Report #1

Design of Energy Conservation and Renewable Energy Program for Residential Sector

prepared by
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for
Humboldt Energy Task Force

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1. EXECUTIVE SUMMARY

This report presents the first results of our work on the design of energy conservation and renewable energy programs for Humboldt County residences. These results are preliminary and subject to revision. The systems discussed here should not be considered recommended standardized systems, but instead represent common or current practice. All economic analyses use June 2001 prices for electricity and natural gas. In this report, cost-effectiveness of measures is presented in terms of simple payback time, i.e. the time period required for energy cost savings to repay the materials and labor costs of implementing the measure. We have not considered savings that would result from bulk purchases of equipment and standardization of systems.

Energy Education

- Educating the public about energy efficiency and conservation techniques would produce immediate savings and would make solar hot water systems and solar electric systems more cost effective.
- Several distinct audiences exist for educational outreach: residential consumers, small business owners, contractors, and government.

Electric Load Reduction

- Lighting consumes 25-30% of household electrical energy use. Replacing incandescent lights with compact fluorescent bulbs in moderate to high use areas in homes generally provides a 1- to 2-year energy savings payback at current prices of electricity. Initial costs would range from $8 to $12 per bulb.
- A "phantom load" reduction effort would yield modest savings of electrical energy but would be simple and inexpensive to implement.

Weatherization

- Weatherization measures would primarily reduce natural gas consumption.
- SERC engineers used a residential energy use model produced by Lawrence Berkeley Laboratory, cost data collected from local contractors, and custom-designed analysis spreadsheets to estimate potential savings, costs, and payback periods for a number of weatherization and lighting efficiency measures applied to generic small, medium and large Humboldt County homes.
- The full package of seven weatherization measures would result in savings ranging from $500 to $1,700 per house per year, depending on house size and other variables. Implementation costs would range from $2,000 to $4,000 per home, resulting in energy savings paybacks between 2.4 and 5.0 years at current prices of natural gas.

Solar Hot Water Systems

- Before investing in a solar hot water (SHW) system, it is more cost effective to invest in making homes more energy efficient. By taking steps to use less hot water and to lower the temperature of the hot water, users will reduce the size and cost of solar water heaters.
- The estimated installed cost of typical SHW systems that are currently being offered locally ranges from $4000 to $4600.
- Depending on the circumstances and at current prices of electricity, SHW systems can be expected to have reasonable (5-6 year) to longer (10 year) payback times when supplementing an existing electric hot water heater.

- When supplementing an existing gas hot water heater, SHW system payback times exceed 20 years at current prices of natural gas.
- SHW systems offer many other benefits such as improved environmental quality, enhanced energy security, and local economic development opportunities.

Solar Electric Systems

- Homeowners should first greatly reduce their overall electrical energy use through conservation and efficiency before installing photovoltaic (PV) systems. Humboldt County households use an average of 15 kWh/day of electrical energy.
- It is much less expensive to meet energy needs through conservation and efficiency than to install a larger PV system.
- Homeowners installing PV systems should switch to "net metering" so that they will be billed for net annual electricity use.
- A 1 kW system would cost approximately $5200 installed after the California Energy Commission (CEC) rebate. With good solar access, such a system could meet 100% of the net annual electricity use of an extremely energy efficient home (i.e., one that uses 4 kWh/day or about 25% of the current average).
- A 2 kW system would cost approximately $9300 installed after the CEC rebate. With good solar access, such a system could meet 100% of the net annual electricity use of a very energy efficient home (i.e., one that uses 8 kWh/day or about 50% of the current average).
- PV systems offer many other benefits such as improved environmental quality, enhanced energy security, and local economic development opportunities.

Economic, Regulatory, and Utility Issues

- Energy efficiency and conservation measures are almost always a less expensive way to avoid energy costs than installing renewable energy generation equipment. Local government and homeowners should thus ensure homes are as energy-efficient as possible before investing in solar thermal or solar electric (photovoltaic) systems.
- To effectively use solar energy to heat water or generate electrical power a building must have good solar access. The building must have an unshaded, south-facing roof area. The legal right to receive solar energy across another person's property (a solar easement) is guaranteed by California state law and by ordinance in Arcata. More active enforcement of these laws may be required to protect solar access.
- Solar water heating is generally a more cost-effective measure than photovoltaic electricity generation.
- Rebates offered by the State of California make PV systems more affordable, but these rebates alone do not make PV an inexpensive investment. Bulk purchasing discounts leveraged by local government and customer time-of-use metering could, however, give grid-connected residential PV systems a much faster economic payback. Administrators at the Sacramento Municipal Utility District (SMUD) have expressed willingness to allow Humboldt County governments to take advantage of discounted bulk PV equipment purchase agreements already used by SMUD as part of their existing residential PV program.
- Local government could significantly reduce the cost to the consumer of SHW and PV systems by:
  1) Buying in bulk. Local government could pay less for system components and help the consumer avoid crating charges.

2) Creating standardized SHW and PV systems. Building permits can be made less expensive and quicker to generate. These standardized systems may be quicker to install, reducing labor costs.

2. ENERGY EDUCATION

The objective of this section is to present methods for educating the public about the energy efficiency and conservation techniques outlined in this report. Educational outreach methods should be designed to reach a large audience in a cost-effective manner. We have identified the following four separate audiences that should be targeted: residential consumers, small business owners, contractors, and local government building and planning officials. The following lists describe possible educational outreach methods.

Residential Consumers and Small Business Owners:

- **Community Fairs:** Host energy education booths at community fairs (e.g. July 4th, Humboldt County Fair, North Country Fair) to make energy efficiency and conservation information available to the public. Community fairs are opportunities to promote simple solutions, such as racks to dry clothes and power strips to eliminate phantom loads, and to provide information on more complex measures, such as weatherization.
- **Workshops:** Present energy education workshops at community centers throughout the county. In addition to general information, these workshops should include instructions for implementing energy conservation measures, such as weather stripping and insulating a home. The workshops should also educate consumers about state, federal and utility rebates and other energy system cost savings programs. Local government may provide incentives to attend these workshops, such as free compact fluorescent light bulbs or energy audits.
- **Mailing Lists:** Distribute informational postcards or packets to county residents and businesses informing them of the program and inviting them to request an appointment for a free or low-cost energy audit. The mailing could include interesting facts about energy, phrased both in terms of dollars saved and the overall value of conservation.
- **Tours:** Organize tours of energy-efficient homes and businesses in Humboldt County to showcase and explain technologies.
- **Youth Education:** Encourage local performing arts groups, such as Del Arte, to develop dramatic presentations for county schools that focus on energy efficiency and conservation. These presentations should be developed with input from local teachers to maximize their effectiveness.

Contractor and Government Official Education:

- **Workshops:** Present energy education workshops for contractors and local building and planning department officials to educate them on measures that reduce the need for energy expenditures in a home or business. Local government should survey contractors and building and planning officials to determine appropriate content for these workshops. An important aspect of this survey would be to determine if workshops should be tailored to specific disciplines.
- **Tours:** Organize tours of energy-efficient homes in Humboldt County to showcase and explain technologies.

3. ELECTRIC LOAD REDUCTION

The objective of this section is to present low-cost measures for reducing electrical loads, which should always be the first step in the design of a renewable energy system. Two load reduction measures are considered in this section: compact fluorescent lights and phantom load reduction.

Compact Fluorescent Lights
Lighting consumes 25-30% of household electrical energy use. Compact fluorescent (CF) light bulbs use less power (in watts) to deliver the same number of lumens as incandescent or halogen lighting. The quality of CF bulbs has improved dramatically in recent years. Many types of CF bulbs are available, and their light quality varies from a cool blue hue to warm yellow tones. People's preference for certain brands differs depending on the desired application and light quality. CF light bulbs operate most efficiently when they are used in fixtures that are left on for over 2 hours per day. They may fail prematurely if they are turned “on” and “off” excessively.

Table 3.1 summarizes a cost and payback time analysis based on a typical CF bulb (life expectancy of 10,000 hrs), compared to incandescent bulbs (life expectancy of 750 hours) and halogen bulbs (life expectancy of 2,000 hours). An initial investment of $8 to $12 per bulb would result in a payback time of 12 to 14 months.

Also included is a comparison of the cost of purchase and operation of a CF torchiere light compared to a halogen torchiere light. Initial cost of the CF torchiere fixture (approximately $75) might be a barrier to consumer acceptance and could be offset using a torchiere trade-in program. These programs entail the consumer exchanging their halogen torchiere, along with $15 to $35, for a new CF torchiere fixture with a CF bulb. CF torchieres also offer a safety advantage, as halogen torchieres pose a serious fire hazard. Utility and/or state conservation funds have supported many successful torchiere trade-in events in other communities in recent years.

Phantom Loads
Many home appliances and consumer electronics products are using electricity constantly, even when their power switch is in the “off” position. Examples of such “phantom loads” are the clocks in VCRs and microwave ovens, the small black wall cubes that adapt DC appliances to run on AC house current, and the instant-on features in televisions and home entertainment centers. These loads typically range from 1 to 10 watts per appliance. A study by Lawrence Berkeley National Laboratory estimated the average standby power load in California residences to be 67 watts. While this may appear to be a fairly small waste of energy, it amounts to a lot of power when added up community-wide. Based on 67 watts per household, Humboldt County’s approximately 50,000 households have a total phantom load on the order of 3.4 MW, or nearly one and a half times the total output capacity of Matthews Dam hydroelectric plant at Ruth Lake.

A phantom load reduction program should consist mainly of consumer education. Phantom loads can be reduced by teaching residents to remember to unplug appliances that are not in use, to enable Energy Star® power-down modes on computer equipment, and to buy products with Energy Star® labels, which have little or no standby power consumption. Local government could also distribute low-cost power outlet strips (available for $4-$10 each) that would allow residents to disable phantom loads. Estimated payback time for this measure would be approximately one year, assuming that each household could reduce their phantom load by one-third by using three outlet strips.

Table 3.1. Comparison of the Costs of Compact Fluorescent, Incandescent, and Halogen Bulbs and their Respective Electrical Use

	60 W Incandescent	15 W CF	75 W Incandescent	20 W CF	100 W Incandescent	25 W CF	275 W Halogen	55 W CF
Number of bulbs purchased*	13	1	13	1	13	1	5	1
Total cost of bulb(s)	$ 6.50	$ 8.00	$ 8.45	$ 10.00	$ 9.75	$ 12.00	$ 24.95	$ 24.95
kWhrs. used in 10,000 hrs.	600	150	750	200	1,000	250	2,750	550
Cost to operate @ 0.13/kWhr.	$ 78.00	$19.50	$ 97.50	$ 26.00	$ 130.00	$ 32.50	$ 357.50	$ 71.50
Fixture Cost	N/A	N/A	N/A	N/A	N/A	N/A	$ 15.00	$ 75.00
Total cost to purchase bulb(s) and to operate for 10,000 hours	$ 84.50	$ 27.50	$ 105.95	$ 36.00	$ 139.75	$ 44.50	$ 382.45	$ 96.45
Cost savings over lifetime of CF bulb	$ 57.00		$ 69.95		$ 95.25		$ 286.00	
Simple payback time**	14 months		14 months		12 months		w/o fixture cost - 8 months w/ fixture cost - 29 months	

* To provide 10,000 hours of illumination.
** Calculated at 3 hrs./day use. N/A means not applicable.

4. WEATHERIZATION

The objective of this section is to present the potential energy savings that could be achieved through a basic set of home weatherization measures. In order to estimate the potential savings, we set up three before-and-after computer models representing 1000-, 1500-, and 2000-ft^2 ("small", "medium" and "large") homes. The models were developed using Lawrence Berkeley National Laboratory's online energy analysis tool, "Home Energy Saver" (HES), which is available at http://hes.lbl.gov. HES is very user-friendly and uses the industry standard building energy analysis computer program, DOE-2, to perform its internal calculations. The analysis is quite sophisticated, incorporating local weather data to calculate year-round energy costs for the modeled home.

We made a number of assumptions in setting up the models to reflect "typical" local homes. The homes are assumed to have been built in 1956 with wood siding, attics and vented crawl spaces, and use natural gas for space and water heating. The space heating system is a central forced air unit with ducts in the crawl space. Existing insulation is assumed to be R-11 in the attic with no wall or floor insulation. While HES also analyzes gas and electric use by appliances such as dryers and stoves, the present discussion considers only energy used for space and water heating.

In addition to changing the house's square footage to create the different models, we also adjusted the home's features in proportion to the size of the house. These features include the number of occupants, heat output capacities of the furnace and water heater, total window square footage, number of laundry loads per week, and other minor features. The 1000- and 1500-ft^2 homes are single-story, while the 2000-ft^2 home is two-story.

The package of weatherization measures analyzed included:

- weather stripping all doors and windows;
- increasing attic insulation from R-11 to R-49 (*Note*: R-49 is the level of attic insulation recommended by the U.S. Dept. of Energy for the local climate zone. California Title 24 residential standards require only R-19 for ceiling/attic insulation in new construction.);
- insulating water heater and hot water pipes;
- tuning up furnace to raise efficiency from 78% to 83%;
- adding heating duct insulation;
- sealing heating duct leaks; and
- installing a programmable thermostat.

Figure 4.1 illustrates where these measures would be incorporated in a typical home.

Table 4.1 shows the results of the analysis. Base case (pre-weatherization) annual space and water heating costs range from $933 to $3,226, depending on house size. These costs come down to $446 - $1500 with the weatherization package implemented, resulting in annual savings of $487 - $1,726. In other words, the model indicates that this package of energy efficiency measures could reduce water and space heating costs in typical area homes by more than half.

(Insert Figure 4.1)

(Insert Table 4.1)

We also used the model of the 1500-ft^2 house with each of the seven measures implemented individually in order to rank the measures according to energy savings value. The results of these runs are shown in Table 4.2. Weather stripping, which presumably is defined in HES as general infiltration reduction (door and window weather stripping and caulking of other gaps) achieves the greatest savings, followed by duct insulation, programmable thermostat installation, and attic insulation.

Cost estimates were generated by surveying local contractors and by seeking “typical” weatherization cost data on the Internet, primarily from Lawrence Berkeley National Laboratory’s “Home Improvement Tool” (HIT) website (http://hit.lbl.gov). For each measure, our collected cost data showed a fairly wide range. We used the lowest and highest reported costs for each measure to estimate the “best” and “worst” energy savings payback periods, respectively.

As shown in Table 4.3, estimated payback periods range from less than half a year to over eight years. Weather stripping, duct insulation, programmable thermostats, and furnace tune-ups all show rapid paybacks (i.e. less than three years), while attic insulation, hot water system insulation, and duct sealing showed longer paybacks. (Note that our model assumed existing R-11 insulation in attics; insulating a completely uninsulated attic would provide a faster payback.) Overall payback for the full package of seven measures ranges from two and a half to five years. These are favorable results, as even a five-year payback represents a 20% annual return on investment.

With the exception of duct sealing, each of the analyzed measures has an expected useful lifetime well in excess of its payback period, assuming that the measures are performed by trained contractors using quality materials. Tune-ups are recommended for gas furnaces every three to five years.

Plans for Further Study

As part of our further study of weatherization measures, we plan to perform the following tasks:

- Analyze more weatherization measures.
- Coordinate with RCAA’s weatherization manager, Val Martinez, to avoid program duplication.
- Acquire NEAT (U.S. Dept. of Energy’s National Energy Audit Tool) software.
- Investigate PG&E (and other) certification programs for weatherization contractors.
- Analyze potential benefits of introducing local “beyond Title 24” energy codes for new construction.
- Refine recommendations for energy education program.

(Insert Table 4.2)

(Insert Table 4.3)

5. SOLAR HOT WATER SYSTEMS

The objective of this section is to determine the cost-effectiveness of solar hot water systems based on their expected performance in our geographic area. A typical system that is appropriate for our area is examined. In addition, the basic types of solar hot water systems are discussed, the importance of energy education and hot water conservation measures are considered, and recommended guidelines for a solar hot water program are presented. Finally, plans for further study are outlined.

Background

Solar water heating systems use energy from the sun to heat water for domestic use. A typical system consists of flat plate solar collectors mounted on the roof, a solar hot water storage tank, an auxiliary water heater (either gas or electric), and miscellaneous components such as pumps, valves, controls, and heat exchangers. The basic function of the system is to circulate water or some other heat transfer fluid through the solar collectors and thereby collect solar heat. This heated fluid then transfers energy to potable water in the solar storage tank. The solar storage tank acts as a pre-heater for the auxiliary water heater. Cold potable water enters the solar storage tank and is heated. When hot water is demanded, water from the solar storage tank is fed to the auxiliary water heater and is further heated, if necessary, before being provided to the end user.

Numerous types of solar hot water systems are available. Four general types are:

- Forced circulation, or “active” systems, which use a pump to circulate fluid through the collector;
- Integral collector storage systems, or “batch” water heaters, which combine the collector and storage tank into one;
- Thermosyphon systems, which have a separate storage tank above the collector that allows fluid to naturally circulate through the collector; and
- Self-pumping systems that use a phase-change or other passive means to cause the fluid to circulate through the collector.

The most common system type is the forced circulation system. Within this system type there are several freeze protection strategies. These include draindown systems, drainback systems, recirculation systems, and closed loop anti-freeze systems. The appropriate type of freeze protection depends on local climatic conditions. The most common type of system installed locally is a forced circulation drainback system. A schematic of this system and its components is shown in Figure 5.1.

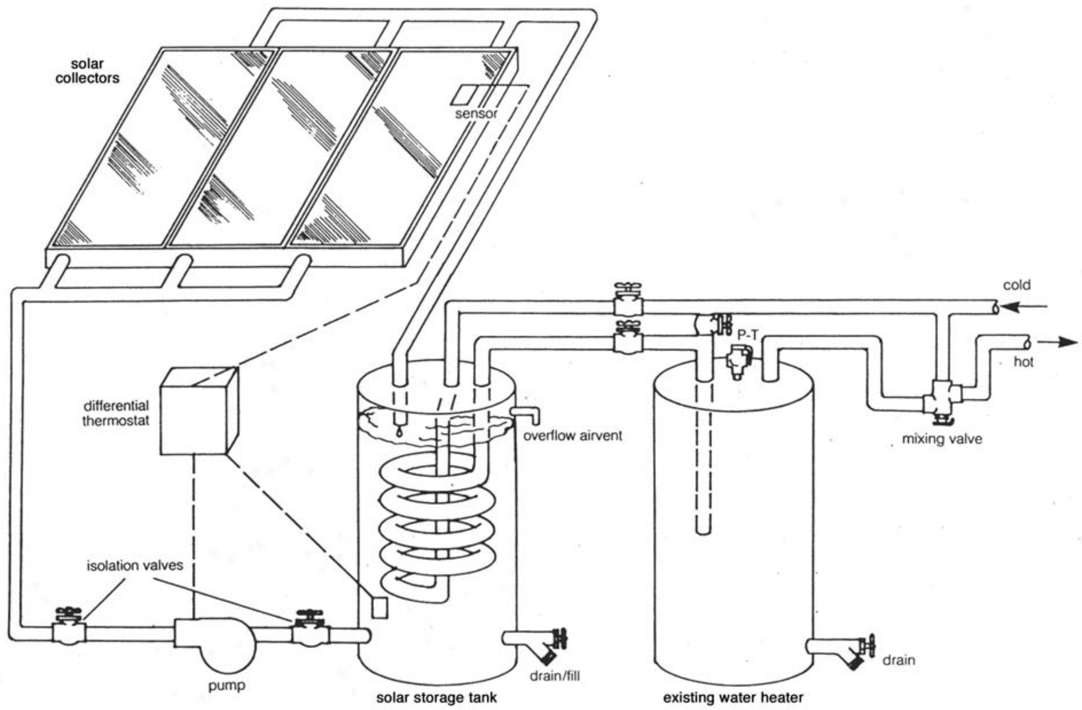


Figure 5.1. Forced Circulation Drainback Solar Water Heating System

Solar hot water systems have been in use for many years. In the 1860's rooftop solar water heaters became popular, but then lost favor when natural gas became readily available. In the 1970's and 1980's, the solar water heating industry saw another resurgence in interest due to a perceived energy crisis and favorable tax credits. Unfortunately, many non-reputable vendors sprang up and installed systems that were less than optimal. As the years passed, however, there was a shake-out in the industry so that most of the systems manufactured and installed today are generally reliable and of high quality.

Many solar hot water collectors and complete solar hot water systems are now certified and rated by the Solar Rating and Certification Corporation (SRCC). SRCC was incorporated in 1980, and is a non-profit, independent third-party certification entity. They are the only nationally recognized certification agency. The SRCC certification criteria cover the following: system design, reliability, durability, safety, operation, servicing, installation, operation and maintenance manuals, and system performance.

The California Energy Commission (CEC) is offering grants of up to $750 for solar hot water systems through their Solar Energy and Distributed Generation Grant Program. To qualify for these rebates the installed system must meet the following criteria:

- The complete solar hot water system must be certified by the SRCC.
- The system must have a minimum Solar Energy Factor (SEF) rating (from SRCC) of 1.4 for systems using electric supplemental heaters and of 0.8 for systems with gas supplemental heaters.
- The system must be covered by a 3-year warranty.

- The system must be installed and operated in accordance with all laws, codes, regulations, standards and manufacturer specifications.
- The system must be installed by a licensed contractor (Class A, C-46, C-53) or the homeowner.

Conservation Measures and Energy Education
As part of a solar hot water program, consumers should first be educated about the importance of using energy wisely. Before investing in a solar hot water system, it is more cost-effective to invest in reducing hot water use. Good first steps include:

- installing low-flow showerheads and faucet aerators;
- insulating existing water heater;
- insulating hot water pipes;
- lowering the thermostat setting on the water heater to 120°F-130°F;
- replacing the washers in any dripping faucets;
- using the cooler cycles on your clothes washing machine whenever possible;
- using cold water, not hot whenever possible; and
- using a timer to turn the electric heating element off during times when hot water is not needed.

In addition, consumers should be informed about how to get the most out of their newly installed solar hot water system. This information should include:

- Shower and wash clothes and dishes late in the day, after the sun has heated your water.
- During warm, sunny weather, turn the electric heating element off completely.

Cost and Savings Analysis for Solar Water Heating
SERC evaluated the potential cost and savings of two solar water heating systems that are currently being offered locally. These were both forced circulation drainback systems featuring SRCC certified SunEarth 4’x10’ flat plate collectors. One system, consisting of two collectors and a 120-gallon solar storage tank, had an estimated installed cost of $4000. The second system, featuring three collectors and a 210-gallon solar storage tank, had an estimated installed cost of $4600. Assumptions used in the analysis were for a typical single family residence in the U.S. (a household of 3 or 4 people) and were generally consistent with SRCC rating assumptions. Analyses were performed for systems with either electric or gas auxiliary water heaters. Economic evaluations included the $750 CEC rebate.

Results shown in Table 5.1 incorporate the current cost of electricity or natural gas for quantities below baseline usage. As shown in the table, solar water heating is much more economically attractive if the resident is currently using an electric water heater. The payback times in this case may range from 8 to 10 years, whereas the payback times are nearly three times as long for somebody who is currently using a gas water heater. These numbers will vary based on numerous system conditions. However, the variables that by far make the most difference are the initial installed cost of the system and the cost of the auxiliary fuel (electricity or gas).

Table 5.1. Savings and Payback Periods Associated with Solar Hot Water Systems

System Size	Energy Use/Yr (before)	Energy Use/Yr (after)	$ Savings/ Year	Payback Period (yrs)	SSF*	SEF**
Electric auxiliary water heater						
2 collectors, 120 gal. storage	5468 kWh	2643 kWh	$327	10	52%	1.9
3 collectors, 210 gal. storage	5468 kWh	1813 kWh	$431	8.9	67%	2.7
Gas auxiliary water heater						
2 collectors, 120 gal. storage	187 therms	90 therms	$122	27	52%	1.9
3 collectors, 210 gal. storage	187 therms	62 therms	$167	23	67%	2.7

*SSF = Solar Savings Fraction. This is the percent of the hot water load met by the solar water heating system.
**SEF = Solar Energy Factor. This factor is calculated as the ratio of the delivered hot water energy divided by the total non-solar energy (gas or electric) required to heat the water. This factor is analogous to the Energy Factor (EF) rating that is given to all electric and gas water heaters.

Table 5.2 examines the effect of the higher electricity prices associated with usage over baseline quantities. If a household uses 130% to 200% of baseline, their electric rate for their above baseline usage will be $0.194/kWh, and for 200% to 300% of baseline, the cost rises to $0.238/kWh. These increases in cost dramatically reduce the payback period for a solar water heater to about 5 to 6 years.

Recommended Solar Hot Water System Guidelines

The following is a list of recommended criteria that participants in a solar hot water program should meet:

- All sites should have clear solar access between at least 9 a.m. and 3 p.m. solar time throughout the year.
- The collector orientation should be within 15° of true south.
- The collector slope should be in the range of 26° to 56° (within 15° of our latitude of 41°N).
- Installed systems should be SRCC certified and should meet CEC requirements.
- Participants should be encouraged, or even required, to adopt basic hot water conservation measures as listed above.

Table 5.2. Payback Times for Solar Hot Water Systems Based on Above Baseline Electric Rates

System Size	$ Savings/ Year	Payback Period (yrs)
Electric auxiliary water heater 130% to 200% above baseline		
2 collectors, 120-gal. storage	$503	6.5
3 collectors, 210-gal. storage	$664	5.8
Electric auxiliary water heater 200% to 300% above baseline		
2 collectors, 120-gal. storage	$617	5.3
3 collectors, 210-gal. storage	$815	4.7

Plans for Further Study

As part of our further study of solar hot water systems, we plan to perform the following tasks:

- Research and analyze other available systems.
- Investigate the availability of solar installers.
- Verify system installed costs.
- Identify the most cost-effective systems for our locale.
- Examine the option of replacing the existing water heater with an on-demand water heater.
- Research the possibility of making bulk purchases of solar hot water systems at a reduced cost.
- Research the lessons learned in other solar hot water programs, such as those promoted by the Sacramento Municipal Utility District (SMUD) and by the State of Florida.

6. SOLAR ELECTRIC SYSTEMS

The objective of this section is to provide approximate installed costs, energy production potential, and typical equipment for two example residential photovoltaic (PV) systems. The two systems specified would generate a peak of approximately 1 kW (AC) and 2 kW (AC), respectively. They would be grid-connected with no battery backup. Lifecycle costs are based on an expected lifetime of 20 years. Participating homeowners would switch their electrical service to “net metering” and would be billed for net annual grid electric use subject to a minimum monthly charge, which is $5.

A residential PV system would allow homeowners to stabilize their electricity costs, contribute to generating electricity in our area, and reduce the environmental impact of their electricity use by generating electricity from a renewable source (the sun).

We assume that homeowners who have PV systems installed will also greatly reduce their overall energy use through conservation and efficiency measures. It is much less expensive to meet energy needs through conservation and efficiency than to install a larger PV system. Average residential electricity use in Arcata is approximately 450 kWh/month (15 kWh/day). In a very energy efficient home, electricity use could be reduced to approximately 240 kWh/month (8 kWh/day). In an extremely energy efficient home, it could be reduced to approximately 120 kWh/month (4 kWh/day). At a site in Arcata with good solar access, a 1-kW system could, on a yearly basis, meet 100% of the electricity needs of an extremely energy efficient house. A 2-kW system at the same type of site could, on a yearly basis, meet 100% of the electricity needs of a very energy efficient house.

Battery backup was excluded from these conceptual designs because it would:

- approximately double the lifecycle cost of the system;
- produce approximately 20% less net energy for the same number of solar panels;
- require battery replacement approximately every five years;
- require active involvement by the homeowner in maintaining the system; and
- require a dedicated shed or room for batteries and other support equipment.

Tables 6.1 and 6.2 list the typical equipment required for 1-kW (AC) and 2-kW (AC) PV systems and their associated costs. The PV modules make up almost 75% of the total hardware costs. A typical configuration for a 2-kW system is shown in Figure 6.1.

Table 6.1. Typical Equipment for a 1-kW (AC) Residential PV System

Quantity	Item	Manu-facturer	Model	$/ea	Watts total	$ total
12	PV Module	Photowatt	PW1000-95	$370	1025 (DC)	$4,440
1	Inverter	AES	GC-1000	$1,000	953 (AC)	$1,000
2	Rack	UniRac	U-GR/160	$325		$650
					Total	$6,090

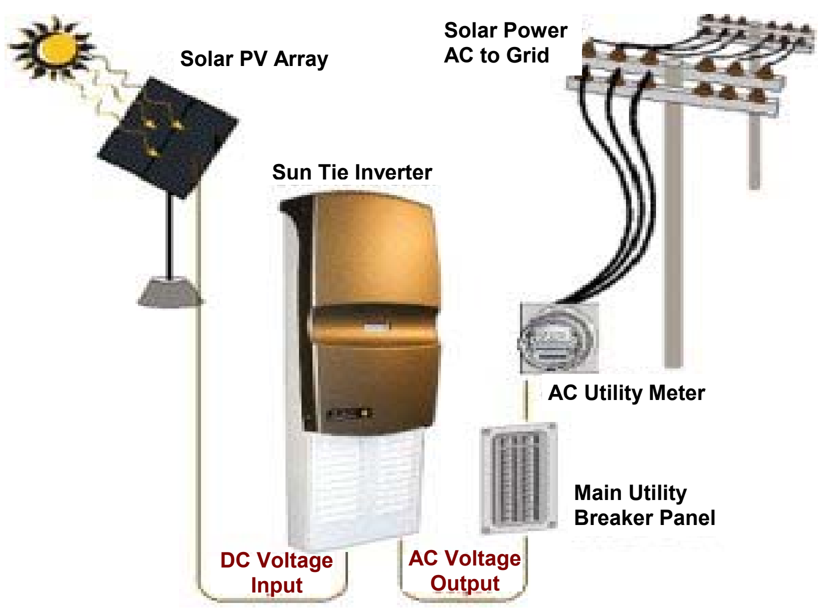
Table 6.2. Typical Equipment for a 2-kW (AC) Residential PV System

Quantity	Item	Manu-facturer	Model	$/ea	Watts total	$ total
24	PV Module	Photowatt	PW1000-95	$370	2050 (DC)	$8,880
1	Inverter	Trace	ST-2500	$1,865	1906 (AC)	$1,865
4	Rack	UniRac	U-GR/160	$325		$1,300
					Total	$12,045

Note: The modules listed are nominally 95 Watts, but are derated to 85.4 Watts by the CEC. The AES inverter has a CEC-rated efficiency of 93%. The Trace inverter has a CEC-rated efficiency of 94%.

SMUD has provided us with a quote for PV modules and inverters for a quantity of 100 2-kW systems. We do not yet have information on the cost of mounting racks. The modules quoted are made of amorphous silicon, which has approximately half the efficiency of the Photowatt multi-crystalline modules and would therefore require twice the module area as compared to the system listed in Table 6.2. Assuming that mounting racks would cost approximately the same as racks for modules of similar size, the hardware cost for a 2-kW system using the quoted modules would be approximately $2000 less than the cost listed in Table 6.2. Installation costs are likely to be significantly higher than the system listed in Table 6.2.

Table 6.3 presents the estimated monthly output at local latitude using local insolation data for a site with good solar access.



Source: Trace Engineering

Figure 6.1. Typical Residential PV System Configuration

Table 6.3. Monthly Output for PV Systems in Arcata with Good Solar Access

System Size	AC Watts total	kWh/month (ave)
1 kW	953	120
2 kW	1906	240

Note: kWh/month is based on average solar insolation for Arcata.

Installed Cost

Based on conversations with four PV installers in Humboldt County and one in Mendocino County, installed costs are approximately $9 to $10 per watt for a 1-kW (AC) system ($9000 to $10,000 total) and $8 to $10 per watt for a 2-kW (AC) system ($16,000 to $20,000 total). The difference between these installed costs and the equipment costs listed in Tables 6.1 and 6.2 reflect the labor costs for installation and the costs of balance-of-system components, such as wires and disconnect switches. Costs will be significantly higher for difficult installations. Output will be significantly lower for sites with a large percentage of shading or roof orientations that are far from optimal.

Solar Access

A site has good solar access if it has:

- minimal shading between 9 a.m. and 3 p.m. solar time year-round;
- roof facing within 15° of true South; and
- tilt within 15° of our latitude of 40.9° on the south-facing roof.

California Energy Commission Rebates

CEC rebates are $4.50/AC Watt or up to 50% of total installed system cost, whichever is less.
For the specified 1-kW (AC) system the CEC rebate would be $4300.
For the specified 2-kW (AC) system the CEC rebate would be $8670.

Summary

Residential 1-kW and 2-kW photovoltaic systems are available that can meet up to 100% of the annual electric use for very energy efficient homes with good solar access. Typical installed costs after CEC rebates are $5200 and $9300 respectively.

Areas for Further Study

- Time of use electric service in conjunction with refrigerator and other timers to improve cost-effectiveness of PV systems
- Group purchasing with SMUD or other organizations to reduce equipment costs
- “Stay-clean” coatings for PV panels
- Develop outreach to builders to include PV systems in new construction
- Develop tie-in with U.S.Department of Energy “Million Solar Roofs” program (http://www.eren.doe.gov/millionroofs/).
- Work with local lenders on low-cost financing of PV systems. Include PV systems in “energy-efficient” mortgages. (http://www.consumerenergycenter.com/homeandwork/homes/inside/mortgages.html)
- Encourage PV systems as mitigation for environmental impact of new construction.
- Expand and publicize solar access ordinances in Humboldt County.

- Develop database of PV systems and PV installers in Humboldt County.
- Expand PV education in Humboldt County.
- Educate news media about PV and expand coverage.
- Encourage local manufacturing of PV system components.

7. ECONOMIC, REGULATORY, AND UTILITY ISSUES

In this section, we consider economic, regulatory and utility-related concerns that local government should take into account in creating residential renewable energy programs. Solar hot water systems are discussed briefly. Greater attention is given to PV systems, as many special issues, including rebates, permits, utility rates, and grid interconnection, all come into play when using this technology.

First, we must state some observations:

- We don't always spend the minimum possible amount of money to get a product or service. For example, people are not necessarily attracted to the cheapest form of transportation: some of the least expensive cars are some of the least sought-after, and mass transit is often the cheapest but least chosen option. Glamour, status, attractiveness, etc. are also factors.
- Our system of economics doesn't tell the whole story of costs. It doesn't recognize externalities (the value of avoided CO_2, SO_2, NO_X). It cannot recognize the value of things that we don't pay for (for example, peace and quiet, elimination of risk of future price increases, philosophical stance).
- Plugging the "leaks" in energy systems by improving efficiency and reducing consumption is almost always cheaper and better for the environment than finding new sources of energy.

Table 7.1 lists examples of energy cost reduction measures and their associated capital costs and payback periods. Of the activities that require some investment, installation of simple, low-cost conservation measures such as CF light bulbs and clothes drying racks probably give the best return per dollar spent. The most beneficial use of solar energy for most consumers is to install a solar hot water heater.

Solar Access
Using passive and active solar energy can substantially reduce energy needed from other external sources, such as electricity and natural gas.

To effectively use solar energy:
- A building must be properly oriented.
- Shading from other buildings and from vegetation must be minimized.
- Installation of solar energy systems must not be prohibited or unreasonably restricted.

Minimizing shading on active solar collectors such as solar waters heaters and solar electric panels is especially important.

Table 7.1. Examples of Energy Cost Reduction Measures, Capital Costs, and Payback Periods

Activity (in decreasing order of cost-effectiveness)	**Cost**	**Estimated Payback Time** (at current local utility rates)
Turn off unused lights (porch lights, etc.)	zero	immediate
Hang up clothes on a drying rack	$20	5-8 months
Change incandescent bulb to CF	$8-12	12-14 months at three hours/day
Reduce unneeded "phantom" loads	$10	1 year
Install a solar hot water system	$4,000	5-10 years (replacing electric heater) 20-30 years (replacing gas heater)
Install a solar PV system	$5,000 - $25,000	19-37 years (see economic analysis)

A legal right to receive solar energy across another person's property is termed a solar easement. Solar easements are guaranteed by California state law and by ordinance in Arcata.

The California Shade Control Act (AB 2321, 1/1/1979) "prohibits any tree or shrub occurring subsequent to the installation of a solar system on another property from casting a shadow greater than 10% over the collector area between the hours of 10 a.m. to 2 p.m.. standard time."

The California Solar Rights Act of 1978 (AB 3250, 9/25/1978) gives people the right to install solar energy systems, grants solar easement rights to property owners and requires that subdivisions be configured to maximize passive solar heating and cooling opportunities.

Arcata city ordinance Section 1-0311 (Solar Siting and Solar Access) defines rules for solar easements and requires that:

- One building may not shade another by more than 10% from 10 a.m.-2 p.m. at any time of the year.
- In subdivisions, 80% of buildings must be oriented within 15° of N-S/E-W.

Legal rights to solar access already exist in state law and Arcata city regulations. Making citizens and planning agencies aware of these laws and regulations can increase enforcement and contribute to increased use of solar energy in Humboldt County.

Solar Hot Water Heaters

California residents who install solar hot water heaters are eligible for a CEC rebate of $750/system. This offer expires June 29, 2001. CEC expects a renewal/extension but will not know for sure until the state budget is signed. The CEC will continue to accept and hold applications pending reauthorization of rebates.

Local government could increase adoption of solar energy by Humboldt County residents by offering pre-approved, reliable solar hot water heating packages purchased in bulk. See the solar hot water section of this report for the analysis of solar hot water systems.

Solar Electric Systems
PV electricity is still more expensive than grid electricity. The cost of PV electricity is highly variable, depending on the capital cost of the system and the assumptions made in the economic analysis. PV electricity rates vary from $0.18/kWh to $0.60/kWh in the Eureka-Arcata area. These costs continue to decrease over time. By buying equipment in bulk and making it easy for consumers to install pre-approved packages (reducing the cost of the building permit and installation), local government can minimize the total cost to the consumer. See the economic analysis section below for more specific information.

The CEC's Emerging Renewables Buydown Program offers a rebate of $4.50/watt or 50% of system cost, whichever is less. The commission derates the output of the system to account for normal operating conditions, so the rebate often turns out to be slightly less than indicated by manufacturers' product specifications. Any homeowner wishing to take advantage of the CEC rebate must use PV modules and inverters that are on the CEC's lists of approved equipment. To be eligible for the rebate, the customer must have a site located in PG&E territory, and the system must be grid-connected. The consumer can install the PV system and still be eligible for the rebate, provided that she/he is able to understand wiring schematics, electrical codes, and mounting techniques.

Space Requirements
As part of this analysis, we examined 1-kW and 2.4-kW systems. The areas required by the sample 1-kW and 2.4-kW crystalline systems are approximately 5' x 20' and 6' x 36' respectively. The best place for such systems is on a south-facing, unshaded roof (within 15 degrees of south and at a tilt of 25 to 55 degrees from horizontal).

There is no minimum system size to qualify for the CEC buydown. The smallest CEC-approved systems are available as 100-W modules with small inverters mounted on the back. These systems tend to be more expensive per watt generated, but offer the possibility of modular expansion. To qualify for the CEC rebate, the maximum size cannot be more than 125% of the site's annual historical or current needs.

Electricity Produced
In one year, a 1-kW system installed in the Arcata-Eureka area will produce about 1200 kWh of electricity. A 2.4-kW system will generate about 3100 kWh per year.

Under California "net metering" law, the homeowner will be credited for this energy by PG&E at the same rate that the homeowner buys electricity. Essentially, the customer's electric meter will run backward as the PV electricity is generated and forward as the house draws electricity from the utility grid. Net metering can be accomplished by using the existing electricity meter. Most families consume between 3 and 30 kWh/day, or 1095 to 10,950 kWh/year. At least once a year, the resident will be charged for the net energy consumed over the past 12 months. In addition, regardless of PV output, PG&E assesses a minimum charge of $0.16 per day for electric service (about $5/month) and will not pay the customer for a net surplus of electricity produced over a 12-month period.

Economic Analysis
We present here three economic measures: $/watt, payback period, and levelized cost ($/kWh). The $/watt figure is simply the initial cost of the system divided by the number of peak watts expected from the system. The payback period is the number of years that elapse before the system generates enough electricity to pay for itself. And the levelized cost is the average annual cost that the resident will pay per kWh of PV electricity.
The conclusions of any economic analysis can change dramatically as the assumptions are varied. For now, however, we use the following: an electricity cost of $0.1332/kWh, an interest or investment rate of 8%, and an inflation rate of 4%. Note that homeowners may be able to combine net metering with time-of-use electric rates to substantially improve the economics of a PV installation. Time-of-use rates are not considered in this preliminary analysis.

The full materials cost of the 1-kW (to be precise, 960 W) system (assuming no discounts), before the CEC rebate, is $8798. Installation charges, including the building permit, are estimated to amount to another $1450, for a grand total of $10,248. The full materials cost of the 2.4-kW system materials is $20,901, with installation charges of approximately $2,150, for a total of $23,051.

The CEC buydown is based on the generating capacity of the PV system. The current rebate amount of $4.50/W will be reduced over time as program funds are depleted. Rebates are given on a first-come, first-served basis. Consumers or retailers can reserve a rebate amount at a specified funding level block. The system must be installed within nine months from the date of reservation. For this analysis, we assume the maximum rebate level of $4.50/W.

Table 7.2 outlines the costs of the 1-kW and 2.4-kW PV systems and their associated economic measures. This analysis shows the cost of PV systems to be quite high, even when the CEC rebate is included. However, these costs need not be a deterrent to the adoption of renewable energy in Humboldt County. Many cities are implementing renewable energy programs that are successful and popular. By using local government bulk purchasing power and permit process streamlining to reduce the upfront cost of the system, we get very different results.

Table 7.2. PV System Costs and Associated Economic Measures

Full Price Systems	System Size	
	960 W	**2.4 kW**
Materials Cost	$8,798	$20,901
Labor Cost	$1,450	$2,150
Total Cost	$10,248	$23,051
CEC rebate	$3,582	$8,704
Net Cost of System	$6,666	$14,347
Net $/watt (peak)	$6.94	$5.98
Payback Time (at .1332/kWh)	37 years	35 years
Levelized Cost	$0.65/kWh	$0.52/kWh

If local government buys PV system components in large volume and streamlines the permitting process to be inexpensive and quick (which would require pre-approved PV system packages), renewably generated electricity can be made affordable and accessible for most people. In the next scenario, we assume a 30% price break on the cost of the PV modules and inverter, a crating fee of zero (for a bulk purchase), and a $50 permitting fee (as opposed to a $350 fee). Table 7.3 outlines the costs of the 1-kW and 2.4 kW PV systems and their associated economic measures based on these price reductions. Labor costs could be reduced even further if installation were simplified with a single contractor performing large numbers of similar installations.

Financing

If the cost of the system is incorporated into the cost of a new house, then the interest payment is tax deductible, in that it is part of the mortgage interest paid. For those customers who are adding a PV system to an existing house, a home equity loan will allow the taxpayer to deduct the mortgage interest. Rates of various types of loans and the tax effect of these loans should all be taken into account when deciding the appropriate financing option.

The only federal incentive for PVs is a 10% tax credit or five-year accelerated depreciation for the cost of equipment. This incentive is available to business taxpayers and not to individuals.

Table 7.3. Discounted PV System Costs and Associated Economic Measures

Discounted Systems	System Size	
	960 W	2.4 kW
Materials Cost	$6,217	$14,192
Labor Cost	$1,150	$1,850
Total Cost	$7,367	$16,042
CEC rebate	$3,582	$8,021
Net Cost of System	$3,785	$8,021
Net $/watt (peak)	$3.94	$3.34
Payback Time (at .1332/kWh)	23 years	19 years
Levelized Cost	$0.27/kWh	$0.18/kWh

Property Taxes

All PV systems installed from 1999 to 2006 will not be subject to property taxes. However, the PV systems would significantly increase the sales value of the homes.

Interconnection Agreement

In order to connect to the grid, the resident must enter into an interconnection agreement with the utility and apply for a net metering rate. The interconnection agreement includes technical requirements, system permitting, maintenance obligations, and metering arrangements.

The main utility interconnection standard calls for an inverter that contains all the protective relays and disconnects necessary to protect both the homeowner and utility line workers. This equipment must comply with the standards listed in the Institute of Electrical and Electronic Engineers (P929) and Underwriters Laboratories, (subject 1741). The CEC is sponsoring classes for electricians who would like to be able to install grid-intertied systems. The two-day workshop costs $75 and takes place in a variety of Bay Area locations. Details may be found online at http://www.endecon.com/html/training.html.

The utility interconnection agreement will also specify minimum insurance requirements that the resident must keep. Standard homeowner's insurance may be adequate to meet these requirements. California law prohibits utilities from requiring the homeowner to purchase additional insurance for a PV system.

Permits

A building permit and possibly an electrical permit are required upon the installation of a PV system. Local government can help by making the permitting process fast, efficient, and inexpensive. It would also be helpful if the community or neighborhood approval process were streamlined (for example, compliance with covenants, codes, and restrictions or CC&Rs)

After the PV system has been installed, the local permitting agency, usually a building or electrical inspector, and the utility will need to inspect and approve the system. Corrections to the system installation may be required for approval.

The CEC requires a copy of the building permit showing final inspection and a recent utility statement showing electrical service at the installation location before it begins the rebate process. In addition, the CEC requires a minimum five-year full system warranty against defective parts, workmanship, or unusual degradation of output. For professionally installed systems, the warranty must also include the labor of removing and reinstalling any defective components and shipping costs. Retailers must also provide a five-year warranty against breakdown or degradation in electrical output of more than 10% of the rated output.

Installers

Properly licensed and knowledgeable installers exist in the Arcata area. Contractor costs can range from $500 for a simple installation to $2500 or more for a more complex system. Contractors holding an "A" (general engineering), "C-10" (electrical) or "C-46" (solar contractor) license would be appropriate installers.

The CEC provides many resources for those wishing to install PV systems. These include a consumer guide, a guidebook for the program, lists of eligible PV modules and inverters, links to relevant websites, etc. All of these can be found online at http://www.energy.ca.gov.

Recommendations

Because even the discounted 1-kW system has a consumer cost of nearly $4,000, we would recommend consideration of smaller PV systems, from 0.5 kW to 1 kW in size. Local governments should consider what levels of investment would be comfortable for the target residents. Participating local government agencies could also consider subsidizing the purchase of PV systems through grants or low interest loans.

Another argument in favor of smaller systems is that the area needed for smaller systems is more likely to be available on most rooftops. Note also that because crystalline PV modules have a higher efficiency than amorphous ones, they will take less room for the same output. Homeowners may also wish to fit solar hot water collectors alongside their PV modules. However, the cost per kWh generated increases as the size of the system decreases. In addition, more installations will be necessary with smaller systems to supplant grid power with green power.