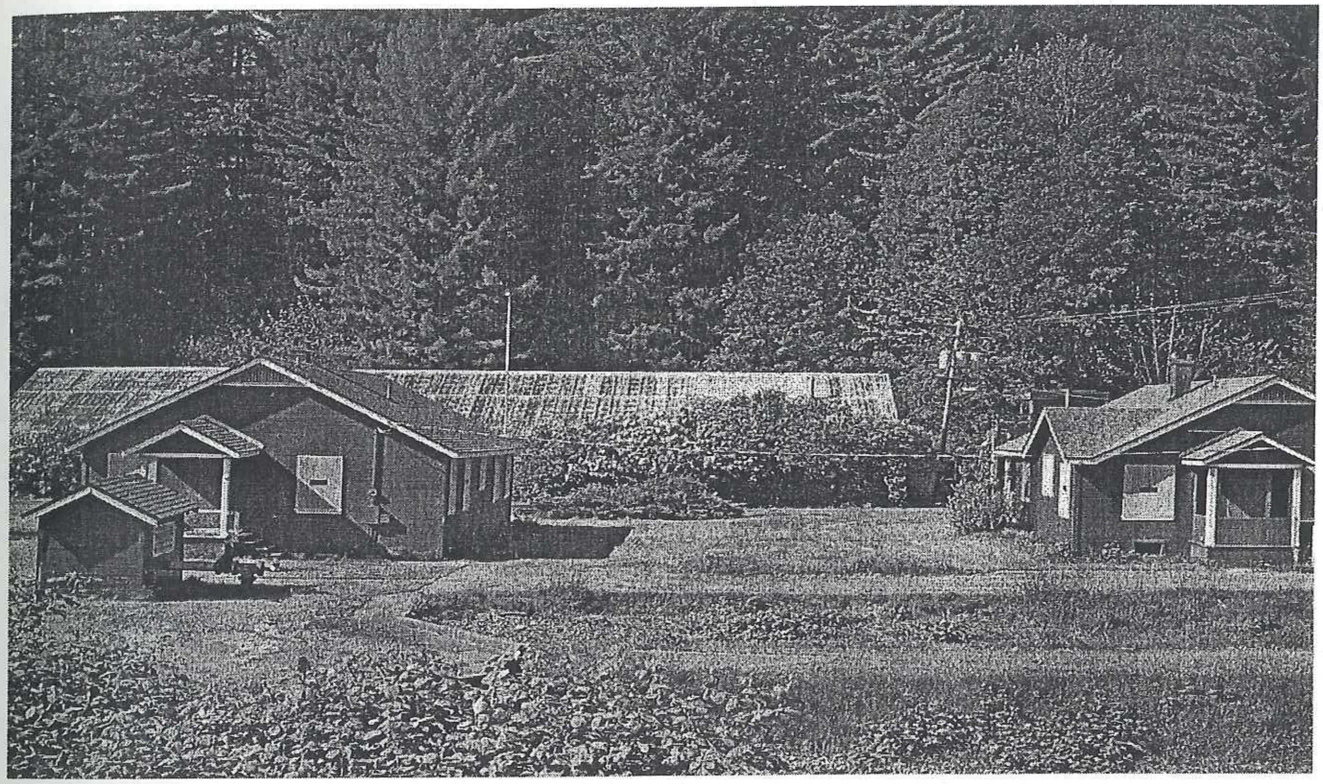
# Implementing Renewable Energy
## To Prairie Creek Historical Fish Hatchery



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# 1 Problem Statement

The Prairie Creek Fish Hatchery (PCFH), future site of the Redwood Creek National Watershed Center (RCNWC), does not currently have plans for creating a sustainable method of generating energy from a renewable source and implementing energy efficiency technologies

# 2 Background

## *2.1 Brief History of the Prairie Creek Fish Hatchery (PCFH).*

The Prairie Creek Fish Hatchery (PCFH) site is located 3 miles north of Orick and has been in operation from 1928-1993. In 1927 the Department of Fish and Wildlife (DFW) surveyed the northwest coast in order to obtain Cutthroat Trout eggs (RCNWC 2001). With these eggs, the (DFW) decided to create a temporary fish hatchery with traps placed on Prairie Creek; creating what is now known as the Prairie Creek Fish Hatchery (PCFH). The PCFH temporary facilities, built in 1928, contained racks, traps, a tent hatchery with eight troughs, a large flume that diverted water from Lost Man Creek, and two cabins for employees (Bradley 1997). In 1936 the site was given permanence and the California Department of Fish and Game built the hatchery, two houses, a garage and, a shed. The focus at this point became rearing a variety of salmonid speciesn (RCNWC 2001). Much of the facilities that existed in 1936 still exist today and the facilities are now recognized and protected as a national historic site (Bradley 1997).
After the closing of the Prairie Creek Fish Hatchery, people began to develop ideas on how the old hatchery site could be utilized. Through a collaborative effort of local organizations, it was determined that the best use for the hatchery site would be to serve as an educational center focused on watershed based management. Paula Fitzgerald Yoon is the Project Coordinator of the Redwood Creek National Watershed Center Advisory Committee, which is composed of 60 member organizations that include Orick Economic Development Corporation, Orick Chamber of Commerce, RNSP, Yurok Tribe, HSU and others (see appendix 3 -Advisory Committee Members)(Yoon, 2002).

## 2.2 Brief History of the Redwood National Park (RNP).

In 1968 the Redwood National Park was created adjacent to the PCFH site. Later, the Redwood National Park became integrated with the Redwoods State Park and is now recognized as the Redwoods National and State Parks. The parks transformed 160,000 acres of private timberlands into public land, encompassing old-growth forests, and previously harvested timberlands.

## 2.3 The "Birth" of the Redwood Creek National Watershed Center (RCNWC).

The mission of the Redwood Creek National Watershed Center (RCNWC) is to "...create opportunities for people to experience the beauty of the redwoods ecosystem and learn about it while taking part in watershed scientific and practical field programs, thus connecting people with the natural world and responsible actions to sustain it."(Appendix 3: Mission, 2002) Educational and interpretive programs will be provided by the RNCWC with facilities that include a classroom, an interpretive center with a focus on Ecotourism, and wet and dry labs where participants will get hands on experience. There will also be training seminars and workshops on watershed assessment, restoration, and research techniques giving participants field experience.

## 2.4 The Public, the RNP, and the Hatchery

In 1968, when the Redwood National Park was created by federal legislation, public reaction was strong. The national park dramatically reduced the number of timber related jobs in the community of Orick. This resulted in a precipitous fall in the local economy followed by a sharp decline in the local population.

Local community issues between pro-timber and pro-national park became polarized. However, the opportunities and services presented by the RCNWC will help to reconcile these differences in opinion by promoting the integration of good land management and sustainability.

# 3 Objectives

- Develop an energy generating system that can, at optimum conditions, produce enough power to meet the demands of the site and possibly give back to the utility grid.
- Find a location for the system that is in accord with the guidelines of the National Register of Historic Places.
- Energy generating system must utilize sustainable technologies, incorporating a mixture of solar, wind, hydrogen and micro-hydro electricity generation.
- Technologies must be appropriate and not emit toxins, greenhouse gases or extract non-renewable resources from the environment.
- Promote the RCNWC's message of interconnectedness between people and the environment through the implementation of aforementioned alternative technologies.
- Use the best available technologies
- Develop a reliable energy infrastructure that will maintain structural and functional integrity with the varying weather conditions of the RCNWC site.
- Choose technologies that can be implemented and maintained through local means.
- Implement energy efficiency measures that reduce overall energy demand.

# 4 Weighing Alternatives

## *4.1 Literature Review*

### 4.1.1 Micro-hydro Power

Small-scale hydropower systems are those that generate between .01 to 30 MW of electricity. Hydropower systems that generate up to 100 kilowatts (kW) of electricity are often called *micro-hydro systems*. Most of the systems used by home and small business owners would qualify as micro-hydro systems. In fact, a 10 kW system generally can provide enough power for a large home, a small resort, or a hobby farm. Turbines are more commonly used today to power small hydropower systems. The moving water strikes the turbine blades, much like a waterwheel, to spin a shaft. (DOE 2 2002).

*Pros*

- There is a stream on the site.
- Retired dam provides a choke point with increased water velocity. Randy Klein, RNP hydrologist, indicated that this dam might be removed in its entirety to allow for salmonid passage.
- Maximum power is provided during the winter when the sun is at its lowest point.
- Can provide power 24 hours a day.
- The systems are relatively affordable (Real 2002).

*Cons*

- Turbines can impede anadromous salmonid passage.
- Most systems require a water diversion or dam.
- Dams damage riparian zones and fish passageways.
- Diversion removes water that would otherwise provide flow for salmonid passage.
- Turbines are susceptible to debris buildup.
- Systems are noisy.
- Micro systems do not produce a significant amount of power.
- More effort is required for installation (Real 2002).

#### 4.1.1.1 Harris Systems' Small Pelton Wheel

The Pelton wheel uses the concept of jet force to create energy. Water is funneled into a pressurized pipeline with a narrow nozzle at one end. The water sprays out of the nozzle in a jet, striking the double-cupped buckets attached to the wheel. The impact of the jet spray on the curved buckets creates a force that rotates the wheel at high efficiency rates of 70 to 90 percent. Pelton wheel turbines are available in various sizes and operate best under low-flow and high-head conditions (DOE 2, 2002).

*Pros*

- Contains fewer gears
- Require less material for construction

- Suited for mountainous areas,
- It's a closed system,
- Simple,
- Easy Maintenance,
- Generates-30 Kwh per day.
- Has the least complex design

*Cons*

- Needs a significant drop,
- Requires high pressure,
- Produces DC Power, so it needs to be stored or converted to AC
- It is difficult to transmit power from turbine to batteries (Real, 2002).

#### 4.1.1.2 Jack Rabbit

The Jack Rabbit is the drop-in-the-creek turbine that can generate power from a stream with as little as 13 inches of water and no head. Output from the Jack Rabbit is a maximum of 100 W, so daily output averages 1.5 to 2.4 kilowatt-hours, depending on the site.

*Pros*

- It is good for less drop and more volume as seen in flatter sites.
- This system is far less costly.
- It is a relatively a small system. (12.5" diameter)
- AC Power.

*Cons*

- This system is harmful to fish if they are not swayed from it.
- Only provides 1.5-2.4 Kwh.
- Maximum Output is 100 watts.
- It is difficult to transmit over long distances or large quantities of power (Real 2002).

#### 4.1.1.3 Run of the River

Run-of-the-river hydro projects use a portion of a river's water and divert it to a channel, pipeline, or pressurized pipeline or penstock that delivers it to a waterwheel or turbine. The moving water rotates the wheel or turbine, which spins a shaft. The motion of the shaft can be used for mechanical processes, such as pumping water, or it can be used to power an alternator or generator to generate electricity (DOE 2, 2002).

***Pros***

- Do not require large storage reservoirs
- Run-of-the-river systems are commonly used for small-scale, hydro-power projects

***Cons***

- Requires more material and construction
- Diverting water may have environmental impacts

**Basic components:**

- Water conveyance—channel, pipeline, or pressurized pipeline (penstock) that delivers the water
- Turbine or waterwheel—transforms the energy of flowing water into rotational energy
- Alternator or generator—transforms the rotational energy into electricity
- Regulator—controls the generator
- Wiring—delivers the electricity.

#### 4.1.1.4 Lost Man Creek

Lost Man Creek is a low head river, which means the change in elevation is less than 10 feet. A vertical drop of less than 2 feet will probably make a small-scale hydro-electric system unfeasible. For extremely small power generation amounts, a flowing stream with as little as 13 inches of water can support a submersible turbine (e.g. Jack Rabbit).

Flow data for Lost Man Creek was acquired from RNP's head hydrologist Randy Klein (Appendix 7.1). Lost Man Creek has not been gauged and data had to be extrapolated using data from the smaller, once gauged basin, of Little Lost Man Creek.

**Estimating power output for Lost Man Creek:**

The net head is the vertical distance available after subtracting losses from pipe friction and flow is the quantity of water falling, measured in gallons per minute.

$$\frac{[\text{Net Head (ft) x Flow (gpm)}]}{10} = \textit{Watts}$$

$$\frac{[\text{Net Head (ft) x Flow (gpm)}]}{10} = \textit{Watts}$$

This equation can be used to estimate the power output for a system with 53 percent efficiency, which is representative of most small hydropower systems.

### 4.1.2 Wind Power

Wind turbines generally have two or three propeller-like blades mounted on a rotor, though they do come in many different designs. The turbines are placed at an elevation of 100 feet or more above ground where the wind is stronger and less erratic.

The blade of a wind turbine acts much like an airplane wing with low-pressure air collecting on the side of the blade facing downwind creating lift. On the upwind side of the blade the wind force creates drag and the together, the lift and drag makes the rotor to spin like a propeller. The rotor in turn spins a shaft, which spins a generator, and electricity is created.

Wind turbines can be connected to a utility power grid, batteries or, can be used just for pumping or communications. When a large number of wind turbines are used to create energy on a large scale, they're called wind farms (DOE 3, 2002).

***Pros***

- Produces a significant amount of power. ("Micro turbines will generate about 300 Kwh per year at sites with average wind speeds of 5.5 m/s")(Gipe 29)
- Wind is highly availability in the right locations.
- Durable and strong,
- Minimal Space usage

- Pay for themselves quicker then most renewable energy production systems.
- Potential cash rebates available.
- Maintenance is minimal (Campus 2002)

*Cons*

- Noise, yet less of an issue nowadays.
- The turning blades can kill and maim birds.
- The site may not have enough wind.
- Difficult to maintain on this site, primarily due to access
- Difficulty in finding proper locations for the wind turbines.
- Wind is intermittent.

#### 4.1.2.1 Small Wind Turbines

*Configurations*

*Vertical-Axis*

An example of a vertical Axis turbine is the Darrieus turbine. It looks a lot like a giant eggbeater with vertical blades that are bent like a crossbow for archery.

- Not "economically competitive" with Horizontal Axis Wind Turbines.
- "Can harness winds from any direction without the need to reposition the rotor when the wind direction changes."
- The shape causes difficulties in the manufacture, transportation and installation of the curved blades."(Godfrey 280)

*Horizontal Axis*

"...Today nearly all small wind turbines are upwind, horizontal axis turbines, where the rotor spins in front of the tower, about a line parallel with the horizon." (Gipe 25)

- Two or Three Blades: Two blades cost less than three, however, you get what you pay for. Turbines with three blades tend to run more smoothly therefore putting less wear on the rotor.

- Materials of the Blade: Most Blades are made of fiberglass, some are made of wood, and some are composites. Aluminum however, is not used due to its susceptibility to fatigue.
- Orientation: "Nearly all small wind turbines use tail vanes to point the rotor into the wind."
- Sturdiness: The heavier the turbine the more likely it will be able to sustain the forces of the wind and the rotor. The higher specific mass the better, relative to the area covered by the rotor.
- Overspeed Control or method by which the speed of the rotor can be controlled when it is spinning too fast in high winds. "Most micro and mini wind turbines furl, or fold about a hinge so that the rotor swings toward the tail vane. Some furl the rotor vertically, others furl the rotor horizontally toward the tail."
- Generators: "Most small wind turbines use permanent-magnet alternators. This is the simplest and most robust generator configuration and is nearly ideal for micro and mini wind turbines."

(Gipe 25-28)

**Topographical and meteorological features associated with high or low wind speeds. Those features indicative of high mean wind speeds are:**

- gaps, passes, and gorges in areas of frequent strong pressure gradients
- long valleys extending down from mountain ranges
- high elevation plains and plateaus
- plains and valleys with persistent strong downslope winds associated with strong pressure gradients
- exposed ridges and mountain summits in areas of strong upper-air winds
- exposed coastal sites in areas of
- strong upper-air winds or
- strong thermal/pressure gradients.
- Features that signal rather low mean wind speeds are:

- valleys perpendicular to the prevailing winds aloft
- sheltered basins
- short and/or narrow valleys and canyons
- areas of high surface roughness, e.g., forested hilly terrain.

### 4.1.3 Solar Power (Photovoltaics)

#### 4.1.3.1 Pros

- Reliable time-tested equipment is available with 20-30 year manufacturer's warranties.
- The amount of solar insolation of a possible site can be easily gathered.
- Rebates available through Government programs can cut the initial startup costs in half.
- They are most reputable and widely familiar alternative energy generating devices.

#### 4.1.3.2 Cons

- The steep initial expense.
- Overcast weather conditions lower efficiency of power generation.
- The photovoltaic cells are fragile.
- A substantial sunny area is required to provide enough capacity to help power the RCNWC site.
- Photovoltaic arrays are large and cumbersome, providing little aesthetic flexibility.

***Photovoltaic Construction***

Types: single crystal, multicrystaline, and amorphous or thin film

***Single Crystal***

Single crystal photovoltaic panels are the most efficient and therefore require the least area to be committed for creating a viable array. Single-crystal designs also come from a well-developed and clean manufacturing process. The drawback is that they are the most expensive.

### *Multicrystaline*

Although cheaper than the single-crystal, multicrystaline designs are less efficient and not as sturdy. This equates to a larger area being required for a photovoltaic array.

### *Amorphous*

Amorphous photovoltaic panels are the least efficient and newest design, but offers some advantageous attributes. They come in innovative designs, such as in the form of roofing shingles, and are flexible and lightweight. Amorphous designs are optimal for mobile applications or when sturdiness is a high priority (Real 2002).

## *Photovoltaic Mounting and Tracking*

Types: fixed, top of pole, active tracking, and passive tracking (Real Goods).

Fixed: fixed mounts are stationary and placed at an angle to the sun. Some fixed mounts offer the option of angle adjustment to account for the different incidence of summer and winter sunlight and must be manually adjusted twice a year.

Top of the pole: top of the pole mounting optimizes the use of space by not requiring an existing structure. This allows easier location of a photovoltaic array for optimum insolation and out of the way placement.

Active tracking: active tracking devices expend minimal amounts of electricity to allow a top of the pole photovoltaic array to follow the sun through out the day for maximum insolation.

Passive tracking: passive tracking is a simple and efficient way to maximize the incidence of solar radiation falling on the photovoltaic panels by using the sun's heat to guide the direction of the PV array through the day. A mechanical means of expanding and contracting liquid, dependent on the heat of the sun, acts to move the photovoltaic array without the use electricity (Real 2002).

### *Fixed*

**Pros**

- Variable tilt,
- Simple.

**Cons**

- Requires new or existing structures for mounting.
- Doesn't track daily movements of sun.

*Top of Pole*

**Pros**

- Most cost efficient,
- Naturally elevated with the least area required,
- Provides most leeway for different placement sites,
- Pole prevents theft and damage.

**Cons**

- Doesn't track without addition of tracking system mount.

*Active Tracking*

**Pros**

- Most efficient tracking of the sun throughout the day,
- More economical the larger the arrays,
- Negligible power demand.

**Cons**

- Most expensive,
- Increased chance of mechanical malfunctions.

*Passive Tracker*

**Pros**

- Effective and low maintenance,
- Allows for tracking of the sun throughout the day,
- Best performance in mild climates.

**Cons**

- More expensive than fixed and non-tracking pole mounts,

- Severe wind and cold weather affects performance(Real 2002).

#### 4.1.3.3 Incident Solar Radiation of RCNWC site

The average incident solar radiation of the RCNWC can be determined through measuring techniques using pyranometer over time.

### 4.1.4 Solar Water Heaters[1]

A solar hot water heating system will greatly reduce the energy costs at the RCNWC site. Solar water heating technologies have been used since the early 1900's to heat water efficiently and new technologies are reliable and relatively cheap.

#### 4.1.4.1 Pros

- 30% of the heat demand goes into heating.
- Solar water heaters significantly reduce the energy demand on active systems.

#### 4.1.4.2 Cons

- Doesn't necessarily fit into the historical theme of the site.

#### 4.1.4.3 Active Systems

***Open Loop***

***Pros***

- Efficient and lowers operating costs,
- Popular in nonfreezing climates.

***Cons***

- Not appropriate if your water is hard or acidic because scale and corrosion quickly disable the system,

[1] The information on Solar Water Heaters are taken from the Department of Energy website (www.energy.gov, 2002)

- Install in mild but occasionally freezing climates. But must consider freeze protection,
- Pump will not work and the system will freeze when the power is out.

*Closed Loop*

*Pros*

- Closed-loop glycol systems are popular in areas subject to extended freezing temperatures because they offer good freeze protection,
- There are no valves to fail.
- When the pumps are off, the collectors are empty, which assures freeze protection and also allows the system to turn off if the water in the storage tank becomes too hot.

*Cons*

- Glycol antifreeze systems more expensive to buy and install.
- Glycol must be checked each year and changed every 3 to 10 years, depending on glycol quality and system temperatures.

*Pumps*

*Pros*

- Have low power requirements,
- Some companies now include direct current (DC) pumps powered by small solar-electric,
- Cost nothing to operate and continues to function during power outages.

#### 4.1.4.4 Passive Systems

*Batch Systems*

*Pros*

- Generally more reliable than active systems,

- Possibly longer lasting than active systems,
- Systems can be less expensive than active systems,
- Inexpensive and have few components,
- Less maintenance and fewer failures,
- Mounted on the ground or on the roof.

***Cons***

- Must be protected from freezing or drained during the winter,
- Pipes must be well insulated to prevent the tank from freezing,
- Some of these pipes can't withstand unlimited freeze/thaw cycles before they crack.

***Thermosyphon***

***Pros***

- Generally more reliable, easier to maintain, and possibly longer lasting than active systems.
- Systems can be less expensive than active systems.
- Reliable and relatively inexpensive,
- Can be freeze-proofed by circulating an antifreeze solution through a heat exchanger.

***Cons***

- Require careful planning in new construction because of heavy water tanks.

### 4.1.5 Hydrogen Fuel Cells

Hydrogen fuel cells are fueled by hydrogen, which can be electrolyzed from water; the electron in the hydrogen atom is used to provide electricity to an object. The hydrogen is then oxidized and the only byproduct is water. "Fuel cells convert chemical energy directly into electricity with greater efficiency than any other current power system." (Schatz 2002)

#### 4.1.5.1 Pros

- Hydrogen is often safer than fossil fuels it is non-toxic and if it leaks, it will quickly dissipate into the outer atmosphere.
- Fuel Cells are generally long lived.
- Independent of environmental factors once sheltered from them.
- It's a new technology that can use the promotion.
- The only byproduct produced is water.
- Hydrogen fuel is clean and relatively easy to obtain.
- The site may be able to arrange an agreement with Schatz that benefits both parties.
- Potential cash rebates available.
- A fuel cell is very quiet with proper operation

(Schatz 2002)

#### 4.1.5.2 Cons

- They are currently expensive to manufacture.
- Not many types are commercially available.
- The maintenance demand may be high.
- New technology means that reliability and longevity are a question.
- The systems are complex; containing many delicate parts requiring specialist technicians.

#### 4.1.5.3 Primary Fuel Cell Technologies

***Phosphoric Acid Fuel Cells***

"A phosphoric acid fuel cell (PAFC) consists of an anode and a cathode made of a finely dispersed platinum catalyst on carbon paper, and a silicon carbide matrix that holds the phosphoric acid electrolyte. This is the most commercially developed type of fuel cell and is being used in hotels, hospitals, and office buildings. The phosphoric acid fuel cell can also be used in large vehicles, such as buses (DOE 1, 2002)."

**Pros**

- This is the most commercially developed type of fuel cell (DOE 1, 2002).

- Operated at more than 40% efficiency.
- "Nearly 85% of the steam this fuel cell produces is used for co-generation"
- "Can use impure hydrogen as fuel"
- This is the most "mature" of the fuel cell technologies
- It has outputs of 200 kW- 1 MW.
- Temperatures are in the range of 300 to 400 degrees F (150 - 200 degrees C)". (Fuel, 2002)

## Cons

- Expensive platinum is the catalyst.
- Generates low current and power comparably to other types of fuel cells.
- It generally has a large size and weight (Fuel, 2002).

### *Proton-Exchange Membrane Fuel Cells*

"The proton-exchange membrane (PEM) fuel cell uses a fluorocarbon ion exchange with a polymeric membrane as the electrolyte. The PEM cell appears to be more adaptable to automobile use than the PAFC type of cell. These cells operate at relatively low temperatures and can vary their output to meet shifting power demands. These cells are the best candidates for light-duty vehicles, for buildings, and much smaller applications (DOE 1, 2002)."

## Pros

"These cells operate at relatively low temperatures and can vary their output to meet shifting power demands." (about 175 degrees F or 80 degrees C)

- These cells are best for light-duty vehicles, buildings, and smaller applications (DOE 1, 2002).
- They have a high power density.
- They can vary their output quickly to meet shifts in power demand.
- Quick startup is possible.
- The solid electrolyte reduces corrosion and "management problems."
- Cell outputs range from 50 to 250 kW.

**Cons**

- "This type of fuel cell is, however, sensitive to fuel impurities." (Fuel, 2002)

### *Solid Oxide Fuel Cells*

"Solid oxide fuel cells (SOFC) currently under development use a thin layer of zirconium oxide as a solid ceramic electrolyte, and include a lanthanum manganate cathode and a nickel-zirconia anode. This is a promising option for high-powered applications, such as industrial uses or central electricity generating stations (DOE 1, 2002)."

***Pros***

- Option for high-powered applications (DOE 1, 2002).
- Efficiencies could reach 60% and 85% with co-generation
- Tubular forms have produced as much as 220 kW.

***Cons***

- Operating temperatures reach 1,800 degrees F or 1000 degrees C
- The cell output is up to 100 kW (Fuel, 2002).

### *Direct-Methanol Fuel Cells*

"A relatively new member of the fuel-cell family, the direct-methanol fuel cell (DMFC) is similar to the PEM cell in that it uses a polymer membrane as an electrolyte. However, a catalyst on the DMFC anode draws hydrogen from liquid methanol, eliminating the need for a fuel reformer (DOE 1, 2002)."

**Pros**

- Eliminates the need for a fuel reformer (DOE 1, 2002).
- Efficiencies of about 40%
- Operates at a temperature between 120-190 degrees F or 50 -100 degrees C. (low temps. make this fuel cell attractive for tiny to mid-sized applications i.e. cell phones and laptops.)
- "Higher efficiencies are achieved at higher temperatures." (DOE 1, 2002)

**Cons**

- Fuel can cross over "…from the anode to the cathode without producing electricity." (Fuel, 2002)

### *Molten Carbonate Fuel Cells*

"The molten carbonate fuel cell uses a molten carbonate salt as the electrolyte. It has the potential to be fueled with coal-derived fuel gases or natural gas (DOE 1, 2002)."

**Pros**

- "It has the potential to be fueled with coal-derived fuel gases or natural gas, "
- Efficiencies, "about 60% normally or 85% with co-generation." (DOE 1, 2002)
- They have been operated on "hydrogen, carbon monoxide, natural gas, propane, landfill gas, marine diesel, and simulated coal gasification products."
- It has outputs of 10 kW to 2 MW
- The high operating temperature implies higher efficiency and flexibility to use more types inexpensive fuel catalysts.

**Cons**

- Operates at about 1,200 degrees F or 650 degrees C "…high temperatures enhance corrosion and the breakdown of cell components." (Fuel, 2002)

### *Alkaline Fuel Cells*

"The alkaline fuel cell uses an alkaline electrolyte such as potassium hydroxide. Originally used by NASA on space missions, it is now finding applications in hydrogen-powered vehicles. (DOE 1, 2002)"

**Pros**

- "Originally used by NASA on space missions, it is now finding applications in hydrogen-powered vehicles.(DOE 1, 2002)"
- Efficiencies of up to 70%
- "They were used on the Apollo spacecraft to provide both electricity and drinking water."

- "Operating temperature is 150 to 200 degrees C (about 300 to 400 degrees F)"
- Higher performance.

**Cons**

- Relatively lower outputs of 300 watts to 5 kW
- "Until recently they were too costly for commercial applications" (they are now examining ways to reduce that cost.) (Fuel, 2002)

### *Regenerative or Reversible Fuel Cells*

This special class of fuel cells produces electricity from hydrogen and oxygen, but can be reversed and powered with electricity to produce hydrogen and oxygen (DOE 1, 2002)."

**Pros**

- "…Can be reversed and powered with electricity to produce hydrogen and oxygen." (DOE 1, 2002)
- It is a closed-loop form of power generation.

**Cons**

- "Still a very young member of the fuel cell family." (Fuel, 2002)

### *Zinc-Air Fuel Cells (ZAFC).*

**Pros**

- Closed-loop system,
- Battery recharging time is not an issue,
- It has a high specific energy.
- "Due to the abundance of zinc on earth, the material costs for ZAFCs and zinc-air batteries are low."
- Has a wide range of applications (Fuel, 2002).

### 4.1.6 Energy Conservation[2]

Energy efficiency and conservation is the most cost effective and economical way to reduce energy consumption. There is a energy efficiency List in Appendix 7.2 with more information.

#### 4.1.6.1 Steps you can take:

***Light***

- Use day lighting, by installing skylights on north ends to avoid over heating
- Use devices that reflect light deep into the building and avoiding glare by using window sills, walls, louvers, reflective blinds
- Use low watt fluorescent light bulbs

***Heating***

- Use windows with heat absorbing glazing
- Purchase wood stoves instead of fireplaces

***Water***

- Lower the temperature of the hot water
- Installing low-flow shower heads or flow restrictors in shower heads and faucets
- Insulating your current water heater,
- Insulating any hot water pipes that pass through unheated areas
- Lower the thermostat on your water heater to 120°F (49°C).

***Insulation***

- Ducts and vents
- Walls and doors
- Piping
- Weather striping
- Thermal curtains

***Passive Heating and Cooling***

[2] The information on energy conservation are taken from the Department of Energy website (www.energy.gov, 2002)

- Use stone masonry, brick, or water as thermal mass to store the sun's heat.

## 4.2 *Alternative Solutions*

### 4.2.1 Energy Generation Solutions

#### 4.2.1.1 Solar Tracking Hatchery (*Figure1*)

This solution utilizes the reliability and high-energy output of photovoltaic cells. An array of 24 panels is divided into three sections. Two sections of the photovoltaic panels are on passive tracking racks, mounted at the top of 2 poles. The third section of photovoltaic panels is mounted on a tilted rooftop rack. Due to the buildings' historical value, the third section of photovoltaic panels is placed on the roof of a structure built at proper distance from the renovated buildings. This newly built structure provides the dual benefit of elevating the solar panels while providing an additional sheltered area. Some ideas for the use of the sheltered area are:

- Car Port
- Information Display
- Picnic Tables
- Outdoor Lab Station

The combined area of the solar arrays will be around 400 square feet. The arrays will be wired to a 2500-watt electricity inverter that will be mounted near the PG&E electricity meter. A grid intertie system will remove the need for battery storage as well as make the power lines available when solar power production on the site is in deficit or surplus. Intertie systems, similar to the one described above, are available either as packaged systems or sold individually from retailers.

- Skylights on the northern hatchery roof (hidden from outside view)
- Top-of-pole passive tracking racks
- Rooftop tilted mount racks
- Intertie power system utilizes utility grid
- Package deal: 24-120watt PV panels, mounts and 2500watt inverter for $18,500.00 (estimate)
- PG&E rebate of $10,730.00 (estimate)

#### 4.2.1.2 Topsy Turby (*Figure 2*)

This solution depends on the powerful natural forces of wind and water. A small wind turbine and several small in-stream micro-hydro propellers will be used to generate power for this design. The wind maps of the Orick area are, to date, unavailable. Therefore in order to determine if there is a significant wind flow around the RCNWC site some testing would need to be done. With a steady flow of wind, wind turbines can produce a significant amount of electricity, which makes them a viable alternative power generating technology. In this solution a 3-blade, wind turbine will be placed near the Watershed Center and will act as a gauge to examine the reliability of the wind currents in the area. With this data, the future potential of a more substantial investment in wind power production can be determined.

The second half of this solution involves the stream, Lost Man Creek, adjacent to the Watershed Center. If determined to have sufficient flows, the stream, at the location of the non-operative dam, can be used to power several submersible water turbines called Jack Rabbits. The Jack Rabbit micro-hydro generators are an in-stream design that resembles a boat prop 12.5inches in diameter. In this solution, three to five Jack Rabbits will be placed on a lever system that will enable height adjustment or the removal of the units during unstable flows. The propellers would have to be screened in order to prevent aquatic animal mortality. Both wind and hydropower would be electrically connected to a substation housing a power inverter

***Wind Turbine***

- Three bladed turbine near RCNWC
- Assess future potential of wind reliability.
- Wiring can be subsurface

***Micro-Hydro***

- Located at a defunct dam.
- A cantilever or hydraulic system will allow for manipulation of the turbines in the waterway.

***Substation***

- Located between wind and hydro units
- Houses an inverter

### 4.2.1.3 It's a Sign (*Figure 3*)

This next solution primarily takes into consideration the maximum use of space. It involves using the sign welcoming visitors to the center as a structure for the placement and housing of power generating machinery. The top of the structure supports a solar array and within the building is housed an inverter and a hydrogen fuel cell. The room within the sign structure, that houses the fuel cell and inverter, has proper ventilation, is protected with security doors and, is just big enough to allow for maintenance access. Through crafty design and native plant landscaping the structure, though of substantial size, can be cloaked in the historical theme of the Watershed Center.

***Sign***

- Located at main entrance
- Contains business information

***Fuel Cell***

- Located within structure
- Good security
- PEM fuel cell stack obtained and maintained through cooperation with Schatz Energy Lab on HSU campus

***Solar Panel***

- Tilted mounts on top of structure
- Amount of PV cell determined by structure size.

### 4.2.2 Energy Efficiency Solutions

#### 4.2.2.1 Solar Water Heater (*Figure 4*)

Thermal solar systems do not directly convert the suns' energy into electricity but they still capture it in the form of heat. Heating water in a place of business or residence can require a large percentage of the electricity or gas demand for a site. This final solution involves the use of a thermosyphon solar water heater. The water is passively heated by the sun and is then stored into a *solar tank*. The hot water then rises and transfers via insulated pipes into the building's hot water heaters. As the water in the *solar tank* cools it sinks and gets drawn back into the thermosyphon system where the sun heats the water and the cycle repeats.

***Thermosyphon System***

- Located either below or on existing aeration tower
- Size as big as area will allow
- Water is pumped here first from well source
- Solar radiation heats water
- Warm water is pumped or rises into solar tank

***Solar Tank***

- Located at west side of aeration tower
- Warm water is transferred to existing water heater tank inside
- Water cools and is drawn back to solar siphon system

***Existing Tank***

- Inside of hatchery building
- Transfers water according to demand

***Pipes***

- Well insulated

**Figure 1. Solar Tracking Hatchery**

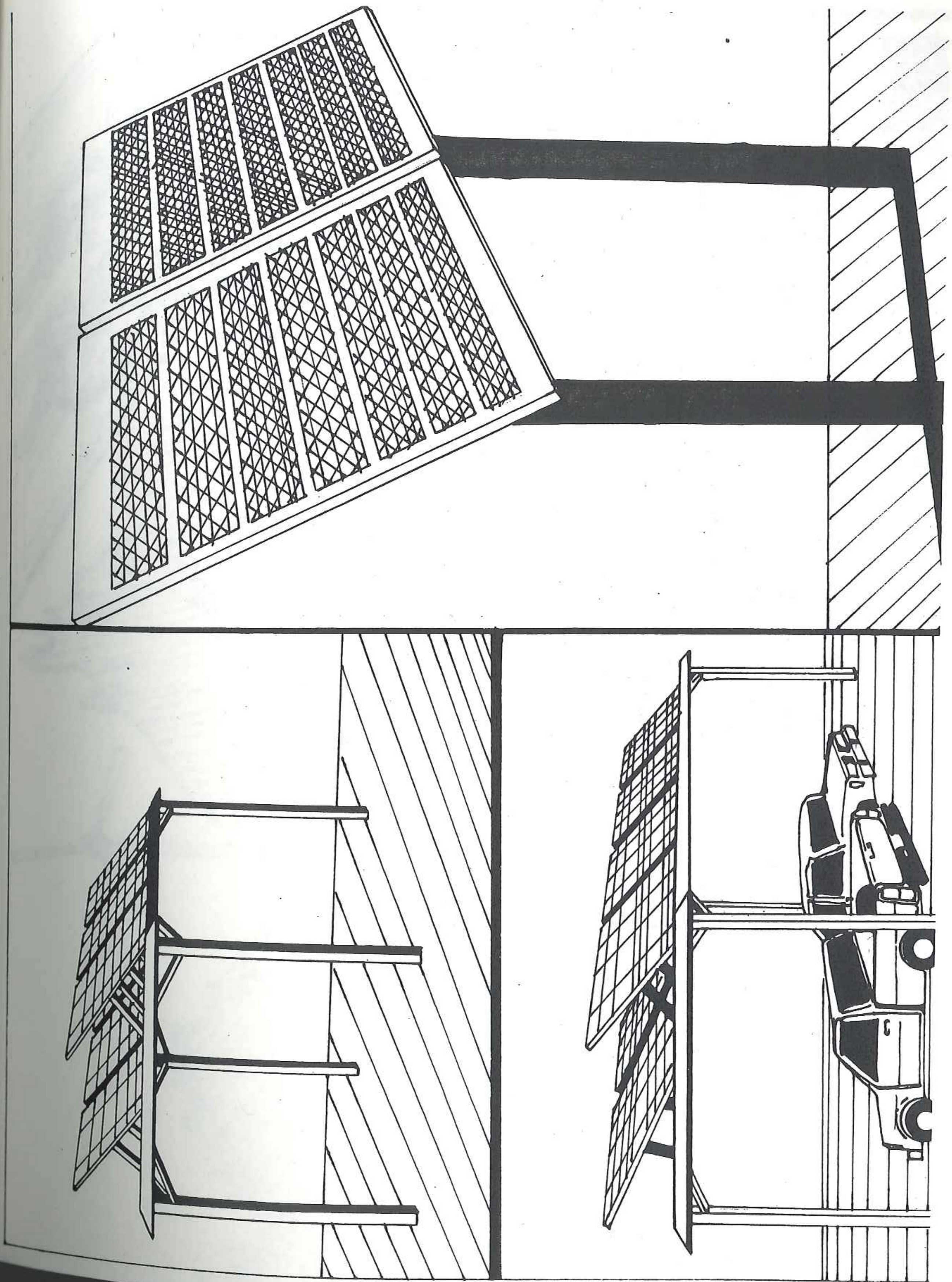


**Figure 2. Topsy Turby**

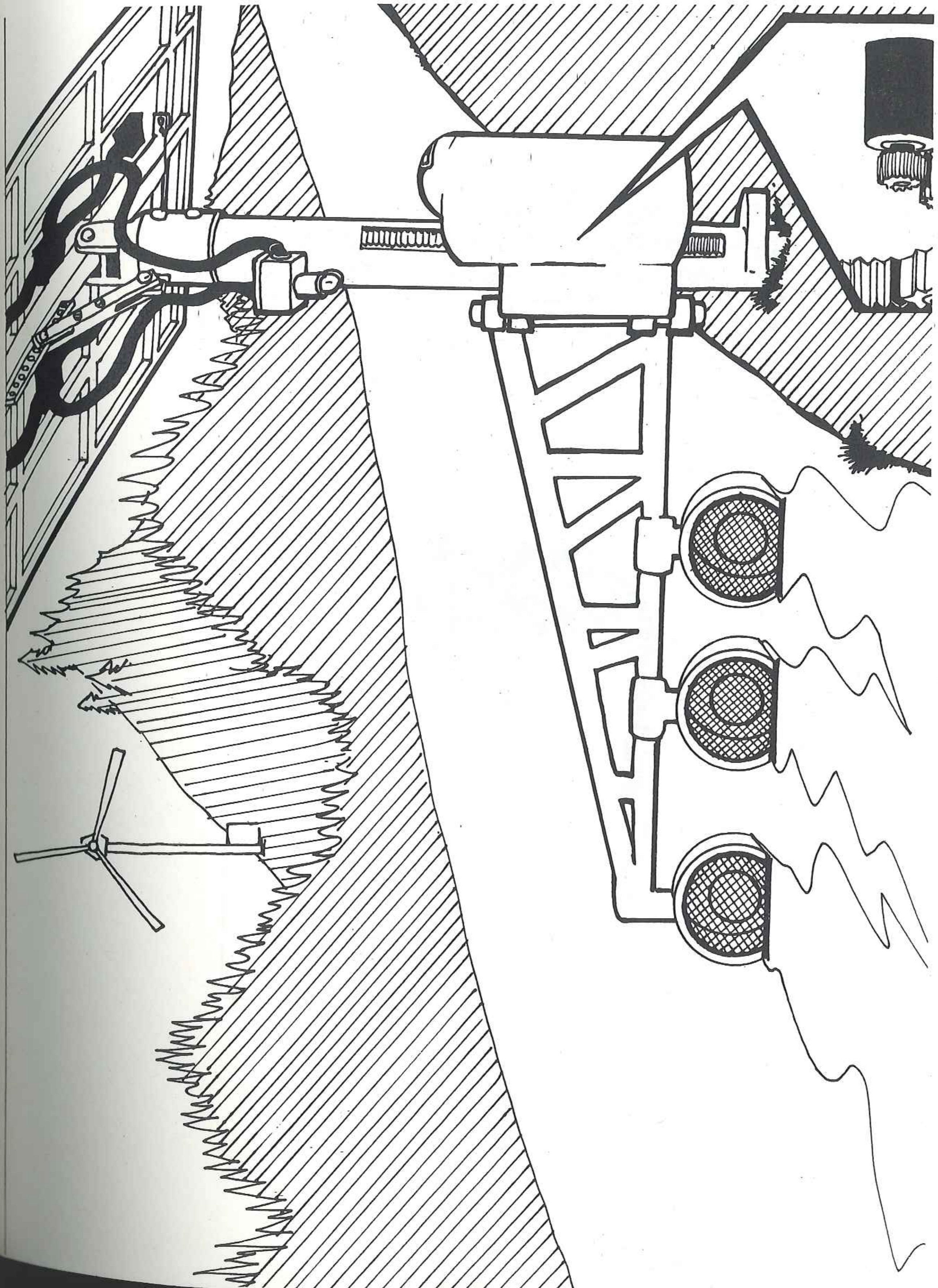


**Figure 3. It's A Sign**

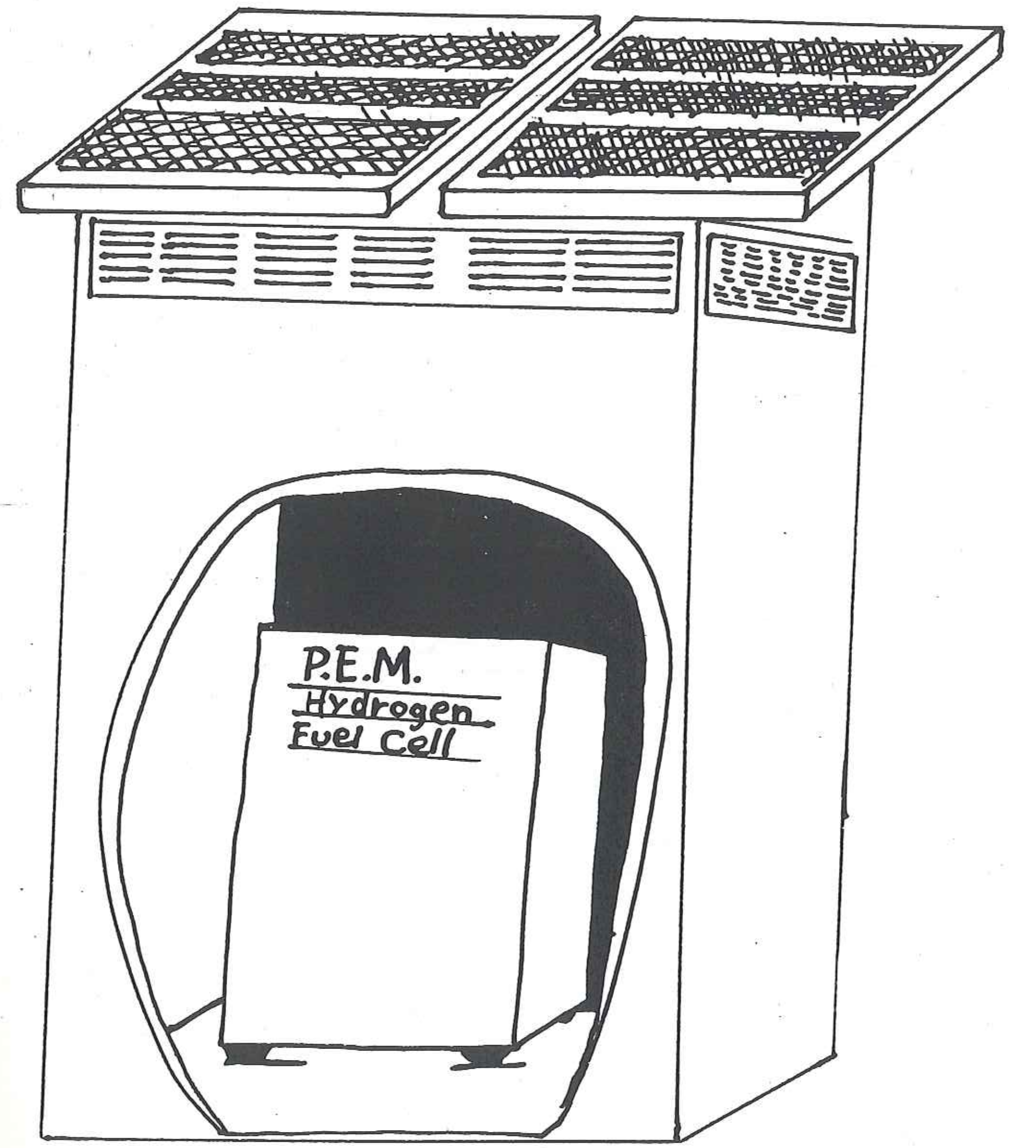
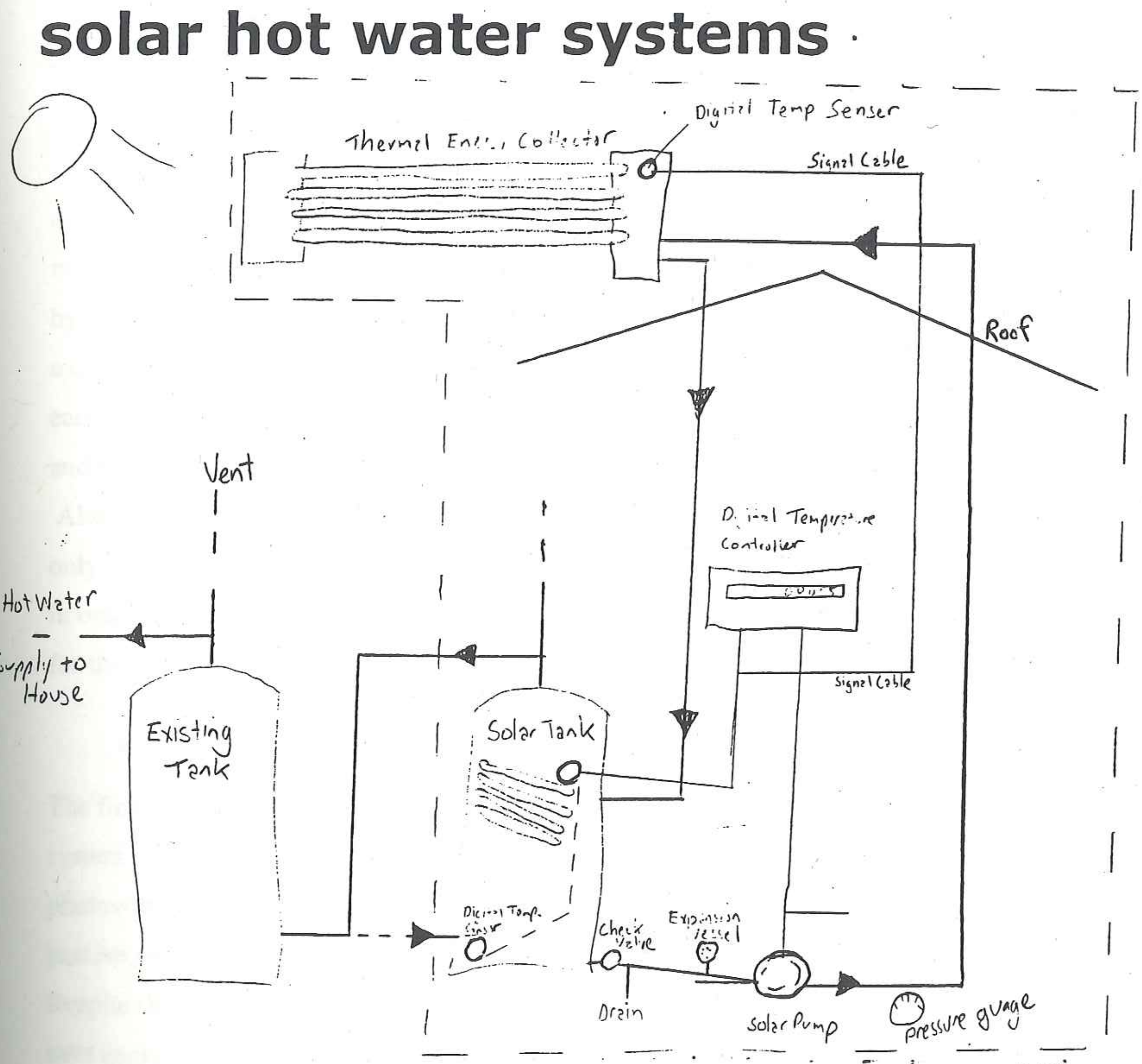


**Figure 4. Solar Water Heater**




Drawn by: Melinda Lucht

## 4.3 Decision Matrix

A decision matrix was developed as a quantitative tool for the unbiased assessment of our four alternative solutions. First, we created a list of 14 criteria, Appendix 1-E, for which the alternative solutions would be measured. Second, our group gave each criterion a number, from 1-14 based on its importance relative to the other objectives (14 being most important). Third, we rated each of the four alternative solutions according to each criterion, 1 being unsatisfactory in meeting the criterion to 10 being exemplary in meeting the criterion. The net amount of points each solution acquired was determined by multiplying the totals given to each criteria for each solution times the values given to each criterion. Fourth, we took the average of each group members' sets of scores for each alternative solution. The final step was to average the total scores for each solution and the solution with the highest total was the one chosen through this process.

Although the decision matrix provides an overall best score for a particular solution, we only used the results as a guide. We left the final decision making up to group discussion in order to allow for the best possible solution in determining the final. See Appendix 7.4 for the Decision Matrix.

## 4.4 Final Solution

The final solution is a hybrid between a solar photovoltaic system, a solar water heating system, and the implementation of efficiency technologies. Our solution involves a photovoltaic array divided into three sections, two sections are mounted on a top of a pole passive tracking system and the third section is mounted on top of a structure.

Despite the effort of using renewable generation methods, the most economical way to save energy is to invest in making your business energy efficient. Thirty percent of the energy use in a home is used to heat water. Therefore we suggest adding a solar hot water heating system that reduces energy demand from the utility grid. Another part of our solution involves energy efficiency components that should be installed when rehabilitating the buildings. We have included a list of these efficiency solutions in *Appendix 7.3,* which is further discussed in Section IV-B of this report.

# 5 Implementation

## 5.1 Group Implementation Plan

### April 16, 2002

Our plan of implementation for the next four weeks begins with altering the Pros and Cons section into a Literature Review. Each member of our group will type up a description of the systems they have researched. Daria will cover hydrogen fuel cells and wind turbines, Melinda will cover solar water heaters, energy efficiencies and rainwater catchment, and Andrew will covers solar panels and micro-hydro systems. We will then send our final product to Daria, via email, and she will put it into one format. Daria will edit the Literature Review and send it to Melinda who will edit the same draft as well. Melinda will then send the twice-edited literature review to Andrew for the last finishing touches. Andrew will send our final draft out to the group. Further clarifications and additions for the report will be communicated during the editing process.

The group will go over the Objectives and revise as needed. The Monitoring and Evaluation section will be discussed and developed by the group. We will then assign tasks, such as writing, typing, and editing for completion of the section.

Next, the group will discuss how to improve on the Alternative Solutions section and the Implementation section. Melinda will add the Rainwater Catchment into the Alternative Solutions and separate out of this category the Efficiency Solutions and the Generating Solutions. We will then repeat the fore mentioned editing process for those sections. Melinda will contact Paula by email in regards to our progress. As a group, we will discuss a date to meet with Paula at which point we will contact her by phone to schedule an appointment. Furthermore, our group will devise an agenda of what we would like to discuss with as well as questions we would like her to answer.

In turn we will put together our final report. Each group member will have an opportunity to individually review our final draft in its entirety. We will fix up any last minute details, put together a PowerPoint presentation and rehearse it.

## 5.2 Site Implementation

### 5.2.1 Implementation of the Energy Generation Solution

#### 5.2.1.1 Top-of-the-pole

The top of the pole passive solar tracking system makes up half of the electricity generating facilities of our final design's PV arrays. Passive tracking is a simple and efficient way to maximize the incidence of solar radiation falling on the PV panels. It uses the sun's heat to guide the direction of the PV array throughout the day. The PV array is attached to a tracking unit mounted on top of a sturdy metal pole. This allows the passive manipulation of the arrays direction. The company Zomeworks has a decades' old design, which comes with a 10year warranty. The Zomework's product TR070 ($1,359.00) will hold ten 100-120 watt panels and makes up half the PV area of the total solar power generation system in our solution. The western side of the Hatchery building would be an ideal setting for the top of the pole passive solar tracking system.

#### 5.2.1.2 The Structure

One half of the photovoltaic system in our design solution is to be mounted on top of two poles, while the other half is to be mounted on the rooftop of a structure. It is recommended that a structure be developed which accommodates both energy needs and the needs of the visitors to the center while maintaining the historical integrity of the site. We therefore propose that a carport, picnic area or other structure be built so that an array of solar panels could be placed on the top of its roof. The location of this structure would serve the site best in an area of sufficient solar insolation. The location that receives more sun is the southwest side of the hatchery building.

### 5.2.1.3 Photovoltaic Modules

Table 1 is a list of companies with Certified Photovoltaic Modules from the California Energy Commission Emerging Technologies Buy-Down Program list. See the website: http://www.consumerenergycenter.org/buydown/certified_pvmodules.html for product model numbers.

There are several distributors in the region that carry or can order several of these products and/or install them.

**Table 1. Photovoltaic Manufacturers**

| Company | City, State | Phone Number |
|---|---|---|
| ASE Americas, Inc. | Billerica, MA | 800-977-0777 x5985 |
| AstroPower, Inc | Concord, CA | 800-800-8727 |
| BP Solar | Fairfield, CA | 707-428-7800 |
| Evergreen Solar | Chico, CA | 530-894-5590 |
| Kyocera America | Woodland Hills, CA | 818-932-9480 |
| Matrix Solar/Photowatt | Albuquerque,NM | |
| Midway Labs, Inc | | |
| Powerlight Corp | Berkeley, CA | 510-540-0550 |
| Sanyo Electric Co. Ltd | | |
| Schott Applied Power Corp | Willits, CA | 1-800-344-2003 |
| Sharp Corporation | | |
| Siemens Solar Industries | Camarillo, CA | 805-482-6800 |
| Solec International, Inc | | |
| United Solar Systems Corp | | |

### 5.2.1.4 PV Mounting Structures

The Northern California Solar Energy Association (NCSEA) has a great website for solar equipment manufacturer information. It is: http://norcalsolar.org/resources/pvsystems.html.

According to their listing there are only a few companies mentioned who manufacture photovoltaic mounting equipment called racks. These racks are a very important for our final design solution. Two manufacturers that appear to be versatile and accessible are the following:

**UNIRAC, INC.**
2300 Buena Vista Dr. SE., Suite 134
Albuquerque, NM 871066
Phone 505-242-6411 Fax: 505-242-6412
Email: tracker200@unirac.com
Website: http://www.unirac.com

**ZOMEWORKS**
1011 Sawmill Road NW
Albuquerque, NM 87125 USA
Vox: 505-242-5354 Fax: 505-243-5187
Toll free: 800-279-6342
Email: zomework@zomeworks.com
Website: http://www.zomeworks.com

Both of these companies sell racks for the passive tracking, top-of-the-pole design as well as for the roof tilted-mount design. They also design the racks to fit the various photovoltaic models, refer to Figure 1. Having minimized the selection of racks down to two manufacturers, the locations through which you will be able to find distributors that sell all of the desired solar products will be minimized. One fairly local company that sells the Unirac, Inc. product line is Schott Applied Power Corp. located in Willits, CA, 1-800-344-2003. For further information on local distributors contact Unirac and Zomeworks directly.

#### 5.2.1.5 Inverters/Intertie

An inverter will allow the solar power generation facilities to be tied to the local power utility grid. The companies' Trace and Sunny Boy are both reputable brands that make 2500-watt inverters.

**TRACE ENGINEERING**
5916 195th Northeast
Arlington, WA 98223 USA
Phone: 360-435-8826 Fax: 360-435-2229
Toll free:
Email: inverters@traceengineering.com
Website: http://www.traceengineering.com/
http://www.xantrex.com

**SMA AMERICA, INC. (Sunny Boy)**
20830 Red Dog Road
Grasss Valley, CA 95945
Phone: 530-273-4895 Fax: 530-274-7271
Email: berdner@SMA-America.com
Website: http://www.SMA-America.com

There are also several other manufacturers listed on the www.norcalsolar.org website mentioned in the pv structures paragraph earlier in this section.
The inverter could be placed at the eastern end of the Hatchery building next to the existing PG&E pole and the electricity meter.

#### 5.2.1.6 The Energy Commission's Emerging Renewables Buydown Program

"The California Energy Commission is offering **cash rebates** on eligible renewable energy electric-generating systems through the **Emerging Renewables Buydown Program**." The following website contains a list from the California Energy

Commission. "This list represents retailers and vendors that have participated in the Energy Commission's Emerging Renewables Buydown Account or requested to be included on the list." The cost of the labor can be counted towards the total eligible system if it is a contractor-installed system.
http://www.consumerenergycenter.org/buydown/retailers.html
The RCNWC will receive $4.50 for every watt of renewable energy that they invest in (Real 2002). For the 2500 watts system, the rebate totals over $11,000.00, which is approximately half the cost of the proposed system.

#### 5.2.1.7 Implementation time

The most appropriate time for the PV panels, the structure, and the Inverter to be added to the site is early in the construction phase. The contractors hired to renovate the existing buildings and develop the site are likely to require access to a power source. Power availability is a very important part of any business or organization. If the entire system is implemented early situations that arise could be compensated for in time for an energized and smooth flowing grand opening.

### 5.2.2 Implementation of the Energy Efficiency Solution

#### 5.2.2.1 Solar Water Heater

***Manufactures***

The different types of thermosyphon systems can be ordered through Six Rivers Solar in Eureka, CA. or from Real Goods in Hopland, CA.

***Six Rivers Solar: Eureka, CA***

**Table 2. Solar Water Heater Panels**

| Gallons | Price | Panels |
|---|---|---|
| 55 | $2695 | 1 (4'×8') |
| 100 | $3495 | 2 (4'×8') |
| 120 | $3895 | 2 (4'×10') |

Radco ™

SunEarth ™

***Light Heat: Eden, Utah***

**Table 3. Thermosyphon Types**

| Type | Price |
|---|---|
| 2-Gobi 4'×10' flat plate<br>Heat exchanger connected to water heater<br>Sid-pump<br>1-20 Watt PV panel | $2900 |
| 1 Thermomax 30 tube collector (most efficient)<br>Heat exchanger connected to water heater<br>Sid-pump<br>1-20 Watt PV panel | $3659 |
| 1 Thermomax 30 tube collector<br>Heavy insulated storage tank with internal heat exchanger<br>Sid-pump<br>1-20 Watt PV panel | $4259 |

#### 5.2.2.2 Skylights

***Manufactures***

***Sun-dome***

- 21" skylights light 600 square feet.
- 10-year warranty
- 6-pack kit that includes 3 10" and 3 13" lights for a total of $1224

Contact: 1-800-596-8414

***Velux***

- 601 Rough Opening Size = 44-3/4 x 28inch

- Comfort Glass consists of two panes of tempered safety glass dual-sealed and injected with argon gas.
- A double layer of exclusive low-E coating provides excellent thermal performance.

Price: $244.00

**Table 4. Local Distributors of Skylights**

| | | |
|---|---|---|
| ARCATA LUMBER | 1296 11TH ST DO IT BEST #5075 ARCATA CA 95521 | (707) 822-1769 |
| BRACUT INTERNATIONAL CORP. | PO DRAWER 4779 ARCATA CA 95518 | (707) 826-9860 |
| WEST COAST WINDOW CO | PO BOX 500 ARCATA CA 95521 | (707) 826-2600 |
| CRESCENT ACE HARDWARE | 840 EAST WASHINGTON BLVD BMA #87464 CRESCENT CITY CA 95531 | (707) 465-5865 |
| SCHMIDBAUER LUMBER INC | FOOT OF WASHINGTON PO BOX 3293 EUREKA CA 95502 | (707) 443-7025 |
| MYRTLETOWN LUMBER & SUPPLY INC | 2800 HUBBARD LANE DO IT BEST #6505 EUREKA CA 95501 | (707) 445-8436 |
| PIERSON BUILDING CENTER | 4100 BROADWAY BMA #0404800 EUREKA CA 95503 | (707) 441-2700 |

***Where***

Install 2–3 skylights on the north side of the hatchery building placed in order to illuminate the three largest rooms: research room; exhibit hall; and the classroom.

*When*

The skylights can be installed at anytime during the reconstruction of RCNWC, but should be installed before the interior remodeling is done.

*How*

Consult the retail companies from which the skylights are purchased. They may have people to install them or a manual will be included for simple installation having it done by a person with construction skills.

#### 5.2.2.3 Windows

*Manufacturers*

***Architectural Wall Solutions, Inc.***

Tukwila, WA98168

Phone: (206) 277-9760

***Benson Industries, Inc.***

1650 N.W. Naito Parkway, Suite 250

Portland, OR97209

Phone: (503) 226-7611

Fax: (503) 226-0070

*Where*

Install double-pained windows that gas filled with low-emissivity coatings (low-e) to reduce heat loss. The low-e coatings work best on the inside window pain, on the side that faces toward the outside. Use heat -absorbing glazing on the windows facing south.

*When*

Consult with the contractor already assigned to rehabilitate the exterior windows on when should be the best time to replace or re-glaze existing windows.

*How*

Consult the retail companies from which the windows are purchased. They may have people to install them or a manual will be included for simple installation having it done by a person with construction skills.

**Table 5. Independent Power Providers**

| Company | Name | Address | Phone Number | Email Address |
|---|---|---|---|---|
| Offline | Don & Cynthia Lowenburg | P.O. Box 231 North Fork, CA 93643 | 559-877-7080 | ofln@aol.com |
| Suntricity | Chuck Heath | 1647 Bollinger Sebastopol, CA 95472 | 707-829-7883 | sunpwr@ips.net |
| Energy Outfitters | Bob Maynard | P.O. Box 1888 Cave Junction, OR 97523 | 503-592-6903 | sales@ energyoutfitters.com |
| Mendocino Solar Service | Rob Harlan | 42451 Road 409 Mendocino, CA 95460 | 707-964-4816 | mendosol@mcn.org |
| Peltz Power | Jay Peltz | P.O. Box 2391 Redway, CA 95560 | 707-923-3477 | jay@asis.com |
| Solar Wind Northern Lights | Chris May | P.O. Box 2185 Redway, CA 95560 | 707-498-2804 | swnl@asis.com |
| Cinematogrophy | Eric Stromberger | P.O. Box 966 Mendocino, CA 95460 | 707-937-3866 | erics@mcn.org |

**(http: //i2p.org, 2002)**

# 6 Evaluation and Monitoring

## *6.1 Photovoltaic*

- Keep Solar Panels clean according to the manufacturer's instructions.
- Adhere to the manufacturer's care and maintenance instructions for the photovoltaic modules purchased.
- When cleaning the solar panels, look for anything unusual such as cracks or abnormalities in the cells.

- Compare the system specifications with the actual performance as revealed through the PG&E statements. Check this monthly until you have determined that the system is working properly and then check yearly or otherwise specified by the distributor. If the module is not living up to the specifications for the product then contact the distributor from which you purchased the system. Below is a table of how to quantify the site's energy budget with two rows filled out as an example.

**Table 6. Example Energy Budget (units=Kwh)**

| 1. Month Of Year: ______ | 2. Theoretical Generation Kwh/mo | 3. Actual Generation Kwh/mo | 4. Kwh required from PG&E | 5. Kwh Given to PG&E |
|---|---|---|---|---|
| January | | | | |
| February | | | | |
| March | | | | |
| April | | | | |
| May | | | | |
| June | | | | |
| July | | | | |
| August | | | | |
| September | | | | |
| October | | | | |
| November | | | | |
| December | | | | |

- If the photovoltaic panels are not performing up to theoretical energy yields, then use a checklist that can be created in cooperation with the distributor. The following is an example checklist that can be created together with the distributor chosen to install the system. If the checklist does not reveal what is causing a problem then you should consult a solar energy system professional.

**Table 7. Example System Checklist**

| ✔When inspected | System |
|---|---|
| | Photovoltaic Modules |
| | Rack alignment |
| | Tracking |
| | Wiring |
| | Inverter |
| | Intertie with PG&E |
| | Water heater tanks |
| | Thermosyphon |

- Remove anything such as vegetation that comes to block the photovoltaic cells from the sun.
- The law requires a 5 year full-system warrantee with the purchase of a photovoltaic system to qualify for rebates (CEC 2, 2000). However, much more extensive warrantees are available. Be aware of your warrantee and be sure to adhere to the maintenance required in order to keep the warrantee valid.
- If your modules are not performing at peak capacity even on the sunniest of days, reconsider their location.

"In general, the PV modules are the longest-lived component of a PV system. Top-quality modules are designed to last at least 30 years and carry a 20-year warranty. They are designed to withstand all of the rigors of the environment including arctic cold, desert heat, tropical humidity, winds in excess of 125 mph (200 kph), and 1 inch (25mm) hail at terminal velocity." (BP, 2002)

## 6.2 Racks

### 6.2.1 Passive Tracking Racks

- Moving parts will need oiled according to manufacture's specifications.

- The thermodynamically controlled system of movement is made possible by fluids inside the tracking mechanism. These areas of the tracking system should be checked for leaks every few months.

### 6.2.2 Adjustable fixed racks

- These mounts will require changing their angle for maximum solar radiation. This will need to be done twice a year: once at the start of summer March 21 and again at the start of winter December 22.
- Steel parts will have to be monitored for rust and repainted periodically.
- It is important to remember that the racks will show wear more quickly than the photovoltaic cells and should be cared for accordingly.

## *6.3 Inverter*

- Modern high quality inverters are exceptionally reliable, having failure rates of less than 1% (Real, 2002). In the chance of problems arising a qualified technician will need to be consulted.
- Newer models of inverters are capable of supporting computers and other devices with specific electrical needs. Since the operation of office equipment is tied to the inverter, office equipment malfunctions could be indicating a faulty inverter.

## *6.4 PG&E*

- Monitor the amount of surplus electricity that is being produced on the site within a 12-month period (see Table 6). Utility companies are required under law to buy back any electricity that households and businesses generate in excess of their needs. That excess energy is then "banked" and you are given credit for that energy. However, it not mandated by law for the utility company to carry that credit for more than a year (CEC 2).
- Monitor the performance of the photovoltaic modules by your PG&E statement. Compare the statement to the product specifications of your photovoltaic modules (see Table 6).
- A logbook should be created to keep track of the net energy given to PG&E or the net energy required from PG&E.

### *6.5 Solar Hot Water Heater*

- To ensure high quality and satisfactory performance of solar water heating systems, authorized rating and certification programs have been established to test systems, rate their performance and ensure the integrity of their design. These criteria have been established to assure customer satisfaction and to simplify the purchase of a system.
- Calculate efficiency of collector by doing a Mass Flow Energy Analysis.
- The energy output of the system can be determined by comparing the temperature of the water coming in and the temperature of water going out.
- Keep track of how much hot water is being used on a monthly basis by monitoring how much water goes through the thermosyphon system on an average day or week during different seasons of the year. A flow meter can be used to measure this.
- Keep track of the therms used on the PG&E bill, every month. During the winter months, therm requirement will be much greater compared to summer months. This should be recorded and put into a database for further analysis. This will keep record of energy requirements of site over a period of time.
- Record initial cost of implementation and other cost needed to maintain system. You can figure out the economic benefits. The simplicity of solar water heating systems means that maintenance is minimal and does not require more money to be put into the system.
- Table 3 is an example of how to calculate the system's efficiency.

**Table 8. Monitoring Efficiency**

| **Base case heating fuel type** | **Quantity** |
|---|---|
| Number of SWH collectors | 1 |
| Area per collector | 2.00 $m^2$ |
| Net GHG emission reduction | 1.03 TCO2/yr |
| Avoided cost of heating energy | 1.20 $/kWh |
| Initial costs – Total | $1,000 |
| Annual costs – Total | $40 |
| Annual Savings – Total | $2,525 |
| Simple Payback | 0.4 Years |

# 7 Appendix

## *7.1 Flow Data for Lost Man Creek*

Mean Monthly Discharge (cfs) for Little Lost Man Creek (drainage area = 3.46 square miles), 1995-2001

| WY | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1995 | 0.40 | 9.52 | 16.15 | 46.68 | 12.76 | 34.66 | 15.47 | 7.26 | 4.68 | 2.06 | 0.57 | 0.19 |
| 1996 | 0.12 | 0.81 | 40.76 | 32.05 | 30.76 | 19.20 | 18.27 | 10.32 | 3.78 | 2.66 | ***1.22*** | 0.01 |
| 1997 | 1.93 | 11.23 | 61.90 | 53.81 | 18.70 | 10.90 | 12.02 | 10.97 | 3.25 | 1.50 | 1.08 | 1.25 |
| 1998 | 2.63 | 10.42 | 22.58 | 63.32 | 67.44 | 31.49 | 18.35 | 15.07 | 6.86 | 2.41 | 1.01 | 0.50 |
| 1999 | 1.20 | 64.24 | 39.99 | 16.30 | 26.03 | 18.89 | 10.60 | 6.90 | 1.52 | 0.64 | 0.16 | 0.08 |
| 2000 | 0.82 | 12.24 | 25.50 | 48.97 | 25.42 | 19.30 | 3.58 | 7.17 | 1.68 | 0.64 | 0.99 | 0.51 |
| 2001 | 1.45 | 2.50 | 4.29 | 4.05 | 8.94 | 4.22 | 5.92 | 3.06 | 1.40 | 0.57 | 0.26 | 0.07 |
| **Average** | **1.22** | **15.85** | **30.17** | **37.88** | **27.15** | **19.81** | **12.03** | **8.68** | **3.31** | **1.50** | **0.76** | **0.37** |

***bold italics = estimated***

Estimated Mean Monthly Discharge (cfs) for Lost Man Creek at mouth (drainage area 12.1 square miles)

| OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***4.26*** | ***55.32*** | ***105.28*** | ***132.21*** | ***94.75*** | ***69.13*** | ***41.98*** | ***30.29*** | ***11.55*** | ***5.23*** | ***2.64*** | ***1.30*** |

C:/Hydrology/Data/LLM mean monthly.xls

## 7.2 Efficiency List

### Water Heater

Set thermostat at $110^0$ F

Add insulation to water tank at least 1.5 inches

Insulate Hot water pipes

Install timers to turn off at night and when not in use

Install heat trap – a simple piping arrangement that prevents hot water rising up in the pipes and losing heat.

Drain a quart of water from tank every 3 months to remove sediment that prevents heat transfer and lowers unit efficiency.

* If using a solar water heater a ration of a least 1.5 gallons of storage space to 1 square foot of collector area.

### Insulation

Add R-11 to R-28 insulation for exterior walls.

Using a combination of wall cavity insulation such as batts, and insulating sheathing or rigid foam boards.

Add at least R-22 to attic insulation.

Insulate ducts that are in unconditioned spaces, or use one that have insulation already installed.

Consider installing an energy-efficient heat pump. They do double duty as a central heater.

### Lighting

Use daylighting by installing skylights on the north slope of roof to avoid over heating.

Look for windows with selective glazings that transmit most viable light.

Use dual paned windows with high-performance glass.

Use fluorescent light bulbs.

### Weather striping

Replacement weather-stripping should be used around doors and windows.

For best results, you should make certain that the weather-stripping material would stay flexible under extreme weather conditions. Also be sure to follow the manufacturer's instructions. In general, you should:

1. Weather strip the entire jamb
2. Apply on continuous strip along each side
3. Make sure the stripping meets tightly at the corners
4. Use a thickness that, when the door closed, tightly presses between the door and the jamb without making it difficult to close.

## 7.3 Criteria and Definitions

**Fourteen Criteria: listed according weights**

1. Simplicity- ease of form and function
2. Time/consumer tested- warranties and lineage of positive public feedback
3. Meets power demands- potential to give power back to utility grid
4. Maintenance costs- low cost
5. Public education- access of knowledge to public
6. Appropriateness for site- reliability of energy source
7. Ease of maintenance- easily maintained with local service and resources
8. Cost- equipment cost low relative to other solutions
9. Aesthetics- doesn't take away from the visual appearance of the RCNWC
10. Durability of equipment- lasts long enough to get pack the monetary value invested
11. Installation costs- installation cost does not exceed equipment costs
12. Environmental impact- having little or no negative environmental consequences
13. Energy generation efficiency- generates sufficient electricity with low entropy
14. Historical preservation- does not infringe on the historical structures

## 7.4 Decision Matrix

| Melinda Lucht | | Solar Tracking | | Topsy Turby | | It's a Sign | | Water Heater | |
|---|---|---|---|---|---|---|---|---|---|
| **Criteria** | **Weight** | Raw Score | Weighted Sum | Raw Score | Weighted Sum | Raw Score | Weighted Sum | Raw Score | Weighted Sum |
| Energy generation efficiency | 13 | 6 | 78 | 8 | 104 | 6 | 78 | 5 | 65 |
| Appropriate for site | 6 | 10 | 60 | 6 | 36 | 9 | 54 | 9 | 54 |
| Aesthetics | 9 | 6 | 54 | 7 | 63 | 9 | 81 | 7 | 63 |
| Historical preservation | 14 | 7 | 98 | 7 | 98 | 7 | 98 | 7 | 98 |
| Durability of equipment | 10 | 7 | 70 | 10 | 100 | 7 | 70 | 8 | 80 |
| Ease of maintenance/repair | 7 | 9 | 63 | 5 | 35 | 5 | 35 | 10 | 70 |
| Meets power demand | 3 | 8 | 24 | 9 | 27 | 9 | 27 | 6 | 18 |
| Less environmental impacts | 12 | 10 | 120 | 5 | 60 | 8 | 96 | 9 | 108 |
| Low installation cost | 11 | 5 | 55 | 2 | 22 | 7 | 77 | 9 | 99 |
| Simplicity | 1 | 8 | 8 | 5 | 5 | 4 | 4 | 9 | 9 |
| Time/consumer tested | 2 | 9 | 18 | 9 | 18 | 6 | 12 | 8 | 16 |
| Low maintenance costs | 7 | 8 | 56 | 6 | 42 | 6 | 42 | 8 | 56 |
| Costs | 8 | 6 | 48 | 5 | 40 | 4 | 32 | 8 | 64 |
| Public education access | 5 | 10 | 50 | 8 | 40 | 9 | 45 | 10 | 50 |
| **Total Score** | | | 802 | | 690 | | 751 | | 850 |

| Andrew Rogers | | Solar Tracking | | Topsy Turby | | It's a Sign | | Water Heater | |
|---|---|---|---|---|---|---|---|---|---|
| **Criteria** | **Weight** | Raw Score | Weighted Sum | Raw Score | Weighted Sum | Raw Score | Weighted Sum | Raw Score | Weighted Sum |
| Energy generation efficiency | 13 | 6 | 78 | 4 | 52 | 6 | 78 | 3 | 39 |
| Appropriate for site | 6 | 5 | 30 | 3 | 18 | 7 | 42 | 5 | 30 |
| Aesthetics | 9 | 3 | 27 | 8 | 72 | 7 | 63 | 5 | 45 |
| Historical preservation | 14 | 4 | 56 | 7 | 98 | 5 | 70 | 5 | 70 |
| Durability of equipment | 10 | 8 | 80 | 4 | 40 | 4 | 40 | 5 | 50 |
| Ease of maintenance/repair | 7 | 5 | 35 | 3 | 21 | 4 | 28 | 4 | 28 |
| Meets power demand | 3 | 8 | 24 | 5 | 15 | 4 | 12 | 2 | 6 |
| Less environmental impacts | 12 | 9 | 108 | 3 | 36 | 9 | 108 | 9 | 108 |
| Low installation cost | 11 | 6 | 66 | 3 | 33 | 4 | 44 | 6 | 66 |
| Simplicity | 1 | 7 | 7 | 3 | 3 | 6 | 6 | 8 | 8 |
| Time/consumer tested | 2 | 8 | 16 | 6 | 12 | 5 | 10 | 8 | 16 |
| Low maintenance costs | 7 | 6 | 42 | 3 | 21 | 3 | 21 | 5 | 35 |
| Costs | 8 | 4 | 32 | 3 | 24 | 5 | 40 | 6 | 48 |
| Public education access | 5 | 7 | 35 | 4 | 20 | 7 | 35 | 6 | 30 |
| Total Score | | | 636 | | 465 | | 597 | | 579 |

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