Electricity Generation, Distribution and Free Markets

An Interactive Qualifying Project Report
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by

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Abstract

We study issues pertaining to electricity markets, from technical aspects in generation and distribution to their social and economic impact. We investigate details of electricity generation, transmission and distribution, leading to discussions with environmental, economic and political ramifications. Pros and cons of deregulation policies for electricity markets are reviewed, exploring the nature of this market and analyzing current issues in deregulation. The evidence suggests that a hybrid system of regulation and free markets may be optimal.

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1. Introduction

Today's life style for most people requires the use of electricity. We use electricity in order to keep our food cold, to cook, to get the weather forecast, find out about the traffic condition, transfer money and use our computer at work. Without having electricity life is hard for everyone. We wouldn't find out how this electrical energy is important in our life unless we lose it for only a few hours.

The production of electricity starts with converting other sources of energy to electrical energy; this process is usually done with generators. Usually the main sources that the generators use to convert energy to electrical energy are fossil fuel, nuclear energy, wind power, solar energy and hydropower. In the past the generation companies were handling the generation, transmission and distribution, but with the start of the twentieth century the electricity market entered a whole new phase. The monopoly electricity market that used to be regulated from bottom to top by state and federal government is now entering the phase of competition and deregulation. As a result of this, the users have to pay lower prices than before. Now generators, transmission companies and distribution companies are working separately but in one united system. The generators provide the electricity and sell it to distributors through transmission companies. The distribution companies are in charge of the billing and distribution of the electricity.

Now regulation by state still makes some rules over the whole market but not as much as when the whole system was monopoly. In today's market the distribution and the transmission companies are more regulated than the generation companies, and the reason for this is because there is less competition in them.

The primary goal of this paper is to shed some light into the very current issue of electricity markets. In particular, we would like to understand better the pros and cons of the current deregulation policies across the USA. In order to do that, we will first investigate some general technical aspects regarding generation, transmission and distribution. Along the way, we will point out economic, environmental, and political issues that arise. Finally, we will describe the current state of the electricity market in the USA, and some recent crises. We hope, this project contributes to a better understanding of the complexities that permeate the electricity market in the USA.

2. Generators

Basically production of electricity from other energy sources happens by generators; usually the generators use fossil fuels, nuclear fission, water falls, wind and solar power.

The demand for power is mostly dependent on the contract that is made between the generator and the distributor companies. This is mostly dependent on the time of the day, the season of the year, the weather, the amount of users and the level of economic activities. The three important aspects that generators and distributor companies have to be aware of are: base load demand, peak load and intermediate. The base load is the amount of electricity that is approximately constant from day to day. The Peak load is the time that the electricity demand reaches to its extreme due to the hot time of the year that people have their air conditioner on. The period of time that demands changes between the peaks and bases is intermediate.

Because storing electricity in batteries is not an efficient solution in high voltage, the generators have to always provide electricity base on demand for distributor companies. The problem with generating at all time is that all generators cannot be fully operational all of the time. There are four factors that can help to determine which generators to use during peak, base load and intermediate demand: variable cost, ramping cost, transmission constraints and environmental considerations.

Any company has two different basic costs, the fix cost which is mostly the cost for equipment and building and the variable cost which is the cost that is usually smaller and is distributed over time. In the generation companies, the variable cost is the cost that depends on how much power the generators are generating. The cost for fuel to run the generator is the most important part of the variable cost. Usually in the generation business the generators which have the lowest variable cost to generate electricity are the ones that are usually used to meet the base load demand (i.e. Nuclear and coal power plants).

The ramping cost is the cost to turn the generators on. Some generators take a long time to warm up and get back online, but some are easy and cheap to turn on and off. It is more efficient to use the generator with the lower ramping cost for the peak load (i.e. hydroelectric and combustion turbines).

Another issue with the generators is that they should meet the transmission line's capacity. If the transmission lines are not powerful enough to handle the load from the generator it will be loss in the power lines, which means that the system would not be efficient.

The fixed cost, variable cost and the ramping cost are not the only costs that the generator companies have to be concerned about; another important issue is the environmental problem. Most of the generators expose hazards in environment; in order to prevent the environment from getting destroyed by these hazards, these companies have to pay fees to the government for the damages to the environment.

In United States, the Nuclear and coal power plants are usually used to meet the base load period, since they have a high ramping cost and low variable cost; because of the low variable cost, the coal and nuclear energy make up 52% and 20% respectively of USA's electricity production. Depending on the fuel price and plant location the hydroelectric power plants (8% of US electricity production) and gas turbines (2% of US electricity production) are used during the intermediate period. The figure below presents the US electricity production by different generators.

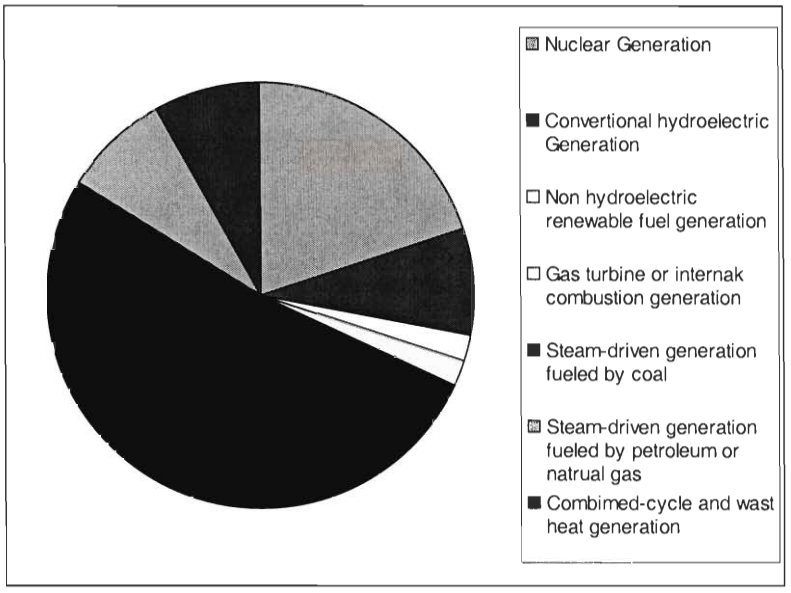


Figure 1: Percentage share of electricity generation by technology and fuel, 1999

The base of electricity market is generation companies, these companies are in charge of converting other energy to electricity, the conversion of electricity from other sources is explained in the next few sections.

2.1 Fossil Fuels

There is imminent concern over the future availability of fossil fuel in that the current supply and demand indicators point to a near term shortage. A shortage will occur years before these fuels are completely exhausted but there will come a peak for each of the fuels in which the amount of fuel being produced will peak and began a decline. From the point at which production of that fuel peaks on, there will be a shortage in that demand will not be met by the amount of fuel produced/recovered. There is a general consensus that the peak for oil will be the first to show itself along with natural gas and coal respectively. Some believe the production of oil is currently at its peak, although it will take a couple of years to verify this claim. Natural Gas production is expected to peak within a decade or so following the peak of oil while there may be significant coal supplies lasting a hundred years.

While energy is one market for fossil fuels, it must be considered that fossil fuels, especially oil, are used substantially for other industries as well. For instance, roads, plastics, rubber, etc… all require oil to be produced. Thus these industries play a role in the depletions of such resources and are susceptible to disaster should these fuels become unavailable or prohibitively expensive for viability.

Environmental

The primary pollutant common to all fossil fuels is Carbon Dioxide (CO_2). CO_2 emissions are dependent on a variety of factors associated with the combustion of fossil fuels. The more carbon contained in the fuel, the more CO_2 will be released into the air. However, this is not the only factor that determines CO_2 output; CO_2 emissions also depend on the anti-pollution control systems installed at the power plant. These systems can rely on a variety of both wet and dry filtration as well as special reactions to decrease carbon dioxide emissions. Carbon dioxide is a primary contributor to global warming and is not only produced by electricity generation and automobile emissions; it is generated naturally by decomposing organic matter. For instance when the leaves fall off of trees in the fall, they decompose leaving some of their carbon on the form of soil and some in the form of CO_2 gas. CO_2 is also a bi-product of animal respiration and decomposing waste in landfills. While decomposing tree leave create CO_2 during certain times of the year, in the grand scheme trees can remove more CO_2 from the air than they add to it. Trees are primarily composed of carbon captured from the CO_2 in the air. Given the right conditions, tree's can decompose and eventually turn back into fossil fuels, however this process typically takes millions of years. Therefore this is not considered a renewable cycle of events. Excess carbon dioxide not only leads to global warming, it also creates acid rain. A reaction occurs when CO_2 reacts with water in the atmosphere to create carbonic acid. Acid rain is damaging to natural ecosystems resulting in the loss of plants and animal and is also quite damaging to the surface of buildings, cars and other man made structures.

There is no doubt that some fossil fuels contain far more carbon than others. Unfortunately the most abundant fuels tend to be the dirtiest, or contain the most carbon. For instance, coal the most abundant of the fossil fuels is by far the dirtiest while the more scarce fuels (gas and oil) are significantly lower in their carbon content.

2.1.1 Oil

Since the industrial revolution, man has become increasingly dependent on the energy produced by oil. Machinery powered by oil as well as machinery powered by oil derived electricity has given man the ability to be more productive and accomplish tasks with far greater ease. However this trend will naturally have to cease as the supply of oil is essentially finite in that it takes millions of years to form what is used in only a single year. Recent crude oil prices have surpassed a 13 year high and gasoline prices have approached all time highs. While there are many factors that can affect the price of refined fuels, the most influential factor has been the increased cost associated with recovering and transporting raw crude oil. Oil exploration companies such as Shell have come under fire in that their proven reserves are not what they were expected or reported to be. Shell has decreased its estimated proven reserves twice this year.[1]

[1] Shell Denies Auditor Refused to Sign Accounts, 2004, Reuters News Service http://www.forbes.com/home_europe/newswire/2004/03/21/rtr1306358.html

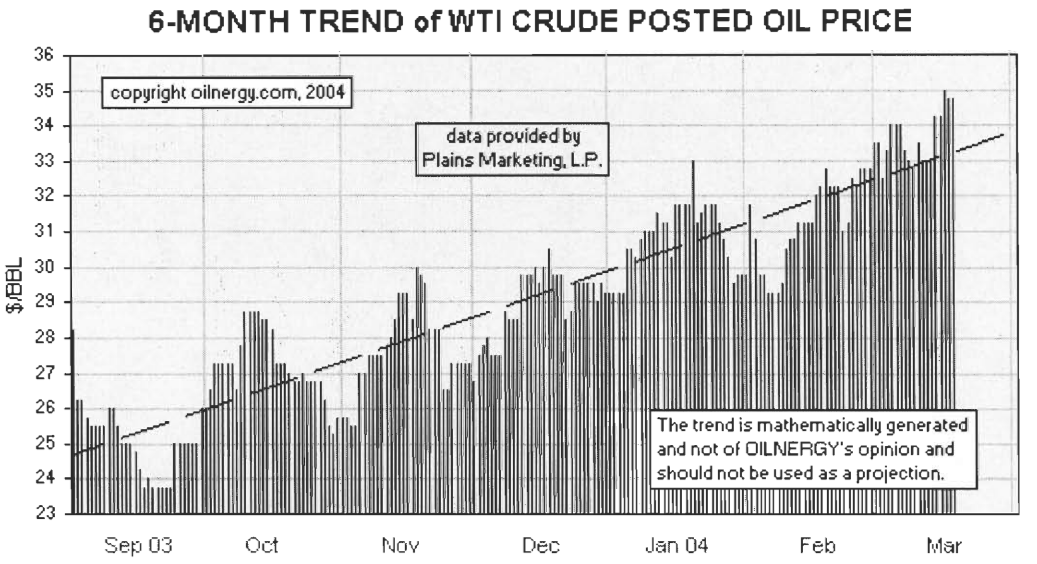


Figure 2: OIL Prices, www.oilnergy.com

In terms of oil production (as well as Natural Gas) there is a commonly overlooked factor impacting production. While there may still be a significant amount of oil resources remaining in the ground, the process of recovering those resources can be energy intensive in itself. Most of the crude oil recovered today is recovered at a relatively low cost in that it is easily obtainable. However, as these cheap oil supplies diminish, oil producers must turn to advanced recovery techniques requiring more energy and capital. One example is CO2 injection where CO2 is injected into the ground in order to pressurize a difficult to recover oil supply and force it to the surface. These methods are less efficient and more costly than conventional oil recovery. The efficiency problem also means that oil resources will become so difficult to recover that the amount of energy needed (oil burnt) will exceed that respective amount recovered from the process. This is a very important idea to keep in mind when reports estimate resources to be plentiful as many of reported resources may not be practically recoverable.

It is likely the issue of oil production peaking will be the greatest concern with the fuel in the near term. Most predictions anticipate a peak in oil production before 2030 with experts following the work of Hubbert and Campbell predicting the peak to occur between this year and 2010.

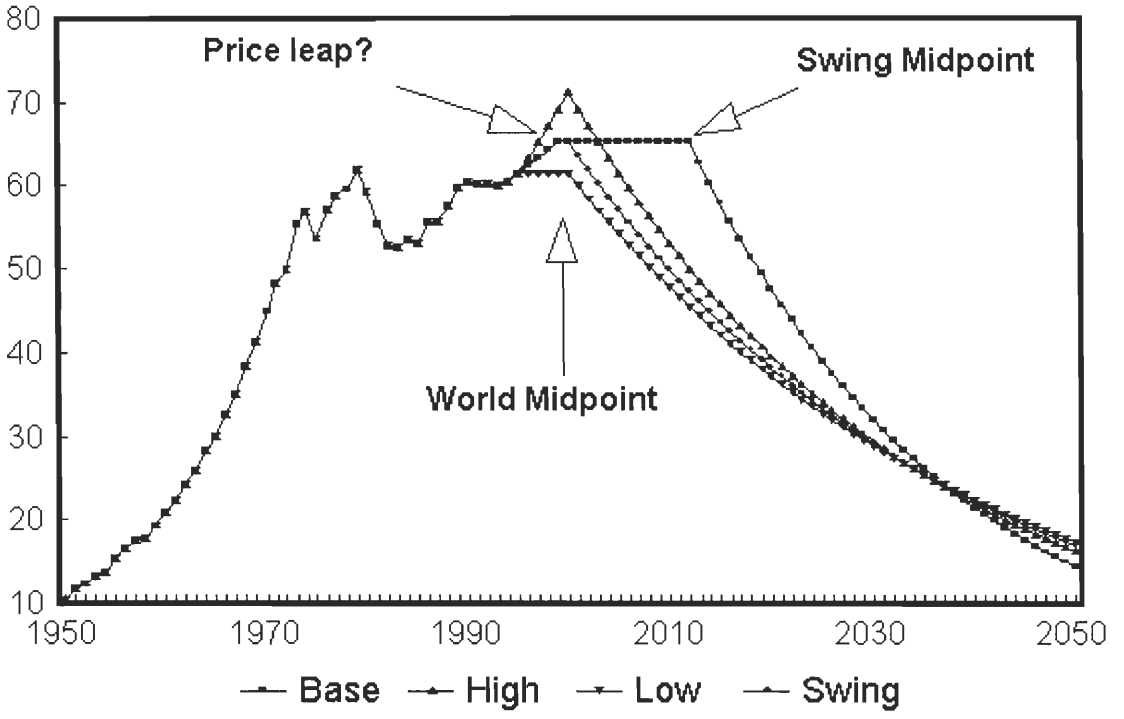


Figure 3: Oil prices from 1950 to 2050

Dr. Hubbert's predictions have been well respected in that his 1950's prediction that oil production in the US would peak in 1970, his prediction was only off by about 10 years in that they actual peak occurred in the early 1980's.

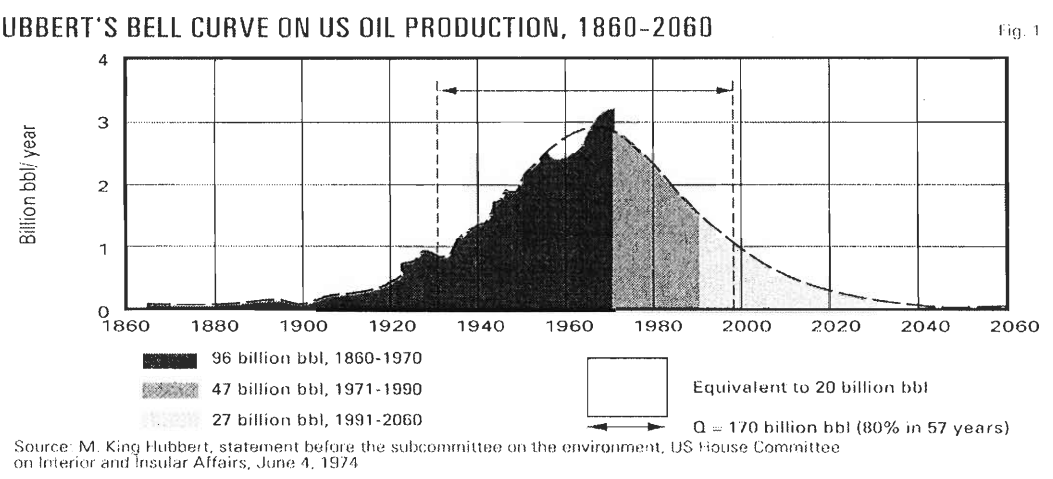


Figure 4: Hubbert's Bell Curve, Source: www.hubbertpeak.com/hubbert/

OPEC, the Organization of Petroleum Exporting Countries plays a major role in immediate changes in price and availability of oil. OPEC's membership is composed of eleven different countries; Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates and Venezuela. The combined output of these countries represents 40% of global oil production. This number has been and is expected to continue to rise as other sources of oil are diminished. Of OPEC's member's Saudi Arabia contains the largest amount of known oil resources with 262,790,000 known barrels of oil remaining in the ground.[2] This gives OPEC a great amount of political power in the global setting as the world depends on the oil produced by its members. A major looming concern is with a potential leadership change in Saudi Arabia occurring within a few years. Currently the leadership in Saudi Arabia is on very good terms with the United States and other industrialized countries, however this is vulnerable should the royal family be replaced.

[2] Organization of Petroleum Exporting Countries (OPEC), www.opec.org

In addition to enhanced oil recovery, there are additional options that can be taken to produce oil from non-ideal resources. For instance, Canada has an abundance of heavy tar sands, a resource than can be refined into oil and further refined into fuels such as gasoline. Unfortunately the refining necessary to utilize these resources is quite substantial and energy intensive. This leads to significantly higher costs on end products such as gasoline as compared to conventionally produced fuels.

2.1.2 Natural Gas

Natural gas is the cleanest of the three primary fossil fuels, in that it releases far less dirty pollutants into the air. Just as oil supplies are dwindling, natural gas has become scarcer and prices have are have doubled in just the last couple of years. The United States Department of Energy (DOE) reports that the majority of Natural Gas obtained today is recovered from depths greater than 5,000 feet. However, the DOE is pursuing research and development into the ability to increase the amount of natural gas recovered from depths greater than 15,000 feet. Currently about 7% of natural gas is recovered from this depth.[3]

> Natural gas hit a modal high of consumption in the early 1970s, the U.S. natural gas consumption has declined to a low of 16.2 trillion cubic feet in 1986. Since then it has increased at an average annual rate of about 2.4 percent. Total natural gas consumption in the United States reached 22.8 trillion cubic feet in the year 2000, a 4.8 percent increase over the previous year. This occurred while the industrial

[3] "Deep Trek" and Other Drilling R&D, United States Department of Energy, http://www.fossil.energy.gov/programs/oilgas/drilling/

consumption declined and an increase in other sectors such as electricity generation and the residential and commercial sectors[4].

Part of the difficulties associated with natural gas is not only the fact that the fuel is scarce, it is difficult and costly to transport long distances (especially overseas). Natural gas must be compressed and liquefied in order to ship it overseas and this process is becoming increasingly necessary in that the number of remaining sources of natural gas is becoming scarcer. Like enhanced recovery procedures, this requires a significant amount of energy in itself, thus reducing the efficiency of the fuel from time of recovery until its end use. This directly and negatively impacts the cost of the fuel as well as electricity derived from it.

2.1.3 Coal

Coal was the first fossil fuel to be widely used. When electricity was first introduced, the majority of it was generated by coal fired power plants. The general principle being that burning coal can be used to heat water and generate steam which turns some kind of generator. This is the same principle used in modern power plants, although some emissions reduction equipment has been added to modern coal fired plants. Coal being the dirtiest of the fossil fuels, yields a substantial amount of soot and carbon dioxide, thus there is a great amount of pressure put on coal plants to filter these pollutants out of their emissions. Many argue that even if emissions can be greatly reduced, coal plants will still be far more harmful to the environment than renewable energy sources. There also still remains the fact that the world's supply of coal is finite. A major problem with emissions reduction is that the filtered out pollutants, ash, soot,

[4] Energy Information Administration, Natural Gas Monthly, Washington, DC, March 2001.

carbon; must be dealt with in an environmentally friendly manner as well. While most experts believe the future of energy lies in the promises of large scale renewable energy and eventually nuclear fusion, the Bush administration favors an idea of creating a zero emissions coal power plant. $1 Billion has been allocated to a project called Future Gen which aims to demonstrate a zero emission coal powered plant within the next decade.[5] In addition to ability to produce liquid fuel from coal, there is technology that allows for coal to be made into gas (coal gasification). This process would be used in conjunction with carbon sequestration technology to enable the emission free coal powered electricity plant to work.

Another one of coals major disadvantages is the limit to which applications it is appropriate for. The majority of heating systems, both residential and commercial alike are dependent on liquid or gaseous fuels (Natural Gas and Oil), therefore coal is not easily suited to that market. In addition cars, trucks, trains, planes, ships, etc… are almost always designed nowadays to utilize a form of oil for power. This makes coal a very unsuitable fuel for a large portion of the energy market. Coal can however be transformed into a liquid fuel by a process known as coal liquefaction. Unfortunately this process is energy inefficient and generates a fuel that is significantly more costly than easily recoverable oil. Coal can also be used to manufacture gas, however similar problems exist with respect efficiency and economics to that process as well.

2.2 Nuclear Energy

One of the most powerful energies in the world is the energy that stored in the uranium atoms, this element can be find in Canada, Australia and South Africa. The

[5] http://www.fossil.energy.gov/programs/powersystems/futuregen/

reaction between two type of uranium and a plutonium atoms can create heat which is use to boil water and turn turbine. One pound of the uranium can generate three million times the energy that can be generated by one pound of coal. The nuclear energy is one of the non-renewal energies.

The nuclear power plants are the most expensive power plants to build and the reason for that is to prevent radio active emission. The maintenance cost for this plants are high too, and the reason for maintenance is to keep the environment safe and meet the safety regulation by NRC (Nuclear Regulatory Commission). An average size nuclear plant can generate approximately 1000MW, which this means that the cost to build, maintain and get inspected can be cover by the price of electricity that generates by this plant; the price of electricity from the nuclear plants is around 1-2 cents/KWh.

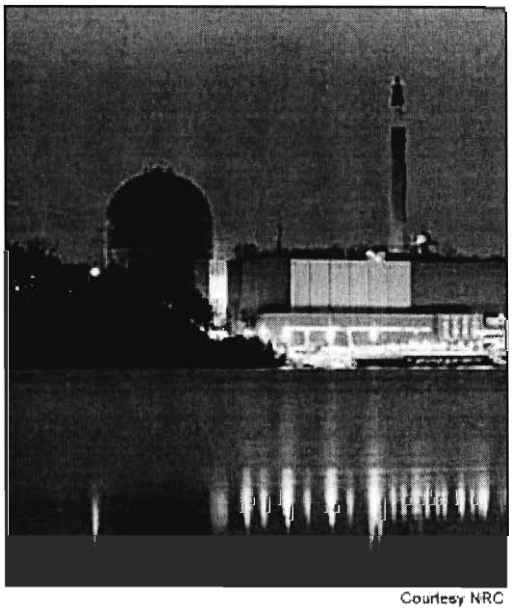


Figure 5: Indian Point Nuclear Power Plant in Buchanan, New York.

Environment

The nuclear power does not pollute air with sulfur dioxide, carbon dioxide and nitrogen oxide like Fossil fuels do but it cases the air emission which is really dangerous for human life. Although that the plants structure is protecting the environment from radio active emission, it will still emits small amounts of carbon-14 and iodine-131. The radio active hazards are dangerous for the environment and to protect the environment from the hazards they keep them in a big poll. The other major issue with nuclear plant is that it uses water to cool done the reactor and this putts the fish life in danger.

2.3 Wind Energy

One of the most important energies in the world is wind energy. Since 1991 the production of electricity from this source increased from 2GW to over 31GW, the average annual rate growth during this time was roughly 26%. Since the start of production of electricity from wind turbines the price of wind turbines and cost of producing of electricity has been decreased. We can say that the wind energy in the world is very cheap and unfinished[6].

The graph below shows the increase in production of the electricity in past couple years.

[6] Sesto, Ezio; Casale, Claudio, 1998. "Exploitation of wind as an energy source to meet the world's electricity demand".

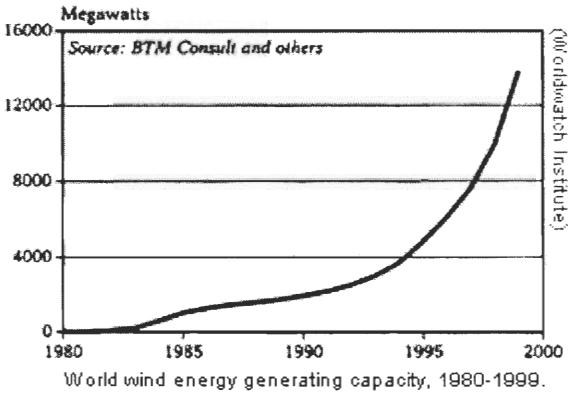


Figure 6: World Wind Energy Generating Capacity

Source: http://www.riverdeep.net/current/2000/11/112200_worldwatch.jhtml

The wind turbines have become more useful since they got introduce to the world. Back in 200 B.C., the turbines were getting used on grinding grain and pumping water, but now they are getting use on producing one of the most valuable energy which is electrical energy. They were two type of turbines were getting used to grind and pump, Savonius Turbine which developed in Finland and Darrieus turbine which developed in France; this turbines were vertically axis and due to slow speed of rotation, they could not get used in producing electricity. Today the turbines are horizontal axis, these turbines have three to two blades and they are installed in a tall tower. The structure of these turbines allows them to rotate at a fast rate which means they can produce electricity[7].

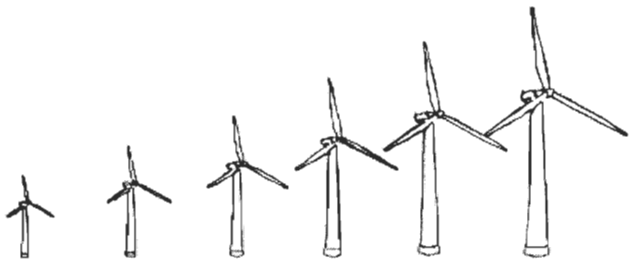
[7] http://www.sciam.com/search/search_result.cfm

Figure 1-3-12 *On wind "farms," hundreds of windmills can generate large amounts of electricity. It is estimated that Texas has the potential to generate 10 percent of the entire country's energy requirements through wind power.*

Figure 7: Wind turbine

2.3.1 Wind Turbines:

As mentioned before there are two different type of turbine: vertical-axis or "egg beater" style and horizontal-axis. The horizontal-axis is the most common one since it generate more electricity, this kind of turbine can generate electricity between 25W to 1.8MW. In future the turbines are going to generate more electricity, the figure below shows the different turbines type and the amount of electricity that they can generate.



	1981	1985	1990	1996	1999	2000
Rotor (meters)	10	17	27	40	50	71
KW	25	100	225	550	750	1,650
MWh	45	220	550	1,480	2,200	5,600

Figure 8: Size of turbine vs. producing electricity.

As we can see the out put of the turbines is depended to the size of the blades, there is another aspect that affects the output of these turbines, the speed of wind trough the turbine. A10KW wind turbine generates about16MWh annually, which is enough to provide the power for a typical household (a typical household uses about 10000 kilowatt/hours). A1.8MW turbines can produce 5600MWh annually, which can cover the need of more that 500 average household.

One of the problems with wind power is that it fueled by the wind at one point and is not at other time that there is no wind, the only solution is to store the electricity and at this time there is not a good solution with storing the electricity in large scale. At this time the engineers are trying to get a higher energy per hour by making better blades and measurements. During the 1980s, the cost for generating electricity through the wind power was 30 cents per kW-hour. Now the American wind Energy Association (AWEA) estimated that the cost for electricity through the wind power is 5 cents per KW-hour

(this does not include the tax). It is expected that the generation of the electricity through wind will compete with gas which is the cheapest way to generate electricity now.

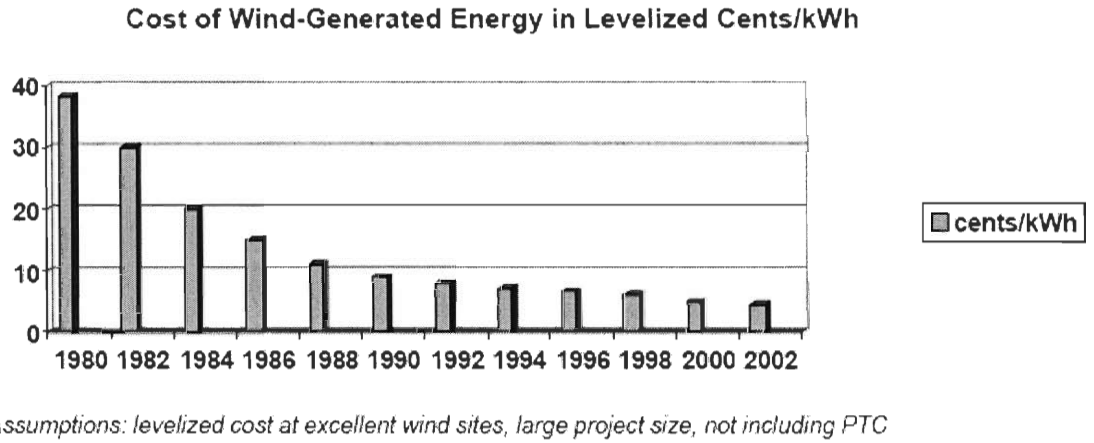


Figure 9: Cost of Wind Generated Energy

Source: National Renewable Energy Laboratory

2.3.2 Economics of Wind Power

The wind power technology is one of the fastest growing technologies in the world now. Over past 20 years the cost of production has drop by more than 80%. In the United State this technology has not grown as much as other places, in USA companies having problem finding investors on this project. The reason for this is that they want to make sure that how this project is working in other countries. The U.S has only .5% of its energy from wind turbines but Denmark has 12% of its total energy through wind power. Europe is expecting to have 50% of their energy through the wind turbines. Europe produces over 70% of the world's wind power. If US get enough investment troughs this design they can quickly go from .5% to 12%. The following table shows the comparison of cost in the wind energy and other energy sources. The numbers and

statistic from this table is from the California Energy Commission's 1996 Energy Technology Report.[8]

Fuel	Levelized costs (cents/kWh) (1996)
Coal	4.8-5.5
Gas	3.9-4.4
Hydro	5.1-11.3
Biomass	5.8-11.6
Nuclear	11.1-14.5
Wind (without PTC)	4.0-6.0
Wind (with PTC)	3.3-5.3

Table 1: Levelized Cost of Energy

Source: Energy Technology Status Report

Unlike the Wind power produces cost the gas price has increased since 1996, so the Leveled cost of gas at present time is more than what is shown in this table. In January of 2001, the cost of the natural gas that used to produce power was around 15-20 cents per kWh. The cost of the energy that gets produce by wind power is not the same at all time and everywhere; this is because the wind power's cost is depended to the speed of the wind and the size of the plant, speed of the wind is not the same at all time. But the average cost for producing the wind power is 4.8 cents/kWh in 16mph winds. The other factor that determines the cost of the wind power is the size of the wind plant; a 3-MW wind plant generates the electricity at the rate of 5.9 cents/KWh but the 51MW plant can generate electricity at rate of 3.6 cents/kWh.

8

http://www.ingenta.com/isis/searching/Search/ingenta;jsessionid=2m77ctg5nnc8s.crescent?form_name=home&title=aerodynamics+of+wind+turbines&database=1

2.3.3 Wind Farms Environmental Impact

The wind power is one of the cleanest powers to produce electricity, it doesn't produce hazard and waste and it doesn't pollute air and water. The other important thing about the wind power is that it doesn't deplete the natural resources. Using wind power as the main resource to produce electricity can help the environment clean.

In 1997, U.S. electrical power plants produced 70% of the sulfur dioxide, 34% of carbon dioxide, 33% of nitrogen oxides, 28% of particulate matter and 23% of toxic heavy metals released into our nation's environment, mostly the air. These figures are currently increasing.

The sulfur dioxide produces acid rain which is harmful for the forests and lakes. Nitrogen oxides are the main reason for having unclear and fogy sky. Carbon dioxide is the reason for the global warming, the reason for that is that this gas traps the sun ray's on the earth. One of the reason that US has to start increasing the use of wind power generators is that, it is producing 23% of the worlds CO2.

Although that wind power is a good source for improving the environment, it has some problems such as it put the life of birds in danger, makes interfaces with radio station and produces noise. But since this technology is improving with a fast rat we can expect that all this problems be solve in couple of years.

2.3.4 Wind Energy Potential

The potential of the wind power in United States is so good that according to Battelle pacific, federal research lab, it could produce 20% of the nation's electricity. In

order to start using this source seriously in United Sates all the transmission companies have to renew and change their transmission system. This transmission companies have to use high voltage transmission lines that is for large distribution instead of small distribution. In the distribution market the transmission companies set contract with producer companies and if the producer companies fail to deliver certain amount of electricity then the producer company would have to pay a high penalty. So in order that the production of electricity from wind power increase, two things have to happen; one producer companies figure out a way to store electricity, two, the companies who produce electricity from wind plants have another generator like generators that uses coil, this way when they couldn't produce enough electricity they can use they coil generator.

As the space for windmills go, the producer can put them any where that the speed of wind is fast and it is not in the view of human. In united state this includes east and west cost and part of Central America which is flat and wind speed is good.

2.4 Solar Energy

Solar Energy is one of the renewal energies that gets deliver directly from the sun, In order to do this we have to use solar collector. There are two different types of the solar collectors, the passive and active solar collector. Basically passive collectors are how the houses and buildings get design to take advantage of the lighting and heat of the sun. The active collectors are the ones which get created by designing an equipment to

take the sun's energy for generate heat and electricity. There are three major different active solar collectors, solar ponds, solar reflectors and photovoltaic cells[9].

2.4.1 Solar Ponds

The sun causes the water in ocean and lakes to vaporize and human use the vaporized water to turn turbine and generate electricity. The University of Texas El Paso back in may of 1986 came up with solar pond to prevent the vaporization of the water in free air and instead using it through turbines to generate electricity. The solar pond has three layers which have different concentration of salt in water, these three layers are the surface zone, the gradient zone, and the storage zone, the figure x shows the structure of solar pond.

The gradient zone is under the surface zone and on top of storage zone. As the dept of water in the pond increase the concentration of salt in water increase too. The water in gradient zone can not rise above the surface zone because it contains more salt and it is more dens, same in the case of the storage zone that can not rise above the higher lever water. Since the water in storage zone can not skip to free air it will stay warm in the bottom of the lake and it will get pipe to vaporize and turn the turbine and generate electricity.

The solar pond can produce electricity up to 70kw. The advantage of this kind of solar panel is that it can produce electricity even at night time or when the sky is cloudy. The other advantage of this solar panel is that it can be built in the desert and the areas

[9] Alternative Energy, Unit one-Energy. p.103

that human don't use that often. This type of solar panel does not pollute the air or other ponds.

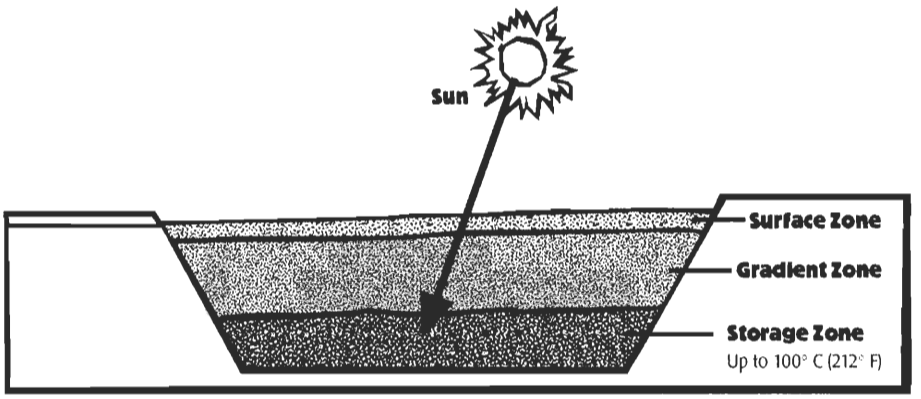


Figure 10: Solar pound.

2.4.2 Solar Reflectors

The other way to produce electricity using the sun is that to concentrate the suns energy in one point and heat up a liquid to produce vapor for generating electricity. There are three different common methods to concentrate the sun, parabolic troughs, dish engine system and power towers.

2.4.2.1 The parabolic

This type of the solar plans are using collector filed to focus the sun on the single beam that is aligned on the north-south pole. The collector filed contains many parabolic mirrors that their focus is on a single beam. This collector filed track the sun from east to

west. After the liquid in the beam vaporized it would turn the turbine and generate electricity. This type of plants can generate the 14 to 80MW of electricity.

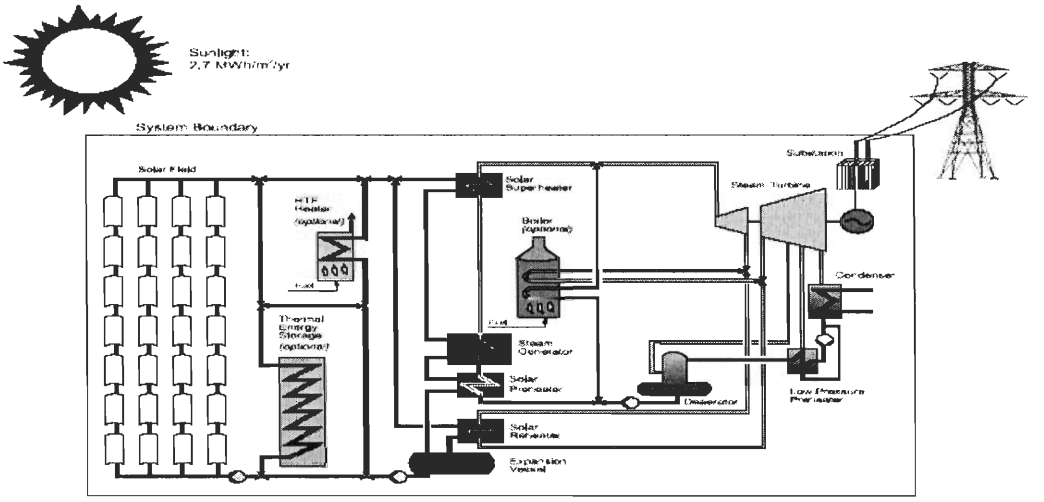


Figure 1. Solar/Rankine parabolic trough system schematic [1]

Figure 11: Parabolic Trough System

2.4.2.2 Dish Engine

The structure of this solar panel is similar to the parabolic though, but instead of using many parabolic mirror is using a large single parabolic mirror that will concentrate the sun's energy at its focus. There is a receiver at the focus of this mirror that contains a liquid that will get heated to 750 C, this liquid will cause the turbine to turn and generate electricity. This kind of solar panel generate electricity anywhere from 7 to 25KW. Because of the high optical efficiency and low startup loss, this solar panel is the most efficient technology.

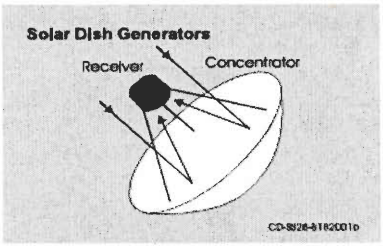


Figure 3. Solar dish/engine system.

Figure 12: Solar Dish Generators

2.4.2.3 Power tower

The other kind of the solar plant that vaporizes the water by focusing the Sun energy at one point by uses a flat mirror. The mirror uses sun tacking system that tracks the sun and always reflect the sun rays on a receiver on top of the tower, the water at top of the receiver will vaporize and it will turn the turbine to generate electricity. This kind of the solar panel generate anywhere from 30 to 400 megawatts of electricity.

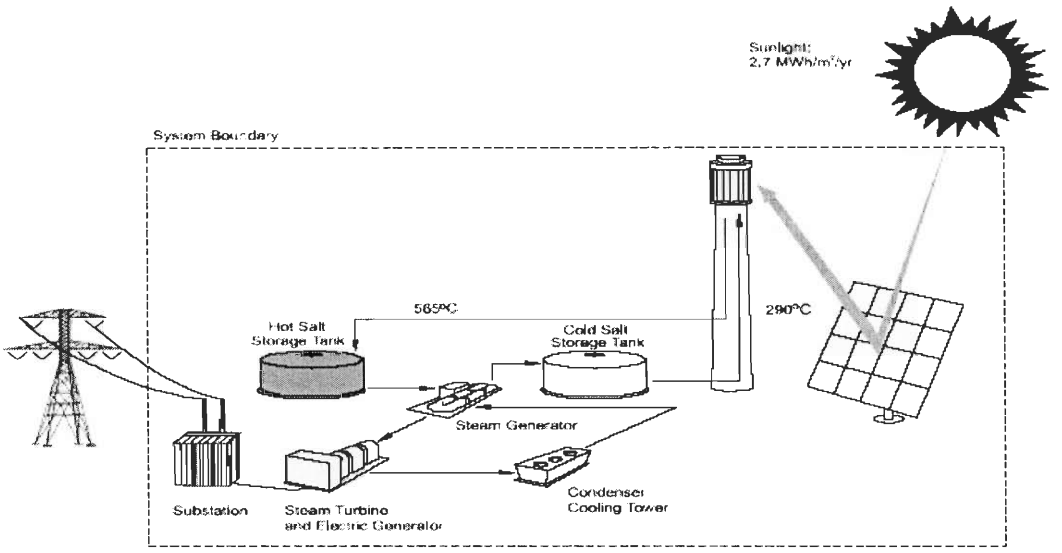


Figure 1. Molten-salt power tower system schematic (Solar Two, baseline configuration).

Figure 13: Power Towers

2.4.3 Photovoltaic cell

This device produces electricity directly from sun's energy. This device is made of two layer of semiconductor, which the first layer contains positive charged and the other layer contains the negative charge. When the photons from light hit the second layer the electrons become free and they flow through the first layer, this action creates the electric current and can be use to act same as battery.

2.5 Hydropower

Hydropower is one of the renewal energies that causes to electricity gets generated by putting the potential energy of water that is a result of gravitational energy by earth through the turbines. The potential energy of water resulting from the gravitational energy usually gets created in two different ways, the natural way that is the water falls and the human made way which is dams[10].

2.5.1 Water falls

In the natural way, by taking the advantage of the water falls and putting turbines at the lower part of the water fall electricity can be generated. This technology was the start of producing electricity using hydropower; in 1882, two years after Thomas Edison created the light bulb the first moving wheal used on Fox River in Wisconsin to generate electricity.

2.5.2 Dams

Dames are basically using the same idea that water falls are using, which is taking advantage of the elevation and gravitational energy. There are three types of dams, which are impoundment, diversion and pumped storage.

[10] Alternative Energy, Unit one-Energy. P.100

The impoundment dame, store the water from lakes and river behind a wall which calls dame and the water move through this wall and turn the turbines inside of this dame. The diversion dame uses the high pressure of water to turn the turbines, the high pressure water can be created by passing the water from river through a narrow canal which contains turbines, the turbines will turn when the water is passing through it and it can generate electricity. The pumped storage dame can generate electricity by pumping the water from lower altitudes to the higher altitudes, and the water will be stored and then release from there, then this water can turn the turbines at the lower altitude.

Hydropower dames do not create pollution as much as fossil fuels and nuclear plans and dames can cause the human population around them. The only costs for dames are the fix cost for repairing them and making path way for the fish. Since the fuel cost for dames is almost zero the operation cost for them are close to zero too. The hydro power in US contains close to 98% of the renewal energies and 8% of the total energies that produces electricity.

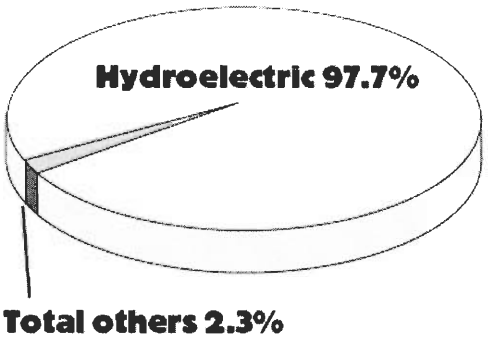


Figure 1-3-6 Generation of electricity by renewables 1998.

Figure 14: Percentage share of Electricity Generation by renewal energy

United State and Canada uses the hydropower energy more than any other country to generate electricity.

2.6 Conclusion for generation

In conclusion to the generating electricity we have to know that most of the energies that can be use to generate electricity are limited and in order to we don't run out of these energies in the short time we have to use them smartly. One of the solutions is to create more efficient wind turbines, solar panels and dams and decrease the use of fossil fuels.

3 Transmission

The other important part of the electricity market is the transmission companies that providing the transmission line. The transmission lines allowing the electricity to follow from higher potential electricity areas, which are the generators, to lower potential electricity places, which are the users. In order to decrease the loss across the power lines the transformers decreases the current of the generators and increase the voltage coming out of them (stepping up the voltage). After steeping up the voltage, electricity will follow to its destination through the high towers and underground and it will get transform again for stepping down (decrease the voltage). Most of the cost for transmission companies are the constructions and maintaining the lines (which are mostly fix cost) but there are some cost during the transmitting too, and that's the electricity loss.

There is usually 10% loss across the lines at high voltage due to the resistance in the wires[11].

One of the important responsibilities that transmission companies have is that they have to protect the transmission lines from thermal breakdown. The thermal break down can be caused by the heat due to the high power across the line. In order to they protect the lines they have to decrease the output of certain generators and increase the output of other generators.

One of the technologies that being use to transfer the electricity is the loop flow, loop flow is one of the characteristic of the electricity, electricity takes all available routes to get from one point from another. The reason for using the loop flow is that transferring all the power across one line is not practical and efficient.

In the loop flow the use of lines by any customer or generator will affect the amount of transmission capacity available to all users. In the Figure 15 we can see that if transmission company1 agrees to transmit the power from generator 1 at point A to the costumer 1 at point B, some of that power would flow through the transmission utility 2's lines. So if the transmission company 2 increases the capacity of its lines the benefit would not just go to the itself it would affect the transmission utility 1 and any other transmission utility that are using the same grid. The same idea works with the phone companies, for example if MCI decide to increases its network it will reduces the cost for AT&T to carry its phone calls.

[11] Alternative Current. p.12

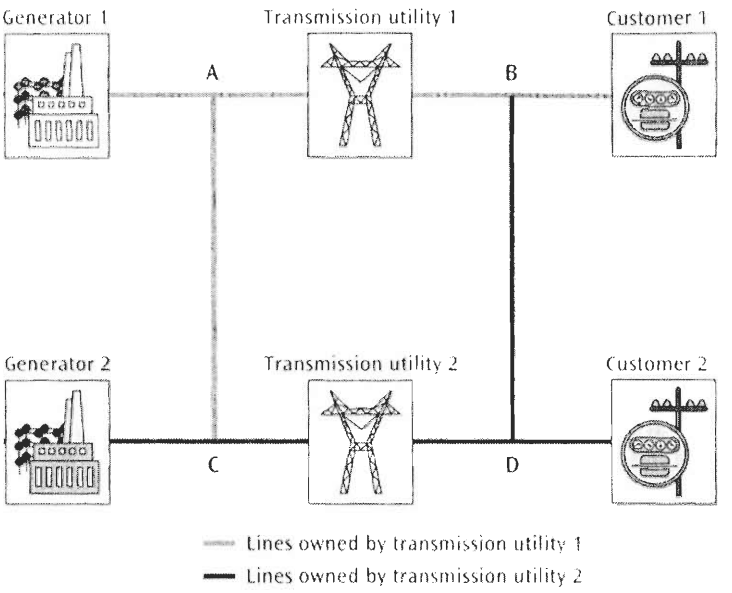


Figure 15: Simple Diagram of an Electricity Network

In the loop flow keeps the transmission utilities that share the same grid from making their own pricing, this is because the decision from one company will affect the capacity of other transmission companies. In this case these companies cooperate with each other to determine the pricing instead of competing. The costs for transmission are getting cover in the regulated rates since there is no competition. There are three transmission grids that serve In United State.

- Easter Interconnected system, which serves the eastern part of United State and Canada.
- Western Interconnected system, which serves the western United State, Canada, Mexico and part of Texas.
- The Texas interconnected system, which serves most of Texas and it is connected to West and East grids.

The transformation companies are in charge of the transporting the electricity from the generators to the distribution companies. As now the transportation of the

electrons in the weir is not efficient yet, and there are researches to transfer the electricity optically underground. But up to that time the loop flow is one of the decisions that prevent lots of loss across the weirs.

4 Distribution

The process of delivering the electricity to factories, households, governmental offices and households is distribution. The fix cost for distribution companies is high which includes the cost for building distribution substations, the distribution lines and main switches. But the variable cost or cost for additional customer is low and this is why this companies stay monopoly in their service area. The distribution companies are responsible for advertising, billing and customer relations.

The responsibility and market of the distribution companies are explained in the next section in detail.

5. Electric Market

There are two different kind of sell in electricity market, the retail sale and the whole sale. The retail sale is when the power is being sold to the users, and the whole sale is when the power is being sold to other sellers, in this market the distributors. In United States there are five different types of sellers[12]:

- Investors-Own Utility (IOU), these companies are mostly the companies that generate, transmit and distribute the electricity, and serve the living customers that are in territory. IOU cover the most sealing in United States
- Publicity-Own Utility, sales to the final customers which include municipal utility (in Los Angels and Jacksonville), public power districts, irrigation discrete, and state authority. This system mostly is being use in the small towns but some big cities like Los Angels is using this system.

[12] Alternative current. P.22

- Rural electric cooperatives are the utilities that electricity gets produce by the farmers and community which serves the residential of that area.
- Federal Owned utilities, includes five federal wholesale and four federal marketing administration. Mostly these five wholesale companies market their power through one of those administrations.
- Independent power producers, which are the non-utility companies and includes more than 2000 generators that are not owned by one of the utility companies.

The graph below presents the amount of selling each company is covering.

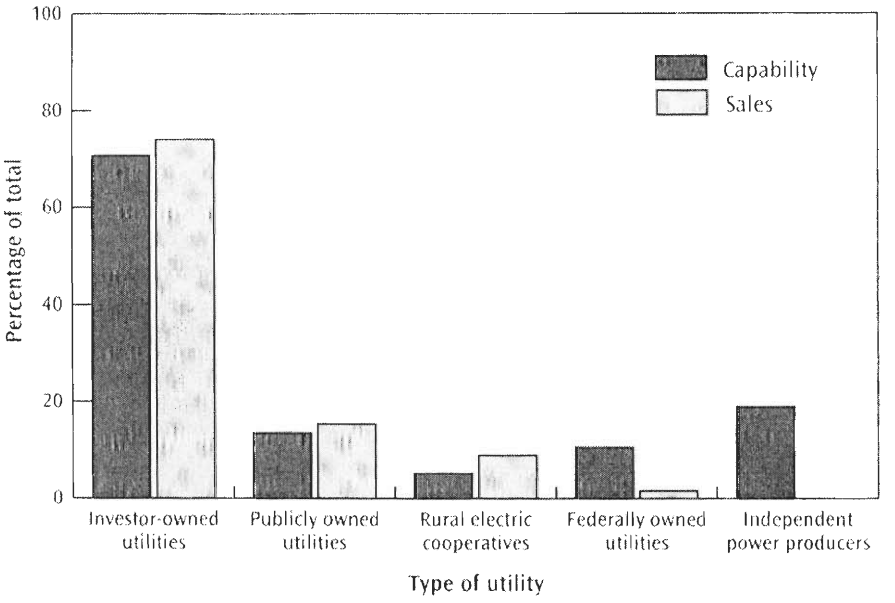


Figure 16: Percent share of Total generation capability and of final sale by type of Utility, 1999

There are three types of the buyers in the electricity market, the residential, the commercial customers and Industrial customers[13].

- Residential customers and house holds which in US is close to 180 million households.
- Commercial customers, which includes the schools, business companies and governmental offices.
- Industrial companies, which there are more than 500,000 of them in United State. In an interest to deregulate the electric utility market, a new model is being phased in many regions of the United States.

[13] Alternative current. P.22

A good example of a similar transition was the breakup of AT&T in the 1980s. AT&T was split into the "baby bells" by region and in addition, telephone services resellers began their existence. The idea was to reduce the *market power* of such a large monopoly. AT&T essentially had 100% control over the market price of phone service throughout the country prior to its government mandated breakup.

The idea of free market competition in electric utility service was long overlooked in that it seemed impractical or near impossible to run separate power lines from each company of which to choose electrical service from. Thus a relatively recent model of electricity marketing has begun to gain popularity. In this model a single distribution company is responsible for electricity delivery while several generation companies sell electricity to the distribution company. Customers are now in some cases given the choice of which generation company they wish to purchase their electricity from and then the distribution company purchases that respective amount from each generation company. This somewhat unusual marketing concept has been developed to break the electric utilities from their *natural monopoly* status. Natural monopolies are common in any utilities (i.e. phone companies, cable, gas, water, etc…) due to the proprietary distribution infrastructure. For instance, since the cable company owns the coax running to the home, no alternate company has the means to provide that service without running their own line to the home.

A more common form of competition that is largely transparent to the consumer is the competition among generation firms for contracts. In this scenario a common electricity distributor will receive bids from various generation companies for various

contracts. The generation company with the lowest cost for each contract is typically rewarded that contract. The contracts are, for the most part, broken down by load type (base, cyclical and peak). Power sources that provide a large amount of sustained power, such as coal and nuclear plants typically provide the base load, while gas hydropower plants are brought online during the higher demand portions of the day. In the case of peak demands (for instance a hot day where air conditioners are in heavy usage) gas generators are often called upon.

The Since 1970's, regulation over the electricity market became less popular and the deregulation dominate over the market. From the experiment of telecommunication we can see that In United State the competition is much easier and efficient than the regulation. In the competition the companies set the prices themselves. Unfortunately the electricity market is not completely deregulated.

In United state since is a big country the generation of the electricity by several companies is efficient but in small countries like Cuba there will be a big loss on the fix cost of the companies. The fact that generation by several companies is possible in United States makes the competition between these companies possible. But in transmission and distribution there is more regulation. The reason for staying with the fashion market in the transmission and distribution is the lines. In the distribution, once one company builds the facility to serve an area they can transmit as much electricity as the user needs. In order to another company compete with the first company, the second company has to use its own lines and this cause a high fix cost. The other reason for distributors to stay monopoly is that electricity can not be stored and the amount of the electricity that distributors diver should be equal to the amount that the users need, and

because of this it is hard for several companies to know how much electricity they should order from the generators.

Now that the generation company mostly doing the generation and not the distribution, they make contract with the distribution companies to provide electricity for them as long as these companies agreed upon the contract. This system has some advantage and some disadvantages. The advantage of this system is that the system is not monopoly anymore, but the disadvantage of this system is that if one day of the year the user needed more than what the distributed company expected, the distributors have to order for more electricity from the generator and since this is something outside of the contract the generators will sale the electricity at a higher price to them. Since the distributor companies have to provide the electricity for user they have to buy the electricity at the higher price, but they can search around in different generator companies to find the chipset price for buying electricity for that day. If the distributor company couldn't provide the power that the user needed on time and causes the power loss there is a good chance that the distributor company go out of business, so in order to they don't go out of business this companies make an estimate that how much electricity users going to use in each perpendicular day of the year and base on that they will make contract with generators companies. When the distributor companies make their contract with the generator companies they request more electricity than they estimated in their calculations. The estimation that the distribution companies do are base on the time of the year, time of the day, the weather and population of the users.

The graph below shows the forecast demand, actual demand and the available resource. The forecast demand is shown by blue line and it shows the expected demand

that calculated base on the data from previous years and the whether on that day. The actual demand which is shown by red line is the actual demand in that day. The available resources are shown by green light is showing the actual available electricity that the distributor can offer to the user.

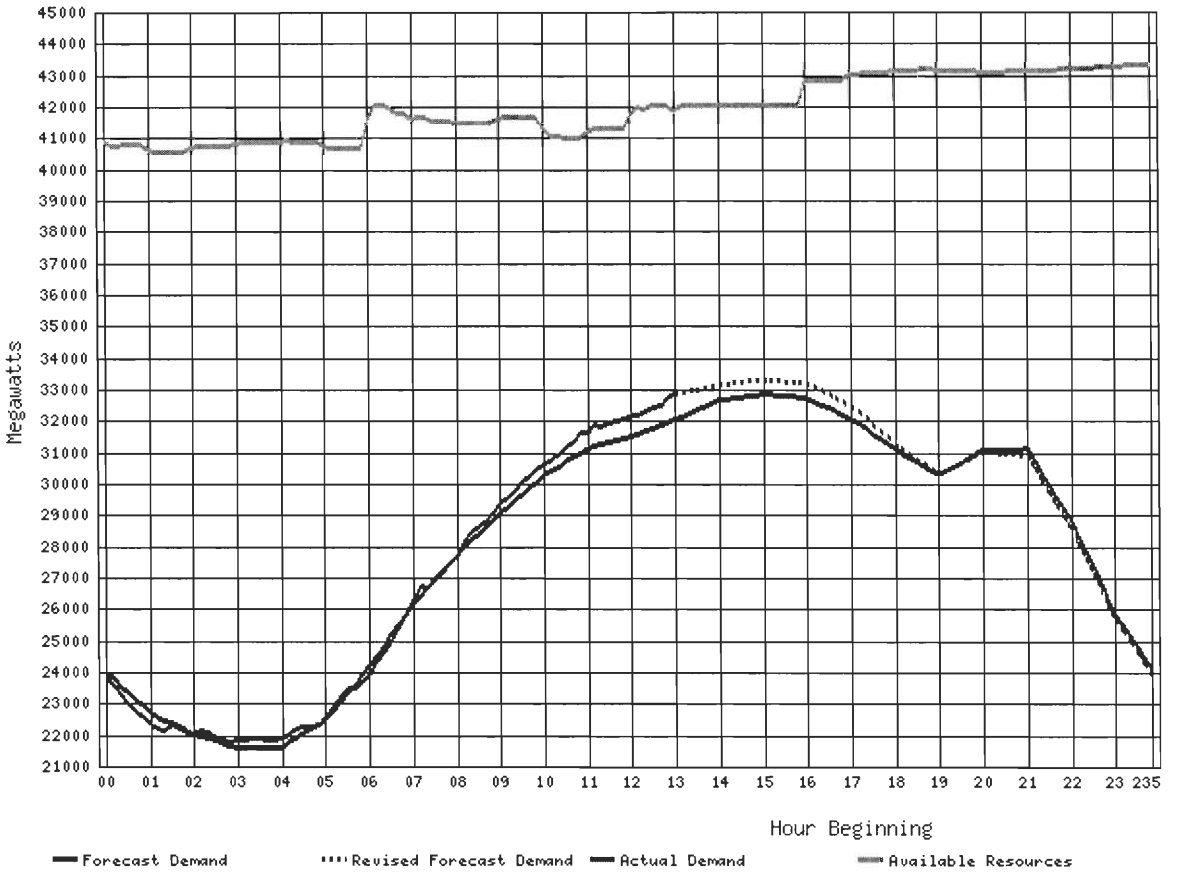


Figure 17: California ISO, outlook on May 06, 2004

So as we can see in above figure the available resources are higher than the actual demand, and the reason for that is to prevent the power loss.

One of the examples that can help us to learn more about the electricity market and its strong and week areas is California Power Loss that is explained in the next section.

5.1 California's Crisis

In California before summer of 2000 there were no problem with the electricity, everybody were happy with the system that was providing electricity in California. The utility companies in California were successful with every thing including possible non competitive prices, congestion management, dispatch policies of independent system operators (ISO) and transmission rate structures. In California the electricity prices remind low and before summer of 2000 the wholesale prices did not exceed 3.5 cents per kilowatts and during the peak period wasn't a more than penny higher. Before summer of 2000 there were only a few times that emergency stages happened because of the high usage of the users, and this occasions only happened during the hot days of summer, which before of summer of 2000 it was maximum of three stages at most[14].

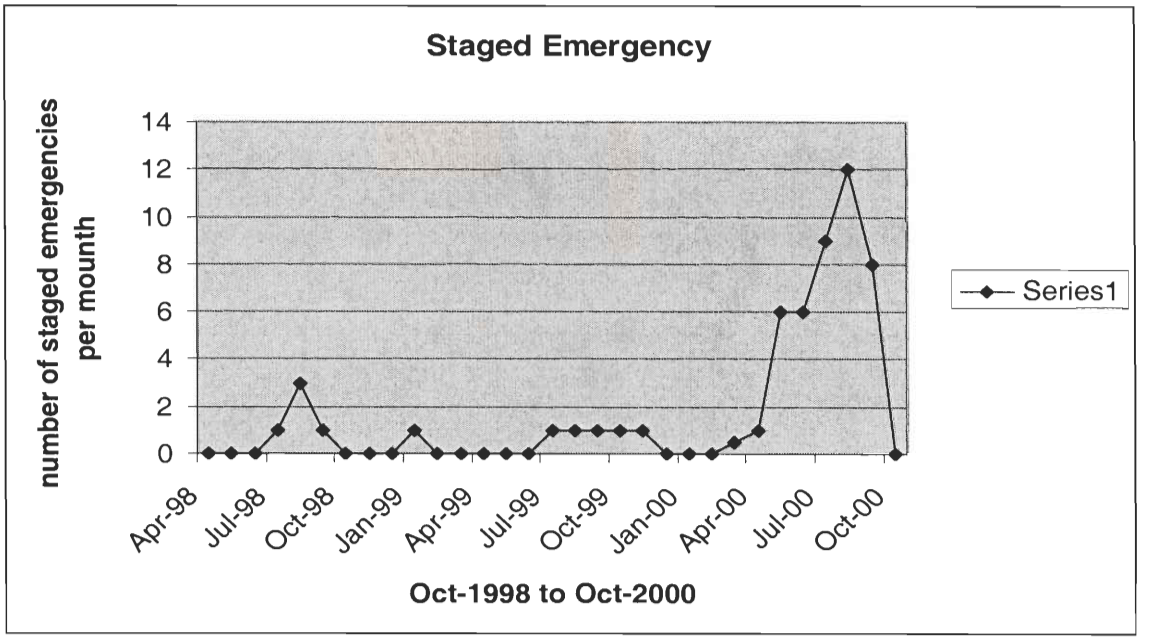


Figure 18: California's Staged Power Emergencies, 1998--May 22, 2001

[14] Alternative current. P.46

After deregulation in California the wholesale and retail sale prices increased and it caused the high billing; the wholesale prices in summer of 2000 actually became three times of what retail prices use to be during the summer of 1999. High billing caused the state to re-regulate the retail prices in September of 2000. Since the retail prices were regulated and the wholesale prices were kept unregulated the utility companies were unable to keep up with the market. By the fall of 2000 it was deficit of more than $14 billion that no one was willing to pay. Since the utility companies had to cover the high prices they teetered to bankruptcy and the power producer refused to sell them more electricity, and then came a threat of blackout through out the state.

One of the reasons that state of California didn't regulated the generation companies were because they were not expecting the fraud by Enron and some other generation companies. Due to the investigation of the Federal Energy Regulatory Commission (FERC) Enron used the false information to manipulate the prices. In a report by FERC, it was mentioned that this companies manipulate the gas prices, which caused the market by $8.9 millions. Toby Eckert stated in COPLEY NEWS SERVICE that "The investigation picked up steam three months later, when Enron disclosed internal memos that outlined tactics its traders apparently used to drive up electricity prices. The tactics – with code names like Death Star, Ricochet and Get Shorty – included sending electricity out of state and then re-importing it to avoid price controls and create phony congestion on the state's power grid, which Enron would get paid to relieve"[15]. The Companies that the FERC was suspicious too were Enron Power Marketing Inc.; Enron Capital and Trade Resources Corp.; Portland General Electric Co.,

[15] http://www.signonsandiego.com/news/reports/power/20020814-9999_1n14energy.html

an Enron affiliate in Oregon; and two utilities, Avista Corp. of Spokane, Wash., and El Paso Electric Co. of El Paso, Texas[16].

Finally in October of 2002 Timothy Belden, 35, the president of the Enron's top West Coast energy trader admitted that crises in California during the summer of 2000 were due to the fraud by their company. He also stated that the manipulation in prices increased their annual revenue from $50 million to $800 million. Belden faced five year of prison and charge of $2.1 million that he admitted that was from his illegal action[17].

5.2 Conclusion about the electricity market

Since 1970's, regulation over the electricity market became less popular and the deregulation dominate over the market. The generation companies are competing against each other because it is efficient in United State to have many generation companies since United State is a big country, but it is unreasonable to deregulate the transmission and local distribution companies since they act like the cable and gas companies. The state and federal government still have some minor regulations for generation companies. One reason for that is to avoid the cause, similar to the 2000 California crisis.

6. Efficiency

An important consideration to take into account when exploring energy policy is the efficiency of the distribution infrastructure. Total efficiency is a term used to

[16] http://www.signonsandiego.com/news/reports/power/20020814-9999_1n14energy.html
[17] Enron trader guilty of rigging California prices By Howard Mintz and Brandon Bailey Mercury News in Thu, Oct. 17, 2002

describe the sum of all losses and is represented in terms of output over input. In its most general sense, loss in terms of energy distribution is the amount of energy needed to transport the energy that is actually usable at its destination. For instance to provide a gallon of gasoline to an automobile, it requires a significant amount more raw crude than that which makes its way into the gasoline itself. Energy must be used to recover, refine and transport the end product; gasoline. There is also a great deal of loss in the combustion of gasoline. Another example of loss can be observed in electrical utilities where a significant portion of energy is loss in the distribution grid, in the form of heat and electro magnetic radiation.

Considering efficiency in fossil fuel production more in depth is worthwhile as this study is and will become more and more critical. This is greatly due to a number of factors suggesting that efficiency will (and may already) be in significant decline. One cause of declining efficiency will come from the fact that fossil fuels will require more and more energy to recover as easy to obtain fuels become increasingly scarce. This breaks down into two situations; the first being situations where oil is so deep that enhanced (energy intensive) oil recovery processes must be used, the second being less than ideal sources of oil such as tar sands that must be greatly refined (again highly energy intensive) into suitable fuels. As coal is expected to last significantly longer than oil or gas, this fuel may be increasing liquefied or converted into gas as well to help meet demand for those fuels. Another situation that suggests a future decline in efficiency is in the implementation of renewable energy. Renewable energy sources (more specifically wind and solar) can be sited in one of two formats, distributed on site installations (this would entail roof top solar panels and/or backyard windmills) or centralized installations

(fields of solar panels or wind turbines are sited in an optimal location). In the case of large wind farm installations, it is likely that these would be sited a significant distance from the end users (demand) on large open windy plains. To transport power from these installations to cities would require power lines of significant length (considering longer lengths = larger losses). Power line losses are considered in greater detail later on in this report.

In addition to considering the efficiency involved in supplying oil derived fuels, there are also many factors that should be considered in the case of natural gas. Natural gas is typically considered the most difficult of the fuels to transport in that in most cases, the fuel must be liquefied for transport. This includes liquefying the gas for transit in pipelines as well as liquefaction for storage in tanks (as would be found on ships, trains or trucks). The process of liquefaction requires powerful compressors which consume a great deal of energy. Compression of gaseous fuels is a debated topic in that the more a gas is compressed, the greater it's storage density; however compression uses a great deal of energy and evaporation is more problematic (the gases seep out of the tanks as they warm). There is currently fierce competition as to whether future hydrogen powered vehicles will used compressed hydrogen or gaseous hydrogen (among other storage means).

A very important type of loss to consider is that of power lines. While loss characteristics vary from line to line, the most significant variable affecting loss over a distribution system is the distance between the load and source. The efficiency of a power line (η) is computed by dividing the power output from one end of line by the power input at the opposite end of the line. This relationship can be expanded as follows:

$$\eta = \frac{Pout}{Pin} = \frac{Pout}{Pout + \Delta P} = 1 - \frac{\Delta P}{Pin}$$

Losses are often in the thousands of kW per kilometer and are greatly dependent on current. As the current increases, power lines act increasingly like resistances and thus more power is loss, usually in the form of heat.[18] There are now superconductive cables with essentially no loss available to date, however these cables are actually less efficient overall due the power needed to chill them to a temperature cold enough for superconductivity.

In conclusion, there are many factors in the production and transportation of the electricity that cause loss. As now there are many solutions for these factors. In the case of the power loss across the lines, there is current research on transporting electricity optically under ground. In the case of the power loss in generation, one possible solution is to use alternative sources like solar, wind and hydropower which lead to less potential loss.

7. Conclusion

Now we are more familiar with the regulation, policies and the construction of the electricity markets as well as issues pertaining to the regulatory environment for electricity markets in the USA.

The electricity market is made from three major types of companies which are generating companies, transporting companies and distributing companies. The generating companies are generating electricity and will transport it through the transmission lines to the distribution companies.

[18] P. 205 Freeman: Electric Power Transmission & Distribution

In order to use electricity we have to convert other forms of energy to electrical energy; moreover, the production of electricity is related to other industries. Electricity is mainly produced by using Fossil Fuels, Nuclear energy, Wind power, solar energy and hydropower. Cost of production electricity using some of above energies is dependent on the fuel cost (i.e. coal, gas oil, uranium) and in some other cases the cost of production is just fixed and depends on maintenance (i.e. Wind blades, solar pounds, solar reflectors and dams). In United States, usually the Nuclear and coal power plants are being use to meet the base load period since they have a high ramping cost and low variable cost. Depending on the fuel price and plant location, the hydroelectric and gas turbines are being use during the intermediate period. There are some losses in production of electricity using the fossil fuels due to the fact that fossil fuels require more and more energy to being extended, and fuels become increasingly scarce. This problem can be solved by using other energies (solar, wind and hydropower) to generate electricity.

The transmission companies are in charge of transporting the electricity from the generators to the distribution companies. The transmission of the electrons in the wires is not efficient yet, and there is current research regarding the transfer electricity optically underground. But up to that time the loop flow is one of the best technologies available to prevent loss.

Since 1970's, regulation over the electricity market became less popular and the deregulation dominated over the market. The generation companies are competing against each other because it is efficient in United State to have many generation companies since United State is a big country, but it is unreasonable to deregulate the transmission and local distribution companies since they act like the cable and gas

companies. The state and federal government still have some minor regulations for generation companies. One reason for that is to avoid the cause, similar to the 2000 California crisis.

It is true that the electricity generation, transmission and distribution are not all under the same company but they are all related to each other and they cooperate with each other. Now the generating companies provide the electricity for distribution companies through the lines that transmission companies are in charge for (there is a loss in this lines and if the generation companies are closer to the distribution companies the loss is less), and the distribution companies sell the electricity to all the users. The generation companies usually make contract with the distribution companies to provide them the electricity that they order that day. When the distributor companies make their contract with the generator companies they request more electricity than they estimated in their calculations. The estimation that the distribution companies do are base on the time of the year, time of the day, the weather and population of the users.

After reviewing the previous body of research, it seems to me that the electricity markets in USA are still being developed and in need of important improvements. First, generation of power seems to be not diversified enough. For instance, Denmark, with only a fraction of the territory of the USA is able to produce electricity from wind at a much greater rate. Second, while it seems that a separation between generation, transmission and distribution is critical for a free market, this scheme needs to be weighted against the potential problems seen in the 2000 California Crisis (where a handful of companies can take advantage of a poorly regulated market). Third, Increase of generation of electricity using the Solar system will help the environment. A very

important point for the future is to improve the storage of electricity (i.e. research of fuel cells). Storing the electricity will lessen the risks involve in production, generation, transmission and any inefficiencies present in partial deregulation strategies such as the current one.

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