospital for a small low-temperature, organic rankine cycle (ORC) turbine or a Stirling engine system to be practical. Alternatively, waste heat could be recovered and used to serve summer chilling requirements, which are larger than hot water needs. However, the cooling season is short and does not justify the added expense replacing the electric chiller with that of an absorption chiller for a building of this size.

Compounding the problems of small thermal needs, operation and maintenance costs are, in general, disproportionately greater for small systems than for larger system. We estimate this option would have a simple payback of more than 40 years, assuming a wood pellet cost of $200 per ton and an installed cost of $10,000 for a micro-CHP system.

If a biomass CHP system were large enough to fulfill all emergency power needs, it may be an approved backup source of electricity, per IBC Section 909.11 and NFPA 110, allowing for removal of the diesel generator, saving about 5% of the overall diesel use, $2,000/yr in fuel. This also is not cost effective.

Power Generation with a Hot Water Boiler and Organic Rankine Cycle Turbine System

Organic rankine cycle turbine systems are available for small- and medium-scale power generation to serve low temperature thermal needs. For small scale systems, however, the conditions must be optimum to be cost effective. In particular, it is important is to have a year round use for waste heat and to size the system so as much waste heat serves a useful purpose as possible. We considered two options, as discussed below, and neither was cost effective in this case

System Consideration #1: CHP for Preheating Potable Hot Water at McCall Memorial Hospital

Conceivably, a low-temperature organic rankine cycle (ORC) turbine could be used to preheat water for potable hot water uses at the medical campus. In such a system, a biomass-boiler would provide 180F to 200F water to an ORC, such as Infinity's ITmini (http://www.infinityturbine.com). This turbine could preheat well water to approximately 75F from heat recovered from electricity generation. The biomass boiler would be used to bring the hot water up to the set point temperature.

The hot water volumes at the hospital and an adjacent clinic were estimated from propane billing records as a total of about 1,100 gallons per day. An ORC unit sized for this water volume is in the range of 500W to 1 kW, which is considered "micro"-CHP.

The ORC equipment cost is approximately $4,500, based on correspondence with a manufacturer's representative. We estimate additional costs of installation, such as plumbing modifications, will bring the installed cost to $10,000. After adding estimated operation and maintenance costs, the payback is more than 40 years.

We also investigated the possibility of a small Stirling engine to generate electricity and hot water needs. Units at the residential and small commercial scales are available in Europe (for example, Stirling Power Module, http://www.stirlingpowermodule.co). These units are not available in the U.S. however.

System Consideration #2: CHP to Serve Space Heating Needs

It is not technically possible to use a low temperature ORC, such as Infinity's, to preheat water for space heating purposes because the preheat temperature that can be achieved at the ORC's condenser coil (75F) is lower than the return temperature in the building's hot water loop (140F to 160F).

A steam boiler and an ORC operating at higher temperatures would be required to be technically feasible. A high pressure steam boiler would have greater equipment and operating costs, and would require greater operator skill and attention. In any case, higher temperature ORC's are not available at the small scale that would be required for this building.

Even if available, using CHP for variable loads, such as space heating, presents technical and financial challenges. The number of hours of operation of the plant is less than for a load that is constant year round. A modular system with staged operation would be required, increasing cost and complexity.

Power Generation with Steam Turbine or Thermal Oil Heater

A thermal oil heater or steam boiler can provides higher temperature heat to a turbine than a hot water boiler, which may in turn enable higher temperature heat to be recovered from the turbine for space heating. A thermal oil heater would be used in combination with an ORC, while a steam boiler would be used with a steam turbine. To be practical, CHP systems must be sized to meet the thermal needs of the project, not the electrical needs, which results in power generation capacity that is much less than the demand of the hospital. This, and that turbines appropriate for this application and size of project are not available, result in this option being infeasible.

It is important to note that if a biomass-fired hot water boiler is installed in a heating-only system, as is recommended, the option of installing a higher temperature CHP system to serve space heating needs in the future is precluded.

System Consideration #1: Steam Boiler and Steam Turbine

The hospital base electricity demand is about 200 kW year round. In the summer, a 100 ton chiller results in an additional 95 kW of demand. Space heating requirements are much less than the heat that would be generated by a turbine of this size.

For example, General Electric now has a small 125 kW steam turbine, which they developed especially for biomass power generation.[15] Let's consider the waste heat produced from power generation by a unit of this size. The efficiency of small, simple steam plants which make electricity as a byproduct of delivering steam to processes or district heating systems have efficiencies of 10% or less[16]. With 10% efficiency of a 125 kW turbine and 70% effectiveness of heat recovery equipment, approximately 770 kWt or 2.7 MMBtu/h of heat would be available for thermal uses. To be cost effective, this unit would need to run a good percentage of the time – 80% to 90% is typical of good CHP applications. This far exceeds the heating requirements of the building. As shown in Table 12, the heating average monthly heating requirements for winter months (October to April) range from 0.6 MMBtu/h to 1.1 MMBtu/h.

A unit one third as large – approximately 40 kW -- could serve the hospital for this 6 months, but steam turbines this small are not available and would not be cost effective, if they were available, with such low operating hours per year.

System Consideration #2: Thermal Oil Heater and ORC

Turboden offers a system with a thermal oil heater with an ORC that they developed for biomass district heating.[17] To be practical for district heating, the cooling temperature at the condenser of the ORC must be high enough to heat water to 180^{o}F, as required for space heating. Infinity's small scale ORC, for comparison, requires a condenser temperature of no more than 90^{o}F.

An advantage of a thermal oil heater over a steam turbine is that it operates at lower pressure and so does not require a boiler operator, reducing O&M expenses. However, the electrical output of an ORC sized to serve thermal needs would be even less than that of a steam turbine due to its lower efficiency. The smallest unit Turboden offers for this purpose is 250 kWe.

---

[15] General Electric website, http://www.genewscenter.com/content/Detail.aspx?ReleaseID=12594&NewsAreaID=2#downloads, http://www.ge-energy.com/products_and_services/products/steam_turbines/biomass_steam_turbines.jsp

[16] http://www.epa.gov/chp/documents/catalog_chptech_steam_turbines.pdf

[17] "Biomass Cogeneration, Turoboden website, accessed May 30, 2013, http://www.turboden.eu/en/applications/applications-biomass.php

Table 12. Monthly heating degree days for McCall, Idaho averaged over 2010-2012[1], estimated fuel oil use and estimated average monthly space heating needs

Month	Monthly Heating Degree Days	Estimated Fuel Oil for Space Heating (gallons)	Average Monthly Heating Requirements (MMBtu/h)
January	1,259	7,452	1.14
February	1,141	6,752	1.03
March	1,044	6,179	0.94
April	839	4,967	0.76
May	637	3,772	0.58
June	360	2,127	0.33
July	0	0	-
August	0	0	-
September	283	1,676	0.26
October	647	3,827	0.59
November	1,026	6,072	0.93
December	1,264	7,479	1.14
Totals	**8,500**	**50,302**	
Winter Averages[3]	**1,031**	**6,100**	**0.93**

1. Source: Western Regional Climate Center website, http://www.wrcc.dri.edu/cgi-bin/cliMONthdd.pl?id5708 (accessed April 2013)
2. Average monthly heating requirements is estimated by converting the fuel use to MMBtu, multiplying by system efficiency (assumed to be approximately 80%) and dividing by the number of hours in a month.
3. Winter months are assumed to be October to April

Biomass-Fired District Heating

Two options for district heating were considered: one central heating system to serve all three sites and, one central system to serve only the hospital and school. Neither of these district heating options is recommended for several reasons. Most of the buildings are electrically heated and the cost of wood pellets does not compete well with the cost of electricity. Even if wood pellets can be obtained at a lower cost than assumed in this report, the cost of installing a hot water or steam distribution piping between small buildings cannot be justified economically. The benefit of the greater efficiency of a central plant does not outweigh the penalty of the greater installation cost and the greater operation costs of the hot water distribution system for electrically heated buildings.

Overview of Small Scale Electricity Generation Technology

Organic Rankine Cycle Turbines

ORC turbine systems are based on the same principles as steam turbine systems. Both types of systems have four primary components: a boiler or evaporator to evaporate the working fluid, a turbine fed with vapor from the boiler to drive the generator, a condenser or other means of condensing the exhaust vapors from the turbine, and a means (such as a pump) for recycling the condensed fluid to the boiler. In a steam cycle, water is circulated through these components as the working fluid. In an ORC system, the working fluid is a refrigerant[18].

ORC systems can also be compared to air conditioning systems operating in reverse. In fact, some designs of ORCs make use of standard HVAC[19] equipment, reducing cost by taking advantage of the equipment standardization and high volume production. For example, in early 2007 Carrier Corporation and United Technologies Corporation (UTC)[20] began marketing an ORC system they derived from a centrifugal compressor design. Much like large HVAC equipment, ORC systems are available as packaged, modular units and so are relatively easy to transport and install and easy to interface with the hot and cold sources on site.

Most ORC systems range in size from 50 kW to about 2 MW. Smaller units, down to 5 kW, are under development. Infinity Turbines has been a leader in reducing the scale of commercially available organic rankine cycle (ORC) turbines for electricity generation from waste heat and renewable resources. Units available range from 10 kW to 250 kW. These units require a heat source temperatures of approximately 180°F. For more information, visit http://www.infinityturbine.com/ORC/IT10_ORC_System_For_Sale.html

Turboden has developed ORCs suitable for space heating, due to their higher condenser temperature. These units are available from 200 kWe to 2.5 MWe.

Stirling Turbines

Biomass-fired Stirling cycle turbines are available in Europe at the micro-scale that would be required for this site. They are not currently available in the U.S. For more information refer to http://www.bios-bioenergy.at/en/electricity-from-biomass/stirling-engine.html

---

[18] A refrigerant is a liquid that has a lower boiling point than water, typically a refrigerant such as R134a or R245fa, a hydrocarbon such as iso-pentane, silicon oil, or ammonia.

[19] HVAC = Heating, Ventilating and Air Conditioning

[20] Carrier is wholly-owned subsidiary of UTC. UTC has since switched the product sales to Pratt & Whitney and then sold the product line to Mitsubishi.

Project Funding Possibilities

Project funding possibilities include utility incentives, USDA grants, and a low interest loan from the state of Idaho, as summarized in Table 3 above. These projects are not eligible for tax incentives because they are not taxable entities.

USDA REAP or Similar Grants

Biomass heating systems and energy efficiency improvements at all three campuses may be eligible for USDA REAP grants.
http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US05F&re=1&ee=1

Contact Daryl Moser, Director, Business Programs from USDA Rural Development Idaho.

Woody Biomass Utilization Grant Program, U.S. Forest Service

The Woody Biomass Utilization Grant program provides grant funding for the planning of wood energy projects by funding the engineering services necessary for final design and cost analysis. This program is aimed at helping applicants complete the necessary design work needed to secure public and/or private investment for construction.

Contact Scott Bell from the Rural Community Assistance program of the USDA Forest Service.

Idaho State Loan Program

Schools, hospitals, and healthcare facilities in Idaho are eligible for a 4% interest loan up to $100,000 over a five year term for energy efficiency and renewable energy projects.
http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ID02F&re=0&ee=0

Utility Energy Efficiency Incentives

Idaho Power may offer incentives for the energy efficiency measures we have recommended. Idaho Power's customer service representative in McCall is

Kurtis Hall
(208) 465-8610

To email him,
visit https://www.idahopower.com/ServiceBilling/Business/Service/energyExpert.cfm

Bonus depreciation – not eligible

As non-taxable entities, neither the hospital nor the school are eligible for bonus depreciation, which allows equipment used in biomass heating systems to be depreciated with a seven-year property class. The federal *Economic Stimulus Act of 2008* included "bonus depreciation" of 50% in the first year of operation, but this expires in 2013 and so was not included in this analysis.
http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1

Investment Tax Incentives – not eligible

These facilities are not eligible for the 10% federal business energy investment tax credit, both because they are not privately-owned and because biomass heating-only systems are not eligible.

References

Hustwit, Craig, James Baker, Dean Graham, "Preliminary Biomass Feasibility Study, Payette National Forest – Krassel Yeard, McCall, Idaho", prepared by National Energy Technology Laboratory, prepared for William L. Perry, Supervising Civil Engineer, Payette National Forest, March 2011

Kauffman, Marcus, Chad Davis, and Phil Change, "2011/2012 Oregon Biomass Heat Case Studies", Central Oregon Intergovernmental Council, Oregon Departments of Forestry and Energy, Sustainable Northwest, 2012, http://www.sustainablenorthwest.org/blog/posts/oregon-biomass-heat-case-studies

P-Squared Group, "Heating with Biomass: A Feasibility Study of Wisconsin Schools heated with Wood", P Squared Group LLC and Biomass Energy Resource Center, February 2008, http://www.biomasscenter.org/pdfs/WI_School_Wood_Energy.pdf

Yellow Wood Associates, "Preliminary Feasibility Report: Biomass Heating Analysis for Southern Fulton Elementary School, Warfordsburg, Pennsylvania", Prepared by Yellow Wood Associates, Inc. and Richmond Energy Associates, LLC, December 2011 http://na.fs.fed.us/werc/woody_biomass/pa/pa-southern-fulton-elementary-school-biomass.pdf

For More Information

DSIRE Database of State Incentives
http://www.dsireusa.org/

U.S. Forest Service Woody Biomass Utilization Team, websites,

- http://www.fs.fed.us/woodybiomass/index.shtml
- http://www.fs.fed.us/woodybiomass/documents/CharterFINAL_17Aug04.pdf
- http://www.fs.usda.gov/prc

Appendix A: Utility Data

Table A-1. Summary of Electricity Billing Data

Location	Address	Floor Area (ft^2)	National Median Energy Use (kW/ft^2)*	Site Energy Use (kWh/ft^2)	Annual Electricity Use (kWh)	Annual Energy Cost ($)	Minimum Demand (kW)	Maximum Demand (kW)
HIGH SCHOOL								
Main Building	120 Idaho St.	90,189	8.4	15.4	1,389,275	$90,275	165	980
Portable CRs		2,000	8.4	21.6	43,203	$2,922	2	20
Practice Field		0			8,430	$883	0	15
FOREST SERVICE								
Payette Office	12057 Payette	12,438	18.9	Not built	235,078			
HOSPITAL CAMPUS								
McCall Memorial Hospital	1000 State St.	38,000	245	337	1,424,000	$71,350	195	305
Medical Office Nokes	200 Forest St.	4,000	26.5	29	113,100	$6,994	19	55
Lake Street Therapy	1010 State St.	5,995	26.5	37	169,120	$9,181		
Integrative Medical Clinic	203 Hewitt St.	1,480	26.5	69	30,046	$2,347	5	22
Our Savior	100 E. Forest St.	5,479		6	31,680	$2,417	8	24
St Luke's Clinic	211 Forest St.	14,219	26.5	18	129,000	$7,691	21	55
TOTALS		**173,800**			**3,572,932**			

http://www.eia.gov/emeu/consumptionbriefs/cbecs/pbawebsite/education/educ_howuseelec.htm

Table A-2. Summary of Fuel Consumption Data, Hospital Campus

Location	Address	Diesel Use (gallons)	Annual Diesel Cost ($)	Propane Use (gallons)	Annual Propane Cost ($)
McCall Memorial Hospital	1000 State St.	52,000	$176,800	250	$725
Medical Office Nokes	200 Forest St.	0	$0	55	$160
Lake Street Therapy	1010 State St.	0	$0	1853	$5,374
Integrative Medical Clinic	203 Hewitt St.	0	$0	0	$0
Our Savior	100 E. Forest St.	0	$0	0	$0
St Luke’s Clinic	211 Forest St.	0	$0	4,300	$12,470
TOTALS					

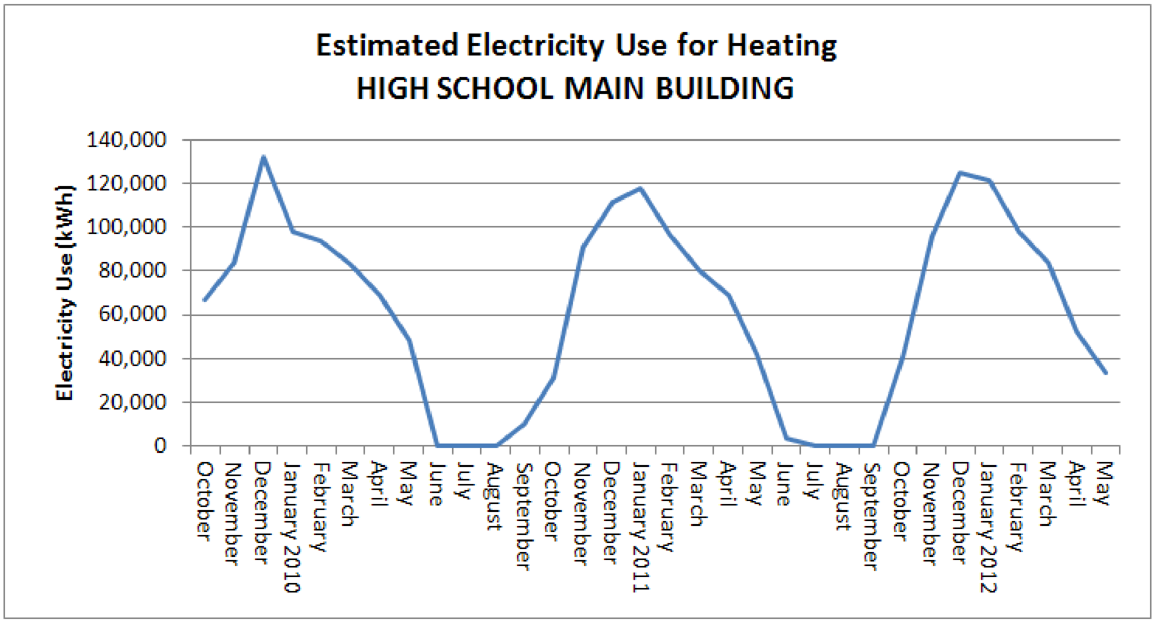
Electricity Billing Records

High School Main Building

This building has a base load of approximately 80,000 kWh/mo, estimated as the average of May and June energy use. The base load covers lights, hot water, etc. Above the base load is the load assumed for space heating, including the energy use of the boiler and ancillary equipment such as fans and pumps.

Average demand for this building in the 2011-12 school-year was 33% less than that in the 2009-10. Energy use, however, has not declined.

Figure A-1. Estimated electricity use for heating the McCall-Donnelly High School's main building*



* Heating energy use is estimated from billing data as that energy above the average of May and June's energy use. This includes energy use for auxiliary heating equipment such as fans and pumps on variable speed drives.

Figure A-2. Electricity energy use and demand of the McCall-Donnelly High School's main building

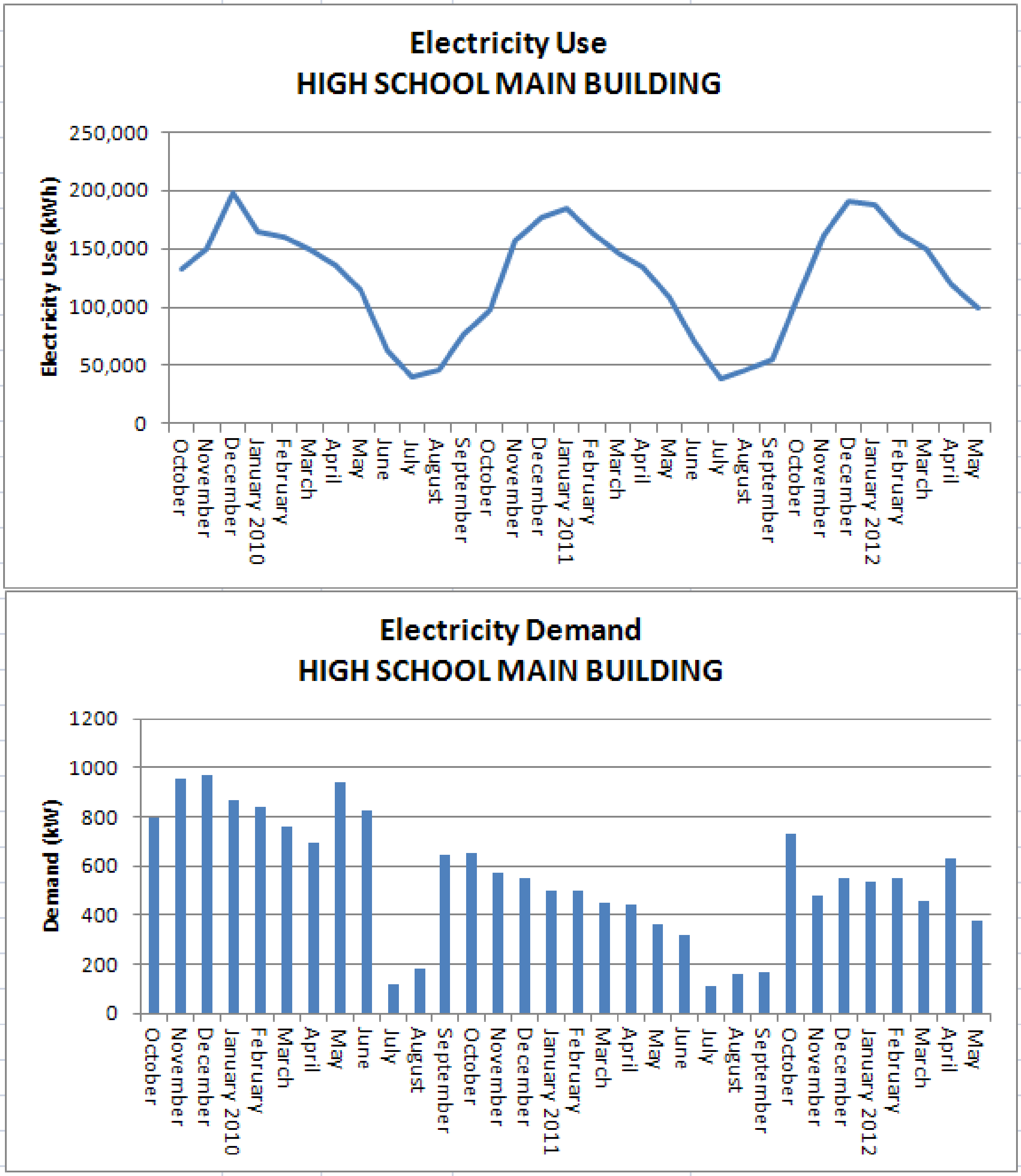
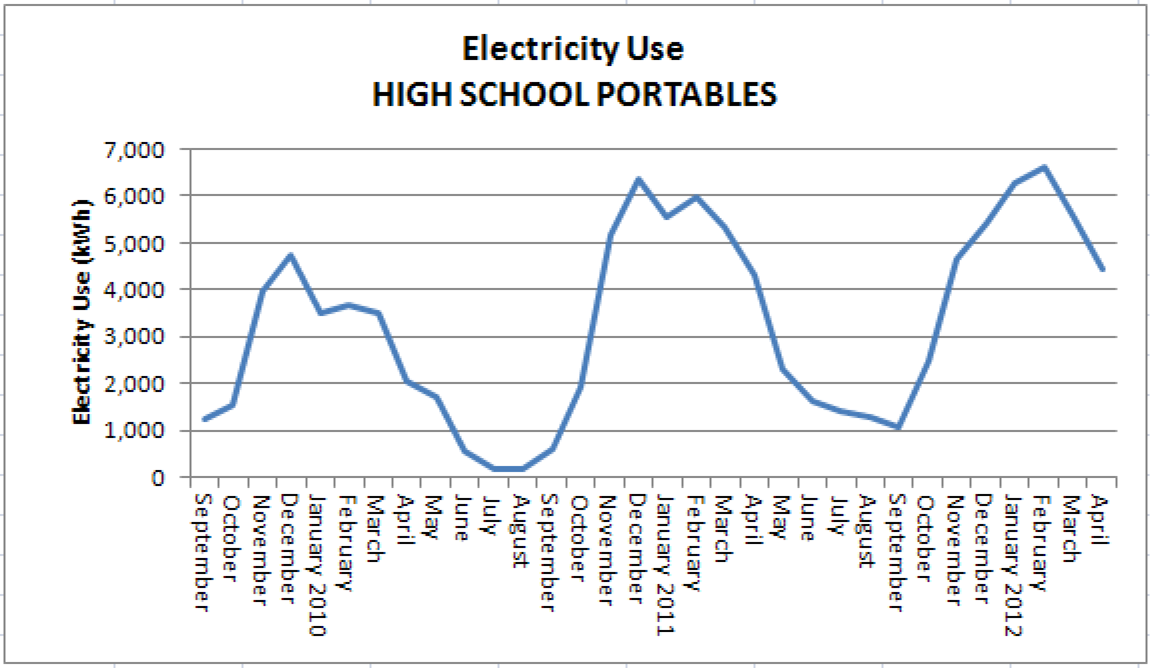


Figure A-3. Electricity energy use and demand of the McCall-Donnelly High School's two portable buildings



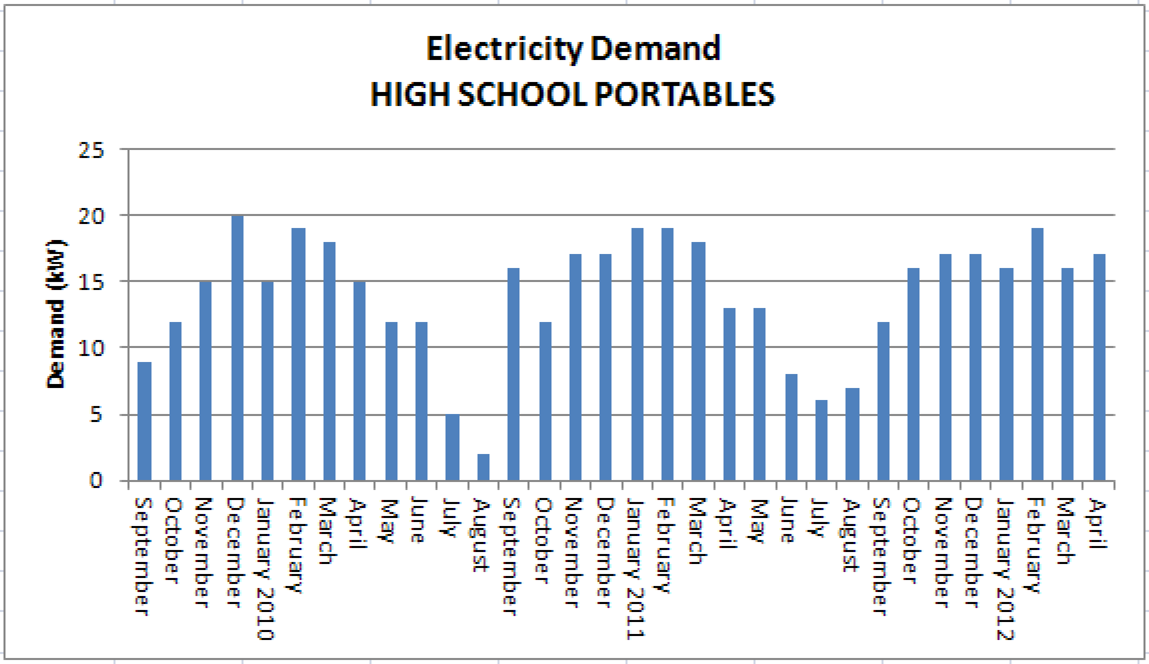
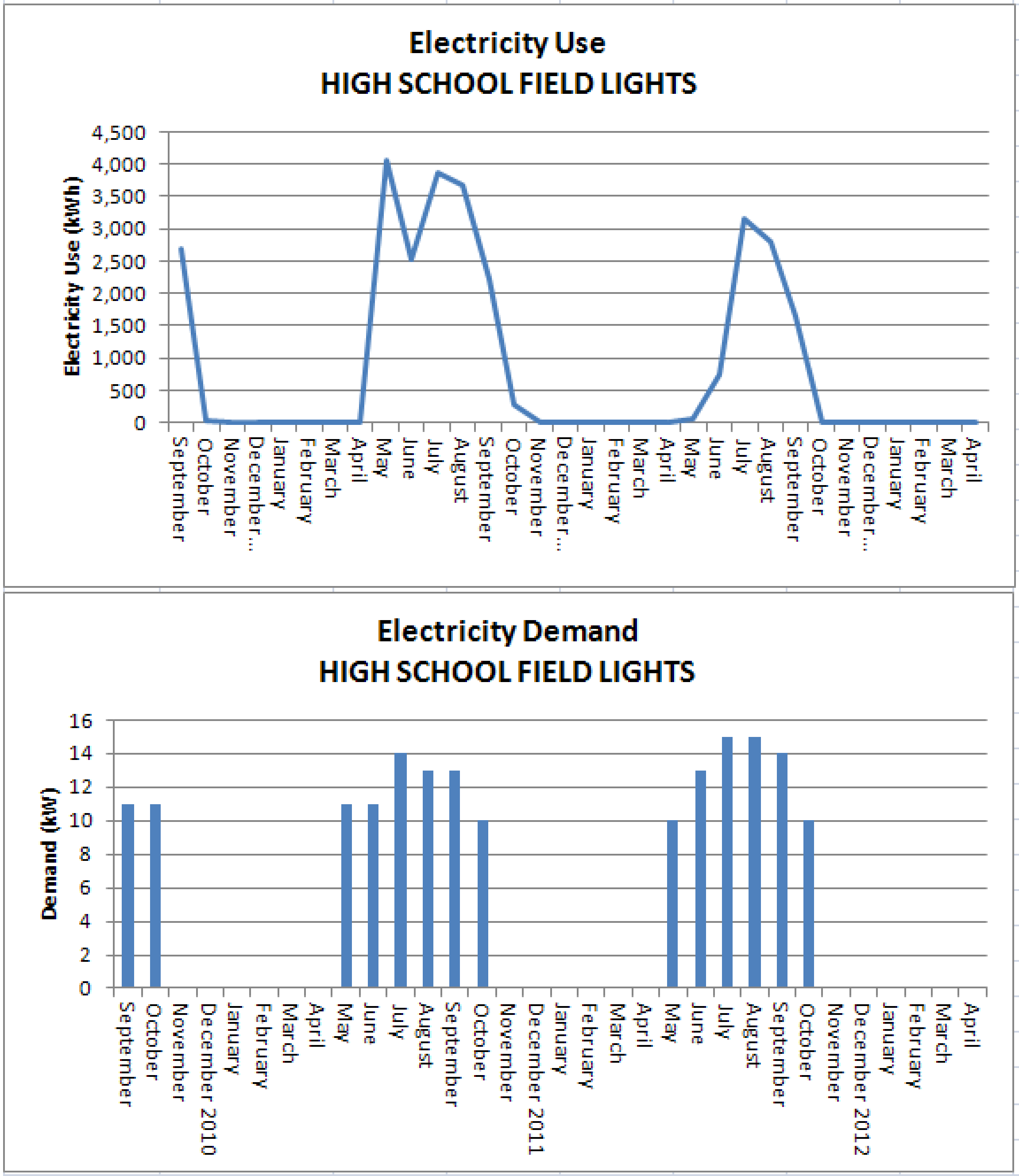


Figure A-4. Electricity energy use and demand of the McCall-Donnelly High School's ball field lights



McCall Memorial Hospital

McCall Memorial Hospital has a base load of approximately 110,000 kWh/mo. Energy use above the base load in the summer – about 90 kWh/mo. -- is attributed to coooling, including the energy use of ancillary equipment such as fans and pumps.

Figure A-5. Electricity energy use and demand of the McCall Memorial Hospital

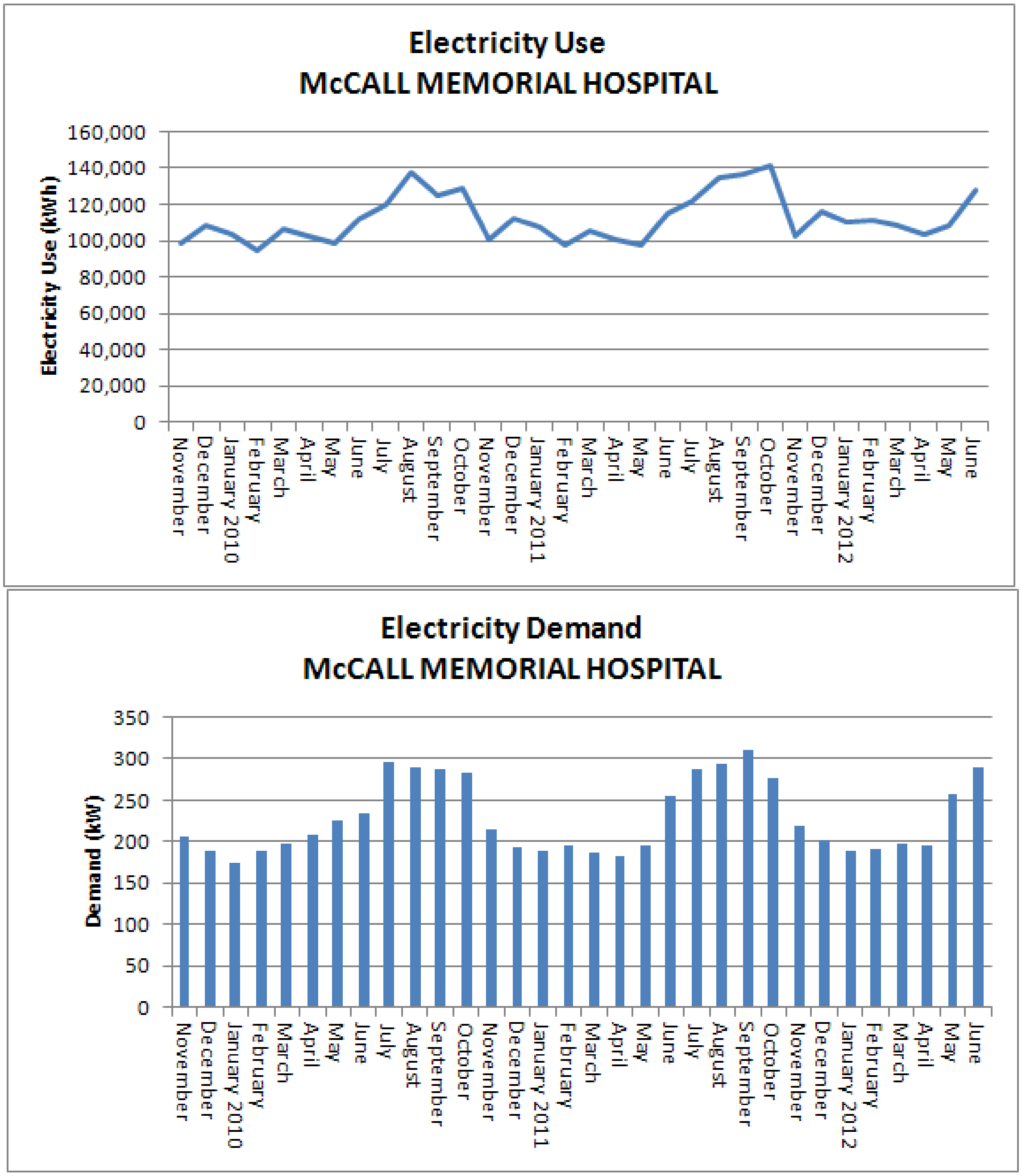
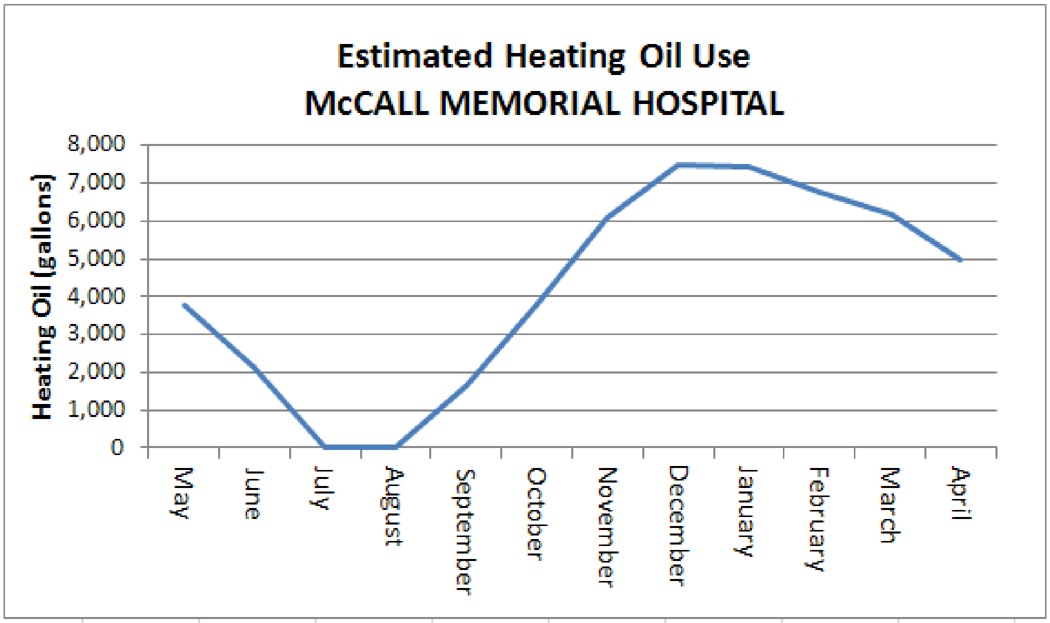
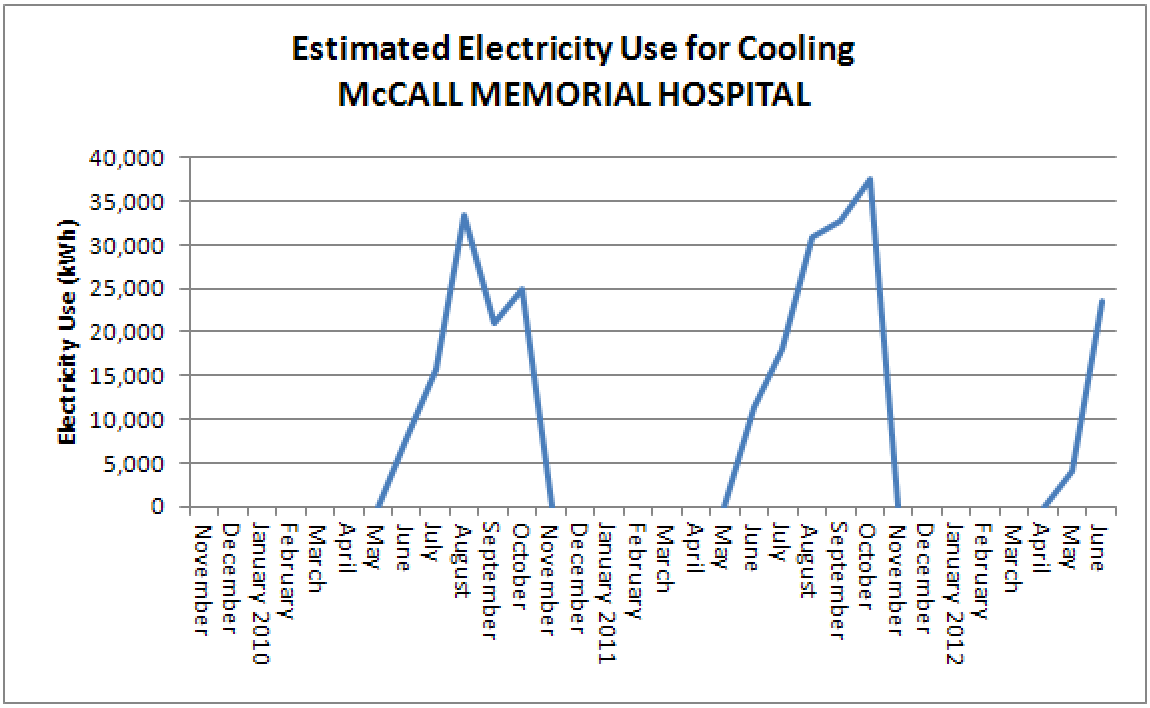


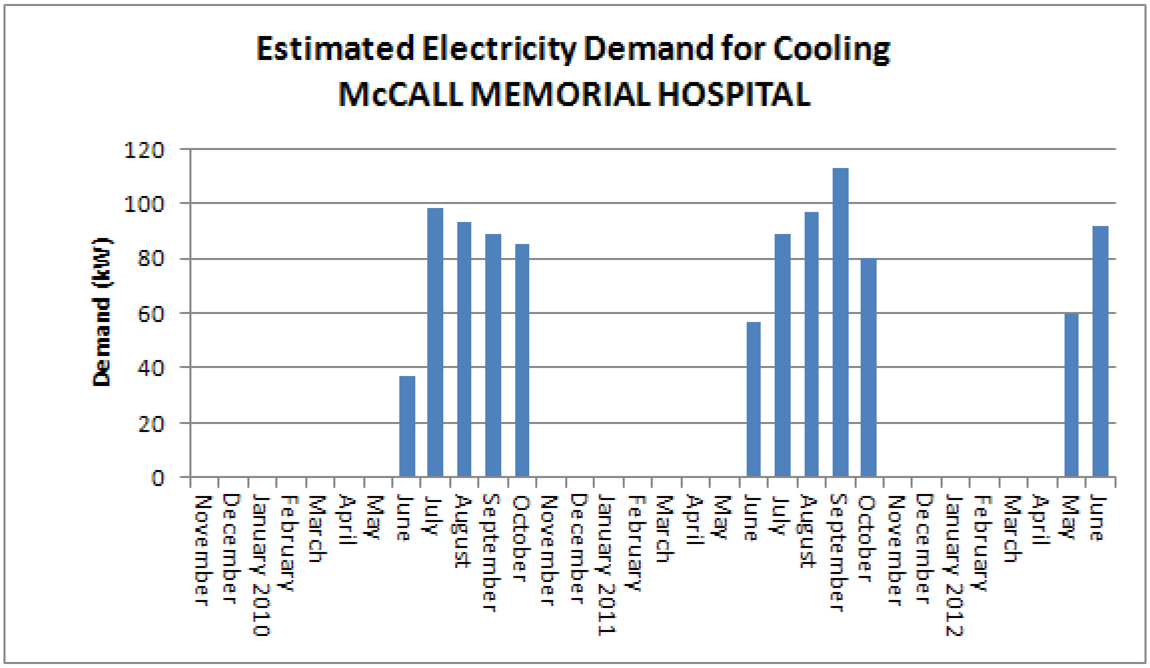
Figure A-6. Estimated fuel oil used for space heating at McCall Memorial Hospital[1]



1. Fuel oil use for heating was estimated from the annual average totals from 2010 to 2012 using average monthly heating degree days for McCall, Idaho over the same period.

Figure A-7. Estimated electricity use and demand for air conditioning at McCall Memorial Hospital[1]



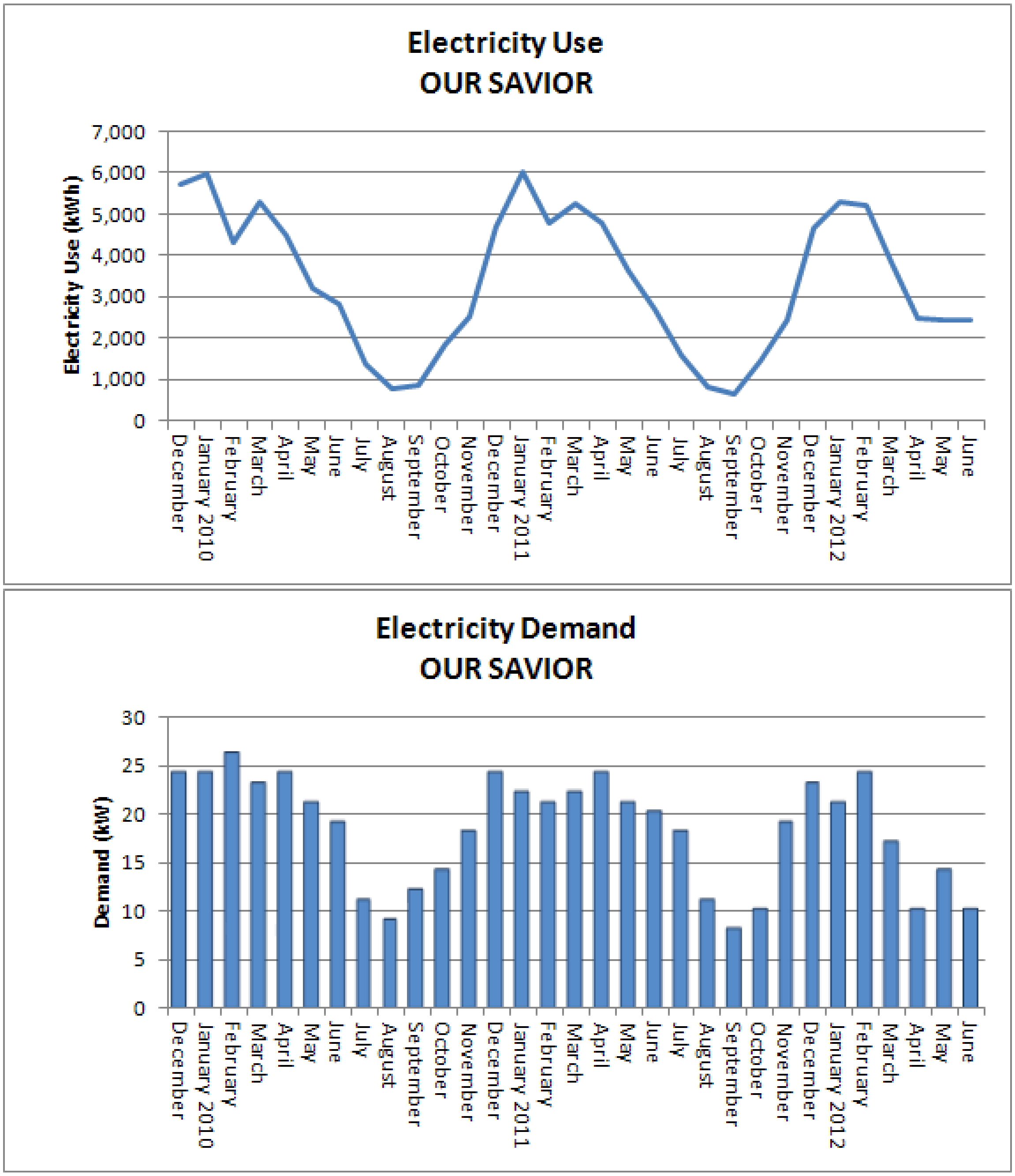


[1] Energy and demand use for space cooling was estimated by subtracting winter average use and demand from summer use and demand, respectively.

Our Savior Chapel

The chapel has a base load of approximately 1,000 kWh/mo. Energy use above the base load – approximately 20,000 kWh/year -- is attributed to space heating.

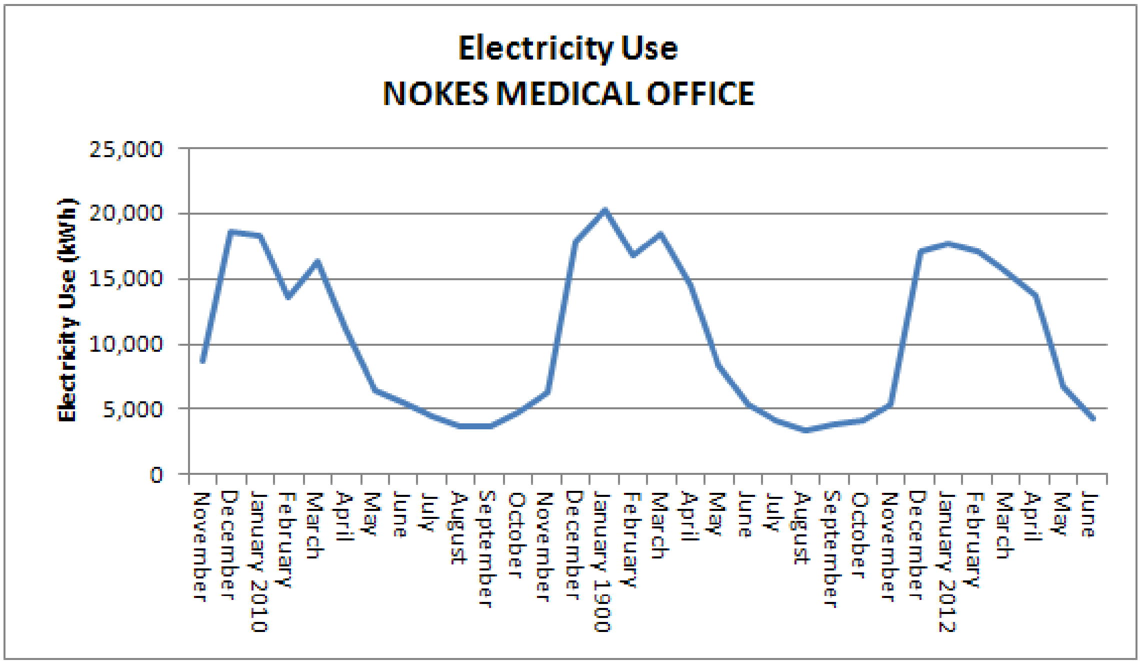
Figure A-8. Electricity energy use and demand of the medical center chapel.

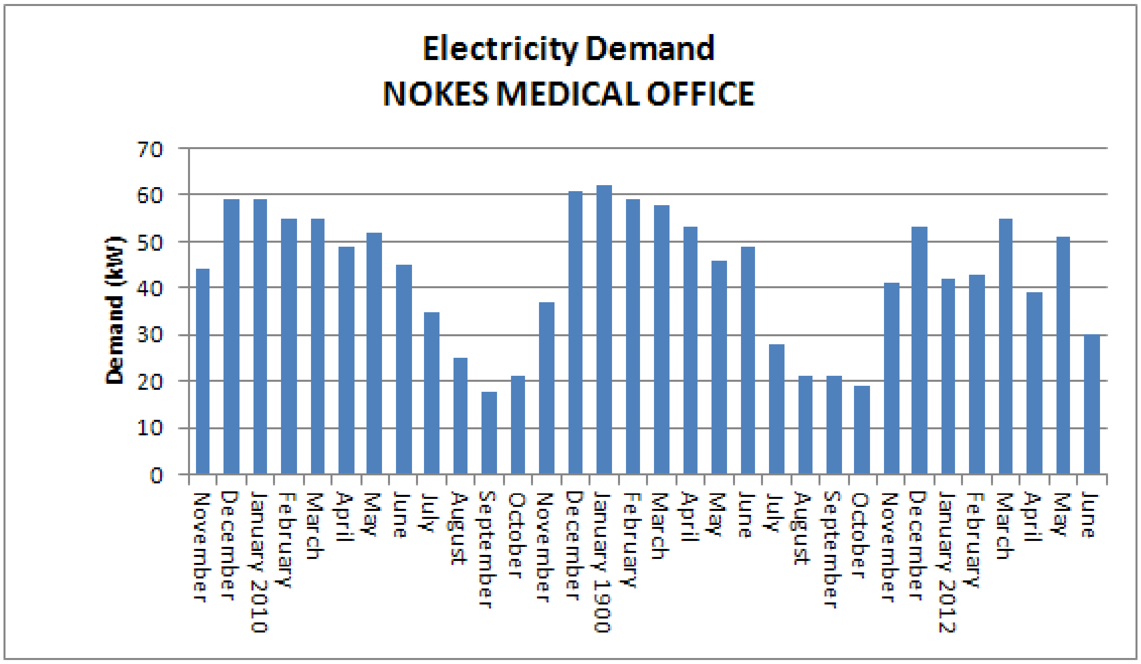


Nokes Medical Office

Nokes Medical Office has a base load of approximately 5,000 kWh/mo. Energy use above the base load – approximately 60,000 kWh/year -- is attributed to space heating.

Figure A-9. Electricity energy use and demand of the Nokes Medical Clinic

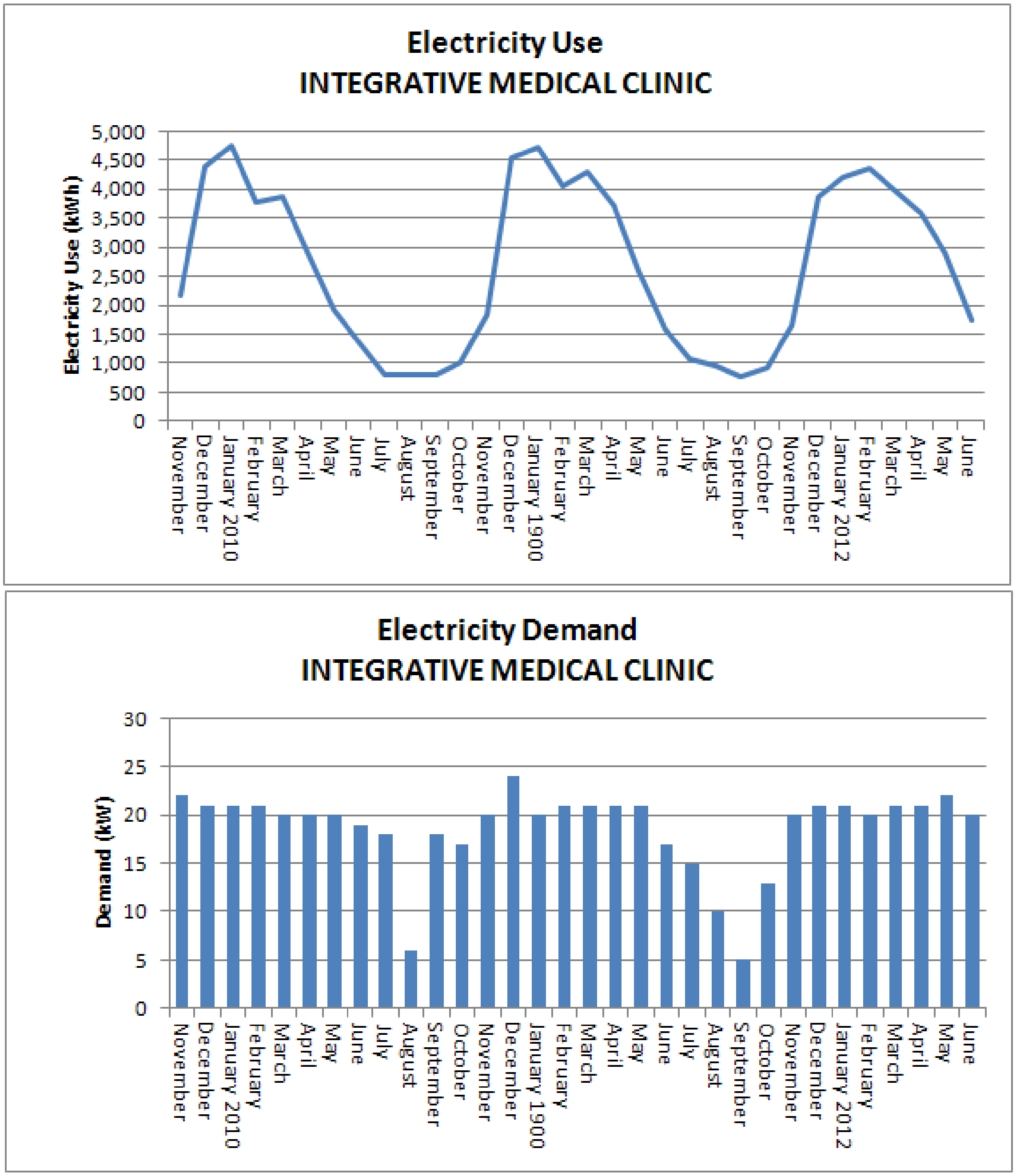




Integrative Medical Clinic

The Integrative Medical Clinic a base load of approximately 1,000 kWh/mo. Energy use above the base load – approximately 16,000 kWh/year -- is attributed to space heating.

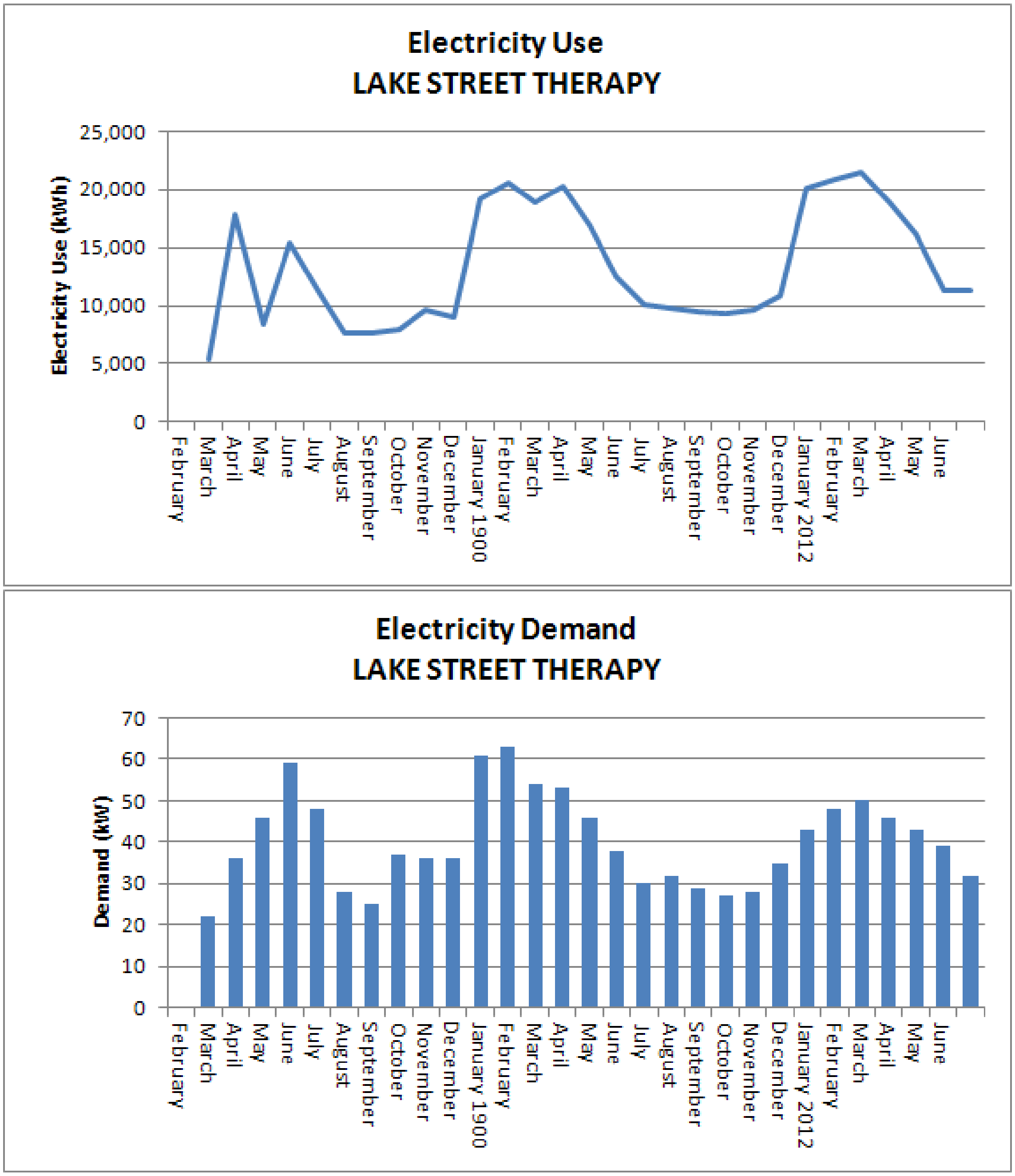
Figure A-10. Electricity energy use and demand of the Integrative Medical Center



Lake Street Therapy Building

The Lake Street Therapy Building had a base load of a base load of approximately 10,000 kWh/mo from July to December with an addition 10,000 kWh/mo from January to May. It was not determined what the energy use above the baseload – approximately 22,000 kWh/year – could be attributed to.

Figure A-11. Electricity energy use and demand of the Lake Street Medical Center

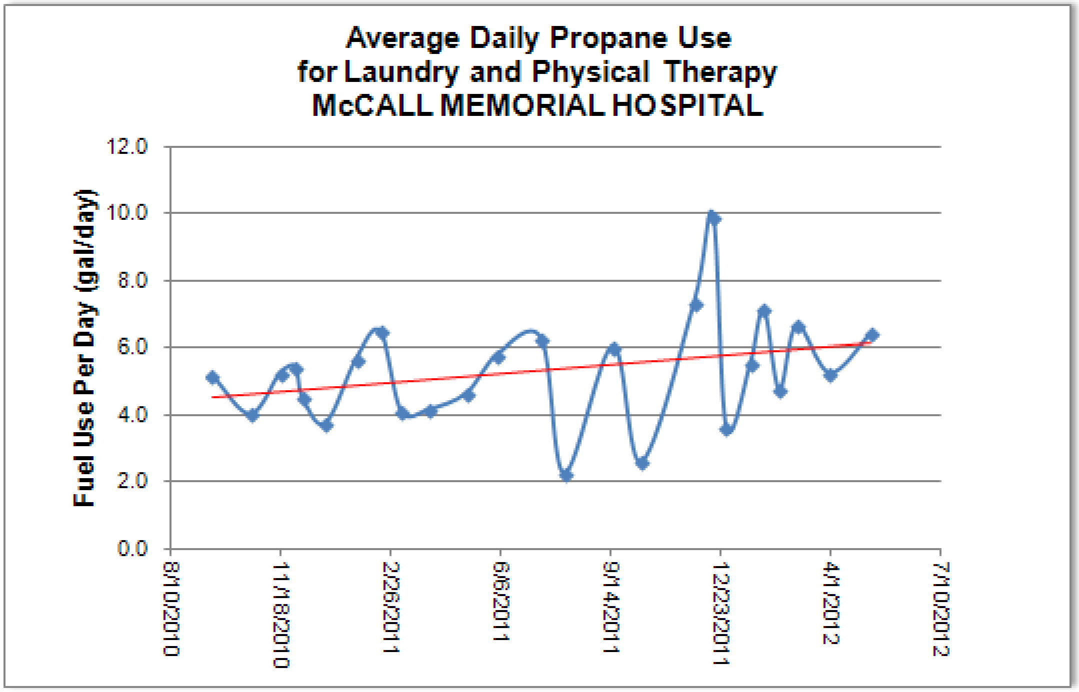


.

Propane Billing Records

McCall Memorial Hospital
Average daily propane use at McCall Memorial Hospital for laundry and physical therapy uses is an average of 5.3 gallons per day.

Figure A-12. Average daily propane use at the McCall Memorial Hospital



Appendix B:

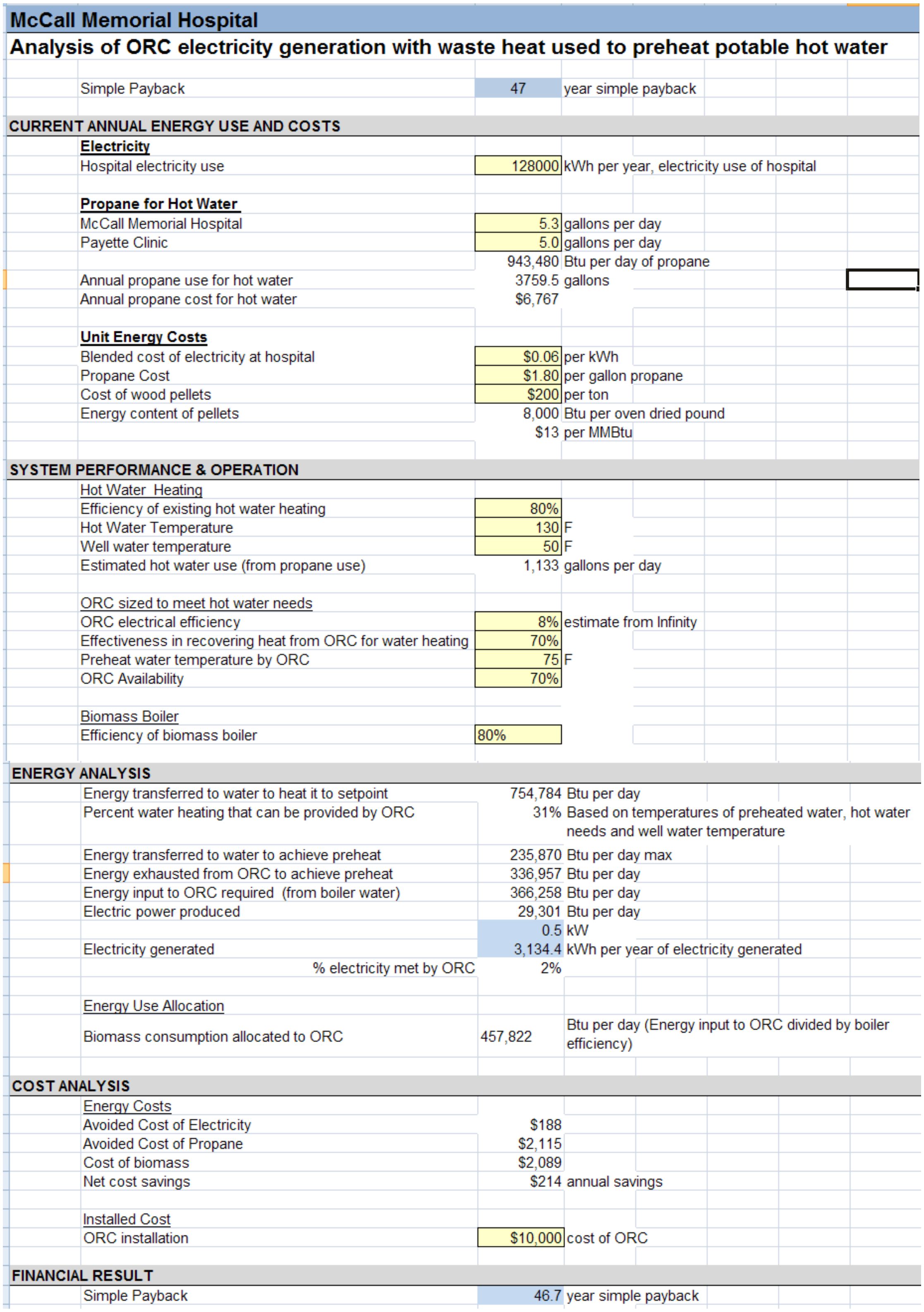
Cash Flow Statements for Recommended Options

This appendix includes cash flow statements for the following options, which all have good discounted paybacks:

1. Biomass Heating at McCall Memorial Hospital
    a. Pellet System
    b. Wood Chip System]

2. Waste Heat Recovery from Industrial Facility for District Heating:
    a. McCall Memorial Hospital Only
    b. McCall Memorial Hospital, Nokes Medical Offices and Lake Street Therapy Building

Appendix C: CHP Analysis with ORC System



McCall Memorial Hospital		
Analysis of ORC electricity generation with waste heat used to preheat potable hot water		
Simple Payback	47	year simple payback
CURRENT ANNUAL ENERGY USE AND COSTS		
Electricity		
Hospital electricity use	128000	kWh per year, electricity use of hospital
Propane for Hot Water		
McCall Memorial Hospital	5.3	gallons per day
Payette Clinic	5.0	gallons per day
	943,480	Btu per day of propane
Annual propane use for hot water	3759.5	gallons
Annual propane cost for hot water	$6,767	
Unit Energy Costs		
Blended cost of electricity at hospital	$0.06	per kWh
Propane Cost	$1.80	per gallon propane
Cost of wood pellets	$200	per ton
Energy content of pellets	8,000	Btu per oven dried pound
	$13	per MMBtu
SYSTEM PERFORMANCE & OPERATION		
Hot Water Heating		
Efficiency of existing hot water heating	80%	
Hot Water Temperature	130	F
Well water temperature	50	F
Estimated hot water use (from propane use)	1,133	gallons per day
ORC sized to meet hot water needs		
ORC electrical efficiency	8%	estimate from Infinity
Effectiveness in recovering heat from ORC for water heating	70%	
Preheat water temperature by ORC	75	F
ORC Availability	70%	
Biomass Boiler		
Efficiency of biomass boiler	80%	
ENERGY ANALYSIS		
Energy transferred to water to heat it to setpoint	754,784	Btu per day
Percent water heating that can be provided by ORC	31%	Based on temperatures of preheated water, hot water needs and well water temperature
Energy transferred to water to achieve preheat	235,870	Btu per day max
Energy exhausted from ORC to achieve preheat	336,957	Btu per day
Energy input to ORC required (from boiler water)	366,258	Btu per day
Electric power produced	29,301	Btu per day
	0.5	kW
Electricity generated	3,134.4	kWh per year of electricity generated
% electricity met by ORC	2%	
Energy Use Allocation		
Biomass consumption allocated to ORC	457,822	Btu per day (Energy input to ORC divided by boiler efficiency)
COST ANALYSIS		
Energy Costs		
Avoided Cost of Electricity	$188	
Avoided Cost of Propane	$2,115	
Cost of biomass	$2,089	
Net cost savings	$214	annual savings
Installed Cost		
ORC installation	$10,000	cost of ORC
FINANCIAL RESULT		
Simple Payback	46.7	year simple payback