Wolf Creek Outdoor School
Energy Efficiency and Renewable Energy Design Project

Written By Steve Koldis & Matthew Rhode

University National Park Energy Partnership Program
and
Schatz Energy Research Center
HSU, Arcata, CA 95521
707-826-4345

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For:
Wolf Creek Outdoor School
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Executive Summary

Located 48 miles north of Eureka, California, and set amongst second growth redwood trees in Redwood National Park is the Wolf Creek Outdoor School (WCOS). The school provides comprehensive natural resource and environmental education to children and adults.

This proposal seeks funding to install energy efficient and renewable energy technologies at WCOS. Implementation of such technologies will reduce operating costs at the facilities and will set a precedent for similar facilities in the national parks. Technical renovation of WCOS will also have a positive effect on the public by providing information about renewable and efficient uses of energy, which visitors and park staff can apply in their own homes, classes, and businesses.

The design for the renovation was created by Steve Koldis and Matthew Rhode, Humboldt State University (HSU) students who have been working in conjunction with the Schatz Energy Research Center (SERC) and the University-National Park Energy Partnership Program (UNPEPP). Their paid internship is one of many UNPEPP projects across the nation helping to reduce energy costs and environmental impacts at national parks.

The proposed renovation of the facilities will include the utilization of solar energy to assist in heating water and air for the restrooms and to provide on-site environmentally-friendly electric generation. The restrooms will be modified to accommodate laundry facilities and a heat recovery ventilation system. Also included in the renovation will be the addition of energy-efficient lighting for pathways, cabins, and the amphitheater.

The forecasted electrical energy savings is 40% of the current energy consumption, saving a potential $2,000 per year. The cost of the materials for this renovation will be approximately $35,000. The cost of labor has been left out, as it has not yet been determined whether the renovation project will be accomplished by park staff or by outside contractors.

By bringing the WCOS up to an environmentally-sound technological standard, the national parks will move one step forward in protecting the nation's natural resources and unparalleled beauty.

Introduction

The University-National Park Energy Partnership Program (UNPEPP) develops renewable energy and energy efficiency projects in National and State Parks across the country. The program gives students an opportunity to apply classroom knowledge in a professional setting. In Northern California the UNPEPP interns are students at Humboldt State University working within Redwood National Park to promote renewable energy and conservation practices. This year, the UNPEPP interns are focusing on the Wolf Creek Outdoor School (WCOS). The park staff recommended outfitting WCOS with energy efficiency and renewable energy technologies due to the copious amount of electrical energy consumed at the site.

Statement of Problem

When the WCOS was built, components that were considered to be standard at the time were used to heat water, heat space, provide light, and run a variety of electrical appliances. However the majority of the components are inefficient and inappropriately applied by current standards. This inefficiency results in a large energy operating cost for the facilities of $ 4,500 per year. Furthermore, as WCOS expands, additional needs have arisen. Pathway lighting, amphitheater lighting, and an addition of laundry facilities are needed to provide safe access around the grounds and to maintain hygienic conditions in the cabins.

Statement of Purpose

The intent of the project is to reduce consumption of electrical energy while maintaining comfort and functionality. Another objective is to provide on-site production of electrical energy from renewable sources, focusing on solar energy. An additional aim of the project is the education of park staff and the public, so that they may discover for themselves the importance of wise energy use. Furthermore, the implementation of pathway, interior, and stage lighting will provide safe access around the grounds of WCOS during the nighttime hours.

Statement of Need

Installing new, efficient equipment at WCOS to heat water, heat air, provide light, and provide on-site electrical generation is necessary to reduce annual operating costs. In addition, the implementation of energy efficient components will reduce the national park's energy use and will maintain the park's long tradition of stewardship of natural resources. Through the promotion of energy efficiency, the national parks will set a precedent the public will look to as a model of healthy and economic living.

As is the case in many renewable energy and energy efficiency projects, the WCOS renovation calls for a substantial up-front investment that will be repaid with long-term energy cost savings. Due to the high initial cost of implementing renewable and energy efficient technologies, the financial support for such a project must come from special project funds allocated through the Project Management Information System (PMIS) and regional office for Redwood National Park. The allocated funds will be used to purchase all of the necessary materials to renovate the current heating and electrical systems to renewable and efficient systems. The funding will benefit WCOS by reducing the annual cost for energy, create a model for other facilities at the national parks to follow, and educate the public and staff.

Project Description

Background

Beginning in 1994, the California State Parks and the National Park Service (NPS) merged to manage four parks, collectively known as Redwood National and State Parks. The parks are located roughly 50 miles north of Eureka, on the North Coast of California, Figure 1.
The parks have been designated a World Heritage Site and a Biosphere Reserve, thus protecting the world's tallest living trees, 14,000 acres of coastal old-growth redwoods.

Wolf Creek Outdoor School is located 8 miles north of Orick, California, in the heart of a second-growth redwood forest. The school is part of Redwood National Park. From early spring to late fall, the facilities at WCOS are occupied by children and teachers from local elementary and middle schools. In addition to the class field trips, other private organizations also use WCOS as a base camp for educational experiences, teaching adults and children about the importance of ecosystem preservation. The Wolf Creek Outdoor

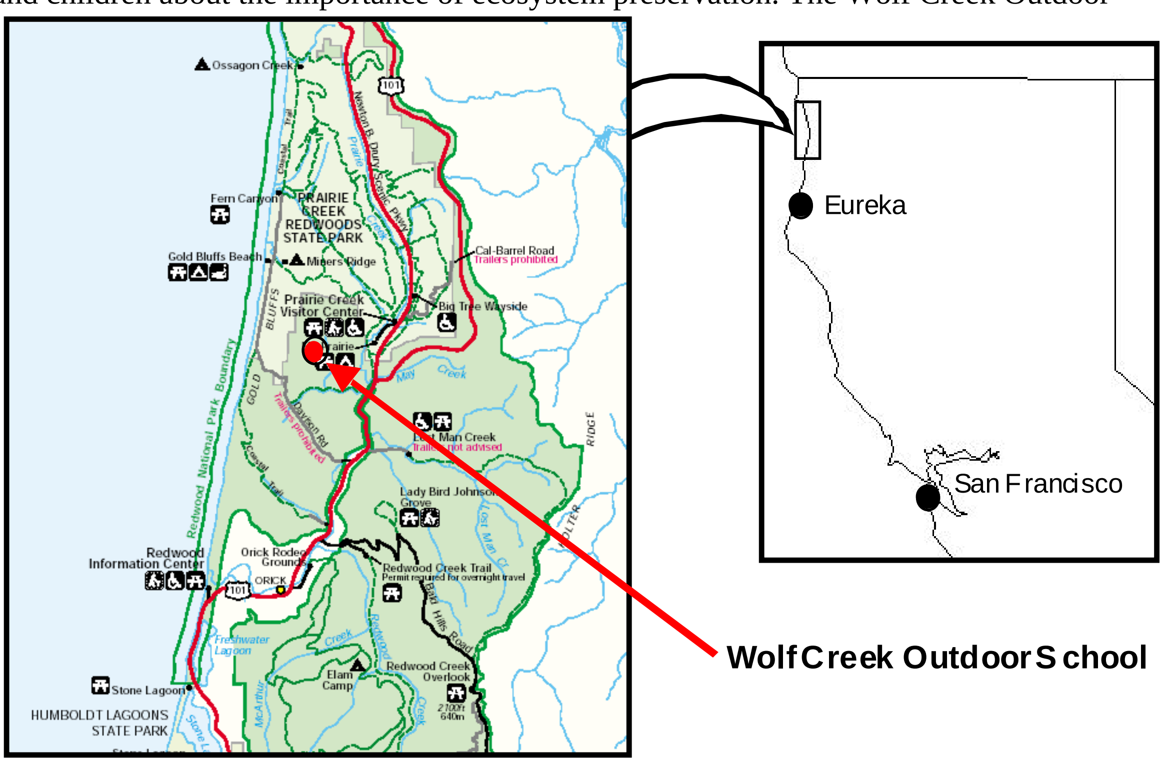

Figure 1. Wolf Creek Outdoor School Location Map

School contributes to the understanding of natural resource preservation by promoting hands-on educational experiences. The implementation of renewable energy systems and energy efficiency practices at WCOS will strengthen the visitor's educational experiences by demonstrating the conservation of natural resources. Furthermore, the implementation of these practices will reduce the amount of energy consumed at the school, cutting costs and pollution at the same time.

Existing and Expanding Facilities and Technologies

The WCOS facility is composed of six cabins, a restroom with six showers, a large lodge with kitchen, office, and presentation space, and an outdoor amphitheater. WCOS is nestled in a young stand of Redwood, Douglas fir, and Sitka spruce trees. The focus of the UNPEPP interns at WCOS will be directed towards the cabins, amphitheater, and restrooms. At this point, only energy conservation recommendations will be made concerning the lodge.

Each cabin is outfitted with enough bunks to sleep 16 people. Currently, the cabins do not have a source of electricity or heat and are not insulated.

A 350-foot pathway meanders under the redwood canopy to the outdoor amphitheater. The seating for the amphitheater is made up of 20 redwood planks. At this time, there is no electrical service to the amphitheater. The staff at WCOS have been using propane-fired lights for stage lighting and flashlights for trail lighting. Most of the presentations in the amphitheater take place during nighttime hours.

The Wolf Creek Outdoor School provides a total of six showers in the men's and women's restrooms. Water for these showers is heated by an electric hot water heater. Each shower has a flowrate of two gallons per minute. At the current shower flow rate the water heater's stored hot water is used up after all six showers are used for ten minutes. The water heater will heat additional water at a rate of 30 gallons per hour.

Space heating is provided by ceiling mounted electric heaters. Separate thermostats in the men's and women's restrooms control the space heaters. Indoor lighting is achieved by the use of twelve 4-foot single-tube fluorescent fixtures, six in each side. During the nighttime hours the entrance to the bathroom is lit by two high-pressure sodium (HPS) lights that are controlled by a photo-switch. In each bathroom, there is a ventilator that is activated by a timer. There are two skylights in each side of the restroom that measure 15 ft^2 each, providing adequate daylighting. There are no windows in either bathroom.

Equipment Expansion

Upon request of the staff at WCOS interior lighting for the cabins is part of the project, as well as lighting for the pathway and amphitheater stage. Laundry facilities have also been requested and will account for a large increase in electrical consumption.

Hot Water System Data Acquisition

Factors considered for proposal of a solar hot water system are water use, water temperature, shower flowrate, and available local solar energy. System water temperature was recorded by attaching temperature sensors coupled with a data acquisition system to the water heater inlet and outlet pipes. The temperature sensors were attached to the hot water outlet pipe and the cold water inlet pipe of the hot water heater by wrapping each sensor with insulation and tape. The hot water tank inlet temperature remains steady at 63^{o}F. The shower delivery water also remains relatively constant between 110^{o}F and 118^{o}F.

A four-liter graduated cylinder and a stopwatch were used to measure the maximum shower flowrate. Numerous trials were conducted to ensure accurate results. Each trial had one person operating the timer and another person collecting shower water in the graduated cylinder. Results from these trials determined the maximum shower flowrate to be two gallons per minute.

WCOS occupancy varies monthly. During the regular school year WCOS can expect a maximum of 85 kids in any given week for three consecutive days. Summertime occupancy is expected in the future and will range from 30 to 45 kids in any given week for five consecutive days. WCOS will not be occupied from late November to early March.

The volume of hot water consumed each day by showering is determined by multiplying the volume that each individual shower consumes by the number of expected showers per day. This volume indicates the amount of hot water storage that must be available. The size of the hot water storage tank can be varied if the number of shower cycles is varied. If all of the showers are taken at one time of the day, then the size of the hot water storage must be large. If there is more than one time of the day when showers are taken the storage tank can be smaller. To avoid installing a very large and expensive solar hot water system, it is recommended that WCOS adopt a two-cycle showering schedule for facility users. Table 1 depicts how shower duration and time of day would affect hot water use and hot water storage tank size. The table assumes that no more than 45 people will shower in one day.

Table 1. Volume of water and tank size estimated when shower duration and shower cycles are varied.

Flowrate (gpm)	Shower Cycles per day	People Showers per day	Shower Duration (min)	Volume Hot Water Used per Cycle (Gallons)	Tank Size
2.11	1	45	5	473.78	3-120 gal tanks
2.11	1	45	3	284.27	2-120 gal tanks
2.11	2	45	5	236.89	2-120 gal tanks
2.11	2	45	3	142.14	1-120 gal tank

To forecast the hot water production of a solar hot water system in a given location solar windows were evaluated. The solar window is the number of sunlight hours that can be expected in any day of each month when shading is considered. The roof of the bathroom is the recommended location for a solar hot water system. Other locations have been considered, but have been ruled out due to inefficiencies and potential for vandalism. If some of the smaller or injured trees to the southwest of the restroom were removed, the amount of available energy would increase. Chart 1 compares the current available energy collected on the roof of the bathroom to the projected energy available if the trees to the east of the bathroom were removed. If these trees are to be removed, monthly insolation would increase by 25%.

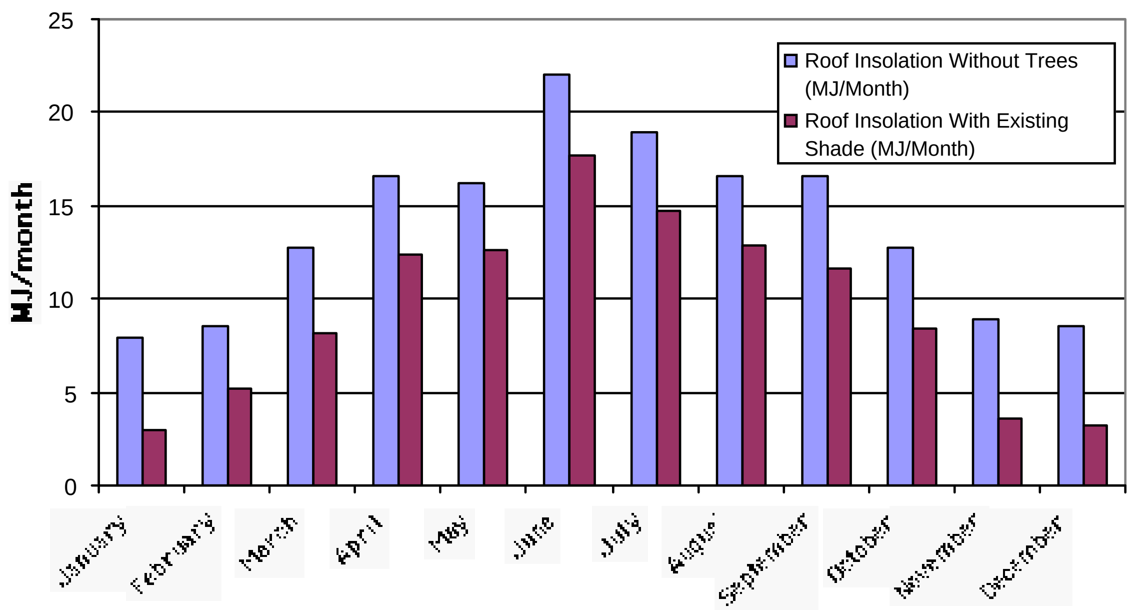

Chart 1. Shading Influences on Bathroom Roof

Solar Hot Water System Specifications

The proposed hot water system will take the place of the current electric hot water system. A typical drain back solar hot water system is depicted in Figure 2**.** The solar system will utilize solar radiation to heat water within four 4-foot by 10-foot flat plate collectors. Water will be circulated from the Six Rivers Solar 210-gallon storage tank to the collectors when the differential temperature control, with temperature sensors located both in a collector and in the tank, determines that heating is possible. A 210-gallon storage tank is recommended to replace the existing 120-gallon tank so that the sun's energy will be more fully utilized for hot showers. One 210-gallon tank is also preferable to two 120-gallon tanks to save space in the utility room. This tank would need to be custom-made with a width no larger than 35 inches in order to fit through the utility room doors. The water will begin to circulate from the tank to the collectors by activation of a Taco 008 pump (for use in systems with height differences less than 14-feet between pump and top of collector). When heating is not possible, the differential temperature control signals the pump to turn off. By turning off the pump, the drain back system is initiated and all of the system water drains from the collectors back into the storage tank. This drain back system is necessary for preventing the possibility of pipes freezing and system failure. A diagram of a typical drainback system can be seen in Figure 2.

Solar energy will be the main source of heat to the 210-gallon storage tank. Additional heat may also be applied to the storage at times when solar energy is not available, utilizing the auxiliary water heater. In this way the tank will be maintained at 90^{o}F minimum. Domestic hot water (DHW) and space heating will be accomplished in similar ways.

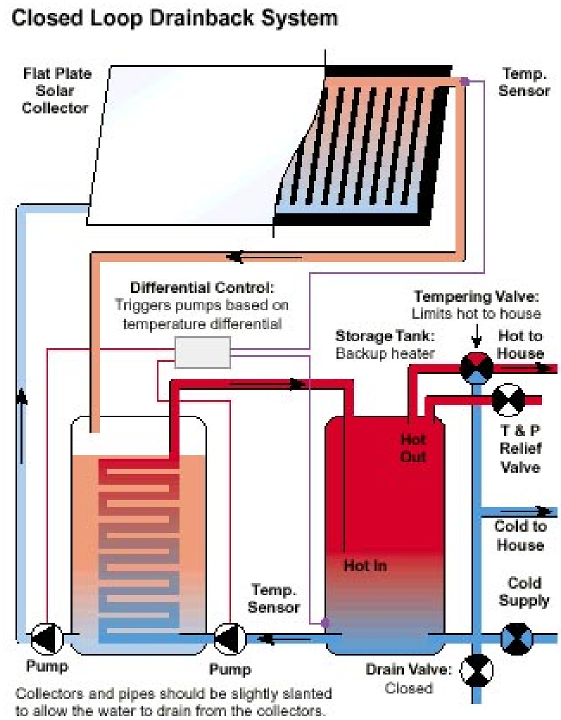

Figure 2. Typical drain back hot water solar system.

A propane storage tank located behind the restroom is recommended for simplicity. A new propane storage tank located in the vicinity of use will reduce the amount piping required, reduce soil impacts, and reduce installation time.

The hot water system should be accompanied with a means of saving hot water. The first step to save water is to post a sign in the shower stalls promoting shorter showers. The sign will be a good reminder for the shut off valve that will be placed in line with the shower nozzle and water source. The recommended shut off valve has the added advantage of maintaining the desired shower water temperature. A low-flow shower head is recommended, rated at 1.5 gallons per minute (gpm) to conserve water and energy. A detailed list of the necessary components can be found in Appendix 5.

American Standard Propane Water Heater

The propane water heater will be located in the utility room. In this system shower water is pre-heated through a heat exchange coil in the solar storage tank. This water ends up in the 100-gallon propane water heater where heat is added until it reaches an acceptable delivery temperature. Water for the showers is taken directly from this water heater. The propane water heater will also maintain a storage of heat in the solar hot water tank at a minimum of 90^{o}F. Any temperature above 90^{o}F will decrease the efficiency of solar collection. A differential control will determine whether the heater water should enter the heat exchanger in the solar hot water tank to maintain its 90^{o}F temperature. A second parallel connection to this loop will provide heat energy for the space heating. A flow schematic is located in Appendix 1.

Space Heating Data Acquisition

Data required for analysis of space heating was room temperature, outside temperature, insulation type, room area, and room volume. Room air temperature was recorded by extending a temperature sensor through the wall of the men's bathroom. The sensor was located 3-feet below one of the existing space heaters. This location was ideal for determining how often the heaters turned on, the maximum room temperature, and the minimum room temperature. The temperature of the bathroom was determined to be set too high because space heating forced the room temperature above 76^{o}F**.** On June 19, 2001, the thermostat to the space heaters was set to turn on at 65^{o}F instead of 73^{o}F. This setback resulted in a noticeable decrease in heater on-time and possibly a huge electrical savings. Chart 2 shows the temperature of the bathroom over time for a typical summer day.

To record the outside air temperature a temperature sensor was strung through a pipe between the bathroom utility room and the outside. The outside temperature was necessary for making correlations between heater on-times, time of day, and outside temperature.

Heat transfer characteristics of the room are dependent on room temperature, volume, and insulation type. The bathroom insulation was determined to be R-11 type insulation. Insulation type is important for characterizing the heat flux through the walls and ceiling of the bathroom. Each bathroom's dimensions are 9-feet by 37-feet by 9-feet high.

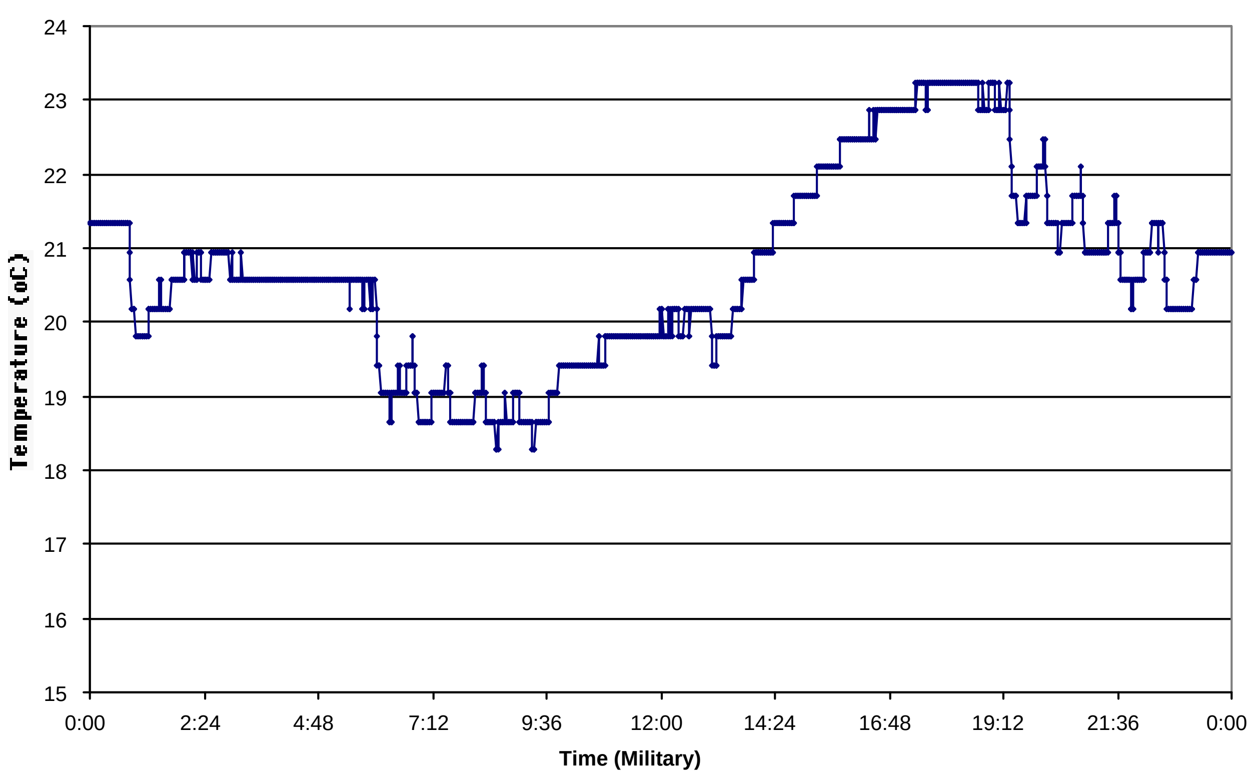

Chart 2. Ambient bathroom temperature over a typical day.

Space Heating System Specifications

Propane as a heat source is preferable to the current electric heat source, as demonstrated in Table 2**.** To provide the same amount of heat energy, electric heat will cost the consumer a third more than propane heat.

Table 2. Cost comparison of propane heat and electric heat.

	Electric		Propane	
Heat Demand	30000	Btu/hr	30000	Btu/hr
Utility Cost	$0.12	per kWh		
	$35.00	per million Btu	$18.00	per million Btu
Heat Demand Cost	**$1.05**	per hour	**$0.65**	per hour

Hydronic Heat Exchange Ventilator/Heater

A combined hydronic heat exchange ventilator and heater will provide a sufficient means of central heating. The 40 DHW Life Breath Clean Air Furnace is recommended for this heating option. This heater is efficient because it exchanges exhaust air heat to preheat the intake air so that less heat must be applied when heating is necessary. This system needs 140^{o}F supply water temperature to provide necessary heating. The solar hot water storage tank will assist the water heater by providing it with preheated water, which in combination with the air-to-air heat exchange will provide central heating to the building. The heat exchanger and the hydronic coils with blower will be located in the utility room. Insulated ducting will extend from the heating unit into the attic space and then end at vents in the ceilings of each of the bathrooms.

Figure 3 is a flow chart of the HRV Furnace.
1.Warm, Stale air from the bathrooms is returned to the Life Breath ventilator
2.Outdoor air travels through the fresh air intake and is brought into the integrated HRV
3. The fresh and stale air pass through opposite sides of the HRV heat exchanger
4. Heat from the stale air is transferred to the fresh air.
5. Stale air is exhausted outside.

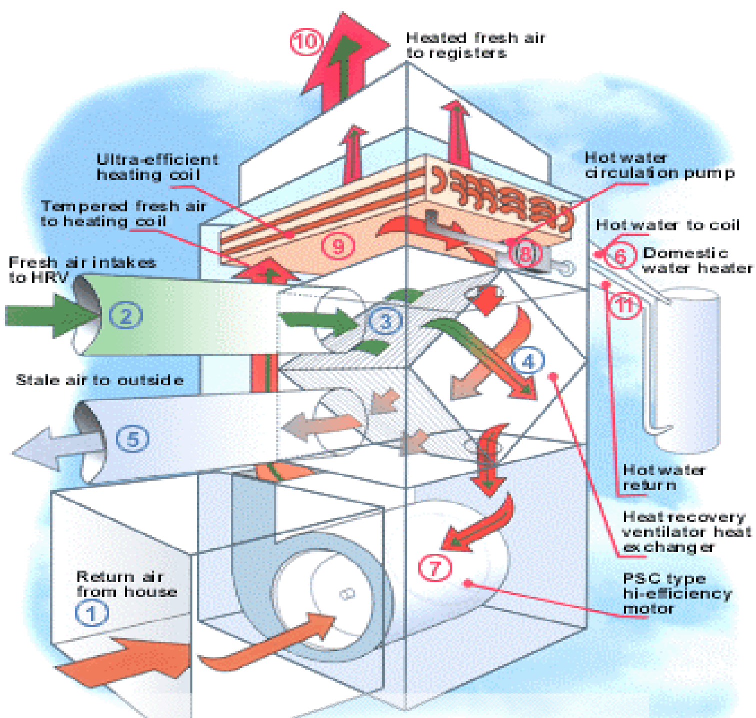

Figure 3. Diagram of hot air system.

Meanwhile,
6. Hot water is sent to the heater core from the hot water tank.
7. A high efficiency fan blows the tempered fresh air from the HRV into the coil.
8. The circulation pump distributes the water through the coil.
9. The circulating hot water heats the air to the desired temperature.
10. Warm, fresh air is distributed through insulated ducting to the bathrooms.
11. The hot water returns to the tank for shower use.

Sensors

A thermostat, an occupancy sensor, and an electric timer are recommended for controlling the heater. The proposed system would provide heat to the room only when necessary, as compared to the existing system, which maintains the set-point temperature in the restrooms regardless of occupancy. Many WCOS visitors will desire a warm restroom in the morning. If the thermostat is already triggered and if a clock triggers the heater at 5:00 A.m. then the bathroom will be warmed up each morning. By warming the bathroom in the morning mold and mildew will be combated throughout the unoccupied winter months and the first people to shower in the morning will have a warm room. The occupancy sensor ensures that unnecessary heating of the bathroom is eliminated and energy is saved. In order for a timer and an occupancy sensor to work in conjunction with each other, they must be wired in parallel. The occupancy sensor can also be used to trigger the ventilator to turn on for a designated period of time (20 minutes). Appendix 2 includes a schematic of the recommended wiring setup for the sensors and switches.

Electrical data acquisition

When first presented with electrical information from WCOS, it was indicated that the facilities had been consuming, on average, 200 kWh per day. The first task was to determine the electrical use by facility, then use by individual device, which includes when the equipment is on or off. The service meters were recorded twice a week. It was determined that the customer-owned meter records energy consumption of the restrooms. There is a separate meter for the lodge, and a third meter which records the total consumption of energy of the facilities. Table 3 refers to the recorded energy consumption from each meter.

Table 3. Daily energy usage by building.

	Average Usage kWh/Day		
Date	PG&E	Bathroom	Lodge
6/1/2001			
6/1/2001	137.87	45.96	91.91
6/5/2001	76.08	50.20	25.88
6/12/2001	119.02	63.89	55.13
6/15/2001	90.64	54.86	35.78
6/19/2001	72.43	46.88	25.55
6/22/2001	40.20	5.51	34.69
6/26/2001	39.10	5.04	30.27
6/29/2001	38.48	12.27	28.20
7/3/2001	35.88	6.02	29.61
7/6/2001	29.45	5.63	23.16
7/10/2001	58.02	14.38	42.63
7/13/2001	99.71	33.02	65.03
7/17/2001	56.13	17.14	38.25
7/19/2001	111.24	46.44	62.25
7/23/2001	35.39	8.91	25.74

In order to determine the electrical load of single devices, an electrical transducer to measure the amount of current in a wire was used. The transducer was used to determine the duty cycle on the water heater.

The existing water heater is a 4.5 kW Rheemglass Standard Energy Miser electric water heater. The water heater holds 119.9 gallons and has a first hour rating of 110 gal/hr. During heavy use by WCOS visitors, the water tank is completely drained of hot water in 15 minutes.

Upon the UNPEPP interns initial visit, an electric timer turned on the ventilation system one hour per day. At the one-hour per day setting, the air exchanges per day were inadequate to provide fresh air and mildew prevention to the restrooms. Due to the inadequacy in ventilation, mildew would easily form on the walls and ceiling of the restroom. Prior to the UNPEPP affiliation with WCOS the park staff would combat the mildew problem by using spacing heating to dry out the air inside the restroom. The space heating has since been turned down and the ventilation system has been adjusted to come on for three hours per day. If any mildew problems arise, it would be in the women's side of the restroom. The women's restroom is to the north, and receives less heat and light than the men's side of the restroom.

The ventilation system is composed of a single ventilation fan in each the men’s and women’s restrooms. The fan is located in the center of the restroom and is rated at 950 cubic feet per minute (cfm), with a rated electrical draw of 400 watts. There is an intake duct on the east side of the restroom ceilings. Whether filters are in place for the intake or the exhaust of the ventilation system was not determined. Once again, the transducer was used to determine the duty cycle and energy use of the ventilation system for a period of two weeks.

As the electrical analysis continued, it became evident that the six electric space heaters in the bathroom were consuming large amounts of energy. The space heaters are made by Cadet and are rated at 1.5 kW each. The six space heaters consume a total of 9 kWh per hour when operating constantly. Due to the high thermostat setting, the heaters were on for an average of 9 hours per day. This represented the largest electrical load in the bathroom. It should also be noted that the heaters are on factory recall for the potential of causing fire or hazardous conditions. Energy consumption before and after the thermostat for the space heaters was turned down are evident in Chart 3.

The interior lighting of the restrooms consists of a total of twelve 4-foot fluorescent lights. These lights are efficient and should not be replaced. However, significant energy waste occurs when visitors leave the lights on. On numerous occasions it has been noted the lights have been accidentally left on, even after the visitors have left. The current transducer was used to measure the lights and ventilator duty cycle.

The bathroom exterior is lit by single 50-watt high pressure sodium (HPS) bulbs above the men’s and women’s restroom entrances. The transducer was used to record the duty cycle and energy consumption of the outdoor lighting for a four-day period.

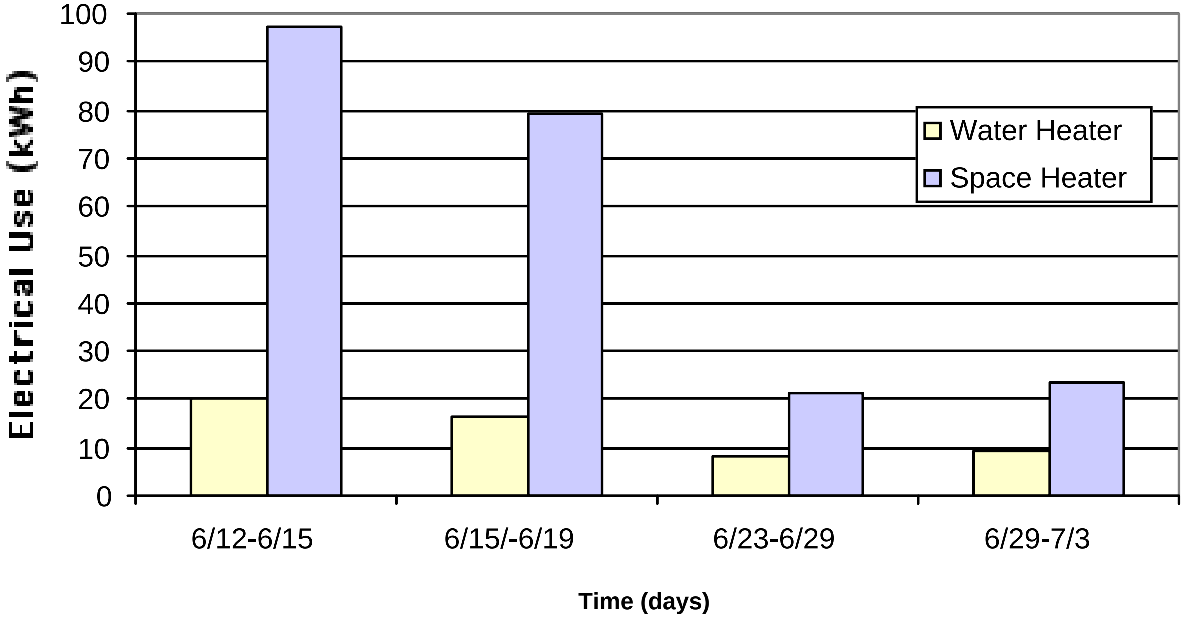

Chart 3. Space heater and water heater electrical usage (kWh) before and after June 19, when the thermostat was adjusted.

Since there is no existing lighting equipment in the cabins or at the amphitheater, projections were made of expected electrical use at each location. Lighting was chosen based on energy efficiency, cost, life cycle, and needs at each site. The amount of time each light will be on is based upon estimations of typical use of lighting at night, and WCOS Educational Coordinator Jay Moeller's description of activities at the amphitheater. The six cabin lights have been estimated to be on for a maximum of 5 hours per night, for 9 months out of the year. In the amphitheater, it was estimated the trail lighting and stage lighting would be on for two to three hours a night for 9 months out of the year. Refer to Table 4 for expanding electrical system details.

Table 4. Description of expanding electrical system

Expanded	Electrical system						
Amount	**Load description**	**Watts**	**Volts**	**Amps**	**Hrs/day**	**Hrs/wk**	**Total Whr/day**
2	Maytag Washer/ gas dryer	1400	240	5.83	1.5	4.5	4200
2	Occupancy sensors	5	24	0.21	24	72	240
2	Temperature Diff. Sensors	4	25	0.16	25	75	200
1	Taco 008 pump	38	120	0.32	7	21	266
2	Circulation pumps	40	120	0.30	7	21	560
20	LED Seating lighting	2.2	120	0.03	2	14	88
2	Fluorescent stage lighting	52	120	0.43	2	14	208
1	Projector/overhead & slide	400	120	3.33	2	8	800
6	Fluorescent lights	20	120	0.17	5	35	600
100	LED Post Path Lighting	2.2	120	0.03	3	35	660
						kWh/day	**7.8**

Electrical System Recommendations

Cabin Lighting

To provide nighttime lighting in each of the visitor's cabins, a single 15-20 watt tube-type fluorescent is recommended. Fluorescent lights are commonly found in local hardware stores. Furthermore, running a standard 110-volt AC power line to the cabins is recommended to supply energy for the lighting, and a single ground fault interrupter (GFI) protected outlet in each cabin.

Trail Lighting

The trails that need lighting are the path connecting the lodge to the outdoor amphitheater and the walkway in front of the cabins. The combined length of both pathways is 1000 feet. Efficient, durable, and long lasting light can be achieved when LED lighting products are used as pathway indicator lights. LEDs use small amounts of energy, typically 4 watts or less, and last for over 100,000 hours. A Petaluma company, Holly Solar, offers a wide range of LED lighting products and has worked with the state and national parks in the past. They offer a 3-LED saucer light that consumes 2.2 watts and provides a sleek and durable light that is easily fitted to the look of WCOS. The recommended distance between lights is 10 feet, mounted on 4 x 4-redwood posts or railing. Over 100 saucer lights are needed to provide pathway lighting at WCOS. These lights should be operated by a photo-switch in line with a manual switch to ensure that lights don't get left on and so that the lights won't be on during winter months and off-times. The UNPEPP interns have purchased sample LED lights, field tested them and have received positive feedback from NPS staff. Figure 4 demonstrates the look of these lights on the grounds of WCOS.

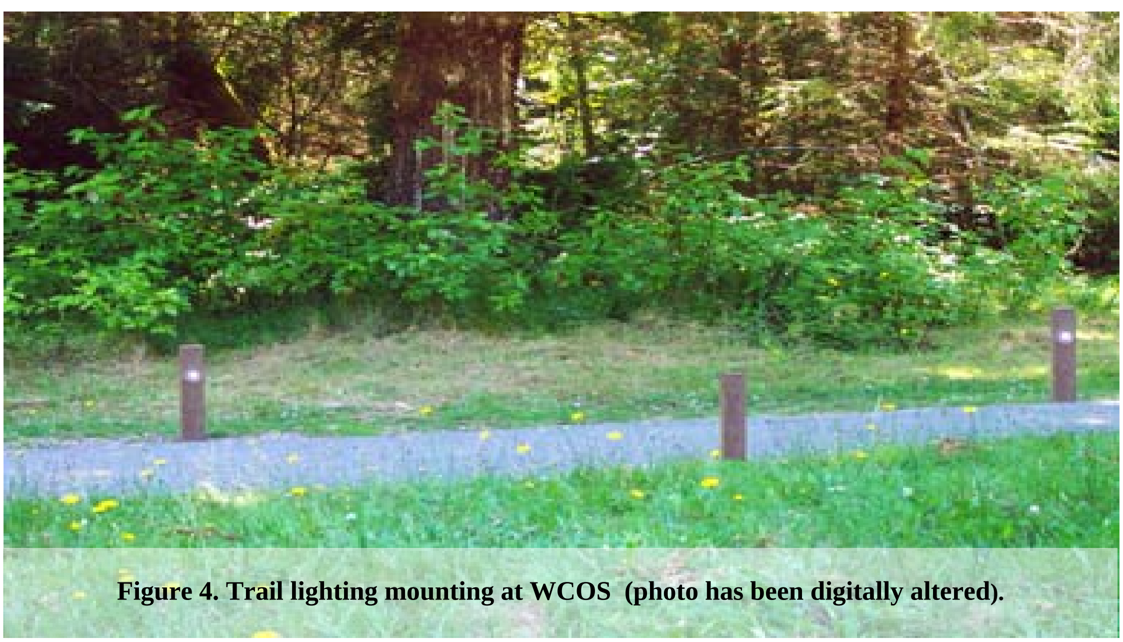

Figure 4. Trail lighting mounting at WCOS (photo has been digitally altered).

Amphitheater

The outdoor presentation theatre requires stage and seat lighting, and an outlet for a film and/or slide projector. To maintain a uniform look, while maintaining energy conservation, the same LED lighting that is recommended to be employed for pathway lighting is recommended for seating lighting. Also, post-mounted 20-watt compact fluorescent lighting housed in flood light fixtures is recommended for stage lighting. To establish an outlet for a projector an AC line must be run from the service panel of the lodge. The same AC line will provide power to the pathway and seat lighting.

Washer/Dryer

WCOS has plans to install laundry facilities to maintain hygienic conditions throughout the facilities of the school. To conserve energy, water, and space, two Maytag Neptune MLG2000 washer/ gas dryers are recommended. They could be located within the utility room of the restrooms at the premises. This is a stackable washer/ gas dryer, which has been selected due to its high ranking on the energy star listing, compact dimensions, and its capability of handling large loads. Figure 5 is a picture of the Maytag Neptune.

Figure 5. Maytag MLG2000

Restroom lighting

Replacing the 50-watt high pressure sodium (HPS) outdoor lights with 9-watt compact fluorescent lights will reduce overall energy consumption. Compact fluorescent lights are rated up to 10,000 hours, which is less than HPS. Yet, the energy saved with the smaller wattage of lights will pay for the lights in 20 months.

The existing interior lights of the restrooms are already efficient fluorescent tubes. It is recommend to install occupancy sensors in series with a photo-switch in place of the existing on/off switches. The occupancy sensor should keep the lights on for 20 minutes to allow for all bathroom activities, refer to Appendix 2. These measures will prevent the interior lights of the restrooms from being turned on during the day or for extended periods at night.

Ventilation System

According to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 62, the minimum recommended flow of outside air into a bathroom is 0.5-cfm/ ft^2. The WCOS bathrooms are 333 ft^2 each and therefore require 167-cfm of outside air by Standard 62. Installation of a 200-cfm Life Breath heat-exchanging ventilator into each restroom is recommended. This ventilator is much smaller than the current ventilator and much more efficient. The recommended ventilator will be equipped with an 80% efficient heat exchanger utilizing exhaust air heat to warm intake air.

In order for the ventilation system to fulfill its purpose it must be turned on every time that the bathroom is occupied. A timed occupancy switch, which will turn the ventilation system on for a minimum of ten minutes, is recommended for each restroom. As long as there is movement within the rest room, the ventilation system will remain on. Figure 6 is a cut out view of the Lifebreath ventilator.

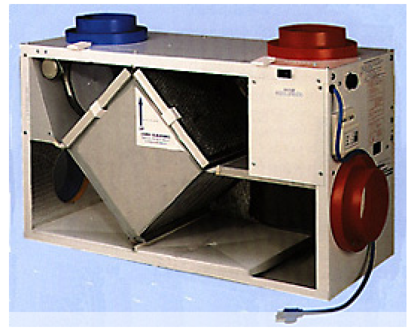

Figure 6. Cut away view of Lifebreath heat recovery ventilator.

Solar Analysis

Solar data was collected to estimate the amount of solar energy (insolation) available at WCOS to provide heat to water using flat plate collectors and electricity from photovoltaic panels. A pyranometer was used to measure the amount of insolation available at WCOS. A Solar Path Finder was used to find the amount of shading at various locations on the ground. The pyranometer was installed on the north east of the parade ground. The pyranometer was mounted 8 feet into the air to minimize potential damage and shading by visitors at the school. The Solar Path Finder was used in numerous locations at the school. The site map Appendix 3 shows the location of the proposed solar site. Chart 4 shows the amount of solar energy available at each site recorded by the Path Finder.

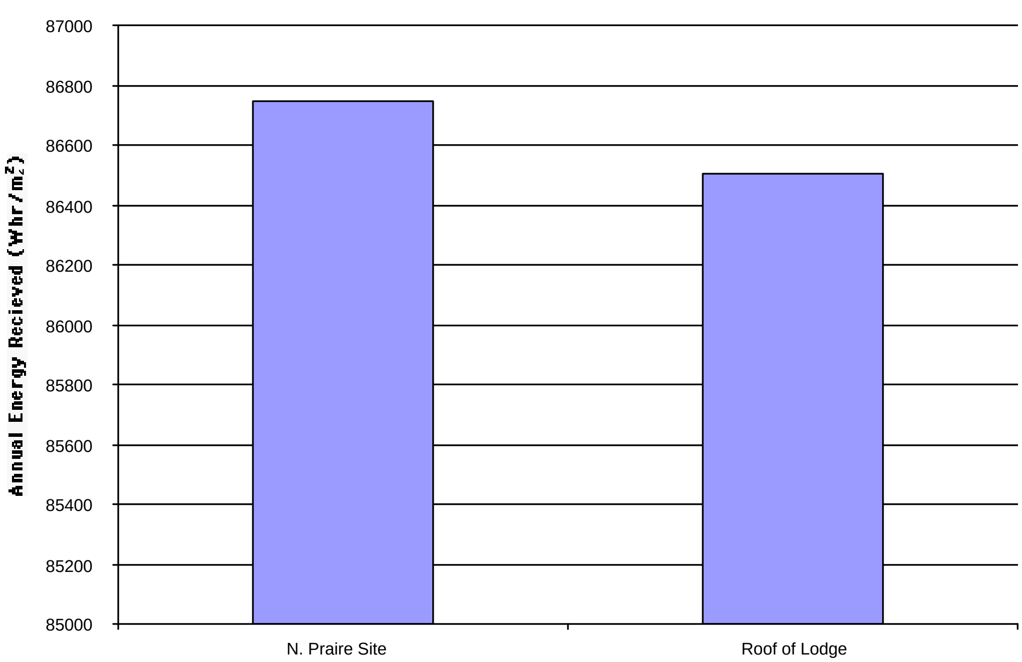

Chart 4. Annual solar energy for two sites at WCOS.

Once enough solar insolation data was collected at WCOS, it was compared and correlated to solar insolation data at the Trinidad Marine Laboratory. A comparison of the WCOS hourly insolation data with Trinidad hourly insolation data was beneficial in determining whether Trinidad data could be used for site analysis. This data was compared because of close proximity to the project site and because of the large quantity of historic insolation data collected at the Marine Lab. Average hourly solar radiation collected at the two sites was compared from June 16 through June 25, 2001. Chart 5 shows the close correlation between the two sites. The close correlation is an indication that cloudy and sunny conditions will be experienced in both locations on the same day. This correlation allows the use of historic Trinidad insolation data for determining the amount of monthly incident radiation at the WCOS site.

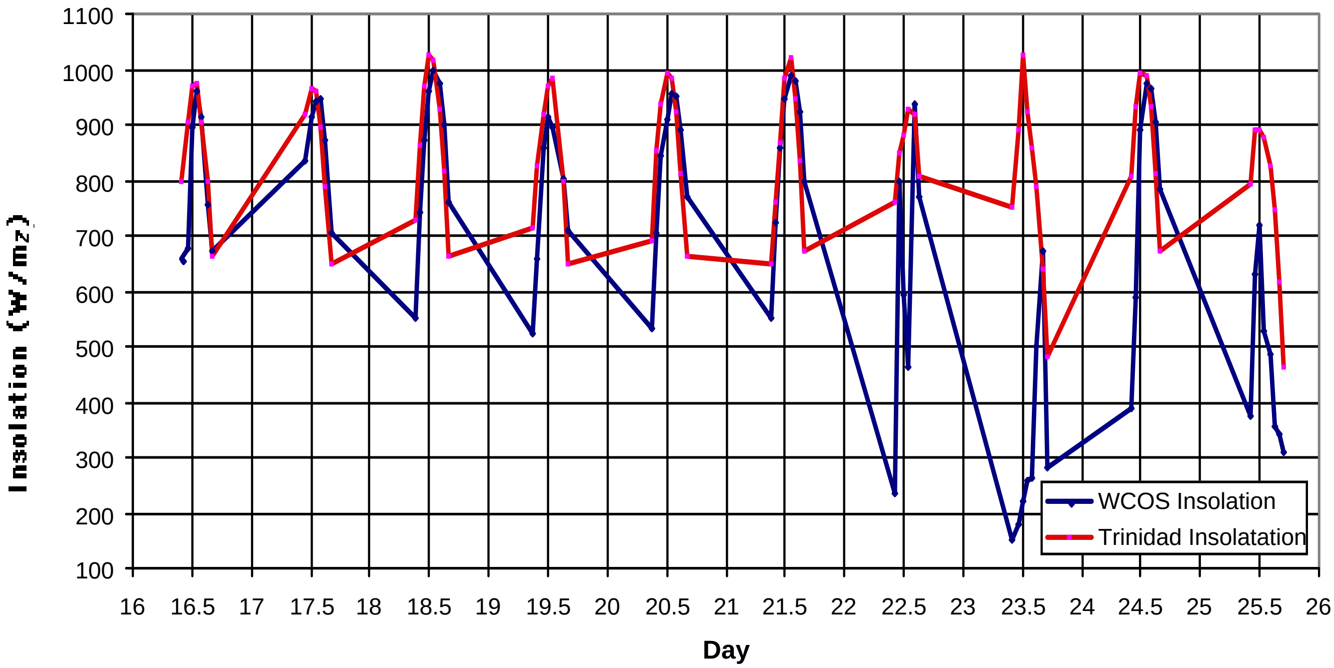

Chart 5. Comparison of hourly insolation at WCOS and Trinidad CA, in June, 2001

By multiplying the total monthly radiation by the monthly fraction of insolation determined by the solar window, actual incident solar radiation can be determined. An estimate of annual solar data was modeled for WCOS utilizing the Trinidad Marine Lab insolation data and correcting that data for WCOS with the aid of the site analysis of the Solar Path Finder.

Photovoltaic Utility Intertie System

To offset some of the energy used by WCOS, a grid-connected photovoltaic (PV) system is recommended. A grid-connected PV system is composed of a solar array, mounting structure, a utility-interactive inverter, and a lockable disconnect, Figure 7.

A PV array at WCOS can produce electricity on site, while educating visitors about renewable energy technologies. The goal of producing on-site electricity is to offset all expansions of the electrical system and the restroom electrical consumption. In order for a grid-connected system to be installed, an interconnection agreement must be signed between the park service and the electrical provider, in this case PG&E. Furthermore, Time-Of-Use (TOU) metering could decrease the amount of time for the system to pay for itself. Also, the California Energy Commission is now offering rebates for grid-connected renewable energy systems. The rebate could be up to 50% of the cost of the system, or up to $4.50 per rated watt of the system, whichever is less.

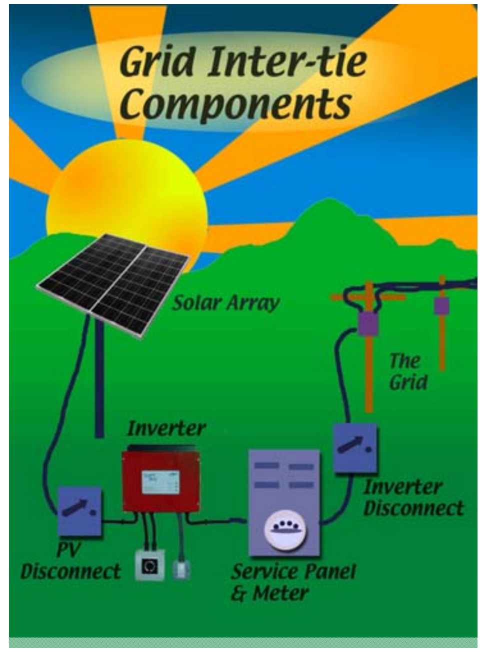

Figure 7. Grid connection component diagram.

PV technologies differ by type of silicon cell used, mounting technique and physical size of system from one site to another. Included in all different configurations of solar systems is a mandatory lockable ground fault interrupter (GFI) disconnect to which the electrical provider has access.

At the recommended site, there are numerous trees that pose a potential hindrance to the solar window. The majority of trees at WCOS are young second-growth redwoods, Douglas fir, and Sitka spruce that will continue to grow taller in coming years. In order to maintain, or improve the solar window, a vegetation maintenance plan must be implemented.

Figure 8. SunnyBoy inverter

The inverter chosen to change the DC electricity into AC electricity is a SunnyBoy series inverter. A picture of a SunnyBoy inverter is shown in Figure 8. The SunnyBoy is capable of inverting 2500 watts. The size of this inverter is larger than is needed, which will allow for expansion of the PV array in the future. An expansion of the PV array might be needed due to increased shading by fast growing trees within the solar window of the site. The maximum efficiency of the inverter is 94 percent, one of the highest on the market. Furthermore, the SunnyBoy inverters are rated for outdoor installation by the manufacturer, SunnyBoy inverters are series string inverters, meaning that they operate at high voltage DC. Only qualified electricians are recommended to install the SunnyBoy inverters.

North Parade Ground

At the northeast edge of the parade ground, a shade structure is recommended to provide shelter for the outdoor picnic tables, a place for interpretive displays, and a mounting structure for the PV panels.

Figure 9. Picture Pathfinder and the solar window at the N.Parade Ground.

The type of PV technology recommended at this site is amorphous silicon that can be adhered to Galvalume metal roofing. Amorphous silicon has the advantage of working better than other types of silicon in partial shaded conditions and at higher surface temperatures. Also, they can take direct hits from golf balls without damage. A disadvantage of amorphous silicon is the large area needed to generate an equivalent amount of energy compared to other types of PV panel technology, due to the low efficiency of amorphous silicon. Figure 9 shows the shading which will occur on the panels through the year. An example photo of field applied amorphous panels is found and a simple drawing of a shade structure can be found in Appendix 4.

Trees to the east will hinder morning sunlight, while trees to the south will hinder winter energy production. All trees in this area are healthy.

Lodge Recommendations

The lodge at WCOS represents the majority of the on site energy consumption since the space heaters in the restroom have been turned down to a lower thermostat setting. The lodge has not been a major focus of the UNPEPP program. However, UNPEPP interns made observations that could reduce the amount of energy consumed by the lodge. Potentially, the largest electricity-consuming device is the walk-in freezer. It has been noted that the freezer is empty for the majority of the year. In order to decrease the duty cycle of the freezer it is recommended to stock it with thermal mass. This thermal mass can range from large bottles of water to large quantities of stored food. This would reduce temperature swings and cut freezer run-time considerably. Also, when the freezer is not used at in the winter months, it should be turned off completely.

The lighting in the lodge is an inefficient technology. Energy conservation can be achieved by simply switching incandescent light bulbs to compact fluorescent bulbs through the entire lodge.

Installing heavy/thermal curtains on the windows will drastically reduce the heat loss of the building. Even if the curtains are not drawn during the summer days, closing them down during the winter months will save energy.

Budget

Table 5 gives the general cost of the materials necessary for the major components of the recommended system. Detailed costs of the proposed system are found in Appendix 5. A list of manufacturer and distributor contact information can be found in Appendix 6.

Table 5. Material cost of proposed system.

Recommended System	
Combined Propane and Solar Hot Water System	$ 7,840
Heat recovery Ventilator	$ 2,600
Hot Air Space Heater	$ 3,186
Lighting	$ 2,819
Amorphous PV	$ 13,355
Washer/Dryer	$ 3,818
Total	**$ 33,618**

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Abbreviations

AC	Alternating Current
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BTU	British Thermal Units
BTUH	British Thermal Units per Hour
CFM	Cubic Feet per Minute
DC	Direct Current
DHW	Domestic Hot Water
GFI	Ground Fault Interrupter
GPM	Gallons Per Minute
HPS	High pressure sodium
HRV	Heat Recovery Ventilator
HSU	Humboldt State University
KW	kilowatt
KWH	Kilowatt Hour
LED	Light Emitting Diode
NPS	National Park Service
PG&E	Pacific Gas & Electric
PV	Photovoltaic
RNP	Redwood National Park
SDHW	Solar domestic hot water
UNPEPP	University National Park Energy Partnership Program
WCOS	Wolf Creek Outdoor School

Appendix 6. Dealer and Manufacturer contact information

Solar Domestic Hot Water System

Complete package

Six Rivers Solar. INC.
818 Broadway
Eureka, CA 95501

707-442-0110
norm_ehrrlich@hotmail.com
www.sixriverssolar.com

Low flow shower head

Dealer: ECO Distributors
9116 Cleo Smith rd., Pass Christian, MS. 39571
twg@ecodistributors.com
(866) 255-7796 or Fax (228) 255-8664

Solar Electric Components

Field applied Uni-Solar amorphous panels

Dealer: Jade Mountain
717 Popular Ave.
Boulder, CO,80304

1-800-442-1972
info@jademountain.com

SunnyBoy 2500 Grid Intertie Inverter
UniRac U-GR PV mounts
Disconnects

Dealer: Schott Applied Power
P.O. 339
Redway, CA 95560

1-888-840-7191
www.solarelectric.com

Lighting

LED pathway & seating lights

Dealer: Holly Solar
1340 Industrial Avenue,
Suite D
Petaluma, CA 94952

1-800-622-6716
www.hollysolar.com

Compact fluorescent flood lights
Vandal proof outdoor compact fluorescent

Dealer: Solar Depot
61 Paul Drive
San Rafael, CA,94903

1-800-822-4041
www.solardepot.com

Appendix 6. continued…

Ventilation

Life Breath heat recovery ventilators

Sales representative: Chuck Patterson
7305 Sunwood way
Citrus Heights, CA,
916-721-3123

Space Heating

Life Breath hydronic forced air furnace.

Sales representative: Chuck Patterson
7305 Sunwood way
Citrus Heights, CA,
916-721-3123
www.lifebreath.com

Laundry Facilities

Maytag Neptune MLG 2000A

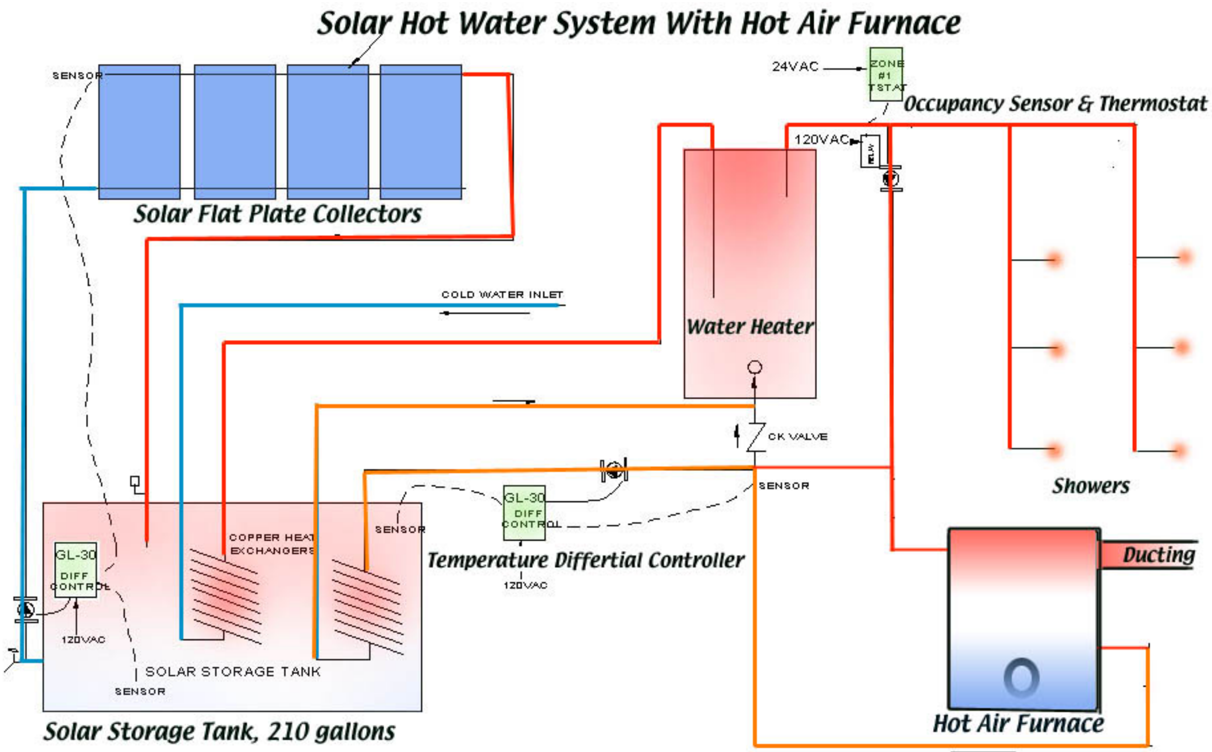
Dealer: Amerigas Propane, L.p.
Div A P Propane Inc
625 K St
Arcata, CA 95521
Phone: (707) 822-2188

Sensors

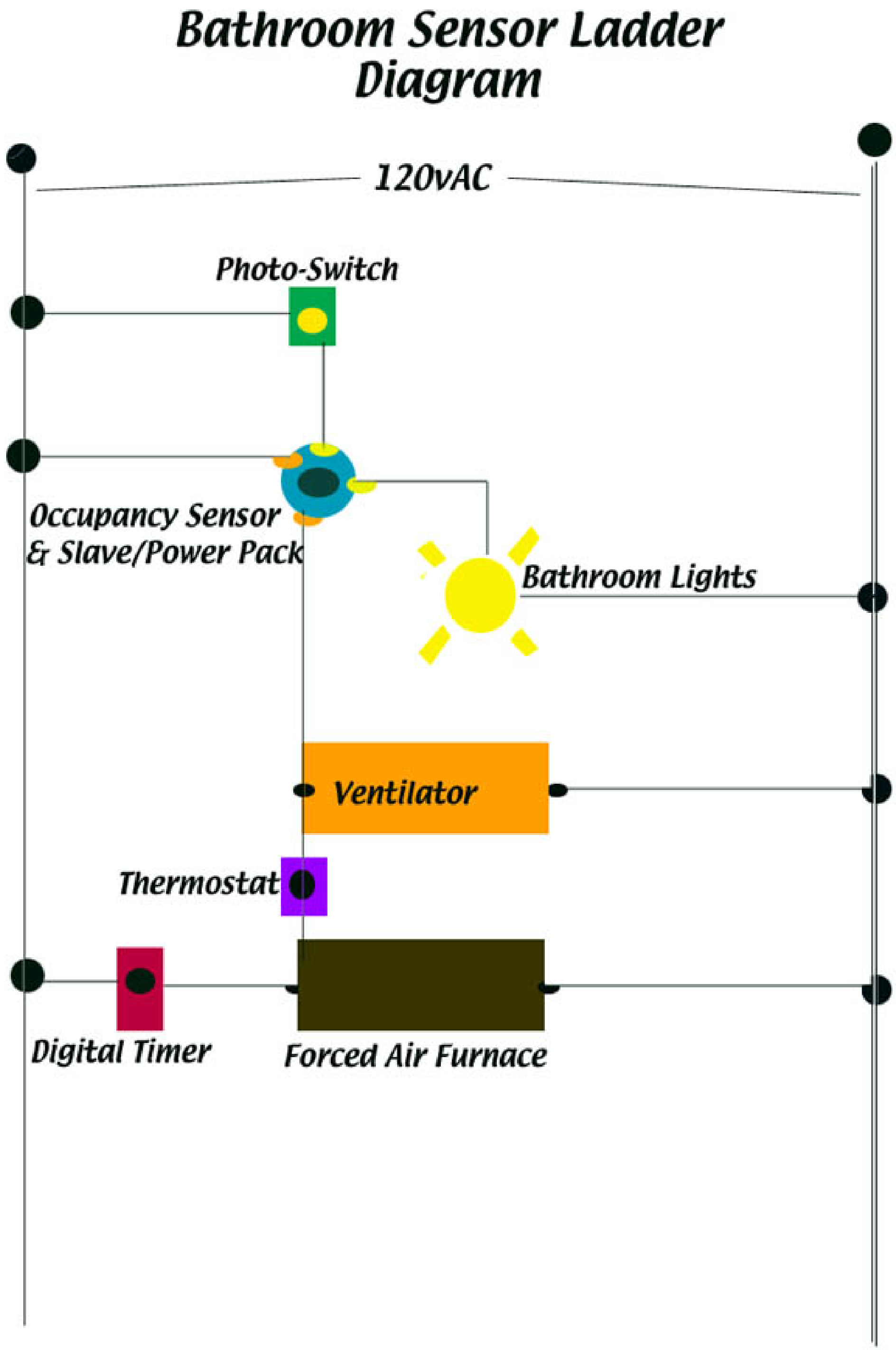
Occupancy Sensors

Manufacturer: Watt Stopper & Intermatic
Dealer: Platt Electric
939 Koster
Eureka, Ca 95501
707-444-8031

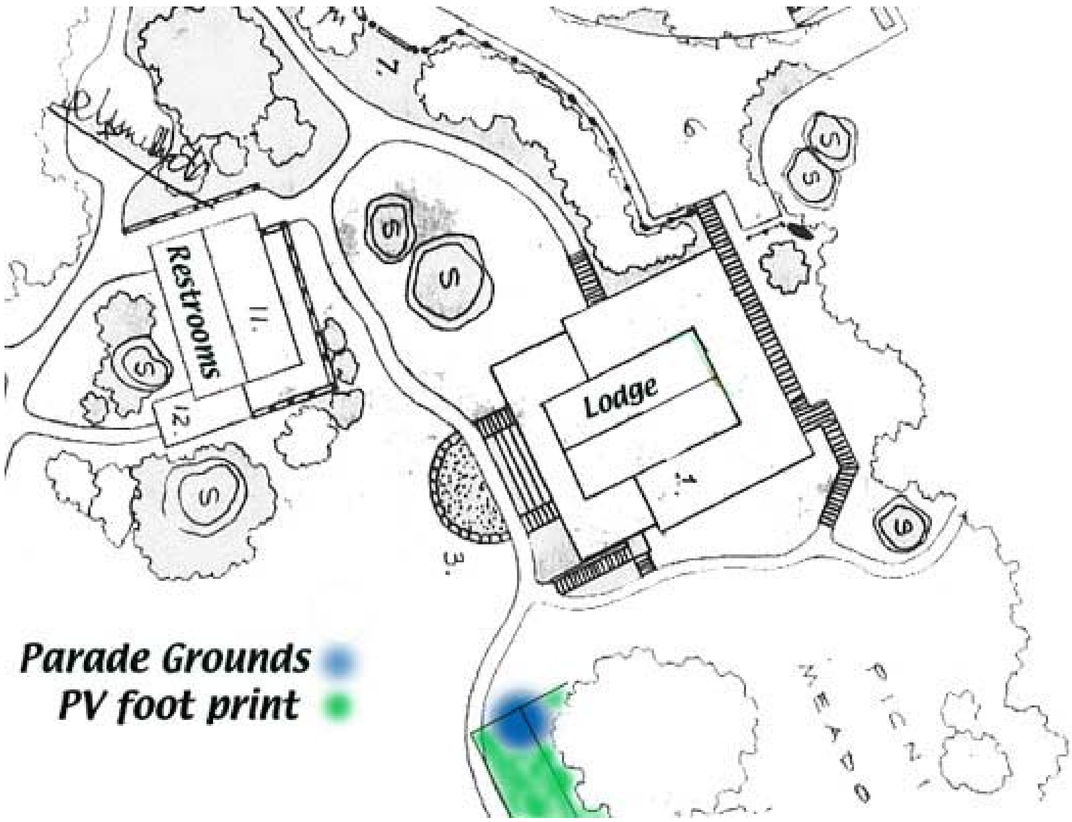
Appendix 1. Solar Hot Water & Forced Air Furnace Schematic.



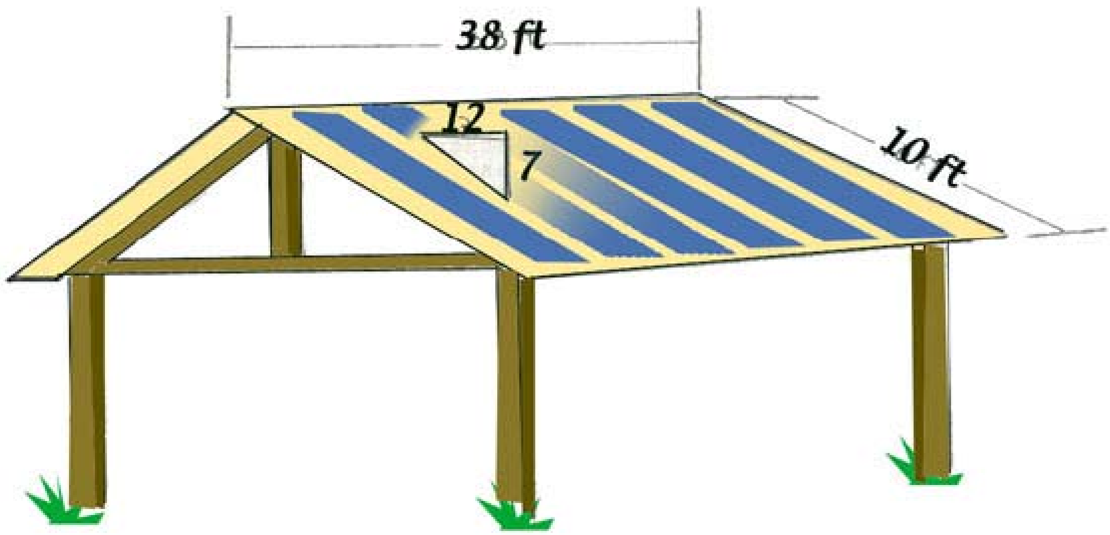
Appendix 2. Ladder diagram of sensors & switches for each restroom.



Appendix 3. Site map for location of solar array.



Appendix 4. Sample drawing of shade structure and integrated amorphous PV mounting.



Appendix 5. Detailed description, cost, and model numbers of materials for recommended system.

	PV System Cost Estimation						
Product	**Description**	**Dimensions**	**Quantity**	**Price Each.**	**Total Cost**	**Manufacturer**	**Notes**
SunnyBoy	2500 watt		1	$ 2,500.00	$ 2,500.00		5 yr warranty
Panel Mounts/Roofing		2' x10'	56	$ 13.59	$ 761.04	Galvalume	Metal Roofing
GFI Disconnect	Lockable		1	$ 150.00	$ 150.00		Required
Photovoltaic Panels							
Field Applied Amorph.	PVL-64	1.15 m^2	28	$ 298.00	$ 8,344.00	Uni-Solar	1.7 kw Peak
Wire,conduit, Misc.					$ 1,000.00		
Wooden shade structure		720 sq.feet			$ 600.00		
				Total	**$ 13,355.04**		

Product	**Description**	**Quantity**	**Price Each.**	**Total Cost**	**Manufacturer**	**Notes**
Solar Package	Four,4*10 collectors, storage	1	$ 6,600.00	$ 6,600.00	Six Rivers Solar	Complete package.
	tank, heat exchangers, pumps,					SDHW 210
	and all hardware.					
Water Tank	Propane 100 gallon, 83,000 BTU	1	$ 1,000.00	$ 1,000.00	American Standard	100-83-AS
Shower head	1.5 gpm	6	$ 27.00	$ 162.00	Omni	#A-749
Shower valve	On/off valve for shower user	6	$ 13.00	$ 78.00	Omni	#A-711
			Option 1 Total	$ 7,840.00		

	Laundry Facilities	Dimensions	Quantity	Price Each	Total Cost	Manufacturer	Notes
Washer/Dryer	Stackable washer/gas dryer	27"x72"x27"	2	$ 1,909.00	$ 3,818.00	MayTag Neptune	MLG2000A
				Total	$ 3,818.00		

	Lighting					
Product	**Description**	**Quantity**	**Price Each.**	**Total Cost**	**Manufacturer**	**Notes**
	Trail Lighing					
AC LED suacer's	2.2 watts each, 120vac	100	$ 18.00	$ 1,800.00	Holly Solar	AC 3 LED Saucer
hardware	conduit/hardware	1	$ 660.00	$ 660.00		
	Cabin Lighting					
flourescent tube	15 watts tube lights	6	$ 15.00	$ 90.00		
Outlets	GFI	6	$ 4.00	$ 24.00		
Hardware	wire,etc..	1	$ 100.00	$ 100.00		
	Restroom Lighting					
Outdoor CF	9 watt compact fluorescent	2	$ 44.65	$ 89.30	Solar Depot	LT/WF-1209
	Amphitheatre					
C.F. Floodlights	Stage lighting, 26 watts	2	$ 60.50	$ 121.00	Solar Depot	LT/WF-513-2
LED's	seating lights	20	$ 18.00	$ 360.00	Holly Solar	AC 3 LED Saucer
Hardware	wire, conduit, etc	1	$ 100.00	$ 100.00		
Outlets	Projector and media equipment	1	$ 5.00	$ 5.00		
			Total	$ 3,349.30		

Appendix 5. Continued…

	Heating						
Product	**Description**	**Dimensions**	**Quantity**	**Price Each.**	**Total Cost**	**Manufacturer**	**Notes**
Hydronic/air	Clean Air Furnace	30"x19"x48"	1	$ 1,400.00	$ 1,400.00	Lifebreath	40 DHW
Sensors							
Sensor accessory	Occupancy sensors		2	$ 120.00	$ 240.00	Watt Stopper	WT-1100
Timers	Power and Slave pack		2	$ 42.00	$ 84.00	Watt Stopper	B120 E-P
Propane Storage	Electric timed switches		2	$ 56.00	$ 112.00	Intermatic	ET 100C
Propane Hardware	500 gallon tank		1	$ 1,200.00	$ 1,200.00		
	tubing, fittings, etc..			$ 150.00	$ 150.00		
			Lifebreath	Option 2 total	$ 3,186.00		

	Ventilation						
Product	**Description**	**Dimensions**	**Quantity**	**Price Each.**	**Total Cost**	**Manufacturer**	**Notes**
HR Ventilator	Recovers 80% of heat	19"x33"x15"	2	$ 1,300.00	$ 2,600.00	Nutech Life Breath	Max200
				Total	$ 2,600.00		