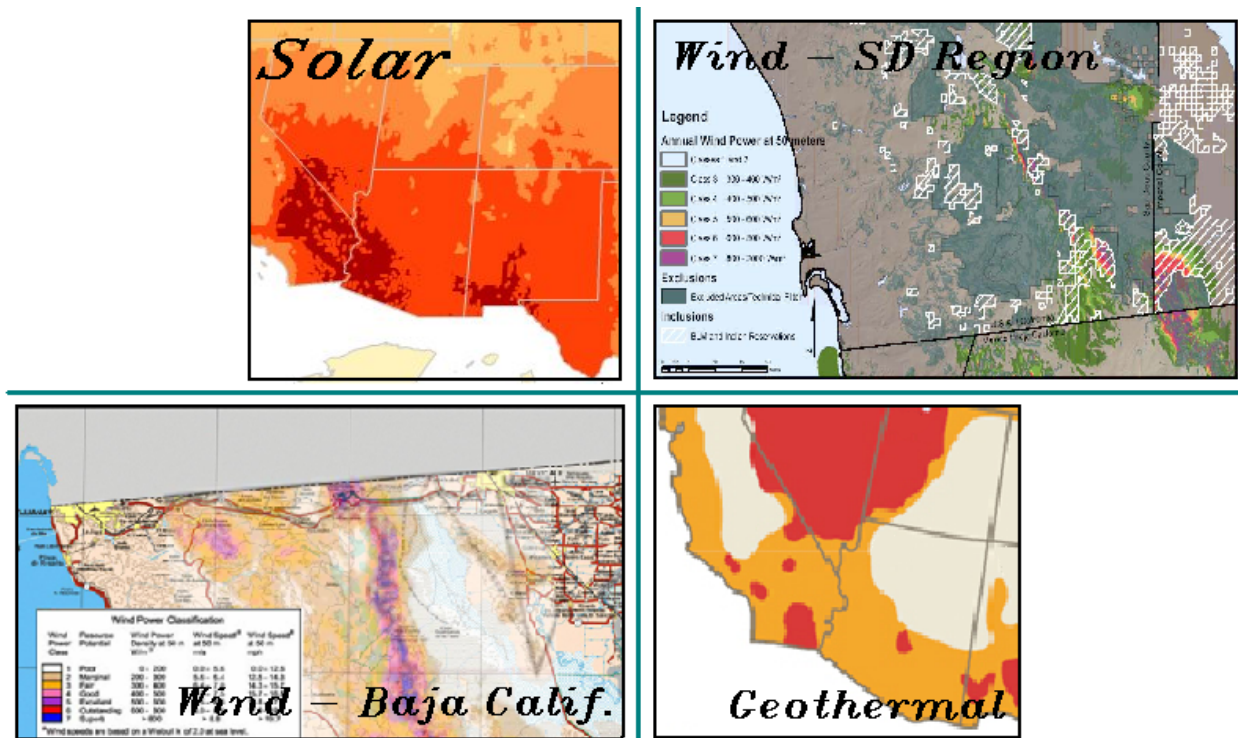


## San Diego Regional Plan for 100% Renewable Energy



September 2010

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## Abstract

This report focuses on the analysis of various groups researching the renewable energy potential within the San Diego Region. While those plans in San Diego's Regional Energy Strategy (RES) focused on bringing San Diego County to 40% renewable energy by 2030<sup>1</sup>, this report looks further. In a clear and concise manner, it attempts to raise the possibility of having our electricity powered by 100% renewable energy.

In working to find a solution toward this inquiry, effort was directed at three smaller questions, which together, could examine the possibility of 100% renewable energy in the San Diego Region:

1. Do we have the capability of meeting our peak capacity daily?
2. Do we have enough base energy to fulfill our total energy demand?
3. Can we do so without heavily relying on positive outcomes of intermittent resources?

After research and review of many technical reports done within the San Diego Region, a vibrant "YES" was reached in response to all three questions. Our prime location and advancements in renewable energy technologies together create our capability to effectively harness abundant sources of (most prominently) geothermal, solar, and wind energy.

**A major part of this report was made possible by the rigorous effort of the San Diego Regional Renewable Energy Study Group in their report titled: *Potential for Renewable Energy in the San Diego Region*, published in August 2005<sup>2</sup>.** Other major groups or reports that helped in putting together this report include the California Energy Commission, SDG&E, and the California Center for Sustainable Energy.

Quotes, ideas, figures, and tables are cited at the bottom of each page for ease of reference.

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1. REPAC, SDREO, and SANDAG. *The San Diego Regional Energy Strategy 2030*. Rep. SDREO, May 2003. *California Center for Sustainable Energy*. Web. 6 Aug. 2010. <<https://energycenter.org/>>.

2. "Potential for Renewable Energy in the San Diego Region." *SD Regional Renewable Energy Study Group*. SDREO, Aug. 2005. Web. 06 Aug. 2010. <<http://www.renewablesg.org/>>.

# 1 Introduction

## 1.1 Our Current Energy Supply

From the 2005 report of the SD Regional Renewable Energy Study Group, the system peak demand in 2004 was 4,065 MW, while the total energy required was 20,578 GWh.<sup>3</sup> Only 10% of our increasing energy demand today is supplied by renewables, while the majority of our electricity comes from natural gas. Figure 1 below shows SDG&E’s projected energy sources for 2009.

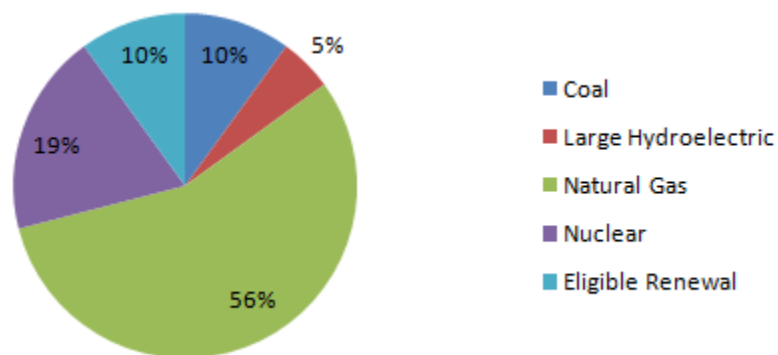


Figure 1: Energy Sources, SDG&E, 2009 (projected)

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Out the renewables that are deployed in the Region, the majority come from geothermal within Imperial County to the east and Northern Baja California to the south, and also a continually increasing capacity from photovoltaics locally. The spread of renewable energy at that time shows as follow in Table 1 below.

Table 1: Renewable Resources Deployed in the Region in 2005

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3. SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region*. Pg. 3 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.

4. SDG&E, 2009, Equinox, 2009

5. SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region*. Pg. 4 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.

SOLAR PV - Commercial and Residential			SOLAR - Concentrating Solar Power (CSP)			WIND		
	Capacity (MW AC)	Energy (GWh)		Capacity (MW AC)	Energy (GWh)		Capacity (MW)	Energy (GWh)
SD County	12.6	27.3	SD County	0	0	SD County & Parts of Imperial County and Northern Baja California, Mexico	0	0
			Imperial County	0	0		0	0

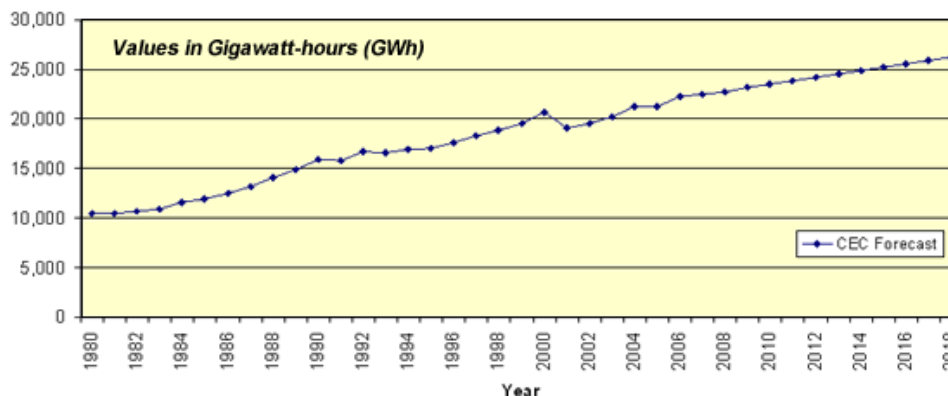
BIOMASS (SD County)			SMALL HYDRO			GEOTHERMAL		
	Capacity (MW)	Energy (GWh)		Capacity (MW)	Energy (GWh)		Capacity (MW)	Energy (GWh)
Landfill Gas	10	128	SD County	0.02	15	Imperial County	537	1,700
Other Biomass	0	0	Imperial County	86.5	11.2	Northern Baja CA, Mexico	120	5,000

5

## 1.2 Expected Energy Growth

While the population continues to increase, several models have predicted certain energy demand and peak load increases for 10, 20, or 40 years into the future. Not only an increasing population, but also trends of greater technology usage, increased usage of electric vehicles, and increasing average temperatures (to name a few) can cause significantly higher energy needs. According to a report of the San Diego Regional Focus 2050 Study Group, **we will use 60% more energy in 2050, with peak electric demand increasing by 70% and warmer weather contributing 7% of the increase**<sup>6</sup>. This corresponds to over a 33,000 GW-h total energy demand and roughly a 7,000 MW peak electricity demand by 2050.

Figure 2 below shows SDG&E's previously recorded and projected annual electric loads until 2018, with data from the California Energy Commission, done by Mr. John Westerman.



7

Figure 2: Annual Electric Loads for San Diego County

6. The San Diego Foundation, comp. *San Diego's Changing Climate: A Regional Wake-Up Call*. Issue brief. San Diego Foundation, 2005. Print.

7. Westerman, John. "CEC Forecast: Annual Electric Loads." *Energy Data Source*. Web. 16 Aug. 2010. <<http://sdenergydata.com/ElectricitySD.html#elecfore>>.

8. Westerman, John. "CEC Forecast: Annual Peak Demand for SDG&E." *Energy Data Source*. Web. 16 Aug. 2010. <<http://sdenergydata.com/ElectricitySD.html#elecfore>>.

Shown below is another graph done by Mr. John Westerman on the Annual Peak Demand for SDG&E.

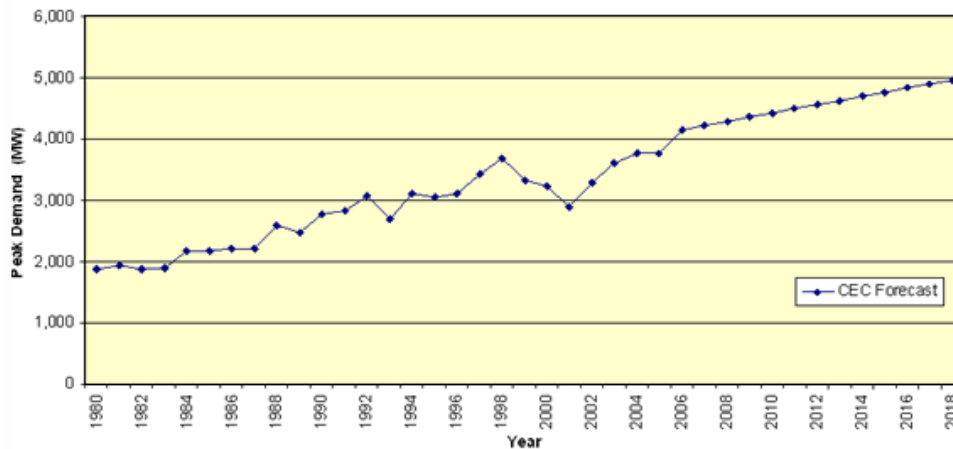


Figure 3: Annual Peak Demand for SDG&E

8

## 2 A Background on Renewable Energy

### 2.1 An Overview

#### Solar Energy:

*Through Photovoltaic Cells (PV):*

The sun projects solar radiation on photovoltaic cells, which triggers moving electrons within semiconductor materials, in turn creating useful electrical energy.

*Through Thermal Energy (Concentrating Solar Thermal or CSP):*

Solar rays projected onto a cylinder or any basic compartment, housing any of a variety of liquids ranging from molten salt to water, increase the temperature of the substance inside. This higher temperature produces steam, which then spins a turbine creating an electrical current.

**Wind Power:** The movement of air molecules possesses a kinetic energy that wind turbines capture. The revolution of these turbines about their axis creates either mechanical energy (most often in remote locations for pumping water) or electrical energy.

**Geothermal:** Heat stored within the earth is extracted by pumping down a liquid to have it then pumped to the surface at a higher temperature. This increased thermal energy either heats household water or produces steam that powers turbines that create an electrical current.

**Biomass:** Any biological material such as wood, biodegradable wastes, plant or animal matter, or certain gases can generate electricity. Depending on the material,

biomass creates energy through either a) incineration, b) creating plant matter into a bio-fuel, or c) harnessing methane produced from decaying wastes within landfills.

**Hydro Power:** The potential energy within water moving downhill translates into useful mechanical energy by causing the direct spin of a turbine, which then creates electrical energy.

## 2.2 A Brief Analysis of CSP Thermal Storage Capacity

### 2.2.1 A Background

A promising new technology that is emerging comes from the basic idea of storing and using solar energy at night. There are several methods capable of storing energy, like battery storage, air compression, pumping water uphill, but the one that has proved most efficient in laboratory tests including ones done by the National Renewable Energy Lab, has been storing thermal energy within molten salt at high temperatures.

NREL senior engineer Greg Glatzmaier explains the high storage efficiency of molten salt:

***"There's a term called round-trip efficiency. Basically, it's a measure of how much electricity is produced if the thermal energy that's generated is first stored and then used compared to just directly taking the energy. That number is around 93 percent... [For] things like compressed air and mechanical type storage, there's more significant losses."<sup>9</sup>***

Molten salt thermal storage can be used with three different Concentrating Solar Power Systems; Parabolic Troughs, Linear Fresnel Systems, and Power Towers. This salt, a mixture of roughly 60% sodium-nitrate and 40% potassium-nitrate<sup>10</sup>, is stored in Hot Salt Storage Tanks as shown in the figure below.

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9. Biello, By David. "How to Use Solar Energy at Night: Scientific American." *Science News, Articles and Information* | *Scientific American*. 18 Feb. 2009. Web. 18 Aug. 2010.

<<http://www.scientificamerican.com/article.cfm?id=how-to-use-solar-energy-at-night>>.

10. "Sandia National Laboratories - Solar Thermal Designated User Facilities." *Sandia National Laboratories: Securing a Peaceful and Free World through Technology*. Ed. Sandia Corp. 10 Jan. 2006. Web. 18 Aug. 2010.

<[http://www.sandia.gov/Renewable\\_Energy/solarthermal/NSTTF/salt.htm](http://www.sandia.gov/Renewable_Energy/solarthermal/NSTTF/salt.htm)>.

11. Ortega, J. Ignacio, J. Ignacio Burgaleta, and Felix M. Tellez. *Central Receiver System Solar Power Plant Using Molten Salt as Heat Transfer Fluid*. Tech. Vol. 130. ASME, 2008. Print.

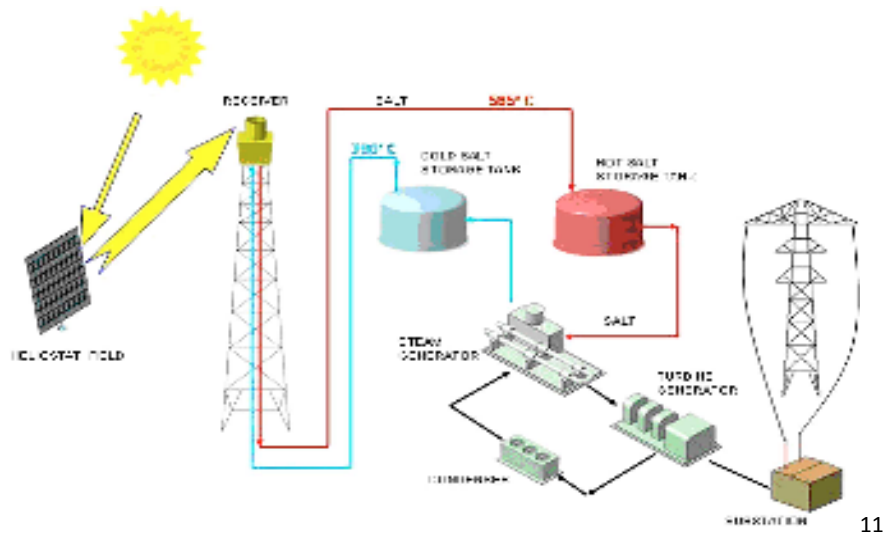


Figure 4: Solar TRES flow schematic with Molten Salt Storage

### 2.2.2 Thermal Storage used Today

Today this technology has been tested not only in the laboratory, but also within the commercial setting. In Spain near Granada, the *Andasol 1* power plant produces 180 GW-h per year with a capacity of 50 MW, enough to produce electricity for 7.5 hours into the night at full capacity<sup>12</sup>.

*Solar Two*, a power tower in the Mojave Desert in California, had a hot salt storage tank and the ability to produce a capacity of 10 MW. Boeing, one of the largest aerospace and defense contractors in the world, stated:

***"This technology has been successfully demonstrated and is ready for commercialization. From 1994 to 1999, the Solar Two project demonstrated the ability of solar molten salt technology to provide long-term, cost effective thermal energy storage for electricity generation."***



Figure 5: Aerial of Solar Two in the Mojave Desert in California

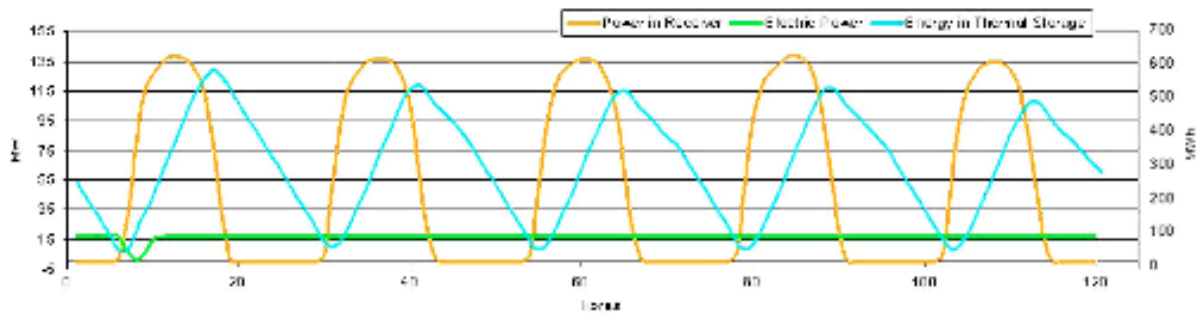
Because of the success from *Solar Two*, Torresol Energy has been building *Solar Tres Power*

*Tower* in Spain, expected for 15 MW of commercial electrical production. Its large thermal storage tank will be able to hold 600 MW-h, or 16 hours of the energy production at full capacity. Figure 6 below illustrates an example of application of the power dispatch capacity of Solar TRES into the grid. This helps to remove some of the intermittency of CSP systems.

12. Solar Millennium. *The Parabolic Trough Power Plants Andasol 1 to 3*. Tech. Solar Millennium AG, 2008. Print.

13. "UBC SOLAR." *ECE Teams*. 2010. Web. 20 Aug. 2010 <<http://teams.ece.ubc.ca/ubcsolar/sustainability.html>>

14. Ortega, J. Ignacio, J. Ignacio Burgaleta, and Felix M. Tellez. *Central Receiver System Solar Power Plant Using Molten Salt as Heat Transfer Fluid*. Tech. Vol. 130. ASME, 2008. Print.



14

**Figure 6: Solar TRES power dispatch capacity for 4 day period in August**

Solar thermal storage has a significantly higher potential within the commercial sector than what has been reached thus far. Any CSP system with a storage tank can not only serve essential for daily peak demand but for intermediate and base loads going into and throughout major portions of the night.

### 3 Technical Potential for Renewable Energy in San Diego County (provided by the SD Regional Renewable Energy Study Group)

#### 3.1 A Summary

In August of 2005, the San Diego Regional Renewable Energy Group compiled a report analyzing the technical potential of promising renewable energies in San Diego County. The renewables that were analyzed in depth include Solar Photovoltaics (PV), Concentrating Solar Power, Wind, Biomass, Small Hydro, and Geothermal. In concluding the study, the report showed clear results:

***“The results of a collaborative, 18-month study by a group of local energy experts confirm that there is significant technical potential in the Region for development of several types of renewable energy sources. This conclusion is supported by a rigorous technical examination of data and can be the foundation of the Region’s renewable energy policy and implementation strategies<sup>15</sup> .”***

Table 2 below shows an overall summary of data of the Technical Potential of each renewable energy within the San Diego Region.

**Table 2: Region’s Renewable Energy Technical Potential in 2020**

15. SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region. Executive Summary* Ch.1 Pg. 3 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.

16. SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region. Executive Summary* Ch.1 Pg. 1 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.



SOLAR PV - Commercial and Residential			SOLAR - Concentrating Solar Power (CSP)			WIND	
	Capacity (MW AC)	Energy (GWh)		Capacity (MW AC)	Energy (GWh)	Capacity (MW)	Energy (GWh)
SD County	4,691	10,224	SD County	2,900	5,080	SD County & Parts of Imperial County and Northern Baja California, Mexico	
			Imperial County	29,000	50,808	1,650 - 1,830	4,530 - 5,020
BIOMASS (SD County)			SMALL HYDRO			GEOTHERMAL	
	Capacity (MW)	Energy (GWh)		Capacity (MW)	Energy (GWh)	Capacity (MW)	Energy (GWh)
Landfill Gas	72	505	SD County	8.32	15	Imperial County	2,500
			Imperial County	86.5	152	Northern Baja CA, Mexico	840
Other Biomass	75	525	Northern Baja CA, Mexico	75	131		6,000

16

As seen above, greater energy gross and capacity potential exists for Geothermal, Wind, Solar PV, and CSP, with minor, but still crucial necessities for Biomass and Small Hydro. This section now shows a brief analysis of each renewable energy, in order to put the pieces of a 100% renewable energy plan together.

### 3.2 Solar Photovoltaic Electric

Measuring the Potential for Solar PV within San Diego is a rigorous process outlined in detail by the San Diego Regional Renewable Energy Group in their 2005 Report. But, in all, it is mostly correlated with the available rooftop area within the region, organized in a way that narrows down those that can be used for photovoltaic panels, both residential and commercial.



Figure 7: Residential Photovoltaic Panels

Through the process, the group measured a Total Technical Potential Capacity of 4,691 MW and a Gross Energy of 10,224 GWh in 2020.

That being said, the reality of PV installation relies on the Market Penetration Rate, which can be increased by various factors such as subsidies, higher efficiencies, or even increasing awareness in the necessity for renewable energies. Table 3 below lays out the Technical Potential of both Residential areas and Commercial areas, with example penetration rates for 2005, 2010, and 2020.

Table 3: Technical Potential of PV Systems in San Diego County

17. Morrissey, Dan. "Solar Photovoltaic Energy | Go Solar Energy For Life." *Renewable Energy, Solar Energy and You! | Go Solar Energy for Life*, Faeco Solar Web. <<http://www.gosolarenergyforlife.com>>

18. SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region. Solar Photovoltaic Electric* Pg. 2 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.

	Capacity (MWAC) <sup>1</sup>			Energy (GWh)		
	Today <sup>2</sup>	2010	2020	Today	2010	2020
<b>Potential PV:</b>						
<b>Residential</b>	2,539	2,772	2,965	5,782	6,310	6,756
<b>Commercial</b>	1,575	1,624	1,726	3,165	3,263	3,468
<b>Total Technical Potential for PV</b>	<b>4,114</b>	<b>4,396</b>	<b>4,691</b>	<b>8,947</b>	<b>9,573</b>	<b>10,224</b>
<b>Potential PV Market Penetration:</b>						
<b>1%</b>	41	44	47	89	96	102
<b>5%</b>	206 <sup>3</sup>	220	235	447 <sup>4</sup>	479	511
<b>10%</b>	411	440	469	895	957	1,022

<sup>1</sup> Capacity is defined as nameplate peak power rating

<sup>2</sup> May 2005 SDG&E's existing PV grid-connected installation is 12.6 MW which equates 0.31% of SDG&E's peak demand

<sup>3</sup> 5.1% of SDG&E's peak demand using a 2004 peak of 4,065 MW

<sup>4</sup> 2.4% of SDG&E's 2004 total energy sales of 19,000 GWH

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Since photovoltaic panels operate when the sun shines, they significantly reduce our daily peak capacity. Increasing the capacity of Solar PV energy added to the energy grid will shift the peak later in the day. Figure 8 below gives an example of what different amounts of PV capacity can do to a daily energy demand.

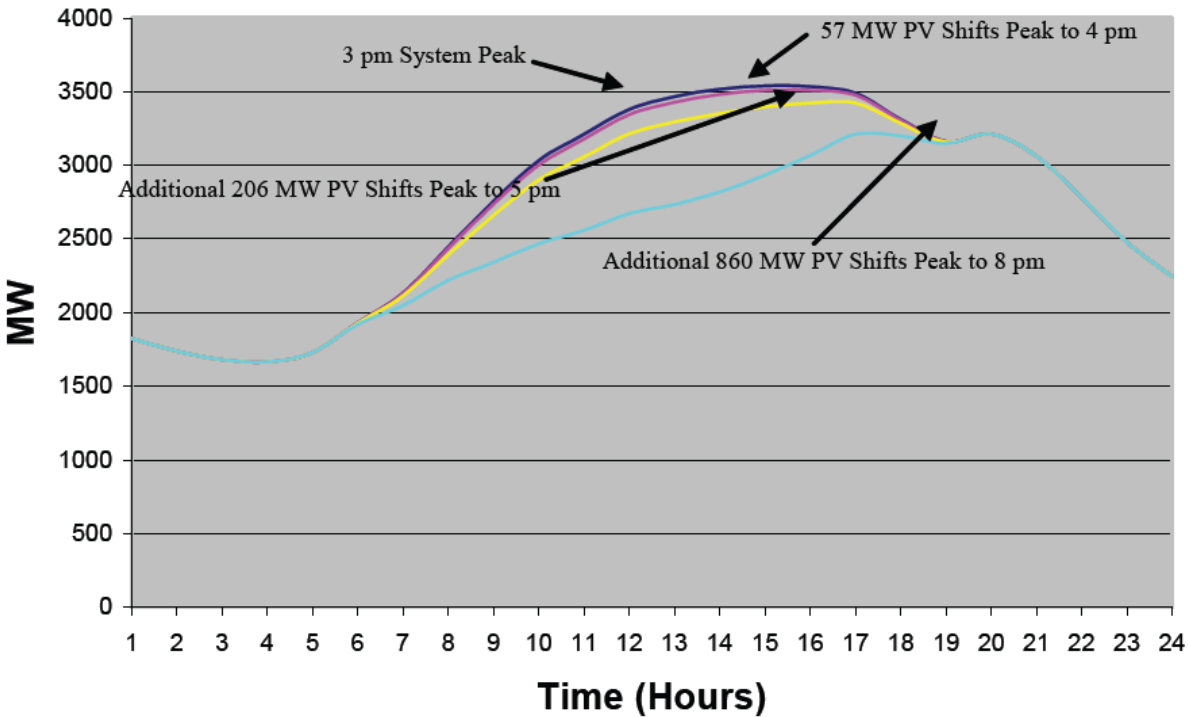


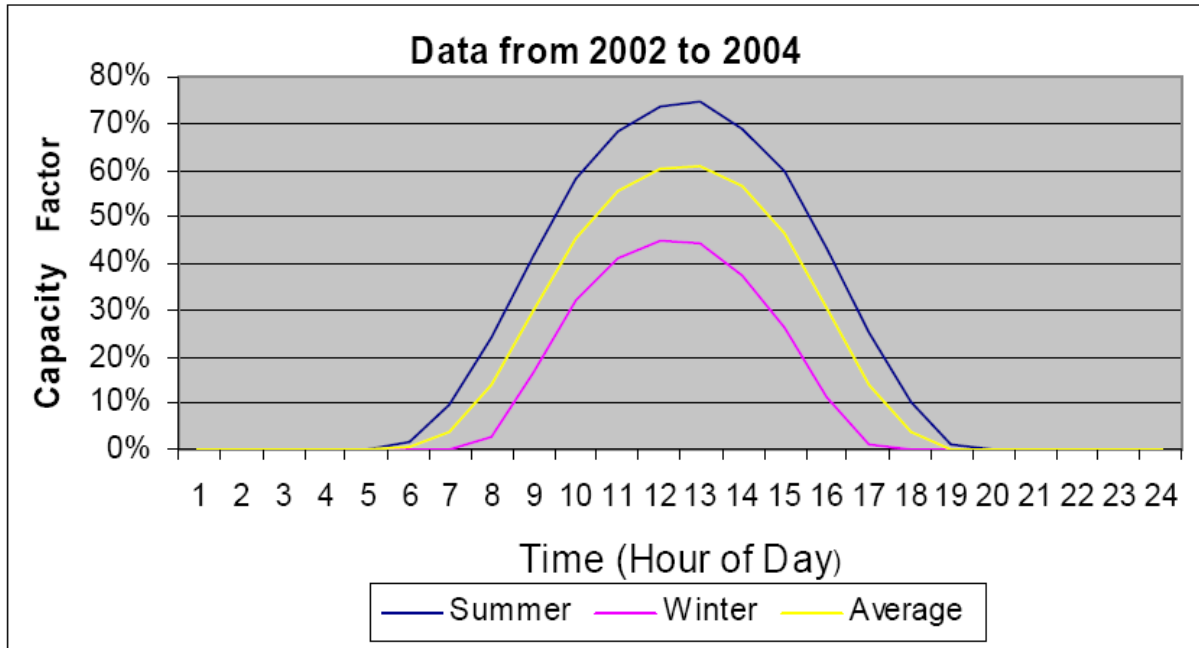
Figure 8: Effect of PV on 2002 System Peak

19

It is important to remember that the effectiveness of PV systems vary from season to season. Summer months have the highest potential for sun exposure, whereas winter months have a slimmer potential. Provided by the SD Regional Renewable Energy Group, figure 9 on the following page shows the average peaks over a two year spread or summer hours and winter hours.

Although solar intensity is not highest among the coast, compared to a hot desert like Blythe, we factor in the slight loss of resulting power harnessed when the power is transported long distances. Bill Powers, an Electrical Engineer in San Diego, speaks to the situation:

*“...yes, the solar intensity in Blythe, is 10 to 15 percent better than it would be on average in coastal San Diego, but the amount of losses that transmission line will incur — especially on a hot summer day when you’re trying to deal with your peak loads — is also in the 10 to 15 percent rang<sup>20</sup>”.*



21

**Figure 9: Yearly Average Hourly Capacity Factors at Large PV Sites in San Diego**

Therefore, without lacking efficiency, Photovoltaic panels can have a significant impact on a 100% Renewable Energy Plan for San Diego County.

### 3.3 Solar - Concentrating Solar Power (CSP)

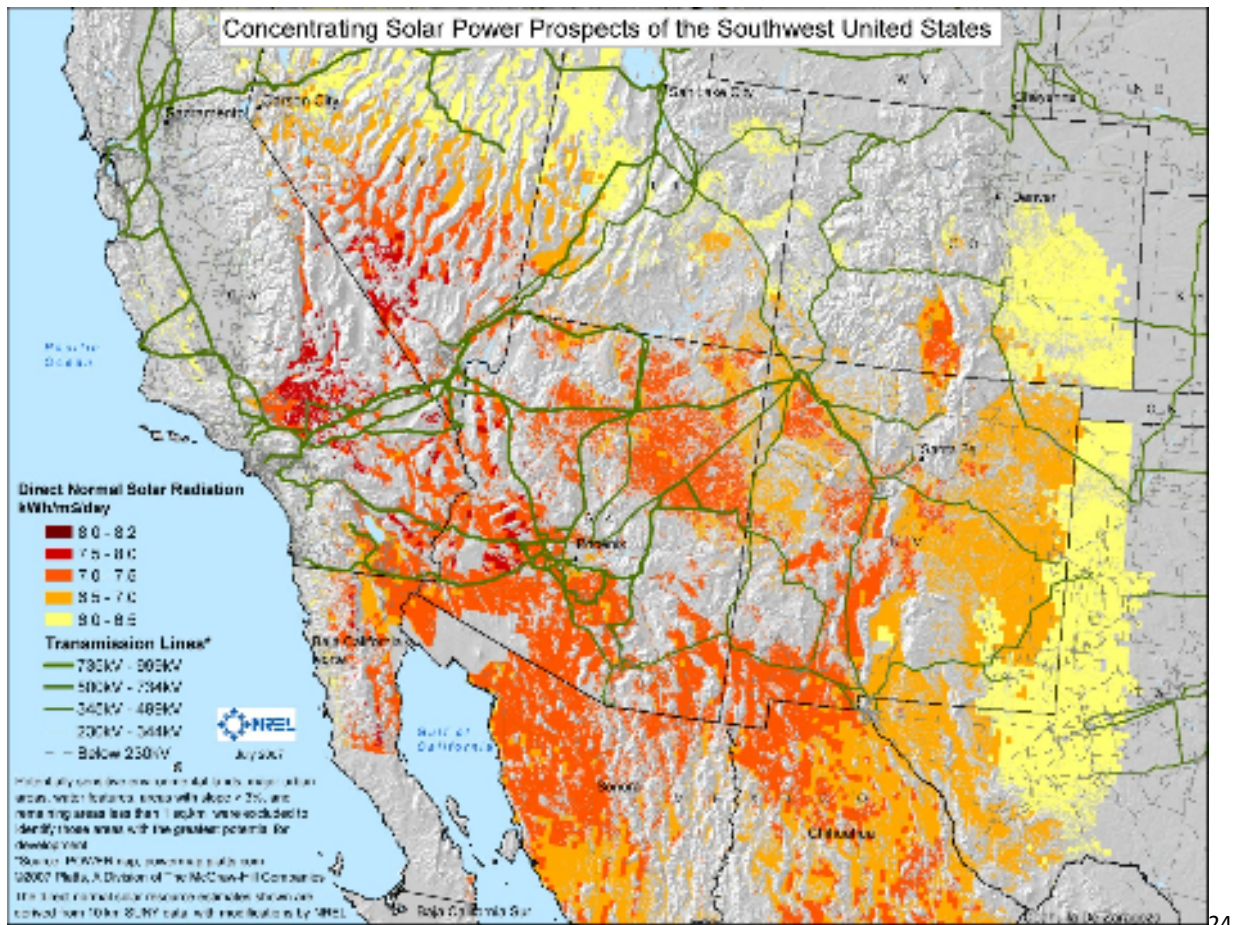
***“Southern California is potentially the best location in the world for the development of large-scale solar thermal power plants. The Mojave Desert and Imperial Valley have some of the best solar resources in the world<sup>22</sup>.” – National Renewable Energy Laboratory***

Because of San Diego’s geographical location, our backyard receives some of the highest solar intensities across the globe, with minimal cloud coverage to diminish it. Here is a general figure by the National Renewable Energy Laboratory (NREL) of our resource for CSP in the Southwest US with a technical land filter explained on the following page.

21. SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region. Appendix E: Solar Thermal – Concentrating Solar Power* App. E Pg. 1 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.

22. SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region. Solar Thermal Electric* Ch. 3 Pg. 1 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.

*“Potentially sensitive environmental lands, major urban areas, water features, areas with slope > 3% and remaining areas less than 1sq. km were excluded to identify those areas with the greatest potential for development<sup>23</sup> .”*



**Figure 10: Concentrating Solar Resource for the Southwest US**

As a result of research done by NREL and then further filtering by the SD Regional Renewable Energy Group, technical potentials for both Imperial and San Diego counties were assessed. A capacity of 31,900 MW and a gross energy supply of 55,888 Gw-h from the combined counties prove this abundant harvest. Table 4 on the next page outlines the technical potential for CSP as analyzed by the SD Regional Renewable Energy Group.

23. NREL, Platts “POWERmap.” *Concentrating Solar Power Prospects of the Southwest United States*. 2007 Platts, <<http://www.powermap.platts.com>>

24. NREL, Platts “POWERmap.” *Concentrating Solar Power Prospects of the Southwest United States*. 2007 Platts, <<http://www.powermap.platts.com>>



**Table 4: Technical Potential for CSP after Filtering**

(Solar Resource > 6.75 kWh/m <sup>2</sup> - day) Technical Potential in GW. Area in (km <sup>2</sup> )					
San Diego – Borrego Springs			Imperial Valley		
Land Filtered for:	GW	km <sup>2</sup>	Land Filtered for:	GW	km <sup>2</sup>
Undeveloped Land with a 1% Slope	2.9	58	Non-Agriculture Land	29	580

25

There are a variety of experimental models for CSP in the works today. However, the ones that have proved most successful include Parabolic Troughs, Solar Power Towers, Concentrating Linear Fresnel Reflectors, and Dish/Engine Systems.

### Parabolic Troughs

Parabolic Troughs concentrate solar radiation at a linear tube at the focal point, which carries a substance capable of storing a large amount of thermal energy. This substance, whether it is water, oil, molten salt or a different fluid, eventually lets out that thermal energy in the form of steam, which then spins a turbine to produce electrical energy. Currently Parabolic Trough Technology is the most proven concentrating solar technology, as over nine plants have been built, most prominently in the Mojave Desert and Spain.



**Figure 11: Solar Parabolic Troughs**

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### Solar Power Towers

Solar Power Tower Technology is comprised of a central tower with hundreds to thousands of mirrors, known as heliostats, surrounding it. Each heliostat, oriented differently, reflects the sun's rays to a central point near the top of the tower. At the top of the tower, molten salt heats up to a significantly higher temperature than that of parabolic troughs, and creates steam to spin a turbine. This molten salt can also be stored and used within the night or at times of intermittency. Today, the 11MW PS10 and

25. SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region. Solar Thermal Electric* Ch. 3 Pg. 3 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.

26. "PRESS RELEASE: CLEAN POWER FROM DESERTS." *DESERTEC-UK*. Nov. 2007. Web. 14 Sept. 2010. <[http://www.trec-uk.org.uk/press/brussels/prince\\_hassan\\_presentation.html](http://www.trec-uk.org.uk/press/brussels/prince_hassan_presentation.html)>.

20MW PS20 plants have been completed in Spain, while the Solar Tres Power Tower, capable of 17MW, is still in construction.



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**Figure 12: Solar Power Tower – Solucar PS10 in Spain**

### Concentrating Linear Fresnel Reflector

Linear Fresnel Reflector (LFR) technology uses long mirror sheets to reflect solar radiation onto a linear tube. The difference it has with Parabolic Troughs is that within the Linear Fresnel, the linear tube is fixed and elevated above the mirrors. It uses the same technology as Power Towers and Parabolic Troughs in creating electrical energy through thermal energy. In March of 2009 PE 1, led by Novatec Biosol, was constructed, and because of its commercial success, a 30MW capacity plant called PE2 started construction in 2010 in Murcia, Spain.



**Figure 13: Linear Fresnel Reflector (Ausra)**

28

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27. Afloresm. "File:PS10 Solar Power Tower 2.jpg." *Wikimedia Commons*. 23 Sept. 2007. Web. 14 Sept. 2010. <[http://commons.wikimedia.org/wiki/File:PS10\\_solar\\_power\\_tower\\_2.jpg](http://commons.wikimedia.org/wiki/File:PS10_solar_power_tower_2.jpg)>.

28. "Pgegreenenergy. "Ausra's Compact Linear Fresnel Reflector." *Anilalur.mp - Home*. Flickr. Web. 14 Sept. 2010. <<http://anilalur.mp/?s=1867>>.

## Dish/Engine Systems

Dish Technology is comprised of a series of individual parabolic dishes that concentrate solar radiation at their own focal point. They use an engine, located at the focal point, that uses a Stirling thermodynamic cycle to produce electricity without producing steam. These systems can achieve a high efficiency rating (30%), but this energy is unable to go into thermal storage. Electricity that comes from Dish/Engine Systems is used right when it is produced.



**Figure 14: Prototype 150 kW dish/Stirling Power Plant at Sandia National Laboratory**



### 3.4 Wind Power

Advancements within Wind Power in the last decades have made wind energy one of the most cost effective renewable energies in the market. Now competitive to coal, natural gas, and petroleum, wind farms have sprouted up with the Midwest and along the east coast. Although the heart of San Diego County does not provide wind speeds economical for wind power development, the outskirts of San Diego Region, parts of Imperial County and the northern edge of Mexico all together have significant potential.

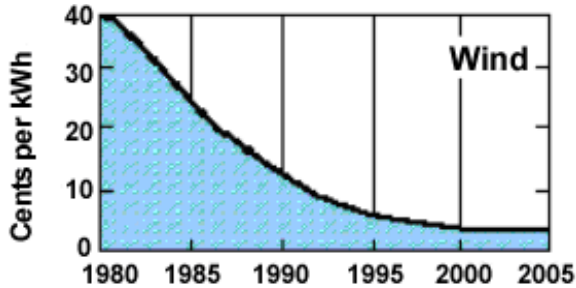


Figure 15: Wind Cost/kWh over Decades<sup>29</sup>

According to the San Diego Regional Renewable Energy Group, an energy gross of 4,530-5,020 GW-h with a capacity of 1,650-1,830 MW area available for harnessing within these areas.

**According to the San Diego Regional Renewable Energy Group, an energy gross of 4,530-5,020 GW-h with a capacity of 1,650-1,830 MW area available for harnessing within these areas.**

To determine areas that are economically feasible for harnessing wind power, the average wind speed and density need to be recorded and rated within a classification system. Classes 3 or lower areas represent wind speeds of 15.7mph and below, which are not normally used to collect wind energy. However, Classes 4 to 7 hold an average speed of around 15.8 mph - 19.7 mph, with a density ranging from 400 W/m<sup>2</sup>-2000 W/m<sup>2</sup>, all readily available as an energy resource. Outside of these main variables, a technical filter is drawn to show where wind power development is realistically feasible. Figure 16 below shows these classified areas based on wind density within and around the San Diego County.

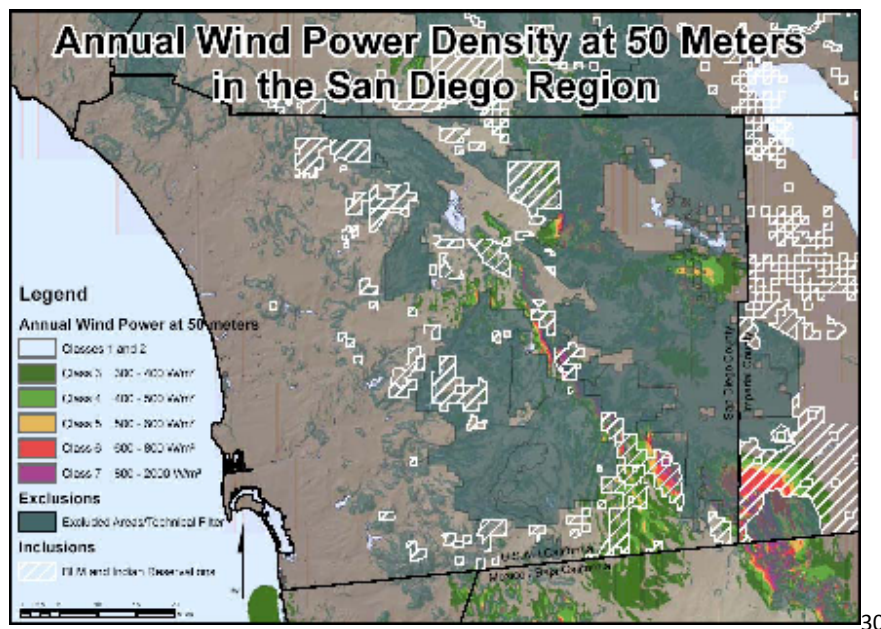


Figure 16: Wind Power Densities within the San Diego Region

Furthermore, beyond those areas closely examined by the SD Regional Renewable Energy Group, certain areas within Baja California, such as the La Rumerosa area (between Mexicali and Tijuana) and Juarez Mountains have tremendous potential for wind power. In 2003, a study by the Center for Higher Education and Research of Ensenada titled “Wind Energy in Potential Productive areas in Baja California”

was conducted in order to measure the wind intensity and patterns of the Rumerosa mountain range<sup>31</sup>. Figure 17 below shows these results within Baja California Norte with Wind Power classes, ranging from darker colors representing a higher class and lighter colors for a lower class.

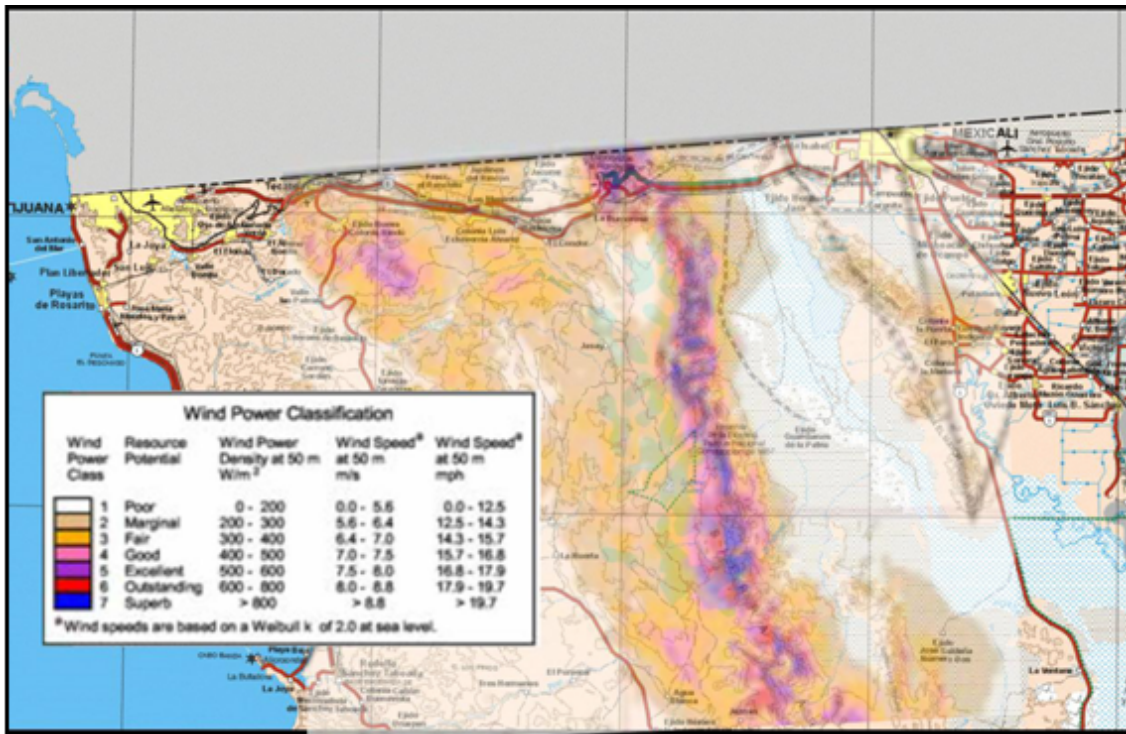


Figure 17: Wind Power Densities at 50 meters – Baja California Norte

As an abundance of accessible wind power has been noticed, it is clear that wind energy can be a crucial part to a 100% renewable energy plan. It is important to be aware of, however, that even though gross energy stays relatively constant throughout the year, wind patterns change noticeably with each season.

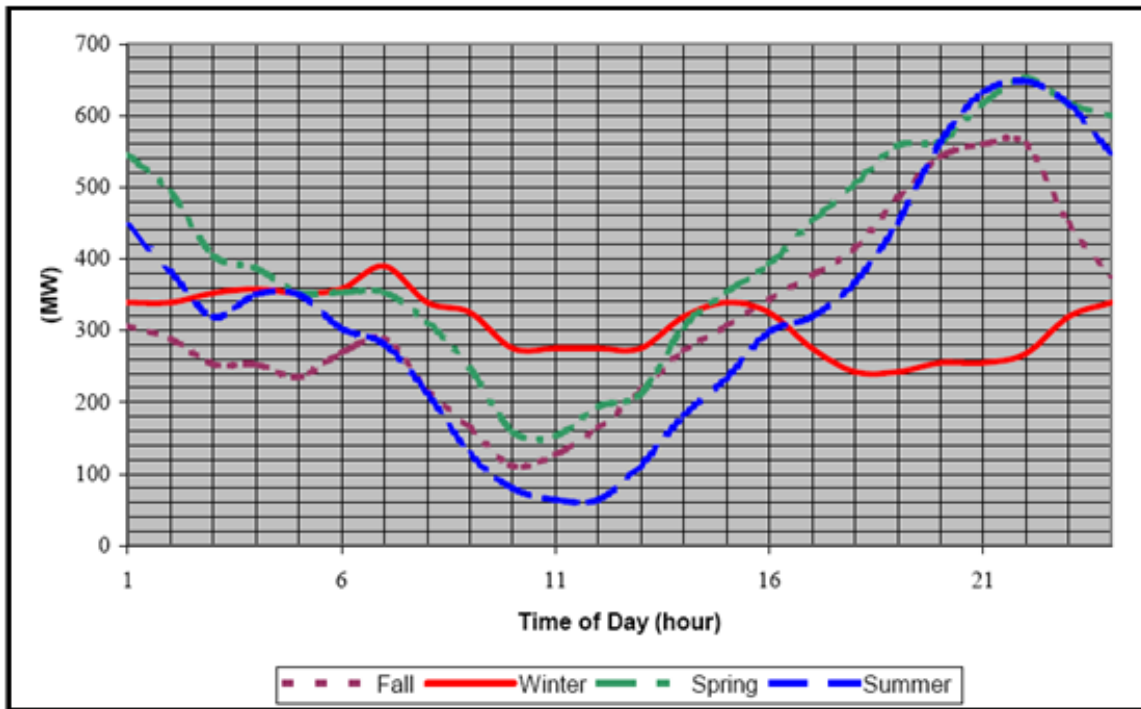
***“The largest power potential from wind in the spring, summer, and fall typically occurs in the evening and early morning when the regional load demand is not at its peak. Although the wind resource peak power potential does not coincide with the peak of the regional load demand, wind can still be used to meet some of the Region’s energy needs<sup>33</sup>.”***

Figure 18 below maps approximately the expected seasonal hourly wind output within the SD Region.

31. SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region. Renewable Resources in Baja California*. Ch. 7 Pg. 5 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.

32. SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region. Renewable Resources in Baja California*. Ch. 7 Pg. 9 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.

33. SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region. Wind*. Ch. 4 Pg. 4 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.



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Figure 18: Seasonal Hourly Wind Output in the San Diego Region.

### 3.5 Geothermal

Even though geothermal is not the most commonly mentioned renewable energy mentioned on the street, it is a crucial resource for not only San Diego County but for California as a state in order to move towards a sustainable energy plan. Over the past two decades, the total cost for producing geothermal energy has declined to that of conventional power plants; 5-7cents per kilowatt-hour to cover the capital costs for a geothermal plant, compared with 4-7 cents per kilowatt-hour for the price of natural gas<sup>35</sup>. Furthermore, it is **available 24 hours a day, 7 days a week, and it is abundant.**

*“The Center for Energy Efficiency and Renewable Technologies estimates that geothermal resources could provide 20% of the State’s total electricity needs<sup>36</sup>.”*



Figure 19: Geothermal Power Plant in Imperial Valley<sup>37</sup>

34. SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region. Wind* Ch. 4 Pg. 5 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.

35. The Center for Energy Efficiency and Renewable Technologies. April 7, 2005. [www.ceert/geothermal.html](http://www.ceert/geothermal.html)

36. The Center for Energy Efficiency and Renewable Technologies. April 7, 2005. [www.ceert/geothermal.html](http://www.ceert/geothermal.html)

37. Geothermal Education Office “Introduction to Geothermal Energy” Slide 57 of 122. 2000

There are over 2000 MW of geothermal energy ready for development in Imperial County<sup>38</sup>, totaling close to San Diego County’s average capacity demand for a normal day. South of the Mexican border is Cerro Prieto, which has a hot reservoir capable of producing 6,000 GW-h of energy. Table 5 outlines the capacity and energy gross of 2005, along with the technical potential in 2020 with the development of geothermal power plants.

**Table 5: Technical Potential for Geothermal Energy in the San Diego Region.**

	2005 Capacity	2005 Energy	2020 Capacity	2020 Energy
<b>Imperial County</b>	537 MW	~4,700 GWh	2,500 MW	~22,000 Gwh
<b>Cerro Prieto</b>	720 MW	~5,000 GWh	840 MW	~6,000 GWh
<b>Total</b>	1,257 MW	~9,700 GWh	3,340 MW	~28,000 GWh

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Throughout the past century, geothermal energy has grown as the most reliable and constant renewable energy resource. The US currently has over 3,000 MW of installed capacity in nine states, with 188 projects in consideration or in development<sup>40</sup>. Karl Garwell, Geothermal Energy Association’s executive director states:

***“In the past 50 years, geothermal energy has blazed the trail for renewable power in this nation. But this industry has not yet peaked<sup>41</sup>.”***

Proving its reliability, geothermal energy can be a huge asset to a 100% Renewable Energy Plan. There are significantly more sites ready for geothermal power production within California alone. Figure 20 on the following page outlines Known Geothermal Resource Areas (KGRAs), provided by the California Energy Commission.

38.SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region. Geothermal* Ch. 5 Pg. 1 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.

39. SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region. Geothermal* Ch. 5 Pg. 5 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.

40. "Utility-Scale Geothermal Turns 50." *Renewable Energy World*. 23 Aug. 2010. Web. 12 Sept. 2010. <<http://www.renewableenergyworld.com/rea/news/article/2010/08/u-s-utility-scale-geothermal-turns-50>>.

41. "Utility-Scale Geothermal Turns 50." *Renewable Energy World*. 23 Aug. 2010. Web. 12 Sept. 2010. <<http://www.renewableenergyworld.com/rea/news/article/2010/08/u-s-utility-scale-geothermal-turns-50>>.





Figure 20: Known Geothermal Resource Areas in California

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### 3.6 Biomass

Even though biomass does not have the capabilities that solar, wind and geothermal possess, it is still important to recognize its potential. A community located near a forest that regularly generates a large portion of forestry wood wastes can provide a significant amount of energy demanded by the community. Or, furthermore, a town near a landfill can do the same by harnessing the methane gas

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42. [www.energy.ca.gov](http://www.energy.ca.gov), California Energy Commission Website.

produced by decomposing wastes also preventing it from escaping into the atmosphere. If cost effective compared to alternatives within the situation, biomass should be considered.

There are four resources capable of producing useful energy: urban wood waste, forestry wood waste, agricultural waste, and landfill gas. Besides agricultural waste, which is more economically valuable as a fertilizer, the SD Regional Renewable Energy Group analyzed the approximate capacity able to be generated from biomass. Table 6 below outlines this energy potential, all within San Diego County.

**Table 6: San Diego Regional Biomass Potential**

Source Category	Capacity and Energy Potential
Urban Wood Wastes	40 - 100 MW, or 300 – 800 GWh, per year
Agricultural Wastes	Negligible, more economically valuable use as fertilizers
Forestry Wood Wastes *	5 - 8 MW, or 34 – 57 GWh, in 2005
	3 - 5 MW, or 20 – 33 GWh, in 2006
Landfill Gas	72 MW, or 505 GWh

\* The sustainability of forestry wood wastes is highly uncertain and hard to predict for the long run.

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### 3.7 Small Hydroelectric

Small Hydropower within San Diego County today is limited because of a limit of indigenous water resources within the Region. Approximately 15% of the state’s electricity comes from large and small hydropower, with roughly 1.6% of that constituting as “small.”

About 75 MW have been shown available in Baja California, consisting of proposed “Tecate’s 1994 Hydroelectric Project” capable of a capacity of 60 MW utilizing water within the Rio Colorado-Tijuana Aqueduct. Furthermore, studies conducted within and near the valley of Mexicali to show a technical potential of 15 MW of small hydroelectric power<sup>44</sup>. Even though these numbers are small, they are beneficial.

Figure 21 to the right is a micro-hydropower plant in Gaviotas Colombia that generates electricity off a 1 foot vertical drop.



**Figure 21: Micro-hydropower plant in Gaviotas, Colombia**

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43. SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region. Other Renewable Resources*. Ch. 6 Pg. 4 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.

44. SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region. Renewable Resources in Baja California*. Ch. 7 Pg. 12 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.

45. Knowlton, Hollister. “Gaviotas: Eco-village that is Green and Creating Jobs” Prosy. Dec. 13, 2008. <<http://my.barrackobama.com/page/community/blog/prosydelacruz>>

## 4 Regional Energy Trade

### 4.1 Overview

When looking outside our county lines into the whole region, we are able to tap into an abundant amount of energy. As seen from the results of the report done by the SD Regional Renewable Energy Group, that abundance would provide for us, even with our possible increase in energy demand 40 years into the future. **CSP potential in the Mojave Desert in Imperial County was analyzed to be 50,808 GW-h while Wind potential from the Rumorosa mountain range in Baja California alone were shown to contribute far beyond the 4,530 – 5,020 GW-h analyzed by the SD Regional Renewable Energy Group.**

With these high potentials within Imperial County and Baja California, keeping positive energy trading agreements and having a high capacity electric grid would both be essential for a 100% Renewable Energy Plan for San Diego County. In fact, in mid-July of 2010, the US Forest Service approved SDG&E's plans to build a 1,000 MW capacity transmission line from remote areas in Imperial Valley to San Diego. Gary Wyatt, a member of Imperial County Board of Supervisors states:

***“The Sunrise Powerlink is a vital connection to sustainable economic development in Imperial County. This project will tap into the vast sources of locally-generated renewable energy and facilitate the creation of green jobs. These advances will make a tangible difference for residents and help benefit our region for generations to come<sup>46</sup> .”***



**Figure 22: High Capacity Transmission Lines in California**

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### 4.2 Baja California Norte, Mexico

The Mexico government handles cross-border energy trade differently whether the energy source runs privately or government owned. Government owned power infrastructures deal with the Comisión Federal de Electricidad (CFE), a government enterprise that permits and regulates plants proposed for development or improvement. On the other hand, privately owned plants are regulated and approved by Comisión Reguladora de Energia (CRE), who is an independent regulatory agency that has jurisdiction over the gas and electrical industries<sup>48</sup>.

Groups further have to file an Environmental Impact Assessment and a Risk Analysis of the project to Secretaria del Medio Ambiente y Recursos Naturales (SEMARNAT), the Secretariat of the Environment

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46. SDG&E. "U.S. Forest Service Approves SDG&E's Sunrise Powerlink." *San Diego Gas & Electric Powerlink*. 13 July 2010. Web. 06 Sept. 2010. <<http://www.sdge.com/sunrisepowerlink/release14.html>>.

47. Greentech Media. "California Lukewarm to Sunrise Powerlink ." *Green Technology | Cleantech | Green Energy - News, Research, & Resources*. 10 Nov. 2008. Web. 06 Sept. 2010. <<https://www.greentechmedia.com/articles/read/california-lukewarm-to-sunrise-powerlink-5143/>>.

48. SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region. Renewable Resources in Baja California*. App. G Pg. 2 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.

and Natural Resources. Through these and a few further regulations, increased cross-border energy trade can supply jobs and meet our demand on electricity while lowering dependence on foreign oil and coal. However, the SD Regional Renewable Energy Group notes:

***“...although fears about energy exports to the U.S. causing higher domestic rates have been reported in the Mexican press, as well as Mexican concerns about the U.S. becoming too dependent on energy supplies from Mexico<sup>49</sup>.”***

There has continually been trade of natural gas and electrical energy across borders on Path 45, a cross border 800 MW capacity transmission line. Table 7 below shows the energy transferred from Mexico to California and back from 1992 to 2003.

**Table 7: Transborder Energy Exchange (1992-2003)**

GWh												
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Mexico to California	2023	1995	1947	1920	1258	17	45	31	66	112	164	765
California to Mexico	24	44	166	228	355	406	480	646	927	82	311	45

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The SD Regional Renewable Energy Group suggests:

***“To meet the growing demand for electricity and natural gas, the cross-border transfer of significant amounts of electricity and natural gas is increasingly integrating the energy sectors of both California and Baja California<sup>51</sup> .”***

### 4.3 Imperial County

There has been a recent breakthrough connecting and harnessing solar resources of Imperial County to the needs of San Diego County. The largest, as mentioned above, has been the approval of the Sunrise Powerlink, a transmission line which a capacity of 1000 MW, increasing the overall amount of energy able to be carried between counties. Figure 23 on the following page, by SDG&E, shows the approved route for the Sunrise Powerlink in green and blue. Dian M. Grueneich, commissioner at the CPUC, states (on the following page):

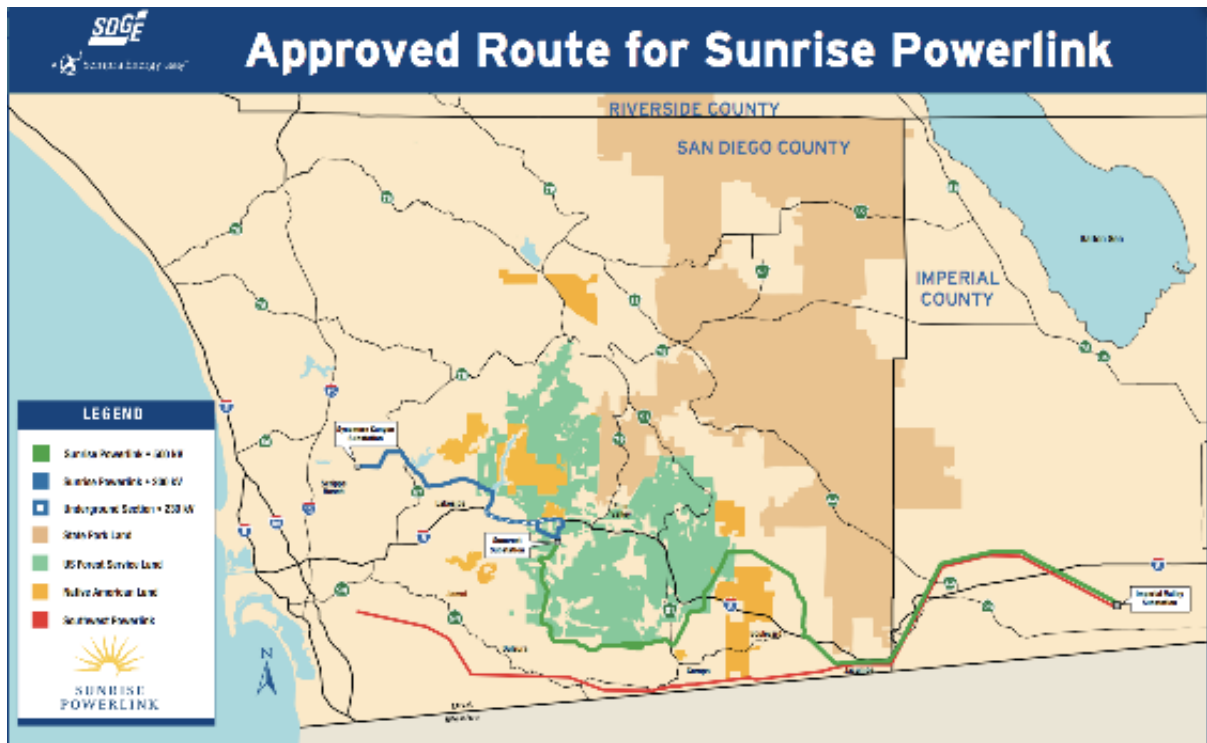
49. SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region. Renewable Resources in Baja California*. App. G Pg. 1 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.

50. SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region. Renewable Resources in Baja California*. App. G Pg. 8 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.

51. SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region. Renewable Resources in Baja California*. App. G Pg. 1 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.



***“The Sunrise Powerlink will help shape California's clean energy future. It will bolster renewable energy development in the Imperial Valley, bringing clean energy jobs to that region, and help us to reach our state's clean energy goals<sup>52</sup> .”***



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**Figure 23: Approved Route for the Sunrise Powerlink**

No major barriers halt development of renewable energy projects within Imperial County. The SD Regional Renewable Energy Group notes in their Report: Potential for Renewable Energy in the San Diego Region:

***“This desert region is unique for the proximity of such an excellent solar resource to a highly populated residential and commercial region<sup>54</sup> .”***

52. SDG&E. "U.S. Forest Service Approves SDG&E's Sunrise Powerlink." *San Diego Gas & Electric Powerlink*. 13 July 2010. Web. 06 Sept. 2010. <<http://www.sdge.com/sunrisepowerlink/release14.html>>.

53. SDG&E. "Sunrise Powerlink." *San Diego Gas & Electric Powerlink*. <<http://www.sdge.com/sunrisepowerlink>>

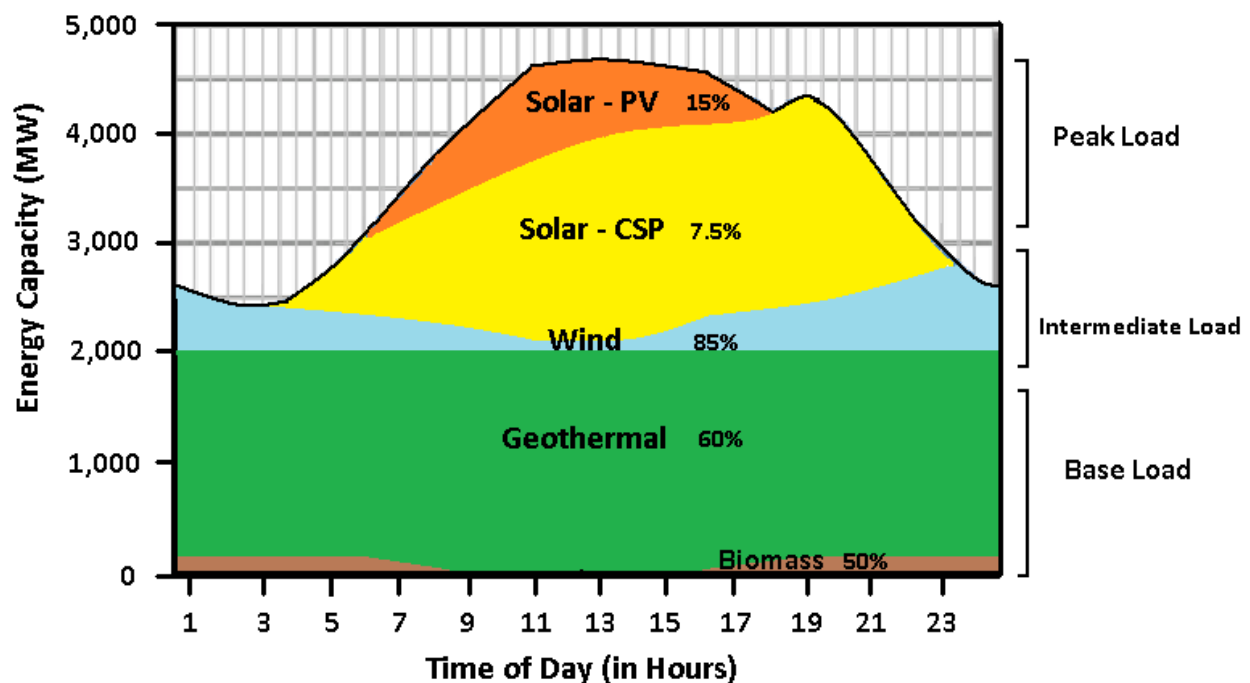
54. SDREO, SDSU, and SDG&E. *Potential for Renewable Energy in the San Diego Region. Solar Thermal Electric*. Ch. 3. Pg. 1 Rep. San Diego: San Diego Regional Renewable Energy Group, Aug. 2005. Print.

## 5 100% Renewable Energy Scenario: Conclusion

After reviewing the Technical Potential of Renewable Energy in the San Diego Region, **it is evident that more energy exists than is needed for a 100% Regional Renewable Energy Plan for San Diego County.** However, the crucial part is making a system that works for our daily energy demand, including the summer day when mid-day peak is high. Figure 24 below shows an example of a summer energy capacity being met by Peak, Intermediate, and Base Loads of Renewable Energy Technologies.

**A few things to note about these graphs include:**

- Percentages to the side represent the amount of Technical Potential that is reached in each Scenario. **These are only ballpark estimates, and true values should be further analyzed.**
- CSP Thermal Energy (Molten Salt) Storage is utilized little in Scenario #1, and greater in Scenario #2. This is in an effort to work as an intermediate load and also to **buffer any intermittency that may be present.**
- Wind percentage is based only on Technical Potential analyzed by the SD Regional Renewable Energy Group, and **does not include wind potential from the Rumorosa Mountain Range.**
- Because of a lack of necessity for detail, **Small Hydro is not considered in these scenarios.**
- These scenarios represent only examples of the millions of possibilities for a 100% Renewable Energy Plan for San Diego County.



**Figure 24: Energy Demand in SD County during Summer with RE Scenario #1**

Figure 24 takes a stance of a greater use of Geothermal Potential from Imperial County. The Technical Potential for both solar technologies is only skimmed in this scenario. Figure 25 on the next page shows Scenario #2 for 100% Renewable Energy on a summer energy demand.

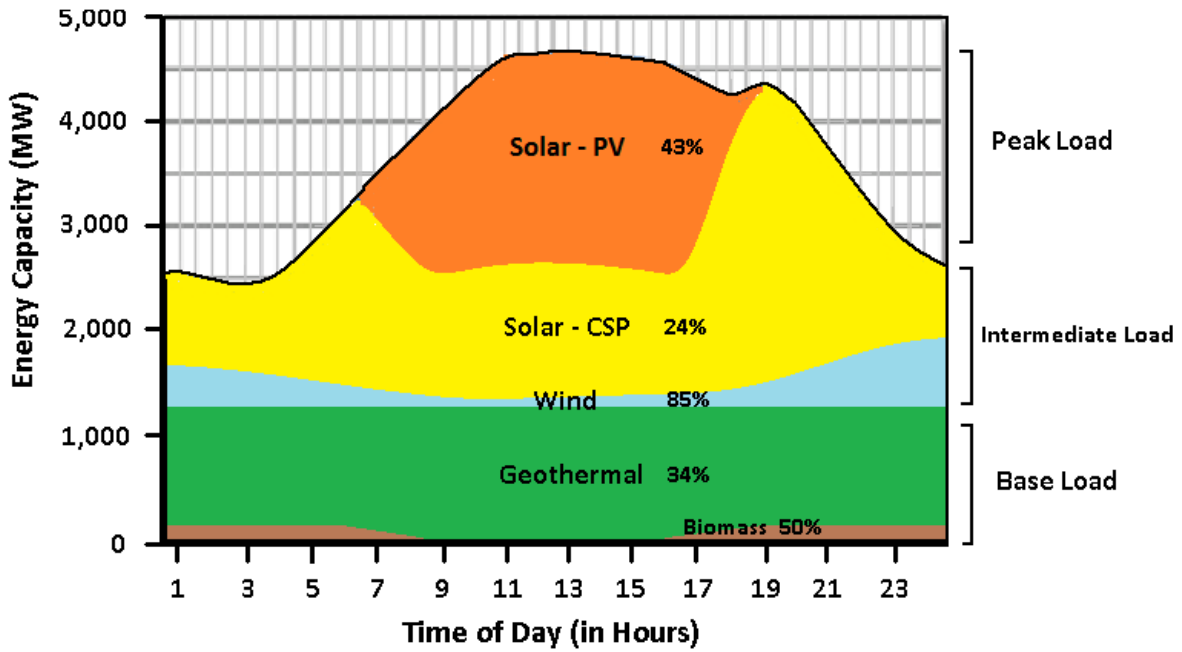


Figure 25: Energy Demand in SD County with RE Scenario #2

Scenario #2 takes a stance of an increased use of Concentrating Solar Power and its Thermal Energy Storage capabilities. Solar photovoltaic panels are also used more widely in this scenario. Figure 26 below represents a high projection for future energy demand.

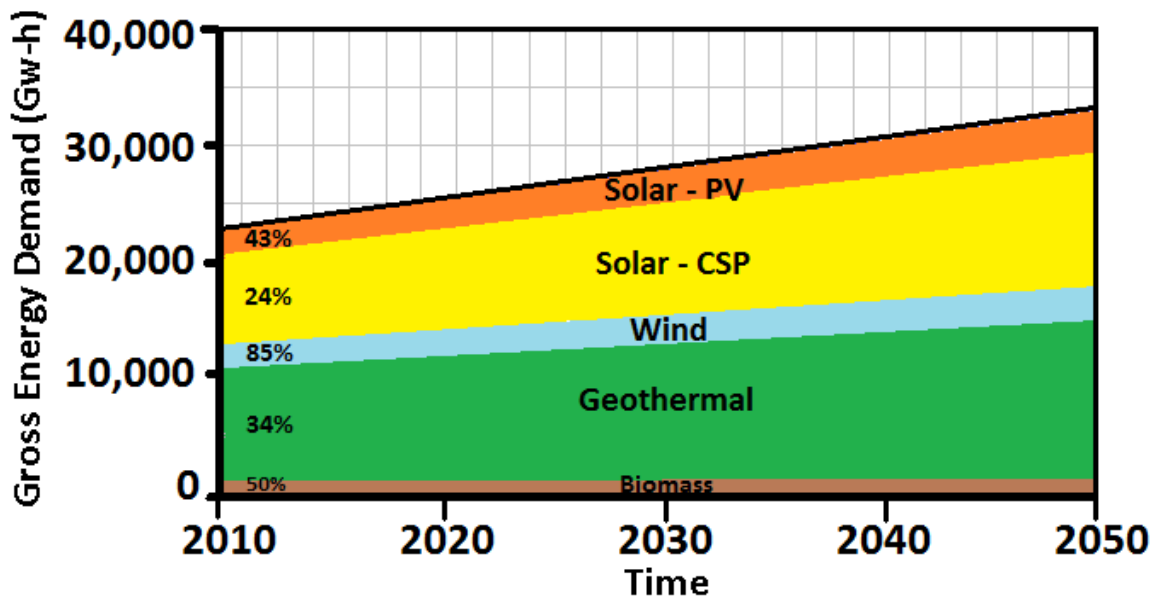


Figure 26: Projected Gross Energy Demand for SD County with RE Supply

The figure, using estimate RE applications from Scenario #2, shows how even with a significant increase in energy demand until 2050, we will still only partially use our available renewable resources.

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