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Design Engineering

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Final Report

Team West

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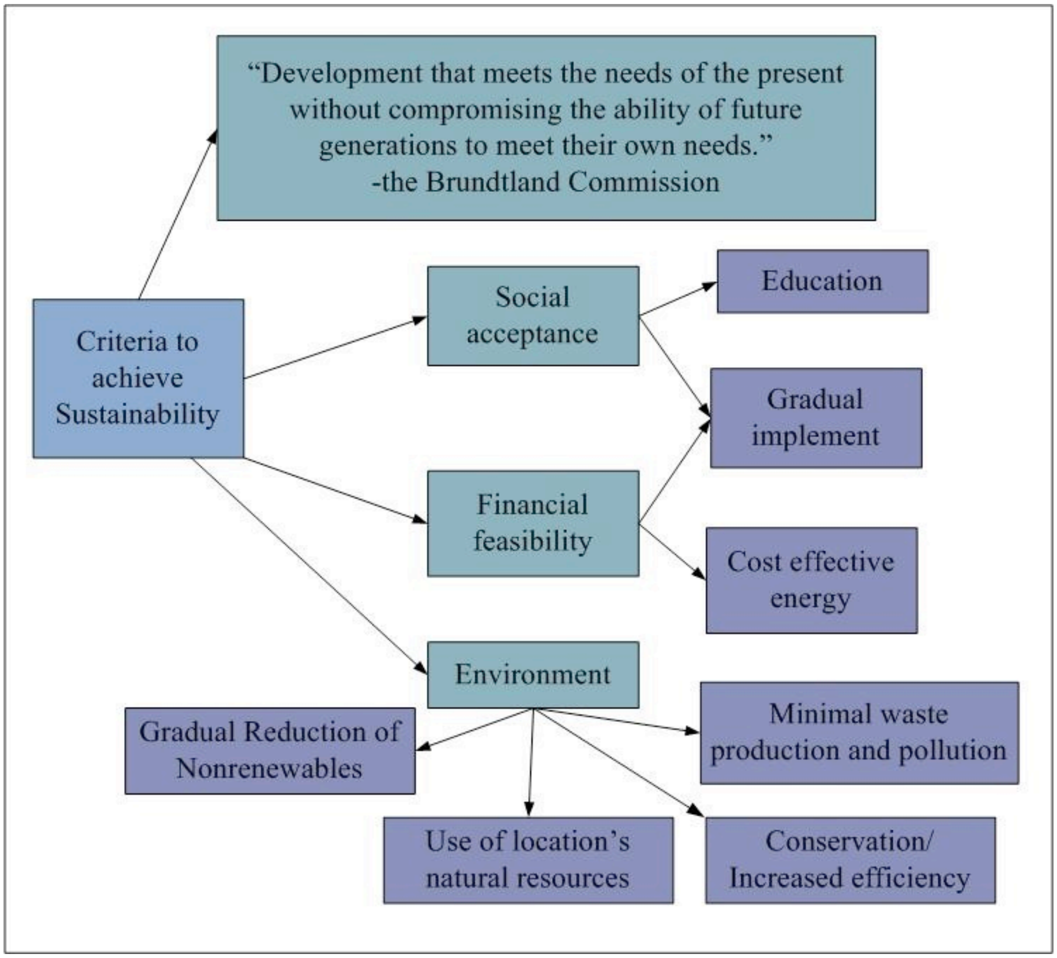
1 Our Objectives for a Sustainable Energy Policy

1.1 Definition of Sustainability



1.2 Specific objectives of our sustainability plan for the West

Our plan encompasses several specific objectives. They include the reduction of emissions, the implementation of renewable energy, the reduction and eventual elimination of the use of fossil fuels, and the production of enough energy to meet the needs of the people in the Western region of the United States. This plan is specifically aimed at providing a plan of sustainability for the West. The states in the West are: Alaska, Washington, Oregon, California, Idaho, Nevada, Montana, Wyoming, Utah, Colorado, Arizona, and New Mexico. Our plan makes projections for both 2030 and 2050 and projects how close we would be able to come to our objectives at both of these future dates.

One of our primary objectives is to reduce all emissions and to reduce CO_2 emissions to minimal levels, near zero emissions. Our plan is based upon creating all of the energy used in the United States in the form of electricity. We believe enough electricity can be produced from renewable sources to significantly reduce emissions. Transportation and heating consume the largest amount of energy that is not in the form of electricity. In our plan, we consider vehicles run on electricity and electric heating in order to simplify our plan by producing all of our clean energy in the form of electricity.

In our plan, we wish to start implementing renewable energy power plants and reducing the number of fossil fuel powered power plants. We feel that fossil fuels are not a sustainable resource since they produce land, air, and water pollution, and natural gas and oil are not available locally in the quantities necessary to fuel our energy needs. Coal is the only fossil fuel that is available locally in sufficient quantities, and carbon sequestration could be used to reduce the CO_2 emissions from this source. However, CO_2 sequestration is not a proven technology, and coal produces other harmful emissions that could not be fully eliminated. Therefore, our objective is to convert to renewable energy power plants. Life cycle analyses have been performed on each renewable energy source to ascertain the positive energy value of each source. Based upon the information gathered in our literature review, not very main sources of biomass have a positive energy value, and biomass has the least favorable life cycle analyses of all of the renewable energy sources considered. For this reason, biomass does not play a role in our sustainability plan. Hydrogen was also not considered in our sustainability plan due to the lack of sustainable production methods. Nuclear power was considered a possibility to help in the conversion from fossil fuels to renewable resources because of its low emissions and currently viable technology, but based upon our renewable energy estimates, it was not necessary to implement nuclear power into our plan. However, if there is difficulty with the transition to renewable energy sources, we have not ruled out the short term implementation of nuclear power.

We feel that the implementation of renewable energy resources would provide the United States with a clean environment that would not sacrifice the wellbeing of future generations for the needs of current generations and would provide the United States with energy security. By implementing renewable energy as the sole energy sources in the U.S., we would not be dependent upon unstable and possibility unfriendly countries for our energy resources. Therefore, the economy of the United States would also be more stable and would pour fewer resources into foreign governments.

2 Energy Policy in the West

Introduction

Several Western state policies that were discussed in the literature review would help to reduce energy consumption in the West. The following policies were decided upon to help implement our CO_2 emission reduction goals, increase energy conservation, implement renewable energy utilities, and transition to an electricity based transportation sector.

Policies

Washington State decided to enact a carbon cap and trade policy. Our policy will be simpler with a straight forward carbon tax. A carbon tax of $35 per ton of CO_2 would effectively double electricity prices. The increase in the price of electricity would cause consumers to reduce their electricity consumption by 10-18% in the Midwest (Blumsack, 2008). We will assume that a carbon tax of $35 per ton of CO_2 will reduce electricity consumption by 14% in the West. In 2006, the United States used 99.87 quadrillion BTUs of energy and used 41.27 quadrillion BTUs of electricity (D.O.E., E.I.A.-Annual Energy, 2007). Therefore, electricity accounts for 41.32% of the United States' total energy consumption, and a carbon tax of $35 per ton of CO_2 would cause a decrease in the overall energy consumption in the West by 41.32%*14%= 5.8%. In addition to decreasing electricity consumption, the carbon tax would increase the price of fossil fuel powered electricity plants thereby encouraging the funding of renewable energy power plants.

The states of Oregon and Arizona added a fee to consumers' electricity bills to create a fund for energy conservation programs and for renewable energy resource development (Alliance: AZ, 2005; Alliance: OR, 2005). One of the main reasons to choose a carbon tax rather than a cap and trade policy is to provide this fund. Since an increase in electricity costs in addition to the carbon tax would be too much of a burden, the funds earned from to the carbon tax would be used to implement energy efficiency programs, to build renewable energy power plants, and to help the poorest part of the population pay for the higher electricity costs. The energy efficiency programs would include appliance trade-ins where consumers receive help paying for Energy Star appliances when they turn in their old, inefficient appliances. Other programs would help citizens replace inefficient windows and lighting and increase their homes' insulation.

Building efficiency codes would be updated to demand better efficiency in new buildings, including in the insulation, heating, air conditioning, and lighting systems. The LEED (Leadership in Energy and Environmental Design) standards would be encouraged and would be the standard in areas that could afford to enforce such high energy efficient standards. Stricter regulations would also be placed on the sale of appliances to ensure that the more efficient appliances are sold.

Tax incentives similar to those in California, Oregon, and Arizona would also be given to people who purchase efficient appliances, vehicles, or homes (Alliance: AZ, 2005; Alliance: CA, 2005; Alliance: OR, 2005).

In addition to reducing electricity use, reducing the energy used by the transportation sector would also be a priority. The emissions regulations passed by the California Air Resources Board with the aim of reducing passenger cars' and light trucks' greenhouse gas emissions by 30% from 2002 levels by 2016 would be adopted (Alliance: CA, 2005). Throughout the time span of our sustainability plan's implementation, fuel economy would continually be re-evaluated based upon the technology available and increased to minimize vehicles' energy consumption. Other incentives would also be provided to encourage the purchase of fuel efficient vehicles, such as a larger tax on gasoline and diesel, which would be used to help provide greater funding for public transportation in areas that have a great enough population density to be able to support public transportation. Our policies would provide incentives for people to use public transportation. For example, policies that decrease available parking, increase the price of parking, and increase the price of gasoline and diesel could be implemented until an electric vehicle fleet can replace fossil fuel run vehicles. By the time that electric run vehicles become prevalent, we hope that public transportation will have become more habitual and will continue. New public transportation systems such as subways can easily be run on electricity to work toward our goal of running the West on clean electricity.

The transition to hybrid electric vehicles should not be made immediately but should wait until a significant portion, such as ¼ to ½, of the West's electricity supply is from renewable resources. At that point, policies would make it financially advantageous (through gasoline and diesel taxes, tax incentives for purchasing hybrid electric vehicles, and taxes on the purchase of fossil fuel powered vehicles) to transition to an electricity powered transportation sector. Governmental fleets and public transportation will be required to purchase electric vehicles, which will cause the automotive industry to start mass production and will make these vehicles a more reasonable price. These policies will cause the transition from a fossil fuel powered transportation sector to one powered by electricity.

Conclusions

All of the policies described in this section will help reduce energy consumption in the West, although it is difficult to estimate the full impact of such policies. Sections to follow will go into greater detail about the amount of energy that we believe an increase in building, appliance, and lighting efficiency will conserve. Today, there is not a great enough monetary incentive to pay for the more expensive but more efficient appliances, homes, or vehicles, but the taxes, incentives, regulations, and increases in electricity and fuel prices that are given here will help encourage energy conservation and help fund renewable energy power plants and public transportation.

Within this section, we have also determined that our carbon tax of $35 per ton of CO_2 will conserve approximately 5.8% of the total energy consumed in the West.

3 Energy Estimates from Renewable Energy Sources: 2030 & 2050

3.1 Wind Power

Introduction

According to previous work on the life cycle assessment, the energy expended in manufacturing a wind turbine can be paid back in under 0.4 years (Schleisner, 2000) or from 1-12.6 months, depending upon the size and efficiency of the turbine (Lenzen & Munksgaard, 2002). As for the cost of wind generated electricity, the electricity costs from 2.88 cents/kWh-6.56 cents/kWh (AWEA, 2007). This estimate is most likely without the cost of maintenance and wind farm workers factored in because in California in December 2007, electricity cost 14.35 cents/kWh in the residential sector (D.O.E., Electric Power, 2007). When including maintenance costs, wind energy would still provide reasonably priced electricity.

Wind generated electricity is viable today, and our plan involves implementing wind farms, especially in high wind velocity areas, at the earliest date possible.

Calculations

The following equation has been compiled for calculating wind power. It is a combination of equations from Pisupati (2006) and Elliot et al. (1991):

$$P_{out} = N_t C\eta\left(\frac{1}{2}A\rho v^3\right)$$

where P_{out} is power, N_t is the number of turbines, C is the average capacity of a turbine, η is the efficiency of the turbine, v is velocity, A is the area of the wind turbine, and ρ is density of air (Pisupati, 2006; Elliot, 1991). Since the theoretical maximum limit on efficiency for wind power is the Betz limit, or 59.3% of the wind energy (Sahin et al., 2006), and since current turbines achieve an efficiency of 20 - 40% (Pisupati, 2006), an efficiency of 40% was chosen for these calculations.

We estimate that the wind turbines will operate at approximately 80% of full capacity (Denholm, 2005).

According to the D.O.E., larger wind turbines are more efficient and cost effective, so large scale turbines were chosen for these estimates (D.O.E., Wind, 2006). Let us assume that the air density is approximately 1.225 kg/m^3, which corresponds to dry air at atmospheric pressure and 15° C (Danish Wind, Wind Energy, 2003). Each wind class corresponds to a given range of wind speeds. The average of the range was used for calculations for each class. See table below for wind speeds.

Table 1: Wind speed correlated to wind power class. Classes 1 and 2 have undevelopable wind resources, so their average wind speed was not listed (D.O.E., Wind, 2005).

Power Class	Wind Speed (m/s)	Wind Speed (mph)	Calculated Avg Wind speed (m/s)
1	0-5.6	0-12.5	-
2	5.6-6.4	12.5-14.3	-
3	6.4-7.0	14.3-15.7	6.7
4	7.0-7.5	15.7-16.8	7.25
5	7.5-8.0	16.8-17.9	7.75
6	8.0-8.8	17.9-19.7	8.4
7	> 8.8	> 19.7	~9

<u>Inland</u>

Both 750 kW and 1.5 MW wind turbines were recommended for wind farms, so the larger 1.5 MW turbine was chosen for these calculations (Haley, 2008).

A 1.5 MW turbine has a rotator diameter of 64m (Danish Wind, Size, 2003). For diameter = 64m, r = 32m, and A = 3217 m.

If turbines are placed too closely together, there will be power losses due to the wake from other surrounding turbines. Therefore, turbines are placed approximately 5-10 rotor diameters apart (Haley, 2008). Let us approximate that our turbines will average a distance of 8 rotor diameters, or 512 m, apart. You can place approximately 4 wind turbines in 1 km^2 without creating wake problems since the turbines are still greater than 5 rotor diameters apart, see figure below for an illustration.

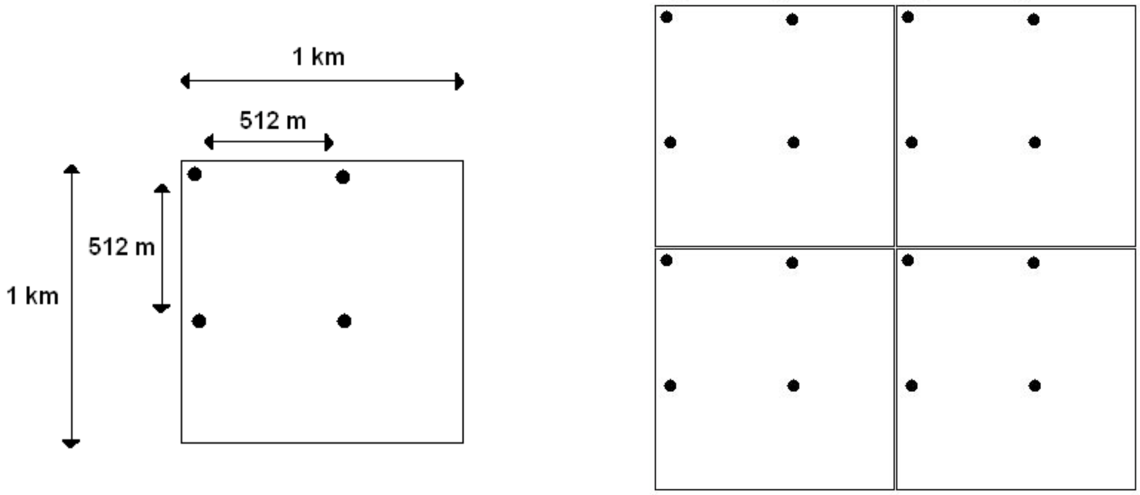


Figure 1: Wind turbine placement for 1.5 MW turbines on 1 km^2 of land. Right image shows how several adjacent 1 km^2 land plots fit together and still provide sufficient distance between wind turbines.

Land area for each wind power class was determined by Elliot et al. (1991), based upon the Environmental & Moderate Land Use Exclusions Scenario. This scenario excludes all the environmentally protected land (refuges, etc) and urban land, 50% of the forest land, 30% of the agricultural land, and 10% of the range land. This excludes 35% of the land area that would have class 3 or higher wind power potential under the scenario that does not make any exclusions (Elliot et al., 1991).

<u>Sample calculation for Class 3:</u>

$$P_{out,1turbine} = .80 * .40 * \left(\frac{1}{2} * 3217m * 1.225 \frac{kg}{m^3} \left(6.7 \frac{m}{s} \right)^3 \right) = .190 \text{ MW for 1 wind turbine}$$

For 1 km^2, we have determined that we have approximately 4 wind turbines, $N_t = 4$, so:

$$P_{out,1km\char`^2} = 4 * .190 \text{ MW} = 0.759 \text{ MW for 1 km}^2$$

For the contiguous states in the West, class 3 wind potential covers 156,772 km^2 of land using the fairly conservative Environmental & Moderate Land Use Exclusions Scenario (Elliot, 1991). Therefore, for class 3 wind potential we have:

$$P_{out,West} = 156772 \text{ km}^2 * 0.759 \text{ MW/km}^2 = 118921 \text{ MW}$$

For one year, the potential wind energy output for class three in the West is:

$E_{out,West} = 3.75029\ 10^{18}$ J = $1.04175\ 10^{12}$ kWh

For all of the contiguous states in the West, the following tables give the total wind power calculations for each class of wind power potential.

Table 2: Wind power calculations for the Contiguous U.S. states based on the land area from the Environmental & Moderate Land Use Exclusions Scenario (Elliot, 1991)

Power Class	Power output for 1 turbine (MW)	Contiguous U.S. West Land Area of given wind class (km^2) (Elliot, 1991)	Energy output for 1 km^2 for 1 year (kWh)	Power output for West (MW)	Energy output for West for 1 year (J)	Energy output for West for 1 year (kWh)
3	0.1896	156772	6644991.141	118921.07	3.750E+18	1.042E+12
4	0.2403	95120	8419455.733	91422.22	2.883E+18	8.009E+11
5	0.2935	9658	10284308.74	11338.57	3.576E+17	9.933E+10
6	0.3737	16856	13095070.97	25197.55	7.946E+17	2.207E+11
7	0.4597	260	16106364.62	478.04	1.508E+16	4.188E+09
				Total:	7.801E+18	2.167E+12
				Total w/o Class 3:	4.050E+18	1.125E+12

<u>Alaska:</u>

Alaska did not have any treated data on the land area covered by each wind class, but a map of Alaska wind classes from the D.O.E. (D.O.E., Wind, 2005) was analyzed using a pixel counting program so that the land area of each wind class was estimated.

Making the assumption that 60% of the land will not be able to be developed due to environmental protection, urban areas, inaccessibility, or lack of proximity to energy consumers, we obtain the following table using the same equations and assumptions stated above.

Table 3: Wind power calculations for Alaska, assuming 60% of the land area covered by each wind power class cannot be utilized.

Power Class	Wind class area (km2)	Power output for AK (MW)	Energy output for AK for 1 year (J)	Energy output for AK for 1 year (kWh)
3	244900	111463	3.515E+18	9.764E+11
4	150030	86519	2.728E+18	7.579E+11
5	86694	61068	1.926E+18	5.350E+11
6	39349	35293	1.113E+18	3.092E+11
7	34228	37760	1.191E+18	3.308E+11
		Total:	1.047E+19	2.909E+12
		Total w/o Class 3:	6.958E+18	1.933E+12

Off Shore

The same equation for determining the power produced by a wind turbine applies to both inland and offshore wind power calculations. There were two studies that determined the offshore wind potential in the West. However, one study concentrated on California (Dvorak et al., 2007) and the other explored the offshore potential of CA, WA, and OR (Musial, 2005). There was no available information on the offshore wind potential of Alaska. In addition, only the study on CA contained the surface area data necessary to making my own calculations.

The surface area for each wind class can be estimated for Alaska, but there is no information on the ocean depth for each wind class, and it is necessary to know the ocean depth in order to determine the feasibility of developing a wind resource. Alaska's extreme weather conditions also might make offshore wind development difficult. Some of Alaska's significant offshore class 7 wind resources might have favorable sites for an offshore wind farm. However, with tides, offshore Alaska has large a large change in ocean depth. Therefore, at high tide, the ocean depth would likely be fairly deep and not conducive to off shore wind turbines, especially with the depth limits of current technology. And, from 2004 data, Alaska's energy consumption was 779139 billion BTU=2.283×10^{11} kWh (D.O.E., E.I.A.-State Energy, 2008). Based on the inland wind potential calculations that wind power can provide $1.933\ 10^{12}$ kWh without class 3 wind resources, offshore wind power shouldn't be needed to fill Alaska's energy needs. For all these reasons, Alaska's offshore wind potential has not been explored.

For the off shore wind turbine towers, monopile structures, which are the oldest and cheapest technology, can be used up to 20m in ocean depth. New water jacket tripods/quadrapods can be used up to 50m in depth. Floating turbine structures will be developed in the next 15 years, similar to the platforms used in offshore oil and gas production, and can be used up to 200m in depth (Dvorak et al., 2007).

California: Dvorak et al. study

Dvorak et al. (2007) noted that due to maintenance requirements and the desire to minimize underwater transmission cables, larger turbines are used offshore than onshore. Dvorak et al. (2007) used 5 MW turbines with 126.0m rotor diameters for their estimates. A spacing of 4-rotor diameters by 7-rotor diameters was used between turbines. In addition, it was assumed that 33% of the surface area with viable wind potential would not be available for offshore wind farms due to shipping lanes, wildlife preserves, etc.

Based upon the above assumptions and making the same assumptions of a capacity of 80% and efficiency of 40% that were used for inland wind potential calculations, the offshore wind potential of CA was calculated. The table below gives the offshore wind potential and compares our calculations with the calculations of Dvorak et al. (2007). Possible reasons for discrepancies include the fact that Dvorak et al. (2007) had their own equation for determining wind capacity and had greater information on the actual wind speed in each location. Dvorak et al. (2007) also had greater information on the actual shape of the land available and could have fit more turbines into the area. However, my calculations are comparable to Dvorak's, and the orders of magnitude are reasonably in line, especially considering the roughness of my approximations

Table 4: Wind power calculations for offshore CA. The wind speeds given are for a height of 80m above the ocean. The rightmost column contains the calculated wind potential from Dvorak et al. (2007), which is comparable to this paper's calculated wind potential to its left.

Ocean depth	Wind speed (m/s)	CA Offshore Surface Area (km2) (Dvorak, 2007)	CA Offshore S.A. w/ 33% exclusion (km2)	# turbines per type wind area	CA Offshore Wind Power Capacity (MW)	CA Annual Offshore Wind Energy Capacity (kWh)	CA Annual Offshore Wind Energy Capacity (TWh)	Dvorak's CA Annual Offshore Wind Energy Capacity (TWh)
0-20	7.25	447	298	670	624	5.47E+09	5.5	10
	7.75	99	66	148	169	1.48E+09	1.5	2
20-50	7.25	1205	803	1807	1683	1.47E+10	14.7	27
	7.75	360	240	540	614	5.38E+09	5.4	9
50-200	7.25	13664	9109	20492	19085	1.67E+11	167.2	293
	7.75	2784	1856	4175	4750	4.16E+10	41.6	67

The assumed wind speed of 7.25 m/s corresponds to Dvorak's "≥7.0 m/s", and the wind speed of 7.75 m/s corresponds to Dvorak's "≥7.5 m/s". The resources with wind speeds ≥7.5 m/s are currently developable, but areas with wind speeds ≥7.0 m/s are only developable with future technology (Dvorak et al., 2007). Also, ocean depths of 0-50m are currently developable resources. Depths of 50-200m depend upon future technology. We will assume that any currently developable resources can be available by 2030 and the resources requiring future technology can be available by 2050.

<u>California, Washington & Oregon: Musial study</u>

The work of Musial (2005) does not give surface area or wind speed data so the calculations cannot be repeated. Musial (2005) made more conservative estimates than Dvorak (2007), excluding all of the zone near shore for five nautical miles and excluding 67% of available surface area in the zone 5 to 20 nautical miles from shore, and excluding 33% of surface area in the zone 20-50 nautical miles from shore. Since this estimate is extremely conservative, especially compared to methods employed in the Dvorak (2007) study, I have multiplied the Musial (2005) data by 1.5 for our estimates. The data given by Musical was in GW and has been converted to annual kWh for uniformity within this paper.

Table 5: Wind power calculations for offshore CA, OR, and WA. The top two rows are data from Musical (2005), the bottom two rows are Musial (2005) data multiplied by 1.5 to offset Musial's conservative estimates.

	Annual kWh by Depth (m) (Musial, 2005)			
Region	0-30	30-60	60-900	>900
CA	0	9.46E+12	1.51E+15	5.30E+15
WA+OR	0	5.05E+13	3.17E+15	2.15E+15
CA*1.5	0	1.42E+13	2.26E+15	7.95E+15
(WA,OR)*1.5	0	7.57E+13	4.75E+15	3.23E+15

Concluding Remarks

The tower height of 30m was used in the power classes determined by Elliot et al (1991), and according to Dvorak et al. (2007), if their 80m tower height above the ocean's surface were increased to 100m, one could obtain approximately 7.6% more wind power. With higher wind towers, greater wind speeds can typically be accessed. Therefore, the West's wind resources could potentially produce even more energy than given in these estimates.

Making the assumption that currently developable resources can be available by 2030 and that the resources requiring future technology can be available by 2050, inland wind estimates will be for wind power classes 4-7 for 2030 and for power classes 3-7 for 2050. Offshore wind estimates for 2030 will not include Dvorak's data for wind speeds less than 7.5 m/s or ocean depths greater than 50m, and 2030 offshore wind estimates will not include Musial's data for ocean depths greater than 60m. All calculated offshore wind potential will be included in the estimates for 2050. Dvorak (2007) data was used for CA estimates rather than Musical (2005) data.

Table 6: Wind power projections for 2030 and 2050 in the West.

Total annual wind power projections in West (kWh)		
2030	Inland U.S., Contiguous West	1.13E+12
	Offshore U.S., Contiguous West	7.57E+13
	Inland AK	1.93E+12
2050	Inland U.S., Contiguous West	2.17E+12
	Offshore, U.S., Contiguous West	8.05E+15
	Inland AK	2.91E+12

As is evident, there is an abundance of offshore wind power available. However, one objection to wind power is that it is an intermittent power source. Batteries or other storage methods could be used to make wind a more reliable electricity source. Typically, if the wind farms cover enough area, there will always be some wind resource capable of producing electricity, but batteries or other storage methods could be used to make wind an even more reliable electricity source. Of course, storage methods would reduce the quantity of power produced, but the offshore wind resource have vast potential, and, once fully developed, could easily stand to lose some power to storage.

3.2 Solar Power

Introduction

Solar irradiation onto the Earth in one hour (4.3×10^{20} J) is comparable to the world energy consumption in a year (4.1×10^{20} J). (DOE, 2005) In other units, while the world consumption is 13 TW (terawatts), the energy from the solar energy potential exceeds 120,000 TW. This indicates if 10 % efficient solar cells or other solar energy converting devices are widely adopted, 0.1 % of land on the planet could provide enough energy for current consumption. As shown in Figure 2 below, most of the west states are the best location that could enjoy the much of solar irradiation.

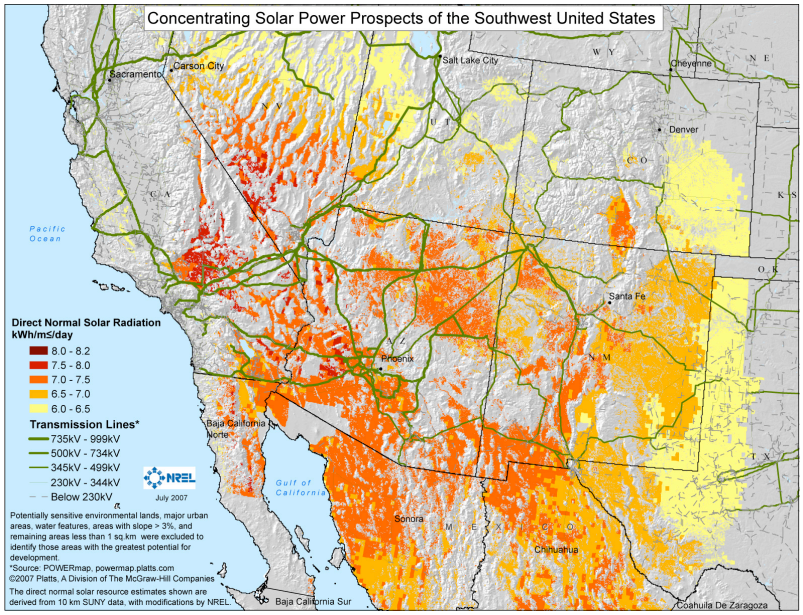


Figure 2. Concentrating Solar Power Prospects (NREL website)

Solar power plants (Concentrating Solar Power)

Strong candidate for the west: Within the United States, CSP plants with over 350MW of capacity, all in west states, exist and have been operating reliably for more than 15 years. (Arizona, California, and Washington.)

Calculations

A current typical CSP requires 5 acres to produce 1 MW of electricity. (This equals to 200 kW/acre.) This estimation assumes that only lands with average solar radiation of 7 kWh/m^2 are economically feasible as CSP potential. West land area is approximately 4.5×10^6 km^2. For unit conversion, 0.004047 km^2 is 1 acre. If 0.1 % of land can be used for CSP,

Available land area: 4.5×10^3 km^2 = 1.1×10^6 acres

Possible power generation: $\frac{1.1\times10^6}{5} = 2.2\times10^5$ MW = 220 GW (1.9×10^{12} kWh/year)

In an energy report by Western Governors' Association (WGA), the potential for CSP is estimated 200 GW, which confirms the validity of our simple calculation. Electricity consumption in the West in 2004, on the other hand, was approximately 7,300 trillion Btu. Using the fact that 1 W equals to 3.41 Btu/h, this could be converted into watt.

$$\frac{7300 \times 10^{12}}{365 \times 24} \div 3.41 = 0.24 \times 10^{12} \text{ W} = \underline{240 \text{ GW}}$$

This indicates the potential for CSP is quite abundant and comparable to the electricity consumption in the West.

Future Projections

State projection of peak demand growth by 2015 and corresponding allocations for CSP are summarized in Table 7. (WGA). Assuming the same goal as California, renewables should be able to provide 20 % of 34 GW of demand growth by 2015. This aim is to deploy 7 GW of renewable energy. As shown below, 4 GW is allocated to CSP.

Table 7. Estimated CSP Deployment by State

State	Peak Demand Growth (GW)	Allocation (GW)
California	1.16	2.0
Arizona	6.1	1.0
Nevada	5.1	0.5
New Mexico	4.3	0.3
Colorado	5.3	0.1
Utah	1.7	0.1
Total	34.1	4.0

The question is then whether this goal is likely to be achieved or not. CSP industry projects that their capability will be around <u>13.4 GW (1.2×10^{11} kWh/year) by 2015</u>, even though this is less than the estimated maximum target of market is 47 GW. The message here is that CSP capacity in the West will strongly continue to grow and is very likely to satisfy the target.

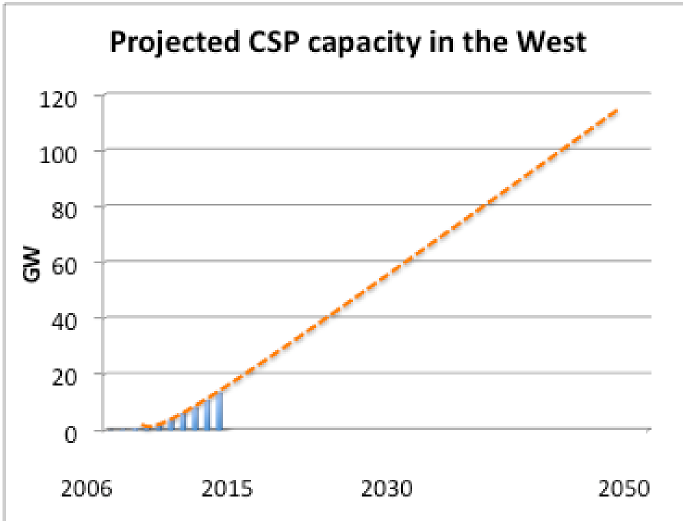


Figure 3. Projected CSP capacity in the West

If we assume the same growth rate after 2015, CSP capacity may reach 55 GW (4.8×10^{11} kWh/year) by 2030, and 120 GW (1.1×10^{12} kWh/year) by 2050, as presented by a dotted line in Figure 3. This assumption is not necessarily very accurate because it is just made by extending a projection trend linearly after 2015. This projection by 2050 is almost 50 % of the potential that was calculated above. As an example of progress in deployment, there is already an ongoing project in Mojave Desert in California to expand the CSP plants and its capacity will be increased to 553 MW from current 354 MW by 2011. In summary there is abundant resource for CSP in the West and technology is well developed, which makes CSP an inevitable part of future energy choice in this region.

Photovoltaic (PV)

PV cells generate electricity by directly converting light energy. PV is considered to be more suitable for distributed implementation rather than a huge PV plant, which is a major difference of PV from CSP technology. As of 2007, capacity of installed PV in the West is estimated 526 MW. (WGA)

Calculations

Rooftop availability: Within the area of West states, the estimated rooftop space suitable for installation of PV is over 22 billion square feet. (1 square feet = 0.0929 m^2) (WGA) This estimation neatly eliminates the inappropriate rooftop considering shading and orientation factors such as excessively steep angles. To conduct simple estimation of potential for PV, factors are assumed as below.

- Average solar irradiation in US: 200 W/m^2
- Overall efficiency: 10 %

If we assume all of the available rooftop of residential and commercial buildings are fully covered with PV cells, the potential for rooftop PV is calculated as

$$22\times10^9\times0.0929\times200\times0.1=\underline{4.1\times10^{10}\text{ W} = 41\text{ GW }(3.6\times10^{11}\text{ kWh/year})}$$

The reported value (WGA) is calculated as annual production and ranges 274-316 TWh. (300 TWh = 300×10^{12} Wh = 3.0×10^{11} kWh.) It is proven that the value obtained by hand calculation is nicely close to the reported value. The difference comes from various factors, but a part of them should be the fact the efficiency for a flat and top-faced PV cell is lowered as the irradiation angle of the sunlight changes. Although PV potential is not exceeding that of CSP, there are still plenty of resources available in the West.

Future projections

WGA sets an aggressive target for PV solar that aims <u>4 GW of installation by 2015</u>. This could be achieved by continuous 32 % annual growth over the next ten years. Extensively strong energy policies by state to encourage distributed solar technologies are essential to reach this goal. However, such a growth rate is thought to be reasonable according to that of the past decade as shown in Figure 4 below.

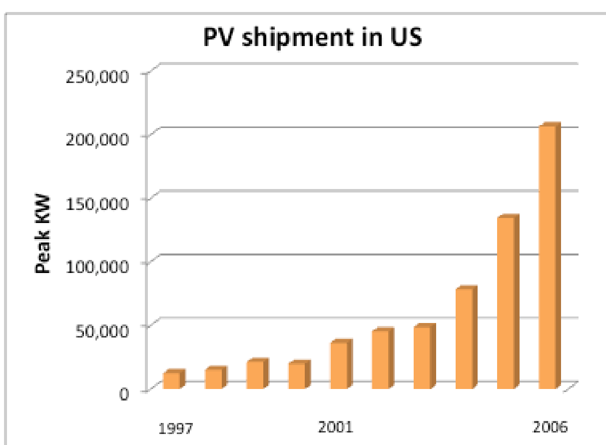


Figure 4. PV shipment in U.S.from 1997 to 2006
(Produced based on the data from EIA website)

In terms of impact on climate change, implementation of possible distributed solar technology by 2015 will avoid 4.0-4.8 million metric tons of CO_2 emissions annually. By 2025 another 30 GW (34 GW in total) could be expected as a result of an average 20 % annual growth after 2015. It is possible to achieve this if currently implemented incentive programs among the West states are continued. Successful continuous deployment of PV panels might be able to reach close to the maximum potential before 2050.

Concluding Remarks

Table. 8 summarize the reported and calculated values of solar potential for CSP and PV and projections. As we reviewed in our last literature review and the beginning of this chapter, West states have a great deal of potential for solar energy, which far exceeds the overall energy demand of the region. Concentrating Solar Power technology is the most promising and effective pathway to convert that abundant energy into electricity. The capacity of CSP is expected to grow at an accelerated rate. CSP industry projects that it will be able to provide 13.4 GW by 2015. Our estimation concluded that the capacity could reach 55 GW by 2030 and 120 GW by 2050. On the other hand, photovoltaics (Distributed Solar) could supply 34 GW by 2030. However, since possible fundamental development for PV is somewhat uncertain, significant advancements in efficiency of the solar cell might be able to boost the current maximum of the potential in the next few decades.

Table 8. Summary of solar technology potential and projections

	CSP		PV	
	GW	kWh	GW	kWh
Potential	220	1.9E+12	41	3.6E+11
Current status	0.35	3.1E+09	0.53	4.6E+09
Projection 2015	13.4	1.2E+11	4	3.5E+10
Projection 2030 (2025 for PV)	55	4.8E+11	34	3.0E+11
Projection 2050	120	1.1E+12	Close to the potential	

*Projection 2030 and 2050 for CSP are estimated by assuming the same growth rate that is expected in the short-term by 2015.

3.3 Hydroelectric Power

Introduction

Based upon the analysis of hydroelectric resources available in the West that was performed in the literature review, the authors of this paper have decided not to expand the West's hydropower resources but wish to maintain the current levels of hydroelectric power production.

Calculations

The United States Department of Energy provides data on the electricity generation from each power source in each state in the United States. Unfortunately, the data on hydroelectric power that was obtained by the authors of this paper is only for the month of December in 2007 (D.O.E., E.I.A.-State Energy, 2008). Therefore, the annual estimate of hydropower available in the West was determined by multiplying the Western states' total hydroelectric power for December 2007 by twelve.

According to our compilation of hydroelectric power in the Western states from D.O.E. data, 9,890 MWh were produced in December 2007 (D.O.E., E.I.A.-State Energy, 2008). Therefore, our estimates for hydroelectric power for one year are:

9,890 MWh *12 = 118680 MWh = $1.19 * 10^8$ kWh annually.

Concluding Remarks

Since we have decided to keep hydroelectric power constant, the hydroelectric power estimates for both 2030 and 2050 is $1.19 * 10^8$ kWh annually.

3.4 Geothermal Power

Introduction

The installed capacity, (MWe), is defined as a value set by the manufacturer as its target output when the plant is operating under design condition. Values of west coast available energy resources and maximum amounts of power available were based on literature reviews.

Kilowatts-hours, (KWh), are defined as energy used or delivered. Life time expectancy 30 to 40 years of any type geothermal power plants was assumed (Dipippo 1998).

Calculations

In equation – (1) - calculate mega watts of installed capacity (MWe) as a function of power plants life time (t) in seconds (30 years = $9.46*10^8$ sec). Constant values, for total recover thermal energy (Q_{rec} = 1.0 $X10^{21}$ kJ from 2008 to 2030), and (Q_{rec} = 5.0 $X10^{23}$ kJ at from 2030 to 2050) were assumed. The net cycle thermal efficiency (η_{th}) was based on a constant value obtained for energy conversion factor as a function of temperature resources.

Available power; MWe = η_{th} (Q_{rec}) (1 MJ/1000kJ) (1/t) - (1)-

$Q_{rec} =$ (0.02)*(1.0*10^{21} kJ) = $\underline{2.0*10^{19}\text{ kJ}}$ - (2)-

Available MWe = (0.11)*(2.0*10^{19}kJ/1000 kJ)*(1/9.46*10^8 sec) = $\underline{2.33*10^{12}\text{ MWe}}$

η_{eff} % = [(Power Generated MWe) / (Available Power from recover thermal energy MWe)]*100 -(3)-

η_{eff} % = [(1.36*10^{11})/(2.33*10^{12})]*100 = $\underline{5.83\%}$

The above calculations provide the power available from total recover thermal energy during the first 30 years. In 2030 the total energy production or generated was 1.36*10^8 kWh. The total energy conversion efficiency percent η_{eff} = 5.83% from 2008-2030 was calculated by equation-(3)-. The 5.83% conversion efficiency was based on 2% total recover thermal energy Q_{rec} calculated by equation-(2)-. The value of Q_{rec} = 1.0 $X10^{16}$ kJ was used from 2030 to 2050 at a temperature of 200°C for geothermal power plants, and the η_{th} = 14% for energy conversion was used. (Wilcox 2007)

Table 9. Average electricity production per West States by geothermal power plants from 2008 to 2050.

West States 10^3 kWh										
Years	**2008**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Alaska	0.00E+00	1.00E+04	2.40E+04	3.36E+04	4.37E+04	3.00E+04	3.60E+04	1.20E+04	3.64E+03	6.00E+03
Arizona	0.00E+00	1.00E+04	2.40E+04	3.36E+04	4.37E+04	3.00E+04	3.60E+04	1.20E+04	3.64E+03	6.00E+03
California	1.30E+07	7.71E+06	1.85E+07	2.59E+07	3.37E+07	2.31E+07	2.78E+07	9.25E+06	2.80E+06	4.63E+06
Colorado	0.00E+00	1.00E+04	2.40E+04	3.36E+04	4.37E+04	3.00E+04	3.60E+04	1.20E+04	3.64E+03	6.00E+03
Montana	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nebraska	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nevada	1.26E+06	1.38E+06	3.32E+06	4.64E+06	6.03E+06	4.14E+06	4.97E+06	1.66E+06	5.02E+05	8.29E+05
New Mexico	0.00E+00	4.00E+04	9.60E+04	1.34E+05	1.75E+05	1.20E+05	1.44E+05	4.80E+04	1.45E+04	2.40E+04
Oregon	0.00E+00	1.90E+05	4.56E+05	6.38E+05	8.30E+05	5.70E+05	6.84E+05	2.28E+05	6.91E+04	1.14E+05
Utah	1.85E+05	2.07E+05	4.98E+05	6.97E+05	9.06E+05	6.22E+05	7.47E+05	2.49E+05	7.54E+04	1.24E+05
Washington	0.00E+00	2.50E+04	6.00E+04	8.40E+04	1.09E+05	7.50E+04	9.00E+04	3.00E+04	9.09E+03	1.50E+04
Wyoming	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Idaho	0.00E+00	4.30E+05	1.03E+06	1.44E+06	1.88E+06	1.29E+06	1.55E+06	5.16E+05	1.56E+05	2.58E+05
Total (1000 kWh)	**1.45E+07**	**2.00E+07**	**2.40E+07**	**3.07E+07**	**3.27E+07**	**3.50E+07**	**3.61E+07**	**4.20E+07**	**4.64E+07**	**5.01E+07**

Concluding Remarks

Figure 5, shows the total electricity production from geothermal resources in West Coast from 2008 to 2050. The total amount of electricity production was $3.32*10^8$ kWh during a time range of 42 years (2008-2050) different geothermal conversion plants were located on specific areas. Figure 6; combine the electricity production with the average percent efficiency, η, for different conversion geothermal power. Such values are; Single flash power plants ($\eta_=$ 31%) $1.03*10^8$ kWh, Double flash power plants ($\eta_=$ 46%) $1.56*10^8$ kWh, and Binary power plants ($\eta_=$ 23%) $7.62*10^7$ kWh. It is important to keep the sustainability of resources as well beyond 2100, (DiPippo 1998).

Stage I: (2008-2030)

Distribution of estimated accessible resources from 2008 to 2030.

- The average heat content of 150 °C at depth of 6.5 Km, was $1x10^6$ EJ (1EJ = 10^{18} Joules).
- Use 2% of the total recover thermal energy ($Q_{rec} = 2.0 *10^{16}$ kJ) was used.

Stage II: (2030-2050)

Distribution of estimated accessible resources from 2030 to 2100.

- The average heat content of 200°C at depth of 6.5 Km, was 5.0×10^5 EJ ($1 EJ = 10^{18}$ Joules).
- Use 2% of the recover thermal energy ($Q_{rec} = 1.0 * 10^{16}$ kJ) was used.

Figure 5. Average electricity production from geothermal energy resources on West States.

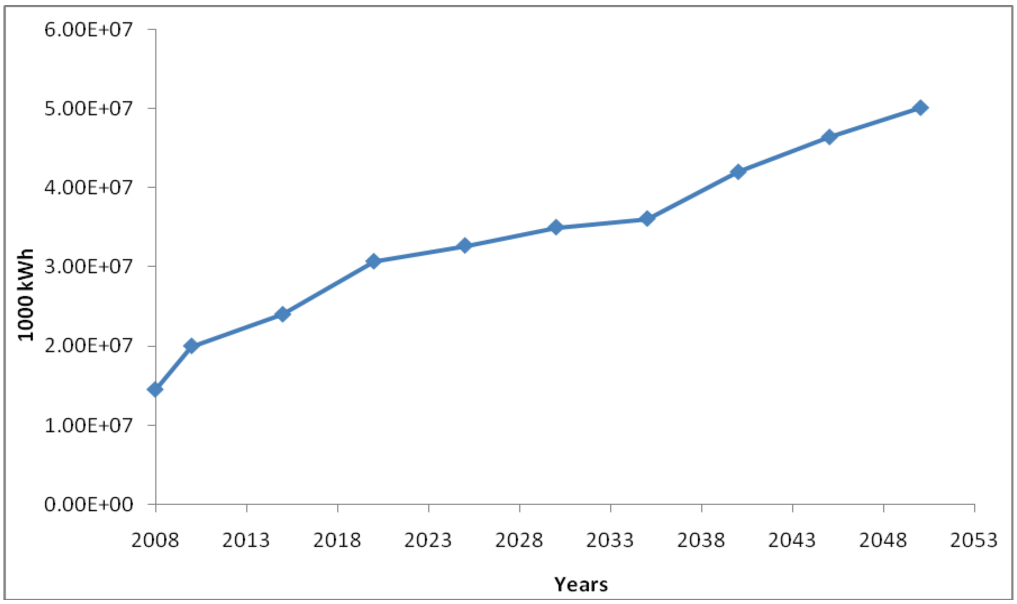
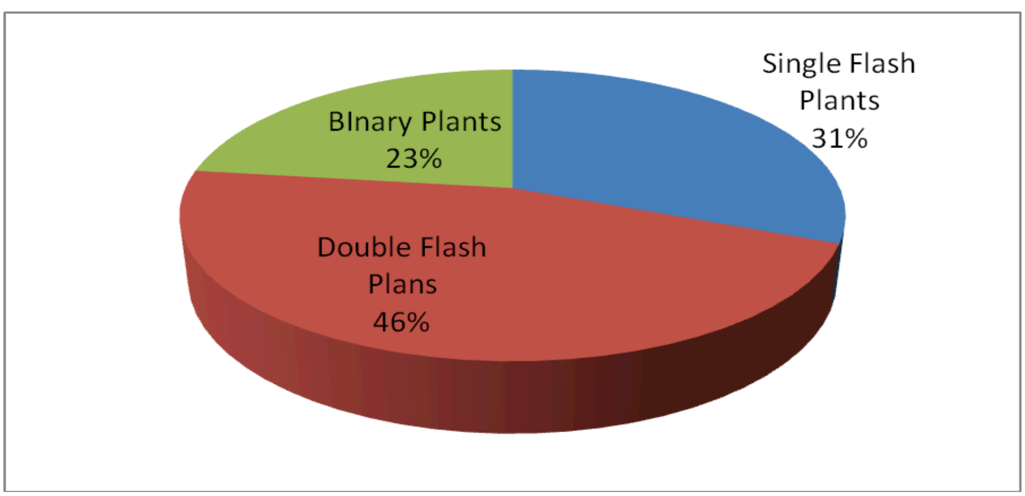


Figure 6. Composition of geothermal plants during (2008-2030).



3.5 Wave Power

Introduction

Wave energy is the capacity of the wave for doing work. The wave energy units are describes in terms of average annual power flux (kW/m of wave crest length). The power of waves is attached to the weather conditions (highly variable). The development of power-matrix in Figure 1 provides a constant energy density at different sea conditions (Pelamis, 2008). Although the oceans waves contain the higher energy density of all combine renewable resources. Total wave energy of the world oceans is $1{,}600 \times 10^{15}$ J, the total wave power in the world oceans is 90×10^{15} W. Vast amount of this energy is produced on a the Northern Hemisphere (35°-40° N) where the west coast longitudinal distribution of wave power is 4.182×10^{5} W.

Calculations

Energy and power, surface area mean power per unit crest width is described on equation – (4)-. On Figure 7(a), show the average values for Power flux (P) of 26.5, 21.1, and 20 kW/m were assumed on Washington, Oregon, California, respectively. Also a constant value for γ = Specific weight of sea water 10.05×10^{3} N/m^3 was assumed. Figure 7(b) shows different values of wave height (H /meter), and period (T /second) related to atmospheric conditions. In equation – (5) – the production power MWe was calculated, as a function of wave crest distance (km), from the available power flux values on equation-(4)-. The wave crest distance was determinate by the ocean surface area (Km^2).

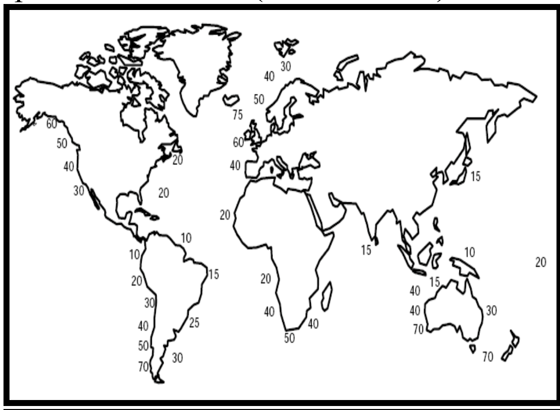
$P = \gamma*(g)*(H\hat{}2)*(T) / 32\pi$ [W/m] - (4)-

$P = (10.05*103 \text{ N/m3})*(9.81 \text{ m/s2})*(3.5 \text{ m})^{2} (1 \text{ year}) / (32\pi) = \underline{3.90*10^{9} \text{ kW/m}}$

kWh/yr = (Average annual Power Flux (kW/m)*(length (Km)) =

$\underline{14.0*10^{10} \text{ kWh/yr}}$ - (5)-

Figure 7. (a) World wave power flux (kW/m). (b) Wave height and period values related to atmospheric conditions. (Pelamis 2008)



Power period (T_{pow}, s)

Significant wave height (H_{sig}, m)	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0
0.5	idle	idle	idle	idle	idle	idle	idle	idle	idle	idle	idle	idle	idle	idle	idle	idle	idle
1.0	idle	22	29	34	37	38	38	37	35	32	29	26	23	21	idle	idle	idle
1.5	32	50	65	76	83	86	86	83	78	72	65	59	53	47	42	37	33
2.0	57	88	115	136	148	153	152	147	138	127	116	104	93	83	74	66	59
2.5	89	138	180	212	231	238	238	230	216	199	181	163	146	130	116	103	92
3.0	129	198	260	305	332	340	332	315	292	266	240	219	210	188	167	149	132
3.5	-	270	354	415	438	440	424	404	377	362	326	292	260	230	215	202	180
4.0	-	-	462	502	540	546	530	499	475	429	384	366	339	301	267	237	213
4.5	-	-	544	635	642	648	628	590	562	528	473	432	382	356	338	300	266
5.0	-	-	-	739	726	731	707	687	670	607	557	521	472	417	369	348	328
5.5	-	-	-	750	750	750	750	750	737	667	658	586	530	496	446	395	355
6.0	-	-	-	-	750	750	750	750	750	750	711	633	619	558	512	470	415
6.5	-	-	-	-	750	750	750	750	750	750	750	743	658	621	579	512	481
7.0	-	-	-	-	-	750	750	750	750	750	750	750	750	676	613	584	525
7.5	-	-	-	-	-	-	750	750	750	750	750	750	750	750	686	622	593
8.0	-	-	-	-	-	-	-	750	750	750	750	750	750	750	750	690	625

Concluding Remarks

Constant Values from 2008 to 2050: (Berdard 2002)

- 10% of the total West Coast wave energy resources was converted to installed power (MWe): 440TWh/year *(0.10) = <u>44 TWh /year</u>.
- Total wave energy of the world oceans: <u>1600x10^15 J.</u>
- Total wave power in the world oceans: <u>90x10^15 W.</u>
- Longitudinal distribution of wave power on the Northern Hemisphere (35-40 N): <u>4.182x10^5 W.</u>

Table 10. Basic information on life cycle analysis on wave energy conversion.

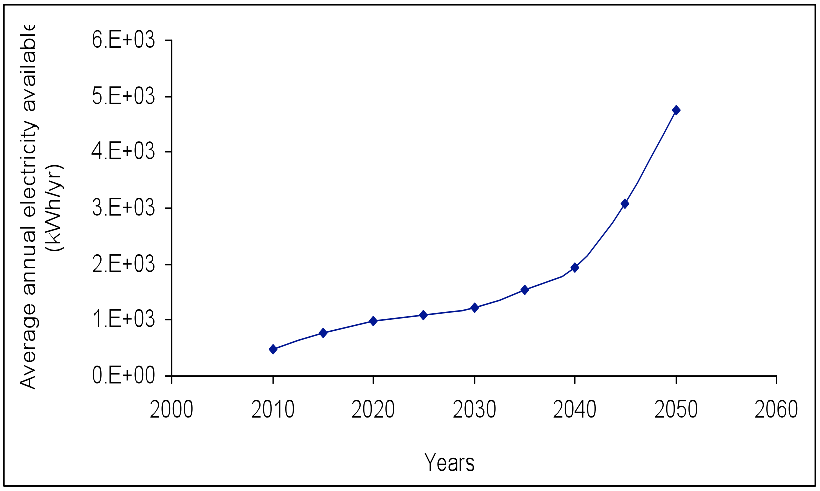
Power Plants	Capacity Factor (%)	Capital Cost ($/MW)	COE (cents/kWh)	CO2 (lbs/MWh)
Tidal In-stream	29 – 46	1.7 – 4.0	4 – 12	-
Wind (class 3-6)	30 – 42	1.2 – 1.6	4.7 – 6.5	-
Coal PC USC (2)	80	1.3	4.2	1760

Table 11. Average Power Flux on West coast

States	CA	OR	WA
Power-Flux (kW/m)	20.0	21.2	26.5

- Design and location are considered by wave climate, availability of grid connection, accessibility for the project team, likely response of the local community to the project, and tidal range (Belfast, 2002).

Figure 8. Average electricity production per 1Km^2 of West Coast.



- Wave energy is the capacity of the wave for doing work.
- The wave energy units are describes in terms of average annual power flux (kW/m of wave crest length). The power of waves is attached to the weather conditions (highly variable).
- The development of better (more detail/ computer simulation) power-matrix will increase the total electricity available on Figure 8.

4 Energy Conservation Estimates

4.1 Geothermal Heating

Introduction

Using geothermal heating for a building can significantly reduce the amount of electricity required to run a heating system. In addition, the cost of installing a geothermal heating system is more than paid back by the savings in heating costs (California Energy Commission, 2006). Installing geothermal heating in a new home can provide immediate pay back since the reduction in energy costs outweighs the increase in mortgage payments caused by financing the installation (California Energy Commission, 2006). With an existing building, the cost of retrofitting the heating system can be paid back in 2-10 years, while the underground piping is guaranteed to last 25-50 years (California Energy Commission, 2006).

To simplify the calculations required for this analysis, we have decided to look on using geothermal heating as an energy conservation technique, as you will see in the calculations section. In other words, the calculations below give the percent of energy savings that could be made by converting buildings that use conventional heating systems to geothermal heat.

Calculations

Calculations will be done by sector using data on the percentage of energy consumption allotted to space heating and air conditioning. To be able to determine the overall percent energy reduction in the West due to conversions to geothermal heating, we must first give the percent of energy used by each sector. Based upon 2004 data, the residential sector consumes 19.74% of the total energy used in the West, the commercial sector uses 18.30%, and the industrial sector uses 27.65% (D.O.E., E.I.A.-State Energy, 2008). The transportation sector is not relevant to our current calculations.

For the residential sector, according to a study by the EPA, energy bills could be reduced by 30-40% due to installation of a geothermal heating system (California Energy Commission, 2006). Since 30-40% seems to be an optimal case, we shall assume that there will be a 30% energy savings.

Another estimate states that converting to geothermal heat can save as much as 80% of heating costs (Pisupati, 2006). Since space heating uses 34% of residential energy and air conditioning uses 11% (D.O.E., Energy Savers: Home, 2008), that would give us 80%*(34+11%) = 36%, which is in line with our 30% estimate. Therefore, a conversion to geothermal heating in the residential sector can save:

(% energy consumption of Residential sector)*(% energy savings) ≈ 19.74% * 30% = 5.9% of the energy consumed in the West

For the commercial sector, assuming a geothermal heating system could save 80% of heating costs (Pisupati, 2006) but will save approximately 70% of the energy used for heating, and using the information that 4% of commercial sector energy consumption goes to space heating, and 10% goes to air conditioning (Flex Your Power, Commercial, 2008), we estimate that:

(% energy consumption of commercial sector)*(% heat energy savings)*(% heating/cooling costs) ≈ 18.30% * 70% * (4+11)% = 1.8 % of the energy consumed in the West

Similarly, for the industrial sector, 12% of the sector's energy consumption goes to HVAC systems (Flex Your Power, Industrial, 2008). Therefore,

(% energy consumption of industrial sector)*(% heat energy savings)*(% heating/cooling costs) ≈ 27.65% * 70% *12% = 2.3 % of the energy consumed in the West

Concluding Remarks

Based upon our calculations for each sector, we estimate that in both 2030 and 2050, converting all buildings to use a geothermal heating system can save:

5.9% + 1.8 % + 2.3 % = 10.0% of the annual energy consumption in the West.

4.2 Solar Heating

Introduction

As previously discussed in the solar energy section, solar is abundant energy resources and provides us various ways of utilization. In this section, solar heating, a great means of taking advantage of solar energy, is briefly reviewed. Solar water heating is one of most popular solar heating technologies for residential sector. Solar water heating systems could greatly enhance the energy efficiency at residential level by reducing the demand for hot water or air-conditioning. Structural sketches of typical active and passive systems are shown below.

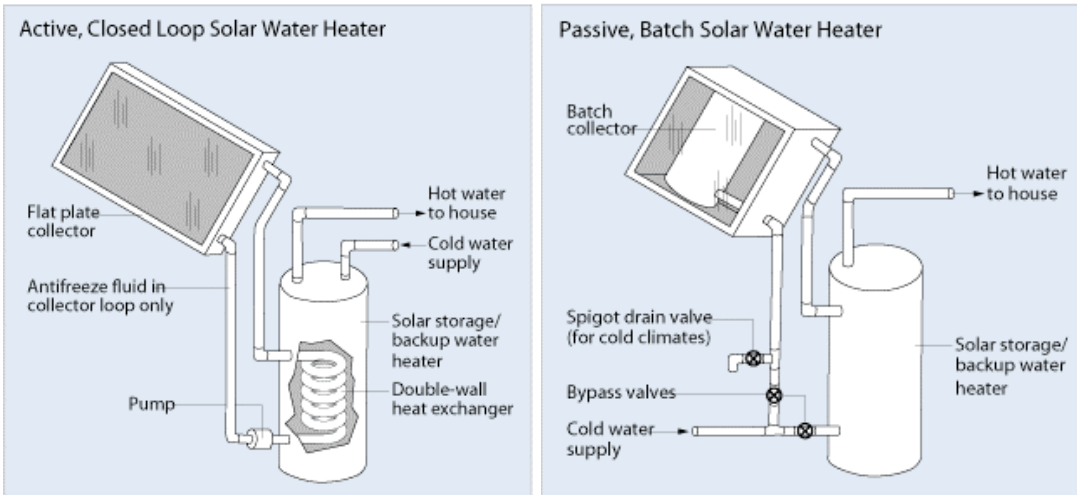


Figure 9. Solar water heating systems (DOE EERE Consumer's Guide)

Currently, only 10,000 systems are being installed in U.S.every year, while about a half million systems are deployed in EU. Based on the increasing market worldwide and the prospected incentives they could learn from EU countries, WGA have set a target of installing at least 500,000 systems by 2015.

Calculations

Here it is possible to estimate how much energy could be saved if we achieve the goal for solar water heating. Each system varies in size, but an average system size can be thought as 5 m^2 for calculation. Equivalency factor of 0.7 kW_{th}/m^2 is used to derive the equivalent electricity generation capacity per area of installed solar thermal collectors. Considering these factors, energy to be saved will be equivalent to

$$500{,}000 \times 5 \times 0.7 = 1.75 \times 10^6 \text{ kW}_{th} = 1750 \text{ MW}_{th} \ (1.5 \times 10^{10} \text{ kWh/year})$$

4.3 Vehicles

Introduction

Our previous literature review revealed that transportation sector is a great contributor for energy consumption in the West U.S. Approximately 35 % of energy was used for transportation in 2004. (EIA) Our main objective of this chapter is to assess the possibility of electric vehicles as a possible solution to the sustainable energy for transportation. Biofuel could be another part of the solution. However, we do not consider it as a good candidate in this report because there are some critical issues of current biofuel, especially corn ethanol, such as the required energy to produce it, environmental impact through excessive land development, and influences on food productions. Next-generation biofuel including cellulosic ethanol and other lignocellulose-derived fuel might be promising. More basic research on such area is necessary to eliminate concerns about biofuel.

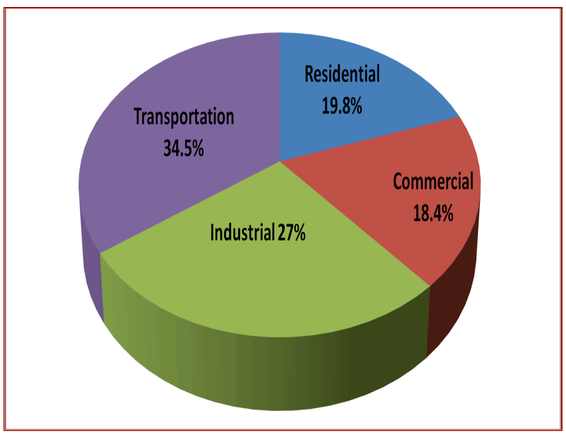


Figure 10. Energy consumption in the West by sector. (EIA)

Considering these difficulties of biofuels, we reached a notion that more electricity-based transportation system should ease the situation, instead of attempting to produce more conventional fuel from renewables. Electric motor produces no emissions and the efficiency should be higher than conventional engines. Therefore, we considered Electric Vehicle as a potential energy saver. There are three types of Electric Vehicles.

<u>Hybrid Electric Vehicle (HEV)</u>

HEVs are equipped with both of internal combustion engines (ICEs) and electric motors. ICEs combust gasoline or diesel fuel in the same way of conventional vehicles and rotate the wheels. Electric motors are powered by electricity stored in on-board batteries and giving additional rotation forces to wheels. The batteries can be recharged by storing the energy as the car slows down. Hybrid passenger cars were introduced into the U.S. market in 2000, and have been accepted as an environmental-friendly and better-fuel-economy car.

Plug-In Hybrid Electric Vehicle (PHEV)

A PHEV is a hybrid-electric vehicle (HEV) with the ability to recharge its electrochemical energy storage with electricity from an off-board source. (Market et al. 2006) PHEVs might be less costly for the consumer to drive than a gasoline-powered vehicle due to the relatively cheap cost of commercial electricity. However, this cost competitiveness should be carefully examined because, as repeatedly mentioned, electricity in U.S. is mainly generated using fossil fuels and the portion of electricity from renewable energy sources is currently negligible. Therefore, to make PHEVs a really clean technology to solve our issues clean power generation is essentially a part of the absolute requisites. It is thus important to enhance the integration with renewable electrical grid (Wind, Solar, Geothermal, Wave). Another factor to be considered is the validity of energy-equivalency of gasoline and electricity. In general, the energy content of 1 gallon of gasoline is equal to 33.44 kilowatt-hours. Although this is a very useful numbers for conversion, it should be noted that this does not include the differences in the supply-chain efficiency of each. Some loss of energy is inevitable during the electricity delivery, which makes it more difficult to conduct an accurate evaluation of EVs as an entire system.

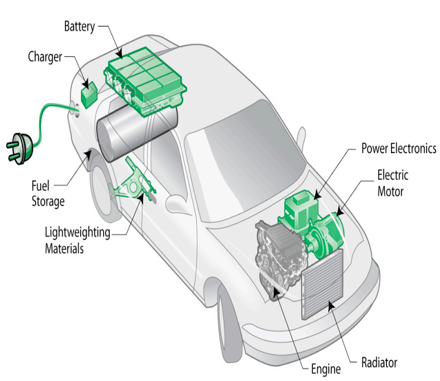


Figure 11. (a) PHEV components diagrams. (b) Argonne laboratory testing plug-in Pyrius model 2010, (Argonne, 2008).

Major challenge for PHEVs is the cost and weight of battery. Substantial funding at the federal and state levels for battery research is required.

Fuel Cell Vehicle (FCV)

Fuel Cell Vehicle is powered by the electricity generated from on-board fuel cell. Fuel cell could generate electricity via oxygen and either hydrogen or other fuel such as methanol. If it use hydrogen as a primary fuel, only by-product from the process is pure water. Fuel cell now draws much attention of many scientists and engineers mainly as a highly efficient clean technology. Yet FCVs are under developing stage and should not be considered feasible at this period of time. Some obstacles includes the cost of catalyst (Platinum) and the lack of sustainable hydrogen production method.

Calculations

In the West Coast the electricity rate from 9 to 12 cents per kilowatt-hour (kWh) was assumed. If a 30 to 40 miles of electric driving will cost 81 cents from a Plug-in, (PIHVE, 2007) then an average US fuel economy of 25 miles per gallon, at $3.00 gasoline will become approximately 75 cents a gallon for equivalent electricity (PIHVE, 2007). Also the Plug-in technology can be combined with different flexible fuel technology reducing the use of gasoline even more dramatically.

It was assumed that an average consumption of 12,000 miles annual driving on the west coast. Also an average from 12 to 16 MPG was assumed per car owner. Equation – (1)-(2), and (3) were used to determine gallons require CO_2e/gallon, and lb CO_2e/miles.

Average miles / Average MPG = 750 Gallons -(1)-

Gallons*(23.6 lb CO_2e/Gallon) = 17,700 lb CO_2e/year -(2)-

23.6 lb CO_2e/Gallon / Average MPG = 1.475 lb CO_2e/mile -(3)-

It was assumed that 1 gallon of gasoline burned was equivalent to 19 lb CO_2e/gallon for tank-to-wheels fuel, and 4.6 lb CO_2e/gallon for well-to-tank emissions, based on Technology and Cost Assessment for Proposed Regulations to Reduce Vehicle Climate Change Emissions Pursuant to Assembly Bill 1493 (California Air Resources Board, 2004).

The CO2e emission for plug-in hybrids communal of 12,000 miles is 4,623 lb CO2e/year (CO2e emissions from gasoline + CO2e electricity use). Now since our electricity is renewable the amount of CO2e from electric utility was cero. In equation (4), and (5) the values for average MPG = 16, and comparison average MPG = 32, respectively. In equation –(7)- shows the amount of electricity equivalent to a gallon of gasoline.

Average gallons used = 12,000 / 16 MPG = 750 Gallons -(4)-

Comparison gallons used = 12,000 / 32 MPG = 375 Gallons -(5)-

Gallons saved = 750 – 350 = 350 Gallons saved -(6)-

Electricity (kWh) consumed /Gallon Save

= (350 Gallons*33.44 kWh/1 Gallons) = 12, 540 kWh/yr -(7)-

The amount of barrel save were determined by equations –(8)-, -(9)-,and –(10)-. It was assumed 1 barrel of oil yields 20 gallons of gasoline. To calculate barrels of oil saved, we compare gasoline used for the comparison cars (plug-in Prius) to the average US fleet vehicle for a 12,000 mile annual driving cycle. The calculation was:

Average barrels used = 12,000 / (20 * average MPG) = 37.5 Barrels used -(8)-

Comparison barrels used = 12,000 / (20 * comparison MPG) = 18.75 Barrels used -(9)-

Percentage saved = 100 * (1 - comparison barrels used / average barrels used)

= 50% saved -(10)-

Table 12. PIHEV annual electricity consumption between 2020 and 2040.

Year	Total PIHEV	Electricity Consumption
2020	1 million	$1.25*10^{10}$ kWh/yr
2040	2 million	$2.51*10^{10}$ kWh/yr

Table 12 shows the amount of electricity consumption were required to supply enough power to 1 million and 2 million PIHEV cars on the streets by the year 2020 and 2040, respectively. The power requires will be produce by renewable resources such as wind, geothermal, and solar. It is noteworthy to mention that there is no intention to eliminate fossil fuel from transportation sectors.

We conducted another simple calculations with more aggressive assumptions to estimate the maximum of energy that could be saved using EVs in the West. Here we assume that all vehicles are powered by electricity and use no petroleum-based fuel, except aviation and water sectors. We surely understand the limited validity of this assumption. The purpose is to figure out how much impact EVs would potentially have. Energy efficiency of electric motors reaches 75 %, while conventional internal combustion engines only convert 20 % of the energy in gasoline to wheels. (DOE EERE Fuel Economy) This indicates that EV is approximately four times more efficient compared to the conventional vehicles. Table 13 summarize the results. It is shown that potential for energy saving by EVs is close to 10 % of total energy consumption. This indicates EVs could greatly contribute reduction of energy demand.

Basic calculation is shown below:

(Total Energy Consumption)*(0.34)*(0.84)*(0.75) = (Energy to be saved)

(Total Energy Consumption) – (Energy to be saved) = (Energy demand for EVs)

Percentage of transportation sector (2004): 34.5 %

Percentage of vehicle sector among transportation (2007): 83.8 %

Energy saving: 75 %

Table 13. Potential for energy saving by complete implementation of EVs

Year / Energy (kWh)	2005	2030	2050	
Energy Consumption Projection	5.46E+12	7.41E+12	9.35E+12	↓ 34.5%
Transportation	1.88E+12	2.56E+12	3.23E+12	↓ 83.8%
Consumption by Vehicles	1.58E+12	2.14E+12	2.70E+12	
Energy saved by EV	4.21E+11	5.71E+11	7.21E+11	
Energy required for EV	1.16E+12	1.57E+12	1.98E+12	

Concluding Remarks

As presented above, we could expect a significant improvement of energy efficiency for transportation if broad use of PHEVs can be realized. Although we need to make sure the primary source for electricity should come from renewables, EVs could potentially remove CO_2 emission by 80-90 and save nearly 10 % of entire energy consumption in U.S. Some obstacles that would hamper this ambitious goal are battery capacity, weight, and cost. Despite these challenges, however, more EVs are now being introduced into market in froms of HEVs. This trend clearly tells us that this technology is not a complete shift of our current system and there are already a firm basis and climate for gradual growth of its market. What it is expected is to stimulate this trend of seeking better fuel economy and accelerate PHEVs technology.

4.4 Appliances, Lighting, and Insulation

Introduction

From the statistics of DOE, electricity usage for heating and lighting in residential, commercial, and industrial sectors are about 30% of total electricity usage for each sector.

Replacing current bulbs and windows with more efficient bulbs and Low-Emission (Low E) glass windows for a building can significantly reduce the amount of electricity required for lighting and heating. For example, replacing one 60-watt incandescent bulbs with 13-watt compact fluorescent bulbs models could save about $40 per year. In addition, Low E glass windows help to reduce condensation on glass. The inside surface temperature of the glass is warmer. The differences can be dramatic. Imagine a cold night with an outside temperature of 0 degrees and a 15 mph wind. The inside temperature of a single pane window would be approximately 26 degrees. Regular double pane glass might register 35 degrees. Hard coat low E glass would be very near 49 degrees. And weighing in at champ would be soft coat low E glass at 62 degrees.

To simplify the calculations required for this analysis, we have decided to look on replacing 60-watt incandescent bulbs with 13-watt compact fluorescent bulbs and replacing single pane windows with soft coat low E glass windows to heat up until 25 degree C.

Calculations

Calculations will be done by sector using data on the percentage of energy consumption allotted to space heating and lighting in residential, commercial, and industrial sectors. To be able to determine the overall percent energy reduction in the West due to using 13-watt compact fluorescent bulbs and soft coat low E glass windows, the residential sector consumes 19.74% of the total energy used in the West, the commercial sector uses 18.30%, and the industrial sector uses 27.65% (D.O.E., E.I.A.-State Energy, 2008). The transportation sector is not relevant to our current calculations.

Second, consumption percentage of heating and lighting in different sectors should be considered. For residential sectors, they are 11% and 34% for lighting and heating respectively. Also, they are 22% and 4% in commercial sectors and 10% for lighting in industrial sector.

Table 14. Energy percentage of sector's energy use

	% of Sector's Energy Use									
Sector	Lighting	Space Heating	A/C	Fridges & Freezers	Appliances	Water Heating	TV, Comp. & Office equip	Pools & Spas	Dishwashers & Cooking	Laundry
Residential	11	34	11	8	11	13				
Commercial	22	4	10	19	11	3	15	6	5	5
	Lighting	HVAC	Process Heat	Compressed Air	Process Fans	Material Handling	Process Refridgeration	Material Processing	Process Pumping	Other
Industrial	10	12	11	8	7	6	5	15	13	13

Sources: (D.O.E., Energy Savers: Home, 2008; D.O.E., Energy Savers: Lighting, 2008; Flex Your Power, Commercial, 2008; Flex Your Power, Industrial, 2008)

Table 15. Electricity Conservation in sectors for lighting and heating

Sectors	Total Electricity Consumption in the west (2004) (kWh)	Total Electricity Consumption in the west by sectors(2004) (kWh)	Electricity Consumption for Heating (2004) (kWh)	Electricity Consumption for Lighting (2004) (kWh)	Electricity Conservation for heating with soft coat low E glass windows(kWh)	Electricity Conservation for lighting with compact fluorescent bulbs(kWh)
Residential	212.67 E+10	41.98 E+10	14.27 E+10	4.62 E+10	11.65 E+10	3.62 E+10
Commercial		38.92 E+10	1.557 E+10	8.57 E+10	1.27 E+10	6.71 E+10
Industrial		58.80 E+10		5.90 E+10		4.62 E+10
Total					12.92 E+10	14.95 E+10

Concluding Remarks

As shown in Table 15, based upon our calculations for each sector, we estimate that in 2004, replacing with 13-watt compact fluorescent bulbs models and ingle pane windows with soft coat low E glass windows can save: 12.92 E+10 kWh and 14.95E+10 kWh, respectively.

5 Energy Consumption vs. Available Clean Energy

5.1 Energy Consumption Projections: 2030 and 2050

As we discussed in literature review, energy consumption projection could be based on population growth and energy consumption usage percentage in each sectors. In final report, we choose our energy consumption projection based upon population growth. In 2030, the total energy consumption is about 7.41 E+10 kWh in the West. In 2050, the total energy consumption is about 9.35 E+10 kWh in the West. The projection is shown as Figure 12 below. Also, in Figure 12, it shows the energy consumption in residential, commercial, industrial and transportation sectors.

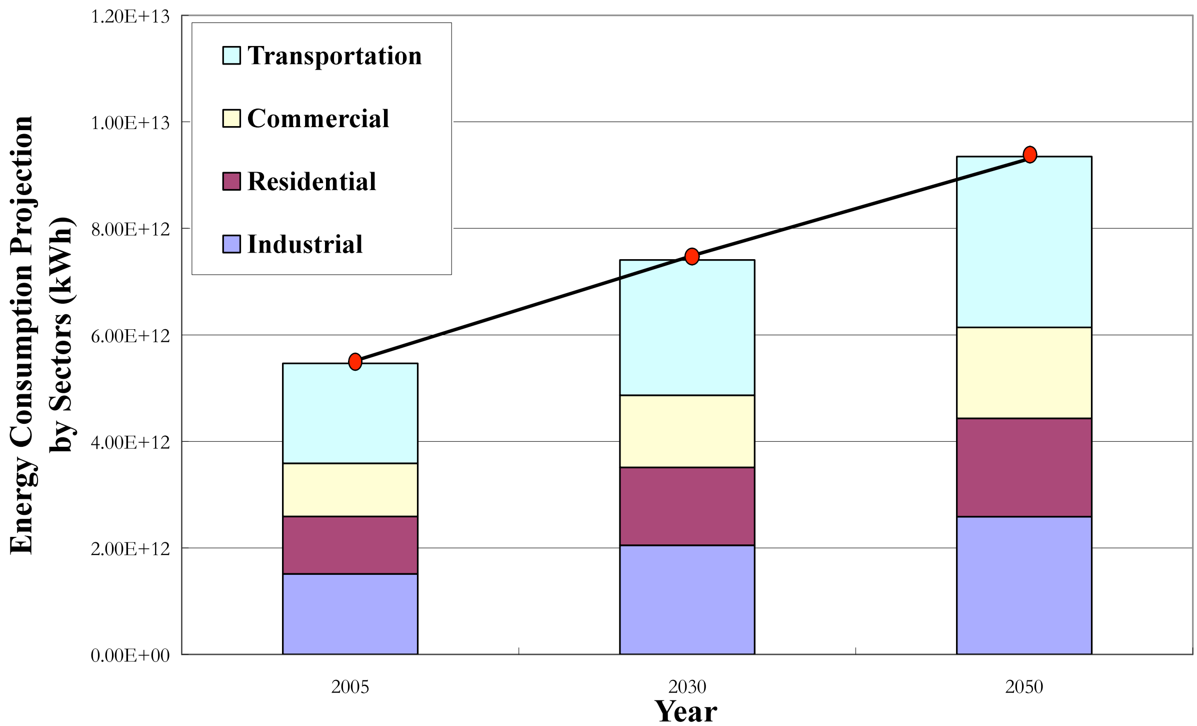


Figure 12. Energy Consumption in 2030 and 2050

5.2 Total Energy Available from Clean Energy Sources: 2030 and 2050

In table 16, it shows the energy consumption projection and the total energy available from clean energy sources for 2005, 2030, and 2050. In all renewable energy resources, Wind energy shows abundant energy available to meet the energy demand in 2030 and 2050 in the west of the United States. Also, solar, geothermal, and wave/tidal energy also provide energy to meet our objective.

Table 16. Total Energy Available from Clean Energy Sources: 2030 and 2050

Year / Energy (kWh)	2005	2030	2050
Energy Consumption Projection	5.46E+12	7.41E+12	9.35E+12
Hydropower	1.19E+08	1.19E+08	1.19E+08
Wind, Inland U.S., Contiguous West	-	1.13E+12	2.17E+12
Wind, Offshore U.S., Contiguous West	-	7.57E+13	8.05E+15
Wind, Inland AK	-	1.93E+12	2.91E+12
CSP	-	4.80E+11	1.10E+12
Solar PV	-	3.00E+11	3.60E+11
Geothermal	1.45E+10	3.50E+10	5.01E+10
Wave/Tidal	1.40E+11	2.20E+11	1.10E+12
Energy Conservation Projection	-	2.02E+12	2.54E+12
Total Renewables Available (Excluded Offshore Wind)	-	3.88E+12	6.59E+12
Total Renewables Available(Included Offshore Wind)	-	7.96E+13	8.06E+15

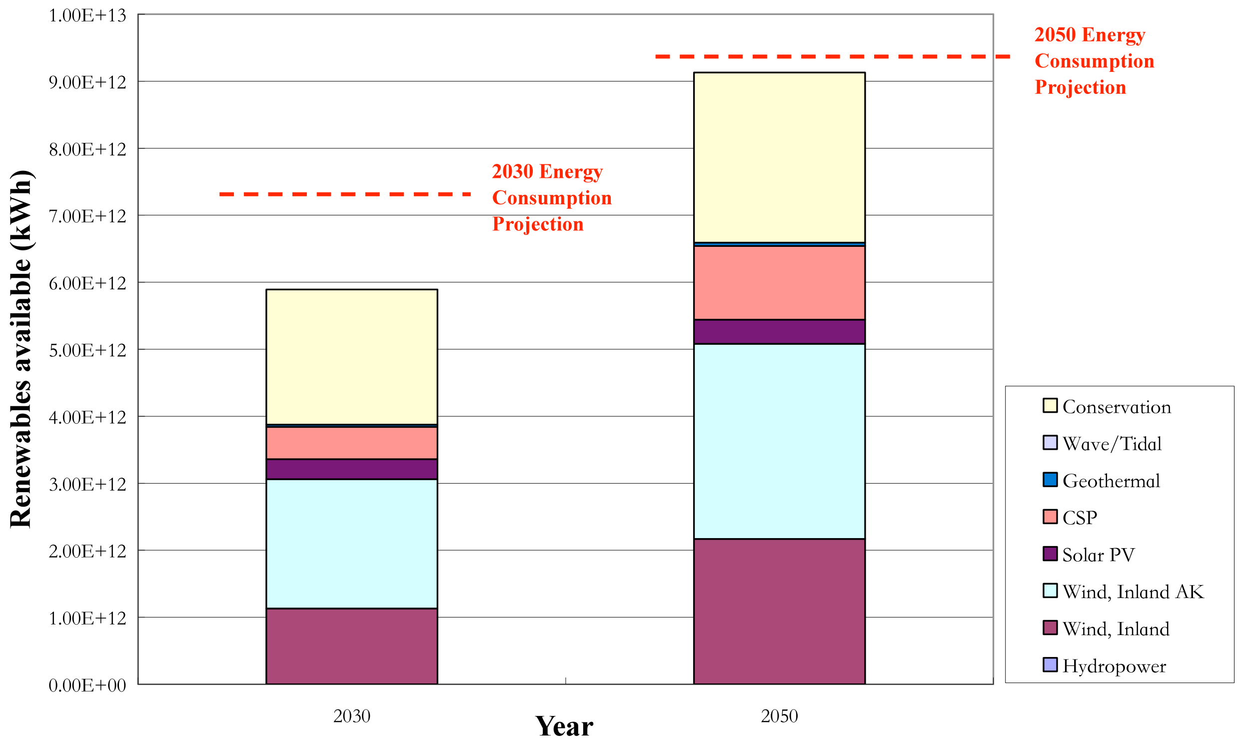


Figure 13. Total Renewable Energy Resources Available (Excluded Offshore Wind)

In figure 13, it shows total renewable energy resources available (excluded offshore wind) in 2030 and 2050. The red dash line indicates the energy consumption projection in 2030 and 2050 respectively. We could notice that total renewable energy resources without offshore wind energy will not be enough to meet the demand of energy consumption in 2030 and 2050. However, it also shows in the west of the United States, we will have almost enough energy to meet the demand of energy consumption in 2050.

6 Conclusion

In implementing renewable power, we would want to start with the most viable of today's technology with the greatest amount of power, so our research would indicate that we should start with the implementation of offshore wind power where it is feasible. Inland wind is also a currently developable resource. With the carbon tax, wind power will be cheaper than the fossil fuel generated electricity, encouraging utilities to build wind rather than fossil fuel power plants. Concentrating solar power (CSP) can also be employed using current technology, and, in the West, the best areas for CSP are in areas where wind potential is less prominent, so solar power can help supply areas without wind resources. If there are areas without a local, reliable power supply and current technology has not been developed to the point that one of our renewable sources can supply enough reliable electricity, nuclear power could be implemented in the short run and later replaced by renewable energy sources. Due to our carbon tax, we can assume that renewable resource based power will be comparable and even advantageous in price to fossil fuel based power. This is one of the main reasons we believe renewable powered electricity plants will be willingly installed by utilities.

A large part of our plan's implementation involves conserving energy and therefore not needing to build as many new, renewably powered electricity plants. Based upon our calculations, we can conserve at approximately 30% of the projected energy consumption due to conservation. However, this is a conservative estimate because we were not able to account for conservation that results from our policies for extended public transportation, stricter building codes, more efficient appliances, and increased building insulation. Therefore, we believe that we may be able to conserve an even greater percentage of the projected energy consumption, making implementing renewable power a more reasonable feat.

As shown in Table 17, based upon the energy consumption projections and projections of renewable energy resources available, we have concluded that for both 2030 and 2050, we are able to meet energy consumption needs with renewable energy. From the calculations given in this report, we believe that the implementation of offshore wind resources is one of the most promising renewable energy source and is currently one of the cheapest renewable energy resources. Conservation can significantly reduce the energy consumption demands in the West, and full implementation of renewable energy resources can provide more energy than the demand created in the West.

Table 17. Total Energy Available from Clean Energy Sources: 2030 and 2050

Year / Energy (kWh)	2005	2030	2050
Energy Consumption Projection	5.46E+12	7.41E+12	9.35E+12
Hydropower	1.19E+08	1.19E+08	1.19E+08
Wind, Inland U.S., Contiguous West	-	1.13E+12	2.17E+12
Wind, Offshore U.S., Contiguous West	-	7.57E+13	8.05E+15
Wind, Inland AK	-	1.93E+12	2.91E+12
CSP	-	4.80E+11	1.10E+12
Solar PV	-	3.00E+11	3.60E+11
Geothermal	1.45E+10	3.50E+10	5.01E+10
Wave/Tidal	1.40E+11	2.20E+11	1.10E+12
Energy Conservation Projection	-	2.02E+12	2.54E+12
Total Renewables Available (Excluded Offshore Wind)	-	3.88E+12	6.59E+12
Total Renewables Available(Included Offshore Wind)	-	7.96E+13	8.06E+15

By reviewing literature, we reached a conclusion that the transportation sector requires a fundamental shift of its power system because the overall efficiency of traditional engines is very low and stimulating production of biofuel is not likely to help meeting our fuel demand. Also, it was revealed that bioethanol, especially corn ethanol does not necessarily have a positive impact on climate change and environmental issues. These considerations led us to support more aggressive development and broader use of electric vehicles (EV). The efficiency of electric motors is almost 4 times higher than that of internal combustion engines. Substantial replacement of passenger car with EVs could potentially remove CO_2 emission by 80-90 % within the transportation sector. This would also save nearly 10 % of entire energy consumption in U.S. The development of better batteries is a major challenge for implementing EVs. Sufficient investments should be to achieve a higher battery capacity with reduced weight and cost.

One of our primary objectives was to reduce emissions, especially CO_2 emissions. Since we plan to replace all current electricity sources with renewable energy sources and to replace the personal transportation fleet with electric hybrid vehicles, the only emissions that we would still have is from the portion of the transportation sector that we could not replace with electricity powered vehicles. Based upon our calculations in the electric vehicle section, transportation that won't be powered by electricity accounts for approximately 16% of the transportation sector. Since the transportation sector accounts for approximately 34% of the total energy consumption, we would only have 5% of the CO_2 emissions originally projected for both 2030 and 2050. Reducing CO_2 emissions by 95% of our projection shows our emission reduction objective was successfully met.

Several possible reasons for error in the implementation of our sustainability plan exist. We were unable to fully calculate the expense of transferring to renewable energy sources, and therefore the plan might be held back by financial constraints. There is the possibility that new renewable energy sources will be created in the future that will surpass current resources, for example, fusion might be the cheapest renewable energy source in the future. Our calculations are based upon current technology and the predictions made about future technology, which might not be accurate. Our calculations were also based primarily upon maximum implementation of renewable resources, which might receive resistance both financially and socially. If there is an unexpected jump in fossil fuel prices, renewable energy resources will be developed quickly, but if there is an unexpected slump in fossil fuel prices, the implementation of renewable resources would meet with resistance. Our energy consumption projections are also based upon the populations growing at its current rates. It is unlikely that the population will increase at greater rates but if it did, energy demand would be above our projections. If the population grows at lower rates or stagnates, energy demand will be below our projections and meeting the West's energy needs with renewable energy will be easier. These are several possibilities that would impact the projections and plan we have discussed.

We feel that this plan achieves the objectives of reducing of emissions, implementing renewable energy, reducing and eventually eliminating the use of fossil fuels, and producing enough energy to meet the needs of the people in the Western region of the United States. In conclusion, there are multiple setbacks to the implementation of our sustainability plan, but we believe we have reached a feasible plan for achieving sustainability in the West.

References

Alliance to Save Energy (2005). Promoting Energy Efficiency World Wide: News: Arizona Statewide EE Policies. Retrieved February 8, 2008, from Web site: http://www.ase.org/content/article/detail/2544

Alliance to Save Energy (2005).Promoting Energy Efficiency World Wide: News: California Statewide EE Policies. Retrieved February 8, 2008, from Web site: http://www.ase.org/content/article/detail/2546

Alliance to Save Energy (2005). Promoting Energy Efficiency World Wide: News: Oregon Statewide EE Policies. Retrieved February 8, 2008, from Web site: http://www.ase.org/content/article/detail/2580

Alliance to Save Energy (2005). Promoting Energy Efficiency World Wide: News: Washington Statewide EE Policies. Retrieved February 8, 2008, from Web site: http://www.ase.org/content/article/detail/2591

Argonne National Laboratory (2006). Argonne to lead DOE's effort to evaluate plug-in hybrid technology. Retrieved April 18, 2008, from Web site: http://www.anl.gov/Media_Center/News/2006/ES061201.html

Blumsack, S. (2008, March). *Short run effects of a price on CO_2 emissions from US electric generators*. University Park, PA: The Pennsylvania State University.

California Air Resource Board (2008). California Environmental Protection Agencies. Retrieved April 18, 2008, from Web site: http://www.arb.ca.gov/cc/ccms/ccms.htm

California Energy Commission (2006). Geothermal Heat Pumps. Retrieved February 8, 2008, from Web site: http://www.consumerenergycenter.org/home/heating_cooling/geothermal.html

Center for Sustainable Building Research, Alliance to Save Energy, and Lawrence Berkeley National Laboratory (2008). The Efficient Windows Collaborative: Window Technologies. Retrieved April 18, 2008, from Web site: http://www.efficientwindows.org/lowe.cfm

Creative Energy technology Inc (2008). Compact Fluorescent Light Bulbs, CFL, Energy Star Rated Bulbs. Retrieved April 17, 2008, from Web site: http://www.cetsolar.com/compactfluorescent.htm

Danish Wind Industry Association (2003). Wind Energy Concepts. Retrieved March 28, 2008, from Web site: http://www.windpower.org/en/stat/unitsw.htm

Danish Wind Industry Association (2003). Size of Wind Turbines. Retrieved March 28, 2008, from Web site: http://www.windpower.org/en/tour/wtrb/size.htm

Dvorak, M.J., Jacobson, M.Z., Archer, C.L. (2007). California offshore wind energy potential. Proceedings from Windpower 2007*: American Wind Energy Association Windpower 2007 Conference & Exhibition*, June 36, 2007, Los Angeles, CA: AWEA.

Eartheasy (2008). Energy-Efficient Lighting. Retrieved April 14, 2008. From Web site: http://www.eartheasy.com/live_energyeff_lighting.htm

Elliot, D.L., Wendell, L.L., & Gower, G.L., (1991). An assessment of available windy land area and wind energy potential in the contiguous United States. Pacific Northwest Laboratory, US Department of Energy. PNL-7789.

Flex Your Power (2008). Flex Your Power-Commercial Sector. Retrieved February 20, 2008, from Web site: http://www.fypower.org/com/

Flex Your Power (2008). Flex Your Power-Industrial Sector. Retrieved February 20, 2008, from Web site: http://www.fypower.org/ind/

Haley, J. (2008). Landowners' Frequently Asked Questions about Wind Development. Retrieved March 28, 2008, from EERE Web site: http://www.eere.energy.gov/windandhydro/windpoweringamerica/pdfs/wpa/34600_landowners_faq.pdf

Lenzen, M., & Munksgaard, J. (2002). Energy and CO2 life-cycle analyses of wind turbines - review and applications. *Renewable Energy, 26*(3), 339-362.

Markel. T. Brooker. J., Gonder. M., O'Keefe. A., Simpson. A., and Thornton. M. (2006). Plug-In Hybrid Vehicle Analysis. Milestone Report NREL/MP-540-40609 November 2006. Retrieved April 18, 2008, from Web site: http://www.westgov.org/wga/initiatives/transfuels/NREL_PEVAnalysis.pdf

Milgard Windows, Inc. (2008). Energy Efficient and Insulated Windows, by Milgard Windows. Retrieved April 18, 2008, from Web site: http://www.milgard.com/getting-started/energy-efficiency.asp

Musial, W. (2005). Offshore Wind Energy Potential for the United States. Proceedings from *Wind Powering America -Annual State Summit*, May 19, 2005, Evergreen Lake House, Evergreen Colorado.

National Renewable Energy Laboratory (2008). Solar irradiation map. Retrieved March 30, 2008, from Web site: http://www.nrel.gov/analysis/repis/online_reports.asp

PIHVE (2008). Pug-In Hybrids Use Cheaper Cleaner, Domestic, Domestic Energy. Retrived April 18, 2008, from Web site: http://www.calcars.org/vehicles.html

Pisupati, S. (2006). "EGEE 101: Energy and the Environment." The Pennsylvania State University. University Park, PA.

Sahin, A. D., Dincer, I., & Rosen, M. A. (2006). Thermodynamic analysis of wind energy. *International Journal of Energy Research, 30*(8), 553-566.

Schleisner, L. (2000). Life cycle assessment of a wind farm and related externalities. *Renewable Energy, 20*(3), 279-288.

U.S. Census Bureau (2007). State Interim Population Projections by Age and Sex: 2005-2030. Retrieved April 13, 2008, from Website: http://www.census.gov/population/www/projections/projectionsagesex.html

U.S. Department of Energy (2005). EERE Consumer's Guide: Compact Fluorescent Lamps. Retrieved April 14, 2008, from Web site: http://www.eere.energy.gov/consumer/your_home/lighting_daylighting/index.cfm/mytopic=12050

U.S. Department of Energy (2005). EERE Consumer's Guide: Solar Water Heaters. Retrieved March 30, 2008, from EERE Web site: http://www.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12850?print

U.S. Department of Energy (2005). Wind and Hydropower Technologies Program: Wind Energy Resource Potential. Retrieved February 8, 2008, from EERE Web site: http://www1.eere.energy.gov/windandhydro/wind_potential.html

U.S. Department of Energy (2006). Solar Energy Technologies Program: Program Areas. Retrieved March 30, 2008, from EERE Web site: http://www1.eere.energy.gov/solar/program_areas.html

U.S. Department of Energy (2006). Wind and Hydropower Technologies Program: How Wind Turbines Work. Retrieved March 28, 2008, from EERE Web site: http://www1.eere.energy.gov/windandhydro/wind_how.html

U.S. Department of Energy (2007). Electric Power Monthly-Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State. Retrieved April 3, 2008, from EERE Web site: http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html

U.S. Department of Energy (2007). Energy Information Association – Annual Energy Review. Retrieved April 15, 2008, from Web site: http://www.eia.doe.gov/emeu/aer/

U.S. Department of Energy (2008). EERE Energy Savers: Your Home's Energy Use. Retrieved February 20, 2008, from EERE Web site: http://www1.eere.energy.gov/consumer/tips/home_energy.html

U.S. Department of Energy (2008). EERE Fuel Economy. Retrieved April 20, 2008, from EERE Fuel Economy Web site: http://www.fueleconomy.gov/Feg/evtech.shtml

U.S. Department of Energy (2008). EIA Renewable Energy-Solar Photovoltaic Data and Information. Retrieved April 2, 2008, from Web site: http://www.eia.doe.gov/cneaf/solar.renewables/page/solarphotv/solarpv.html

U.S. Department of Energy (2008). Electric Vehicle Information. Retrieved April 20, 2008, from EERE Web site: http://www.eere.energy.gov/afdc/vehicles/electric.html

U.S. Department of Energy (2008). Energy Information Administration – State Energy Profiles energy data, information, and maps. Retrieved January 21, 2008, from Web site: http://tonto.eia.doe.gov/state/

U.S. Department of Energy (2008). Energy Information Administration, U.S. data projection (2004): CO_2 emission (AEO, yearly projection to 2030). Retrieved April 15, 2008, from Web site: http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_18.xls

U.S. Department of Energy (2008). Energy Information Administration, U.S. data projection (2004): Energy Supply & Demand Overview (AEO, yearly projection to 2030). Retrieved April 15, 2008, from Web site: http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_1.xls

U.S. Environmental Protection Agency and U.S. Department of Energy (2008). Anatomy of an Energy Efficient Window: ENERGY STAR. Retrieved April 18, 2008, from Web site: http://www.energystar.gov/index.cfm?c=windows_doors.pr_anat_window

U.S. Environmental Protection Agency and U.S. Department of Energy (2008). Compact Fluorescent Light Bulbs: ENERGY STAR. Retrieved April 14, 2008, from Web site: http://www.energystar.gov/index.cfm?c=cfls.pr_cfls

Western Governors' Association (2006). Clean and Diversified Energy Initiative Solar Task Force report. Retrieved April 2, 2008, from Web site: http://www.westgov.org/wga/initiatives/cdeac/Solar-full.pdf

Western Governors' Association (2007). Clean and Diversified Energy Initiative 2005-2007 Progress report. Retrieved April 2, 2008, from Web site: http://www.westgov.org/wga/publicat/CDEACReport07.pdf

Western Governors' Association (2008). Transportation Fuels for the Future (2008). Retrieved April 20, 2008, from Web site: http://www.westgov.org/wga/publicat/TransFuels08.pdf

Wiser, R. & Bolinger, M. (2006). Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends: 2006. Retrieved February 8, 2008, from EERE Web site: http://www1.eere.energy.gov/windandhydro/pdfs/41435.pdf