

Potential low energy strategies for new housing for the Pinoleville Pomo Nation community in Lakeport, CA

Executive Overview

The Pinoleville Pomo Nation (PPN) today is facing several critical challenges associated with the development of housing infrastructure throughout their communities. In order to meet the growing demand of people seeking to return to the lands of the PPN, more housing developments are being undertaken. At the same time, rising energy costs associated with heating and cooling current houses is placing an increased burden on residents. Furthermore, the drought conditions within and around the PPN are also taxing the resources of the residents and the local government. As a result, the PPN is seeking to implement sustainable technology and best practices that will increase their self sufficiency and meet their housing, energy, and water conservation needs.

Some of the sustainable technology and best practices being considered to address the afore mentioned concerns are solar photovoltaic systems, wind turbine systems, passive and active solar water heaters, grey water systems, and passive building design strategies such as passive solar gain and sun shading. The solar photovoltaic and wind turbine systems are being evaluated for power generation capabilities, while the solar water heaters are being evaluated for water storage and heating capabilities. The grey water systems are being considered for its water conservation capabilities, and the passive building design strategies are being considered for their impact on overall household energy usage.

This paper focuses on the design and development of sustainable, energy efficient housing infrastructure for the PPN Lakeport community and the adoption of sustainable technologies and best practices by the residents of Lakeport. This paper will outline the basic caveats and the potential return on investment associated with power generation technology, building design strategies, and water heating technology to meet the needs of the PPN.

1. Understanding the Community Needs – Results from a public innovation workshop

On April 13, 2008, residents of the PPN in northern California and members of the University of California, Berkeley (UCB) Community Assessment of Renewable Energy and

Sustainability (CARES) sustainability consulting and engineering organization participated in an innovation workshop to understand the sustainability and environmental needs of the PPN community and to provide recommendations for housing designs for the community. The underlining principal of the innovation workshop is that the residents of the PPN community are the most knowledgeable about their needs and therefore should be active participants in the design process of their housing.

The innovation workshop began with an ice-breaker session in small groups of 3-5 people. The listening session was then followed by a large group round robin session on good and bad technology in order to increase the comfort level of discussing technology and to learn the impact of different technologies on different members of the community. Next, the participants were divided into three groups (Elders, Adults, and Youth) and the participants described and/or illustrated specific needs related to sustainability in their current environment. Finally, the participants were divided into five groups (Traditional Building Techniques, Energy Generation and Conservation, Exercise and Recreation, Privacy, and Heating, Cooling, and Lighting group) to brainstorm on conceptual design solutions based on the needs generated by the Elder, Adult, and Youth group. Figures 1-6 show images and results from the innovation workshop.

Innovation Workshop Results Presentation



Figure 1: Traditional Building Techniques Group



Figure 2: Privacy Group



Figure 3: Heating, Cooling, Lighting Group

Needs from Elder Group

- Opportunities to Work
- Exercise and Improve
- Fresh Air
- Less Overcrowding
- Host Visitors for Extended Time
- Accessibility around House
- Build Your Own Things with Resources You Have
- Be Able to Grow Your Own Foods (Vegetables and herbs)
- Opportunities to Socialize within Community (Unplanned and Planned)
- Youth to Get Excited and to Build Hands On
- Learn and Use Traditional Techniques
- Buy Equipment to Teach Young Ones Skills

Needs from Adult Group

- More Bedrooms/Big Bedrooms/Bathroom
 - Need: Privacy
 - Activity Space (Sleeping, Playing)
- Solar Panel
 - Need: Lower Electricity Bills
- Asphalt
 - Need: Clean Road (No Dirt when Dry/Mud in Rain)
- Natural Light
 - Need: Save Electricity
 - Cleaner

- Warmth
- Large Kitchen
 - Need: Put All People In
 - Be Able to Gather
 - Cooking Space
 - Storing
- Kitchen Island (Movable)
 - Need: Working Space
 - Shorten Distance Two Sides of Kitchen
- Open Room Between Kitchen & Living
 - Need: To See and Talk to Kids/Guests when Cooking
- Fence Around Community
 - Need: To Protect Against Trespassers (American “Tourists”)
- Fence Between Houses
 - Need: Privacy
- Stray Dogs
 - Need: Protect Little Children Against Bites
- Garage
 - Need: Storage
 - Place to Put Tools

Needs from Youth Group

- | | |
|------------------|------------------------|
| ● Cooling | ● Safety |
| ● Heating | ● Community |
| ● Privacy | ● Exercise |
| ● Individuality | ● Fun |
| ● Swimming | ● Lighting |
| ● Space | ● Power Generation |
| ● Convenient | ● Comfort |
| ● Storage | ● Personal Connection |
| ● Transportation | ● Cultural Integration |

Top Needs from the Elder, Adult, and Youth Groups

- Privacy (10)
- Storage (9)
- Safety (9)
- Comfort (5)
- Exercise (5)
- Conserve Energy (5)
- Lower Energy Costs (4)
- Learn and Use Traditional Techniques (4)
- Space (4)

Sketches of Concepts Brainstormed

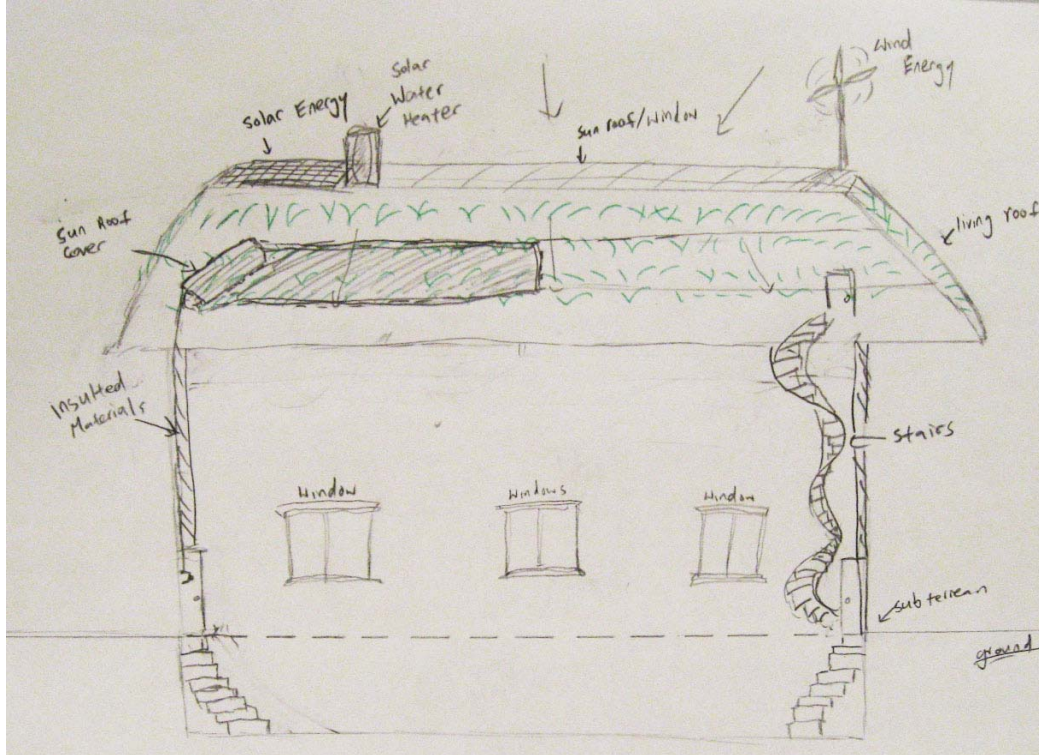


Figure 4: Conceptual Home Design 1 with Solar and Wind Power Generation



Figure 5: Conceptual Home Design 2 Wind Power Generation and Grey Water



Figure 6: Conceptual Home Design 3 with Grey Water, Wind, and Solar Power Generation

Based on the needs and the conceptual home designs generated from the innovation workshop, a new home design shown in Figures 7-11 was generated. The main structure of the design includes a large decagon with five hexagon shaped attachments and a dome shaped roof. We chose to incorporate one large central living space and then smaller added on private spaces to address the needs of community living and openness, but also to address the need for privacy. In our floor plan, you'll see that we allotted the main living area as a split living room and kitchen and then the attachments as private bedrooms or storage. Please see figure 9 for the final prototype.

The design also takes into account cultural and traditional respect for the four directions of North, South, West, and East in addition to Father Earth (down) and Mother Sky (up) for a total of six. We incorporated this into our design with five attachments and one main central unit, making six in total. Overall, we wanted our design to resemble the yurt structure as best as we could while also accommodating for larger families, including space for extended family to stay. In the Pomo Indian culture, the elder family members never move to nursing homes but live with their children when they are no longer able to care for themselves. Therefore, our design allows for "granny units" by using attachments

for additional living space. The roof is dome shaped but flattens out at the top to increase available space for “living roofs”, which we have placed on all roof surfaces.

The living roofs not only have insulating qualities, but also provide space for traditional plants to be grown (addresses needs of optimizing space, energy conservation, and cultural integration). We included lots of windows in our design to take advantage of natural lighting. There are windows above each of the attachments to allow for roof access, large windows in the East and West, and a large circular window at the top of the house in the center of the roof. The opening in the attic allows light to be carried all the way to the lower floor of the house. The window directly on the face of the roof acts as both a sky light and provides access to the roof.

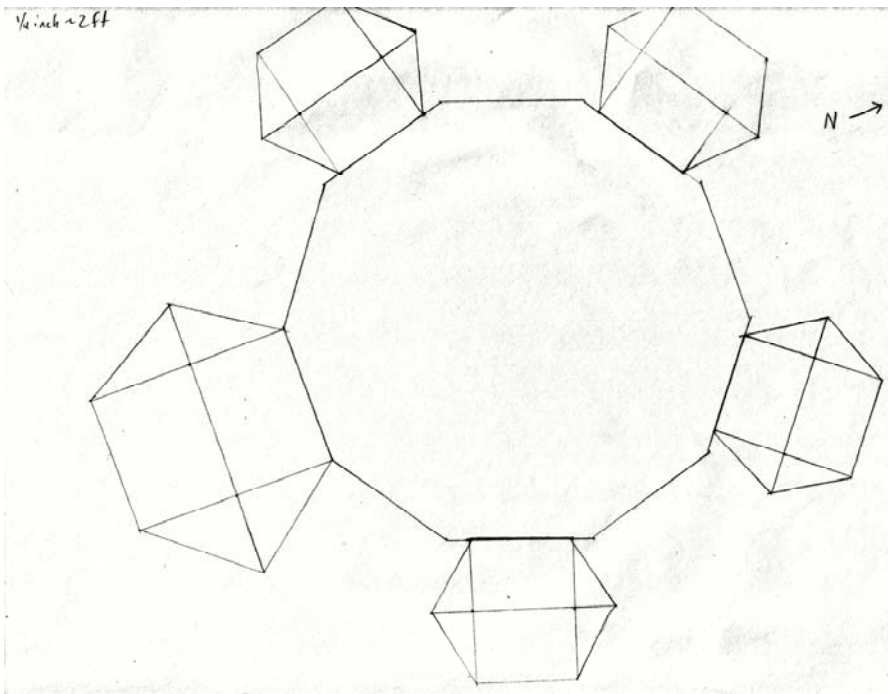


Figure 7: Decagon home with hexagon attached unit

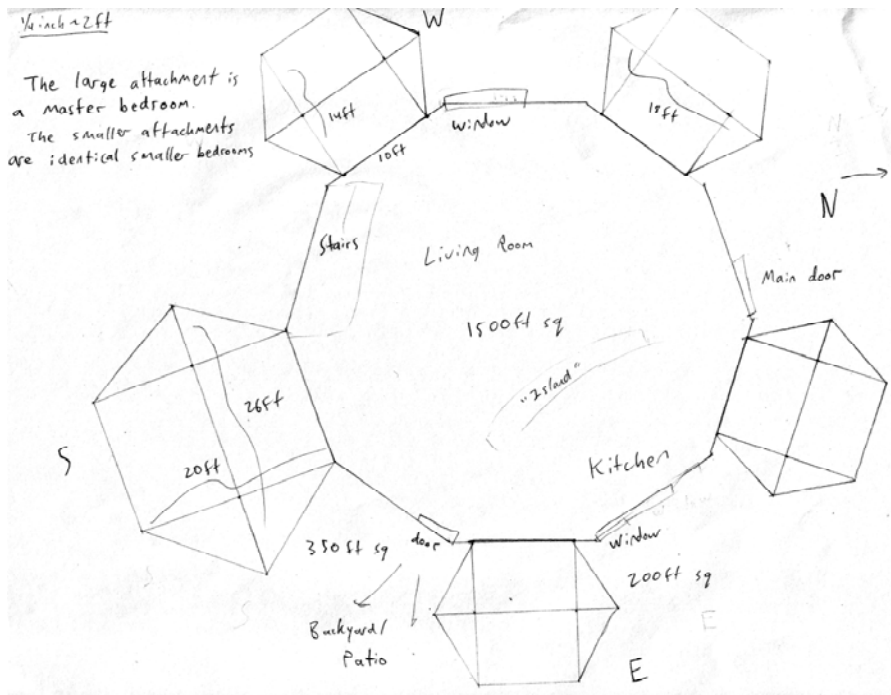


Figure 8: Dimensions of decagon home with hexagon attached units



Figure 9: Final Prototype of Decagon home with hexagon attached units



Figure 10: Prototype of Decagon home with hexagon attached units without roofs

2. Passive Building Strategies

2.1. Climate characteristics and strategies - California Climate Zone 2

The California Energy Commission established 16 climate zones to represent geographic areas in California. Lakeport is located in Lake County and is situated in California Climate Zone 2. This climate is characterized by cold winters and hot summers with a very small number of days within the comfort zone. Figure 11 shows a psychometric map of California Climate Zone 2. This chart represents the temperature and humidity for every hour during a full year. The blue line marked as #1 represents the comfort zone and includes, in this area, only 4.8% of the time.

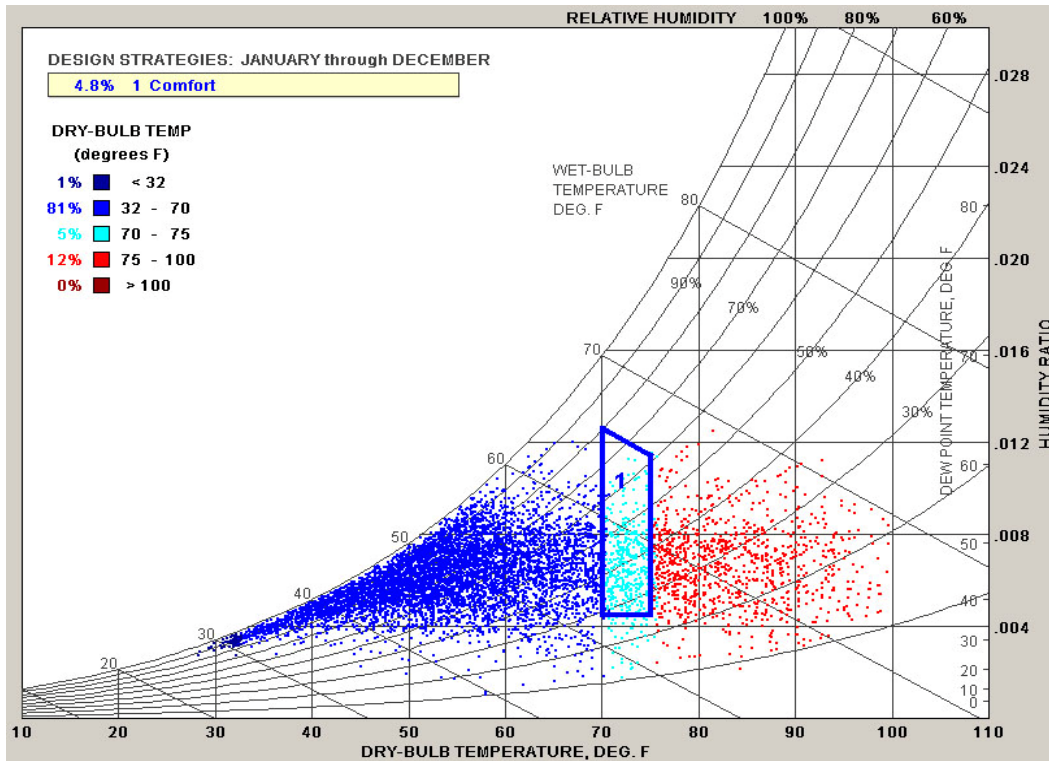


Figure 11: Full year Psychrometric map of California Climate Zone 2

During 12% of the time, the temperature range is above the comfort zone (75-100°F) while during most of the time (81%) the temperature is too cold, ranging between 32-70°F and only rarely getting even cooler than that. This means that this climate suffers both from cold and hot weather and will need climate solutions for both situations to make weather more comfortable. During the winter months the climate is usually too cold, while during the summer months, temperature ranges from being very hot during the day to too cold during the night (Figure 12, 13). The low range of humidity during the summer months makes the heat easier to overcome with passive cooling solutions: building with high thermal mass will reduce the heat load and will add 17.5% of the hours into the comfort zone (marked #3 in Figure 14). The addition of night ventilation to this strategy will help quickly cool down the thermal mass, adding 3.2% more hours into the comfort zone (marked as #4 in Figure 14).

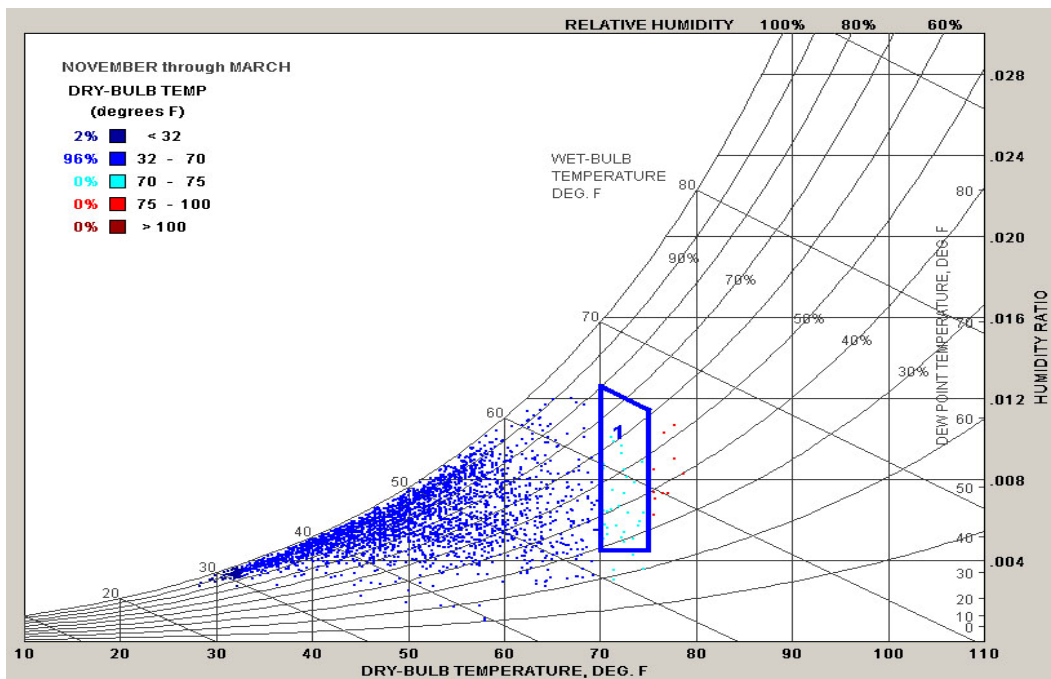


Figure 12: November through March - Psychrometric map of California Climate Zone 2

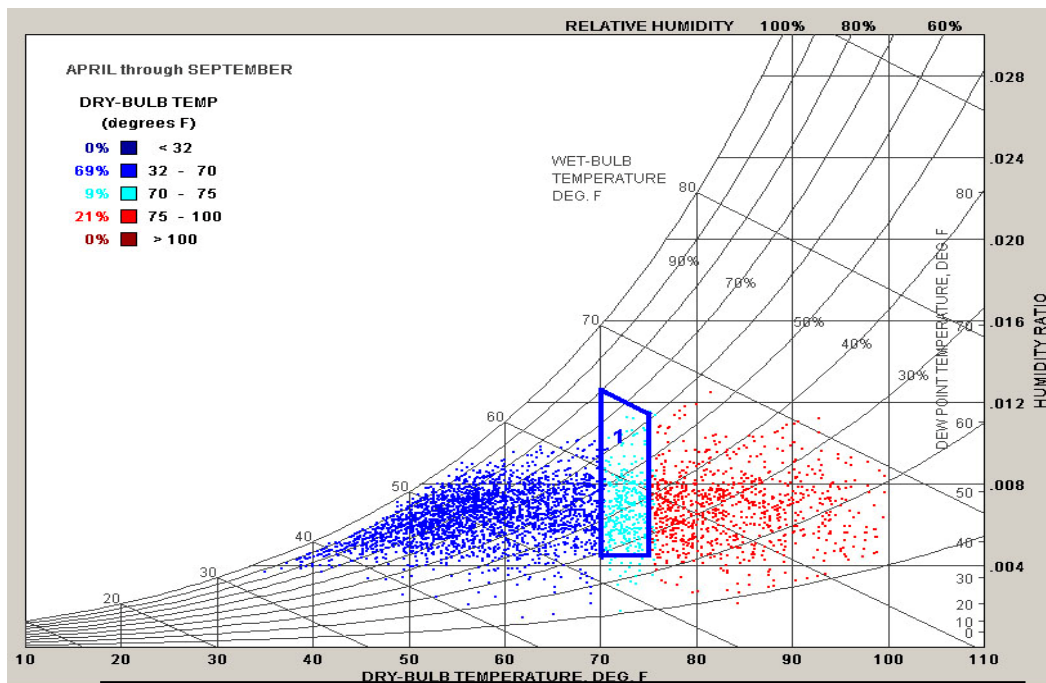
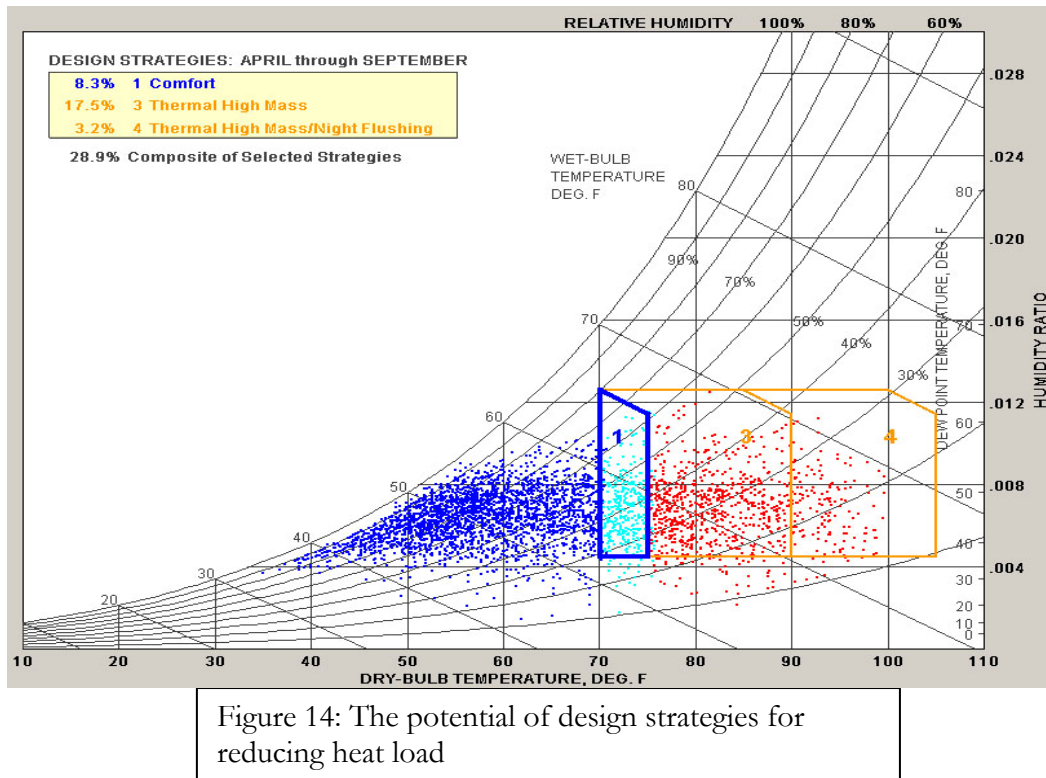


Figure 13: April-September Psychrometric map of California Climate Zone 2



These two strategies will take care of nearly all the over-heated hours and can eliminate completely the need for active cooling systems like air conditioning. The cold weather is more difficult to overcome in this climate as it is spread all throughout the year, during both day and night time. Nevertheless, adding direct internal heat gain through southern windows (marked as #7 in Figure 15) as well as passive direct solar gain through high mass (e.g. heavy wall absorbing direct radiation and radiating it back as heat into the house), marked as #9 in Figure 15, can cover 32% more of the cold hours through the year. These potential strategies bring us to a total of 68% of the time which will not require active, energy-consuming solutions for gaining thermal comfort at home. The rest of the time requires active heating strategies. However, an efficient heating strategy combined with well insulated walls and energy efficient technology can take care of this with minimum energy use. These options will be discussed in the next sections.

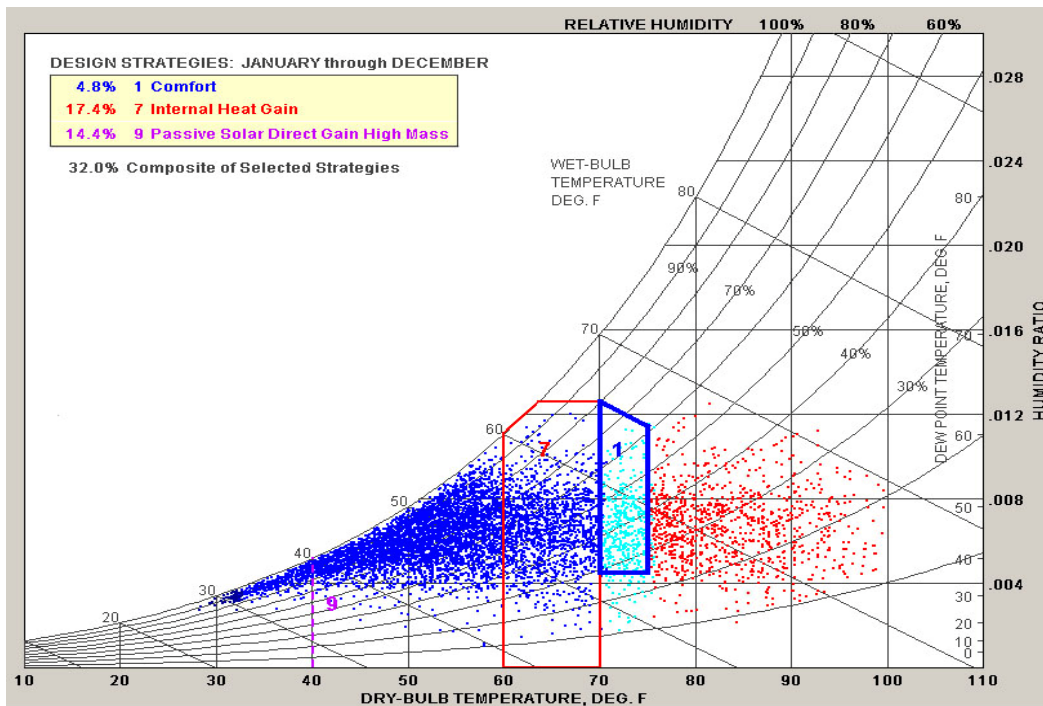


Figure 15: The potential of design strategies for heating

3. Potential Saving through Water Heating Systems

3.1. General information about water heating systems

Solar water heaters come in both active and passive types. Passive systems heat water without the use of moving parts, whereas active systems incorporate pumps and valves to help water circulate. Their main differences are as follows:

- Passive systems do not require moving parts due to the setup (which includes a solar collector, tank, and pipes). Water is heated in the collector, moves up to the tank, and is brought back down through gravity. The reason why it works without pumps and valves is because the tank is placed at a higher position than the collector. Hence, this setup typically includes a tank on the roof.
- Active systems require the use of pumps and valves to keep water circulating. They also use controllers to measure water temperature, energy produced, etc.

Active systems also come in two types: open and closed loop. Open loop systems consist of pumps that circulate water through the collectors. Closed loop systems come in two varieties, one uses a glycol-water mixture to prevent freezing, and the other uses a drain back system. Two types of passive systems include thermosiphon systems and batch heaters. Thermosiphon systems work through natural convection, whereas batch heaters consist of one or more tanks in an insulated box that has a glazed side that faces the sun.

According to the U.S. Department of Energy’s Consumer’s Guide to Energy Efficiency and Renewable Energy, the following solar water heating systems are used for residential applications:

- Flat-plate collector: Glazed flat-plate collectors are insulated, weatherproofed boxes that contain a dark absorber plate under one or more glass or plastic (polymer) covers. Unglazed flat-plate collectors—typically used for solar pool heating—have a dark absorber plate, made of metal or polymer, without a cover or enclosure.
- Integral collector-storage systems: Also known as ICS or *batch* systems, they feature one or more black tanks or tubes in an insulated, glazed box. Cold water first passes through the solar collector, which preheats the water. The water then continues on to the conventional backup water heater, providing a reliable source of hot water. They should be installed only in mild-freeze climates because the outdoor pipes could freeze in severe, cold weather.
- Evacuated-tube solar collectors: They feature parallel rows of transparent glass tubes. Each tube contains a glass outer tube and metal absorber tube attached to a fin. The fin's coating absorbs solar energy but inhibits radiative heat loss. These collectors are used more frequently for U.S. commercial applications.

3.2. Specific Information for choosing a Water Heating System for the PPN Community.

There are many factors to consider in regards to choosing a solar water heating system. The factors include: solar insolation and temperatures of the location, size of the household, price, and Solar Energy Factor (SEF). According to a NASA Surface meteorology and Solar Energy database, Lakeport, CA has the following monthly averaged insolation incident on a horizontal surface:

Table 1: Monthly Averaged Insolation Incident on a Horizontal Surface (kWh/m²/day)

Lat 39.045 Lon -122.918	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
22-year Average	2.11	3.03	4.44	5.75	6.92	7.81	7.88	6.98	5.62	3.98	2.47	1.91	4.91

Due to the nature of Lakeport's climate, it is not recommended to incorporate an ICS system because it is susceptible to freezing. The remaining options are a flat plate collector and evacuated-tube solar collectors. Both could potentially work well under the area's conditions, but evacuated-tube solar collectors will cost more. Lakeport's climate might also call for an indirect circulation system (active system), which is known to work well against freezing conditions. Altogether, the purchase and installation of an active, flat plate solar collector has a price range of about \$2,500 to \$3,500, whereas a passive system has a price range of about \$1,000 to \$2,000. If evacuated-tube solar collectors are desired, they will provide more efficiency but may come at a higher price. The latter only provides a very rough estimate of the initial costs of setting up a solar water heating system, but is primarily based under the assumption that freezing conditions are possible. If that is not the case, then a passive system could be a viable, cheaper alternative.

Using the assumption that the average household in Lakeport, CA has 2.43 people, the average household would need a small (50-60 gallons) storage tank (1-3 people) and roughly 28 square feet of collector area (20 for the first two people, and 8 for each additional person). Based on a rough analysis, the payback rate may be roughly 18 years for gas and 5 years for electric utilities. However, certain factors should be taken into account in regards to this calculation. Most parameters were kept at default, the gas price considered was \$0.60/therm, and the electric price considered was \$.12 /kWh. The latter values were taken from a utilities conservation file from the city of Ukiah, CA. Also, the solar water heating system was assumed to cost \$2000. If it costs \$3500, the payback rate for gas can be nearly 32 years and 8 years for electric. Those two values were considered because solar water heating systems generally range from \$2000 to \$3500.

4. Potential Energy Savings through Renewable Energy Resources: Comparing Wind and Photovoltaic Solar Systems

4.1 Wind Turbine Systems

Wind turbine energy is a great source of renewable energy that produces no harmful byproducts. However, its efficiency greatly depends on the environmental factors associated with the location of the turbine. A prime location must take into account daily wind speeds,

surrounding wildlife, certain building regulations, as well as aesthetic concerns. Wind speeds vary greatly with the height of the turbine. A turbine placed too low not only receives slower, but also more turbulent winds. Turbulence lowers the efficiency of the turbine to harness energy, but more importantly, may cause extra fatigue on the machine and result in damage. According to the California Energy Commission (CEC), the annual wind speed for Lakeport is ~10.1 mph – 11.2 mph at a 98.43 feet elevation, ~ less than 12.3 mph at a 164.04 feet elevation, ~12.3 mph – 13.4 mph at a 229.66 feet elevation, and ~12.3 mph – 13.4 mph at a 328.08 feet elevation.

A small turbine can cost anywhere from \$3,000 to \$50,000 installed, depending on size, application, and service agreements with the manufacturer. A general rule of thumb for estimating the cost of a residential turbine is \$1,000 to \$5,000 per kilowatt. Wind energy becomes more cost effective as the size of the turbine's rotor increases. Although small turbines cost less in initial outlay, they are proportionally more expensive. The cost of an installed residential wind energy system with an 80-foot tower, batteries, and inverter typically ranges from \$15,000 to \$50,000 for a 3- to 10-kW wind turbine without installation costs. The power available from wind is proportional to the cube of its speed. Therefore, (1) little power is generated at low wind speed, (2) increases in average wind speed results in significant increase in the amount of electricity produced, and (3) much more energy available at high wind speeds. Since wind is rather intermittent, it should be noted that the actual power output of a wind turbine is usually lower (~ 25 - 40%) of its rated capacity. An example of a potential wind power system for the Lakeport community can be found from the Bergey Wind Company.

A 10.1 kW, 100 ft Hybrid wind and PV system from Bergey Wind Company is designed for small communities (less than 900 people) that use at least 700 Kilowatts per month and can produce between 750 - 1800 Kilowatt-hours per month depending upon wind and solar resources. This system is designed to operate in areas with annual winds speeds averaging between 9.8 -11.5 mph, includes a battery storage system that can supply 1-2 days of power, and comes with a 30 year warranty. The payback period depends on wind speeds, energy usage, rebate qualifications, and the sale of extra energy produced. The hybrid wind and PV system is estimated to cost \$115, 095, but CEC rebates could potentially lower the cost by

50%. California homeowners pay 12-15 cents/kWh, so if the community uses 1500 kWh/month, at a rate of 12 cents/kWh, it would take about 26.6 years to break even (with the 50% rebate). If only wind is to be considered, the return could come 5 years earlier, but system reliability is reduced due to dependence on only one power source.

4.2 Photovoltaic Solar Systems

Photovoltaic (PV) solar energy systems are another excellent source of renewable energy that takes advantage of the sun and has rather small environment impact. The amount of power generated by a PV solar energy system is dependent upon the amount of sunlight of insolation incident that reaches it, the orientation and tilt of the system, and available square footage. As shown in Table 1, the average annual insolation incident for Lakeport, CA is 4.91 kWh/m²/day. The ideal orientation for a PV solar energy system is true south in North America; however, it should be noted that positioning the system up 45 degrees east or west of true south will not greatly degrade the system's power production performance. The ideal tilt angle for the system is equal to the latitude of Lakeport which is 39.045 degrees. It should be noted that if the PV solar energy system is mounted to the roof of a home, it will have the same tilt as the roof which is typically less than the latitude.

PV solar energy system rated between 1 and 5 kWh is generally sufficient to meet the needs of a typical home. According to the DOE, PV solar energy systems with various efficiencies would need the following square footage:

Table 2: Estimated Square Footage for PV Solar Energy Systems

PV Efficiency (%)	PV Rated Capacity (Watts)	PV Rated Capacity (Watts)	PV Rated Capacity (Watts)	PV Rated Capacity (Watts)	PV Rated Capacity (Watts)	PV Rated Capacity (Watts)	PV Rated Capacity (Watts)
	100	250	500	1000	2000	4000	10,000
4	30 sq ft	75 sq ft	150 sq ft	300 sq ft	600 sq ft	1,200 sq ft	3,000 sq ft
8	15 sq ft	38 sq ft	75 sq ft	150 sq ft	300 sq ft	600 sq ft	1,500 sq ft
12	10 sq ft	35 sq ft	50 sq ft	100 sq ft	200 sq ft	400 sq ft	1,000 sq ft
16	8 sq ft	20 sq ft	40 sq ft	80 sq ft	160 sq ft	320 sq ft	800 sq ft

The estimated PV solar energy system capacity for the Lakeport community is between 2.40 kW - 3.60 kW of peak power capacity with a 300 sq ft area assuming a 750 kWh/month electricity usage and average of 12-15 cents/kWh electricity rate. An example of a potential PV solar energy system for the Lakeport community can be found from the northern California based Sunpower Company. According to SunPower, the estimate cost of the panels and installation is \$38,000 for a household between 1,800 to 2,000 square feet with moderate use of power. Assuming a constant price of \$.12 /kWh, it will take about 15 years to break even. This system also includes a limited 10-year product warranty, which covers repairs, replacements, and refunds remedy in case of a defect in the product. The system also comes with a limited 12-year power warranty and a limited 25-year power warranty, which protects the system from outputting less than 90% and 80% the Minimum Peak Power, respectively. There is a federal tax credit as well as state/utility rebate which can lower the total cost to about \$28,400. Other estimates for a PV solar energy system with a 3.00 kW peak power capacity are \$21,000 – \$32,400 without installation costs for a 1,800 to 2,000 square feet home. The break even point or return on investment point is estimated to be 12 years assuming no property value appreciation.

5. Further Alternatives for Heating Systems

Aside from some simple arrangements that can be done to the house to insulate heat, these are a few, but not all, available technological pathways to limit or even eliminate the usage of propane in heating up the house.

I. First option: switching from cooking with propane stoves to electric ranges.

- i. The cost of one unit starts at around \$400.00 at any local hardware stores.
- ii. This will add about at most \$10 to the monthly electrical bill.

II. Second option: floor heating

- i. Operates on electricity and can act as the “primary heat source” according to WarmlyYours, (Warmly Yours is a company focusing on floor heating development and floor heating products. They have installed floor heating in many households all over United States and Canada)
- ii. The approximate cost of 100 square feet is about \$1200.
- iii. The operating cost of large living room for 8 hours is about \$0.54 per day.

- iv. The system delivers 15 watts per square foot, which is the highest wattage that is “allowed by the National Electric Code”. This wattage can heat the floor from anywhere between “75 to 95 degrees Fahrenheit”.
- v. The system can be installed under any type of flooring, from wood to carpet.
- vi. All systems come with a “10-Year No NonsenseTM Warranty”, which will cover all cost of replacement, labor, and delivery up to 10 years in case of a defect.

These are a few options that we found to be feasible financially, with Option I being the most feasible. The options can be applied by singularly or in combinations. Although Option II seems to be costly, it is important to understand that these as upgrades to your house are to pay themselves off in the long run.

6. Greywater Systems

Greywater is generally defined as water that has been used in a bath, shower, washing basin, dishwasher, kitchen sink, and laundry. It is basically any water that flows from a household except for the water that flows from toilets. It is estimated that 50-80% of residential wastewater is composed of greywater. Reusing greywater reduces the amount of wastewater entering septic systems and increases the amount of freshwater being conserved by a household. The greywater is typically reused for toilet flushing or landscape irrigation. A rough estimate of the daily amount of greywater generated by a household is based upon the number of bedrooms in household. The first bedroom is considered to have 2 occupants while each additional bedroom is considered to have 1 occupant. The estimated amount of greywater generated by each occupant is 40 gallons/day (25 gallons/day due to showers, bathtubs, and washbasins and 15 gallons/day to clothes washer). The estimated amount of greywater generated is equal to the number of occupants multiplied times 40 gallons/day.

A typically greywater system is composed of a (1) plumbing system to transport the greywater out of the household, (2) a surge tank to hold the greywater being generated, (3) a filter to remove foam, hair, and soap debris from the greywater, and (4) a pump to move the greywater from the surge tank to the landscape irrigation system or the toilet. A rough approximation of total greywater system is ~\$500 (\$120 for plumbing parts, \$230 for tank parts, and \$150 for the pump). This does not include the cost of the irrigation system, permit fees, installation, and maintenance costs.

7. Conclusions

It is feasible that the adoption of sustainable technologies and best practices by the residents of Lakeport and the creation of sustainable, energy efficient housing infrastructure for the PPN Lakeport community can lead to a reduction in the amount of energy and water used by the residents of PPN Lakeport community and increase in the independence of the PPN Lakeport community by giving the residents more control over power generation. The adoption of passive building strategies such as sun shading and the usage of building materials with high thermal mass can improve the cooling of households, while the usage of direct internal heat gain from southern facing windows and radiating floor heating can improve the heating of households. Furthermore, the usage of greywater systems has the ability to mitigate the water conservation problems that typically plague the Pinoleville Pomo Nation and its Lakeport community. Further information is needed from the California Department of Water Resources about the permit requirements for implementing residential greywater systems.

Given the low annual wind speed at various heights and the high solar insolation for Lake County, photovoltaic solar energy systems are deemed most feasible for the Lakeport community. It should be noted, however, that the solar insolation and wind speed data obtained in this white paper was for Lake County and the California Climate Zone 2. Therefore, this data is not unique to the Lakeport community. It is recommended that the PPN Lakeport community conduct further analysis on the local wind speed and solar insolation in the community by purchasing a cupped, poled mounted anemometer and a pyranometer sensor to determine which power generation option is most feasible. The equipment needed to conduct these measurements would cost ~ \$930 (~\$220 for a pyranometer sensor, \$625 for a light meter, and \$84 for a pole mounted anemometer).

8. About CARES

The Community Assessment of Renewable Energy and Sustainability (CARES) is a sustainability consulting and engineering organization founded in 2007 that is composed of engineering and architectural graduate and undergraduate students at the University of California, Berkeley. The purpose of CARES is to enable consumers to make informed decisions about sustainability and renewable energy technologies by providing an online platform and database in which users can (1) assess their current level of sustainability, (2)

receive advice on appropriate sustainability and energy solutions, (3) connect with vendors and customers of similar interests to help implement the sustainability and energy solutions, and (4) measure the improvement in their personal level of sustainability and environmental impact. CARES conducts custom user needs innovation workshops, consults with consumers on sustainability and renewable energy technologies and best practices implementation plans, and creates white papers and presentations on sustainability and renewable energy.

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