NORTH COAST RESOURCE PARTNERSHIP

North Coast Resource Partnership Integrated Strategic Plan

CLIMATE CHANGE MITIGATION, GHG EMISSIONS REDUCTION AND ENERGY INDEPENDENCE

Prepared by:
Schatz Energy Research Center, Humboldt State University, 1 Harpst Street, Arcata, CA 95521
Lead Author: Jim Zoellick, jimz@humboldt.edu
Contributing Author: Andy Harris

Redwood Coast Energy Authority, 633 3rd Street, Eureka, CA 95501
Lead Author: Andrea Alstone, aalstone@redwoodenergy.org
Contributing Author: Pierce Schwalb

Presented to West Coast Watershed
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EXECUTIVE SUMMARY

This report provides an overview of the energy picture for the seven counties that comprise the North Coast Resources Partnership (NCRP). These counties include Del Norte, Humboldt, Mendocino, Modoc, Siskiyou, Sonoma, and Trinity. The report synthesizes publically available information. It is intended to serve as a technical background document that can help lead to the development of a sustainable energy strategic plan for the region. Suggested goals for a sustainable energy strategic plan are to increase energy efficiency, develop local renewable energy resources, reduce the consumption of carbon-intensive fossil fuels, and increase local control, including the participation of the local community in shaping their energy future.

The report provides a regional profile of energy consumption and generation and associated CO_2 emissions. In addition, it provides an assessment of energy efficiency, renewable energy, and alternative transportation opportunities in the region. The report concludes with a set of recommendations for further planning and research, and identifies key project and program activities that should be considered for future implementation.

Regional Energy Profile

Of the seven counties in the NCRP region, Sonoma County is by far the most populous, has the greatest population density, and is the most affluent. The six remaining counties rank in the bottom 28% of the 58 counties in California in terms of population density. In general, the NCRP region is rural, sparsely populated, and not very affluent. Four of the counties are on the coast and have rather moderate climates; three of the counties are inland with more extreme temperature profiles.

All of these characteristics tend to impact the energy consumption patterns for these counties. Sonoma, with its larger population, has the greatest energy consumption. However, it also has the lowest electricity consumption per capita. Only three counties (Humboldt, Mendocino and Sonoma) have significant natural gas service. The remaining counties are reliant on propane, fuel oil, wood and electricity to meet space heating, water heating, and cooking needs. Note that data on propane, fuel oil, and wood use for heating are not readily available. Transportation fuels are primarily gasoline and diesel.

The region generates more electricity than it consumes, with Sonoma generating the majority from geothermal power. Other sources throughout the region include hydroelectric, natural gas, biomass, and solar. Almost all natural gas is imported from outside the region, and all gasoline and diesel fuels are imported.

The energy related greenhouse (GHG) emissions in the region appear to be dominated by the transportation sector. However, incomplete data are currently available and further work is needed in this area.

Resource Assessment

The NCRP region has a wealth of sustainable energy resources to draw upon. This includes opportunities for gains in energy efficiency, renewable energy resource development, low-carbon transportation fuels, and fuel switching in the heating sector. It is important to note that in order to meet State of California greenhouse gas emission goals, substantial deployment of low-carbon fuel options will need to be achieved. One effective approach is to "green" the local electric grid with low or no carbon renewable energy resources, while simultaneously switching transportation and heating energy demands to electricity. This can include battery and hybrid plug-in electric and fuel cell vehicles in the transportation sector, and electric heat pumps in the heating sector for both space and water heating.

The first place to start with energy sustainability is with energy efficiency measures, as they are typically the most cost effective. Substantial energy efficiency efforts and programs are already underway in the region, but more work needs to be done and services need to be provided to underserved areas.

The NCRP region is rich in renewable energy resources, including solar, wind, wave, biomass, geothermal, and hydro. With regard to technical development potential, solar and wind power make up the majority of the available resources. An added benefit is that these two resources make up the fastest growing sector of the renewable power market. This is because the costs of wind and solar technology have come down dramatically in recent years, and they are now cost competitive with conventional energy resources.

But renewable power is not just a potential resource, as many local renewable energy resources are already being utilized. In fact, the NCRP region as a whole already generates more renewable electricity than it consumes. However, that does not mean that the region can contractually claim all of the associated renewable energy benefits because much of the power is sold to entities outside of the region. Nonetheless, local generation resources are significant, and there is much room for expansion. In addition, resources are well distributed throughout the region, offering every NCRP county opportunities for development.

In the area of low-carbon transportation fuels, a fair amount of planning and analysis work has already been conducted in the region, but there is much more work to be done. Work is underway to develop a network of electric vehicle charging stations to interconnect and serve the entire region, and numerous stations have already been installed. Planning work is also proceeding for hydrogen fueling infrastructure, and one station is already under development in Sonoma County. Low-carbon, second generation biofuels are also a potential resource for the area. The State of California has very ambitious goals for the penetration of zero emission vehicles, and if the State is to meet these goals then the NCRP region will likely have to make significant strides toward developing low-carbon fueling infrastructure and promoting the rapid deployment of alternative fuel vehicles.

In the heating fuel sector, the greatest opportunity for simultaneous GHG emission reductions and cost savings is associated with electric heat pumps, especially in areas that do not have natural gas service. In these areas there is substantial use of propane, fuel oil/kerosene, and electric resistance heat. In these situations electric heat pumps can offer significant GHG emission reductions, as well as substantial energy cost savings. This is an area that deserves further research and consideration, as there is a good chance that an educational outreach and promotional program that includes monetary incentives could be successful.

Recommendations

This report is intended to provide background technical information that can support the development of a sustainable energy plan for the NCRP region. Next steps should include creation of a vision statement and development of a detailed, regional strategic energy and climate plan. This work should build upon and leverage similar work that has been done in both Sonoma and Humboldt Counties, and should allow for a diversity of options that can meet the needs and desires of each jurisdiction in the region.

Substantial sustainable energy efforts are already underway in Sonoma and Humboldt Counties, as well as smaller efforts in other areas. Both Sonoma and Humboldt have established Community Choice Aggregation programs (also known as Community Choice Energy). In addition, Humboldt, Mendocino and Sonoma Counties have all established Energy Watch partnerships with PG&E in order to deliver effective energy efficiency programs to their residents. If possible, these types of programs should be expanded to cover the entire region.

It is clear that there is vast renewable energy potential in the NCRP region. This potential should be further assessed and key projects that exhibit a high degree of feasibility should be seriously considered for implementation. These efforts can serve to "green" the grid, and they can be complemented by encouraging fuel switching to electricity in both the transportation and heating sectors.

The promotion of energy efficiency, local renewable energy development, and fuel switching strategies along with community-based energy programs such as Community Choice Energy will lead to many benefits in the NCRP region. These strategies can offer social, environmental, economic, and political benefits. Development of local energy projects will mean more energy dollars circulating in the local economy and more local jobs. Reduction of fossil fuel use will mean an improved environment and less stress on the earth's climate. Local projects and local control means greater local participation and a more informed public. All of these benefits can lead to a stronger community.

1 INTRODUCTION

The purpose of this report is to synthesize publically available information and provide a broad overview of the energy picture of the North Coast Resource Partnership (NCRP) region. This report can serve as technical background information for developing an energy vision and implementation strategy to increase energy efficiency, develop renewable energy resources, and reduce the consumption of carbon-intensive fossil fuels via fuel switching. Previous studies and plans developed in the region, including the RePower Humboldt Strategic Plan (RCEA 2013) and the Climate Action 2020 and Beyond: Sonoma County Regional Climate Action Plan, (RCPA 2016) have shown these three strategies to be key to a sustainable and prosperous energy future. The benefits of these strategies include increased economic development and job creation, increased energy security and resiliency, reduced greenhouse gas (GHG) emissions, and increased local control and participation in meeting the energy needs of the region. This report aims to identify opportunities and constraints for pursuing these strategies and provide recommendations for next steps.

The report is structured as follows: Section 2 provides a regional profile of energy consumption and generation and associated CO2 emissions. Section 3 provides a resource assessment for energy efficiency, renewable energy, and alternative transportation in the region. Section 4 identifies information gaps and presents recommendations for further research and program development.

It is important to note our approach for reporting energy statistics for the NCRP region. As shown in Figure 1, the NCRP region is defined by watershed boundaries rather than political boundaries. However, for practical reporting reasons we are treating the NCRP region in this report as the 7 counties that comprise the leadership of the NCRP council. These counties are:

- Del Norte
- Siskiyou
- Humboldt
- Sonoma
- Mendocino
- Trinity
- Modoc

Other important notes with regard to the scope of this report are as follows.

In Section 2.2 we cover energy consumption for the NCRP region. This includes only electricity, natural gas, gasoline and on-highway diesel fuels. We do not provide consumption data for propane, heating oil or wood used for heating, as these data are not readily available. It is expected that propane, heating oil, and wood fuels account for a substantial portion of the heating fuel use in the NCRP region since much of the region (the majority of the population in Del Norte, Modoc, Siskiyou and Trinity Counties) does not have natural gas service. It is recommended that further research be conducted to explore opportunities to obtain data and/or estimate consumption of these fuels in the region. Note that US census data does provide estimates of heating fuel penetration by fuel type for housing units in each county.

In Section 2.4 we provide estimates of the GHG emissions from the energy sector, but this is only a partial estimate due to the fact that some heating fuel use is not accounted for. In addition, it is important to note that there are numerous GHG emission sectors in addition to electricity, heating fuels and transportation. These include agriculture, industrial process, land use, and waste sectors. Climate change mitigation efforts in the NCRP region should address these sectors as well, but that topic is not within the scope of this report.

Figure 1: The NCRP region, outlined by a red dotted line, is defined by watershed boundaries. The red shaded area is not in the NCRP watershed region, but was included in this sustainable energy assessment. The blue shaded area is in the NCRP watershed region, but was not included in this sustainable energy assessment.

2 REGIONAL ENERGY PROFILE

This section provides a broad description of the North Coast Resource Partnership (NCRP) region's energy consumption and generation. The section starts with a general demographic and climate overview in Section 2.1. Section 2.2 presents energy consumption data, by county, for electricity, natural gas, gasoline and diesel fuel. Section 2.3 presents the existing energy generation sources and production for each county. Section 2.4 gives CO_2 emissions estimates by source for each county. Finally, section 2.5 outlines some existing state and local resources available in the region.

2.1 DEMOGRAPHICS AND CLIMATE

This section presents some high level demographic and climate information for each of the seven counties in the region. Table 1 presents population and income data for 2010 and 2014 (Census, 2015) for each county. Data are from the US Census Bureau and are measured in 2010, with a population projection for 2014. Sonoma County has the largest population, population density, and median household incomes in the region by a significant factor. The counties with the lowest population densities, Trinity, Modoc, and Siskiyou, also have the lowest median household income. It is also worth noting that all the counties in the region, except Sonoma and Humboldt, have experienced a decline in population in the last 5 years. These diverse demographics provide varied challenges and opportunities in the region.

Table 1: Population numbers by county and for the region in 2010 and estimated for 2014

	Del Norte	Humboldt	Mendocino	Modoc	Siskiyou	Sonoma	Trinity
Population 2010	28,610	134,623	87,840	9,686	44,900	483,880	13,786
Population 2014 (est)	27,549	135,487	87,701	9,125	43,832	498,756	13,221
Persons per household	2.57	2.46	2.53	2.25	2.25	2.58	2.39
Population per square mile	28.4	37.7	25.1	2.5	7.2	307.1	4.3
Median Household Income	$39,302	$42,153	$43,290	$38,560	$37,495	$63,799	$36,862
Percent of population in poverty	22.4%	21.0%	18.8%	20.2%	21.1%	11.3%	19.9%

The following figures present the mean monthly high (Figure 2) and low temperatures (Figure 3), and the annual average rainfall (Figure 4) for the county seat of each county (Your Weather Service 2015). The county seats are:

- Del Norte – Crescent City
- Humboldt – Eureka
- Mendocino – Ukiah
- Modoc – Alturas
- Siskiyou – Yreka
- Sonoma – Santa Rosa
- Trinity – Weaverville

It should be noted that there can be large variations in temperature and rainfall geographically throughout these counties, particularly for the coastal counties. However, the population density for each county tends to be concentrated in and around the county seat, so the data presented are representative for the majority of residents in each county. The counties with the most extreme temperatures are the inland counties of Trinity, Modoc, and Siskiyou. The coastal counties of Sonoma, Humboldt, Mendocino, and Del Norte have less variation in temperature throughout the year. Not surprisingly, the coastal counties tend to get the greatest rainfall.

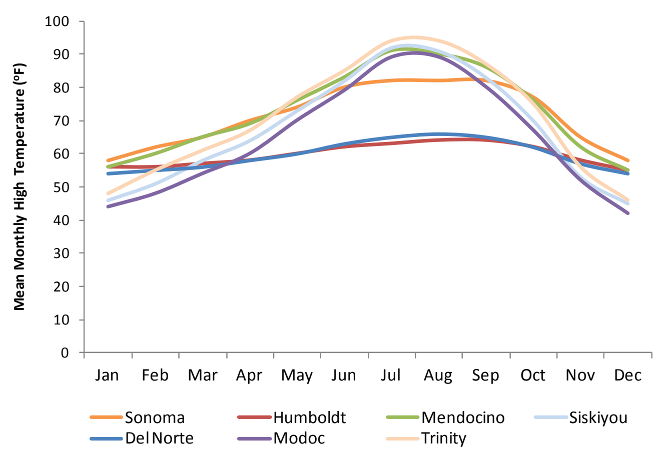


Figure 2: The mean monthly high temperature, in Fahrenheit, in the county seats – Santa Rosa in Sonoma, Eureka in Humboldt, Ukiah in Mendocino, Yreka in Siskiyou, Crescent City in Del Norte, Alturas in Modoc, and Weaverville in Trinity.

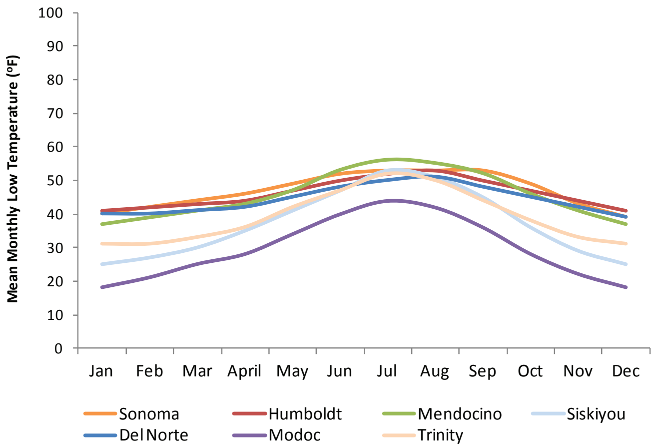


Figure 3: The mean monthly low temperature, in Fahrenheit, in the county seats – Santa Rosa in Sonoma, Eureka in Humboldt, Ukiah in Mendocino, Yreka in Siskiyou, Crescent City in Del Norte, Alturas in Modoc, and Weaverville in Trinity.

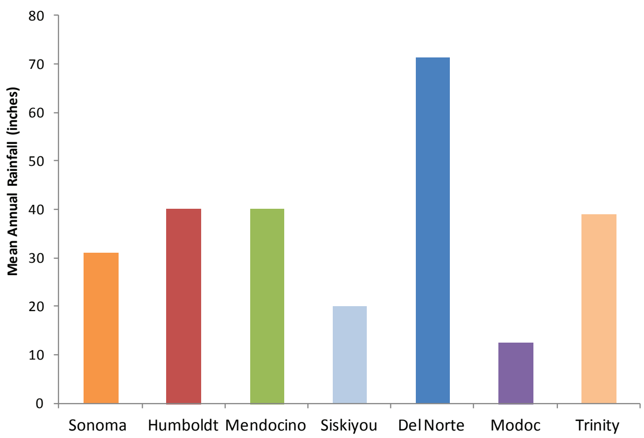


Figure 4: Mean annual rainfall, in inches, for the county seat of each county— Santa Rosa in Sonoma, Eureka in Humboldt, Ukiah in Mendocino, Yreka in Siskiyou, Crescent City in Del Norte, Alturas in Modoc, and Weaverville in Trinity.

2.1 ENERGY CONSUMPTION

Electricity

This section presents the electricity consumption for the region by county. Data were obtained from the California Energy Commission (CEC ECDMS 2016). Figure 5 presents the electricity consumption in the residential sector for all counties in the NCRP region for the years 2005-2015. Figure 6 presents the total electricity consumption for each of the counties in the NCRP region. Sonoma County is the largest consumer of energy due its large population size.

The per capita electricity consumption by county for residential and total energy use is presented in Figure 7 and Figure 8, respectively. In every instance each county's per capita consumption has decreased modestly between 2010 and 2014. This is not surprising for counties in California, where on a statewide basis per capita electricity consumption has been rather flat for the last three decades while national per capita electricity consumption has continued to grow. This is directly linked to the state's aggressive energy efficiency programs. Sonoma County has the lowest per capita consumption.

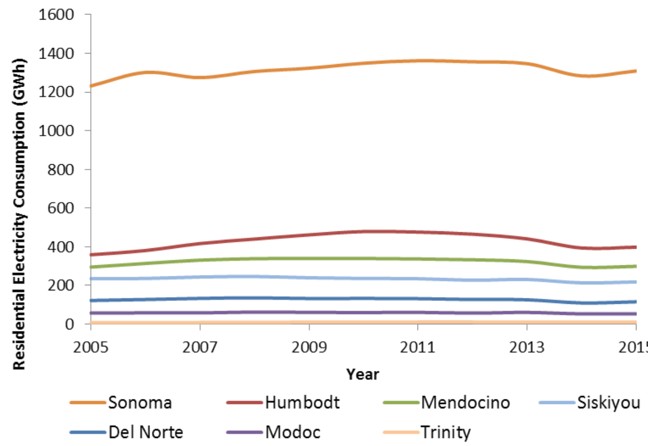


Figure 5: Residential electricity use by county from 2005-2015 in GWh. Sonoma County uses more electricity than the remaining counties combined.

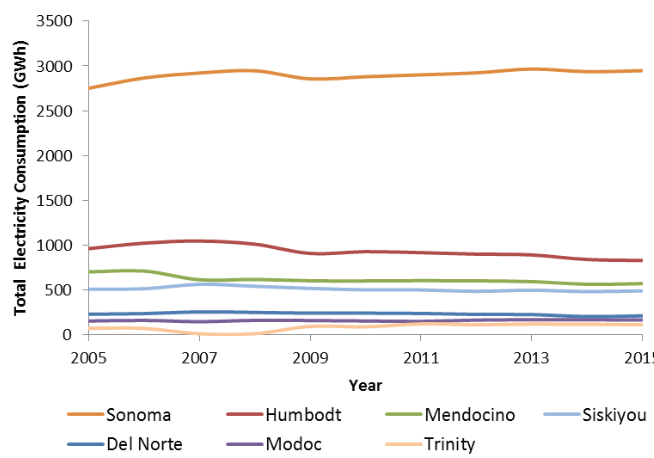


Figure 6: Total electricity consumption for 2005-2015 by county in GWh. Sonoma County uses more electricity than the remaining counties combined. Note that there are large variations in consumption in Trinity County, and we have not identified the source of this fluctuation.

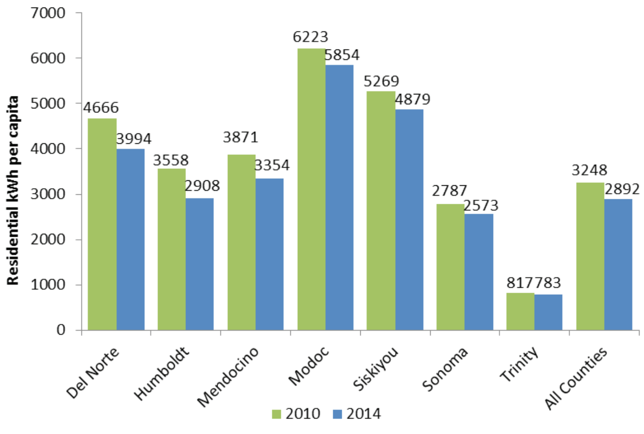


Figure 7: Residential per capita electricity consumption by county, and for all counties aggregated, in 2010 and 2014.

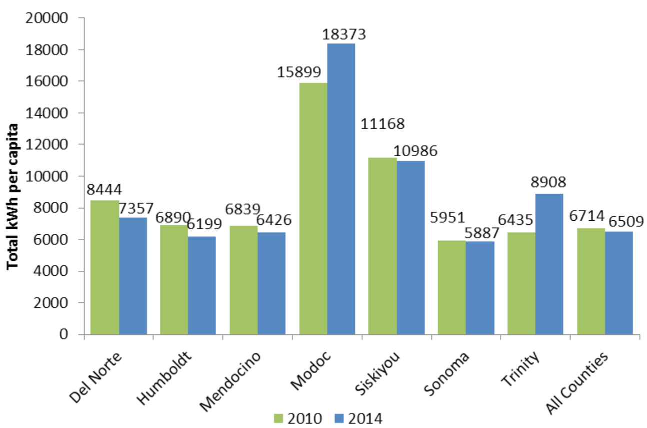


Figure 8: Total electricity consumption per capita by county, and for all counties aggregated, in 2010 and 2014

Natural Gas

Natural gas service is available in Sonoma, Mendocino and parts of Humboldt County. All of the natural gas consumed in the NCRP region is imported from outside the region with the exception of Humboldt County, where about 10% of the gas consumed comes from gas wells located within the county. Del Norte, Modoc, Siskiyou, parts of Humboldt and almost all of Trinity County are not served by a natural gas utility. These areas often use other fuels for heating, such as propane, fuel oil, and wood. However, data to quantify the consumption of these other fuel sources is not readily available. This represents a significant gap in the energy consumption data for the region.

Data are available from the U.S. Census that estimate the number of households that use various primary heating fuels (U.S. Census Bureau 2015). These data were used to estimate the penetration of various primary heating fuels throughout the region as shown in Table 2. As expected, the leading heating fuel in Humboldt, Mendocino and Sonoma Counties is natural gas, though many other fuels are used. Mendocino has the highest penetration of propane gas service. The leading heating fuel in Del Norte is electricity. Fuel oil/kerosene plays a significant role in Siskiyou County, and wood plays a dominant role in Modoc, Siskiyou and Trinity Counties.

Table 2: Primary heating fuel penetration in the residential sector

	Del Norte	Humboldt	Mendocino	Modoc	Siskiyou	Sonoma	Trinity	NCRP Region
Utility gas	7.1%	58.2%	33.1%	5.0%	4.2%	67.0%	5.2%	54.4%
Bottled, tank, or LP gas	4.8%	6.1%	20.1%	6.8%	5.1%	6.3%	13.4%	7.8%
Electricity	58.4%	14.2%	17.5%	18.8%	27.4%	20.8%	29.2%	21.0%
Fuel oil, kerosene, etc.	12.8%	1.3%	5.7%	18.6%	26.4%	0.2%	8.2%	3.3%
Wood	13.7%	17.9%	21.4%	48.0%	35.9%	4.2%	42.0%	11.8%
Other	3.2%	2.3%	2.2%	2.8%	1.0%	1.5%	2.0%	1.7%

Figure 9 presents the annual natural gas consumption in the residential sector for counties with available natural gas service and Figure 10 presents the total natural gas consumption for these same counties (CEC ECDMS 2016). These data include natural gas use in the residential, commercial and industrial end use sectors; they do not account for natural gas used to generate electrical power at utility-scale power plants such as the Humboldt Bay Generating Station in Eureka, CA. Note that there is a drop in the natural gas consumption in the later years in all counties, both in the residential sector and overall. There is not an obvious reason for this drop; it may be due to warmer winter weather conditions, efficiency programs, and/or changes in the reporting protocols for the data.

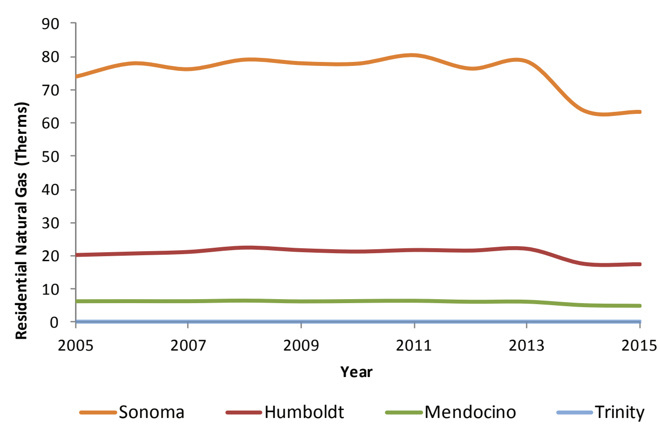


Figure 9: Residential Natural Gas Consumption from 2009-2015 by county in therms. Note there is no natural gas service in Del Norte, Modoc, or Siskiyou

Counties. [Note the drop in Sonoma County. There is not an obvious reason for this decline. It may be a reporting error, the effect of efficiency or fuel switching programs, or a change in reporting protocol].

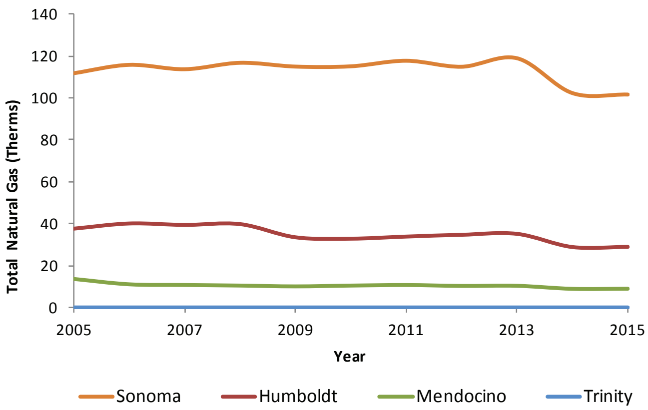


Figure 10: Total Natural Gas Consumption from 2009-2015 by county in therms. Note there is no natural gas service in Del Norte, Modoc, or Siskiyou Counties.

The per capita natural gas consumption for residential use is presented in Figure 11. Note that this plot includes only the population living in households with natural gas as a primary heating fuel. The number of household using natural gas was estimated based on the census data presented in Table 2 and the average persons per household in each county as presented in Table 1. In all counties with natural gas service the per capita residential consumption went down between 2010 and 2014. This is tied to the drop in gas use noted above, and as already stated it is unclear what the reason is for this drop.

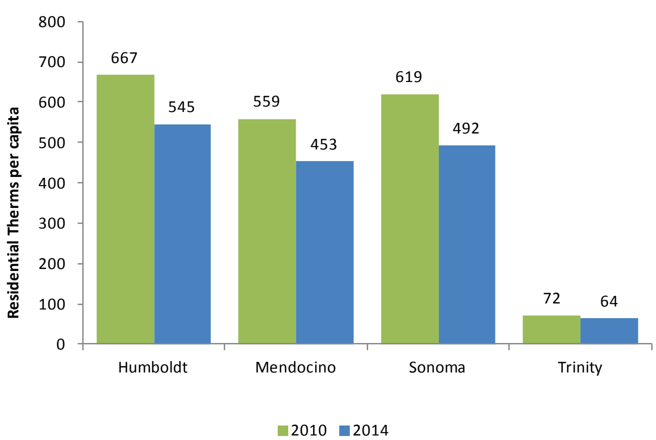


Figure 11: Per capita residential natural gas consumption for counties with natural gas service.

Gasoline and Diesel

Figure 12 presents estimates of regional gasoline sales for the years 2005 through 2015. Estimates are from the EMFAC database (CARB 2014), which estimates the consumption and GHG emissions for vehicles in the state. These estimates are from a model developed for the state Air Resources Board. It is important to note that disaggregating them by county may lead to errors. Nonetheless, these estimates are likely the best available for gasoline and diesel consumption (and emissions) and thus we are including them in this analysis.

All of the petroleum fuels consumed in the NCRP region are imported into the region. Sonoma County has the largest gasoline consumption by a substantial margin, followed by Humboldt, Siskiyou and Mendocino, which are tightly clustered, and then followed by Del Norte, Trinity and Modoc Counties. Like with electricity consumption, these differences are largely driven by differences in the population for each of these counties.

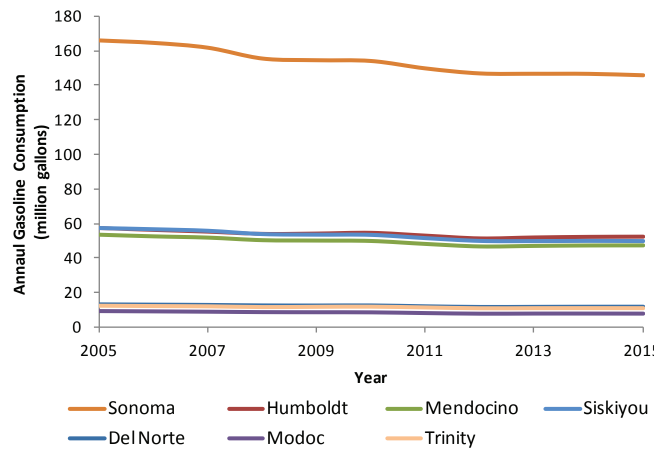


Figure 12: Estimated annual gasoline sales for counties in the NCRP region. Data are from the California Air Resources Board EMFAC model, which estimates transportation fuel consumption and the related emissions.

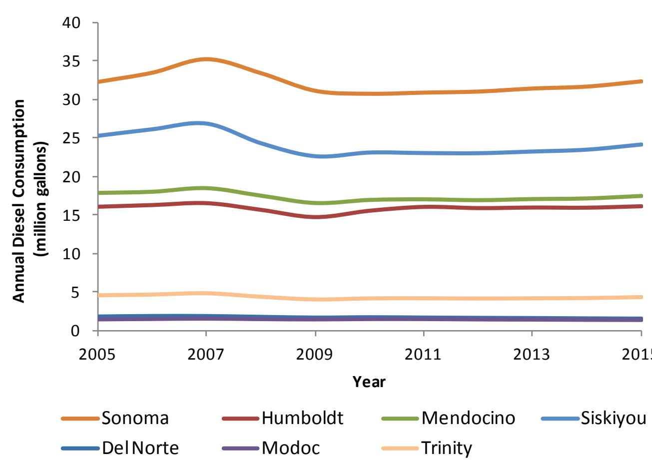


Figure 13: Estimated annual diesel sales for counties in the NCRP region. Data are from the California Air Resources

Board EMFAC model that estimates transportation fuel consumption and the related emissions.

2.1 EXISTING ENERGY SOURCES AND INFRASTRUCTURE

This section presents energy generation data for the region as a whole and by county (CEC Energy Almanac 2016). Table 3 shows the region has a diverse set of power generation sources, with the majority coming from renewable sources. Geothermal comprises the largest fraction of power generation, followed by hydro, natural gas, biomass, and solar, respectively.

Several counties have hydroelectric generators that have been affected in recent years by the historic drought in the Western United States starting in 2011 and continuing through 2015. This can be seen in the dip in hydropower production shown in Figure 14. Biomass power has also decreased slightly over the last few years. The aggregate electricity consumption for the NCRP region is also shown in Figure 14. This shows that the region is a net exporter of electricity. For example, in 2015 the region consumed 5,300 GWh of electricity, whereas about 6,200 GWh of electricity were generated, a net export of 900 GWh. Of the 6,200 GWh that were generated, approximately 5,800 GWh was from renewable energy sources, predominantly geothermal (nearly 90%). This 5,800 GWh of renewable electricity slightly exceeds the region's total 2015 electricity consumption of 5,300 GWh.

Table 3: Generation capacity and number of plant by fuel type for the NCRP region.

Fuel	MW	Number of Plants
Biomass	74.7	4
Gas	176.6	4
Geothermal	1368	13
Hydro	233	15
Landfill Gas	16.0	3
Solar	17.2	13
Total	1886	52

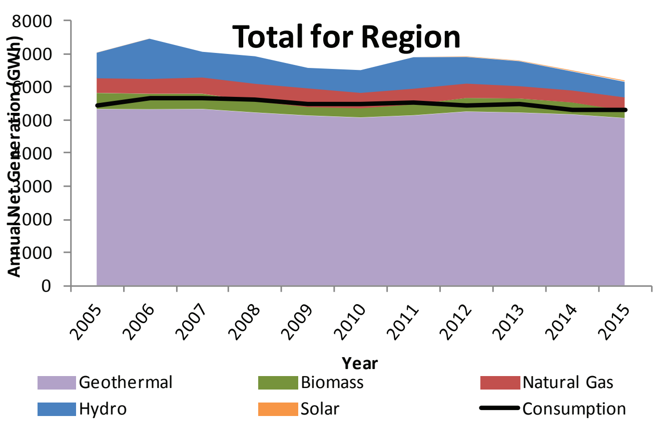


Figure 14: The total consumption in the region and the annual generation by fuel source for counties in the NCRP region.

Humboldt County

Table 4 shows installed electrical generation capacity in Humboldt County. The county's primary electricity generation is from natural gas and biomass. Recent years have seen a decrease in the amount of biomass generation as the cost of natural gas generation has decreased, making the relatively more expensive biomass energy less economical (Figure 15). While electricity consumption in Humboldt County has dropped slightly over the last ten years, it has not kept pace with the drop in generation. This means that the import of electricity into Humboldt County has grown by about 100–200 GWh/yr over the last 10 years.

Table 4: Installed generation capacity and number of plants by fuel type for Humboldt County. Data are current as of April 21, 2016

Fuel	MW	Number of Plants
Biomass	61.3	3
Gas	168	1
Total	229	5

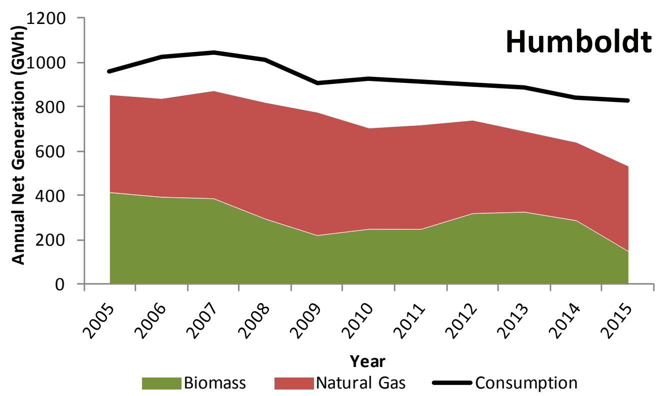


Figure 15: Total annual county consumption and annual Net Energy generation by resource type for Humboldt County 2005-2015, excludes solar PV systems operating with a net energy metering agreement.

Mendocino County

Table 5 shows installed electrical generation capacity in Mendocino County. Hydropower is the dominant electricity generation source in Mendocino County, and recently a large solar electric system was installed at Mendocino Community College. As shown in Figure 16, output from hydro has decreased in recent years due to the historic drought in California. With an average consumption ranging from about 550-700 GWh/yr over the last ten years and only about 15-40 GWh/yr of generation, Mendocino is a clear importer of electricity.

Table 5: Installed generation capacity and number of plants by fuel type for Mendocino County. Data are current as of April 21, 2016

Fuel	MW	Number of Plants
Hydro	12.7	2
Solar	7	4
Total	19.7	6

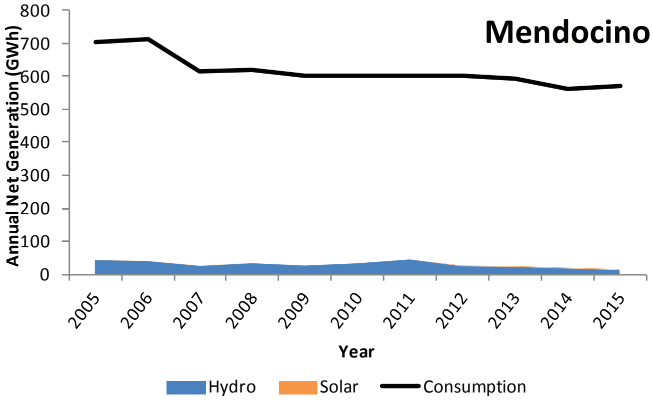


Figure 16: Total annual county consumption and annual net energy generation by resource type for Mendocino County 2005-2015, excludes solar PV systems operating with a net energy metering agreement. The peaks and troughs in hydropower generation are in large part dominated by amount of rainfall received in a given year. Note the decline in output from 2012 to 2015 owing to the California drought.

Siskiyou County

Table 6 shows installed electrical generation capacity in Siskiyou County. Siskiyou County's generation resource is dominated by hydropower, with smaller amounts of biomass generation in the last five years. Siskiyou's electricity demand has been roughly 500 GWh/yr over the last 10 years. As can be seen in Figure 17, in a good year hydro generation can nearly meet the total demand, but most years some import is required.

Table 6: Installed generation capacity and number of plants by fuel type for Siskiyou County. Data are current as of April 21, 2016

Fuel	MW	Number of Plants
Biomass	13.4	1
Hydro	61.8	6
Total	75.1	7

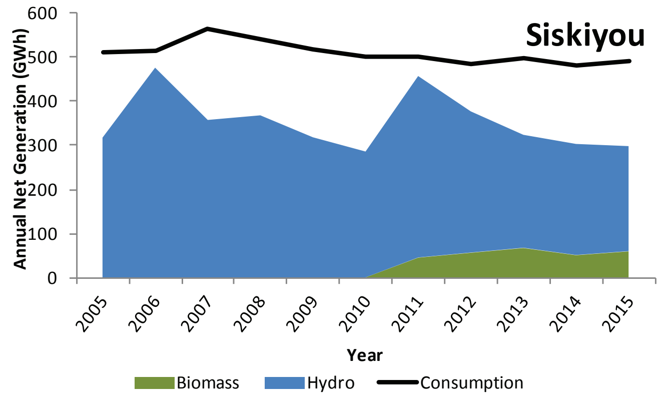


Figure 17: Total annual county consumption and annual net energy generation by resource for Siskiyou County 2005-2015, excludes solar PV systems operating with a net energy metering agreement.

Sonoma County

Sonoma County is the largest power producer in the region with a diverse set of generation facilities. Table 7 shows installed electrical generation capacity in Sonoma County. The overwhelming majority of generation comes from geothermal (Figure 18), though the county also contains more than 90% of the NCRP region's community-scale solar generation capacity. With an annual electricity demand of nearly 3,000 GWh per year and annual generation of over 5,000 GWh/year, Sonoma County is the largest electricity exporter in the NCRP region.

Table 7: Installed generation capacity and number of plants by fuel type for Sonoma County. Data are current as of April 21, 2016

Fuel	MW	Number of Plants
Gas	8.5	2
Geothermal	1368	13
Hydro	2.8	1
Landfill Gas	16	3
Solar	10.2	9
Total	1405	28

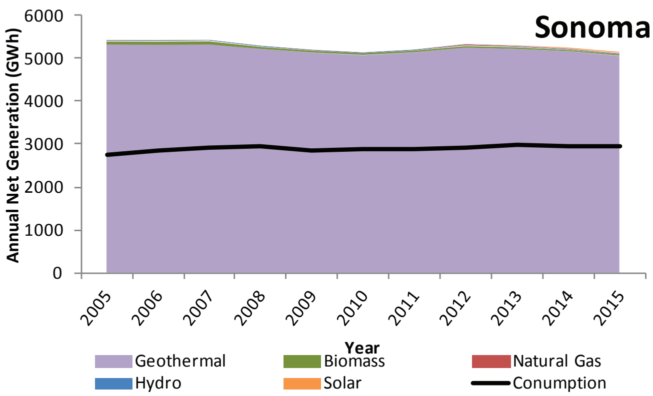


Figure 18: Total annual county consumption and annual net energy generation by resource for Sonoma County 2005-2015, excludes solar PV systems operating with a net metering agreement.

Trinity County

Table 8 shows installed electrical generation capacity in Trinity County. As shown in Figure 19, Trinity County's generation is exclusively from hydro sources. As with other counties with large amounts of hydro generation, the output in recent years has been affected by the historic drought in California. Per data available from the CEC, Trinity County's electric load has varied between 100-150 GWh/yr. Over that same period hydroelectric generation has been 200 GWh/yr or more, so Trinity County has been a consistent exporter of electricity.

Table 8: Installed generation capacity and number of plants by fuel type for Trinity County. Data are current as of April 21, 2016

Fuel	MW	Number of Plants
Hydro	78.6	6

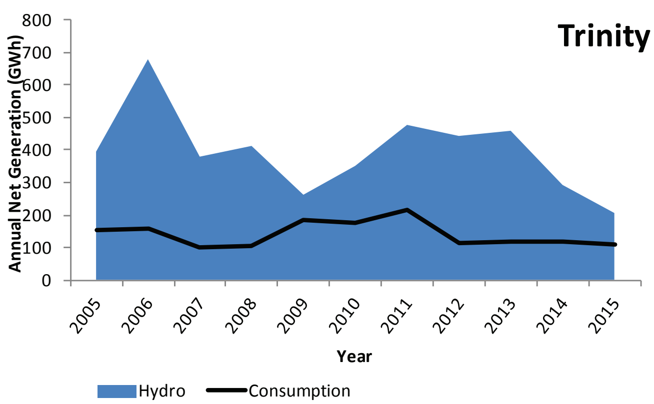


Figure 19: Total annual county consumption and annual net energy generation by resource for Trinity County 2005-2015, excludes solar PV systems operating with a net metering agreement

Solar PV

Table 9 presents the total installed solar PV with net energy metering (NEM) agreements for counties with available data. NEM installations are smaller systems – less than 1 MW of generation capacity – and are often installed on rooftops. The data are taken from the California Solar Initiative project website and are current as of May 30, 2016 (CSI 2016). Sonoma County has the largest amount of installed solar electric generation, both on a gross and per capita basis.

Table 9: Total installed solar PV generation capacity, by sector and county, and total per capita installed generation capacity, current as of May 30, 2016.

	Humboldt		Mendocino		Sonoma		Trinity	
	kW_AC	kW_DC	kW_AC	kW_DC	kW_AC	kW_DC	kW_AC	kW_DC
Residential	3675	3737	4769	4829	48144	49502	60	53
Commercial	950	933	3950	3879	26496	25407	-	-
Industrial	105	104	1965	1232	12413	11242	-	-
Non-Profit	-	-	6	6	20	21	-	-
Educational	-	-	-	-	406	415	-	-
Total	**4730**	**4774**	**10691**	**9946**	**87479**	**86587**	**60**	**53**
Per capita	**35**	**35**	**122**	**113**	**174**	**172**	**5**	**4**

2.1 HIGH LEVEL GHG EMISSIONS ESTIMATES

This section shows Carbon Dioxide (CO_2) emissions from electricity, natural gas, gasoline, and diesel consumption presented in Section 1. It is important to note that the GHG emissions presented here do not represent the total GHG emissions in the region. A more detailed greenhouse inventory that includes all sectors other than energy would need to be conducted to fully quantify the GHG emissions within the region. However, there is value in presenting data on emissions from the energy sector as they represent significant opportunities for emissions reductions.

The data presented here are for CO_2 only; they do not represent CO_2e, which includes other GHGs such as methane, nitrogen oxides, sulfur oxide and others. Data are reported on a CO_2 basis for consistency across emission sources, as data for the other GHGs are generally not available. Emissions for electricity consumption are only provided for counties within PG&E service territory because we were unable to get emission factors for PacficCorp. Trinity County's Municipal Utility gets its energy from hydropower through the Western Area Power Agency (WAPA), and therefore we assume the associated CO_2 emissions are zero.

The CO_2 emissions reported in this section were calculated using published emissions factors. For electricity we used PG&E's published CO_2 emissions factors (PG&E 2015). These factors are based on the mix of generation sources PG&E used to procure electricity in each year. As noted in Section 2.3, there is enough carbon-free renewable electricity generated in the NCRP region to meet regional needs. However, that does not necessarily mean that the carbon-free power can contractually be counted toward meeting the load in the region. For example, if carbon-free hydropower is generated in Humboldt County, but is then sold along with its environmental attributes to a utility in southern California, then Humboldt County cannot claim the use of that carbon-free energy. When it comes to determining carbon emissions, the electricity, along with its environmental costs or attributes, that is purchased to serve customers throughout the NCRP region is the electricity that contractually belongs to the region.

CO_2 emissions associated with natural gas use were determined using the emission factor for the combustion of methane (EPA 2014). Transportation emissions came directly from the EMFAC database and were calculated using the EMFAC methodology (California Air Resources Board 2014).

Figure 20 presents per capita annual CO_2 emissions for four of the NCRP counties. Interestingly, Trinity County has the highest per capita annual emissions even though there are zero emissions from electricity consumption in the county (all hydroelectric) and essentially zero emissions from natural gas (nearly zero natural gas customers). As already noted, no data for propane use are provided in this report. That means that the transportation sector accounts for nearly all of Trinity County's CO_2 emissions. It appears that a relatively high level of diesel fuel consumption and a low population are the key reason Trinity County's per capita CO_2 emissions are higher than the other counties shown.

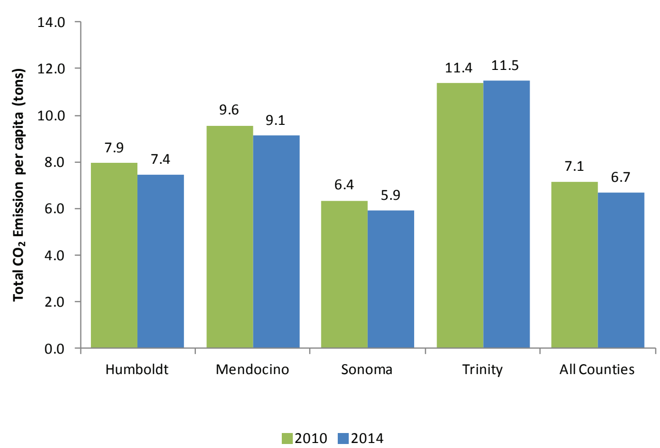


Figure 20: Total per capita annual CO_2 emissions for counties not in Pacific Corps territory in 2010 and 2014.

Figure 21 and Figure 22 show the annual CO_2 emissions associated with electricity and natural gas consumption, respectively. Due to its larger population, Sonoma has the highest level of CO_2 emissions in the electricity and natural gas sectors. In contrast, Trinity County gets all of its electricity from hydropower, so the CO_2 emissions associated with electricity consumption in Trinity County are zero. The spike in emissions in 2007 (Figure 21) is due to an increase of the emissions factors for PG&E electricity in those years; this increase could be due to an increased proportion of fossil fuels in the power mix. An important consideration for the GHG emissions estimates is that we are not capturing the GHG emissions from fuel sources such as propane, fuel oil/kerosene and wood that are commonly used for heating in the areas that don't have natural gas service (i.e., outside of PG&E service territory).

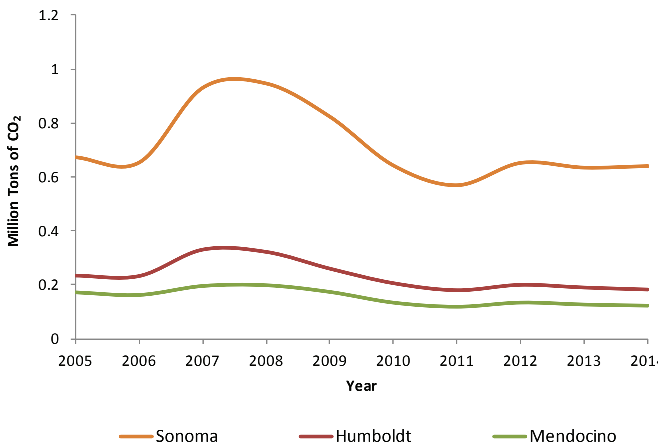


Figure 21: Annual CO_2 emission from electricity consumption for counties in PG&E territory. Note that the data for Sonoma County does not take into account the launch of Sonoma Clean Power in May of 2014.

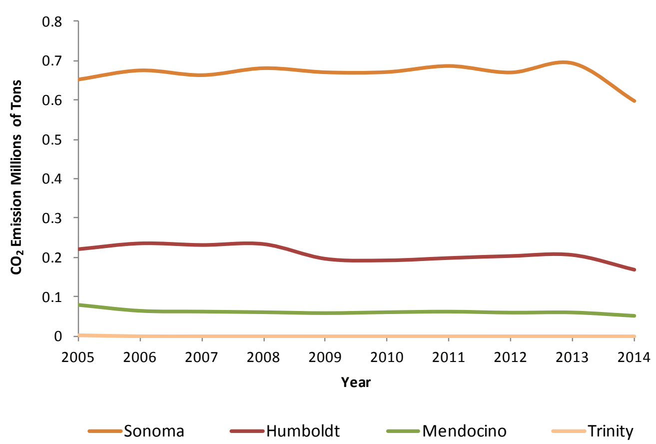


Figure 22: Annual CO_2 emissions from natural gas consumption. Del Norte, Modoc, and Siskiyou Counties are unserved by a natural gas utility.

Figure 23 and Figure 24 show the annual CO_2 emissions associated with gasoline and diesel consumption, respectively. The trends over time are rather flat. Due to its larger population, Sonoma has the highest level of CO_2 emissions in both the gasoline and diesel fuel sectors.

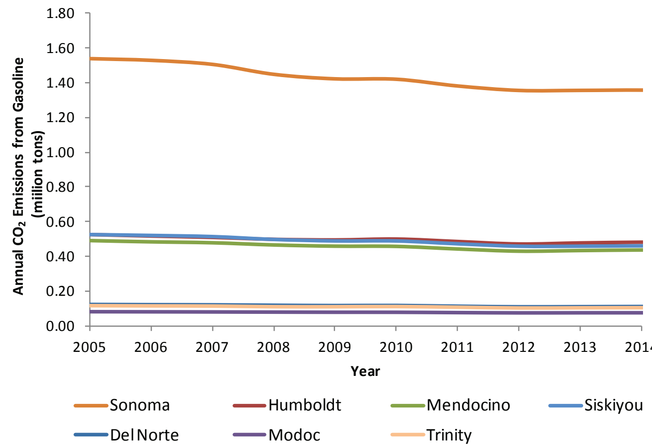


Figure 23: CO_2 emissions estimate from gasoline consumption. Emissions generally follow consumption rate; however, for other GHG emission not included in this report emissions may decrease over time as older polluting cars are retired and newer emissions control technologies reduce tailpipe emissions.

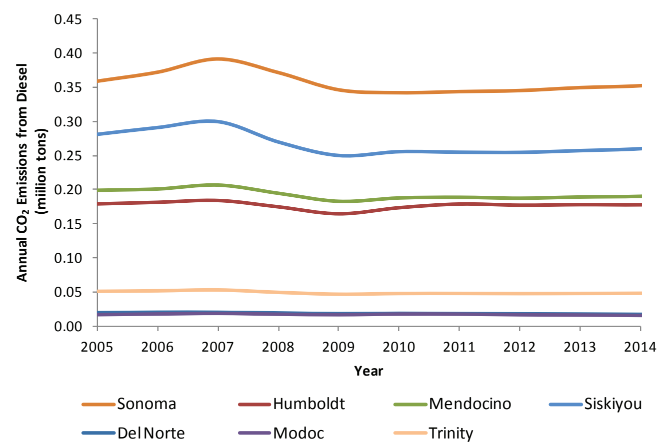


Figure 24: CO_2 emissions estimate from diesel sales. Emissions generally follow consumption rate; however, for other GHG emission not included in this report emissions may decrease over time as older polluting cars are retired and newer emissions control technologies reduce tailpipe emissions.

Figure 25 and Figure 26 present the total CO_2 emissions from electricity, natural gas and transportation fuels for Humboldt and Sonoma Counties. These two counties were chosen because natural gas and electricity (and a modest amount of wood in Humboldt County) account for over 90% of the residential heating fuel for these two counties (see Table 2). Therefore, we would expect the majority of the energy related CO_2 emissions for these counties are accounted for in these plots. As can be seen, transportation accounts for over half the emissions in all cases. This is slightly higher but still comparable to the 47% estimated contribution from the transportation sector for the year 2000 as reported in Sonoma County's Greenhouse Gas Emission Inventory (Climate Protection Campaign 2005). This is not atypical, especially for rural areas where emissions from industry are low and transportation tends to dominate. For comparison purposes, the transportation sector accounted for 37% of total CO_2e emission for the State of California in 2014 (CARB 2016).

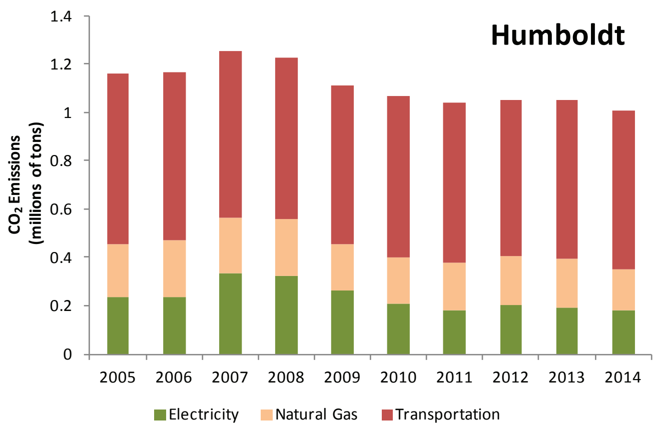


Figure 25: Total emissions by sector for Humboldt County between 2005 and 2014

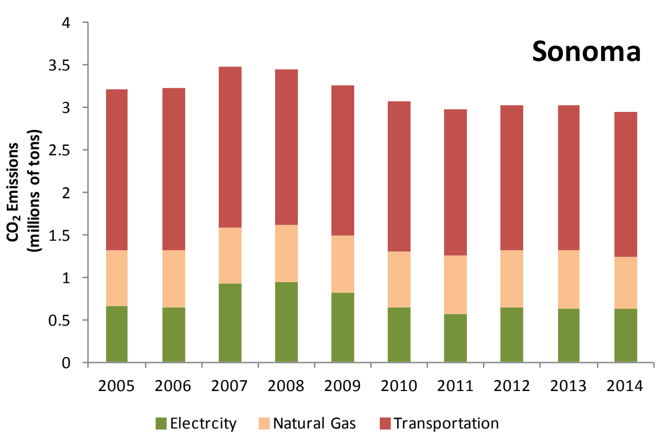


Figure 26: Total emission by sector for Sonoma County between 2005 and 2014

2.1 EXISTING RESOURCES

This section identifies informational, organizational and programmatic energy related resources that currently exist throughout the region.

2.1.1 Regional Organizations

The list below identifies some of the energy related organizations. It provides a brief description of services and includes Internet links for more information.

- The North Coast Resource Partnership (NCRP) is an innovative, stakeholder-driven collaboration among local government, Tribes, watershed groups, and interested partners in the North Coast region of California. The NCRP region comprises seven counties, Tribal lands, major watersheds, and a planning area of 19,390 square miles-representing 12% of California's landscape. The NCRP integrates long term planning and high quality project implementation in an adaptive management framework-fostering coordination and communication among the Region's diverse stakeholders (http://www.northcoastresourcepartnership.org/)
- Redwood Coast Energy Authority (RCEA) is a joint powers authority in Humboldt County whose purpose is to develop and implement sustainable energy initiatives that reduce energy demand, increase energy efficiency, and advance the use of clean, efficient and renewable resources available in the region. In mid 2017 RCEA plans to launch a community choice energy program to the vast majority of customers in Humboldt County (http://www.redwoodenergy.org/)
- Sonoma Clean Power (SCP) is a Community Choice Energy program in Sonoma County. In October 2016 the Board of Directors voted to include Mendocino County in the service region (excluding the city of Ukiah, which currently has a municipal electric utility)(https://sonomacleanpower.org/).
- Trinity County Public Utility District is a municipal utility of Trinity County, which supplies residents with 100 percent hydroelectric power through the Western Area Power Administration. (http://trinitypud.com/)
- The Northern California Center for Alternative Transportation Fuels and Advanced Vehicle Technologies (NorthCAT) creates a physical and virtual network of training and showcase centers and informational resources for alternative fuels and vehicle technologies. (http://northcat.org/)

- The Watershed Research and Training Center's (WRTC's) mission is to promote a healthy forest and a healthy community through research, training, and education. The WRTC was formed in order to rebuild the economy of Hayfork California based on an ethic of land stewardship and restoration. (http://www.thewatershedcenter.com/)
- Redwood Community Action Agency is a Humboldt County based, private non-profit organization that provides a wide range of services to low and moderate income residents of Humboldt County. The long-term goal is to develop programs through which people can become self-sufficient and empowered to improve their own lives. Their weatherization services also cover Del Norte and Modoc Counties. (http://rcaa.org/)
- Community Development Commission of Mendocino County is a public agency whose mission is to provide opportunities for decent, safe, affordable housing and a suitable living environment to low-and moderate-income, special needs households, and communities in an effective, efficient, and respectful manner.
- Teaching Employment, and Community Health Inc. (TEACH) is a broad based, multi-purpose non-profit community organization that serves the population of Modoc County. They offer a wide range of programs including heating assistance for low income households. (http://teachinc.org/)
- Klamath Alliance for Resource and Environment (KARE) is a grassroots, non-profit located in Siskiyou County dedicated to educating the public about the environmental benefits of responsible management of our natural resources on public and private lands with the purpose to inform and educate the public by providing science-based information on forest eco-systems, environmental issues, and the economic benefits of forest resources in our communities. (http://www.klamathalliance.org/)
- Great Northern Services (GNS) is a community organization serving Siskiyou County that seeks to invigorate community by initiating positive social change to improve economic conditions. They offer a variety of services including energy assistance and home weatherization services. (http://www.gnservices.org/)
- Northern California Indian Development Council is a private nonprofit corporation established to research, develop, and administer social and economic development programs designed to meet the needs of Indian and Native American Communities to provide support and technical assistance for the development of such programs, and the conservation and preservation of historic and archeological sites and resources. They are the LIHEAP providers for 48 California Tribes, including many in the NCRP Region. (http://www.ncidc.org/)
- Del Norte Senior Center is a provider of LIHEAP and weatherization service to qualifying low income households in Del Norte County in addition to senior services. (http://www.delnorteseniorcenter.org/home.html)
- North Coast Energy Services is a not-for-profit organization that provides energy conservation, consumer education and advocacy, home improvement, utility assistance, job training, and other services to people in need in Lake, Mendocino, Solano, Sonoma, and Yolo Counties. (http://www.northcoastenergyservices.com/index.html)
- The Regional Climate Protection Authority (RCPA) is a Sonoma County agency that coordinates community-wide climate solutions for a better future. The RCPA is focused on securing grant funding for GHG reduction programs and projects, as well as leading countywide climate planning efforts. (http://rcpa.ca.gov/)

2.1.2 Regional Programs and Policies

The section presents some of the regional programs and policies that promote energy efficiency and renewable energy throughout the region.

Energy Watch is a program administered by PG&E. In the NCRP region the following organizations provide services under Energy Watch. Trinity County has its own municipal utility and Del Norte, Modoc and Siskiyou Counties are outside of PG&E service territory and therefore are not covered by Energy Watch programs.

- Mendocino-Lake Energy Watch (http://mendoenergy.org/)
- RCEA administers the Redwood Coast Energy Watch (http://www.redwoodenergy.org/)
- Sonoma County (http://www.sonoma-county.org/gs/energy/scew/index.htm)

The Rural Energy for America Program (REAP) provides guaranteed loan financing and grant funding to agricultural producers and rural small businesses for renewable energy systems or to make energy efficiency improvements. (https://www.rd.usda.gov/programs-services/rural-energy-america-program-renewable-energy-systems-energy-efficiency)

Property Assessed Clean Energy Financing is a program allowing for energy efficiency, water efficiency, and renewable energy projects to be financed through a voluntary property assessment that is attached to the property, not the owner, and is paid back through the property tax system. These programs are administered by a variety of lenders and public agencies. Information on PACE financing and other programs is available through the Sonoma County Energy Independence Program (http://sonomacountyenergy.org/) or the Redwood Coast Energy Authority's PACE webpage) http://www.redwoodenergy.org/energy-efficiency/pac).

Community choice energy (CCE), also known as community choice aggregation, is a program that allows California cities, counties, and or joint powers agencies to purchase electricity on behalf of the customers in their territories. Transmission and distribution and their maintenance still remain the responsibility of the incumbent utility, as does billing, but CCEs are able to determine their own energy supply mixes and rate structures. Currently Sonoma Clean Power operates in Sonoma County and will be expanding to Mendocino County in 2017. The Redwood Coast Energy Authority is scheduled to launch a CCE program in mid 2017. This will mean that most of the population in the NCRP region will be served by a CCE or municipal utility by mid 2017.

2.1.3 State Policies, Programs and Incentives

California has been on the leading edge of energy policy issues since the oil embargos of the 1970's caused energy prices to spike. This section lists state level programs, policies, and incentives that promote energy efficiency, renewable energy and low carbon transportation fuels.

Assembly Bill 32, the California Global Warming Solutions Act of 2006, was a landmark law requiring California to reduce its GHG emissions to 1990 levels by 2020. Its long term, comprehensive approach to climate change mitigation established California as a leader in the fight against climate change. The passage of AB 32 has lead to the strengthening of current legislation and the introduction of new laws and initiatives to increase energy efficiency, promote renewable energy, and transition to low carbon transportation. In September 2016 Senate Bill 32 amended AB 32 to require California to reduce its GHG emissions to 40 percent below 1990 levels by 2030.

In October of 2015 California passed Senate Bill 350, the Clean Energy and Pollution Reduction Act. The bill lays out the following goals for 2030: A 50 percent reduction in petroleum use, 50 percent of utility power coming from renewables, and 50 percent increase in energy efficiency in existing buildings.

In addition to AB 32 and SB 350 California has passed a number of bills that are working to combat climate change. A list of key ones can be found on the California Climate Leadership website (http://focus.senate.ca.gov/climate/full-package).

Activities of the California Energy Commission in relation to climate change can be found on their website (http://www.energy.ca.gov/climatechange/). The California Energy Commission's role in climate change mitigation can be found on their website (http://www.energy.ca.gov/climatechange/).

3 RESOURCE ASSESSMENT OF REGIONAL OPPORTUNITIES

Section 3 examines opportunities in the NCRP region to reduce energy consumption, develop local renewable energy resources, and switch energy use to low-carbon alternatives while still meeting the regions energy needs in the electricity, heating and transportation sectors. One key objective is to reduce the GHG emissions associated with the energy sector. While substantial emphasis is placed on opportunities to develop and utilize local renewable energy resources for electricity generation, it is critical to note that this will not be sufficient. As can be seen in Section 2.4, electricity use accounts for a relatively small portion of the total energy sector GHG emissions for the region. It is therefore crucial that emissions in the transportation and heating fuel sectors also be addressed. One key strategy in this regard is to convert energy use in the transportation and heating sectors to electricity while simultaneously "greening" the electric grid. Additional options include promoting energy efficiency in these sectors and switching to renewable and low-carbon fuels.

3.1 ENERGY EFFICIENCY

Energy efficiency is key to reducing GHG emissions in the NCRP region. California has been at the leading edge of energy efficiency efforts and thus there is a long history of efficiency programs throughout California and the NCRP region. In California the investor owned utilities are required to collect and spend funds from ratepayers for efficiency programs. Table 10 presents data from the first quarter of 2013 through the third quarter of 2015 (CPUC 2017) The data represent the amount of gross demand reduction (MW), energy savings (GWh), and natural gas reduction (therms) for each county, and the amount of program funding spent per county. These data are only for counties in PG&E's service territory as these are the data that were readily available.

Table 10: Energy efficiency program energy and demand savings and program funding for 2013-2015.

	Demand Reduction (MW)	Energy Savings (GWh)	Natural Gas Savings (MMTh)	Total Program Cost (million $)
Humboldt	1.1	6.1	0.3	**5.6**
Mendocino	0.5	3.6	0.1	**2.6**
Siskiyou	0.0	0.0	0.0	**0.0**
Sonoma	7.8	39.1	0.9	**21.2**
Trinity	0.0	0.0	0.0	**0.0**
Total	**9.5**	**48.8**	**1.3**	**29.3**

3.1 RENEWABLE ENERGY

This section examines the renewable energy development opportunities for the NCRP region. This includes an assessment of biomass, geothermal, hydroelectric, solar, wave, and wind energy resources. The CEC has established a set of eligibility requirements for what qualifies as a renewable energy resource under the State's Renewables Portfolio Standard (CEC 2015). This provides a good set of guidelines. The information presented in this report covers both utility-scale, as well as distributed scale projects. The CEC considers utility-scale projects to be 10 MW or larger; smaller generators are considered distributed scale. The majority of the focus in this report is on renewable electricity generation, but the use of renewable energy sources for heating and as transportation fuels is also considered.

The National Renewable Energy Laboratory (NREL) published a study in 2012 that was a GIS-based analysis that estimated the renewable energy potential throughout the United States on a state-by-state basis (Lopez, A. et al. 2012). This study was utilized; however, to assess the potential for the NCRP region estimates at a county rather than a state level were needed. For this reason we accessed information from an array of additional organizations, including the UC Davis Biomass Collaborative, California Energy Commission, United States Geological Survey, and US Department of Energy. By piecing together these information resources we were able to develop an estimate of renewable energy resource potential at the county level for the key counties included in the NCRP region.

Note that the renewable energy potential estimates presented are very rough. They are intended to give a sense of scale for the opportunities in the region, and a sense of the relative magnitude between various resources. If a strategic plan for regional development of renewable resources is developed, it is recommended that significantly more analysis be performed to better estimate the resource potential in the region and to assess what is technically and economically feasible. In addition, it will be important to assess potential challenges and barriers and identify preferences of the local communities where these resources would be developed.

It is also important to note that the estimates provided here are for technical resource potential. That means this is an assessment of the total resource potential that exists in the region and that technically could be developed. However, there can be many challenges and barriers that can make a technically feasible resource undesirable to develop. These include cost, environmental impacts, and community opposition to name a few. Typically only a very small portion of the technically available resource can be economically developed. For example, NREL's statewide estimate of renewable energy potential in CA estimates that only about 3% of the identified technical potential is economically viable (Brown, A. et al. 2016).

3.1.1 Overview of Renewable Resource Opportunities

The NCRP region is a renewable resource rich region. Developable renewable resources include biomass, geothermal, hydroelectric, solar, wave, and wind power. However, these resources are not uniformly distributed throughout the region. For example, coastal counties in the region tend to be rich in wave and wind energy, while inland counties have a greater solar resource. Other resources, like geothermal and biomass power, are distributed based on unique geological and ecological characteristics. Figure 27 shows the estimated technical potential for renewable electricity generation in the NCRP region broken out by resource. Solar and off-shore wind dominate the region with over 94% of the total technical potential. Onshore wind, wave, biomass and geothermal resources make up most of the remainder. Note that the dominance of solar photovoltaic (PV) power and wind power shown in Figure 20 is consistent with the breakdown shown in NREL studies for the State of California (Brown, A. et al. 2016, Lopez, A. et al. 2012).

Figure 28 shows the breakdown of total technical potential by county. The resource potential is pretty well distributed across the region. Modoc has the greatest potential at 28%, Humboldt, Mendocino, Siskiyou and Sonoma range from 13% to 18% of the total, and Del Norte and Trinity Counties each represent less than 10% of the total technical potential.

	Del Norte	Humboldt	Mendocino	Modoc	Siskiyou	Sonoma	Trinity	Total	Resource % of Total
2014 Electricity Consumption (GWh)	203	839	563	168	482	2,943	118	5,314	
Renewable Electricity Generation Technical Potential (GWh/yr)									
Biomass	168	1,369	1,291	443	1,137	556	748	5,711	0.7%
Geothermal	-	-	430	860	1,505	1,505	-	4,300	0.6%
Hydro (Total)	100	184	50	42	339	48	223	986	0.1%
Hydro - Unpowered Dams	0	13.1	13.1	13.1	45.85	45.85	0	131	
Hydro - New run-of-river (> 1MW)	100	171	37	14	289	-	223	835	
Hydro - In-Conduit	-	-	-	14.3	3.7	2.0	-	20	
Solar	8,452	36,580	61,196	205,753	123,752	53,006	30,461	519,200	68%
Wave	1,916	3,455	3,303			3,560		12,233	1.6%
Wind - Onshore	2,212	4,222	2,132	3,176	8,575	958	1,428	22,703	3.0%
Wind - Offshore	35,683	51,101	57,269			55,947		200,000	26%
Total	48,532	96,911	125,669	210,274	135,308	115,579	32,860	765,133	
County % of Total	6%	13%	16%	27%	18%	15%	4%		

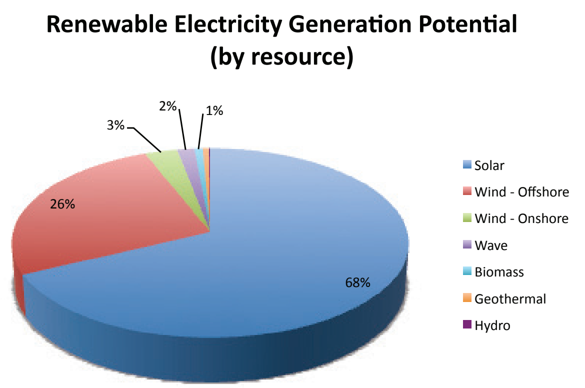


Figure 27: Renewable electricity generation potential by resource (total technical potential = 765 TWh/yr).

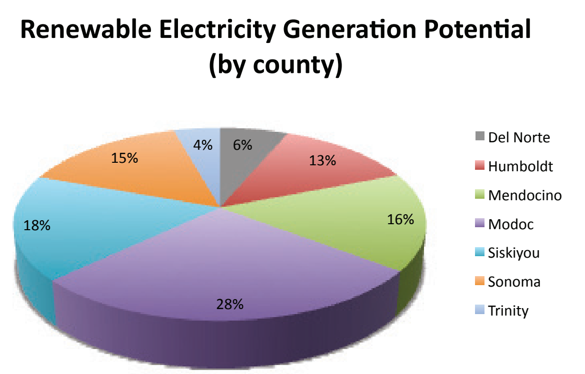


Figure 28: Renewable electricity generation potential by county (total technical potential = 765 TWh/yr).

Table 11 provides more detail with regard to technical potential by resource and county. In addition, Table 11 shows the total electricity consumption in 2014 for each of the counties in the NCRP region. Note that the total technical potential for the region is about 140 times as great as the total consumption. However, as already noted, the economic potential is likely to be only a small fraction of the total technical potential. If the portion of the total technical potential that is economically viable is similar to that predicted by NREL for the State of California (approximately 3%), then the total economic potential will be of the same order of magnitude as the total electricity consumption for the region.

In the sections that follow each of the renewable resources is briefly discussed. This includes a discussion of technology maturity and market status, as well as identification of key opportunities associated with the resource in the NCRP region. We also discuss cost competitiveness and economic opportunities associated with resource development. In addition, potential challenges and barriers are noted, such as infrastructure needs, potential environmental impacts, and other potential regulatory or political issues

Table 11: Renewable electricity generation potential by county and resource, and 2014 electricity consumption totals for the North Coast Resource Partnership region.

Information sources:

Biomass: CA Biomass Collaborative (2015)

Geothermal: Williams, C. et al. (2008)

Hydro: Hadjerioua, B. et al. (2012), Navigant Consulting, Inc. (2006), Kane, M. (2005)

Solar: Simons, G. and J. McCabe (2005), Lopez, A. et al. (2012)

Wave: Kane, M. (2008)

Wind: Yen-Nakafuji, D. (2005), Dvorak, M. et al. (2010)

3.1.2 Grid Integration of Renewable Resources

In this section we discuss some high level challenges and opportunities associated with the development of regional renewable resources. The topics covered include: 1) the intermittent nature of some prominent renewable resources and the value of energy storage and demand response, 2) the need for adequate transmission infrastructure, 3) the challenges and opportunities associated with distributed generation, 4) the opportunity for microgrids and combined heat and power, and 5) power plant ownership.

Intermittent Resources and Energy Storage

Many prominent renewable energy resources are intermittent. For example, solar power is only available when the sun shines; it's not available at night and is much reduced in output when skies are cloudy. Similarly, wind power is only available when the wind blows. Wave power is another intermittent renewable resource. This intermittency presents challenges because the supply of electricity must meet the demand at all times or the grid will experience brown outs, or even worse, black outs. Even modest deviations between supply and demand can cause fluctuations in the voltage and/or frequency of the power supply, thereby causing problems for sensitive electrical loads (e.g., computers and other sensitive electronics).

With intermittent resources there can be times when there is too much or too little resource. One way to handle this is to ramp other power plants up or down as needed to match the net demand. Another option is to curtail intermittent resources if there is too much supply. Energy storage and controllable loads can also be used to help match supply and demand. Common energy storage technologies include pumped hydro (the most prominent by far in terms of installed capacity), batteries, compressed air, flywheels and thermal storage. With energy storage technologies we can capture excess intermittent renewable resources and store them until we need them.

Controllable loads are appliances that can be turned on and off as needed by the electric utility. With smart grid and smart meter technologies (and customer approval), electric utilities are now beginning to have the ability to control smart appliances. To address intermittency problems, smart appliances can be turned off when wind or solar power output dips, and turned back on when the power output increases. This is referred to as demand response. This technique is often used with thermally-based electrical loads such as refrigerators, air conditioners and water heaters.

When intermittent renewable resources make up a large percentage of the power generation capacity for a particular region, there can be issues with local grid stability and reliability. Under these circumstances technologies such as energy storage and smart grid with controllable loads can be used to help stabilize the grid. According to an NREL study (Cochran et al. 2015), the U.S. electric grid could economically accommodate about a 30% penetration of variable renewable resources like solar and wind. They also note that higher penetration levels are technically feasible and could likely be economically viable with technical and institutional changes.

Transmission Infrastructure for Utility Scale Generation Projects

The electric power system is composed of three key components: electrical generators, transmission infrastructure, and distribution infrastructure. Traditionally, power has been generated at large, central station power plants and then transmitted at high voltage over long distances to population centers. When the power reaches the urban centers it is transformed to lower voltages and distributed to customers over the electric distribution system.

If large, utility-scale power projects are to be developed in the NCRP region it will be important to first assess the availability and capability of the existing transmission system to transport the power to where it will be used. If the transmission system does not exist and/or is not adequate, there will likely be substantial additional costs incurred. In some cases this may render a project economically infeasible. Note that many parts of the NCRP region are currently devoid of electrical transmission lines. The main backbone of California's electrical transmission grid runs north to south through the Central Valley, and the high voltage lines connecting us to our neighbors to the north (called the Pacific AC Intertie) comes down through Modoc and Siskiyou counties. A map of the electric transmission lines in northern California can be found here: http://www.energy.ca.gov/maps/infrastructure/3part_northern.html.

The California Energy Commission is responsible for preparing a biennial Integrated Energy Policy Report that is to include a Strategic Transmission Investment Plan. In addition, the California Natural Resources Agency, along with others, have developed the Renewable Energy Transmission Initiative 2.0 (RETI 2.0) that is aimed at identifying options and implications for accessing high-quality renewable energy resources throughout the State of California (California Natural Resources Agency 2017). The Lassen/Round Mountain Transmission Assessment Focus Area is the one area studied in RETI 2.0 that includes part of the NCRP region.

Distributed Generation

As mentioned above, electric power has traditionally been generated at large, central station power plants and then transmitted and distributed to customers over the electric grid. In contrast, it has recently become common for smaller scale power plants (typically less than about 10 MW and as small as a few kilowatts of capacity) to be located at customer sites or at other points on the distribution grid. These small-scale plants are referred to as distributed generators, and rooftop solar is a common example.

The electric grid was originally designed for power to flow in one direction, from central power plants to customers. With distributed generation there can be power flow from one customer to another, and this can result in a reversal of power flow in some parts of the system. This can sometimes cause issues. In addition, depending on the size of the distributed generator, the local distribution system may or may not be sufficiently sized to handle the power output. Consequently, anytime a distributed generator is going to be connected to the electric grid the local electric utility must be notified. If it is a larger plant (e.g., > 30kW), a study may need to be performed to assess the potential for problems and determine what sort of infrastructure upgrades or modifications might be necessary.

One information resource available in PG&E's service territory that can help when planning a distributed generation project is the solar photovoltaic and renewable auction mechanism (PV RAM) project map. The map is designed to help contractors and developers find potential project sites. The map shows electric transmission lines, distribution lines and substations in PG&E's service territory, and provides information such as operating voltages, line capacities and loadings, and substation names. The map can give a project developer an idea of the ease or difficulty they can expect when trying to interconnect a distributed generator to the grid at a particular location. However, the information provided is only intended for general guidance; all projects must still go through the standard interconnection process.

The PVRAM map is available at https://www.pge.com/en_US/for-our-business-partners/energy-supply/solar-photovoltaic-and-renewable-auction-mechanism-program-map/solar-photovoltaic-and-renewable-auction-mechanism-program-map.page.

Distributed generation can also provide benefits to the local electrical grid. By providing power close to where it is consumed there is a decrease in transmission losses. Also, in some cases, distributed generation can help relieve constraints in the local distribution system, thereby eliminating the need for infrastructure upgrades. And from the customer's perspective, a big benefit with distributed generation is the ability to participate in net energy metering (allowed in Pacific Gas and Electric Company and Pacific Power service territories only, not in Trinity Public Utility District territory). Net energy metering allows a customer to generate excess power at certain times (e.g., summer days), send that power back to the utility, and get credited at the retail rate on their bill. They can then buy power when they need it (e.g., at night or in the winter time) and on an annual basis they can net their power bill to almost nothing. Getting compensated at the retail rate is a big economic benefit to these retail customers. A wholesale power generator, on the other hand, gets compensated at the wholesale power rate, which typically might be 4 to 5 times less than the retail rate.

Combined Heat and Power

When distributed generation involves the consumption of a fuel, such as with a reciprocating engine, a combustion turbine, a fuel-fired steam turbine, a microturbine, or a fuel cell generator, there is an opportunity for combined heat and power, or CHP. Combined heat and power involves the oxidation of a fuel to generate both electricity and heat. The heat, which in a central power plant application is usually wasted, is captured and utilized for local process, space heating, or cooling needs. In this way the fuel is utilized much more efficiently. Whereas distributed generators that consume fuels typically have electrical efficiencies ranging from about 15% to 50%, CHP systems can reach overall efficiencies of 60% to 80%. However, not all facilities are well suited to CHP systems. One key challenge is that there must be a proper balance between the need for heat and electricity.

CHP Resources

http://www.pacificchptap.org/

http://www.northwestchptap.org/

https://www.epa.gov/chp

Microgrids

According to the U.S. Department of Energy Microgrid Exchange Group, "A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode." Micorgrids are a concept that is really starting to take hold, and they offer several potential benefits for a rural region such as the NCRP.

Potential microgrid benefits for the NCRP region include energy resiliency. Because microgrids offer small, stable islands of power if the larger electric grid goes down, they can be an important part of energy assurance planning efforts. Microgrids can be designed to provide reliable power supplies to critical emergency services like emergency command centers, police and fire departments, hospitals, shelters, fueling infrastructure, communication facilities, and public works. Microgrids can also be designed to provide numerous benefits during normal, blue-sky conditions, such as energy cost savings, power quality improvement, and environmental and economic benefits.

Energy Assurance Planning Resources

http://www.caleap.org/

http://energy.gov/oe/services/energy-assurance/emergency-preparedness/state-and-local-energy-assurance-planning

Microgrid Resources

https://building-microgrid.lbl.gov/about-microgrids

http://www.microgridinstitute.org/about-microgrids.html

https://microgridknowledge.com/category/resources/microgrid-case-studies/

Power Plant Ownership

One area where there are both opportunities and challenges for the development of renewable energy resources in the NCRP region is power plant ownership. Large utility-scale power plants will likely be owned by either an electric utility (either public or private), or by an independent power producer who sells wholesale power. In addition, a newcomer to the utility-scale power generation market in California is the community choice aggregator, who can either own generation or purchase power for sale to their retail customers.

Retail power customers who serve their own loads via a net metering arrangement are likely to own smaller, distributed-scale power plants. Retail power customers can finance the installation of these distributed generators using third-party power purchase agreements or leasing models, or they can purchase them outright. Alternatively, distributed generation can take the form of community-scale systems that are owned by the incumbent utility, an independent power producer, or a community choice aggregator. Examples of utility sponsored community solar programs in California include Sacramento Municipal Utility District's Solar Shares® program and Pacific Gas and Electric's Solar Choice program.

3.1.3 Biomass

Biomass refers to renewable organic materials, such as wood and wood waste, agricultural crops and waste, and municipal wastes that can be used as a source of energy to produce heat, electricity or biofuels.

Biomass Resource Potential in the NCRP Region

The California Biomass Collaborative based at UC Davis conducted an assessment of biomass energy resources for the State of California that is disaggregated at the county level (CA Biomass Collaborative 2015). The values in Table 11 represent the results of the CA Biomass Collaborative study. The assessment covers biomass waste from the agricultural, forestry and municipal waste sectors. Not surprisingly, the NCRP region ranks high in the area of forest biomass. The NCRP region accounts for 38% of the statewide forest biomass resource, and 17% of the total statewide biomass resource. Within the NCRP region, forest biomass accounts for over 90% of the total biomass resource. Consequently, this section focuses primarily on the forest biomass resource for the NCRP region.

Figure 29 illustrates the biomass technical potential throughout the NCRP region in thousand metric tons per year of biomass. The biomass resource estimates in Figure 29 are based on an NREL study (Milbrandt, A. 2005). Note that the CA Biomass Collaborative estimates of biomass technical potential in California are roughly 2.4 times greater than the NREL estimates. Figure 29 shows that three NCRP counties, Humboldt, Mendocino and Siskiyou, are in the highest resource category listed (greater than 500,000 metric tons per year). The CA Biomass Collaborative report also shows these three counties to have the highest biomass technical potential.

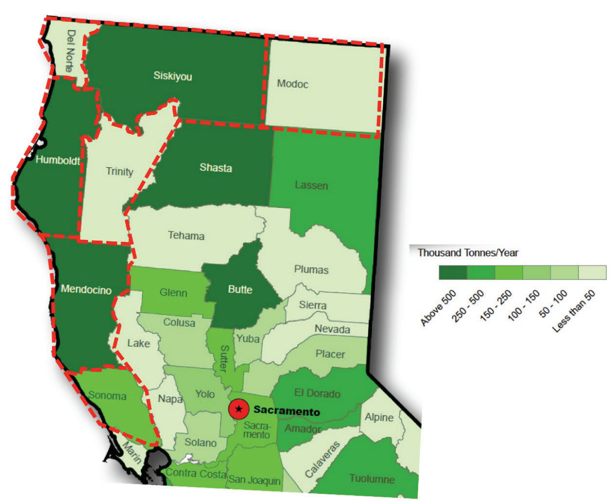


Figure 29: Biomass resource technical potential for the NCRP region (adapted from http://www.nrel.gov/gis/pdfs/eere_biomass/eere_biomass_h_california.pdf).

Biomass resource types

Biomass resource types include wastes from the agricultural, forestry and municipal sectors. Waste types from each of these sectors are outlined in Table 12.

Table 12: Types of biomass resources.

Sector	Agriculture	Forestry	Municipal
Waste Types	Orchard and vineyard prunings/residues Field and seed crop residues Vegetable crop residues Food and fiber processing residues Animal manures	Logging slash Mill residues Forest thinning and management residues Fuel reduction/fire hazard reduction residues	Municipal solid waste - food waste - green waste - paper/cardboard - other organics Landfill gas Biosolids from wastewater treatment Sewage digester gas

Most of the agricultural and municipal wastes are fairly centralized in terms of availability. For example, crop residues are centralized to the fields where the crops are grown, and municipal wastes are centralized to their collection points. Some of the forestry sector wastes are also centralized (e.g., mill residues, logging slash to some degree), but others are not (e.g., forest thinnings and fuel reduction residues). Wastes that are centrally located are much more convenient to deal with since they are easier to collect and often do not need to be transported very far. There is also often a fee associated with disposal of these wastes, and if this fee can be offset when the waste is utilized for biomass energy, then the economics will improve.

In contrast, non-centralized wastes in the forestry sector, such as forest thinnings and fuel reduction residues, are much more difficult to utilize. They tend to be widely geographically distributed, often in very remote and hard to reach areas. In addition, they are bulky and heavy, often very high in moisture content, and generally of low energy density and low value. For these reasons, it is difficult to cost-effectively transport these materials long distances; 50 miles is often used as a rough guideline for how far you can transport forest residues.

Forest sector woody biomass utilization

Forest sector woody biomass is probably one of the most complicated and difficult renewable resources to utilize for power generation. It involves a tremendous number of stakeholders across multiple industries (i.e., the forest products and renewable energy industries), and each industry has it's own unique regulatory structure, market structure, opportunities and constraints. One thing the two industries do have in common is that they need each other. The forest products industry needs someplace to dispose of its residues, ideally with some value added, and the biomass energy industry needs a fuel source. Another complication is that the costs and benefits associated with biomass disposal/utilization are not necessarily equitably allocated between the stakeholders. Some stakeholders may incur more costs and others more benefits, and if these costs and benefits cannot be redistributed fairly, then the required working relationships are sure to breakdown.

Mill wastes are centrally sourced and are therefore the most cost-effective and convenient forest biomass resource to utilize. These wastes are typically cleaner and more consistent than materials that come directly from the forest, and being centrally located they are easily accessed. In some cases these wastes are used right at the mill for combined heat and power applications. In other cases they are transported offsite to a nearby power plant or to some other site for reuse as a soil amendment, landscape product, animal bedding material, etc.

The more difficult-to-use woody biomass sources come directly from the forest as logging slash, forest thinnings, or fuel reduction residues. These materials tend to be quite varied in size, shape, composition, and moisture content. They are often contaminated with dirt and rocks and are located in distant, remote, and hard to access locations. Often it does not pay to transport these materials out of the woods.

Even if these materials can be effectively accessed, there are many challenges to achieving a successful woody biomass energy operation, especially for a smaller, community-scale operation (< 10 MW). Some of these challenges include:

- Finding a suitable use for both the heat and electricity
- Establishing a workable balance between the quantities of heat and electricity generated
- Obtaining a viable price for the sale of electricity and/or heat
- Working out the business relationships between fuel providers, power plant operators, and electricity and heat buyers
- Finding common ground with local community and environmental groups
- Establishing a working relationship with the local electric utility and achieving an equitable and viable interconnection arrangement

- Overcoming the cost challenges associated with small-scale biomass power plants: typically larger plants are more viable because the fixed operating costs make up a smaller portion of the overall operating costs and because the capital costs associated with larger plants are typically less per unit of rated output
- Sorting biomass and using each component (tops, bark, limbs, bole, etc.) for its highest value can help the economics, but it can also complicate the business relationships and dependencies
- Technology choices (which technology to choose, is it reliable and robust, is it cost effective, etc.)
- Financing challenges
- Meeting air quality emissions standards and keeping your neighbors happy
- Securing a fuel supply contract over an acceptable term (10 years?) and at an acceptable price

Three excellent information sources that discuss the challenges and opportunities associated with the utilization of woody biomass in the California forest products and renewable energy markets are:

- Biomass Energy in the North Coast Region: An Assessment and Strategy for Ecologically and Socially Compatible Development (Morris, J. 2011), http://www.northcoastresourcepartnership.org/files/managed/Document/8807/Biomass%20Energy%20in%20The%20North%20Coast%20Region%202011.pdf
- Biomass Energy in California's Future: Barriers, Opportunities, and Research Needs - Draft Report (Kaffka, S. et al. 2013), http://biomass.ucdavis.edu/files/2015/10/Task-5-FINAL-DRAFT-12-2013.pdf
- California Assessment of Wood Business Innovation Opportunities and Markets, Phase I Report: Initial Screening of Potential Business Opportunities (The Beck Group 2015), https://www.nationalforests.org/assets/pdfs/California-Assessment-Wood-Biomass-Innovation-Interim-Report-June-2015.pdf

Another very useful information source listed below examines community-scale woody biomass project feasibility for the Camptonville Community Partnership. This report examines various technology options, presents a list of potential vendors for the technologies considered, and provides a detailed financial analysis.

- Camptonville Community Partnership Biomass Power Generation and CHP Feasibility Study (Black & Veatch 2015), http://ucanr.edu/sites/swet/files/239323.pdf

Woody biomass energy conversion technologies

Woody biomass resources can be used for electricity generation, thermal energy needs, or combined heat and power. They can also be used for the production of second generation, lignocellulosic biofuels, such as bio-oil, cellulosic ethanol, synthetic biodiesel, or synthetic natural gas. The simplest of these processes is using biomass for heating, next in terms of difficulty is electricity production or combined heat and power, and the most complicated and least technologically mature is production of biofuels.

There a number of technology options associated with each of these energy conversion processes. We very briefly discuss some of them here and then provide resources for further information.

Woody biomass can be converted into energy for heat, electric power or both via two main pathways: direct combustion or gasification. Rather than being distinct, however, these pathways are more of a continuum. Everyone is familiar with direct combustion, though not everyone realizes that direct combustion also involves gasification. During direct combustion solid biomass is heated in a rather uncontrolled manner to evolve volatile, flammable gases, which are then combusted in the presence of oxygen. In a controlled gasification process, the biomass is heated with limited amounts of oxygen and the generated syngas can then be directed to a separate process for utilization. It can be burned in a boiler or furnace to generate heat, burned in an internal combustion engine or combustion turbine to generate mechanical power, or potentially even oxidized in a fuel cell generator to directly produce electricity. In addition, the syngas can be cleaned and converted into other forms of fuel, such as synthetic natural gas or gas-to-liquid biofuels.

Direct combustion technologies are technologically mature and commercially readily available. Gasification systems are less mature, but some technologies have been proven to work reliably. However, they are most reliable and robust when used to provide gas that will be burned at atmospheric pressure in furnace or boiler. If the gas is intended for use in an internal combustion engine, combustion turbine, or fuel cell, things get much more complicated. Effective gas cleanup equipment is necessary. While there has been some limited success using biomass derived syngas to power internal combustion engines, there has been little to no success using it to power combustion turbines or fuel cell generators. Research and development continues in these areas.

If the syngas is burned to produce heat, the heat can be used directly, it can be used to generate steam for a Rankine cycle steam turbine (for electricity production) or for process needs, or it can be used to power an organic Rankine cycle turbine.

The following information resources provide further information regarding woody biomass energy conversion technologies:

- Market Assessment of Biomass Gasification and Combustion Technology for Small- and Medium-Scale Applications (Peterson, D. and S. Haase 2009), http://www.nrel.gov/docs/fy09osti/46190.pdf
- Biomass Combined Heat and Power Catalog of Technologies (Energy and Environmental Analysis, Inc. 2007), https://www.epa.gov/sites/production/files/2015-07/documents/biomass_combined_heat_and_power_catalog_of_technologies_v.1.1.pdf
- A Guide to Utilizing Combined Heat and Power in the Wood Resources Industry (Clarke, P. et al. 2012), http://penntap.psu.edu/wp-content/uploads/2012/09/Wood-CHP-resources-guide-Final-1-17-13.pdf

Potential environmental issues associated with woody biomass energy

Conversion of woody biomass into energy can have adverse environmental impacts in some situations. As with any energy conversion technology, the impacts of each proposed project should be evaluated. Areas of potential concern could be:

- Air pollution emissions
- Lack of carbon neutrality
- Unsustainable forest management policies

However, in a well managed system the utilization of woody biomass for energy production can provide many added benefits. It can be an important disposal option for residues from sawmills and other timber production facilities. It can also be used to dispose of logging slash from timber harvest operations and residues from thinning and fuel reductions efforts. Alternatively, residues from these activities are often burned in open piles. Utilizing them, instead, in a biomass power plant will reduce criteria air emissions and can displace the use of fossil fuels for electricity generation. In addition, the value of the biomass fuel can help offset the cost of forest management activities, thereby allowing for greater management activities to take place. These activities can all result in more local jobs, a more vibrant forest products sector, and a more robust forest management system.

Other woody biomass opportunities

In addition to the woody biomass utilization technologies described above, there are other utilization strategies that should be assessed. Because of the many challenges and complications associated with woody biomass utilization, it is important to aim to use the resource for its highest valued purpose. Other utilization strategies can include:

- Densification: Production of pellets, briquettes, or torrefied wood
- Biochar: Production of biochar for use as a soil amendment and to sequester carbon or for use as a higher-value carbon product (activated carbon, carbon fiber, etc.)
- Raw biomass sort yard concept to utilize the raw material for its highest-valued use, such as post and pole production, mass timber, firewood, chips, briquettes, soil amendments, animal bedding, etc.
- Exploitation of symbiotic relationships and co-location of businesses and/or processes (e.g., use of waste heat from one process as energy input to another co-located process)

Biogas from wastewater treatment plants

Wastewater treatment plants (WWTPs) produce a sewage sludge that is rich in nutrients and can be processed in an anaerobic digester to generate low-nutrient solids and an energy rich sewage gas that is high in methane. The sewage gas must be combusted to convert it to CO_2. In the process it can be used to generate heat and/or electrical power. Digester gas from WWTPs is typically used to fuel a reciprocating engine or a microturbine to generate electrical power. This technology is well developed and proven, there are many successful systems deployed throughout the world, and there is a lot of technical assistance and information available. Some key informational resources are listed below:

- Opportunities for and Benefits of Combined Heat and Power at Wastewater Treatment Facilities (Eastern Research Group 2006), https://www.americanbiogascouncil.org/pdf/EPA-Benefits%20of%20CHP%20at%20WWTPs.pdf
- Opportunities for Combined Heat and Power at Wastewater Treatment Facilities: Market Analysis and Lessons from the Field (USEPA Combined Heat and Power Partnership 2011), https://www.epa.gov/sites/production/files/2015-07/documents/opportunities_for_combined_heat_and_power_at_wastewater_treatment_facilities_market_analysis_and_lessons_from_the_field.pdf
- Financing CHP Projects at Wastewater Treatment Facilities with Clean Water State Revolving Funds

(USEPA Combined Heat and Power Partnership 2014), https://www.epa.gov/sites/production/files/2015-07/documents/financing_chp_projects_at_wastewater_treatment_facilities_with_clean_water_state_revolving_funds.pdf

- Combined Heat and Power Potential at California's Wastewater Treatment Plants (Kulkarni, P. 2009), http://www.energy.ca.gov/2009publications/CEC-200-2009-014/CEC-200-2009-014-SF.PDF
- Evaluation of Combined Heat and Power Technologies for Wastewater Treatment Facilities (Wiser, J. et al. 2010), http://www.cwwga.org/documentlibrary/121_EvaluationCHPTechnologiespreliminary%5B1%5D.pdf

Biogas from animal farm manure digestion

Dairies, cattle feedlots and pig farms can generate large volumes of manure that can be processed in an anaerobic digester just like human sewage. These operations are most conducive to manure digestion when they are intensive operations where the animals are kept in close quarters and the manure is centrally collected. Animal farms are less well suited to manure digestion when animals are let out to pasture because the manure is then widely and randomly distributed. Like with many energy conversion technologies, economies of scale come into play so that larger operations tend to be more economical. If there are manure management regulations being enforced, this can also lead to better economic viability for digester systems.

The feasibility study listed below (Reis, A. and R. Engel 2003) was conducted to examine the feasibility of dairy farm digesters in Humboldt County. This study found that economies of scale, land tenure arrangements and open pasture grazing practices are important factors in determining the feasibility of animal farm digester projects. Additional information resources are also listed below.

- Feasibility Study on Implementing Anaerobic Digestion Technology on Humboldt County Dairy Farms (Reis, A. and R. Engel 2003), http://www.schatzlab.org/docs/Biogas_Report_Final.pdf
- Manure Treatment Technologies: Anaerobic Digesters (Meyer, D. and T. Powers 2011), http://anrcatalog.ucanr.edu/pdf/8409.pdf
- Anaerobic Digestion of Animal Wastes: Factors to Consider (Balsam, J. 2006), https://attra.ncat.org/attra-pub/download.php?id=307

Landfill gas

Municipal solid waste landfills are another potential source of bioenergy. As the solid waste breaks down it emits methane gas, a serious climate forcing greenhouse gas. Landfills must be capped to collect this methane gas so that it can be flared and turned into CO_2, a less serious greenhouse gas. This landfill gas can be captured and used to produce heat or electrical power, similar to the digester gas applications described above. Some of the challenges associated with landfill gas capture and utilization include: complications with the landfill closure process, economies of scale issues, and an ability to use generated heat and/or electricity on-site since many landfill sites are remotely situated and do not have substantial heat or electrical loads that can be offset. In addition, you cannot easily feed landfill gas into the natural gas pipeline in California. This is done in other regions of the U.S., but it is not easily accomplished in CA due to potential issues with gas purity and/or contamination (see: http://www.energy.ca.gov/2009_energypolicy/documents/2009-04-21_workshop/comments/Remove_Impediment_to_Utilization_of_Landfill_Gas_04-24_09_TN_51260.pdf). Additional information resources for landfill gas utilization include:

- Request for Proposals, Landfill Gas to Energy Design/Build Project, Cummins Road Landfill, http://www.hwma.net/sites/default/files/rfp-9.pdf
- Design of an Electricity Generating Facility Using Landfill Gas from the Cummings Road Landfill, Knibb, Keith, 1988, A senior project presented to the Department of Environmental Resources Engineering, Humboldt State University
- U.S. EPA Landfill Methane Outreach Program (LMOP), https://www.epa.gov/lmop
- LFG Energy Project Development Handbook, U.S. EPA LMOP, https://www.epa.gov/sites/production/files/2016-11/documents/pdh_full.pdf

Biogas from food waste digestion

The management of food waste should be considered in the larger context of the food recovery hierarchy, where source reduction and the use of extra food is preferred. However, when food waste is headed to the solid waste stream one alternative is to divert and decompose it in an anaerobic digester similar to the anaerobic digestion of municipal sewage or animal manure. While the main benefits of food waste digestion are related more to solving solid waste disposal problems and reducing greenhouse gas emissions, it can also have renewable energy benefits if the generated biogas is utilized for energy generation.

Food waste digestion projects can be associated with the general municipal solid waste stream, or they can be dedicated to specific facilities that generate specific food waste materials, such as breweries, milk production and food production facilities. There are fewer challenges for food waste digesters that are associated with specific food production facilities because the food waste is already collected in one location. In contrast, a key challenge for municipal solid waste food digestion projects is the need to collect and/or separate food waste from the overall municipal solid waste stream. Food waste can be decomposed in a dedicated digester, or it can be co-digested with another waste stream, such as at a wastewater treatment plant or a dairy farm.

While food waste digestion is better established in Europe, there have also been projects developed in the U.S. With regard to food digestion in the general municipal solid waste sector, the East Bay Municipal Utility District (EBMUD) has been a leader. EBMUD co-digests food waste with their municipal wastewater solids. One municipal waste agency located in the NCRP region that has considered a food waste digestion project is the Humboldt Waste Management Authority (Bohn, J. et al. 2010). Other food waste digestion projects in CA include one at U.C. Davis and another in the City of Millbrae. The following sources provide additional information on food waste digestion.

- Food Waste Diversion and Utilization in Humboldt County (Bohn, J. et al. 2010), http://www.hwma.net/sites/default/files/humboldt_regional_food_waste_digester_feasibility_study_0.pdf
- Anaerobic Digestion of Food Waste (East Bay Municipal Utility District 2008), https://archive.epa.gov/region9/organics/web/pdf/ebmudfinalreport.pdf
- Feasibility Study of Anaerobic Digestion of Food Waste in St. Bernard, Louisiana (Moriarty, K. 2013), http://www.nrel.gov/docs/fy13osti/57082.pdf
- Anaerobic Digestion of Food Waste in New England (Fitzgerald, L. 2013), http://www.ct.gov/deep/lib/deep/compost/compost_pdf/ad_of_food_waste_in_new_england.pdf
- Sustainable Management of Food, USEPA, https://www.epa.gov/sustainable-management-food

Additional Biomass Resource Information

Biomass Resource Availability Estimates

- http://biomass.ucdavis.edu/files/2015/04/CA_Biomass_Resource_2013Data_CBC_Task3_DRAFT.pdf
- http://www.nrel.gov/docs/fy06osti/39181.pdf
- http://www.nrel.gov/gis/biomass.html
- http://www.nrel.gov/gis/data_biomass.html

Maps of existing biomass power plants and forest products operations

- http://ucanr.edu/sites/WoodyBiomass/Technical_Assistance/California_Biomass_Power_Plants/
- http://www.calbiomass.org/facilities-map/
- https://www.wood2energy.org/

Woody biomass general information

- http://ucanr.edu/sites/WoodyBiomass/
- http://www.energy.ca.gov/biomass/biomass.html
- http://www.fs.fed.us/woodybiomass/
- http://www.biomasscenter.org/
- http://ucanr.edu/sites/swet/
- http://www.thewatershedcenter.com/?page_id=1265

Location and characteristics of wastewater treatment

- EPA Facility Registry Service (FRS): Wastewater Treatment Plants (GIS dataset) (http://catalog.data.gov/dataset/epa-facility-registry-service-frs-wastewater-treatment-plants)
- Region 9 NPDES Facilities 2012- Waste Water Treatment Plants (GIS dataset) (http://catalog.data.gov/dataset/region-9-npdes-facilities-2012-waste-water-treatment-plants)

Landfill site location and status

- http://www.calrecycle.ca.gov/SWFacilities/Directory/Search.aspx

Location of dairy farms, existence of digesters, dairy digester feasibility

- https://gispub4.epa.gov/AgSTAR/index.html
- https://calmatters.org/media/uploads/mapmethane_digester.png

Example Projects/Case Studies

- Community-scale woody biomass http://www.biomasscenter.org/resource-library/case-studies
- Manure biogas http://www.manuremanagement.cornell.edu/Pages/Resources/Resources-Case_Studies.htm
- http://extension.psu.edu/natural-resources/energy/waste-to-energy/resources/biogas/case-studies

- Landfill gas http://energy.gov/sites/prod/files/2013/11/f5/chp_landfillgas_casestudy.pdf
- WWTP digester gas http://www.stateenergyoffice.wi.gov/docview.asp?docid=26390&locid=160

Information Needed for Feasibility Assessment and/or Project Development

- Long-term (i.e., 10 years) cost and availability of biomass feedstock
- Woody biomass feedstock characteristics (source, type, size, moisture content, etc.)
- Biogas resource characteristics that are specific to the application (i.e., WWTP, landfill, dairy biogas, food waste digester)
- Desired electrical generation capacity
- Desired useful heat output for CHP (temperature and quantity)
- Energy conversion technology options and costs (direct combustion grate boiler with steam cycle generator, gasifier, gas genset, microturbine, etc.)
- Expected value of biomass generated electricity and heat
- Expected air emissions
- Potential locations for biomass power plants and associated characteristics (land ownership, zoning, etc.)
- Electric transmission and distribution grid characteristics in vicinity of proposed power plant location

3.1.4 Geothermal

Accessing underground geologic heat reservoirs can generate geothermal energy. California has used geothermal technology for decades, with major power facilities at The Geysers in Sonoma County and along the Salton Sea in Imperial County. While geothermal power currently accounts for 78% of renewable power capacity within the NCRP region, additional utility scale generation will be hindered by resource constraints, local cultural considerations, and prohibitive costs. However, smaller scale electric and direct heating applications may be viable.

Typical geothermal systems (also called hydrothermal systems) are built where subterranean rock formations have naturally fractured, bringing groundwater in contact with heat reservoirs. Recent research has focused on developing Enhanced Geothermal Systems (EGS), where deep-earth fractures are generated to expand the potential of geothermal energy. EGS technology is still in development, with current projects focusing mostly on the enhancement of existing hydrothermal wells and reservoirs to make them more productive. In contrast, development of EGS projects on land where there is no indication of an existing hydrothermal system are not expected to play a significant role in the geothermal power market for some time to come. Critics cite environmental concerns with EGS technology due to similarities between EGS and hydraulic fracturing, with increased seismicity and potential contamination of groundwater cited as key concerns. However, those in the EGS industry feel these potential issues can be mitigated. The Newberry EGS Demonstration project has been active in central Oregon for a number of years and is working to assess the technology and how it can be successfully implemented (see: http://altarockenergy.com/projects/newberry-egs-demonstration/). The environmental assessment conducted for the Newbury project is also a good source of information (https://www.blm.gov/or/districts/prineville/plans/newberryegs/).

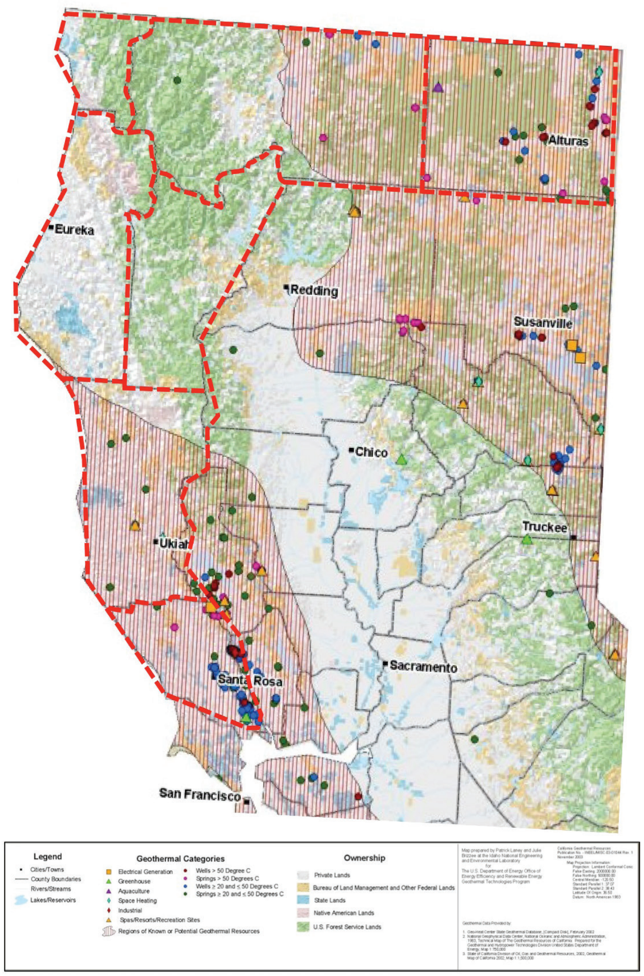
Utility scale geothermal generation is best suited to areas with high temperature (>150°C) thermal deposits, but lower temperature resources can still be useful. Use of lower temperature sources can provide direct heating to local communities, and if electricity generation is needed, Organic Rankine Cycle (ORC) turbines can utilize lower temperature hydrothermal sources to generate community-scale electricity.

Geothermal heat pumps are another way to utilize the earth's low-grade thermal energy. Geothermal heat pumps are heat exchangers, with coils placed several dozen to several hundred feet underground where the temperature is essentially constant. The earth is then used as a heat source/sink for heat pump operation. These systems are discussed further in Section 3.2.11.

Geothermal Resource Potential in the NCRP Region

Geothermal potential within the NCRP counties is concentrated chiefly in Sonoma County, Siskiyou County, Modoc County, and Mendocino County, as listed in Table 11[1]. Figure 30 identifies known geothermal wells within California, and Figure 31 identifies high-temperature geothermal systems with technical potential for development. Energy potential may increase if EGS technology makes additional resources accessible.

1 The table values represent a USGS 95% probability estimate of potential identified resources.

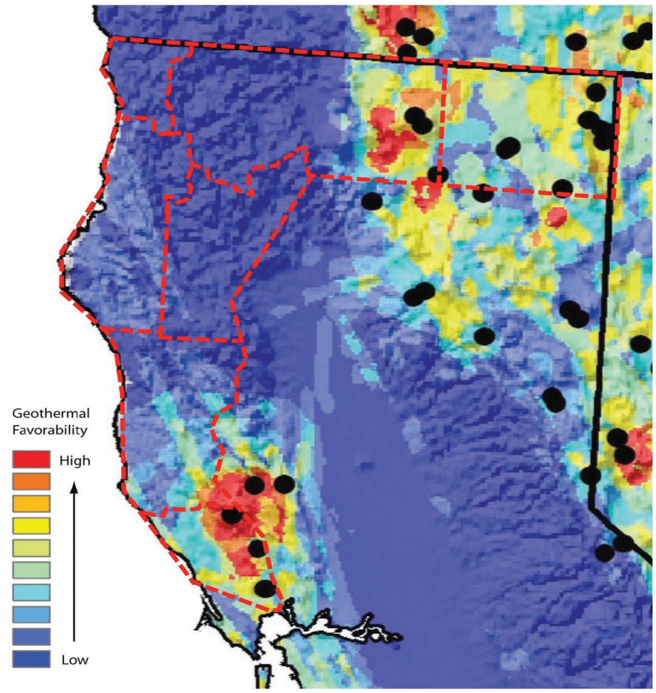


Adapted from Idaho National Engineering and Environmental Laboratory, November 2003
http://geothermal.inel.gov/maps/ca.pdf

Figure 30: Geothermal resource potential for the NCRP region (adapted from http://geothermal.inl.gov/maps/ca.pdf).

Sonoma County currently utilizes much of its geothermal resource with the existing facility at The Geysers. In 2011, the Sonoma County Board of Supervisors approved the expansion of the facility to construct two additional 49-megawatt plants. (Calpine Corporation 2012). Additional expansion of geothermal power in other parts of the NCRP region is most likely in Siskiyou and Modoc counties, although resource exploration will be necessary to determine the true power potential.

Current research suggests some additional geothermal resource potential in these regions. An Idaho National Laboratory/Massachusetts Institute of Technology report identified several locations in Siskiyou and Modoc County with temperature estimates ranging from 150-250°C, varying with depth. (MIT 2006) However, only exploratory drilling can precisely determine heat reservoir depth, temperature, and accessibility. This can prove prohibitively costly, as drilling is no guarantee of project viability. It should also be noted that geothermal energy facilities might also have unique cultural considerations: Medicine Lake in Siskiyou County has excellent geothermal potential, but is also considered a historically significant and sacred site to local tribes.



Adapted from US Geological Survey, 2008
http://pubs.usgs.gov/fs/2008/3082/

Figure 31: Geothermal resource potential for the NCRP region (adapted from http://pubs.usgs.gov/fs/2008/3082/pdf/fs2008-3082.pdf)

Geothermal Resource Information

- NREL Interactive Geothermal Prospector http://www.nrel.gov/gis/tools_gt_prospector.html
- U.S. Department of Energy
  http://www.nrel.gov/geothermal/capabilities.html
  https://energy.gov/eere/geothermal/enhanced-geothermal-systems-0
  https://www1.eere.energy.gov/geothermal/pdfs/evaluation_egs_tech_2008.pdf
- Idaho National Laboratory http://geothermal.inel.gov/publications/future_of_geothermal_energy.pdf
- United States Geological Service
  https://pubs.usgs.gov/fs/2008/3082/pdf/fs2008-3082.pdf
  http://energy.usgs.gov/OtherEnergy/Geothermal.aspx#3880212-data

- CA Energy Commission
  http://www.energy.ca.gov/geothermal/background.html
  http://www.energy.ca.gov/maps/renewable/geothermal_areas.html
- CA Department of Conservation
  http://www.conservation.ca.gov/dog/geothermal/maps/Pages/index.aspx
- CA Geothermal Energy Collaborative
  http://cgec.ucdavis.edu/
- Geothermal permitting guide
  http://cgec.ucdavis.edu/files/2013/09/09-04-2013-CEC-500-2007-027-1.pdf

Information Needed for Feasibility Assessment and/or Project Development

- Resource temperature characteristics
- Desired use of resource (heat, electricity generation, heat pump)
- Desired electrical generation capacity
- Technology options and costs
- Expected value of geothermal generated electricity and heat
- Potential locations for geothermal power plants and associated characteristics (land ownership, zoning, etc.)
- Electric transmission and distribution grid characteristics in vicinity of proposed power plant location

Example Projects/Case Studies

- Black Rock Geothermal Power Project (http://www.energy.ca.gov/sitingcases/saltonsea/)
- Geysers geothermal project in Sonoma (http://www.geysers.com/)
- Newberry EGS Demonstration Project (http://altarockenergy.com/projects/newberry-egs-demonstration/)

3.1.5 Hydropower

Hydropower utilizes the energy in flowing water to spin a turbine and generate electricity. The potential energy available for conversion is a function of the elevation change between intake and turbine and the flow rate. Hydropower technology is fully mature and has been utilized to generate electrical power for over 100 years. Traditional hydropower has involved the construction of dams to impound water and harness it's power.

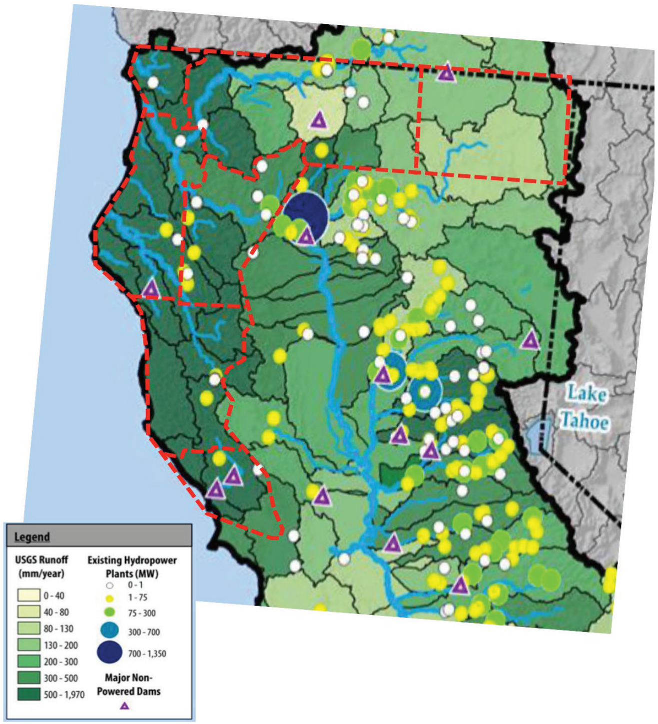
Unfortunately, the construction of dams can pose adverse impacts to river ecosystems. For this reason, the State of California is very careful in its treatment of newly proposed hydropower facilities. Per the CEC's RPS eligibility requirements (CEC 2015), a hydropower facility can only qualify as a renewable energy facility if it does not cause an adverse impact on the instream beneficial uses of the affected waterway. The CEC goes on to say that a facility could have an adverse impact on the instream beneficial uses if it causes an adverse change in the chemical, physical, or biological characteristics of water, including a change in the volume, rate, timing, temperature, turbidity, or dissolved oxygen content of the stream water. In addition, the CEC only considers small hydropower facilities eligible for renewable status, where small means less than 30 MW (or 40 MW if the facility is operated as part of a manmade water supply or conveyance system). These constraints, along with the environmental protections under the California Environmental Quality Act and the National Environmental Policy Act, make it very challenging to get a new stream-reach based hydroelectric facility approved and certified as a renewable power source in California.

While there is potential for new stream-reach hydropower projects, the environmental impact and controversy of a new project makes development difficult. The construction of new dams is very unlikely. However, small to medium sized run-of-river hydroelectric facilities (≤30 MW) can be considered a renewable power resource in CA provided they do not cause harm to the aquatic ecosystem. In addition, other hydropower development opportunities exist that do not involve new stream-reach development. These include conversion of existing non-powered dams to hydroelectric production and upgrades or expansion of existing hydroelectric facilities. In addition, in-conduit hydropower development has been identified as a new potential resource. Anywhere water is conveyed through pipes or channels and there is sufficient head and flow, there is potential for hydroelectric generation.

Stream-reach Hydropower Resource Potential in the NCRP Region

Figure 32 shows the existing hydropower facilities in the NCRP and surrounding north state region. In the NCRP region most existing facilities are less than 100 MW in capacity. Note also the major non-powered dams (purple triangles shown in Modoc, Siskiyou, Humboldt and Sonoma Counties); these represent potential hydropower development opportunities.

Existing Hydropower Plants



Adapted from Kao, S., et. al.2014

Figure 32: Existing hydropower plants in northern California (adapted from https://nhaap.ornl.gov/sites/default/files/ORNL_NSD_FY14_Final_Report.pdf).

New Hydropower Potential

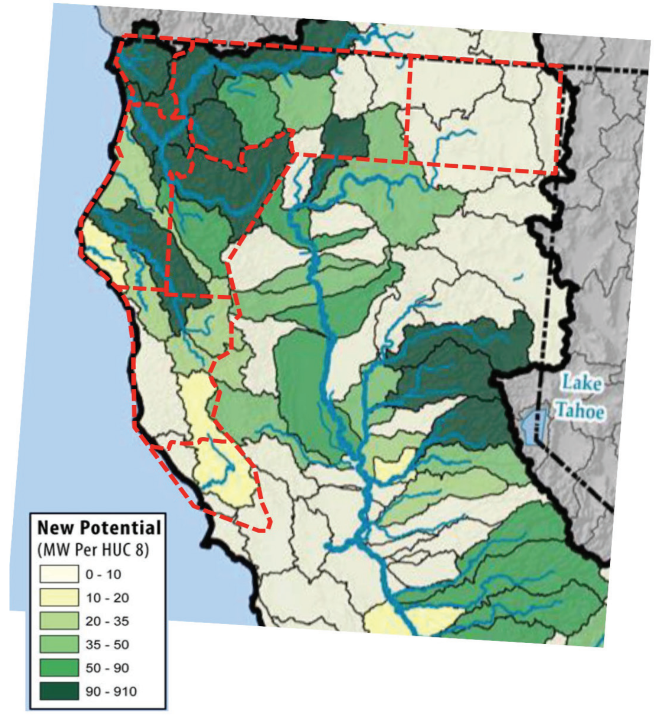


Table 21.2. Summary of Potential New Hydropower Resources in Region 18—California (Stream-Reaches with Potential Capacity >1 MW)

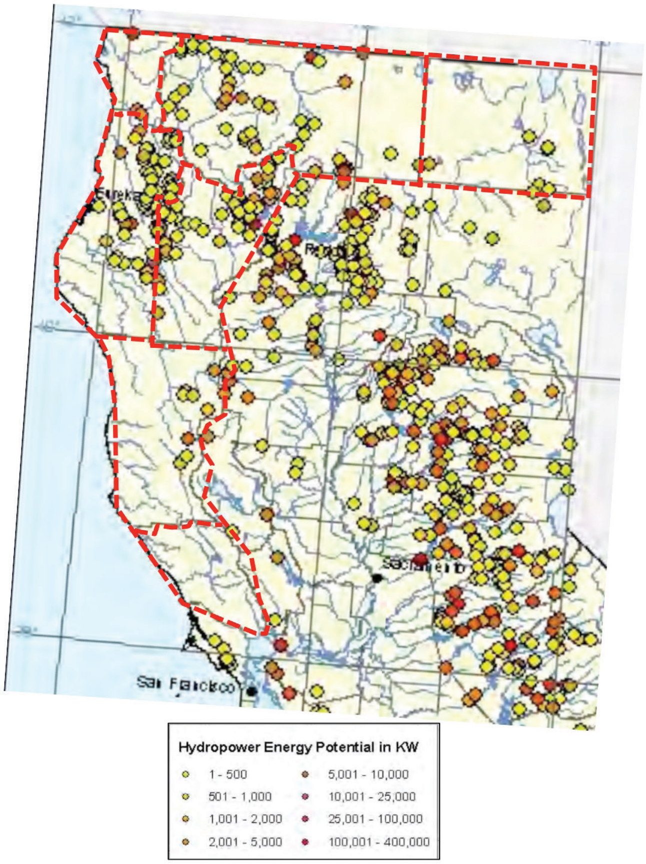
HUC04	HUC04 name	# of stream-reaches	Potential capacity (MW)	Potential energy (MWh)	Average head (ft/reach)	Average flow (cfs/reach)	Average storage (ac-ft/reach)	Average residence time (days)
1801	Klamath–Northern California Coastal	449	2,485.5	12,941,370	30.2	2,782	1,606	0.8

Adapted from Kao, S., et. al.2014

Figure 33: New hydropower potential in Klamath-Northern California Coastal subregion (adapted from https://nhaap.ornl.gov/sites/default/files/ORNL_NSD_FY14_Final_Report.pdf).

A study prepared by Oak Ridge National Laboratory (Kao, S. et al. 2014) estimated the hydropower potential throughout the U.S. associated with new stream-reach development. Figure 33 shows the estimated potential for the NCRP and surrounding north state region. A potential capacity of almost 2,500 MW was estimated for the Klamath-Northern California Coastal USGS hydrologic subregion (USGS hydrologic unit code 1801). The California Energy Commission (Kane, M. 2005) also estimated new hydropower potential in California. The results of this study are shown in Figure 34. As can be seen from these figures, there is a substantial amount of new hydropower potential in the NCRP region, especially in Del Norte, Humboldt, Siskiyou and Trinity Counties.

New Hydropower Potential

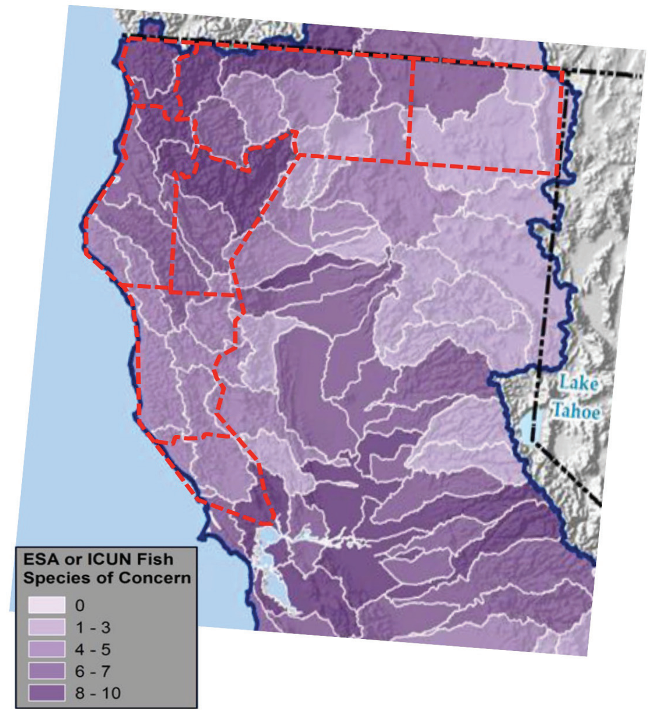


Reference: California Small Hydropower and Ocean Wave Energy Resources, CEC 2005

Figure 34: New hydropower potential in California (adapted from http://www.energy.ca.gov/2005publications/CEC-500-2005-074/CEC-500-2005-074.PDF).

While there appears to be substantial resource development opportunities, it is likely that very few of these opportunities would actually prove feasible. Environmental impacts are one key barrier. The key environmental issues associated with new stream-reach hydropower are potential impacts to aquatic ecosystems, and to fisheries in particular. With a detailed understanding of a watershed it may be possible, in some situations, to build new run-of-river systems with minimal impact. In these run-of-river systems water is taken out at one location, run through a turbine, and returned at a lower location in the stream. In a stream with natural blockages to fish passage these hydropower facilities can be built high in the watershed above the zones where fish can reach, thereby minimizing impacts. This type of development requires detailed knowledge of the stream ecosystem. Figure 35 provides some very brief information about the existence of fish species of concern in the NCRP region. This map shows that the same areas that have good hydropower potential also have significant species of concern.

Fish Species of Concern



Adapted from Kao, S., et. al.2014

Figure 35: Fish species of concern in California (adapted from https://nhaap.ornl.gov/sites/default/files/ORNL_NSD_FY14_Final_Report.pdf).

Conduit Hydropower Resource Potential in the NCRP Region

Conduit hydropower systems refer to systems that extract power from water flowing through manmade conveyance systems. Often in manmade systems there is elevation head that can be exploited. In fact, manmade conveyance systems are often equipped with pressure reduction systems to dissipate the elevation head to acceptable levels. In these cases a hydroelectric turbine can be substituted for the existing pressure reduction equipment. The hydroelectric turbine can provide the desired reduction in pressure while also producing useful electrical power.

As such, conduit hydropower systems can be efficient and cost-effective. With an existing water conveyance system most of the infrastructure for a hydropower system may already be in place, including the intake, penstock, and sometimes even the powerhouse in the form of an existing vault. As a result, the relatively low incremental cost of the turbine can result in a much faster payback than for an all-new hydroelectric project. In addition, conduit hydropower systems are environmentally friendly since they rely on existing infrastructure and impose no added impact on the natural world. Consequently, licensing and permits can be easier to obtain. In fact, the Federal Energy Regulatory Commission (FERC) and a number of states have streamlined the permitting process for conduit projects. Overall, conduit hydropower systems can have fewer hurdles than traditional hydropower systems, and consequently there has been a lot of interest in conduit hydropower at both the state and federal levels over the last few years. A recent study prepared for the CA Energy Commission (Park 2006) estimated that there was approximately 255 MW of small hydropower capacity that could technically be developed in manmade conduits in CA, and that 50-60% of that capacity might be feasibly developed.

Unfortunately, the California statewide assessment (Park 2006) shows little to no conduit hydropower potential in the NCRP region. In addition, not all conduit systems are suitable for hydropower. The first priority in these systems is always conveyance of water and meeting the needs of the water supply or wastewater system.

Small Hydropower Resource Information

- New Stream-reach Development: A Comprehensive Assessment of Hydropower Energy Potential in the United States (Kao, S. et al. 2014), https://nhaap.ornl.gov/sites/default/files/ORNL_NSD_FY14_Final_Report.pdf
- California Small Hydropower And Ocean Wave Energy Resources (Kane, M. 2005), http://www.energy.ca.gov/2005publications/CEC-500-2005-074/CEC-500-2005-074.PDF
- Feasibility Assessment of the Water Energy Resources of the United States for New Low Power and Small Hydro Classes of Hydroelectric Plants (Hall, D. et al. 2006), https://www1.eere.energy.gov/water/pdfs/doewater-11263.pdf
- An Assessment of Energy Potential at Non-Powered Dams in the United States (Hadjerioua, B. et al. 2012), https://www1.eere.energy.gov/water/pdfs/npd_report.pdf
- In-Conduit Hydropower Project – Phase I Report (Allen, G. et al. 2013), http://cdnassets.hw.net/2e/fd/58ca4ccf465ab32ebb17ebc4c588/hydrop1.pdf.
- Recapturing Embedded Energy in Water Systems: A White Paper on In-Conduit Generation Issues and Policies (House, L. 2013), http://smallhydro.ucdavis.edu/files/11-01-2013-ENR-uvdwhite_paper_recapture.pdf.
- Statewide Small Hydropower Resource Assessment (Park, L. 2006), . http://www.energy.ca.gov/2006publications/CEC-500-2006-065/CEC-500-2006-065.PDF.

Information Needed for Feasibility Assessment and/or Project Development

- Potential locations for hydroelectric generators (existing non-powered dams, in-conduit opportunities, run-of-river opportunities)
- For run-of-river opportunities, information about the aquatic ecosystem: Does the stream support anadromous fish? Are there natural barriers to fish passage? Potential environmental impacts?
- For conduit hydro, locations and characteristics of water conveyance systems and their management
- Flow and head characteristics
- Desired electrical generation capacity
- Technology options and costs
- Expected value of hydro electricity
- Electric transmission and distribution grid characteristics in vicinity of proposed power plant location
- FERC licensing requirements

3.1.6 Solar

According to a solar fact sheet available from Sandia National Laboratory (Tsao, J. 2006), sunlight has by far the highest theoretical potential of the earth's renewable energy sources. In fact, enough solar energy strikes the earth's surface every few hours to satisfy a year's worth of worldwide energy consumption. So it is no surprise that the renewable resource with the greatest potential in the NCRP region is solar power.

The solar radiation that strikes the earth can be converted into useful energy via a number of technology pathways. These include active solar thermal systems, passive solar thermal design, concentrating solar thermal electric systems, and solar photovoltaic technology. This section focuses on solar photovoltaic technology, which converts the sun's energy directly into electricity with no moving parts. Passive and active solar thermal technology can also play an important role in meeting energy demands and should not be ignored. These thermal technologies are applied at the facility level (i.e. a household or business). Concentrating solar thermal electric power is only utilized at the utility-scale, and in California is mainly suited to the southern desert where the solar energy intensity is greatest.

Solar photovoltaic (PV) technology is unique in that it is very modular. It can be the size of your thumbnail and used to power a wrist watch, or it can fill square miles of desert land and power over 100,000 homes. This makes the technology very flexible. It can be installed on a rooftop to provide power for a single facility, or a larger community-scale system can be installed to provide power for many homes.

Solar PV is a very mature technology that has come down in price dramatically over the last 10-15 years. The installed cost of a rooftop solar electric system today is less than half the price it was 10 years ago. Although California solar rebates have been exhausted, the price to the consumer today is lower than it has ever been, and there are still 30% federal tax credits available through 2019, after which time they begin to decrease and then expire at the end of 2021. At current prices, solar has become competitive with conventional forms of electricity production. Because of the tremendous drop in prices the installation of rooftop, community-scale, and utility-scale photovoltaic technology has become a very large and well-established industry. In the last decade solar PV has experienced a compound annual growth rate of nearly 60%. In terms of installed capacity in the U.S., California is the clear leader with over 40% market share.

Solar PV systems seem to enjoy the most flexibility among renewable energy sources when it comes to customer purchase options. This is due to the fact that PV has the most well-established and largest consumer market. Purchase options for rooftop PV power include a direct purchase option, leasing options, and power purchase agreements (PPAs). With a PPA the customer agrees to pay a pre-set price for the power that the rooftop system generates. Third party ownership models (leasing, PPA) make up the majority of the residential solar market in California.

Solar Resource Potential in the NCRP Region

The solar resource potential for the NCRP region is tremendous. As shown in Table 11 solar clearly offers the greatest total potential across all the resources examined (68% of the total estimated renewable resource potential). This is due in large part to the fact that the sun essentially shines everywhere. With most every other renewable resource there are more limiting constraints regarding where the resources are available.

The technical potential estimates in Table 11 were developed based on an NREL GIS-based analysis (Lopez, A. et al. 2012) that provided statewide estimates. The California statewide estimate was then disaggregated to the county-level using solar technical potential estimates from a CEC study of California solar resources (Simons, G. and J. McCabe 2005). Note that the CEC study estimates about four times as much solar potential in California as the NREL study; we used the NREL estimates to be more conservative.

Table 11 shows that Modoc and Siskiyou have by far the greatest solar resource potential in the NCRP region, with Mendocino and Sonoma trailing as distant 3rd and 4th place rankings, followed by Humboldt and Trinity. Del Norte ranks very low in solar resource potential. Figure 36 shows the average intensity of solar energy that strikes the NCRP region. Modoc and Siskiyou exhibit the greatest potential because they have a large amount of suitable land area and are situated inland where the solar resource is more intense. Mendocino and Sonoma are next, and their location further south in the NCRP region works to their advantage.

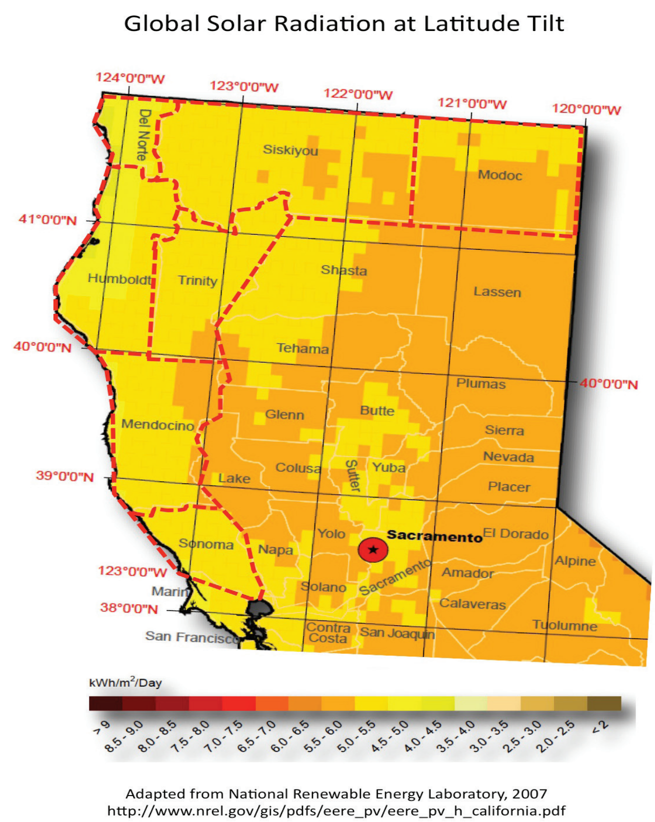


Figure 36: Annual average global solar radiation at latitude tilt in kWh/m²/day (adapted from http://www.nrel.gov/gis/pdfs/eere_pv/eere_pv_h_california.pdf).

Solar Power Resource Information

- California Solar Resources (Simons, G. and J. McCabe 2005), http://www.energy.ca.gov/2005publications/CEC-500-2005-072/CEC-500-2005-072-D.PDF

- A Guide to Community Shared Solar: Utility, Private, and Nonprofit Project Development (Coughlin, J. et al. 2012), http://www.nrel.gov/docs/fy12osti/54570.pdf

Information Needed for Feasibility Assessment and/or Project Development

- Solar resource data (peak sun hours, kWh/m2), weather data
- Shading analysis
- Available land area and orientation
- Desired electrical generation capacity, facility electrical load
- Application details: is system designed to meet on-site loads (via net metering arrangement), is there an desire to sell power back to the grid
- Utility service territory and available programs (net metering, feed-in tariff, PPA opportunities, etc.)
- Electric transmission and distribution grid characteristics in vicinity of proposed power plant location (see PV RAM Map in PG&E territory)

3.1.7 Wave

Wave Energy Converters (WECs) utilize ocean waves to produce power. While the technology is not mature and has yet to see any major installations, wave energy has the potential to provide around-the-clock power to coastal communities. The wave resource in northern California shows great potential. That has led to multiple wave energy projects being proposed for the coastal counties in the NCRP region. Unfortunately, these projects have all been dropped due to the immaturity of the technology, unfavorable project costs, and extensive infrastructure needs.

WECs come in a variety of different designs to harness wave movement in unique ways. Though several companies have produced and successfully installed full size WECs, the technology is still largely in the research phase. In addition to the challenges of producing and installing devices capable of withstanding ocean deployment, there are valid concerns over the cost-effectiveness and environmental impact of wave energy.

Numerical wave energy models are useful for wave resource planning purposes. The National Ocean and Atmospheric Administration (NOAA) developed the open-source WaveWatch III model, and they maintain model results at http://polar.ncep.noaa.gov/waves/ensemble/download.shtml. The Delft University of Technology has also developed the Simulating WAves Nearshore (SWAN) model, which can build upon WaveWatch III data to produce higher-resolution results. However, before a wave project can proceed, actual buoy measurements of wave direction and power are needed. NOAA manages data for 6 buoys off NCRP coastlines: one off Sonoma County, one off Mendocino County, three off Humboldt County, and one off Del Norte county. Information about these buoys can be found at http://www.ndbc.noaa.gov/.

A viable wave energy project location must also consider local infrastructure capacity - a deep-water port is absolutely necessary. WECs are large and heavy, and if they are not produced near the port, then connecting highways or shipping lanes must be appropriate for large cargo. Ongoing maintenance will require regular access to charter boats. Electric transmission and distribution will need to be extended to the WECs as well. Economics is a heavy factor in all of these considerations: the farther a WEC is from these resources, the more expensive the installation and maintenance will be. The required infrastructure in Humboldt County has been evaluated as part of both the WaveConnect™ and CalWave research projects. These projects are briefly mentioned below in the Example Projects/Case Studies section.

Wave energy projects also require a detailed accounting of local ocean uses. All areas within a quarter nautical mile of navigational routes and within one kilometer of undersea cables must be avoided; NOAA provides planning-suitable nautical maps at http://www.charts.noaa.gov/. Avoiding other economic interests (such as fishing) requires engagement with local stakeholders. Finally, sensitive habitat areas must be avoided. Some sensitive areas – such as marine reserves – are marked on nautical maps. Local experts should be included in the decision making process to ensure less-protected, but still sensitive areas are not harmed.

The Northwest National Marine Renewable Energy Center (NNMREC) was established in 2008 by the U.S. Department of Energy to facilitate the development of marine renewable energy technologies via research, education, and outreach. University partners include Oregon State University, the University of Washington, and the University of Alaska Fairbanks. NNMREC is the premier wave energy research center in the continental U.S.

Wave Resource Potential in the NCRP Region

The substantial wave energy resource in the NCRP region is illustrated in Figure 37. Wave energy in the region is not likely to be limited by resource availability, but instead by cost, supporting infrastructure, competing stakeholder needs, regulatory complexity, and public acceptance. While costs are likely to decrease as research leads to further technology developments and as the licensing and approval process becomes more streamlined, cost-competitiveness compared to other renewable energy resources is uncertain.

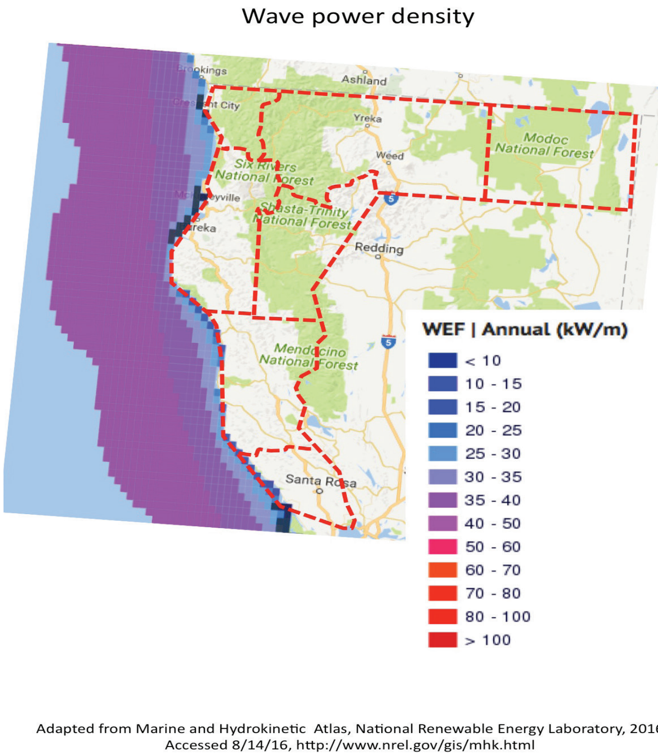


Figure 37: Wave resource power density for the NCRP region (adapted from https://maps.nrel.gov/mhk-atlas/, accessed 8/14/16)

Access to a deep-water port is necessary, and this makes Humboldt Bay the most feasible location for wave energy demonstration and deployment in the NCRP region. Increasing the capacity of the electrical transmission system, increasing access to heavy manufacturing centers, and establishing charter boat service would all likely improve wave energy viability. As sites in Oregon and Southern California develop wave energy projects, proximity to vital wave energy support will likely increase for NCRP counties.

Wave Energy Resource Information

- NOAA Data Buoy Center: http://www.ndbc.noaa.gov/
- NOAA WaveWatch III Data Archive: http://polar.ncep.noaa.gov/waves/ensemble/download.shtml
- NOAA Nautical Maps: http://www.charts.noaa.gov/.
- Humboldt WaveConnect™ Resources: https://www.pge.com/en_US/about-pge/environment/what-we-are-doing/clean-energy-solutions/projects.page
- Northwest National Marine Renewable Energy Center, http://nnmrec.oregonstate.edu/
- Bureau of Ocean Energy Management, Renewable Energy, https://www.boem.gov/Renewable-Energy/
- European Marine Energy Center, http://www.emec.org.uk/marine-energy/wave-devices/

Information Needed for Feasibility Assessment and/or Project Development

- Wave resource
- Availability of supporting infrastructure (nearby deep water port)
- Electric transmission and distribution grid characteristics in vicinity of proposed power plant location
- Potential impacts to other competing uses of ocean area (fishing, shipping lanes)
- Important and/or protected biological areas, fishing grounds
- Potential environmental impacts

Example Projects/Case Studies

Several wave energy projects have been previously proposed in the NCRP region. In 2007, PG&E began feasibility studies for the WaveConnect™ project, which would have established a pilot wave energy facility off the coast of Eureka. While much was learned about establishing a wave energy facility, permitting expense and complexity ultimately ended the project in 2011. In 2012, the Federal Energy Regulatory Commission denied an application to develop wave energy off the coast of Fort Bragg, citing applicant errors in the permitting process (Hartzell 2012). Eureka was again considered for a wave energy facility by the U.S. Department of Energy funded CalWave project in 2014. The project effort led to a thorough accounting of local resources, but concluded that supporting infrastructure was more favorable near another potential project location in southern California.

Development has been more successful in nearby regions, with the Northwest National Marine Renewable Energy Center establishing a test facility off the coast of Newport, Oregon. More information can be found about this facility at http://nnmrec.oregonstate.edu/.

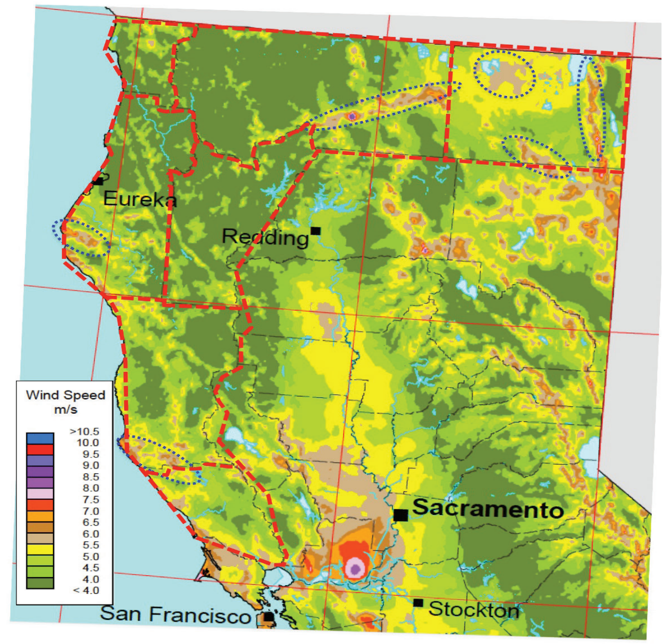
3.1.8 Wind

Wind power is a very mature technology that has been used effectively at a large commercial scale in the U.S. for more than a decade. In that time the industry has grown tremendously. Between 2004 and 2014 the installed wind capacity in the U.S. increased nearly 10 fold, and in 2015 wind power accounted for over 40% of electric power capacity increases in the U.S. Internationally, wind power growth has been even more substantial. Wind power prices are now competitive with conventional sources.

Wind power projects can be constructed at different scales, ranging from small individual turbines designed to power a single house, to large utility-scale wind farms that can power hundreds of thousands of homes. Onshore utility-scale wind farms are typically no smaller that about 50 MW in capacity (typically about 25-30 turbines).

While there are some very good wind sites onshore, the best wind resource is found offshore. The development of offshore wind power is a bit more recent, and while it is well established in Europe, the U.S. just recently completed installation of its first offshore wind farm in Rhode Island. Offshore wind projects can be divided into two categories — deep water versus shallow water. On the East Coast of the U.S. the ocean floor drops off rather gradually (e.g., at 100 miles off of MA and NY the depth is generally less than 100 meters), but on the West Coast the gradient is much steeper (at 50 miles offshore depths greater than 3000 meters are reached). Deep water applications, like those on required on the West Coast, are more challenging, more expensive, and not as technically mature.

Annual average wind speed at 80 m



Adapted from National Renewable Energy Laboratory, 2010
Accessed August 2016
http://apps2.eere.energy.gov/wind/windexchange/pdfs/wind_maps/ca_80m.pdf

Figure 38: Average annual wind speeds at 80 meters for the on-shore NCRP region (adapted from http://apps2.eere.energy.gov/wind/windexchange/pdfs/wind_maps/ca_80m.pdf). Note that key potential wind resource areas are outlined with blue dotted lines.

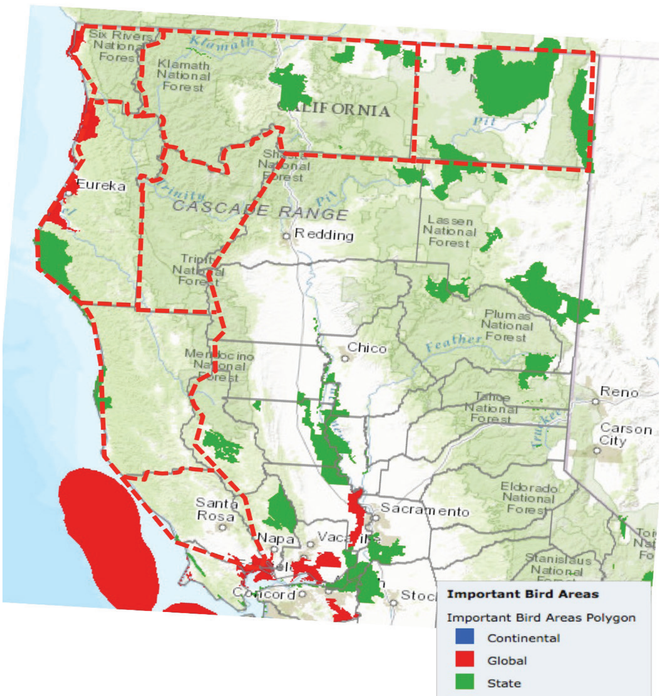
Wind Resource Potential in the NCRP Region

On-Shore Wind Power

The wind resource maps for California show the NCRP region to have a few potentially favorable onshore wind power areas. Shown in Figure 38, these areas are circled with dashed lines and include: 1) an area on the border of Sonoma and Mendocino Counties near the coast, 2) the Cape Mendocino coastal ridgelines in Humboldt County, 3) an area running roughly from east to west in southeastern Siskiyou County that runs adjacent to Mount Shasta, and 4) a few potential locations in Modoc County. However, these maps provide only a very rough guideline. Before any sort of project could get underway at least one year, and preferably multiple years of wind speed data would need to be collected for the proposed site.

In addition, there are many other factors that need to be considered to determine if a particular location would make for a good wind energy site. It is important to find out if there are any important bird or bat areas in the vicinity, as these could present conflicts. Figure 39 does show some important bird areas in close proximity to some of the high wind speed areas that are identified in Figure 38. Other important characteristics for viable wind power sites include access to the electrical transmission grid, adequate road access, and proximity to population centers.

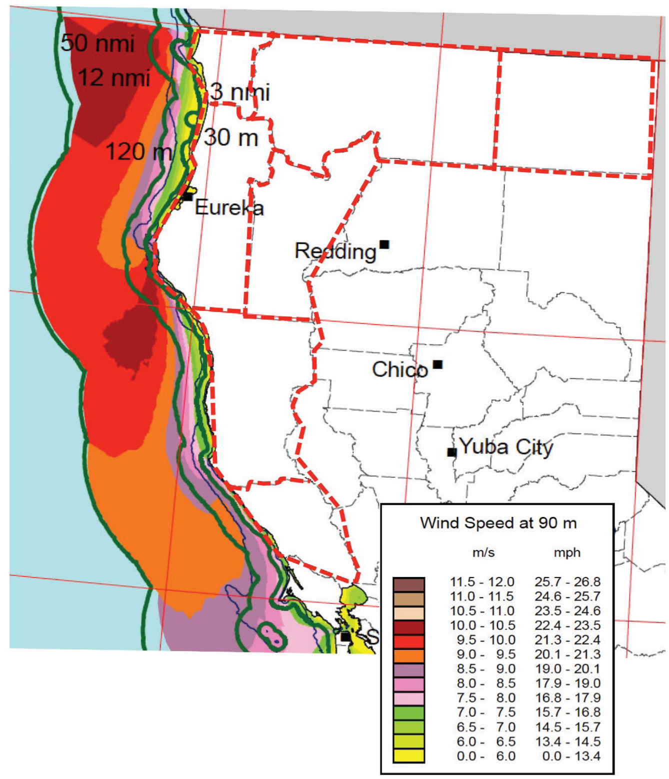
Audubon Important Bird Areas



Adapted from National Audubon Society, 2016
Accessed 8/14/16
http://ca.audubon.org/conservation/california-iba-interactive-site-map

Figure 39: Audubon Important Bird Areas in the NCRP region (adapted from http://ca.audubon.org/conservation/california-iba-interactive-site-map, accessed 8/14/16).

90 m offshore wind speed



Adapted from National Renewable Energy Laboratory, 2010
Accessed August 2016
tp://apps2.eere.energy.gov/wind/windexchange/windmaps/offshore_states.asp?stateab=ca

Figure 40: Average annual wind speeds at 90 meters for the off-shore NCRP region (adapted from http://apps2.eere.energy.gov/wind/windexchange/pdfs/wind_maps/ca_90m_offshore.pdf).

Offshore Wind Power

Offshore wind potential is shown for the NCRP region in Figure 40. The offshore wind resource is generally strong off both Humboldt and Mendocino Counties, with Cape Mendocino exhibiting the strongest resource in the region. Because of the deep ocean depths off the west coast of California (expect ≥ 3000 meters of depth), deep-water turbines would be required. Deep-water turbines are not yet a mature technology, but they are a technology area where there is a lot of interest and a lot of research and development work is being done. The NCRP coastline could be an excellent location to test and demonstrate deep water offshore wind turbines. Similar to the needs for wave energy deployment, offshore wind requires a substantial amount of supporting infrastructure, both at the time of project installation and for ongoing maintenance throughout the life of the project. Offshore wind sites close to Humboldt Bay offer prime opportunities in this regard because of the deep-water port capabilities in the bay.

Wind Resource Information

- California Wind Resources (Yen-Nakafuji, D. 2005), http://www.energy.ca.gov/2005publications/CEC-500-2005-071/CEC-500-2005-071-D.PDF
- California offshore wind energy potential, Dvorak, M. et al., Renewable Energy, Vol. 35, Issue 6, June 2010, pp. 1244-1254.
- Key CA bird area information: http://ca.audubon.org/conservation/california-iba-interactive-site-map
- American Wind Energy Association, http://www.awea.org/
- Distributed Wind Energy Association, http://distributedwind.org/
- Bureau of Ocean Energy Management, Renewable Energy, https://www.boem.gov/Renewable-Energy/

Information Needed for Feasibility Assessment and/or Project Development

- Wind resource data
- Available land area
- Access to project site (roads, right of ways), can equipment be easily transported to the site?
- Information about important bird and/or bat areas, potential impacts to birds/bats
- Potential impacts (real or perceived) to surrounding area, likelihood that surrounding community would be supportive
- Electric transmission and distribution grid characteristics in vicinity of proposed power plant location
- See: http://www.windustry.org/community_wind_toolbox-4-wind-resource-assessment

Example Projects/Case Studies

- Hatchet Ridge Wind Farm, Burney, CA (100 MW, 44 turbines, online 2010)
  http://www.co.shasta.ca.us/docs/Resource_Management/hatchet-ridge/2-ExecSum.pdf?sfvrsn=0
  http://www.co.shasta.ca.us/docs/Resource_Management/hatchet-ridge/Ch_2_ProjDescr.pdf?sfvrsn=0
  https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=23992
  http://wintuaudubon.org/Documents/HatchetRidgeYear2FinalReport3-13.pdf
- Walmart, Red Bluff, CA (1.5 MW, 1 turbine, online 2012)
- There are a number of wind farms, as well as individual turbines installed in the Sacramento Delta area between Sacramento and the SF Bay Area
- Proposed ShellWind project in Humboldt County https://archive.epa.gov/region9/nepa/web/pdf/bearriverridgewindpwrprojnoi.pdf, http://www.schatzlab.org/projects/policyanalysis/wind/

3.1.9 Renewable Resource Opportunities by County

Based on a review of the renewable energy potential in each county and some other key criteria (e.g., Humboldt County's deep water port makes it best suited for wave or offshore wind energy development), a renewable energy opportunity matrix was developed and is shown in Table 13. This matrix is intended to provide general guidance regarding where the best renewable energy development opportunities are likely to be found in the NCRP region.

Table 13: Renewable energy opportunity matrix by county and resource for the North Coast Resource Partnership region.

	Del$Norte	Humboldt	Mendocino	Modoc	Siskiyou	Sonoma	Trinity
Biomass	Low	High	High	Medium	High	Medium	High

3.1.10 Alternative Transportation Fuels

As discussed in Section 2.4, the transportation sector accounts for a large portion of the energy related GHG emissions in the NCRP region. As such, efforts to reduce the consumption of transportation fuels via both fuel efficiency improvements and reductions in vehicle miles traveled are critical, as are efforts to "green" the transportation sector by switching to low- or no-carbon fuels. The State of California has set ambitious goals for reducing greenhouse gas emissions through the adoption of a low-carbon fuel standard and the promotion of domestically produced renewable transportation fuels. On the local level, most of the counties in the NCRP region have undertaken planning efforts to prepare for the adoption of alternative fuel vehicles. "Green" transportation planning efforts in the region include the numerous planning studies listed below, as well as goals to reduce criteria pollutant emissions, "green" public agency fleets, and encourage multi-modal transport options, such as pedestrian and bicycle travel modes.

On the community level, the NCRP Region is home to many committed stakeholders integral to the build-out of alternative fuel infrastructure. Key players have collaborated to develop the following Regional Readiness Plans to address alternative fuel infrastructure in the NCRP region:

- **Upstate and North Coast Electric Vehicle (EV) Readiness Plans**

  Two separate yet collaborative projects focused on identifying electric vehicle infrastructure needs, preferred site locations, and site host engagement.

  (http://www.redwoodenergy.org/images/Files/EV/FINAL%20North-Coast-EV-Readiness-Plan.pdf) (http://www.tehcoapcd.net/PDF/Upstate%20PEV%20Readiness%20Project%20Final%20Report.pdf)

- **Mendocino County Zero Emissions Vehicle (ZEV) Regional Readiness Plan**

A readiness plan providing regional transportation planning. Builds on previous work and promotes ongoing transitions to new vehicle technologies and infrastructure. (http://www.mendocinocog.org/pdf/ZEV/Mendocino%20County%20ZEV%20Regional%20Readiness%20Plan-accepted%208-19-2013-no%20appendix.pdf)

- **Northwest Alternative Fuels Readiness Plan**

  A readiness planning effort focused on identifying the most efficient mix of alternative fuels for the region that can help meet California's Low Carbon Fuel Standard. (https://static1.squarespace.com/static/53764d9fe4b0cb63d6f97b20/t/5723df1522482e5c00259896/1461968663297/ARV-13-012_Task-2.6_Draft-Readiness-Plan-Deliverable.pdf)

- **North Coast & Upstate Fuel Cell Vehicle Readiness Plan**

  This project is focused on identifying anchor sites for hydrogen infrastructure, site level assessment, and stakeholder outreach.

- **Bay Area and Monterey Bay Area Plug-In Electric Vehicle Readiness Plan**

  This plan includes Sonoma County (within the NCRP region) and focuses on actions for local and regional governments in the San Francisco Bay Area and the Monterey Bay Area to help the region move towards PEV readiness. (http://www.baaqmd.gov/~/media/Files/Strategic%20Incentives/EV%20Ready/Summary%20PEV%20Readiness%20Plan%20FINAL.ashx)

Commercially available alternative transportation fuels include biodiesel, electricity, ethanol, hydrogen, natural gas, renewable natural gas, propane, and renewable diesel. Renewable diesel is a "second generation" diesel fuel made entirely from plant and waste oils like biodiesel, but without the gelling or engine performance issues of first-generation biofuels. The alternative fueling infrastructure in the NCRP region, as of December 2016, includes: electric vehicle charging stations (147), propane fueling stations (17), biodiesel fuel pumps (4), and hydrogen fueling stations (1) (DOE 2016). Figure 41 shows the distribution of alternative fueling infrastructure in the NCRP and surrounding north state region.

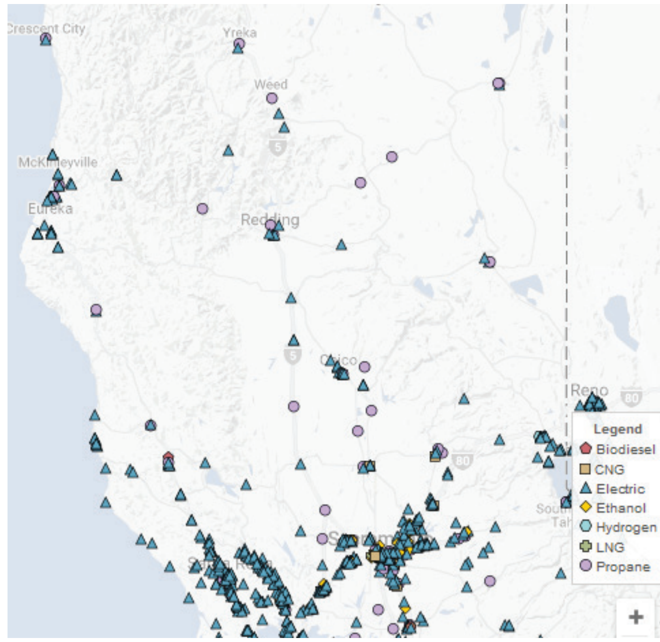


Figure 41: Alternative fuel station located in the NCRP region.

Note that the deployment of zero-emission electric and hydrogen fuel cell vehicles play a key role in California's strategy to reach its GHG reduction goals. The Northwest California Alternative Fuels Readiness Project (Carman, J. and L. Biondini, 2016) examined the near-term opportunities in the NCRP region to help meet California's Low Carbon Fuel Standard goals. By developing a GHG marginal abatement cost curve this study found that battery electric vehicles are the most cost-effective alternative in the near-term, with second generation biofuels (sorghum ethanol, sugarcane ethanol, canola biodiesel) playing a lesser but still important role. The study found hydrogen to be too expensive at present to play a significant role in achieving near-term (year 2020) targets, but noted that with sufficient cost reductions hydrogen has the potential to play a key future role due to its relatively low carbon intensity, breadth of applications, vehicle range, and refueling speed.

There are already a significant number of commercially available alternative fuel vehicles available for purchase in the NCRP region. These include: battery electric, plug-in hybrid electric, biodiesel, natural gas, and propane vehicles. The number of available models of alternative fuel vehicles on the market is expected to continue to rise. Currently the strongest growth in the alternative fuel vehicle market is for flex-fuel (E85), diesel (biofuels), and electric/hybrid electric vehicles.

In California, zero emission vehicles (ZEVs) include hydrogen fuel cell, battery electric and plug-in hybrid electric vehicles. Across California, purchases of ZEVs remain less than 2% of all new vehicle purchases (CA New Car Dealers Association 2016). However, the NCRP region has seen steady growth in ZEV sales as demonstrated by the increasing number of ZEV rebates distributed. The Clean Vehicle Rebate Project (CVRP) offers rebates to buyers purchasing new, eligible zero-emissions vehicles. Since the program's inception in 2010 through August 2016 there have been 3,046 ZEV rebates awarded in the NCRP region totaling $6,470,417 in ZEV purchase assistance. Figure 42 shows the number of ZEV rebates awarded over time in the NCRP region.

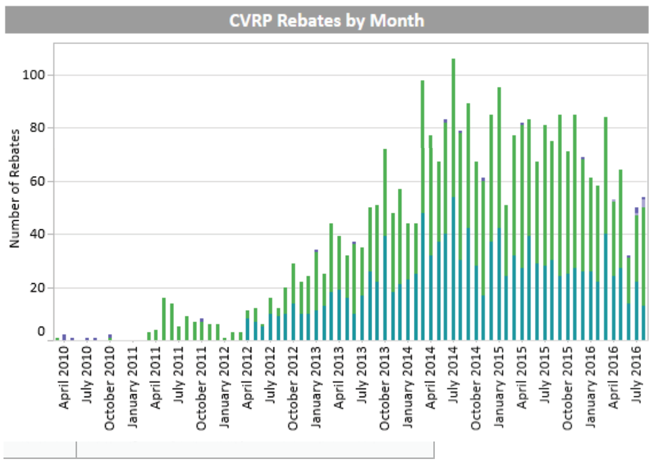


Figure 42: CVRP rebates issued in the NCRP region from April 2010 to July 2016 (Center for Sustainable Energy 2016)

Projected Demand

In March 2012 Governor Brown established a target of 1.5 million ZEVs on California roadways by 2025. For the NCRP region to achieve their portion of this ambitious target will require an estimated 27,187 ZEVs on the road in the NCRP Region by 2025, equivalent to a ZEV adoption of approximately 9% of all light duty vehicles in the region. In 2015, ZEVs made up less than 2% of all light duty vehicles in the region (CARB CHIT 2016).

Many different factors play into the actual ZEV adoption rate in the region. To best predict this adoption rate, models have been developed that incorporate demographic criteria such as income level, education attainment, and previous hybrid electric vehicle (HEV) adoption. One such model, called the California Hydrogen Infrastructure Tool (CHIT), identifies areas that will likely need hydrogen fueling stations.

The California Air Resources Board (CARB) developed the tool and plans to use its output to site and fund hydrogen fueling stations. Within the NCRP region, CHIT projects that the cities of Eureka, Santa Rosa, Petaluma, and Sonoma will experience demand for hydrogen infrastructure (CARB EMFAC 2014).

Figure 43 shows results from the CHIT model for the NCRP region. Note that one retail hydrogen station, to be owned and operated by StratosFuel, is already under development in Rohnert Park, CA.

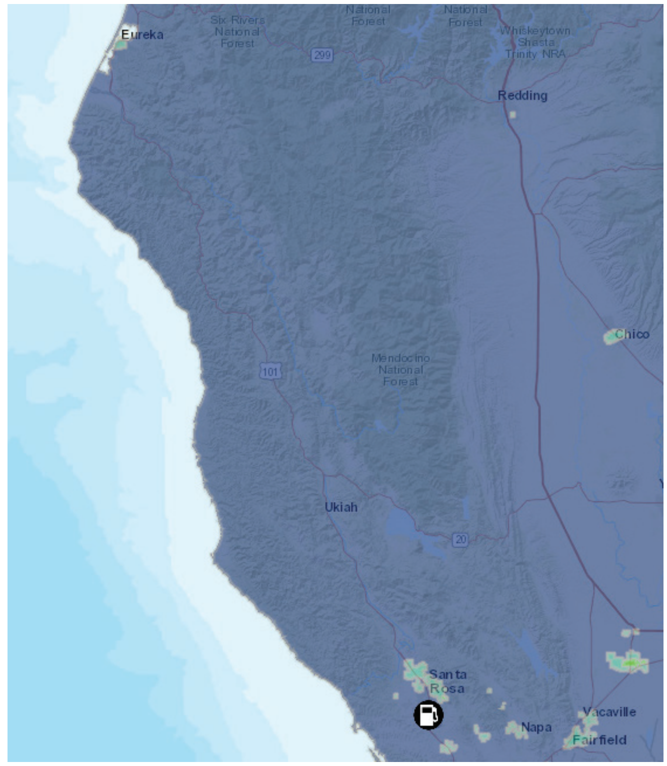


Figure 43: Projected need for hydrogen infrastructure in the NCRP region. Light colored areas indicate an expected need for hydrogen fueling infrastructure.

CARB also projects statewide ZEV adoption based on compliance with existing ZEV regulations. The following list summarizes relevant federal and state regulations related to alternative fuel adoption:

- The Energy Policy Act (EPAct) of 1992 (Public Law 102-486) was passed by Congress to address the country's increasing dependence on petroleum. The act mandated that an increasing percentage of new vehicles purchased by government fleets be alternative fuel vehicles and developed a renewable fuel standard.
- The EPAct requires 75% of new light-duty vehicle acquisitions by covered federal fleets be alternative fuel vehicles. Executive Order 13693 requires federal agencies with 20 vehicles or more to ensure that by 2025 50% of their light-duty vehicle acquisitions are zero-emission vehicles or plug-in hybrid electric vehicles. Certain state governments are subject to similar EPAct requirements. In California, the purchase or lease of alternative fuel vehicles is encouraged for state offices, agencies,

and departments. Any vehicle that the state owns or leases that can run on alternative fuel must operate on that fuel if it's available. The state has also set goals to reduce or displace fleet petroleum use. Additionally, the agencies responsible must work with other agencies to incentivize state employee use of alternative fuels. This may be by providing electric vehicle charging, reduced-cost parking, or other programs. The State Agency Low Carbon Fuel Use Requirement will be in effect starting January of 2017 at which time at least 3% of bulk transportation fuel purchased by the state must be very low carbon fuels, defined as having no greater than 40% of the carbon intensity of the closest comparable petroleum fuel.

- Executive Order 13693 guides planning for federal sustainability in the next decade, and specifically addresses fleet and vehicle efficiency. By the end of 2020, PEVs and ZEVs shall make up 20 percent of all new agency passenger vehicle acquisitions, and 50 percent by 2026. Agencies will also plan for appropriate charging or refueling infrastructure to accommodate the fleet composition.
- Congress enacted Corporate Average Fuel Economy (CAFE) standards in 1975 with the purpose of reducing energy consumption by increasing vehicle fuel economy. The National Highway Traffic Safety Administration (NHTSA) sets standards for five year periods. Final standards have been set for light-duty vehicles, model years 2017 to 2021, and non-final standards have been set for years 2022 to 2025. Standards for medium and heavy-duty vehicles, model years 2018 to 2027, have been proposed.
- California Assembly Bill 32, the California Global Warming Solutions Act of 2006, requires reduction of greenhouse gas emissions to 1990 levels by the year 2020, and 80% below 1990 levels by 2050. AB 32 requires a Scoping Plan, to be updated every five years, that lays out strategies to reduce GHG emissions based on the latest science and technologies. The California Air Resources Board (CARB) was charged with developing the Scoping Plan and subsequent updates. They have implemented several initiatives over the years to reduce GHG emissions across multiple sectors, including the Low Carbon Fuel Standard Program, Zero Emission Vehicle (ZEV) Program, and an Emissions Trading Program (Cap-and-Trade).
- California Senate Bill 375, the Sustainable Communities and Climate Protection Act of 2008, requires metropolitan planning organizations (MPOs) to prepare a sustainable communities strategy as part of regional transportation planning that would include measures to meet regional GHG reduction targets. Regional targets are set by the Air Resources Board and periodically updated as needed.
- California Senate Bill 350 mainly commits the state to more renewable energy and increased energy efficiency. However, it also addresses alternative transportation by tasking electric utilities with investing in electric vehicle charging infrastructure.

Based on compliance with existing regulations, CARB anticipates annual ZEV sales of 200,000 in the next 5-10 years. Once annual sales of ZEVs reach about 16 percent of the light-duty vehicle market, in 2025, CARB believes that the market will be sustainable (CEC ZEV 2015). Figure 44 shows CARB's projections for ZEV sales in California based on compliance with state regulations.

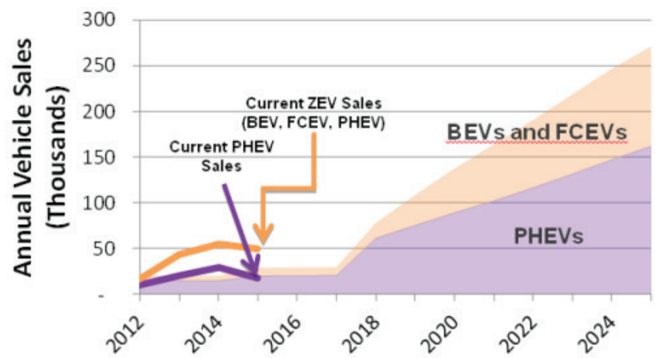


Figure 44: CARB's projections of ZEV annual sales for California based on compliance with ZEV regulation.

Useful informational resource about alternative fuels and alternative fuel vehicles include:

U.S. Department of Energy

Alternative Fuels Data Center (http://www.afdc.energy.gov/)

Clean Cities Vehicle Buyer's Guide (http://www.afdc.energy.gov/uploads/publication/vehicle_buyers_guide.pdf)

State of California

Clean Vehicle Rebate Project (https://cleanvehiclerebate.org/eng)

Drive Clean Buying Guide (https://www.driveclean.ca.gov/)

3.1.11 Fuel Switching in the Heating Sector

It is anticipated that fuel switching in the heating sector will be crucial to achieving GHG reduction goals in the energy sector. As previously noted, the electricity grid in the NCRP region is already supplied with a large quantity of renewable electricity, and there are numerous opportunities for further renewable energy development. With a low-carbon electric grid such as exists in the NCRP region there are big gains to be achieved when switching from fossil fuel based space and water heating systems to electric heat pumps.

Electric heat pumps provide a unique opportunity to replace costly and polluting heating fuels with an efficient electrical appliance. All heat pumps work on the same principle: they circulate a working fluid that absorbs heat from one location and deposits it in another. Air conditioners and refrigerators are essentially heat pumps. However, whereas air conditioners and refrigerators provide only cooling, heat pumps can provide both heating and cooling. Heat pumps *move* heat instead of generating heat. This allows them to provide more heating or cooling energy than the electrical energy they consume. This has led to two metrics for heat pump efficiency: the Seasonal Energy Efficiency Ratio (SEER), which is the ratio of heat energy removed to the electrical energy consumed by the heat pump, and the Heating Seasonal Performance Factor (HSPF), or the ratio of heat energy added to the electrical energy consumed by the heat pump.

Heat pumps are typically classified by their heat source/sink as either air-source or ground source units. Air-source heat pumps (ASHP) use exterior air as their heat source or sink, whereas ground-source heat pumps (GSHP) use the earth as their heat source or sink. GSHPs require a ground bore to a depth where the temperature remains relatively constant, usually tens to hundreds of feet deep. Because of this GSHPs are substantially more expensive to install and are not suitable in all locations, but they are more efficient and perform better in very cold temperatures.

Climate can impact heat pump performance: it is more difficult to remove heat from an extremely cold environment or add heat to an extremely warm environment. While many coastal communities within the NCRP region enjoy fairly moderate temperatures, inland communities face more extreme temperatures. Fortunately, modern heat pumps have been designed to perform in the more extreme conditions generally seen within the NCRP region. A report from the Northeast Energy Efficiency Partnerships (2014) notes that older, conventional ASHP's did not have the capacity or efficiency to sufficiently perform during very cold weather, resulting in heavy reliance on inefficient backup resistance heating systems at freezing temperatures. However, today's high efficiency, high performing ASHP systems can perform at a high level of efficiency even at very low ambient temperatures. Many new ASHP products use variable-speed compressors, which can significantly improve overall system efficiency and performance, and can allow these systems to perform well at low outdoor temperatures (near or below 0°F). In addition, a 2012 report by the CEC examined the viability of GSHPs throughout different California climate zones and found that significant energy savings are available throughout the NCRP region, although antifreeze systems would be required in some climate zones to prevent freezing[2] (Glassley et al 2012).

Heat pump performance and GHG emissions reductions

Some studies have examined actual heat pump performance compared to manufacturer's specifications. A recent heat pump study in Humboldt County (Zoellick, J. et. al. 2016) found that two ductless mini-split heat pump systems outperformed manufactures' specifications, though this was likely due to the mild climate they operated in compared to the conditions under which they are rated. This study went on to compare GHG emissions from air source heat pumps to GHG emissions from existing legacy natural gas furnaces or new high efficiency natural gas furnaces. This study showed that electric heat pumps installed in coastal Humboldt County and PG&E's electricity generation mix are expected to result in an 80% drop in GHG emissions when compared to legacy natural gas furnaces and a 67% drop when compared to new high efficiency natural gas furnaces. Similar results would be expected when compared to propane-fired furnaces.

However, heat pump performance can be significantly impacted by system sizing and installation practices. A study in the Pacific Northwest (Davis, B. et al. 2006) found that system controls, duct system performance, system airflow and refrigerant charge, and estimation of building shell heating load and its relationship to heat pump capacity all can play a significant role in system performance. This study recommends these aspects be considered in any heat pump promotional program to ensure performance meets expectations. A recent field performance study of heat pump water heaters in the Northeast found this technology to be a promising technology that may finally be here to stay, though it went on to say that installers must still address some installation hurdles, including careful consideration of clearance and weight, drain pans and condensate pumps, maintenance, and noise (Shapiro, C. and S. Puttagunta 2016).

Heat pump economics

The cost effectiveness of heat pumps depends on many factors. Key among these is the cost of the heating fuel that is being replaced, and whether or not the application

2 The report gives an important caveat that California's diverse geology precludes a universally definitive analysis.

is a retrofit or new construction project. In general, heat pumps will typically be cost effective when compared to heating technologies using costlier fuels like propane and heating oil. However, heat pumps have a tougher time competing against natural gas. The Humboldt County study mentioned above (Zoellick, J. et. al. 2016) found that the installed cost of a heat pump retrofit was comparable to the installed cost of a high efficiency natural gas furnace if gas service was already available, and that operating costs for the heat pump were higher than for the high efficiency furnace. Heat pumps have also been examined as a climate change mitigation strategy by the City of Palo Alto. In a 2014 staff report (City of Palo Alto 2014) they found that in most cases it is not cost effective for residents to switch from natural gas appliances to electric appliances. However, other studies have found that for new construction applications the added cost of providing natural gas service can make the first cost associated with heat pumps lower than for a natural gas furnace. As mentioned above, ground source heat pumps are substantially more expensive to install, but also are higher performing.

3.1 POTENTIAL BENEFITS AND IMPACTS OF ENERGY OPPORTUNITIES

This section outlines various benefits and impacts associated with the energy strategies outlined in this report, namely increasing energy efficiency, developing renewable energy resources, and reducing the consumption of carbon-intensive fossil fuels via fuel switching. Benefits and impacts can include social, environmental, economic and political related issues.

3.1.1 Social

Energy related issues in the social realm typically refer to social equity and social justice. The National Academy of Public Administration (NAPA) defines social equity as: The fair, just and equitable management of all institutions serving the public directly or by contract, and the fair, just and equitable distribution of public services, and implementation of public policy, and the commitment to promote fairness, justice, and equity in the formation of public policy (NAPA 2000).

Key strategies that can be employed to promote social equity and social justice in energy policy include:

- Ensure that energy programs serve all populations irrespective of income, race, color, ethnicity, or any other discerning demographic characteristic. Ensure access to clean and sustainable energy options to all demographic populations, including low-income populations, renters and those who use public transportation.
- Make sure all communities, irrespective of any discerning demographic characteristics, have equal input into energy decisions, including where energy generation projects are sited and which types of technologies are chosen.
- Promote decentralized, community-based renewable energy generation and demand reduction.
- Create community-based energy programs and ownership structures, such as Community Choice Aggregation, community renewable energy projects, cooperatives, and nonprofit financing and revenue-sharing models where local stakeholders and community members can have a greater opportunity to participate in energy projects and affect energy related decisions.
- Promote equal distribution of social costs and benefits of energy programs and projects.
- Promote clean and environmentally friendly energy projects that do not degrade the communities they are located in.
- Offer energy job skills trainings so that workers within the local communities where energy projects are located can benefit from the jobs created.

3.1.2 Environmental

All energy technologies, even "green" renewable energy technologies, pose some level of impact on the environment. Impacts might include wind energy impacts to bird and bat populations, hydroelectric system impacts to aquatic ecosystems, wave energy impacts to ocean ecology, or biomass energy impacts to air quality and/or forest ecosystems. These impacts must be considered when choosing which energy projects to pursue and which to abandon. Each project must be evaluated on its own merits with ample opportunity for input from local stakeholders. Where feasible, impacts should be avoided or mitigated.

However, it is important to also understand that the "do nothing" alternative also has impacts, and if we continue on our current energy path we are likely to severely overheat our planet. Therefore, local impacts and concerns associated with a new project must be considered in concert with the larger impacts associated with global climate change and a balance must be struck where the majority of the community, and especially those most seriously impacted, can agree on a path forward.

In addition, renewable energy projects can have many associated environmental benefits as well. Foremost among these is that they offer an alternative to conventional fossil fuel energy sources and the serious environmental impacts they can pose.

3.1.3 Economic

The promotion of energy efficiency, local renewable energy development, and fuel switching strategies along with community-based energy programs such as Community Choice Aggregation will lead to more energy dollars circulating in the local economy and more local jobs. Numerous studies have examined the economic impacts of local renewable energy development. One tool available from the National Renewable Energy Laboratory for assessing the jobs and economic development impacts of local renewable energy projects is the Jobs and Economic Development Impact (JEDI) models (http://www.nrel.gov/analysis/jedi/). These models can be customized with local economic data to estimate the impacts of renewable energy projects to local economies. One such study that utilized the JEDI models and estimated local economic impacts was the RePower Humboldt Strategic Planning study. The economic analysis report associated with this study included a JEDI-based economic analysis. This study can be accessed from the California Energy Commissions publications page: http://www.energy.ca.gov/publications/displayOneReport.php?pubNum=CEC-500-2013-020

3.1.4 Political

One of the key political impacts associated with the energy strategies presented in this report is the ability to increase local participation in energy decision making. Distributed generation projects by their very nature engage local stakeholders. Community-based ownership models like Community Choice Aggregation directly engage local stakeholders in energy decision making. This helps educate people about where their energy comes from, and with this greater knowledge hopefully people can make better decisions for their communities and their planet. The promotion of decentralized, local, community-scale energy systems engages and empowers local stakeholders to be responsible and accountable for their energy use. Instead of simply flipping a switch with no thought of where the energy comes from, they instead will be more apt to think about energy sources and their impacts, especially if the energy is generated right next door in their own community.

4 RECOMMENDATIONS

This section makes recommendations for future planning and research efforts and identifies areas where additional information is needed. We recognize that the topics covered in the recommendations section are often intersecting and interdependent; however, we have organized them into several broad topics areas.

4.1 IDENTIFIED INFORMATION GAPS

As this study was performed a number of information gaps were identified. It is recommended that further research be conducted in an attempt to fill most or all of the information gaps listed below.

- There is no data readily available for the quantity of propane or fuel oil consumed in the NCRP region by county. Consumption of these fuels could be tracked based on sales. These heating fuels are especially important in geographic areas not served by a natural gas utility (i.e., the counties of Trinity, Del Norte, Siskiyou, and Modoc). To make a proper assessment of the GHG emissions of the region, this information is necessary. Additionally, it would be useful to have data throughout the region on the number, type and utilization frequency of wood burning stoves, which are numerous in the region. These data are needed to inform program design in the region and characterize the impacts of such programs. The benefits of switching to other sources of heat, for example heat pumps, cannot be measured unless there is a reliable baseline for comparison.
- Data on the number of fleet vehicles, number of organizations with fleet vehicles and the miles traveled by fleet vehicles would be useful to help determine the best opportunities for introducing alternative fuel vehicles into fleets.
- There is a multitude of energy related data that would be useful to have compiled and put into a geographic information system format. This includes: energy infrastructure, energy use, fuel availability, energy generation by source, energy resource potential, sensitive environmental areas, land use characteristics, land ownership, zoning, electric utility service territories, etc.
- Actual gasoline and diesel fuel sales data at the county level.
- Data and info on electric utilities and CCAs in the region, including areas they serve, programs offered, etc.
- Data on electricity distribution and transmission networks, including infrastructure capacities (total and available). An example of this is PG&E's PVRAM map, though it is somewhat cumbersome and difficult to use.
- Complete energy related GHG emission and criteria pollutant emission data associated

with the energy consumed in the NCRP region. Only CO2 emissions estimates are presented in this report, and they are incomplete.

- A survey of boilers in the region to identify potential biomass heating and combined heat and power project opportunities.
- A survey of water conveyance systems in the region and an assessment of those that could offer conduit hydropower opportunities.
- Tracking of distributed generation, energy storage, microgrid, and combined heat and power projects (size, type, ownership, characteristics, output, etc.) in the region.
- Estimation and tracking of jobs and economic stimulus associated with sustainable energy projects and programs in the region.
- Identification and assessment of energy assurance planning needs for the region. Identification of key project opportunities for resilient energy systems for critical services.
- Identification and tracking of key renewable energy and distributed energy generation projects in the region and development of case studies that can encourage replication of successful projects.

4.1 PROGRAMS AND POLICIES

This report is intended to provide background technical information that can support the development of a sustainable energy plan for the NCRP region. It is recommended that this effort be continued, including the following activities:

- Develop a vision statement with broad goals and objectives and a corresponding strategic energy plan for the NCRP region. Allow for flexibility across the region, acknowledging that different jurisdictions may have different goals and objectives.
- Consider creating a regional energy organization, like the Redwood Coast Energy Authority, that could provide energy services to the entire region. Most important is to find a way to meet the needs of those communities that are not currently adequately served. Look for ways to replicate existing programs that have already proved successful in the region.
- Pursue regional funding for energy planning and program and project development.
- Pursue development of demonstration projects that can be replicated.
- Pursue research and development opportunities where special assets in the region distinguish and even favor local project development. For example, the tremendous offshore wave energy potential and the asset of a deep water port in Humboldt Bay make Humboldt County rather well suited to wave energy research and/or demonstration. A similar argument can be made for offshore wind power.

4.1 COMMUNITY ENERGY

As of the writing of this report a large fraction of the population in the NCRP region is, or shortly will be, purchasing electricity from either a community choice aggregation program or a municipal utility. These programs can directly benefit local communities by empowering them to decide where their energy comes from and by allowing them to develop local programs that increase energy efficiency and local renewable energy procurement. Community Choice Aggregation (CCA) should be considered for all jurisdictions that are not currently served by a CCA or a municipal utility.

4.1 TRANSPORTATION

According to the Governor's 2016 ZEV Action Plan, "The consumer confidence needed to adopt light-duty ZEVs relies in large part on adequate charging and fueling infrastructure." (Governor's Interagency Working Group 2016). To address this gap in consumer confidence, it is critical for the NCRP region to accelerate the deployment of alternative fueling infrastructure.

The California Energy Commission performed an analysis of the required number of Charge Points to meet the Governor's ZEV goals, based on region. While the planning regions in Figure 45 do not align with the NCRP region, the projections can be used to inform regional deployment efforts. Estimates for the North Coast, Upstate and Bay area regions can be used to project demand for the NCRP region.

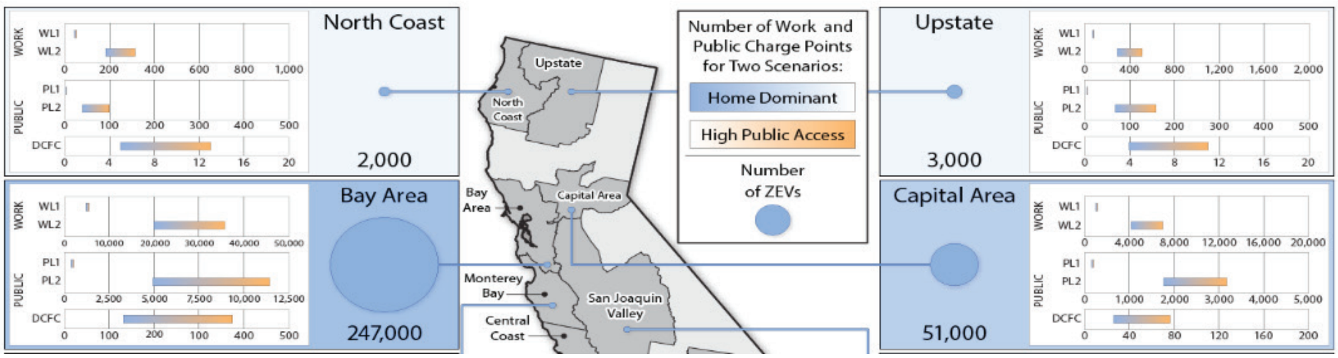


Figure 45: Statewide Charge Point requirements based on projected regional demand (NREL PHEV 2014).

Achieving the region's share of the governor's goal will also require FCEV adoption. Regional stakeholders are currently working to identify critical anchor sites for hydrogen infrastructure through the North Coast & Upstate Fuel Cell Vehicle Readiness Plan. Leveraging state funds to build hydrogen fueling stations at the sites identified in this plan will enable both local FCEV adoption and travel from areas with currently available hydrogen infrastructure, such as the SF Bay Area.

In addition to building alternative fuel infrastructure, continued implementation of supporting activities called for in regional readiness plans is critical to accelerating adoption. For example, the North Coast Electric Vehicle Readiness Plan identifies the follow supporting activities as necessary to facilitate EV adoption:

- Engage with regional permitting entities to encourage the adoption of standardized and streamlined permitting and inspection processes and fee structures.
- Produce a streamlined set of EVCS criteria to assist potential EVCS owners/operators in choosing what equipment to install and to assist contractors with adopting best practices and understanding regional permitting requirements.
- Engage with potential site hosts for EVCS in the North Coast Region and produce preliminary engineering designs and cost estimates for 30-40 sites.
- Install directional signage guiding drivers to at least 10 regional EVCS.
- Promote PEV adoption through public and fleet operator outreach and education campaigns.
- Educate and support regional municipalities on the potential to adopt local building codes that promote PEV adoption.

These activities are currently being implemented in the North Coast through a grant from the California Energy Commission. By continuing to leverage funds to implement regional readiness plans, and developing plans for areas not covered by existing planning efforts, the NCRP region will continue to accelerate the adoption of alternative fuels.

4.1 RENEWABLE ENERGY

There are a tremendous number of renewable energy development opportunities throughout the NCRP region. This section highlights some of the key opportunities that should be considered for further assessment and potential development.

- Distributed generation projects should be pursued.
- Forest biomass is a complicated renewable energy resource with many challenges. That said, it also offers many benefits far beyond the energy related benefits. It can play a critical role supporting the responsible disposal of residues from the logging and forest products industries and it can provide a pathway to help support forest management practices like thinning and fuel reduction efforts. Because of these many faceted benefits associated with biomass energy it is recommended that key opportunities in the biomass sector be pursued. The key counties for biomass energy include Humboldt, Mendocino, Siskiyou and Trinity Counties. Potential biomass energy projects should include both heating and combined heat and power applications, as well as other higher valued products (densified biomass, biochar, torrified material, etc.).
- Where viable, other biomass projects should be considered as well, such as biogas for WWTP digesters, animal farm manure digesters, landfill gas, and woody biomass crop residues.
- Geothermal opportunities exist in the NCRP region, though it appears unlikely that a large-scale power plant like the one that currently exists at the Geysers could be developed somewhere else in the region. Instead, it may be possible to develop a smaller scale electrical generation

or district heating system in Siskiyou or Modoc counties provided the resources were found to be adequate and developable and were located in close enough proximity to a population center where the heat or power could be utilized.

- Hydropower opportunities, while not insubstantial in the region, are likely to face significant challenges with regard to feasibility. Environmental impacts are one of the most difficult barriers to overcome. Conduit hydropower opportunities are another possibility, though there does not appear to be substantial opportunities in the region. Nonetheless, these opportunities should be investigated further and potentially pursued if favorable opportunities are identified.
- Solar power should be pursued throughout the region. It can be deployed anywhere and is now cost competitive with conventional generation sources. While some parts of Siskiyou or Modoc Counties might have adequate solar resources to warrant a large, utility-scale solar power plant, these resources are not near population centers where the power is needed. While power generated could be fed into the electrical transmission system, it seems unlikely that utility-scale solar projects in the region would be competitive with those in other parts of the state. However, distributed scale solar can definitely prove competitive, especially if it is valued at the retail electricity rate via a net metering arrangement. Distributed scale solar opportunities could include larger, community-scale systems that serve groups of customers, or facility level systems that serve one facility (residence, commercial facility, etc.). Distributed solar should definitely be pursued in the NCRP region. Note that both Sonoma Clean Power and the Humboldt County Community Choice Energy Program are pursuing community-scale solar projects, and smaller distributed scale solar projects are common throughout the region.
- Wave power is an immature technology at this point in time. However, the wave energy resource off the northern California coast is substantial, and Humboldt Bay is a well-suited deepwater port that could provide the needed supporting infrastructure for a wave energy project. For these reasons Humboldt County should position itself as a prime location for early wave energy demonstration projects in California.
- Wind energy offers numerous opportunities throughout the NCRP region. There are a few locations where commercial scale wind farms could be sited. Probably the best known is the Cape Mendocino area in Humboldt County. A project on Bear River Ridge was already proposed a couple of years ago and still could come to fruition at some point in the future. There are additional sites with adequate resource in the Cape Mendocino area, but most, other than the Bear River Ridge site, are right in the middle of a an Audubon Important Bird Area. Other potential onshore wind farm sites include locations in Siskiyou and Modoc Counties. It is uncertain if these locations would prove feasible. Perhaps the best wind resource opportunity in the region is offshore. Offshore wind in deep waters (like those off the Pacific Coast of California) is not a yet commercially mature technology. This presents another opportunity for Humboldt County to market the deepwater port in Humboldt Bay and other supporting infrastructure (electrical substations and transmission infrastructure) to support early demonstration projects for deepwater offshore wind energy in the U.S. Finally, smaller community-scale wind projects or facility scale wind projects might prove feasible in the right locations throughout the NCRP region.

4.1 ENERGY EFFICIENCY

The mandates set by the State of California (SB 350) require a 50% increase in the savings generated by energy efficiency measures. Reaching these goals will require deep energy efficiency retrofits that go beyond simple equipment replacement (e.g., replacing inefficient incandescent light bulbs with more efficient LEDs). Deep energy efficiency retrofit programs should look holistically at building energy use and should be based on actual measured energy savings. There are currently many energy efficiency programs that operate in the NCRP region, however programs for areas served by PacificCorp are lacking. We recommend expanding programs into PacificCorp territory.

4.1 MICROGRIDS

We recommend the development of microgrids throughout the region. This type of development increases the resiliency of the grid by allowing sections to remain operational in the event of a larger grid outage. Planning for microgrids should be done as part of a local energy assurance planning effort. Critical facilities should be identified and assessed for microgrid suitability. In addition to providing resiliency, microgrids can also encourage the use of distributed renewable resources, which can delay expensive transmission upgrades and provide other ancillary benefits to the grid. During "blue sky" operation microgrids can offer energy cost savings as well as demand response and energy arbitrage opportunities.

4.1 FUEL SWITCHING IN THE HEATING SECTOR

Under the right circumstances, fuel switching in the heating sector can save money and reduce greenhouse gas emissions. The most economically viable opportunity is to convert propane or fuel oil users over to electric heat pumps. Data should be collected to help determine the potential size of this market and to assess the opportunity in more detail. If the market is of sufficient size and the economic and GHG reduction opportunity is compelling enough, serious consideration should be given to creating a promotional program. However, the key question is who would establish and carry out such a program? While an electric utility provider would typically handle such a program, it may be difficult to get PG&E or PP&L to develop such a program. However, a municipal utility could easily take it on, or if a CCA were serving the entire NCRP region they could offer such a program.

4.1 FUTURE RESEARCH AND PLANNING

The current study has relied upon very gross estimates of renewable energy resource potential in the NCRP region. As a follow-on to this study, we recommend that a more detailed and accurate assessment of the energy resource potential in the NCRP region be conducted. In addition, as part of the follow-on analysis, we recommend that an exercise be conducted to identify the high value and most feasible opportunities. These research efforts should then feed into the development of a regional strategic energy plan.

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