Final Report for Clean, Reliable, Affordable Energy that Reflects the Values of the Pinoleville Pomo Nation

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Contents

Executive Summary

The Pinoleville Pomo Nation (PPN) is a federally recognized, self-governing Native American tribe located in Northern California's Mendocino County on the outskirts of the city of Ukiah; it is dedicated to ensuring that its "members enjoy safe, healthy, and environmentally benign environments, both natural and built"

This report aims to present and analyze information on the potential of renewable energy power systems and electric vehicle charging near the PPN to provide an environmentally-friendly, cost-effective energy and transportation options for development. For each renewable energy option we examine, solar, wind, microhydro, and biogas in this case, we compiled technology and cost information for construction, estimates of energy capacity, and data on electricity exports rates.

During the one year anemometer testing, it was determined that wind speeds were higher than expected (several over 20 MPH), but that the average wind speeds were between 4-8 mph which makes a wind farm or wind utility unfeasible for the PPN. For a biogas utility, it was determined that it had the lowest levelized cost of energy (LCOE) ($133.43/MWh) of the energy sources tested and that there were several sources of organic feedstock for an anaerobic digester; however, it was unknown how much feedstock these sites produce or if PPN would have reliable access to the feedstock. For microhydro, the head from Ackerman Creek at one of its largest velocities was 0.453 feet (0.138 meters); however, CARES determined that ~4 m of head is need for microhydro system to be viable. For a solar electric vehicle charging system, it was determined that the land area required for peak traffic locations becomes restrictive and thus makes a purely off grid solar EV charging system untenable. Finally, it was determined that a 1-3 MW solar utility was the most viable option for the PPN due to its LCOE of $233.07/MWh and its abundant feedstock that is more easily accessible.

Project Overview & Background

The Pinoleville Pomo Nation (PPN) is one of the Tribal Nations involved in the Tillie-Hardwick decision. This court decision re-instated federal recognition to many California tribes. However, during the two-decade fight for re-instatement, the PPN lost control of its land base, saw community life dissolve, and struggled to maintain important cultural practices. The PPN Tribal Council's principle responsibility is to reverse this decline and create a vibrant, resilient Tribal Nation. This means creating employment opportunities and decent, affordable housing on PPN's lands. It means supporting healthy lifestyles and a healthy environment for PPN citizens. It means promoting Pomo cultural practices and skill-building for the emerging U.S. economy. It also means engaging with neighbors as responsible, respected equals.

With less than 50 of the 250 PPN citizens living on tribal lands in Ukiah and Lakeport, and virtually no employment outside of Tribal government, there is much work to be done. The work must be planned carefully, as the land base is small and must meet a wide array of tribal needs. There are just 99 acres within the reservation, and the PPN controls just a third of that. This is the area where housing, commercial activity, administration, social services, recreation and cultural work will start. The Lakeport property is roughly 24 acres and includes some open space for energy production and other activities, but is primarily dedicated to housing. The Sozonni property is just over 100 acres and is designated for a mix of housing, open space, energy and water production, and some cultural and educational activity. A 50-acre parcel that may come under the PPN's control is home to cemeteries and cultural spaces, and is likely to be off-limits for significant energy production.

The primary site for the feasibility study will be on the Pinoleville Pomo Nation's (PPN) federally-recognized tribal lands. These are located just north of the city of Ukiah in Mendocino County, California. The federally-recognized tribal lands cover 99 acres. However, the lands are "checker-boarded", and the PPN holds 2.7 acres in trust, and another 29 acres as fee land. An allotment to the Williams family, covering just less than 10 acres, is also available for renewable energy development.

Objectives

The primary objective for the feasibility study is to design an energy system that can meet PPN needs for residential, public service and commercial power now and into the near future. Current needs are limited, as the PPN has regained control over approximately a third of its federally-recognized lands just within the last decade. However, plans are being developing for an expansion of housing, PPN government functions, and commercial activities that we would like to power through renewable energy. Energy demand projections will be based on new housing designs that will be tested during the course of the project, and the total number of houses to be built. Plans are in place for an expanded greenhouse and garden project, and there are plans for a resort that must be accounted for. Public buildings that have been included in the planning documents and that will need power include new administrative buildings, a new Head Start, a youth center, a recreational center and perhaps a cultural center. Other projects may be added to the list, when an Integrated Resource Management Plan is finalized, and we will anticipate their power needs as well.

The second objective is to make the project self-sustaining. This means covering maintenance and operation costs, but also depreciation, technological upgrades and further training. We will plan to cover these costs by charging power users within the PPN. However, to keep costs reasonable, and to help stimulate PPN housing and commerce, we will look to sell power to others. We will determine whether to do this through sales to the grid or through direct supply, as a small-scale utility, to neighbors. Additional revenue will be sought through the carbon emissions trading network that is currently being developed. The PPN would like to reduce carbon emissions as an inherent good, but is open to increasing revenues by trading credits to those who need them.

The third objective is to reduce pollution. As noted, PPN is anxious to reduce carbon emissions as a way of addressing climate change. Carbon emissions are expected from current levels by 15 to 20 tons. It is expected that additional power generation to carbon neutral – no new emissions will be added despite the expansion of housing, public facilities and commercial enterprises. Shifting to renewable will also benefit local air and water quality, as there is a shift away from propane and inefficient wood stoves for heating, and reduce brush fires as material is collected for biomass energy production.

The fourth objective is to create energy-related jobs. PPN intends to have 3 to 4 PPN workers trained by engineers from a local nonprofit to assess renewable energy potential, and then to make these crews available to partner tribes and other area tribes to assist with their assessments. The trainees clearly won't be able to do the work of engineers, but they could help install, monitor and evaluate readings from equipment used by engineers. This training should also provide a foundation for those interested in pursuing careers in renewable energy installations. The PPN will work with local providers and rehabilitation programs to promote PPN citizen participation in this growing part of the economy.

Description of Activities Performed

The feasibility study is built around a series of workshops with PPN citizens, with on-site research, engineering modeling, economic analysis, GIS analysis, and environmental and social impact analyses informing the workshop discussions. Project goals and objectives have been discussed in earlier dialogues with PPN citizens and Tribal government staff. The first workshop will review the meeting notes, discuss how they apply to the three sites proposed for development, and make adjustments as needed. We will also look at research findings indicating general renewable energy potential at the PPN's three major land holdings before deciding how to obtain site-specific data. We will discuss how to evaluate proposals for renewable energy installations from environmental, economic and cultural perspectives. We'll propose training opportunities for PPN citizens and discuss the potential to sell power to neighbors.

The fourth and last workshop will finalize the system design, identify permits needed, and explore financing options for building, operating and maintaining the system. The partners review the penultimate designs for comment so that we can present these to PPN citizens. Federal and state agency partners will be included in this workshop to help with permit and funding questions. Subsequent workshops will focus on evaluating different renewable energy scenarios proposed by the research team, based on data collected on-site, through archival research, and through various modeling programs. Barriers to successful project implementation will be identified and the partners will determine if and how to overcome them. The workshops will be supported by collecting and presenting information on energy sources already present in the local area: solar and solar thermal, wind, micro-hydro, biogas, biomass, geothermal electric and thermal. Our analysis will address each of the following areas:

- Site-specific energy source analysis, including analysis of different technologies for accessing energy sources (i.e. solar panels vs. solar film). These will be analyzed in terms of cost, ease of maintenance, reliability, and other social, cultural and environmental factors identified by the PPN

- Load assessments, based on an analysis of the prototype "green" house that is being built and on comparative assessments with model green administrative and commercial buildings. The most appropriate buildings will be researched the most appropriate buildings, but believe that the United Indian Health Service building in Eureka might be a model.

- Transmission and connection issues. The principle issues will be whether to connect to the grid or not, and if and how to sell power outside the PPN. Early in the research process, we will contact neighbors to assess interest and begin developing agreements for purchasing power.

- Assessment of economic, environmental, social and cultural benefits and potential negative impacts of each proposed technology and technology systems. The National Environmental Policy Act guidelines will be followed, but add to them an assessment of greenhouse gas emissions as well as other evaluation criteria specified by PPN citizens, including employment potential, impact on contemporary cultural practices, and links to other PPN projects.

- Maintenance & Operation Costs will be assessed, but also the prospect for Tribal employment, support of PPN businesses, opportunities for science education, and other criteria seen as important by PPN citizens.

Based on these inputs, engineers and PPN staff will develop a series of renewable energy system scenarios, with different mixes of energy sources, different site plans, different transmission and connection approaches. We will obtain outside expert advice on the economic and technical merits of the plan during the fourth workshop, and will invite partner agencies to help us set a schedule for obtaining permits and identify sources for financing and training. Research inputs to the workshops will come from 12 field visits by engineers from a local nonprofit and ongoing energy potential monitoring. Environmental, social, economic and cultural impact assessments will be conducted as scenarios take shape so that PPN citizens can consider this information. Economic analysis, including the building of purchase agreements, will also take place concurrent with the field visits so that they can be reviewed in the final workshop. Training opportunities will be incorporated into the field visits, with opportunities for hands-on experience between visits. A formal training opportunity will be located early in the year for those who show interest in careers in assessing and implementing a renewable energy.

Solar Utility Study

Concept Brief

The purpose of this renewable energy feasibility study is the assessment of solar energy potential to generate electricity to be sold on the open energy market. This study will focus on the sites identified by the PPN as the land area under consideration for the solar utility project of 3 MW.

Resource and Site Assessment

The National Renewable Energy Laboratory's (NREL) developed PVWATTS Version 2 photovoltaic electricity energy calculator was utilized to determine the solar radiation of the land areas identified by the PPN. [17, 10] PVWatts Version 2 estimates the energy production performance of locations in the United States 40 km grid cells. It should be noted that each grid cell displayed in the PVWatts Version 2 is a 40km x 40km area of interpolated solar resource data assembled using the Climatological Solar Radiation (CSR) model. The locations selected for this assessment of solar resources has coordinates of 39.084 degrees Latitude and -123.295 degrees Longitude. Figure 1 shows the areas analyzed in this study: 2.19 acres (orange), 2.64 acres (yellow), 3.46 acres (green) and 7.12 acres (red).

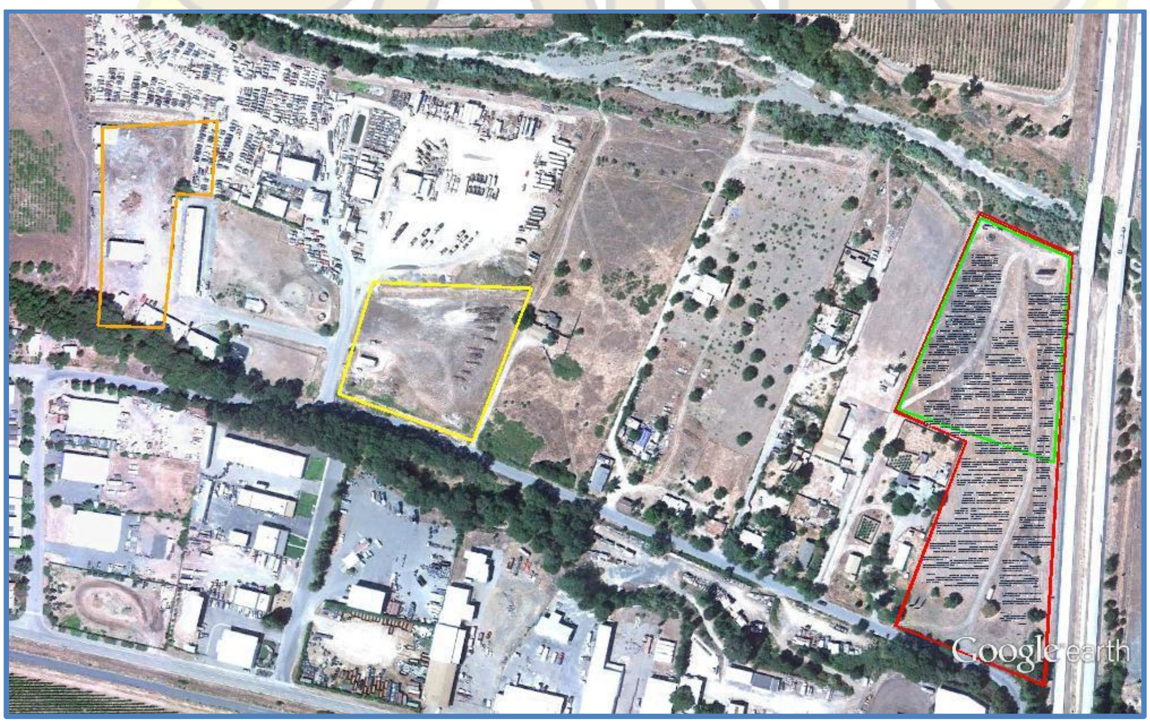


Figure 1: PVWatts Version 2 Average Solar Radiation of 5.36 kWh/m^2/yr @39.084 Lat & -123.295 Long

The annual average solar radiation in this area is estimated to be 5.36 kWh/m^2/day, the total annual energy output is 4,136,319 kWh, and the average monthly energy output is 344,693 kWh (345 MWh) assuming a fixed photovoltaic array fixed facing south. The monthly breakdown of solar radiation can be seen in Table 1.

Table 1: Monthly & Yearly Avg. Solar Radiation for Fixed PV Array Fixed Facing South

Month	Solar Radiation (kWh/m^2/day)	Annual Energy Output (kWh)
1	3.25	220,292
2	4.46	274,598
3	4.98	337,269
4	5.78	373,737
5	6.21	406,748
6	6.35	393,953
7	6.81	432,753
8	6.87	437,957
9	6.64	411,834
10	5.60	368,451
11	4.04	260,048
12	3.29	218,680
Avg. Year	5.36	Total: 4,136,320

It should be noted that both a single axis and a two axis tracking array facing south will result in a higher collection of solar radiation, ~22% and ~27% higher respectively as both arrays can track the sun as it moves across the sky. For 3 MW solar utility with a ***single*** axis tracking array facing south, the annual average solar radiation in this area is estimated to be **6.89 kWh/m^2/day**, the total annual energy output is 5,420,481 kWh, and the average monthly energy output is 451,707 kWh (452 MWh). For 3 MW solar utility with a ***two*** axis tracking array facing south, the annual average solar radiation in this area is estimated to be **7.32 kWh/m^2/day**, the total annual energy output is 5,747,478 kWh, and the average monthly energy output is 478,957 kWh (479 MWh). The monthly breakdown of solar radiation for both a single and two axis array can be seen in Table 2 and Table 3.

Table 2: Monthly & Yearly Avg. Solar Radiation for a Single Axis PV Tracking Array Facing South

Month	Solar Radiation (kWh/m^2/day)	Annual Energy Output (kWh)
1	3.65	249808
2	5.19	322026
3	6.13	421006
4	7.53	496993
5	8.36	564153
6	8.92	576033
7	9.52	624431
8	9.34	611477
9	8.58	542496
10	6.90	456271
11	4.72	306365
12	3.72	249422
Year	6.89	Total: 5,420,481

Table 3: Monthly & Yearly Avg. Solar Radiation for a Two Axis PV Tracking Array Facing South

Month	Solar Radiation (kWh/m^2/day)	Annual Energy Output (kWh)
1	3.78	258,016
2	5.29	327,344
3	6.22	427,523
4	7.87	520,146
5	9.15	616,275
6	10.15	652,206
7	10.64	695,606
8	9.94	651,140
9	8.79	556,383
10	7.05	465,797
11	4.91	316,912
12	3.90	260,131
Year	7.32	Total: 5,747,479

Technology Assessment

This section of the feasibility study covers the substation, transmissions, and photovoltaic systems needed to produce 3 MW. It is estimated that a 3 MW system will utilize ~6 acres.

Substation Location

There are two 115 kV substations within four miles of the Pinoleville Pomo Nation (PPN): Capella Substation (ID #: 4341, ~3 miles away) and Ukiah Substation (ID #: 4277, ~3.8 miles away). There are also several transmission lines near the PPN as well: Mendocino-Ukiah, Mendocino #1+, Ukiah-Hopland-Cloverdale+, and the Mendocino-Philo Jct Hopland+ line. In particular, there is a 12kV distribution line (Calpella 1102) that runs into the PPN's land. The presence of these systems to the PPN makes the development of solar power plant ideal. Please see Figure 2-3 for the substation and transmission line locations.

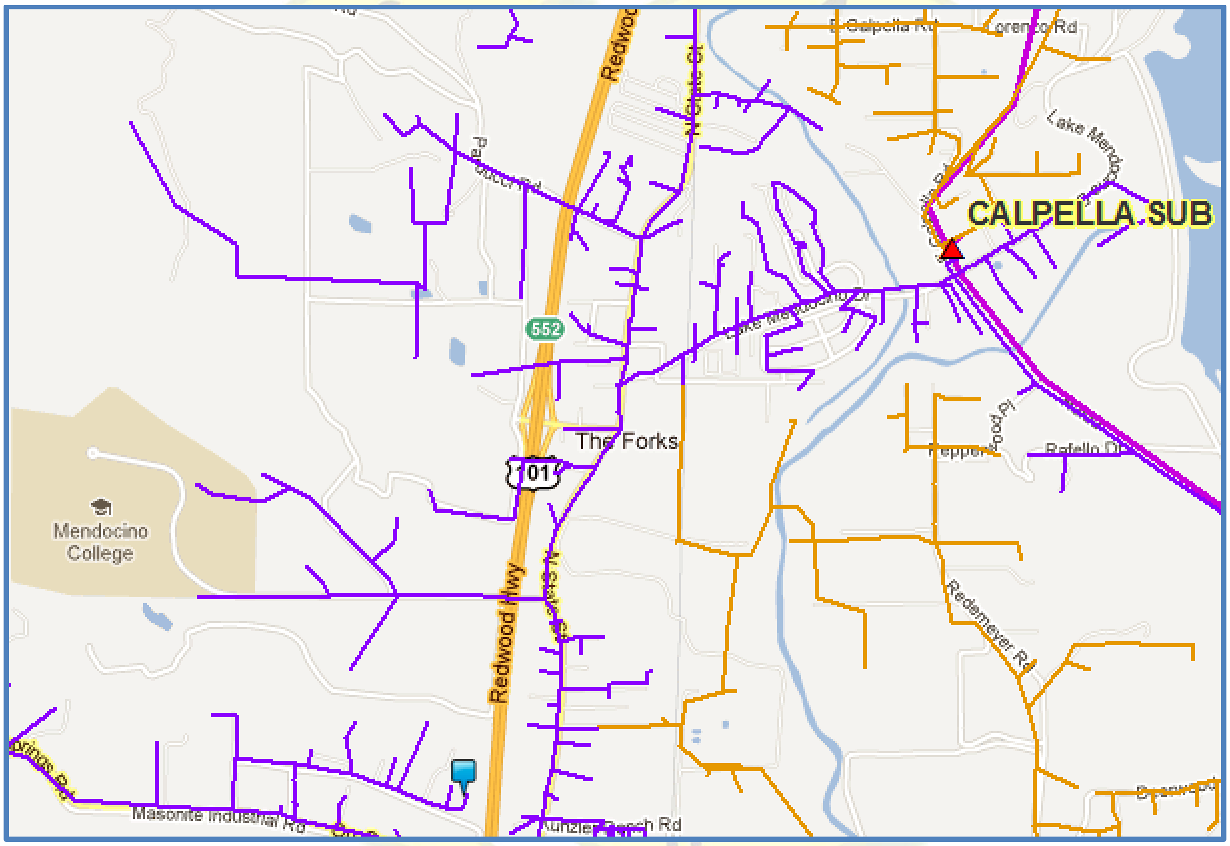


Figure 2: 115 kV Capella Substation (red triangle) and 12kV transmission line near the Pinoleville Pomo Nation (blue square)

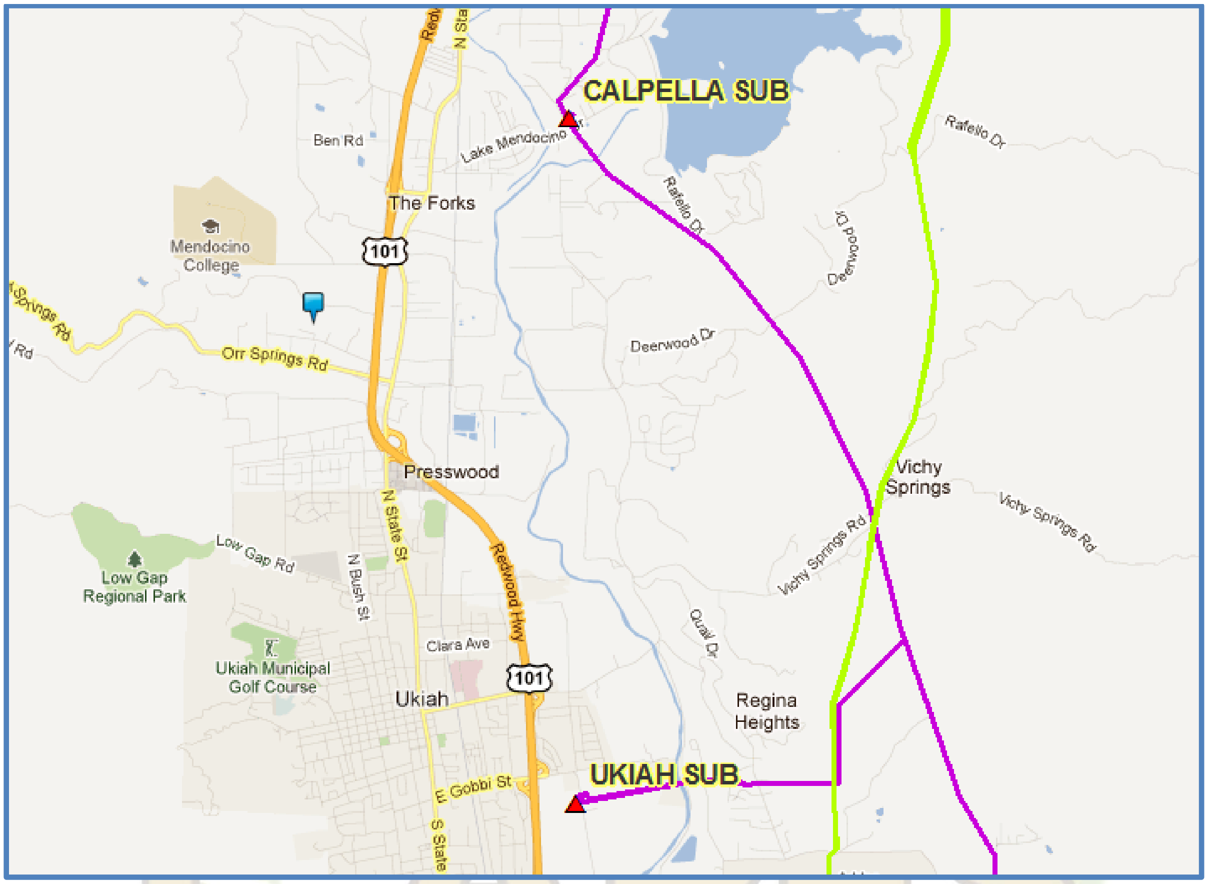


Figure 3: 115 kV Substations (red triangle) near the Pinoleville Pomo Nation (blue square)

Photovoltaic System

Retscreen International Clean Energy Project Analysis software was utilized to selected suitable photovoltaic modules for the 3 MW solar utility. Table 4 provides the summary of the modules and their specifications considered in this study. [12, 6, 7, 8,14]

Table 4: Photovoltaic Modules' Specifications

Module Manufacturer	Model Number	Voltage @ Max Power (Volts)	Current @ Max Power (Amps)	Capacity (W)	Module Efficiency (%)	Area (m^2)	Weight (lbs/kg)
Sharp	ND-198UC1	26.3	7.52	198	13.4	1.48	39.6/18
Sharp	ND-L230Q1	30	7.67	230	14.1	1.63	44.1/20
Heliene	HEE215MA68	30.3	8.22	250	15.3	1.63	41.9/19
Lumeta	PowerPly 400	82	4.88	400	13.8	2.90	65/30
Sanyo	HIP215NKHA5	42	5.13	215	17.1	1.26	35.3/16

Economic Assessment

The National Renewable Energy Laboratory's (NREL) developed PVWatts Version 2 photovoltaic electricity energy calculator and Retscreen International Clean Energy Project Analysis software was utilized estimate the energy value of the electricity exported to the grid based on annual solar radiation and the return on investment time horizon for each photovoltaic module listed in Table 4.

The PVWatts Version 2 calculator uses the following parameters: DC rating, DC-to-AC derate factor, Array type, Tilt angle, Azimuth angle, and Electricity cost or export rate. For the PVwatt analysis, the DC rating was set to 3,000 kW (15 kW), the DC-to-AC derate factor was set to .77, the array tilt was set to 38.444 degrees and the Array azimuth was set to 180 degrees relative to true south. The array type was varied between fixed tilt, single, and two axis tracking over a range of electricity costs or export rates from 11.6 (cents/Kwh) to 13.6 (cents/Kwh) or [116 ($/MWh) to 136 ($/MWh)]. It should be noted that the 2004 average electricity cost or export rate in the Ukiah area was 12.8 (cents/Kwh) or 126 ($/MWh) [17]. Figure 4 shows difference between the energy value from the fixed tilt, single axis, and two axis tracking systems over electricity export rate from 11.6 (cents/Kwh) to 13.6 (cents/Kwh).

As seen in Figure 4, a single axis tracking system results in roughly a 24% increase in energy value of electricity, while a two axis tracking system results in roughly a 28% increase compared to a fixed tiled system. This is due to the fact that a 3MW, single axis system produces **5,420,481 kWh** (5,420.48 MWh), while a 3 MW, two axis tracking system produces **5,747,479 kWh** or 5,747.48 MWh. A 3 MW, fixed tilt system only produces **4,136,320 kWh** or 4,136.30 MWh. It is estimated that a solar fixed array and its components cost $.18/W installed, a single axis tracking system and its components costs $.22/W, and a 2 axis tracking system and its components cost $.27/W installed. There is a ~ 18% cost difference between the fixed and single axis system option and a ~33% cost difference between the fixed and two axis system option. As a result, it is recommended that the PPN select a **single axis** tracking system for their photovoltaic utility as the ~18% cost difference and the 24% increase in energy value of electricity results in a net energy value gain of 6%.

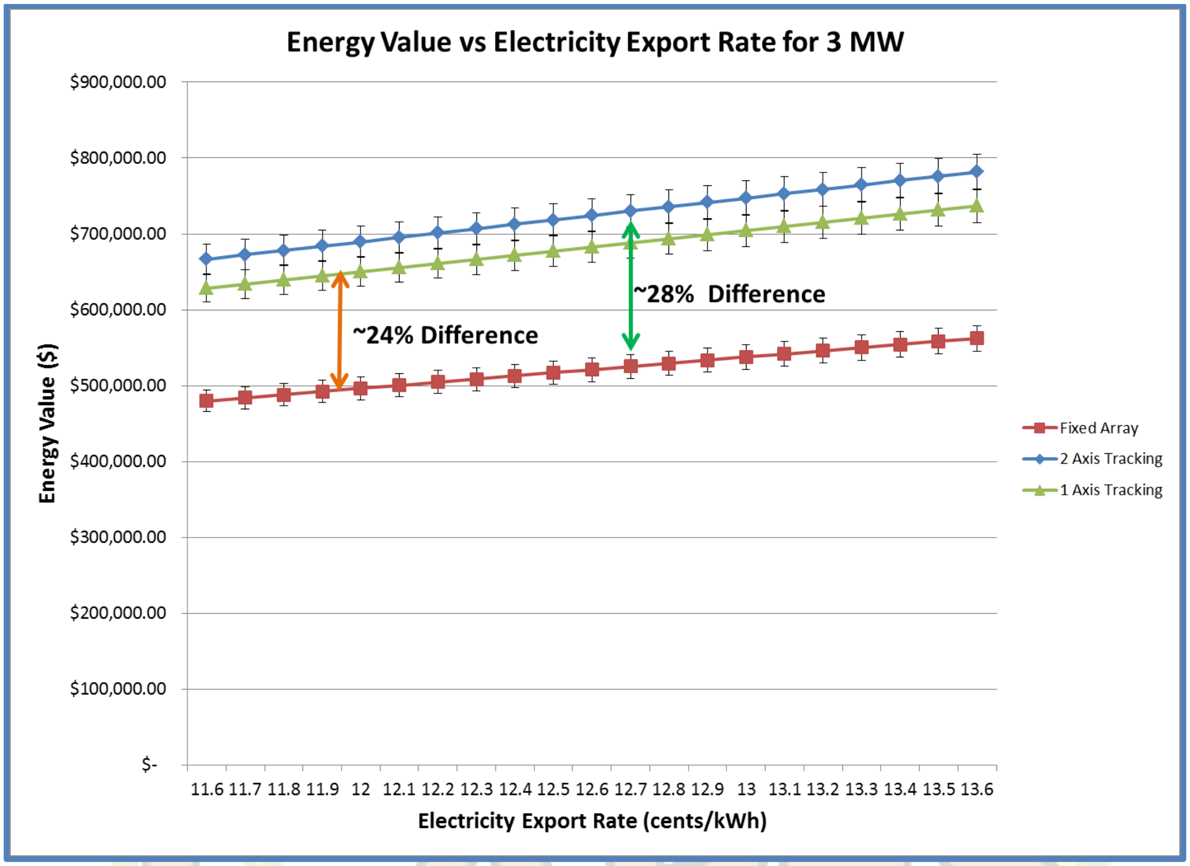


Figure 4: Energy value vs. Electricity Export Rate for fixed tilt, single, and two axis tracking systems

Substation and Transmission Line Costs

The average cost in the US in 2007 to connect generators without large transmission lines to the grid was $91,289/MW. Of this $91,289/MW, the cost of substation and grid upgrades was $65,639/MW and constructing a small transmission line to the existing grid accounts for $25,650 per MW of this cost.

Based on a 2009 Black & Veatch report, the capital cost to build a new 230 kV AC Single phase substation is $35,000,000 [1]. It is estimated that the capital cost to build a new 69 kV AC Single phase substation is ~$10,000,000. The cost to build a new transmission line is $1,600/MW-miles which is an average cost and doesn't reflect the added cost of traversing mountainous terrain. Given that the proposed PPN solar site are ~3.5 miles from the substation and transmission line, it is CARES's viewpoint that the PPN **should not** invest in creating their own substation, but rather should connect to the substation owned by PG&E.

Levelized Cost of Energy for Solar

Even though Figure 4 provides an excellent estimation of the profit the PPN could receive if the solar utility was operating at 100% capacity, it does not take into account the capital, O&M and connection costs that affect the revenue for the solar utility. According to the Energy Information Administration's (EIA) Annual Energy Outlook 2011 released in December 2010, the total levelized cost of energy should be used to assess the overall competiveness of different power generating technologies. [19, 20] Total levelized cost of energy represents the present value of the total cost of building and operating a generating plant over an assumed lifetime converted to equal annual payments and expressed in terms of real dollars to remove the impact of inflation.

Total levelized cost of energy reflects overnight capital cost, connection costs, fuel cost, fixed and variable O&M cost, financing costs, and an assumed utilization rate for each plant type. For technologies such as solar, there are no fuel costs and relatively small O&M costs. As a result, the total levelized cost of energy is driven by overnight capital cost of generation capacity. In this analysis, no incentives are considered to lower the total levelized cost of energy. The equation for the total levelized cost of energy (tLCOE) is as follows: tLCOE= {(overnight capital cost [$/MW] * capital recovery factor + fixed O&M cost [$/MW-yr])/(8760 * capacity factor)} + (fuel cost * heat rate). The capital recovery factor (CRF) is ratio of a constant annuity to the present value of receiving that annuity for a given length of time. The equation for the CRF is as follows: CRF = {i(1 + i)^n} / {[(1 + i)^n]-1}, where i is the interest rate and n is number of annuities over project lifetime. Table 4 shows the estimated EIA total levelized cost of energy from new generation sources connected to the grid in 2016.

Table 5: EIA levelized cost of energy from new generation sources connected to the grid in 2016

Plant Type	Capacity Factor (%)	U.S. Average Levelized Costs (2009 $/megawatthour) for Plants Entering Service in 2016				
		Levelized Capital Cost	Fixed O&M	Variable O&M (including fuel)	Transmission Investment	Total System Levelized Cost
Conventional Coal	85	65.3	3.9	24.3	1.2	94.8
Advanced Coal	85	74.6	7.9	25.7	1.2	109.4
Advanced Coal with CCS	85	92.7	9.2	33.1	1.2	136.2
Natural Gas-fired						
Conventional Combined Cycle	87	17.5	1.9	45.6	1.2	66.1
Advanced Combined Cycle	87	17.9	1.9	42.1	1.2	63.1
Advanced CC with CCS	87	34.6	3.9	49.6	1.2	89.3
Conventional Combustion Turbine	30	45.8	3.7	71.5	3.5	124.5
Advanced Combustion Turbine	30	31.6	5.5	62.9	3.5	103.5
Advanced Nuclear	90	90.1	11.1	11.7	1	113.9
Wind	34	83.9	9.6	0	3.5	97
Wind – Offshore	34	209.3	28.1	0	5.9	243.2
Solar PV1	25	194.6	12.1	0	4	210.7
Solar Thermal	18	259.4	46.6	0	5.8	311.8
Geothermal	92	79.3	11.9	9.5	1	101.7
Biomass	83	55.3	13.7	42.3	1.3	112.5
Hydro	52	74.5	3.8	6.3	1.9	86.4

The EIA estimates that the total levelized cost of energy for solar photovoltaic is $210.70 /MWh. In this analysis, CARES estimates the total levelized cost of energy for photovoltaic in the Ukiah area to be $233.07/MWh. Table 6 lists this report's variables for the calculation of total levelized cost of energy for photovoltaic.

Table 6: CARES estimation total levelized cost of energy for solar utility near Ukiah, CA

Capacity Factor (%)	Levelized Capital Cost ($/MW)	Fixed O&M ($/MW)	Variable O&M (including fuel) ($/MW)	Transmission Connection ($/MW)	CRF	Interest rate	n	Total System Levelized Cost ($/MWh)
25	5,165,592	11,380	0	91,871	0.07882	0.0608	25	233.07

Sensitivity Analysis for Net Project Cost

It should be noted that the Net Project Cost ($/W) is dependent upon local conditions such as interconnection fees from utility providers, equipment costs, and installation costs for regional providers. NREL's CREST model was utilized to estimate the net project costs ($/W) for a fixed 3 MW solar with single axis tracking utility given various solar installation costs in the United States[18]. Based on estimates from the NREL Open PV Project, the 2013 average installation costs in California was $2.76/W [16]. The 2010 average installation costs in the United States was $4.52/W. The latest installation estimates for solar in Ukiah, CA is $6.10/W (zip code: 95482) and $4.72/W (zip code: 95470). It should be noted that NREL is constantly updating its database with the installation costs around the country and these values are valid during the date of accessed on April 12th 2014.

Please note that the Net Project Cost per watt is based upon total installed capacity, generation equipment, balance of plant, interconnection, labor installation, development costs & fee, and reserves & financing costs. Table 7 shows additional cost scenarios and the percent difference from the best case scenario. Figure 6 shows a range of scenarios of net project costs for the 3 MW solar utility without a tracking system. **While the best Net Project Cost that CARES has calculated is $4.40/W, CARES suggests that the PPN should plan for a Net Project Cost of $5.07/W which translates into a total cost of $15,210,000**.

Table 7: Best (yellow), Worst (red), and Suggested (blue) Net Project Cost Scenarios

Capacity (W)	Net Project Costs ($/W)	Total Cost ($)	% Difference from Best Case
3000000	4.4	$13,200,000.00	
3000000	5.07	$15,210,000.00	13.21
3000000	5.3	$15,900,000.00	16.98
3000000	5.58	$16,740,000.00	21.15
3000000	6	$18,000,000.00	26.67
3000000	6.3	$18,900,000.00	30.16

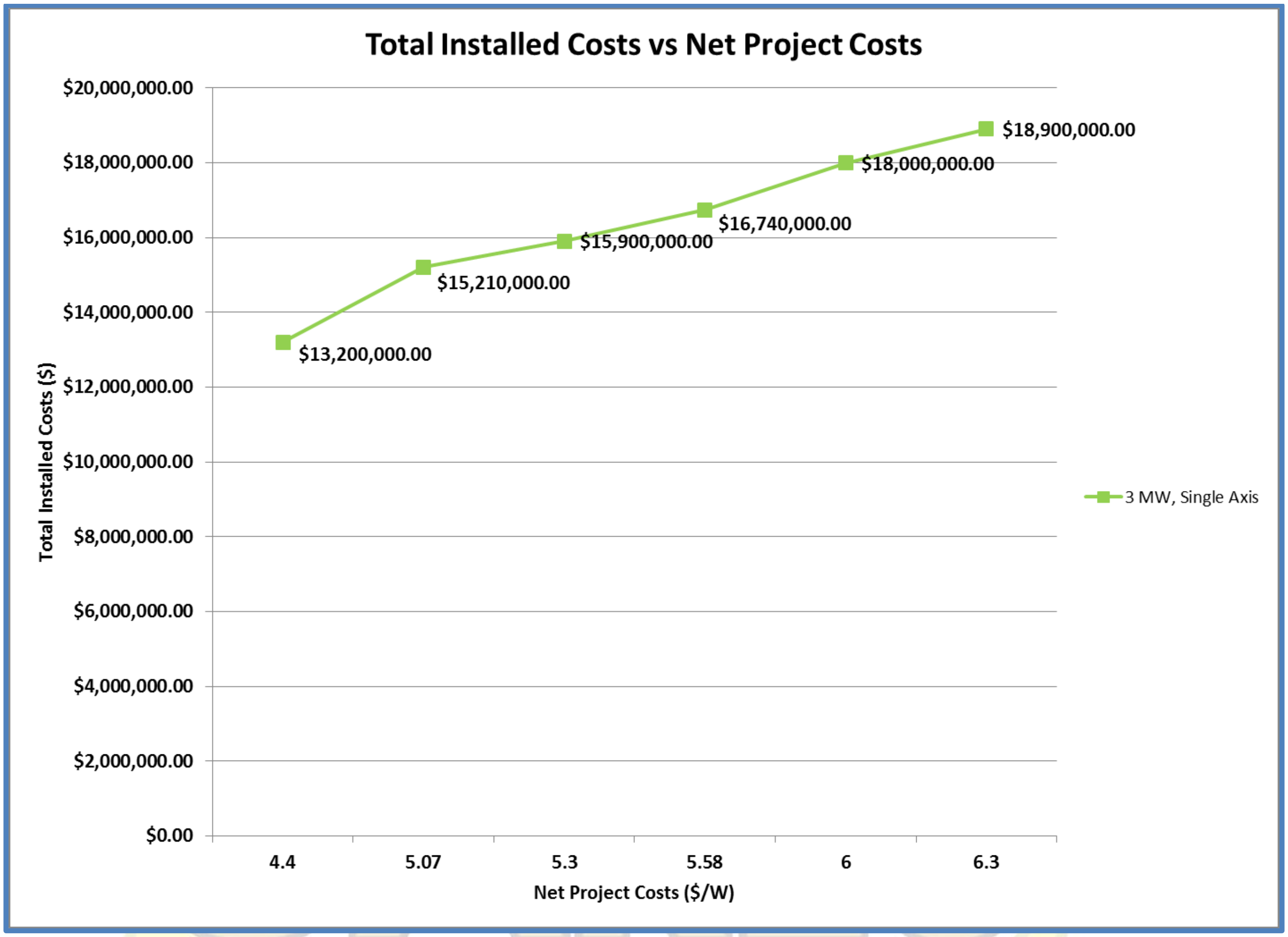


Figure 6: 3 MW, Single Axis System Total Installed Costs with Net Project Costs

Estimated Initial Module and Installation Cost

Utilizing the total system levelized cost of energy (tLCOE) of $233.07/MWh , CARES used NREL System Advisor Model to estimate the initial 3 MW photovoltaic utility cost. Table 8 shows the total system costs for the various photovoltaic modules under review. Of the photovoltaic modules reviewed, it is recommended that the PPN utilize the Lumeta PowerPly 400 module given its capacity of 400 W and PV system cost of $13,222,125. There is a 13.07% difference in the CREST value ($15,210,000) and the CARES tLCOE estimate ($13,222,125.00) for a 3 MW PV system with single axis tracking.

Table 8: RETScreen Photovoltaic Modules and System Costs

Manufacturer	Model #	Target Capacity (W)	Capacity (W)	# of Modules	$/ Module	PV System Cost	PV w tracking
Sharp	ND-198UC1	3000000	198	15152	$698.94	$10,590,000.00	$11,250,000.00
Sharp	ND-L230Q1	3000000	230	13043	$825.95	$10,773,260.87	$11,433,260.87
Heliene	HEE215MA68	3000000	250	12000	$1,486.29	$17,835,480.00	$18,495,480.00
Lumeta	PowerPly 400	3000000	400	7500	$1,674.95	$12,562,125.00	$13,222,125.00
Sanyo	HIP215NKHA5	3000000	215	13953	$974.95	$13,603,953.49	$14,263,953.49

Sensitivity Analysis for Return on Investment

NREL's Cost of Renewable Energy Spreadsheet Tool (CREST) for solar was utilized to estimate the market export rate for electricity generated and the return on investment given a net project cost of $5.07/W, a project lifetime of 25 years and target after tax investor rate of return (IRR) of 15%. The CREST tool for solar is based upon the levelized cost of energy (LCOE) and represents the present value of the total cost of building and operating a generating plant over an assumed lifetime converted to equal annual payments and expressed in terms of real dollars to remove the impact of inflation.

A sensitivity analysis was performed to estimate the return on investment point, cumulative cash flow, and export rate based on a 15% IRR and the Total Installed and Net Project Costs listed section 4.5. Table 9 and Figure 7 shows the cumulative cash flows over the 25 years project lifetime for the 3 MW solar utility. It should be noted that the debt ratio in the CREST model is set at 45% (i.e. 43% for the Senior Debt and 57% for the Equity) and that the export rate or market value list in the tables and graphs below is the minimum value needed to achieve the desired investor after tax rate of return. Furthermore, the year in which the values turn positive (goes from the red to black) in the cumulative cash flow column represents the return of the investor's original cash contribution to the solar utility.

Table 11: Cumulative Cash Flow and After Tax IRR at Net Project Cost of $5.07/W

Project	Tariff or Market Value	After Tax Cash Flow	Cumulative Cash Flow	After Tax IRR
Year	¢/kWh	$	$	%
0		-$8,688,948.46	-$8,688,948.46	N/A
1	47.35	$4,279,737.80	-$4,409,210.67	-0.5074504
2	47.35	$1,522,520.31	-$2,886,690.36	-0.2680544
3	47.35	$1,165,541.22	-$1,721,149.14	-0.1292789
4	47.35	$946,403.00	-$774,746.14	-0.0486
5	47.35	$934,150.58	$159,404.44	0.00841086
6	47.35	$766,054.92	$925,459.36	0.04263266
7	47.35	$597,683.76	$1,523,143.13	0.0632437
8	47.35	$584,420.38	$2,107,563.50	0.07920763
9	47.35	$570,615.87	$2,678,179.37	0.09160977
10	47.35	$687,028.69	$3,365,208.06	0.1034145
11	47.35	$623,299.78	$3,988,507.84	0.11189406
12	47.35	$571,010.15	$4,559,517.99	0.11816429
13	47.35	$532,646.95	$5,092,164.94	0.12295062
14	47.35	$515,437.42	$5,607,602.35	0.12677573
15	47.35	$480,948.46	$6,088,550.81	0.12974597
16	47.35	$439,757.00	$6,528,307.81	0.13202461
17	47.35	$414,068.91	$6,942,376.72	0.13383684
18	47.35	$393,151.36	$7,335,528.08	0.13529729
19	47.35	$1,340,337.88	$8,675,865.96	0.13938355
20	47.35	$1,140,684.52	$9,816,550.49	0.14217468
21	47.35	$1,161,845.92	$10,978,396.41	0.14449567
22	47.35	$1,116,367.53	$12,094,763.94	0.14633167
23	47.35	$1,088,724.62	$13,183,488.55	0.14781769
24	47.35	$1,083,044.19	$14,266,532.74	0.1490517
25	47.35	$1,072,065.29	$15,338,598.03	0.15007602

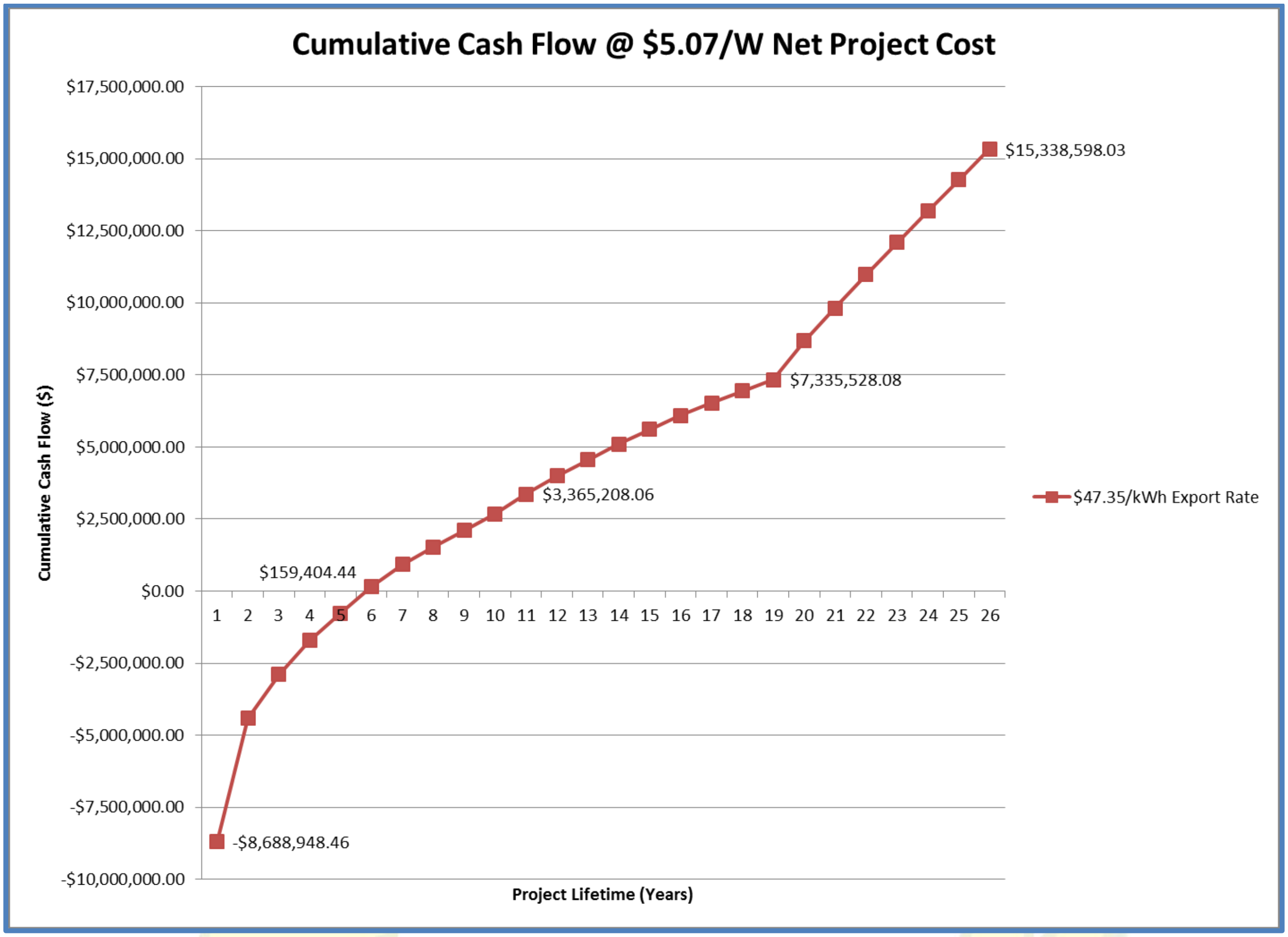


Figure 7: Cumulative Cash Flow at Net Project Cost of $5.07/W

Conclusions and Recommendations

Of the photovoltaic modules reviewed, it is recommended that the PPN utilize the Lumeta PowerPly 400 module given its capacity of 400 W and these modules was utilize the smallest land area: 5.376 acres. At a net project cost of $5.07/W, the installed total costs for a 3 MW, single axis solar utility with Lumeta is $15,210,000. It should be noted that the net project costs was based on regional and state and that CARES suggests that the PPN contact local installers for more quotes on the labor costs per watt installed to get a more accurate estimate of the net project costs. In order to achieve the target after tax investor rate of return (IRR) of 15% over 25 years, an annual electricity export rate or market value of $47.35 is needed in a Power Purchase Agreement (PPA). At this rate, the cumulative cash flow is estimated to be $15,388,598 over the 25 years utility lifetime with a breakeven point in year 5.

Wind Energy Study

Concept Brief

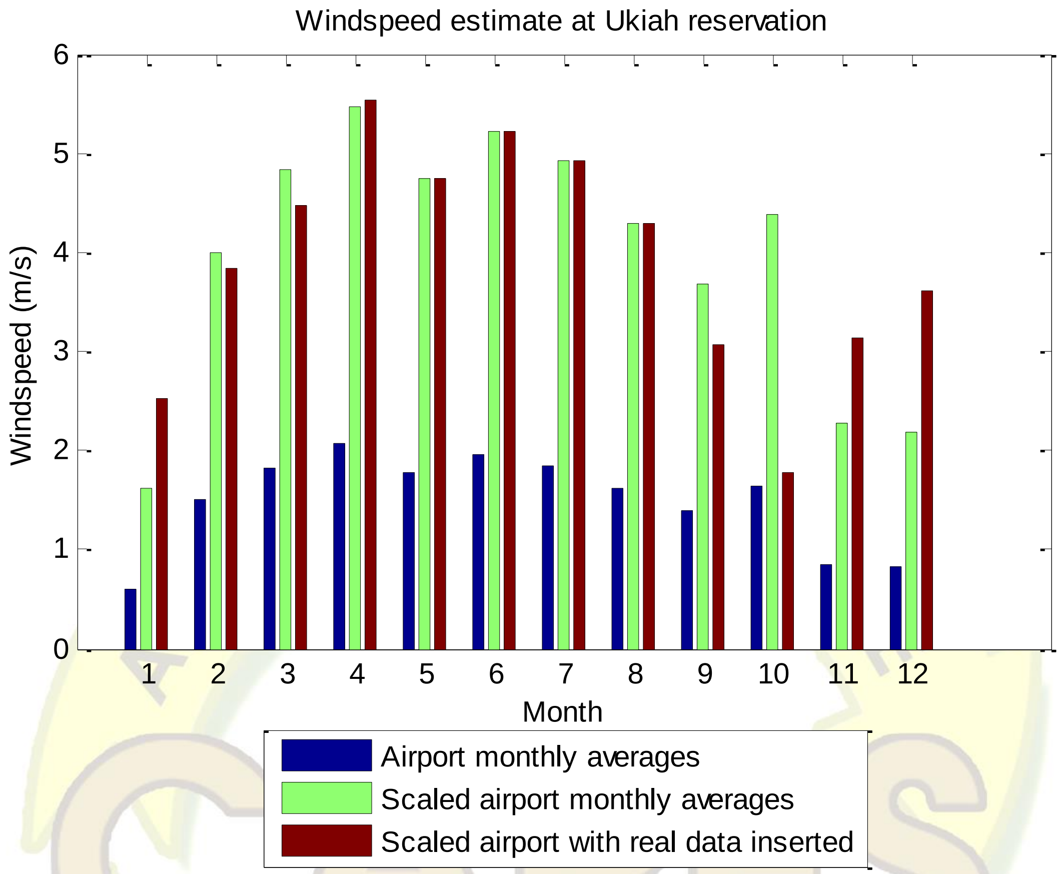
The purpose of this renewable energy feasibility study is the assessment of a wind energy system as potential energy source for localized usage within and near the Pinoleville Pomo Nation (PPN). This study will focus on the technology and economics needed to utilize the wind speeds at a site specified by the PPN. It should be noted that in a December2010 report by CARES on the feasibility of alternative energy technology on Pinoleville Pomo Nation (PPN) lands, the CARES team tentatively concluded that wind energy was not a viable option for the PPN. It was noted in the report, however, that there was an insufficient amount of real wind speed data taken from the Ukiah reservation to issue a strong judgment on the wind potential of the site. In addition, a wind energy system was only analyzed in conjunction with solar PV and micro-hydro systems, and due to the apparently poor wind resource, the finance and construction of wind energy systems were not considered in detail. The goal of this report is to reassess the wind resource of the Ukiah reservation with a larger set of measured wind speed data and to analyze a grid-tied wind energy system in order to obtain a realistic estimate of the cost, or range of costs, of electricity of a wind energy system. This cost can then be compared with that of a solar or micro-hydro system, along with other factors such as capacity, reliability, and aesthetics, when choosing a system to construct.

Wind Resource Assessment

Wind speed at the Ukiah reservation was estimated using a combination of an anemometer and data recorded by the DOE at the Ukiah municipal airport. The anemometer is NRG model #40C and was erected at a height of 20 meters on the Ukiah reservation by the PPN and the CARES team. At the time of writing, data from the anemometer is available between September 27, 2010 and September 29, 2011 with the exception of a gap between 10:00 AM, September 27, 2010 and 10:40 AM September 28, 2010. The anemometer data is recorded on ten minute intervals. As the HOMER model requires a full year of hourly wind speed data, data from the Ukiah airport was collected to account for the gaps in the data taken from the anemometer at the Ukiah reservation. The average wind speed measured by the anemometer is 3.10 m/s, while the annual average from the airport is 1.49 m/s, revealing a discrepancy too significant to treat the airport wind speeds as representative of the Ukiah reservation. A possible reason for this discrepancy is that it is desirable for an airport to be in low wind area.

While the magnitude of the wind speed at the airport is clearly much lower than that of the reservation, it is reasonable to expect that the profile, both daily and annual, would be of a similar shape, due to the geographic proximity of the two sites. For this reason, the average hourly reservation wind speed was divided by the average hourly airport wind speed over the time interval on which reservation data was collected. This quotient yielded a factor by which the airport wind speeds (on the dates where no reservation data could be collected) could be multiplied to obtain a more reasonable estimate of the reservation wind speeds. The calculated scaling factor is 2.66. It should be observed that because generated power is proportional to the cube of the wind speed, when converting the ten minute interval anemometer data to an hourly value, it is more accurate to take the cubic root of the average of the cubes of the wind speeds as opposed to a simple average. The resulting year of hourly wind speeds used in the models is data taken from the anemometer on the Ukiah reservation. The remaining wind speeds were taken from the Ukiah municipal airport and scaled by the method described above.

Figure 2: Monthly Estimates of Wind Speeds at Ukiah Reservation



Model Inputs and Assumptions

The wind turbine modeled was the 2.4 kW Southwest Skystream 3.7. It was chosen because of a low cost per watt installed, and because it is quiet and has an AC output, eliminating the need for a battery and making it ideal for small grid-systems. The complete installation cost of a single turbine is $12,000-$18,000,[1] with an expected value taken to be $15,000 (though analysis with varying costs was conducted and will be discussed below). The turbines are designed to be low-maintenance, so no fixed operation and maintenance cost and a variable cost of $0.025/kWh was assumed. The turbine is assumed to have a lifetime of 20 years, which is taken to be the project lifetime. The cost of electricity from the grid was taken to be $0.12/kWh, which is the current rate from Pacific Gas and Electric (PG&E). PG&E's net metering policy is also assumed, which guarantees that electricity will be purchased from customers at the same price that it is sold to them. Energy demand is based on measured

[1] Cost and power curve data taken from the Skystream 3.7 data sheet available at http://www.skystreamenergy.com/documents/datasheets/skystrea_%203.7t_datasheet.pdf

current usage, as well as anticipated usage for additional sustainable houses, and is assumed to be 1,163 kWh/day, with a peak demand of 284 kW, subject to seasonal variations that are incorporated in the model. The discount rate for current capital is assumed to 6%, and the interest rate on loans for wind energy is assumed to be 7%. Costs were calculated for a single wind turbine, and linear scaling is assumed, except in consideration of government incentives. The only government incentive considered due to its reliability and applicability to the PPN project is the California Self-Generation Incentive Program (SGIP), which grants $1.5/W installed for systems with capacity greater than 30 kW and less than 1 MW[2], which translates to $3600 per wind turbine for systems with at least thirteen turbines.

HOMER Model

The HOMER version 2.68[3] software model was used to model electricity generation and consumption based on hourly resource and consumption data. HOMER was developed by the National Renewable Energy Laboratory (NREL) primarily for rural off-grid projects in developing countries[4], making it applicable to the PPN. HOMER was used because it has the capacity to model both grid-tied and off-grid systems, and it makes hourly calculations, yielding a high level of accuracy of electricity generation, given a wind resource. The model also has built-in power curves for several wind turbines, including the Skystream 3.7, however the data was for the previous 1.8 kW model, so the power curve was manually scaled up to 2.4 kW peak. The HOMER model was used to provide a rough estimate of the cost of electricity (COE), and to provide a reasonably accurate measurement for the capacity factor of the wind turbines.

CREST Model

The Cost of Renewable Energy Spreadsheet Tool (CREST) is another model developed by NREL to assess the financing of a renewable energy project, primarily a wind, solar, or geothermal project.[5] This model allows the user to enter more information about the financing of a project and government grants. Some of the default assumptions of the model were left unaltered, notably that turbine production would decrease by 0.5%/yr, that variable O&M costs would

[2] Information about the SGIP taken from the Center for Sustainable Energy, California at https://energycenter.org/index.php/incentive-programs/self-generation-incentive-program
[3] Software and documentation available online at www.homerenergy.com
[4] http://www.homerenergy.com/history.html
[5] Software and documentation available online at http://financere.nrel.gov/finance/content/CREST-model

begin at $0.025/kWh and would increase by 2%/yr, that a lender's fee of 3% would be attached to all loans, and that all loans required a minimum annual debt service coverage ratio of 1.2 and an actual debt service coverage ratio of 1.45. The CREST model requires a capacity factor that can be calculated with the HOMER model, and allows variation of parameters such as the installation cost, debt ratio, and capacity.

Results

The HOMER model yielded an annual capacity factor of 22.5%, and a levelized COE of $0.302/kWh. Based on the wind resource and the cut-in speed of the Skystream 3.7 (3.5 m/s), it is estimated that the turbine will be in operation 4,108 hrs/yr, or approximately 47% of the time. The CREST model, using the 22.5% capacity factor given by the results of the HOMER model, with a debt ratio of 30% and no government grants, yields a COE of $0.321/kWh. If the SGIP grant of $1.5/W is assumed, the COE drops to $0.257/kWh, which is a significant decrease.

Figure 3: COE Sensitivity to Debt Ratio

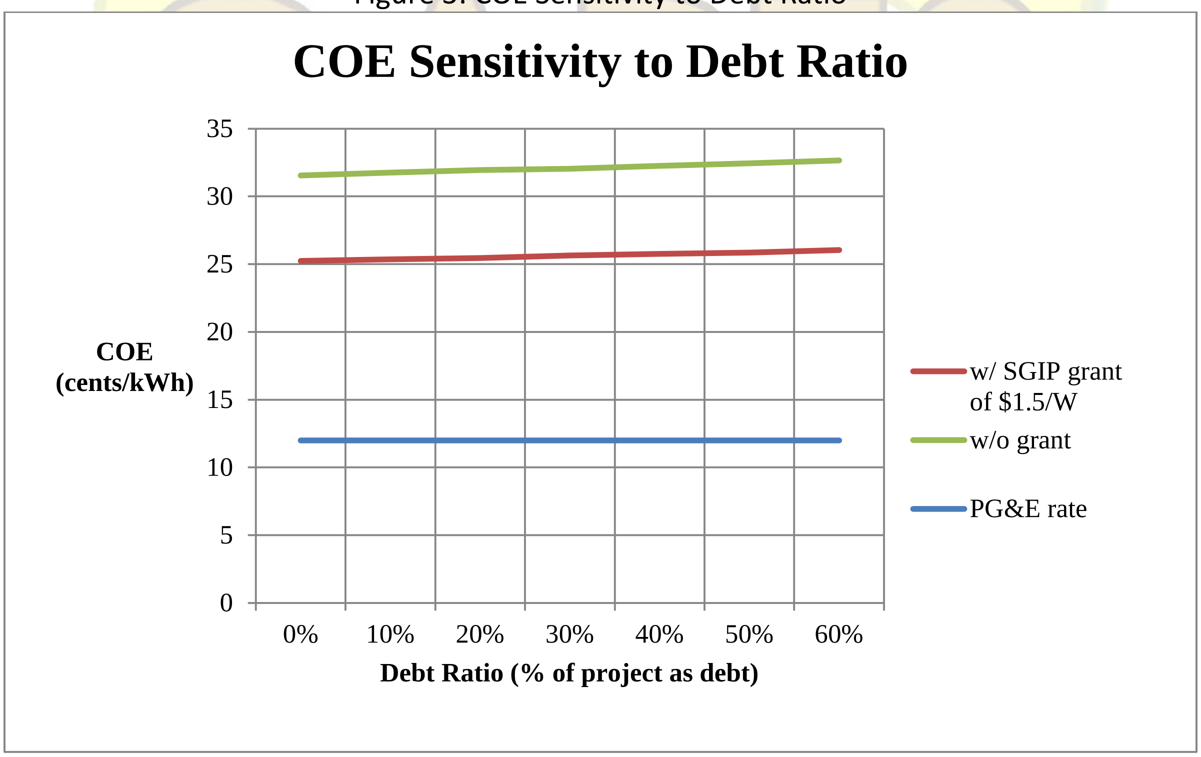


Figure 3 shows that although there is some sensitivity to the debt ratio, the variation is roughly within a cent, suggesting that the parameter is relatively insignificant in the project, and that taking the debt ration as 30% is a reasonable assumption.

Figure 4: Installation Costs and Production w/ Respect to Capacity

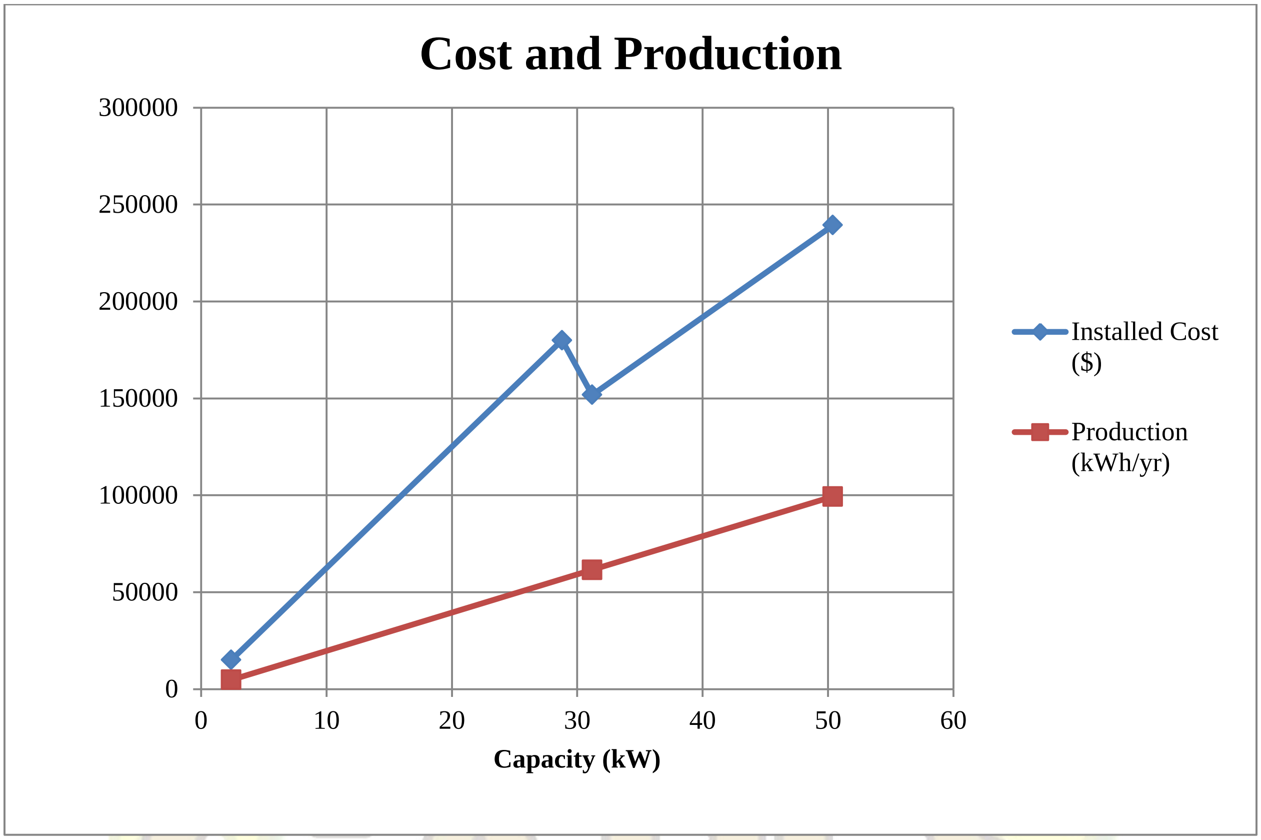
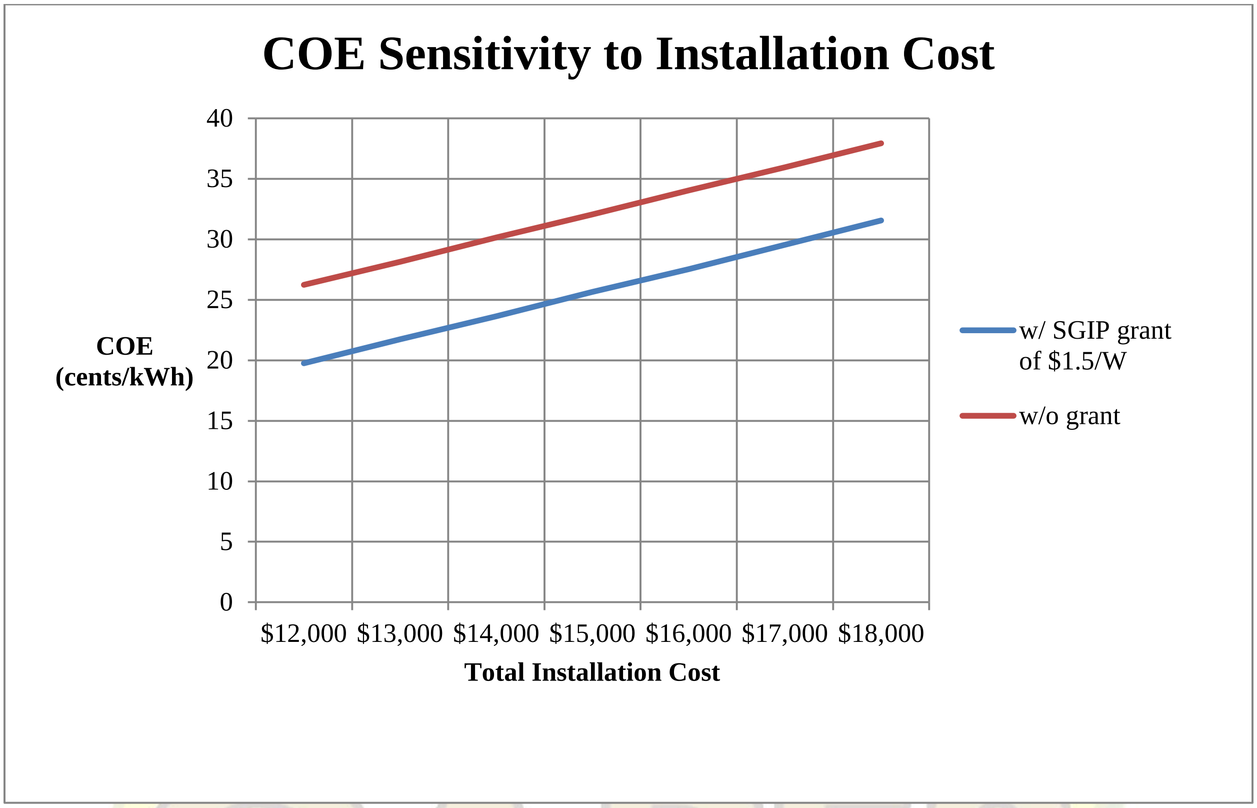


Figure 4 indicates that in order to receive the state subsidy of $1.5/W, which requires a capacity of at least 30 kW, the project will cost above $150,000. This would result in approximately 15% of the PPN's load being met by wind resources. The graph also shows that it will cost approximately the same to install 24 kW of capacity (10 turbines) as 31 kW of capacity (13 turbines).

As it is difficult to obtain an estimate for installation costs of a wind turbine without consulting a contractor, there is some variability associated with the installation cost of the system. Figure 5 shows the sensitivity of the COE to installation costs, both with and without the SGIP grant, over the range of prices estimated by Southwest Windpower. It is clear that the variation of the real installation costs is an important parameter, as the COE could be as low as $0.193/kWh and $0.263/kWh for systems with and without the SGIP grant, respectively, or as high as $0.316/kWh and $0.380/kWh.

Figure 5. COE Sensitivity to Installation Cost



Conclusions

It is clear that there is still significant variability in the COE with respect to installation costs, however the range of values generated with the CREST model suggest that it is unreasonable to expect a levelized COE of much less than $0.20/kWh given the wind resource at the Ukiah reservation. Given this expected lower bound on the COE, wind energy systems should not be considered feasible when compared with solar or micro-hydro systems if the COE of either system is lower than $0.20/kWh. If the expected COE of a different technology is close to that of a wind energy system, estimates of the installation cost should be obtained from a contractor, and a more detailed analysis of the financial capacity of the PPN, as well as loan rates and fees, should be conducted. While the potential for additional grants from the Department of Energy exists, it is likely that such grants could be applied to any type of renewable energy system, and should not be considered when evaluating wind energy against another renewable technology, unless other subsidies specific to wind are made available.

The results also suggest that systems of less than 30 kW should not be considered due to the significant decrease in cost from the SGIP subsidy. As a system of this capacity requires at least thirteen 2.4 kW turbines, if the number of turbines is considered too great for the space requirements of the PPN, larger turbines such as the Bergey Excel 10 kW grid intertie system should be considered. These turbines would have the advantage of being fewer in number, however they will be louder, more visually prominent, and will pose a greater danger to birds and bats. The high difference in wind speed between the airport and the reservation indicate that it is reasonable to expect additional variation between other land parcels owned by the PPN. It is impossible to investigate this accurately without installing an anemometer at the other potential sites, and it will be difficult to make an accurate prediction without monitoring the wind speed over the same season as wind has been monitored at the main reservation, as there are large seasonal variations in wind speed (see Figure 2.1). In addition, placing the turbines far from the main reservation would likely result in increased transmission costs, which could potentially offset the gain of a slightly increased wind resource. CARES therefore recommends that the PPN pursue power generation from other more cost effective renewable energy systems such as solar PV.

Anaerobic Biogas Utility Study

Concept Brief

The purpose of this renewable energy feasibility study is the assessment of an anaerobic digestion system that produces biogas as potential energy source for localized usage within and near the Pinoleville Pomo Nation (PPN). This study will focus on the technology and economics needed to utilize food waste and other feedstock material within an anaerobic digestion system.

Anaerobic Digestion

Anaerobic digestion is a natural process where microorganisms breakdown organic matter such as greases, fats, and foods scraps in an oxygen free (anaerobic) environment. The breakdown of the organic matter results in biogas and a nitrogen rich fertilizer known as digestate. Figure 1 show a basic flow diagram for an anaerobic digester system. A basic anaerobic digester system consists of pumps, a mixing system, a heating system, and a biogas collection system. The biogas can be burned to produce heat, be used in internal combustion engines for combined heat & power (CHP), and/or can be processed to natural gas quality for usage in vehicle fuel applications. The biogas from an anaerobic digester is composed mainly of carbon dioxide (~39%) and methane (~60%). It should be noted that there are trace amounts of water and hydrogen sulfide (<1%) that can be removed with additional processing and conditioning. Anaerobic digesters are airtight containers typically in the form of vertical cylinders, covered lagoons/pools, and/or horizontal tanks and bladders. Within these airtight containers, factors such as alkalinity, solids retention time, temperature, moisture content, and pH levels can be monitored and controlled in order to maximize biogas generation and waste decomposition rates.

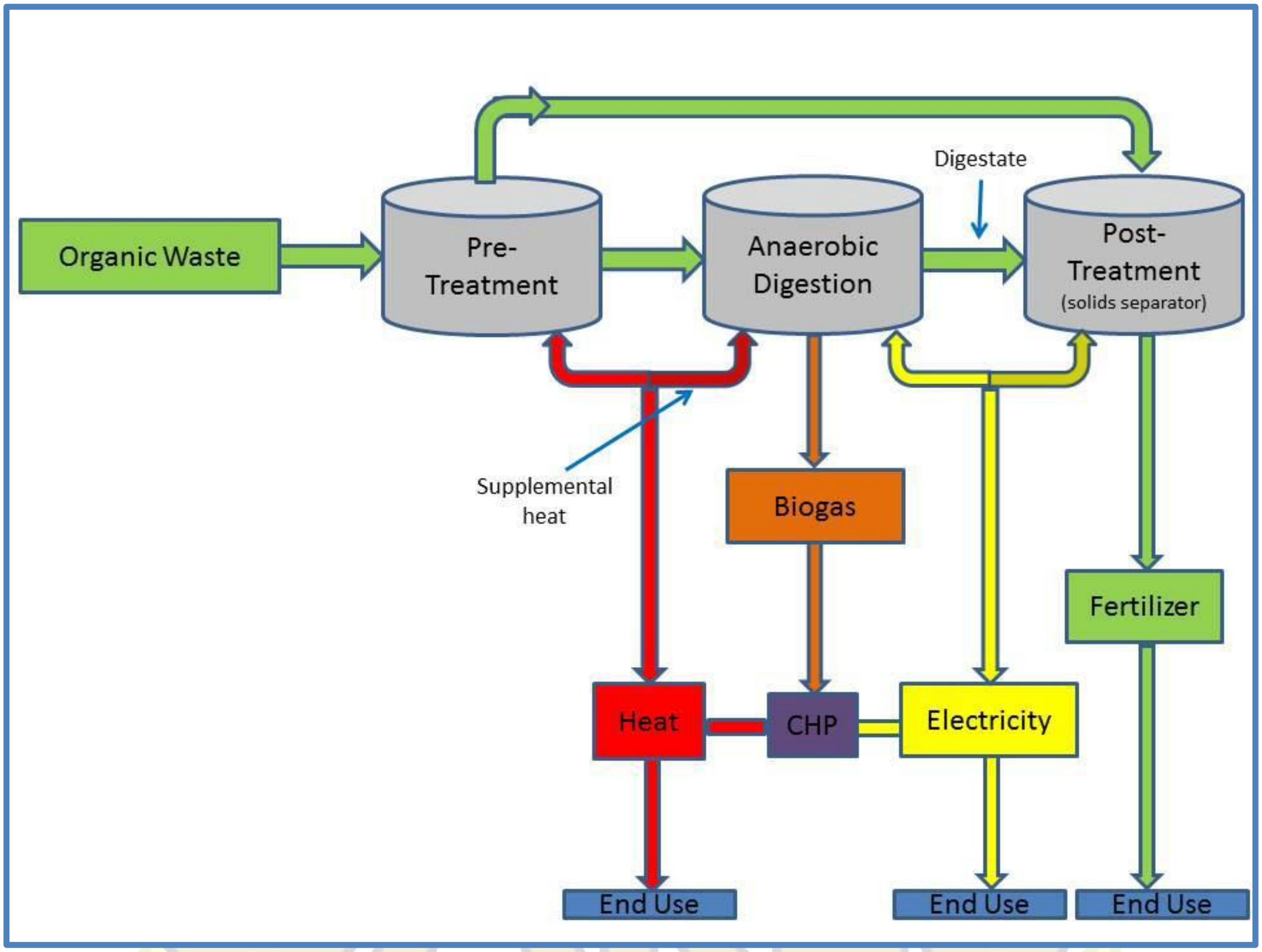


Figure 1: Flow Diagram for an Anaerobic Digester System

Anaerobic Digestion Process

The anaerobic digestion process typically has four stages: (1) hydrolysis, (2) acidogenesis (fermentation), (3) acetogenesis, and (4) methanogenesis. In the hydrolysis stage, the long chained organic molecules of biomass such as carbohydrates, cellulose, starch, proteins, and fats are broken down into simple sugars, amino acids, and fatty acids by fermentative (acidogenic) bacteria. In the acidogenesis or fermentation stage, the products (monomers) of the hydrolysis stage are fermented and results in the production of volatile fatty acids (VFAs) such as lactic, butyric, propionic, and valeric acid. In the acetogenesis stage, bacteria consume the VFAs and produces acetic acid, carbon dioxide, and hydrogen. Finally, methanogenic bacteria consume the acetic acid, hydrogen and some of the carbon dioxide in order to produce methane. Any remaining material not consumed by the bacteria is known as disgstate. There are three biochemical conversion processes that are used by methanogens to produce methane gas. The stoichiometries of the overall chemical reactions are as follows:

1. Acetotrophic methanogenesis (acetate conversion): $4CH_3COOH \xrightarrow{yields} 4CO_2 + 4CH_4$
2. Hydrogenotrophic methanogenesis (methane conversion): $CO_2 + 4H_2 \xrightarrow{yields} CH_4 + 2H_2O$
3. Methylotrophic methanogenesis: $4CH_3OH + 6H_2 \xrightarrow{yields} 3CH_4 + 2H_2O$

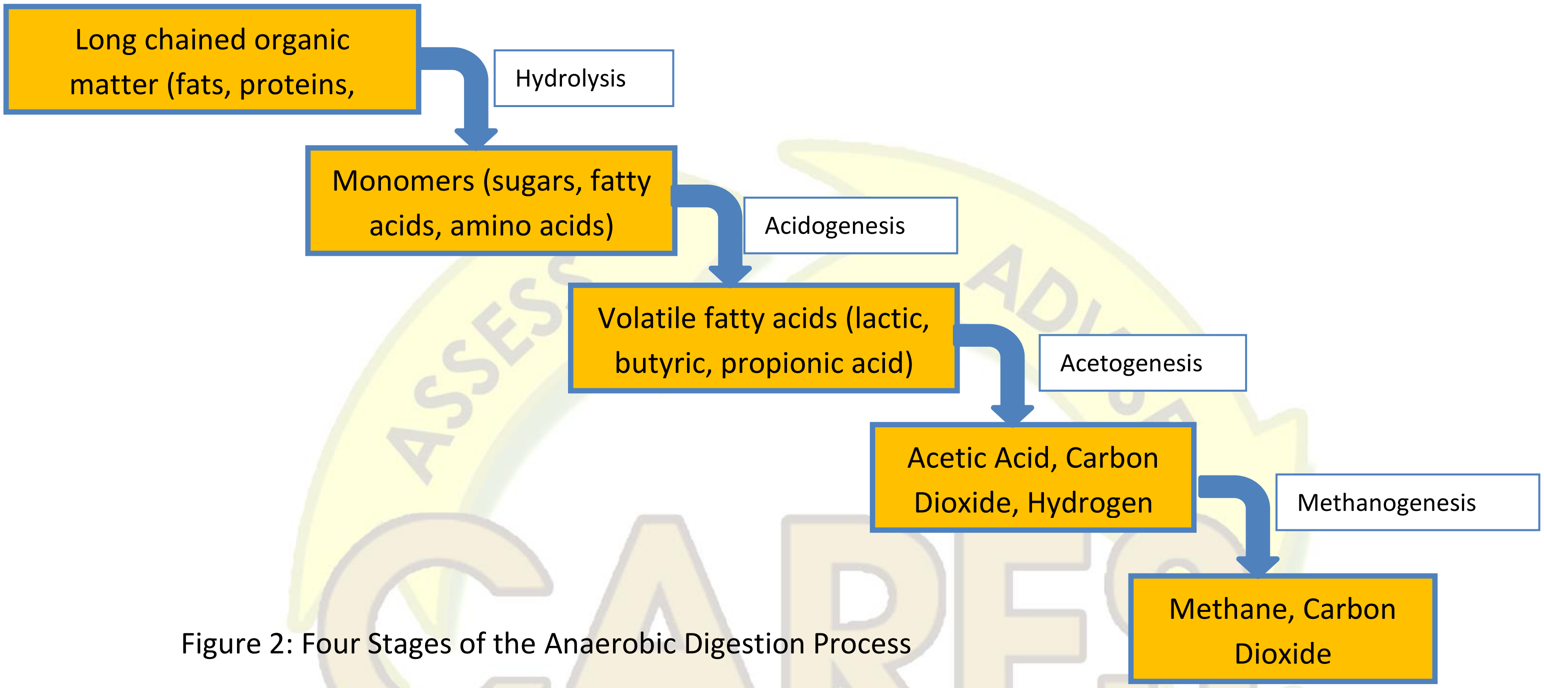


Figure 2: Four Stages of the Anaerobic Digestion Process

The anaerobic digestion process has two main temperature ranges for operation. These ranges are determined by the methanogens in the digesters: mesophilic (~25°C – ~45°C) and thermophilic (~45° – ~55°C). It should be noted that while faster digestion can be achieved at thermophilic temperatures, the methanogens at these higher temperatures are more susceptible to toxins, changes in temperature, pH, and feedstock. This sensitivity can result in the death of the methanogens and, subsequently, the cessation of methane production. Methanogenesis is the final step in the decay of organic matter and occurs between a pH 6.5 to pH 8. Typically, the optimal conditions for the anaerobic digestion process requires a consistent feeding rate of organic material, a constant temperature (mesophilic or thermophilic), and a relatively neutral pH.

Anaerobic Digester Classification

Typically, anaerobic digester types are classified by moisture content, temperature, flow pattern, number of digesters and holding tank type. Anaerobic digesters are typically (1) Wet [~5% - 15% dry matter] or dry [<15% dry matter], (2) mesophilic (~25°C – ~45°C) or thermophilic (~45° – ~55°C), (3) continuous flow or batch process, and (4) single or multiple stage digesters. The simplest form of an anaerobic digester is a batch system (landfill in a box). In a batch system, an operator adds the feedstock to the reactor at the start of the process in a single collection of material and it is sealed for the entire duration of the anaerobic digestion known as retention time. Continuous flow system, on the other hand, has the feedstock added to the reactor at a steady, predetermined rate and while an equal amount of digested material is removed. Batch systems are rather cheap to make, robust when bulky items are used, and have a low technical barrier; however, these systems typically suffer from clogging which leads to a poor biogas yield and can require a larger amount of land than continuous flow dry systems.

Wet anaerobic digesters typically operate at mesophilic temperature settings and require that the feedstock be turned into a homogenous pulp. The reactors used in wet anaerobic digestion are referred to as complete mix or continuous stirred tank reactors (CSTR) which use mechanical mixers or a combination of biogas injectors and mechanical pulp mixers. Dry anaerobic digesters, however, typically operate at thermophilic temperature settings and can general process the feedstock with as it without it being homogenized. The reactors utilized in dry anaerobic digesters usually don't utilized mechanical mixers; instead a cork of feedstock moves through the systems and displaces a similar volume of material. It should be noted that while both processes utilize water, wet anaerobic digesters on average use more energy for heating and more water to create the desired solids concentration.

In single stage anaerobic digester systems, all biochemical conversion processes take place simultaneously in one reactor. Given that the growth rates and pH of the microbial organisms present during the 4 stages of anaerobic digestion are rather different, the usage of a single-stage digester system can hinder the biochemical conversion since the microbial organisms are place in the same operating conditions. Two or multi stage systems allow for more optimal production of biogas by allowing separate reactors for the (1) hydrolysis, (2) acidogenesis (fermentation), (3) acetogenesis, and (4) methanogenesis stage of the anaerobic digestion process. However, single stage systems are the most commonly used in industry since they have a simple design (i.e. smaller number of technical failures) and lower capital cost.

Other anaerobic digester system classifications used in the US include plug flow, complete mix, covered lagoon, and fixed film digesters. Plug flow digesters are rectangular tanks that have a total solids concentration of feedstock between ~11% to ~14%. Typically, plug flow digesters operate at mesophilic temperatures and have an average retention time of ~20 days at the minimum. Covered lagoon digesters are earthen impoundments that utilize an air tight cover designed to collect the biogas produced. These systems typically have average retention time of ~40 days at the minimum and are most optimal at mesophilic temperatures.

Complete mix digesters are also referred to as continuous stirred tank reactors (CSTR) and use mechanical mixers or recirculation create a homogeneous solution of its reactor contents. Complete mix digesters have average retention time ~17 days at the minimum and operate best at mesophilic temperatures. Fixed film digesters utilize a tank filled with plastic media that contains a thin layer of anaerobic bacteria which produces biogas when the feedstock passes through it. Table 3 contains a summary of the anaerobic digester system classifications and characteristics.

Table 1: Anaerobic digester system classifications and characteristics

Features	Covered Lagoon	Plug Flow Digester	Complete Mix Digester	Fixed Film
Digestion Reactor/Tank	Lagoon	Rectangular, In Ground Tank	In or Above Ground Tank	Above Ground Tank
Avg. Retention time	~40 days	~20 days	~17 days	~3 days
Solids Concentration	~1%-~3%	~11%-~14%	~3%-~10%	Max: ~3%
Operation Temperature	Ambient	Mesophilic	Mesophilic	Mesophilic or Ambient
Climate	Warm	All Climates	All Climates	Warm

Status of Anaerobic Digesters in UK & US

It is estimated that there are ~83 anaerobic digestion facilities in the United Kingdom with a breakdown of 32 farm feedstock only (green), 50 waste recovery feedstock only (red), and 1 biomethane injection facility (yellow). Figure 3 shows the location of anaerobic digestion facilities in the United Kingdom according the National Non-Food Crops Centre. It should be noted that some estimates place the number of anaerobic digestion facilities in the United Kingdom near 214 which have an overall capacity to process ~5 million tons of feedstock per year total and a total installed generating capacity of over 170MW of electricity.

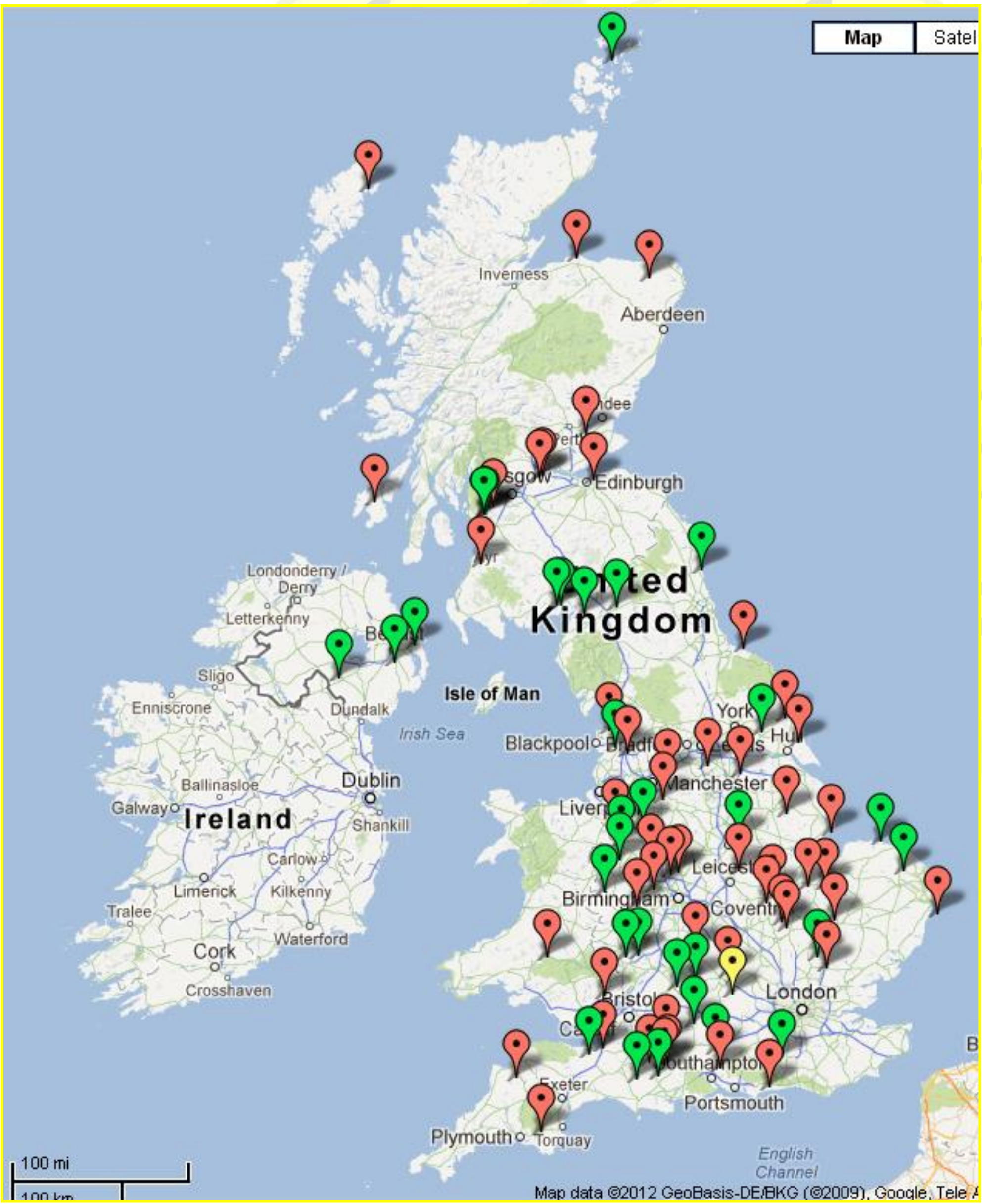


Figure 3: Anaerobic Digestion Facilities in the United Kingdom

As of September 2012, the United States Environmental Protection Agency's AgSTAR program estimates that there are 192 anaerobic digester systems operating at commercial livestock farms in the US and these system produced 586 million kWh annually. In 2011, there were 176 anaerobic digester systems in operation and these systems produced 541 million kWh of energy annually. It is estimate that ~1.2 million metric tons of CO_2e was eliminated in 2011 and ~1.3 million metric tons of CO_2e was eliminated in 2012 due to these anaerobic digester systems.

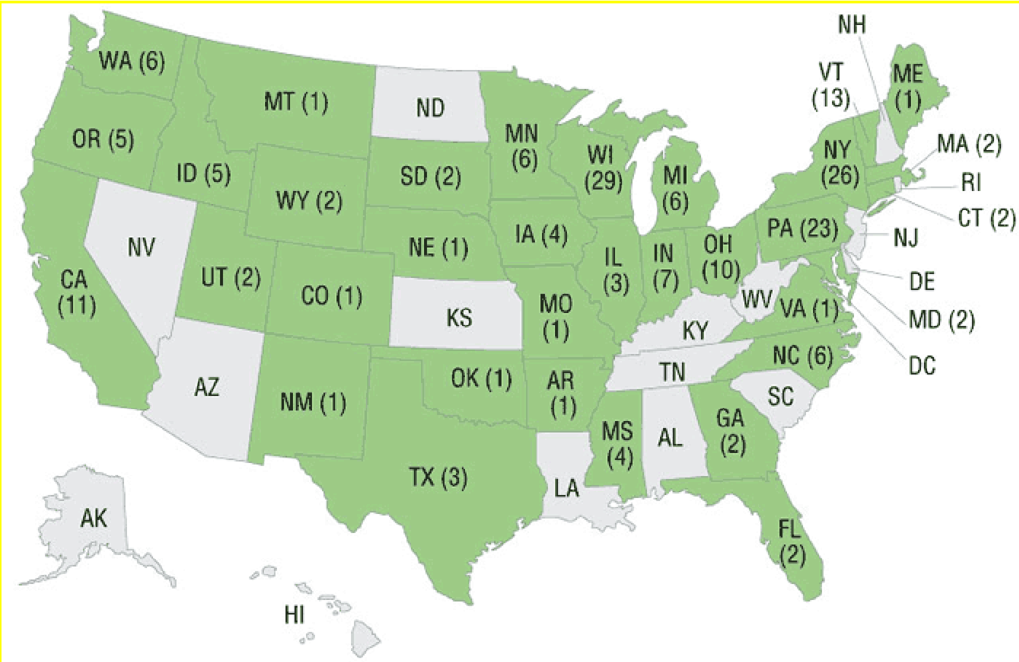


Figure 4: Anaerobic Digestion Facilities in the United States

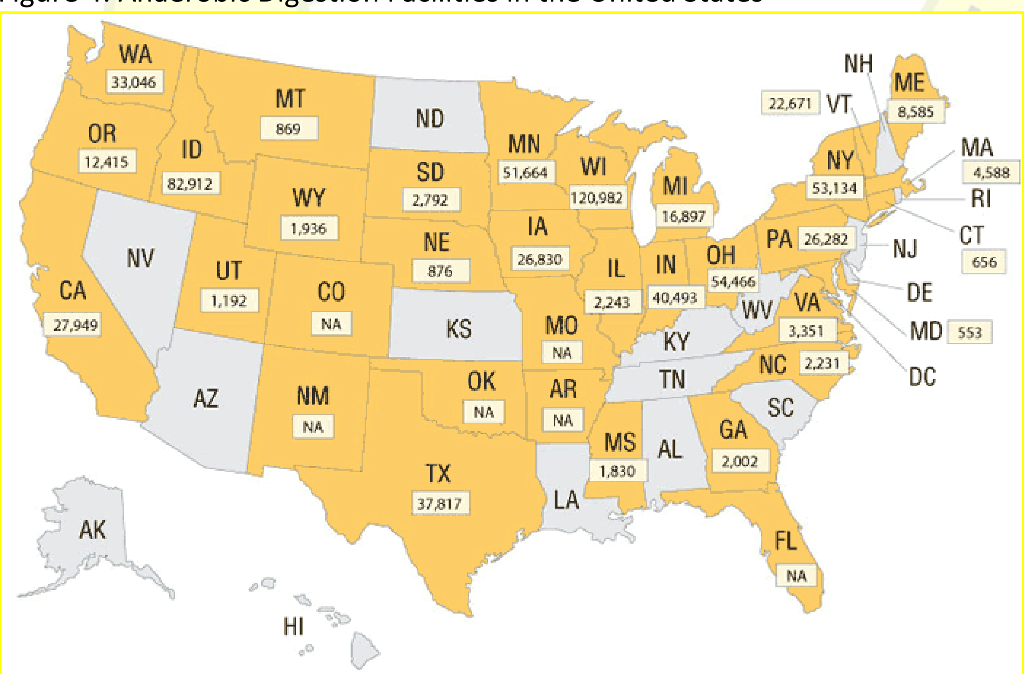


Figure 5: Total Energy Production by Anaerobic Digestion Facilities in the United States

Feedstock Evaluation

The simplest and earliest version of a biogas system was a basic jar placed over a pile of cattle or pig manure to collect the biogas produced. Biogas can be produced from a wide variety of feedstocks that have a large range of moisture contents and composition: (1) food waste, (2) animal manure and slurry, (3) agricultural residues and by-products, and (4) dedicated energy crops such as grains, sugarcane, maize, miscanthus, sorghum, sunflower, clover, leaves, and grass. Tables 2 through 4 provide estimates of the biogas yield from common feedstocks.

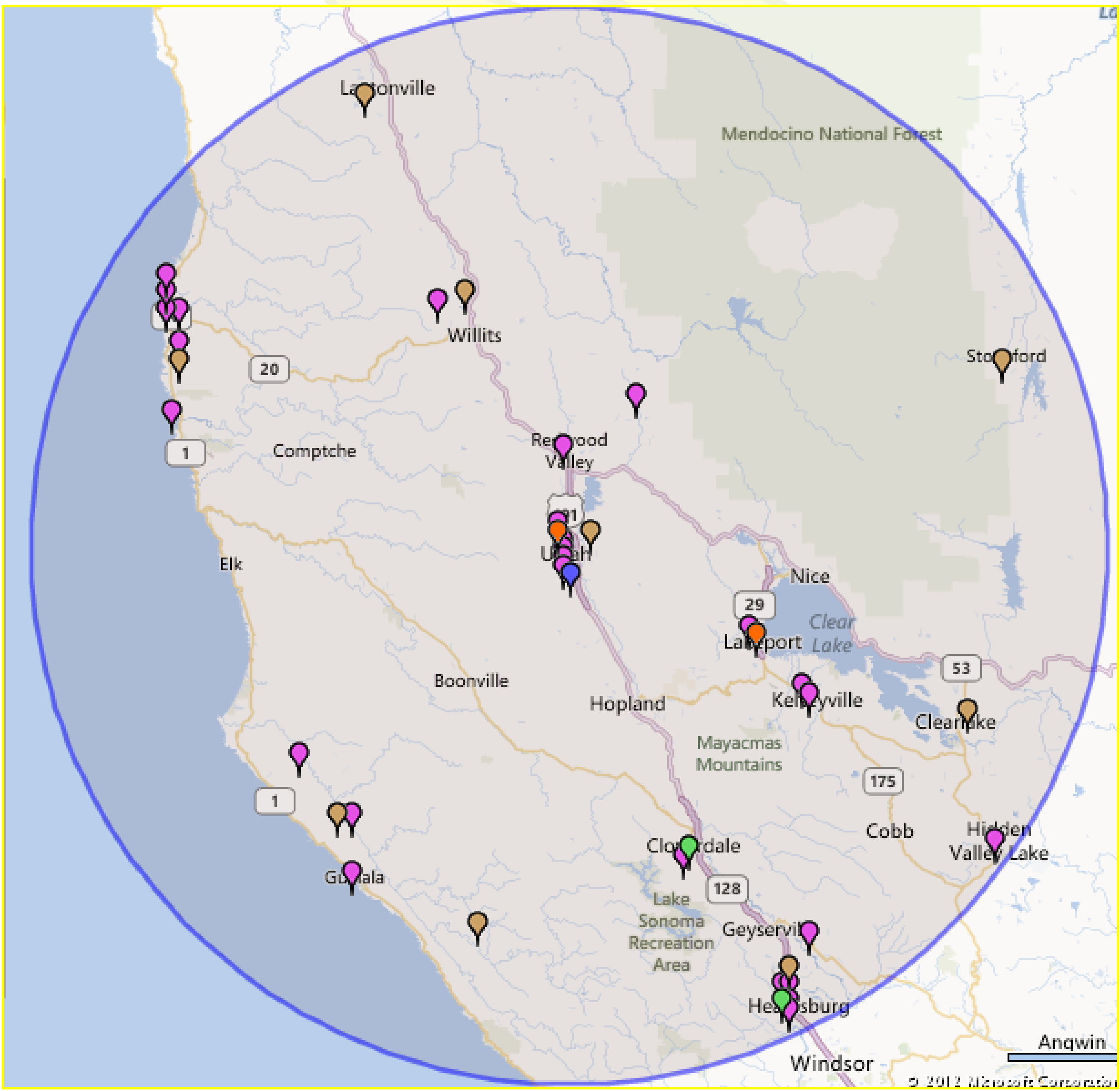


Figure 6: Estimate of Organic Waste Producers, Haulers, and Collection Sites within a 70 miles radius of Ukiah, CA**Error! Reference source not found.**

The US Environmental Protection Agency's Waste to Biogas Mapping Tool estimates that there are 14 fat/oil/grease haulers, 43 food processing facilities, 9 landfills, and 2 organics collection programs within a 70 mile radius of Ukiah, CA. The close proximity of these facilities to the Pinoleville Pomo Nation increases the likelihood of securing a stable source of feedstock for a biogas power plant; however, it is unknown how much waste these facilities produce or haul.

Table 2: IEA Bioenergy Biogas Yield Estimates

Feedstock	Biogas Yield (m^3 CH^4 /ton)	Feedstock	Biogas Yield (m^3 CH^4 /ton)
Maize (whole crop)	205-450	Barley	353-658
Wheat (grain)	384-426	Triticale	337-555
Oats (grain)	250-295	Sorghum	295-372
Rye (grain)	283-492		
Grass	298-467	Alfalfa	340-500
Clover grass	290-390	Sudan grass	213-303
Red Clover	300-350	Reed Canary Grass	340-430
Clover	345-350	Ryegrass	390-410
Hemp	355-409	Nettle	120-420
Flax	212	Miscanthus	179-218
Sunflower	154-400	Rhubarb	320-490
Oilseed Rape	240-340	Turnip	314
Jerusalem Artichoke	300-370	Kale	240-334
Peas	390		
Potatoes	276-400	Chaff	270-316
Sugar Beet	236-381	Straw	242-324
Fodder Beet	420-500	Leaves	417-453

Table 3: Environmental Protection Agency AgStar Estimated Biogas Yield

Food Waste	Biogas Yield (m^3 CH^4 /ton)	Fats, oils, and greases (FOG)	Biogas Yield (m^3 CH^4 /ton)	Crop residues & energy crops	Biogas Yield (m^3 CH^4 /ton)
Potato pulp	50	Food grease	250-340	Lawn clippings	125
Brewery waste	75			Corn residues	150
Food waste	210				
Molasses	230				
Cereal waste	300				
Potato chips	540				

Table 4: National Non-Food Crops Centre Estimated Biogas Yield and Value

Feedstock	Biogas Yield (m^3 CH^4/ton)	Value ($ per ton)
Cattle slurry	15-25	6.44-9.76
Pig slurry	15-25	6.44-10.95
Poultry slurry	30-100	13.04-43.46
Maize silage	200-220	87.56-96.58
Grass silage	160-200	70.02-87.56
Whole crop wheat	170-190	80.48-96.58
Crude glycerine	580-1000	249.49-434.59
Rapemeal	600-650	257.54-273.63

Food Waste

Food waste is considered to be uneaten food, leftovers, and food preparation scraps from residential households and commercial entities such as cafeterias, restaurants, grocery stores, and deli markets. In 2010, the EPA estimated that ~34 million tons of food waste was generated in the United States. This waste represented 13.9% of the total U.S. municipal solid waste in 2010. Figure 6 shows the breakdown of U.S. municipal solid waste in 2010.

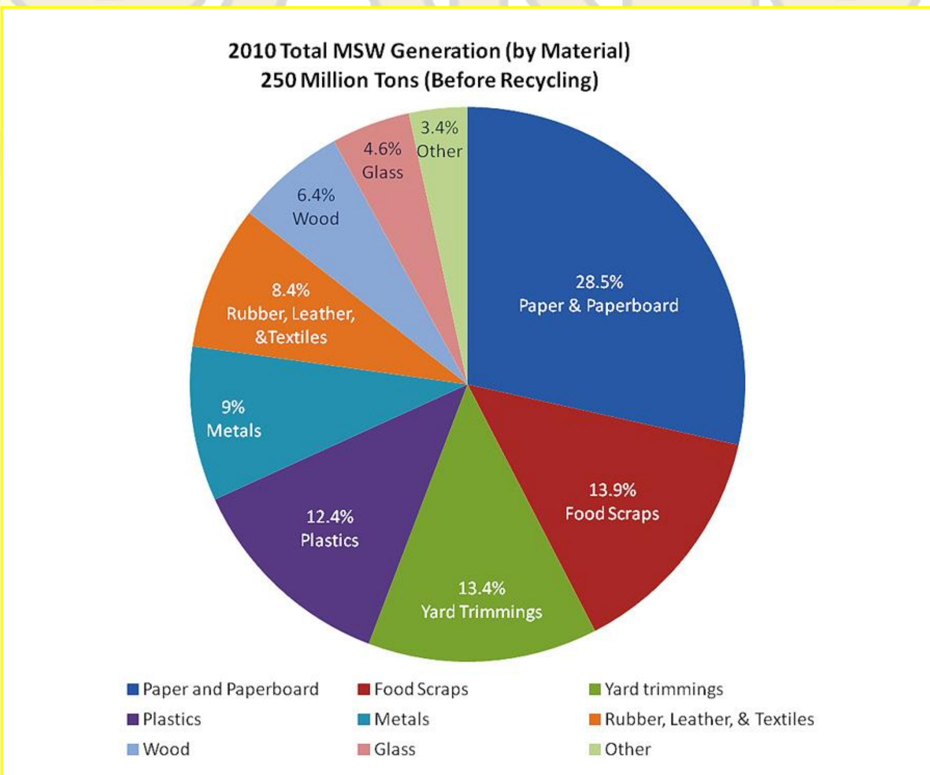


Figure 6: Breakdown of U.S. municipal solid waste in 2010

The California 2008 State Wide Characterization Study determined that 32.4% of materials in its overall disposable waste stream were from organic materials. Organic materials are defined as being food, leaves and grass, prunings and trimmings, branches and stumps, manures, textiles, carpet, and remainder composite organics. Food waste represents ~15.5% (~6,158,120 tons) of material in California's overall disposable waste stream.

CA Residential Disposable Waste Stream

However, California's residential waste stream contains 48.6% of organic material. . Food waste represents ~25.4% (~3,034,040 tons) of material in California's residential disposable waste stream. Figures 7 and 8 provide the overall and residential breakdown of disposable material in California's waste stream.

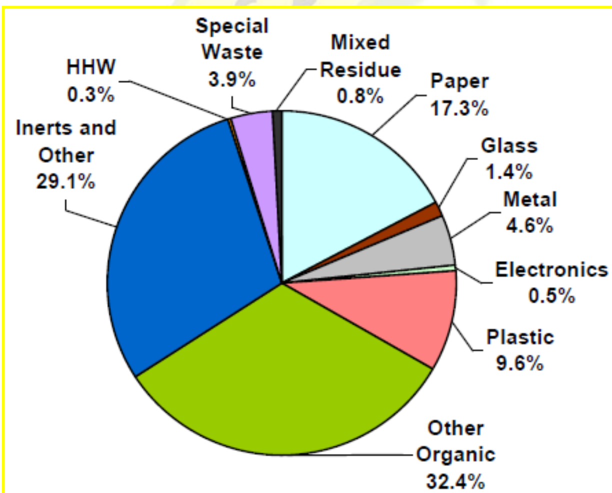


Figure 7: Breakdown of CA Overall Waste Stream in 2008

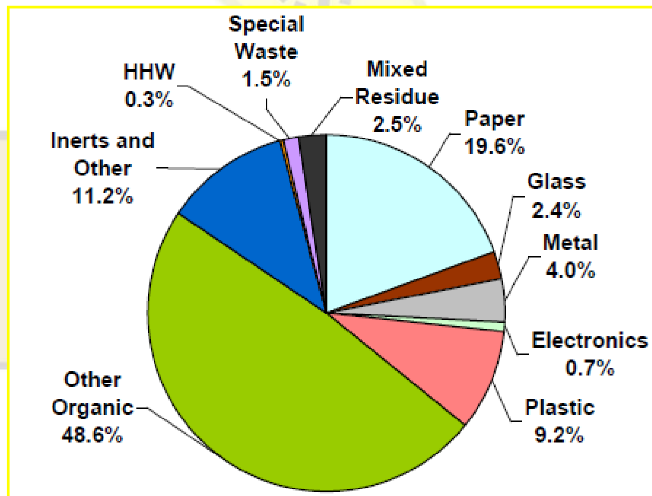


Figure 8: Breakdown of CA Residential Waste Stream in 2008

Animal Manure and Slurry

In California, manure accounted for 0.1% (20,373 tons) of material in California's overall disposable waste stream. Within California's residential disposable waste stream, manure accounted for 0.2% (20,224 tons). In 2011, it was estimated that there are 81,500 farms in California that contain livestock composed of 5,350,000 cattle and calves, 105,000 hogs and pigs, and 570,000 sheep. It is estimated that ~11,800,000 tons of animal manure is produced each year in California. In Mendocino County, it is estimated that there is ~18,300 livestock which includes 8,800 beef cows and 1,900 dairy cows.

Agricultural Residues and Energy Crops

Agricultural residues include rice straw, cassava rhizome, leaves, grass, corn cobs, saw dust, pulp wastes, and paper mill by products that typically are viewed as waste. The California Biomass Collaborative estimates that there was 26,800,000 tons of forestry residue in 2005. The 2005 forestry residue breakdown is 6,200,000 tons from mills, 7,700,000 tons from forest thinning, 8,000,000 tons from logging slash, and 4,900,000 tons from chaparral. In 2010, the EPA estimated that ~33 million tons of yard trimmings were generated in the United States. This waste represents 13.4% of the total U.S. municipal solid waste in 2010. In California, leaves and grass accounted for 3.8% (1,512,832 tons) of material in California's overall disposable waste stream. Prunings and trimmings accounted for 2.7% (1,058,854 tons) in California's overall disposable waste stream. Branches and stumps accounted for 0.6% (245,830 tons) in California's overall disposable waste stream. In California's residential disposable waste stream, leaves and grass accounted for 6% (715,353 tons) of waste. Prunings and trimmings accounted for 1.9% (225,375 tons) in California's residential disposable waste stream. Branches and stumps accounted for 0.1% (17,032 tons) in California's overall disposable waste stream.

Economics

According to the Energy Information Administration's (EIA) Annual Energy Outlook 2012, the total levelized cost of energy should be used to assess the overall competiveness of different power generating technologies. Total levelized cost of energy represents the present value of the total cost of building and operating a generating plant over an assumed lifetime converted to equal annual payments and expressed in terms of real dollars to remove the impact of inflation.

Total levelized cost of energy reflects overnight capital cost, connection costs, fuel cost, fixed and variable O&M cost, financing costs, and an assumed utilization rate for each plant type. For technologies such as solar, there are no fuel costs and relatively small O&M costs. As a result, the total levelized cost of energy is driven by overnight capital cost of generation capacity. In this analysis, no incentives are considered to lower the total levelized cost of energy. The equation for the total levelized cost of energy (tLCOE) is as follows: tLCOE= {(overnight capital cost [$/MW] * capital recovery factor + fixed O&M cost [$/MW-yr])/(8760 * capacity factor)} + (fuel cost * heat rate). The capital recovery factor (CRF) is ratio of a constant annuity to the present value of receiving that annuity for a given length of time. The equation for the CRF is as follows: CRF = {i(1 + i)^n} / {[(1 + i)^n]-1}, where i is the interest rate and n is number of annuities over project lifetime. Table 4 shows the estimated EIA total levelized cost of energy from new generation sources connected to the grid in 2017.

Table 5: EIA levelized cost of energy from new generation sources connected to the grid in 2017[19]

Plant Type	Capacity Factor (%)	U.S. Average Levelized Costs (2009 $/megawatthour) for Plants Entering Service in 2016				
		Levelized Capital Cost	Fixed O&M	Variable O&M (including fuel)	Transmission Investment	Total System Levelized Cost
Conventional Coal	85	64.9	4.0	27.5	1.2	97.7
Advanced Coal	85	74.1	6.6	29.1	1.2	110.9
Advanced Coal with CCS	85	91.8	9.3	36.4	1.2	138.8
Natural Gas-fired						
Conventional Combined Cycle	87	17.2	1.9	45.8	1.2	66.1
Advanced Combined Cycle	87	17.5	1.9	42.4	1.2	63.1
Advanced CC with CCS	87	34.3	4.0	50.6	1.2	90.1
Conventional Combustion Turbine	30	45.3	2.7	76.4	3.6	127.9
Advanced Combustion Turbine	30	31.0	2.6	64.7	3.6	101.8
Advanced Nuclear	90	87.5	11.3	11.6	1.1	111.4
Wind	33	82.5	9.8	0.0	3.8	96.0
Solar PV	25	140.7	7.7	0.0	4.3	152.7
Solar Thermal	20	195.6	40.1	0.0	6.3	242.0
Geothermal	91	75.1	11.9	9.6	1.5	98.2
Biomass	83	56.0	13.8	44.3	1.3	115.4
Hydro	53	76.9	4.0	6.0	2.1	88.9

The EIA estimates that the total levelized cost of energy for biomass is $115.40 /MWh. In this analysis, CARES estimates the total levelized cost of energy for biomass in the Ukiah area to be $133.43/MWh. Table 6 lists this report's variables for the calculation of total levelized cost of energy for biomass.

Table 6: CARES estimation total levelized cost of energy for biomass utility near Ukiah, CA

Capacity Factor (%)	Levelized Capital Cost ($/MW)	Fixed O&M ($/MW)	Variable O&M (including fuel) ($/MW)	Transmission Connection ($/MW)	CRF	Interest rate	n	Total System Levelized Cost ($/MWh)
77	4,820,152	15,200	423,000	18,000	0.09206	0.0668	20	133.43

Biogas Power Utility Sensitivity Analysis

A sensitivity analysis was performed to estimate the annual cash flow, fuel cost, and non fuel expenses. Table 7 and Figure 9 shows the annual cash flows over the 20 years project lifetime for the biomass utility and the sensitivity analysis. It should be noted that the debt ratio in the UC Davis biogas model is set at 90% and the equity ratio is set at 10%.

Table 7: Annual Cash Flows and Fuel Cost 20 Year Biomass Utility

Project Year	Tariff or Market Value ¢/kWh	Annual Cash Flow $	Fuel Cost $	Non Fuel Expenses $
1	11.63	$219,105.58	$32,573.41	$35,345.00
2	11.63	$108,172.61	$33,257.45	$36,087.25
3	11.63	$109,790.83	$33,955.86	$36,845.08
4	11.63	$111,483.66	$34,668.93	$37,618.82
5	11.63	$113,255.38	$35,396.98	$38,408.82
6	11.63	$121,940.81	$36,140.32	$39,215.40
7	11.63	$124,027.70	$36,899.27	$40,038.93
8	11.63	$126,211.03	$37,674.15	$40,879.75
9	11.63	$128,496.36	$38,465.31	$41,738.22
10	11.63	$130,889.56	$39,273.08	$42,614.72
11	11.63	$133,396.90	$40,097.81	$43,509.63
12	11.63	$136,025.05	$40,939.87	$44,423.33
13	11.63	$138,781.11	$41,799.60	$45,356.22
14	11.63	$141,672.60	$42,677.40	$46,308.70
15	11.63	$144,707.57	$43,573.62	$47,281.19
16	11.63	$147,894.54	$44,488.67	$48,274.09
17	11.63	$151,242.60	$45,422.93	$49,287.85
18	11.63	$154,761.44	$46,376.81	$50,322.89
19	11.63	$158,461.35	$47,350.72	$51,379.67
20	11.63	$49,872.68	$48,345.09	$52,458.65

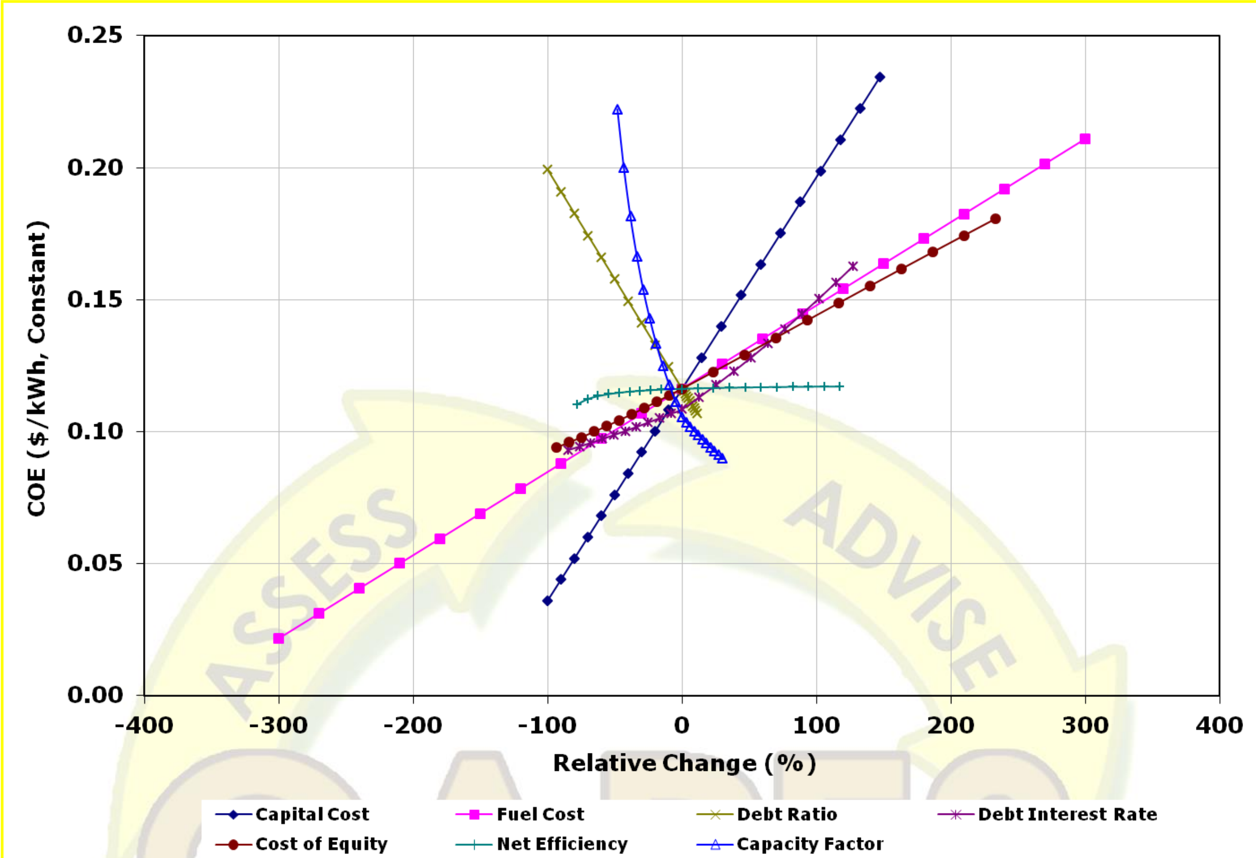


Figure 9: Levelized Cost of Energy Sensitivity Analysis

Conclusions and Recommendations

The close proximity of biogas feedstock to the Pinoleville Pomo Nation increases the likelihood of securing a stable source of feedstock for a biogas power plant; however, it is unknown how much waste these facilities produce or haul. CARES suggests that the PPN contact local waste haulers and facilities for more exact quotes of how much feedstock material is produce and/or hauled. Moreover, the PPN should conduct a review of the amount of food waste and other feedstock material within or near the reservation. CARES does not recommend that the PPN move forward with a biogas system design until an exact determination is made about the availability of feedstock.

Microhydro Power System Study

Concept Brief

The purpose of this renewable energy feasibility study is the assessment of an anaerobic digestion system that produces biogas as potential energy source for localized usage within and near the Pinoleville Pomo Nation (PPN). This study will focus on the technology and economics needed to utilize food waste and other feedstock material within an anaerobic digestion system.

Overview of Microhydro Power Technology

Micro-hydro systems use small water turbines to harness energy of water moving under the force of gravity. Two important variables for these systems are head pressure: the vertical distance the water falls and flow: the quantity of water flowing past a given point in a given period of time. There are two main types of micro-hydro systems high head turbines and low head turbines. A high head turbine is a system in which there is high head pressure created by a significant vertical drop in the height of flowing water. This type of system is ideal for circumstances where a stream or river takes a significant drop such as in a hilly region or mountain. On the other hand, low head turbines tend to be used in scenarios with a slow or fast moving river where the change in altitude is fairly minor over any given distance. In order to get sufficient energy out of a low head turbine, much greater flow must be captured.

PPN Ackerman Creek Site Visit

In December 2010, members of the PPN and the CARES team began gathering measurements on the depth and flow rate from the Ackerman Creek at various sites using a Global Water FP211 meter. Figure 1 shows the location of Ackerman Creek on the PPN reservation and the sites where measurements were taken. Figure 2 shows members of the PPN and CARES gathering the measurements.

Figure 1: PPN Reservation and Ackerman Creek

Figure 2: Gathering Measurements in Ackerman Creek

Ackerman Creek Flow Data

Table 1 shows the Ackerman Creek Flow Data Taken in Dec 2010, Jan 2011, and March 2011

DATE	TIME	LOCATION/TEXT	LOCATION/GPS	IN STREAM LOC.	DEPTH FT	FLOW FT/SEC
12/9/2010	9:25 a.m.	Native Garden	39 10' 58.50" N, 123 13 '19.54" W	SOUTH	1.8	1.5
12/9/2010	9:25 a.m.	Native Garden	39 10' 58.60" N, 123 13 '19.49" W	MID	1.5	
12/9/2010	9:25 a.m.	Native Garden	39 10' 58.44" N, 123 13 '19.30" W	NORTH	0.5	1.9
12/9/2010	9:25	Native Garden -	39 10' 59.15" N,	SOUTH	1.4	1.4

	a.m.	WEST	123 13' 20.83" W			
12/9/2010	9:25 a.m.	Native Garden - WEST	39 10' 59.15" N, 123 13' 20.83" W	MID	1.4	1.6
12/9/2010	9:25 a.m.	Native Garden - WEST	39 10' 59.15" N, 123 13' 20.83" W	NORTH	1.9	2.2
12/9/2010	10:00 a.m.	Williams	39 10' 53.84" N, 123 12' 53.73" W	SOUTH	0.5	2.1
12/9/2010	10:00 a.m.	Williams	39 10' 53.84" N, 123 12' 53.73" W	MID	0.7	3.1
12/9/2010	10:00 a.m.	Williams	39 10' 53.84" N, 123 12' 53.73" W	NORTH	1.6	2.2
12/9/2010	10:00 a.m.	Williams-W of deep hole	39 10' 54.81" N, 123 12' 55.23" W	MID	1.3	4
12/9/2010	10:00 a.m.	Williams-W of deep hole	39 10' 54.81" N, 123 12' 55.23" W	MID	1.3	4
12/9/2010	10:00 a.m.	Williams-W of deep hole	39 10' 54.81" N, 123 12' 55.23" W	MID	1.6	2.5
12/9/2010	10:00 a.m.	Williams-W of deep hole	39 10' 54.81" N, 123 12' 55.23" W	MID	1.6	2.6
12/9/2010	10:35 a.m.	Hwy 101	39 10' 40.23" N, 123 12' 44.06" W	SOUTH	1.4	3.2
12/9/2010	10:35 a.m.	Hwy 101	39 10' 40.23" N, 123 12' 44.06" W	MID	1.4	2.8
12/9/2010	10:35 a.m.	Hwy 101	39 10' 40.23" N, 123 12' 44.06" W	NORTH	1.2	2
12/9/2010	10:35 a.m.	Hwy 101	39 10' 40.23" N, 123 12' 44.06" W	SOUTH	2.2	3.3
12/16/2010	9:45 a.m.	North State St.	39 10' 45.15" N, 123 12' 35.72" W	SOUTH	1.4	3.9
12/16/2010	9:45 a.m.	North State St.	39 10' 45.15" N, 123 12' 35.72" W	NORTH	1.2	1.6
12/16/2010	9:55 a.m.	Hwy 101	39 10' 40.23" N, 123 12' 44.06" W	SOUTH	1.4	2.3
12/16/2010	9:55 a.m.	Hwy 101	39 10' 40.23" N, 123 12' 44.06" W	MID	1.2	2.2
12/16/2010	9:55 a.m.	Hwy 101	39 10' 40.23" N, 123 12' 44.06" W	NORTH	1.2	1.8
12/16/2010	10:10 a.m.	Williams	39 10' 53.84" N, 123 12' 53.73" W	SOUTH	0.5	2.4
12/16/2010	10:10 a.m.	Williams	39 10' 54.07" N, 123 12' 53.67" W	MID	1.1	2.8
12/16/2010	10:10 a.m.	Williams	39 10' 54.23" N, 123 12' 53.53" W	NORTH	1.6	3
12/16/2010	10:10 a.m.	Williams	39 10' 54.47" N, 123 12' 54.36" W	SOUTH	1.2	4
12/16/2010	10:10 a.m.	Williams	39 10' 54.63" N, 123 12' 54.31" W	NORTH	1.4	2
12/16/2010	10:10 a.m.	Williams	39 10' 54.71" N, 123 12' 54.95" W	SOUTH	1	4
12/16/2010	10:10 a.m.	Williams	39 10' 54.71" N, 123 12' 55.14" W	MID	1.4	3.1
12/16/2010	10:30 a.m.	Native Garden	39 10' 58.50" N, 123 13 '19.54" W	SOUTH	2	3.5
12/16/2010	10:30 a.m.	Native Garden	39 10' 58.60" N, 123 13 '19.49" W	MID	0.8	3.3
12/16/2010	10:30 a.m.	Native Garden	39 10' 58.44" N, 123 13 '19.30" W	NORTH	1.5	3.1

1/5/2010	4:05 p.m.	Hwy 101	39 10' 40.23" N, 123 12' 44.06" W	SOUTH	0.8	0.8
1/5/2010	4:05 p.m.	Hwy 101	39 10' 40.23" N, 123 12' 44.06" W	MID	1.2	1.7
1/5/2010	4:05 p.m.	Hwy 101	39 10' 40.23" N, 123 12' 44.06" W	NORTH	1.2	1
1/5/2010	4:05 p.m.	W of Hwy 101 Parcel	39 10' 52.08" N, 123 12' 47.92" W	SOUTH	1	1.9
1/5/2010	4:05 p.m.	W of Hwy 101 Parcel	39 10' 52.08" N, 123 12' 47.92" W	MID	0.7	
1/5/2010	4:05 p.m.	W of Hwy 101 Parcel	39 10' 52.08" N, 123 12' 47.92" W	NORTH	2.5	2.6
1/5/2010	4:05 p.m.	Williams	39 10' 53.84" N, 123 12' 53.73" W	SOUTH	0.6	
1/5/2010	4:05 p.m.	Williams	39 10' 53.84" N, 123 12' 53.73" W	MID	1.1	3.3
1/5/2010	4:05 p.m.	Williams	39 10' 53.84" N, 123 12' 53.73" W	NORTH	0.9	3.4
1/5/2010	4:05 p.m.	Williams	39 10' 53.84" N, 123 12' 53.73" W	NORTH	0.9	5.2
1/5/2010	4:05 p.m.	Williams-W of deep hole	39 10' 54.81" N, 123 12' 55.23" W	MID	1.3	3.9
1/5/2010	4:05 p.m.	Native Garden	39 10' 58.44" N, 123 13 '19.30" W	MID	1.8	1
1/5/2010	4:05 p.m.	Native Garden-East	39 10' 58.42" N, 123 13' 19.06" W	MID	1.5	2.3
1/19/2011	11:10 a.m.	Native Garden	39 10' 58.44" N, 123 13 '19.30" W	SOUTH	1.5	0.6
1/19/2011	11:10 a.m.	Native Garden - 20' east	39 10' 58.42" N, 123 13' 19.06" W	SOUTH	1.1	2.3
1/19/2011	11:10 a.m.	Native Garden - 40' east	39 10' 58.19" N, 123 13' 18.40" W	SOUTH	1.1	1.3
1/19/2011	11:30 a.m.	Williams	39 10' 53.84" N, 123 12' 53.73" W	SOUTH	0.5	0.9
1/19/2011	11:30 a.m.	Williams	39 10' 53.84" N, 123 12' 53.73" W	MID	0.9	2.9
1/19/2011	11:30 a.m.	Williams	39 10' 53.84" N, 123 12' 53.73" W	NORTH	1	1.7
1/19/2011	11:30 a.m.	Williams-W of deep hole	39 10' 54.81" N, 123 12' 55.23" W	SOUTH	1.1	3.6
1/19/2011	11:30 a.m.	Williams-W of deep hole	39 10' 54.81" N, 123 12' 55.23" W	NORTH	1	2.6
1/19/2011	11:50 a.m.	Hwy 101	39 10' 40.23" N, 123 12' 44.06" W	SOUTH	0.8	0.6
1/19/2011	11:50 a.m.	Hwy 101	39 10' 40.23" N, 123 12' 44.06" W	MID	1.6	1.3
1/19/2011	11:50 a.m.	Hwy 101	39 10' 40.23" N, 123 12' 44.06" W	NORTH	1	0.6
3/1/2011	11:50 a.m	Hwy 101	39 10' 40.23" N, 123 12' 44.06" W	SOUTH	1	1.1
3/1/2011	11:50 a.m	Hwy 101	39 10' 40.23" N, 123 12' 44.06" W	MID	1	1.7
3/1/2011	11:50 a.m	Hwy 101	39 10' 40.23" N, 123 12' 44.06" W	NORTH	0.9	1.1
3/1/2011	12:00 p.m.	Williams	39 10' 53.84" N, 123 12' 53.73" W	SOUTH	1	2.5
3/1/2011	12:00	Williams	39 10' 53.84" N,	MID	1.2	3.3

	p.m		123 12' 53.73" W			
3/1/2011	12:00 p.m	Williams	39 10' 53.84" N, 123 12' 53.73" W	NORTH	0.9	3
3/1/2011	12:10 p.m.	Williams-W of deep hole	39 10' 54.81" N, 123 12' 55.23" W	SOUTH	1	2.5
3/1/2011	12:10 p.m.	Willliams-W of deep hole	39 10' 54.81" N, 123 12' 55.23" W	MID	1.8	2.3
3/1/2011	12:10 p.m.	Willliams-W of deep hole	39 10' 54.81" N, 123 12' 55.23" W	NORTH	1.6	2.3
3/7/2011	10:30 a.m.	Williams	39 10' 53.84" N, 123 12' 53.73" W	SOUTH	1	0.3
3/7/2011	10:30 a.m.	Williams	39 10' 53.84" N, 123 12' 53.73" W	MID	1	3,5
3/7/2011	10:30 a.m.	Williams	39 10' 53.84" N, 123 12' 53.73" W	NORTH	1.5	5.4
3/7/2011	10:30 a.m.	Williams-W of deep hole	39 10' 54.81" N, 123 12' 55.23" W	SOUTH	1.4	3.3
3/7/2011	10:30 a.m.	Willliams-W of deep hole	39 10' 54.81" N, 123 12' 55.23" W	MID	1.9	4.1
3/7/2011	10:30 a.m.	Willliams-W of deep hole	39 10' 54.81" N, 123 12' 55.23" W	NORTH	1.2	2.8
3/7/2011	10:00 a.m.	Native Garden	39 10' 58.50" N, 123 13 '19.54" W	SOUTH	1.8	0.8
3/7/2011	10:00 a.m.	Native Garden	39 10' 58.60" N, 123 13 '19.49" W	MID	1.5	2.7
3/7/2011	10:00 a.m.	Native Garden	39 10' 58.44" N, 123 13 '19.30" W	NORTH	0.6	1.8
3/7/2011	10:10 a.m.	Native Garden-20' east	39 10' 58.42" N, 123 13' 19.06" W	SOUTH	1.8	3.1

It should be note that the data was only collect along Ackerman Creek the Dec 2010, Jan 2011, and March 2011. There was not a PPN staff person available to collect data in February 2011. This new flow rate data was then used to more accurately scale the Russian River data obtained from USGS to project the average monthly flow rate in Ackerman Creek throughout the year. The updated flow rate data in cubic feet per second (cfs), along with the Russian River data from which it was scaled (See Table 2) and a chart of the monthly flow rates in L/s used for further energy modeling can be seen in Figure 3.

Table 2: Updated Ackerman Creek flow rates based on Russian River data

Month	Russian River Flow Rate (cfs)	Ackerman Creek Flow Rate (cfs)
1	552	48.46
2	502	60.33653846
3	349	66.41
4	171	32.5899711
5	49	9.324040107
6	12	2.283438394
7	2.4	0.456687679
8	0.65	0.123686246
9	0.61	0.116074785
10	7.5	1.427148998
11	98	18.79006094
12	366	71.03

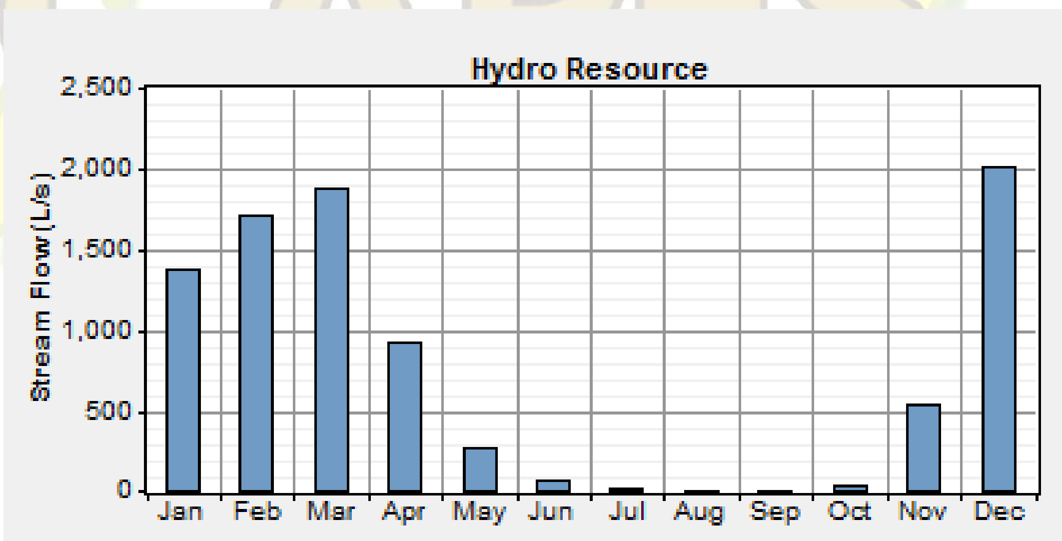


Figure 3. Flow rates (in L/s) shown for each month used for energy modeling.

Though the flow rate information on Ackerman Creek needed to be recompiled for accuracy, the calculated maximum head for the creek was fairly accurate. It was generated by referencing the geographical data collected and stored by Google in the Google Earth topographical visualization program and a provided topographical map of PPN's land and the creek itself.

The largest head found was 4 meters occurring over a distance of more than 900 meters along the length of the river. In order to take advantage of the power created by the moving water, a large pipe would have to carry water 900 meters from the location at the highest altitude in the river down to the William's land near the old levy, as indicated by the purple line in Figure 3.2. The work and expense required to install such a pipe is likely to be enormous, but no longer has to be considered.

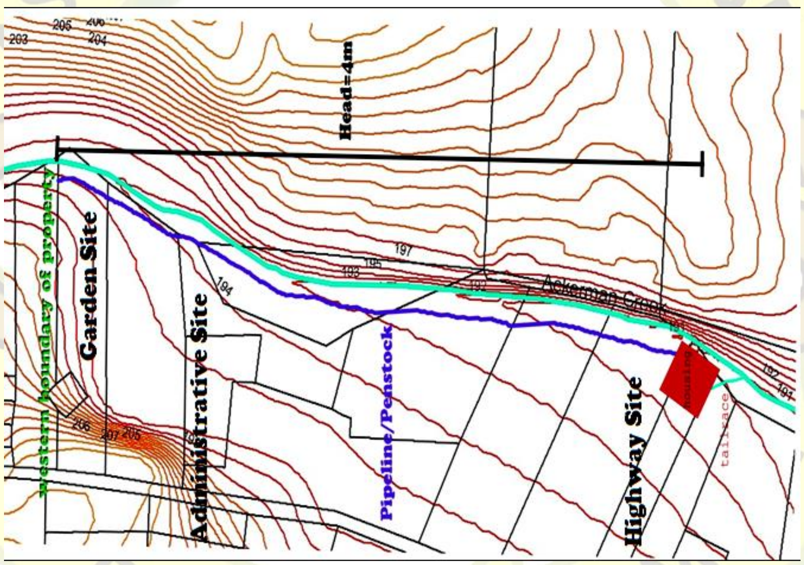


Figure 3 Topographical map of the PPN property

Once provided a map of the land owned by the PPN, the CARES team quickly realized that the piping was no longer an option. The PPN does not own the whole length of the river over which the 4 meters of head exists.

HOMER Model

After running an energy system simulation model in HOMER using the updated flow data given above, we found the power output over various values of head to exhibit a behavior as shown in Figure 4. Based on analysis of this plot, it is clear that at head values below 4 meters the system would not output enough power to be viable for applications in Ackerman Creek

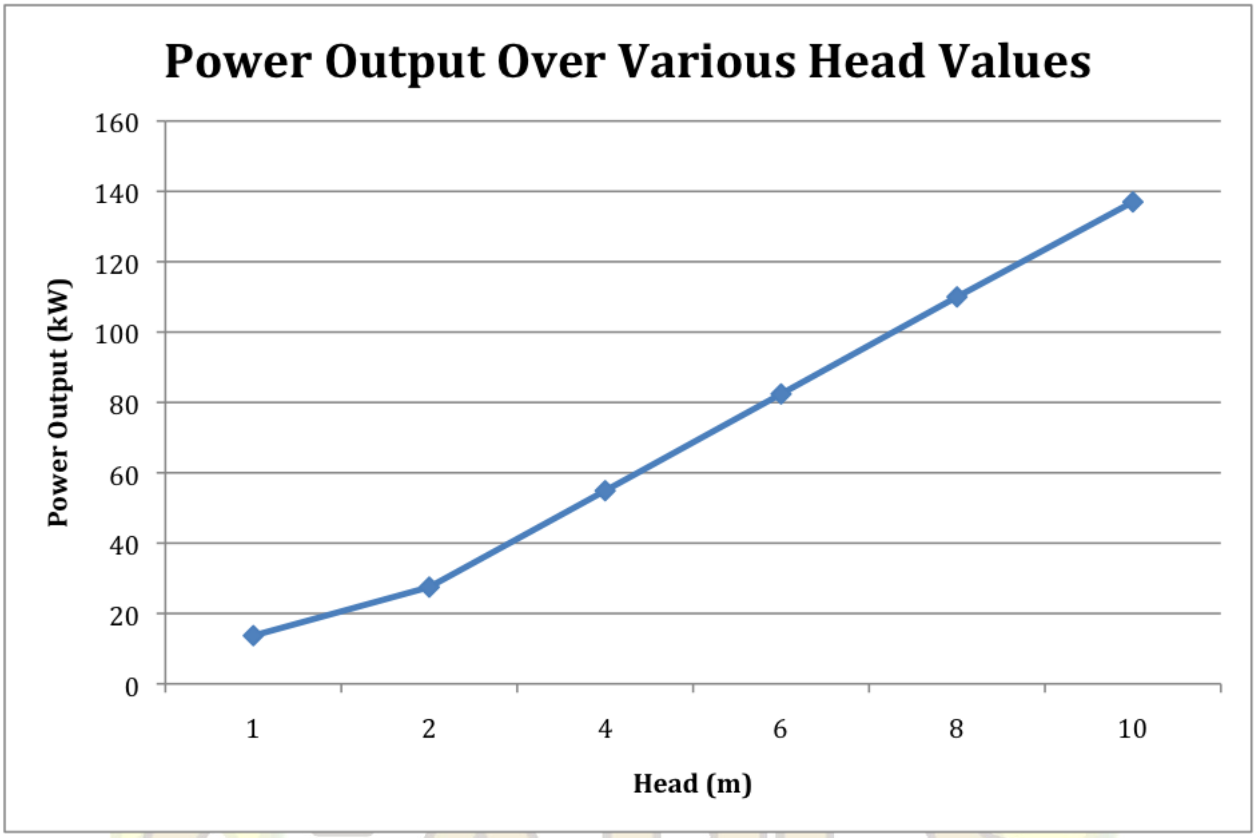


Figure 4: Plot showing power output for various values of head for the Ossberger Turbine.

There is no possibility that a micro hydro turbine will be a viable energy solution for the PPN. A major manufacturer of a micro-hydro turbine, German company Ossberger, was consulted in the summer of 2010 to supply a quote for an installation given the estimated data acquired on Ackerman Creek. The recommended turbine was the Ossberger Turbine operations on 2 meters of head and 40 liters/second at the least. Although the physical measurement of head is no longer valid, the head can be estimated from the velocity of the river. However, even when one of the largest velocities is used to calculate the head, it is 0.453 feet, or 0.138 meters. This is not enough head to operate on any micro-hydro turbine that will output enough power to justify the purchase. A 3 kW turbine needs ~4 m of head to be viable.

Conclusions

Based on the flow data gathered from Ackerman Creek, it has been concluded that the installation of microhydro turbine system for power generation is untenable for the PPN due to the low head of Ackerman Creek. Although the physical measurement of head is no longer valid, the head can be estimated from the velocity of the river. When even one of the largest velocities is used to calculate the head from Ackerman Creek, it is 0.453 feet, or 0.138 meters. This is not enough head to operate on any micro-hydro turbine that will output enough power to justify the purchase. CARES estimates that A 3 kW turbine needs ~4 m of head to be viable. It is therefore recommended that PPN cease operations for the installations of micro-hydro turbine systems for power generation on Ackerman Creek.

PPN Electric Vehicle (EV) Charging System

Concept Brief

The purpose of this renewable energy feasibility study is the assessment of user needs of electric vehicles drivers in order to determine the recommended implementation of electric vehicle charging stations in Northern California on or near the PPN lands. In addition, the study also examines current electric vehicle specifications in conjunction with solar and electric resource data to quantify the requirements for charger implementation. The report explores several test case strategies including: (1) a single localized charging station location, (2) charging locations at peak traffic locations, and (3) locations spaced at even increments. It is recommended that the PPN not pursue a solar EV charging system since solely relying on photovoltaic chargers is impractical due to cost and sizable area requirements.

Background on Electric Vehicles

Currently, drivers of conventional internal combustion engine (ICE) vehicles do not have to be concerned about their ability to refuel their vehicle. In most locations ICE drivers have access to numerous gas stations along their route and can easily refuel when they are running low on fuel. Unlike ICE vehicles which require gas for power, electric vehicles (EVs) are powered by batteries which require charging. Just as ICE drivers stop at a gas station to refuel, EV drivers need to stop at charging stations to recharge. Refueling an ICE vehicle at a gas station and charging an EV are fundamentally different due to differences in ICE vehicles and electric vehicles and the relative infancy of EV technology. First, traditional ICE vehicles currently have a much longer range than electric vehicles. ICE vehicles typically have a range of several hundred miles or more before refueling is required. Electric vehicles typically have a range of only about 100 miles. The reduced range heightens the demand for electric vehicle drivers to finding easily accessible charging stations. Second, an electric vehicle takes between 30 minutes to eight hours to recharge completely. In contrast, a gas tank can be refilled in less than five minutes. The relatively long time required to recharge an electric vehicle makes it imperative that charging stations are located conveniently for EV drivers. EV drivers will be unwilling to endure the long charging times if charging stations are not in close proximity to hotels, shopping, restaurants, etc. Determining ideal locations for electric vehicle recharging stations is a key step in accomplishing large scale adoption of electric vehicles in Northern California near the PPN.

Electric Vehicle Drivers – User Needs

Only a small number of electric vehicles that are not hybrids are presently operating in the United States. These vehicles are typically exceedingly expensive compared with the cost of an ICE vehicle. . Hence, the population of drivers of non-hybrid electric vehicles is so small and unique that the demographics of this group are unlikely to represent the characteristics of the population would buy electric vehicles when the technology become more advanced and affordable to a broader segment of the population.

From the data currently available, demographics of people interested in purchasing the electric vehicles are presented in Table 1.

Table 1: Demographics of Prospective EV Drivers

	Age	**Income**	**Motivations for Purchase**
Nissan Leaf	45 Years	$125,000	Energy dependence and environmental consciousness
Chevy Volt	27 Years	$125,000	Technological advancement

The Nissan Leaf statistics represent people who had preordered an EV in 2010. The statistics for the Chevy Volt represent the manufacturer's target demographic. The statistics indicate that the people that have preordered or are interested in purchasing electric vehicles are older and have higher than average income levels. In addition, many of the people who had preordered the Nissan Leaf currently owned a hybrid vehicle.

Demographically, the broader market for EVs is likely to resemble more closely the characteristics of hybrid vehicle consumers today. Data quantifying the demographics of hybrid vehicle consumer is presented in Figure 1.

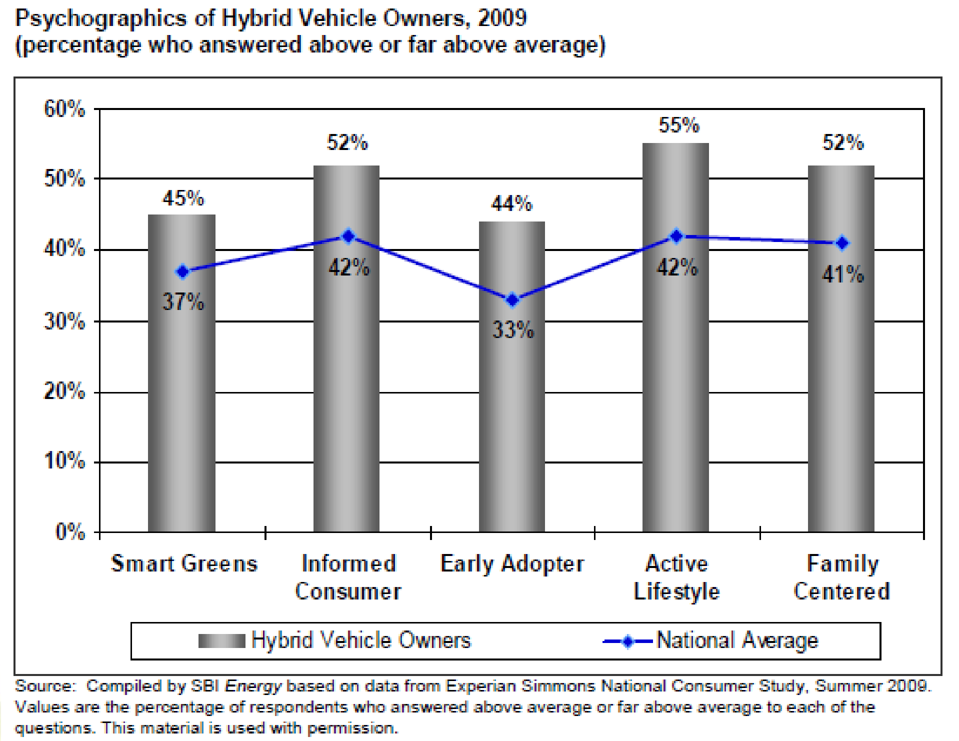


Figure 1: Demographics of the Hybrid Vehicle Consumer (Deschamps)

Demographically, hybrid vehicle users are older and tend to have higher levels of income and education than drivers of ICE vehicles. Typically, hybrid vehicle users are well-informed consumers and show their trendsetting nature with their willingness to be an early adopter of a new technology. Hybrid users also tend to have active lifestyles and are family focused. They tend to be more affluent and environmentally aware that drivers of ICE vehicles. The demographics of mass-marketed, cheaper electric vehicles would mirror the demographics of hybrid vehicle users. They would tend to be older, relatively affluent and highly educated. Californians are some of the strongest adopters of hybrids and electric vehicles. Within the United States, California is a promising market for electric vehicles. California drivers already purchase the highest number of hybrid vehicles each year. In 2009, the registration of new hybrids vehicles in California was 55,553, which represents nearly four times the 15,348 hybrid registrations in New York, the state with the second highest registrations (Deschamps). More than half of the electric vehicles in the Unites States in 2009 are driven in California (Bosik). To better understand the user needs of electric vehicle drivers in Northern California, the demographics of projected electric vehicle drivers is compared with the demographics of visitors to common driving destinations in Northern California. The purpose of this comparison is to determine where it is likely that EV drivers will travel with their electric vehicles and hence, will need to have charging stations available. Four primary attractions considered are parks, wineries, casinos, and shopping destinations. Demographic information for the typical visitor to each location is compared to electric vehicle driver demographics. If many of the demographics overlap, the site is a probable destination for electric vehicle drivers.

Electric Vehicle Adoption Rate

Currently, the number of electric vehicles on the road and sold in the United States is low. Until recently, few electric vehicle models were available to United States consumers. Projections of electric vehicle adoption are needed to estimate the required capacity of infrastructure implementation. Globally, adoption rates for electric vehicles are predicted to range from seven to ten percent by 2020. *The Wall Street Journal* reported estimates that 7.3% of vehicles would be electric vehicles by 2020. The same article cited the Nissan and Renault SA estimate that 10% of vehicles would be electric by 2020 (Ramsey). Other estimates for the adoption of electric vehicles are more optimistic. U.C. Berkeley's Center for Entrepreneurship & Technology (CET) estimates that 64 percent new car sales in the United States in 2030 will be electric vehicles and that 24 percent of vehicles in the United States will be electric (Sidhu). The projected adoption rates worldwide can be used to help determine the capacity of the EV charging network needed.

Caltrans Vehicle Traffic Data

To determine the number of EV charging stations needed, traffic volumes data for the California State Highways from Caltrans is used (Appendix A). The data is collected by measuring the number of vehicles that pass breakpoints in the highway. At the specific breakpoints, the Annual Average Daily Traffic (AADT), Peak Month ADT, and Peak Hour values can be determined. The AADT is the total traffic volume for the year divided by the total number of days in the year. Peak Month ADT reports the average daily traffic for the month of heaviest flow. The Peak Hour is an estimate of the maximum for the year. The Peak Hour value might occur roughly 200 times per year and would be lower than the extreme 30 to 50 highest values (Caltrans).

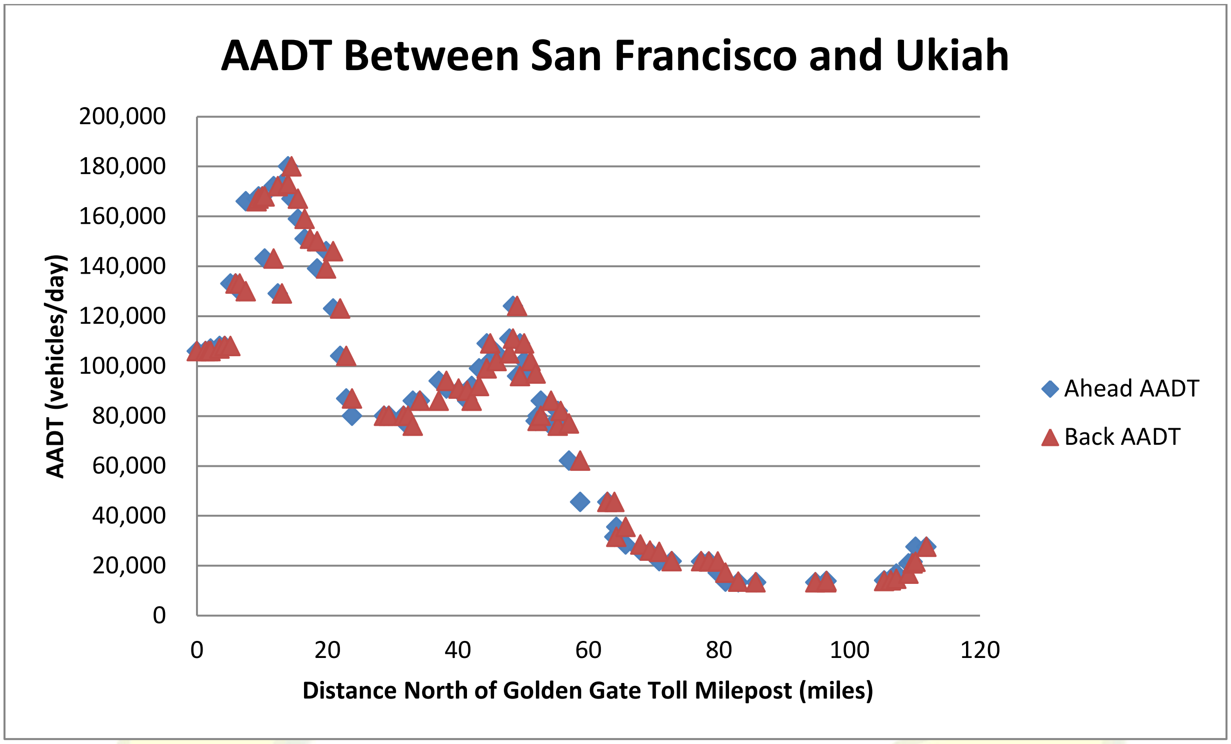


Figure 7: AADT Data for Highway 101 between San Francisco and Ukiah

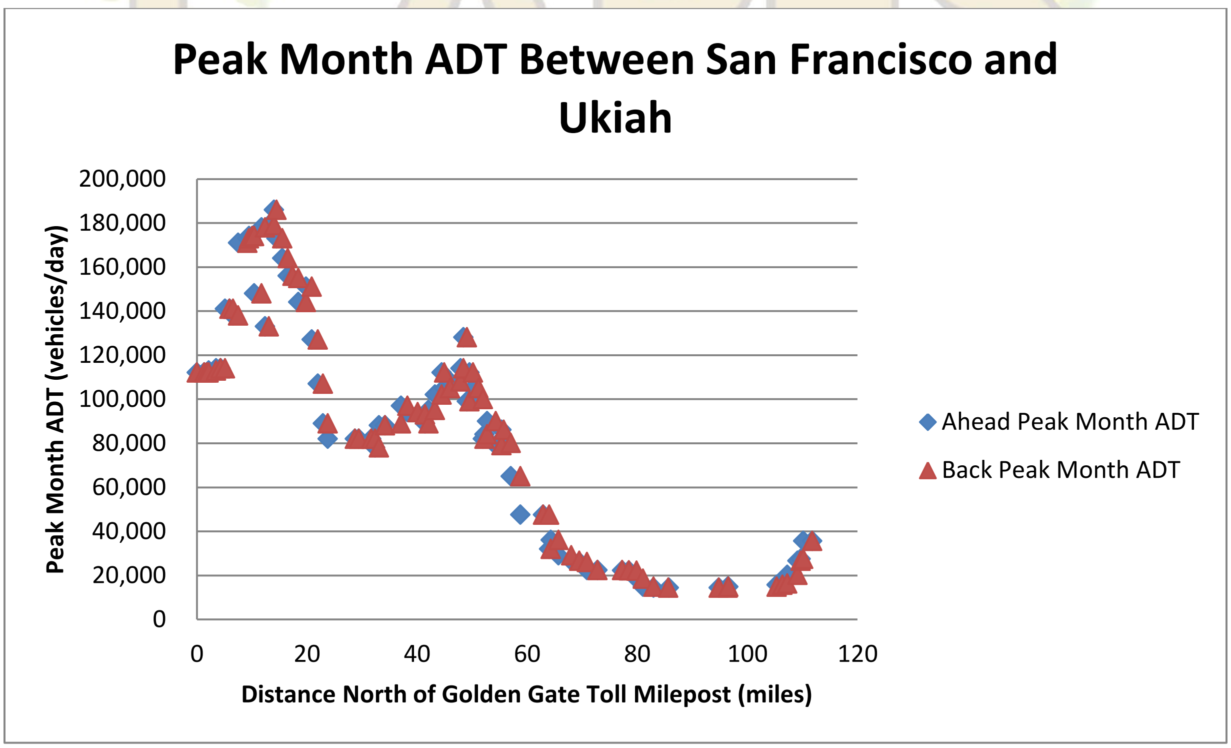


Figure 8: Peak Month ADT Data for Highway 101 between San Francisco and Ukiah

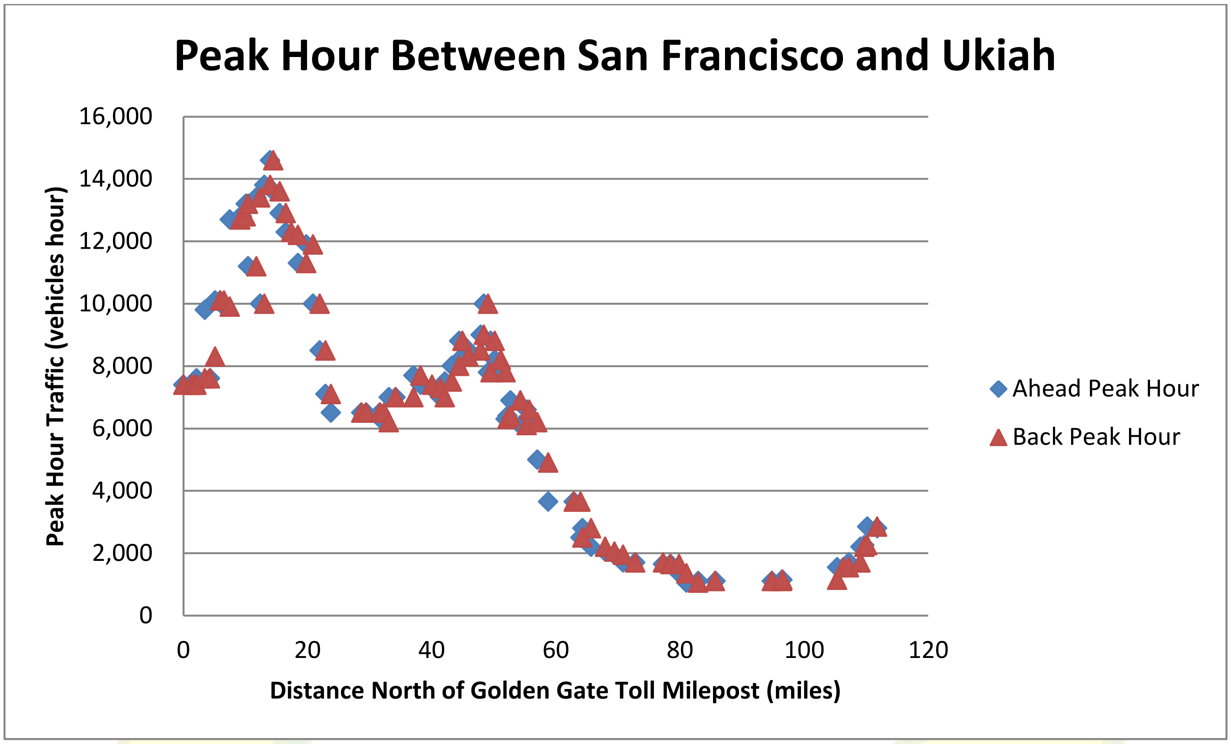


Figure 9: Peak Hour Data for Highway 101 between San Francisco and Ukiah

Key interpretations from the traffic data include that traffic volumes are not constant along U.S. Highway 101. Overall, traffic volumes are much higher in the southern portion of the route near San Francisco than in the northern portion near Ukiah. The traffic data also peaks at three locations, i.e., San Rafael (San Pedro Road Interchange), Santa Rosa (Santa Rosa, Junction Route 12), and north of Ukiah (North State Street Interchange). The trends are repeated across all sets of data.

From the data, the average traffic volumes for Highway 101 between San Francisco and Ukiah are as follows:

Table 7: Average Traffic Volumes for Highway 101 between San Francisco and Ukiah

Back Peak Hour	Back Peak Month	Back AADT	Ahead Peak Hour	Ahead Peak Month	Ahead AADT
6,849	89,799	86,291	6,812	88,842	85,322

The data indicates that the traffic volumes are not constant along the route. The volumes vary along the route with the highest volumes near San Francisco and the lowest volumes in the north near Ukiah. This data suggests that for infrastructure design purposes, the demand for chargers may be higher in the south. However, the number of commuters in the San Francisco

Bay Area is also higher. With a short average commute, commuters in the Bay Area would not need to charge their electric vehicle to get to and from their workplace. Hence, even though traffic volumes on US Highway 101 are much higher in the southern portion just north of the Golden Gate Bridge, this traffic overstates demand for EV charging stations since volumes are inflated by commuters who do not need charging.

Electric Vehicle Charging Application Sites

The main application sites for electric vehicle solar charging site in Northern Califrnoia near the PPN are parks, wineries, museums, and casinos.

Parks

The many parks in Northern California are an ideal destination for an electric vehicle driver. From a Scarborough research survey in 2007, hybrid owners are "twice as likely to claim to go skiing, hiking, or practice yoga than non-hybrid owners" (Profile of Hybrid Drivers). Parks in the Northern California region include California State Parks (State Parks) shown in the maps in Figure 3 and 4. U.S. National Parks in Northern California were also considered in Figure 2.

Figure 2: Northern California National Parks

Figure 3: North Coast State Parks (Buck-Ezcurra)

Figure 4: North Coast State Parks (Buck-Ezcurra)

The maps in Figure 2 shows that National Parks are only located at the southern portion of the region of interest near the San Francisco Bay Area. In contrast, California State Parks are numerous and are located throughout the region. To determine whether park users fit the demographic for potential users of electric vehicles, demographic data for parks users and non-users was analyzed from "The Vision of Excellence" California State Parks Report (Buck-Ezcurra). This document reports detailed demographic data based on telephone interviews with 807 California residents. For purposes of the report, a park visitor was defined as someone who had visited a State Park one to eight times in the past year. A non-visitor was defined as a person who had not visited a State Park in the past twelve months. The poll intentionally interviewed an equal number of visitors and non-visitors to obtain a balance of information. The poll excluded from the results visitors who visited a California State Park more than nine times per year. The poll also excluded people who had no interest in ever visiting a California State Park.

Table 2: California State Parks Report Visitor Demographics

Demographic Group	Visitors (%)	Non-Visitors (%)
Gender		
Men	49	41
Women	51	59
Age		
18-29	13	12
30-39	22	12
40-49	22	21
50-64	26	27
65+	13	25
Education		
High School or less	21	32
Some College	29	29
College Graduate	37	27
Post Graduate	12	12
Ethnicity		
White/Caucasian	71	65
Asian/Pacific Islander	6	4
Latino/Hispanic	15	20
African-American/Black	3	7
All People of Color	27	33
Annual Household Income		
< $30,000	12	19
$30,001 - $60,000	19	23
$60,001 - $75,000	17	14
$75,001 - $100,000	12	12
>$100,000	16	10

Based on the California State Parks Report Visitor Demographics, the demographics of park users follow the same trends as those of EV drivers. Namely, like EV drivers, parks users tend to be more educated than the general population and have higher incomes. Park users are likely to have had education beyond high school and are more likely to be college graduates than non-users. Similarly, parks users are more likely to have higher annual household incomes than non-users. The age demographics for parks users and non-users are almost identical for the 18-29, 40-49 and 50-64 brackets. However, individuals in the 30-39 age bracket shows a stronger park use. In contrast, people in the 65+ age bracket tend strongly to be non-users. The data suggests that individuals in the 30-39 age bracket could be a strong candidates for EV purchase since EV users are typically older and family oriented (Buck-Ezcurra).

California State Parks have high attendance. For example, over 79.5 million people visited California State Parks in the 2007-20/08 fiscal year. One of the top ten state parks by attendance, Sonoma Coast State Park, is located within the region of interest with 1,554,700 visitors in the 2007/08 fiscal year. Visitors can participate in activities including: fishing, picnicking, camping, environmental camping, riding and hiking. Additionally, two of the 2008 Top 100 Family Campgrounds in the U.S. in a survey conducted by Reserve are located in the region of interest: America Richardson Grove State Park and Van Damme State Park. (California State Parks. *Quick Facts*)

In addition to having a visitor demographic that overlaps with the demographic of EV drivers, State Park visitors often use their personal vehicles for leisure travel and to reach State Parks. The *California State Parks Quick Facts* reports as follows:

> The majority of leisure travelers in California use private vehicles for their trips.… The average distance traveled one-way by California residents on leisure trips is 165 miles, bringing many state park units within driving distance of urban centers. Also important to note is that 57% of leisure travel by California residents is for day trips, and 19% is for getaway weekends. California State Parks are convenient destinations for California residents for all types of leisure travel.

Table 3 below presents the origins of travelers in California by mode of transportation.

Table 3: Transportation Usage by Leisure Travelers in California

Point of Origin	Auto (net)*	RV/Campers
U.S. Residents	49%	1%
CA Residents	90%	1%
Total Overseas	71%	2%
Australia/New Zeland	54%	5%
United Kingdom	71%	2%
Japan	66%	1%
Mexico (air travelers)	85%	0.1%

*Autos include private cars, trucks, and small vans. (*California State Parks Quick Facts*)

Notably, 90 percent of California residents use automobiles, trucks and small vans to reach leisure travel destinations, including State Parks. They utilize vehicles more frequently for leisure travel than their counterparts throughout the United States. As indicated in the *California StateParks Quick Facts* data above. Californians travel an average distance of 165 miles one way in traveling to leisure destinations. This data is notable since the range of a typical electric vehicle is only 100 miles. For a shorter range trip, an EV driver might not be compelled to recharge his vehicle at the destination. On the other hand, if the destination exceeds the electric vehicle range, the trip may not be feasible without a convenient option for charging the EV vehicle. If a significant portion of people in the Bay Area adopt electric vehicles, charging stations would be required for State Park accessibility.

Wineries

California wineries are prime destinations, attracting nearly 20 million visitors annually. Over one-third of California's wineries are located in Northern California.

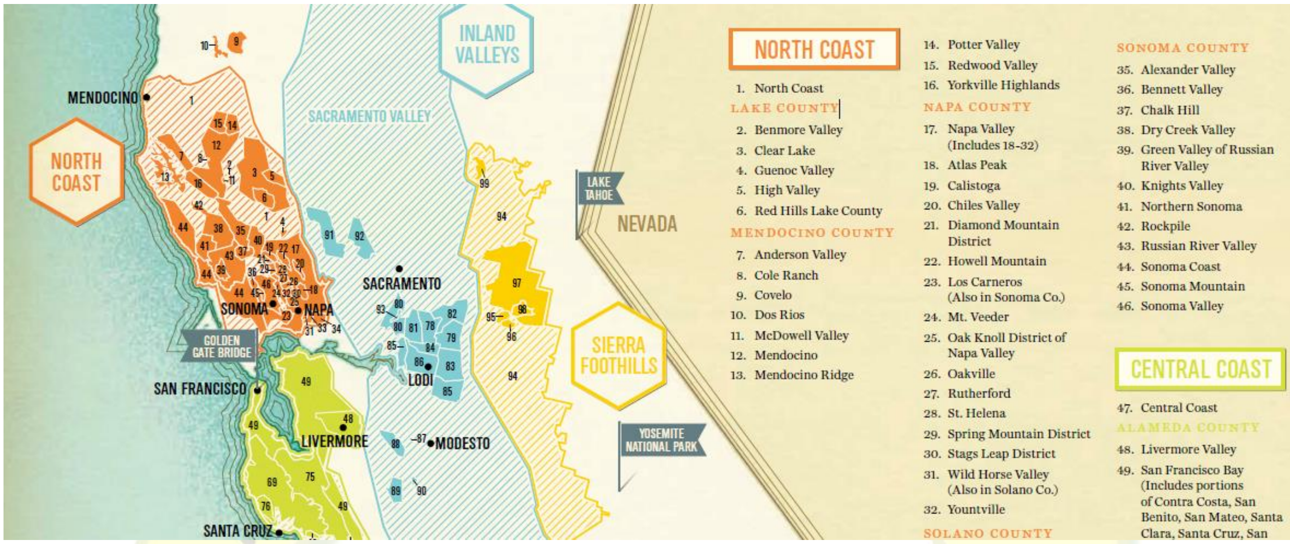


Figure 5: Map of the North Coast California Wine Regions

(Discover California Wines)

In the North Coast region surrounding Highway 101, wineries are spread throughout Napa, Sonoma, Mendocino, Lake, Marin and Solano counties.

Demographically, winery visitors and the EV drivers tend to share common age, education, and income level attributes. Winery visitors are typically well-educated. In addition, winery visitors typically have relatively high incomes, i.e., greater than $100,000 per year (Economic Impact of Wine and Winegrapes).

Examining a profile of winery and culinary travelers is useful in determining additional user needs of the winery visitors. The Wine Institute profile of culinary travelers is as follows:

- **Active Travelers** — more likely to participate in cultural activities, enjoy spa visits, visit state/natural parks and historic sites, and participate in outdoor activities;
- **Highly Experiential** — want new experiences, discoveries and things beyond the norm. To them, having fun is the whole point of life;
- **Indulgers** — want the ultimate culinary, luxury, pampering experiences;
- **Aspirational** — want to experience the good life, have the resources to do so, and will stretch themselves to get a piece of it. They are heavy readers of food and wine lifestyle publications and Web sites;

- **Curious** — they want to see California and experience it for themselves; and
- **Trendsetters** — they are confident leaders and like outrageous people and things.

Similar to EV drivers, winery visitors are trendsetters. Anyone who purchases an EV in the early stages is contributing to a novel trend in transportation. Similarly, the interest of winery visitors in travel and outdoor activities roughly corresponds with the concerns of EV users in the preservation of the environment. Winery visitors with their active, experiential, curious and trendsetting natures make them likely candidates for EV transportation. To serve this population, charging stations must be available in the locale of California wineries.

Museums

Museums are another possible visitor destination in Northern California. Demographic information for museum visitors is presented in Table 4.

Table 4: Demographics of Museum Visitors

	Ethnic Majority	Age	Gender Majority	Education Level
Art Museums	Caucasian	Over 50 years	None	86% with College Degree
Science Centers	Caucasian and Asian	Under 50 years	None	80% with College Degree
History Museums and Historical Sites	Caucasian	Over 50 Years	Female	78% with College Degree
Children's Museums	None	Under 40 Years	Female	81% with College Degree

The demographic data presented in Table 4 indicates that the people that visit museums tend to be older and well-educated. Nearly 80 percent of all museum visitors have college degrees. The average age of the museum visitor varies with the type of museum. Visitors to art and history museums have older visitors than children's museums and science centers. The demographic of museum visitors overlaps with the demographic of the EV driver.

Casinos

Casinos

Casinos located in Northern California are another possible destination for drivers. The demographic for casino visitors is presented in Table 5.

Table 5: Demographics of Casino Visitors

Median Age	47
Average Income ($)	60,000
Education Level	
College post-bachelor's degree	9%
College bachelor's degree	18%
Some college or associates degree	28%
No education after high school	44%
Job Type	
White Collar	41%
Blue Collar	13%
Retired	20%
Other	27%

The median age of casino visitors is similar to Nissan Leaf drivers. However, the average income of casino visitors is much lower than that of both Nissan Leaf and Chevy Volt drivers. This significant difference suggests that casino visitors are unlikely to represent a sizable percentage of EV drivers.

Solar Resources and Cost Estimate Analysis

To determine the feasibility of charging electric vehicles using solar energy, the solar energy resources available need to be determined. The National Renewable Energy Laboratory (NREL) solar insolation calculator PV Watts can be utilized to quantify the solar resources in the corridor along United States Highway 101 in Northern California. PV Watts divides the map into a 40km x 40km grid covering the United States.

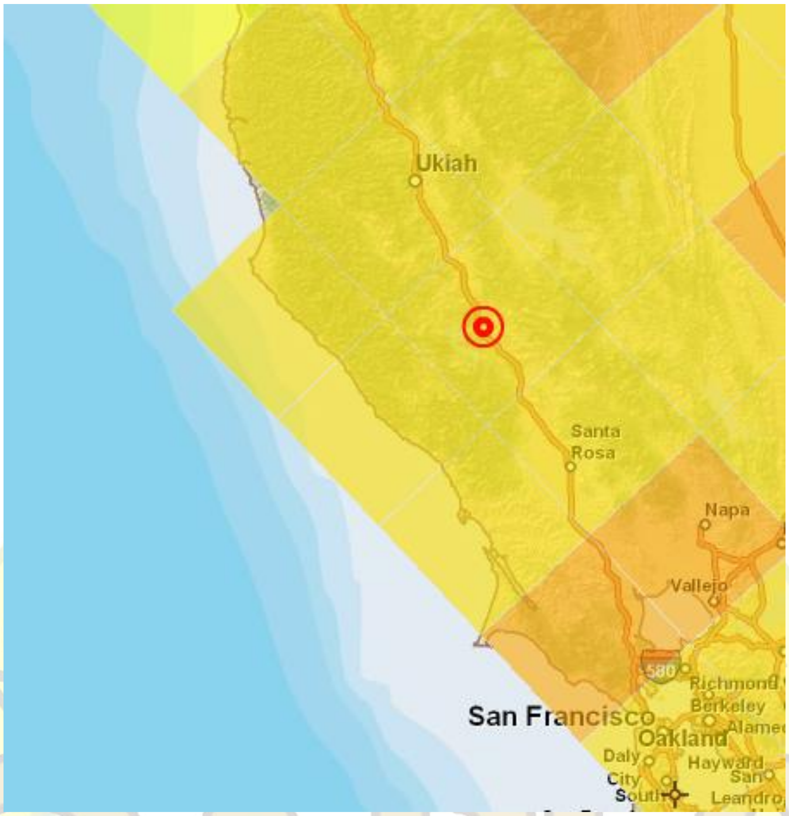


Figure 6: PV Watts Solar Insolation Data Grid between San Francisco and Ukiah

For the nine grid squares surrounding Highway 101, the annual average solar insolation is estimated. Similarly, estimates electric rate for each grid square are estimated. In addition, the energy that can be produced from the solar resources assuming a fixed tilt system with a 4.0 kW DC Rating and a 0.77 DC to AC Derate factor can be calculated. Since the electric rate and solar insolation data did not vary widely from one grid cell to the next, the average solar radiation values were calculated. The data retrieved from the map is presented in Table 6.

Table 6: Solar Insolation Values and Cost of Energy

Cell ID	Description	Annual [kWh/m^2/day]	Electric Rate [cents/kW]	Latitude	Longitude
174347	San Francisco	5.34	12.454	37.739	-122.352
174346	Marin County	5.66	12.595	38.012	-122.669
175346	(Napa)	5.64	12.567	38.263	-122.321
174345		5.16	12.567	38.284	-122.99
175345	Sonoma (Santa Rosa)	5.48	12.747	38.537	-122.642
174344		5.26	12.567	38.556	-123.315
175344	Sonoma (Cloverdale)	5.58	12.752	38.811	-122.967
174343	Medocino County	5.25	12.567	38.826	-123.644
175343	Ukiah	5.36	12.809	39.084	-123.295

Average:		5.46	12.625		

Implementation Nissan Leaf - Case Study

To determine the recommended implementation of electric vehicle charging stations, the changing needs of electric vehicles need to be quantified. Electric vehicles are powered from a battery with a fixed energy capacity. From the energy in the battery, electric motors move the car. For a given battery capacity, the maximum driving range depends on the design of the vehicle, driving habits, terrain, and speed.

For the purposes of this calculation, the Nissan Leaf specifications are used as a standard for electric vehicles. The Leaf's battery capacity is 24 KWh. A single charge of the battery gives the Leaf a range of roughly 100 miles. When the battery needs recharging, the charge times starting from a depleted battery are estimated as follows:

- 30 minutes to 80% at a 480 volt quick-charge station.
- 7 hours at 220/240V (depending on amperage),
- 20 hours at 110/120V.

Nissan Lear Solar Panel Area

To quantify the panel area needed to charge a Nissan Leaf the following is used:

$$Area = 24\ \mathrm{KWh} * \frac{1\,\frac{\mathrm{m}^2}{day}}{5.46\ \mathrm{KWh}} = 4.396\ \frac{\mathrm{m}^2}{day}$$

The calculation shows that to charge a single Leaf battery, a solar panel area of approximately 4.4 m^2 is required. The panel would need to be exposed to solar radiation for the entire day to fully charge the vehicle.

Travel Data from Commuters and PPN Members

Commuters

To explore the needs of commuters, data for commuters between counties of Northern California was collected by the Metropolitan Transportation Commission. Specific counties of interest include San Francisco, Marin, Sonoma, Napa, Mendocino and Lake.

Table 8: Average Traffic Volumes for Highway 101 between San Francisco and Ukiah (Forecast for 2010)

		County of Work					
		Lakeport	Marin	Mendocino	Napa	San Francisco	Sonoma
County of Residence	Lakeport	20,326	164	1,000	1,133	341	2,141
	Marin	4	83,828	28	410	37,572	3,537
	Mendocino	394	188	41,492	38	269	1,769
	Napa	53	1,001	16	49,624	1,689	2,250
	San Francisco	13	5,670	14	213	328,563	690
	Sonoma	341	22,674	444	3,751	11,750	219,132

(Metropolitan Transportation Commission)

From the commuter data, commuter patterns for the six counties surrounding Highway 101 between San Francisco and Ukiah are quantified. For most counties, the majority of commuters in a given county commutes to a workplace and reside in the same county. This is important to note since commuters who commute within their own county would not need to recharge an electric vehicle to commute to work. In addition, in geographically smaller counties, workers may not even need to recharge their vehicle during the day while at work if their commutes are short enough.

PPN Members

To determine the photovoltaic (PV) resources required and cost of implementation for PV EV charging stations, the driving records for the electric vehicles of the Pinoleville Pomo Nation (PPN) are used.

Table 9: Driving Records and Estimates for PPN EV

	Car 1	Car 2	Car 3	Car 4	
Date	**Voc Rehab**	**Head Start**	**Leona (ATTG)**	**Housing Truck (Toyota Tundra)**	
6/21/2009	531	1110	2848	923	
7/21/2009	758	895	2579	923	
8/21/2009	816	1043	2232	923	
9/21/2009	574	765	2926	923	
10/21/2009	719	626	2072	923	
11/21/2009	448	809	2615	923	
12/21/2009	1551	1664	3113	923	
1/21/2010	109	731	3528	923	
2/21/2010				923	
3/21/2010				923	

4/21/2010	1303	1387	3090	923	
5/21/2010	631	54	2404	923	
6/21/2010	597	900	2843	923	**Total**
Miles Driven (miles)	8037	9984	30250	11999	**60,270**
CO_2e per Vehicle (metric tons)	3.67	4.56	13.80	5.48	**27.50**
CO_2 per Vehicle (metric tons)	3.48	4.33	13.11	5.20	**26.13**
Carbon Equivalents (CE) per Vehicle (metric tons)	1.00	1.24	3.76	1.49	**7.50**

Economics of EV Charging System

To determine the cost of implementation, the CREST energy model is used. (CREST Cost of Energy Models). The model estimates the cost of solar charger implementation capacity. From the driving records, the size and cost of PV panels needed is calculated assuming each vehicle is replaced with a Nissan Leaf. First, the mileage that the vehicles drive was converted to annual and daily energy needed and surface area required.

$$Energy = 60{,}270\, miles * \frac{24\ \mathrm{KWh}}{100\, miles} = 14\,464.8\ \frac{KWh}{year} = \ 39.629\ \frac{KWh}{day}$$

$$Area = 39.\,\mathrm{KWh} * \frac{1\,\frac{\mathrm{m}^2}{day}}{5.36\ \mathrm{KWh}} = 7.394\ \frac{\mathrm{m}^2}{day}$$

Sizing the solar system needed taking into account the solar derate factor of 0.77 and a capacity factor of 20%:

$$Energy = 14\,464.8\ \frac{KWh}{year} * \frac{year}{8760\ h} * \frac{1}{0.77} * \frac{1}{0.20} = \ 10.5\ \frac{KWh}{day}$$

Cost estimates for the system can be determined from a simplified model scaling. For simple cost estimates, the cost of the system depends on the cost per watt dc which can range from $4.77 to $8.20 (Farrell) with no incentives. From the values, the cost of the system would likely range from $50,000 to $86,100. Confirming that these estimates are reasonable, one source reports the commercial cost for an 11 kW grid tied system is $43,895.05 (Grid Tie Solar Systems & Panels).

Charger Locations Based on Traffic Peaks

From the traffic data collected, peak traffic volumes were determined. Locating chargers at peak traffic locations where a maximum number of drivers would be able to access the chargers is one possible implementation strategy. The peak traffic volume locations are also suitable because the locations are spaced at reasonable intervals considering the range of electric vehicles. The distance between San Rafael and Santa Rosa, and Santa Rosa and Ukiah are approximately 35 miles and 60 miles, respectively. The locations of the three peak volume locations are displayed on the map in Figure 10.

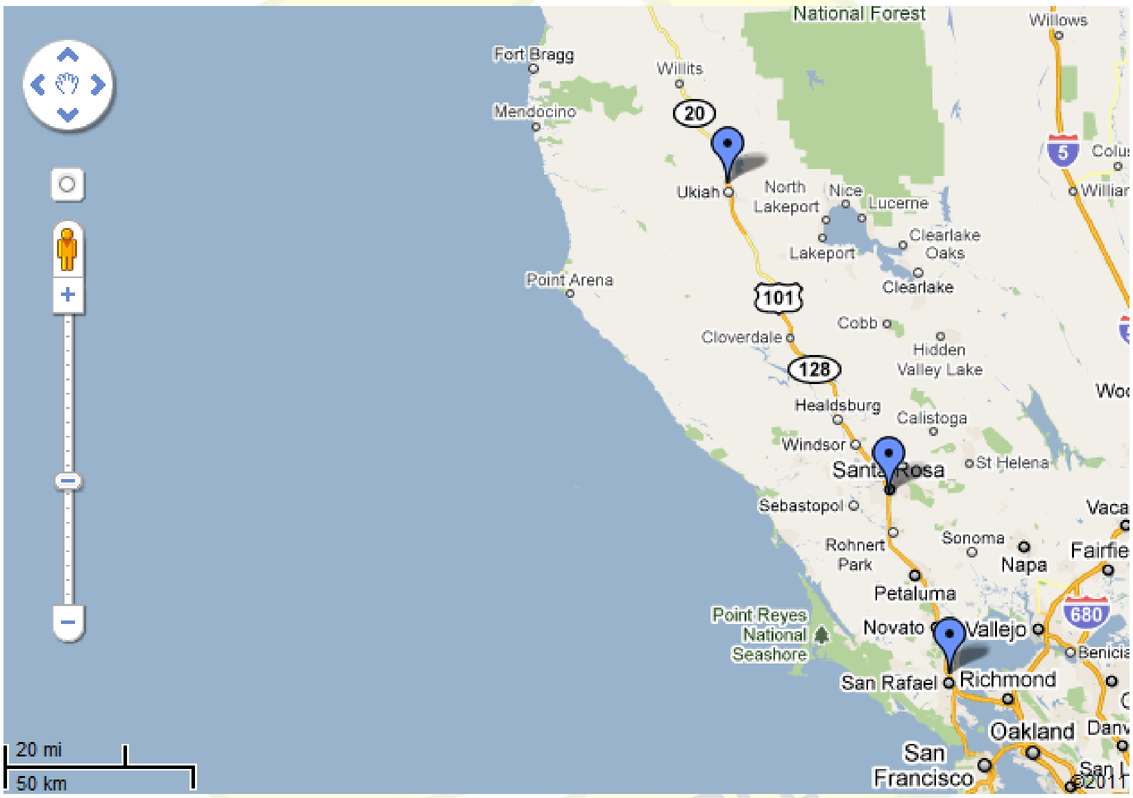


Figure 10: Peak Traffic Volume Charger Locations

To determine the cost of this implementation strategy, the total number of drivers and solar chargers needed is calculated. For each location, the number of drivers using the chargers can be scaled from the total number of drivers.

Assuming a ten percent electric vehicle adoption rate and that 10 percent of electric vehicles would need to be charged at the charging stations, one percent of total vehicles traveling at a particular location would need to be charged. For the chosen locations, estimated capacity for the number of drivers per day is 1860, 1280 and 355 per day from the peak month values.

If each of the drivers require 90% of their 24kWh battery be recharged, then the charging stations would need to provide 40,176 kWh, 27,648 kWh, and 7,668 kWh per day. Taking into account the additional derate factors and capacity factors, the nameplate capacity for each station can be calculated. From the simplified cost calculations, the cost summary for the peak volume charging stations is summarized in Table 10:

Table 10: Cost Summary for Peak Volume Charger Locations

Location	Drivers per day	kWh/day	Nameplate Capacity (kW)	Price Low	Price High
SAN PEDRO RD INTERCHANGE	1860	40176	10636	$50,734,363	$87,216,306
SANTA ROSA, JCT. RTE. 12	1280	27648	7319	$34,913,971	$60,019,824
NORTH STATE ST INTERCHANGE	355	7668	2030	$9,683,172	$16,646,123
			Total	$95,331,506	$163,882,253

Also important to consider in implementation is the area required to capture the needed solar radiation. From the average solar radiation in Northern California, the area required to provide the needed power is summarized in Table 11.

Table 11: Area for Peak Volume Charger Locations

	Average kWh/m^2 with Fixed Tilt Solar Panels: 5.46kWh/m^2	Average kWh/m^2 with 1-Axis Tracking Solar Panels: 6.84kWh/m^2	Average kWh/m^2 with 2-Axis Tracking Solar Panels: 7.32kWh/m^2
Location	Area (Fixed Axis) [m^2]	Area (Single Axis) [m^2]	Area (Double Axis) [m^2]
SAN PEDRO RD INTERCHANGE	7358	5874	5489
SANTA ROSA, JCT. RTE. 12	5064	4042	3777
NORTH STATE ST INTERCHANGE	1404	1121	1048

The area required to implement the solar EV charging stations is relatively large. An area this sizable would need to be purchased or leased. Further the land would need to be maintained. The cost of acquiring and maintaining the land would further factor into the cost of the electric vehicle charging stations. A further cost of operating the charging stations would be the cost of land that would house the electric vehicles while charging. With land costs in Northern California far exceeding land costs in many other parts of the United States, land cost is a major factor to be considered in analyzing charging station implementation.

Chargers Located at Fixed Increments

Spacing EV chargers at even increments is another possible implementation strategy. A map of evenly spaced possible EV charging locations is shown in Figure 11.   For purposes of analysis, a thirty-mile increment was used for placement of the stations. This would accommodate the 100 mile range of electric vehicles and the distance that some drivers would be traveling to reach Highway 101.

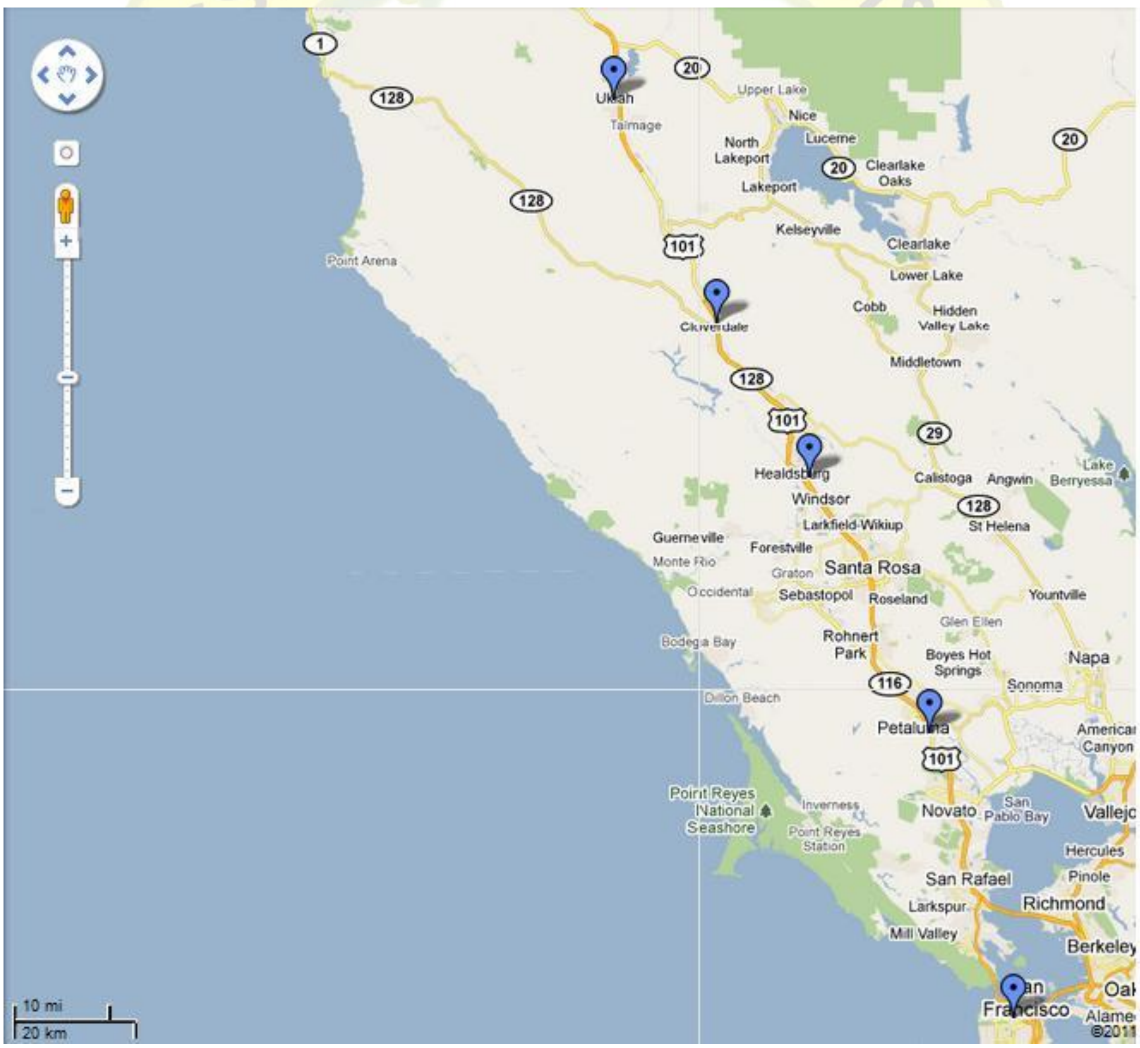


Figure 11: 30 Mile Increment Charger Locations

To evaluate the cost-effectiveness of 30-mile charging stations, calculations were completed to analyze power demand under this model. The results are presented in Table 12 below.

Table: 30-Mile Increment Charger Locations

Estimated Values:	Peak Hour Traffic:99,000 vehicles/day	Average Distance Traveled per Commuter: 115 mi		Average kWh/m^2 with Fixed Tilt Solar Panels: 5.46kWh/m^2	Average kWh/m^2 with 1-Axis Tracking Solar Panels: 6.84kWh/m^2	Average kWh/m^2 with 2-Axis Tracking Solar Panels: 7.32kWh/m^2	
Percentage of Commuters that would Require Chargers	EV/day	total miles driven/day	kWh/day	Area (Fixed Axis)	Area (Single Axis)	Area (Double Axis)	Costs using Crest Model
1.00%	990	113850	27324	5004.4	3994.7	3732.8	$814,368,600
1.50%	1485	170775	40986	7506.6	5992.1	5599.2	$1,224,456,750
2.00%	1980	227700	54648	10008.8	7989.5	7465.6	$1,632,609,000
2.50%	2475	284625	68310	12511.0	9986.8	9332.0	$2,040,761,250
3.00%	2970	341550	81972	15013.2	11984.2	11198.4	$2,448,913,500
3.50%	3465	398475	95634	17515.4	13981.6	13064.8	$2,857,065,750
Values for Each Charging station of a 30 mile model							
Estimated Values:	Peak Hour Traffic:99,000 vehicles/day	Average Distance Traveled per Commuter: 30 mi		Average kWh/m^2 with Fixed Tilt Solar Panels: 5.46kWh/m^2	Average kWh/m^2 with 1-Axis Tracking Solar Panels: 6.84kWh/m^2	Average kWh/m^2 with 2-Axis Tracking Solar Panels: 7.32kWh/m^2	
Percentage of Commuters that would Require Chargers	EV/day	total miles driven/day	kWh/day	Area (Fixed Axis)	Area (Single Axis)	Area (Double Axis)	Costs using Crest Model
1.00%	990	29700	7128	1305.5	1042.1	973.8	$51,107,760
1.50%	1485	44550	10692	1958.2	1563.2	1460.7	$76,661,640
2.00%	1980	59400	14256	2611.0	2084.2	1947.5	$102,215,520
2.50%	2475	74250	17820	3263.7	2605.3	2434.4	$532,372,500
3.00%	2970	89100	21384	3916.5	3126.3	2921.3	$638,847,000
3.50%	3465	103950	24948	4569.2	3647.4	3408.2	$745,321,500

The commuter data indicates that during the peak month of traffic flow, 99,000 vehicles traveled between Ukiah and San Francisco. Using this traffic volume and several different EV adoption percentages, the number of EV vehicles per day traveling along Highway 101 could be calculated. Assuming each EV travels 115 miles (the total distance from San Francisco to Ukiah), the total miles traveled is the product of the total number of EVs and 115 miles. The Nissan Leaf advertises 100 miles for each 24 kWh charge. This ratio equality can be used to solve the total amount of kWh necessary to charge the vehicles.

24kWh/100 miles= Total kWh/Total miles traveled.

Considering a 30-mile model proposal where EV charging stations are placed every thirty miles along Highway 101 between Ukiah and San Francisco, a similar procedure can be used to solve the total kWh necessary at each station by simply replacing 115 miles/vehicle with 30 miles/vehicle. Finally, the CREST model program was used to convert the kWh to the total cost of producing solar panels with corresponding energy outputs. The cost values have proven to be significantly larger than anticipated, and therefore alternatives to pure reliance on solar power need to be considered.

Conclusions

Based on analysis of user needs and demographics of drivers in the Bay Area, Northern California residents, together with their Southern California counterparts, will likely lead the nation in adopting electric vehicles. In order for electric vehicles to reach widespread use, charging infrastructure is required. Although the majority of round trip commutes in the North Bay are within the range of the electric vehicle battery, electric vehicle drivers will require charging stations for non-commute trips. To best serve Northern California electric vehicle users, PPN charging stations should located at heavily traveled destinations as well as in peak traffic areas. Taking into account solar resources, driver needs, and implementation costs, the most restrictive factors for charging station implementation are cost and the surface area required to charge vehicles. If vehicles are solely charged using solar energy, the land area required for peak traffic locations becomes restrictive and thus makes a purely off grid solar EV system untenable. Chargers located at peak traffic locations would need to be grid-tied to feasibly provide power for projected EV demand. CARES, therefore, recommends that the PPN not pursue the development of a standalone solar EV charging; instead, CARES recommends that the PPN pursue a solar PV utility scale system (>1 MW) for its own power generation needs on its reservations as well as selling to the grid via a PPA.

Overall Conclusions and Recommendations

It is was determined that a 1-3 MW solar utility was the most viable option for the PPN due to its LCOE of $233.07/MWh and its abundant feedstock that is more easily accessible. During the one year anemometer testing, it was determined that wind speeds were higher than expected (several over 20 MPH), but that the average wind speeds were between 4-8 mph which makes a wind farm or wind utility unfeasible for the PPN. For a biogas utility, it was determined that it had the lowest levelized cost of energy (LCOE) ($133.43/MWh) of the energy sources tested and that there were several sources of organic feedstock for an anaerobic digester; however, it was unknown how much feedstock these sites produce or if PPN would have reliable access to the feedstock.

For microhydro, the head from Ackerman Creek at one of its largest velocities was 0.453 feet (0.138 meters); however, CARES determined that ~4 m of head is need for microhydro system to be viable. For a solar electric vehicle charging system, it was determined that the land area required for peak traffic locations becomes restrictive and thus makes a purely off grid solar EV charging system untenable. CARES recommends that the PPN pursue the development of a 1 -3 MW solar utility to meet its internal energy usage as well as pursue a PPA to sell excess electricity to the grid.

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