Project Number:

Upcoming Energy Crisis

An Interactive Qualifying Project
Submitted to the Faculty of

Worcester Polytechnic Institute

In partial fulfillment of the requirements for the
Degree of Bachelor Science

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Date: 29 April 2003

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Abstract

Fossil fuels are the world's primary source of all energy produced. According to the most optimistic projections our supply of fossil fuels will be exhausted in as little as three hundred years. Alternative renewable energy sources such as wind and solar energy have the potential to lead the way in aiding our energy needs. The ultimate goal of our project was to formulate the best possible energy policy to counteract the depletion of fossil fuels. To achieve the best combination of renewable sources and fossils fuels, we evaluated social, economic, and environmental impacts the policy will have on modern society.

Executive Summary

Since the beginning of the Industrial Revolution in the early 19th century, the demand for energy sources have been increasing dramatically with each passing year. This demand has created problems such as fossil fuel depletion, carbon dioxide emissions, global warming, etc. The goal of this project is to provide information on improved usage tactics of the remaining fossil fuels while researching alternative sources of energy.

The current energy policy focuses on oil production while hardly even mentioning renewable energy sources. Pushing for more attention to renewable sources of energy will help to protect against oil and gasoline supply disruptions and price spikes, as well as help rid the environment of greenhouse gases. We hope that future policymakers will take our research into account when developing a new energy policy.

Wind and solar energy are the two renewable energy sources we believe have the most potential for future energy use. Both of these alternative methods of energy production have made great strides in improving efficiency and reducing their costs, but it is clear that more money needs to be spent on developing these methods or the cost to produce energy will remain high. Our research has shown the best locations to build wind farms and the best areas for photovoltaic systems. Also, models have been developed to show the potential benefits of one method over another or a renewable energy source versus regular energy from fossil fuels. Wind and solar energy are also the least used of the renewable energy sources. The combination of wind and solar energy makes up only 2% of the energy produced by renewable sources. Hydroelectric, biomass, and geothermal make up 48%, 44%, and 6% of all energy produced by renewable energy sources respectively. Although wind and solar only make up 2% of the current renewable energy produced, they have the most potential of all of the renewable sources. The other renewable sources have barriers that cap off the amount total potential, such as lack of good hydroelectric sites, lack of possible locations for geothermal plants, and the pollutants and hydrocarbons emitted from biomass combustion.

This project was concentrated around development of wind and solar energy, but much attention was also given to fossil fuels because reaching a sustainable energy plan requires better use of the remaining fossil fuels. Currently over 85% of the world's energy supply is fossil based. Hopefully, with continued research and development of renewable energy sources, the world's energy policy will switch from oil dependence to more reliance on methods of renewable energy.

It’s clean that the world’s problem with energy and lack thereof has turned into an energy crisis and can no longer be something that we put aside for a later date. There is a finite amount of time until our fossil fuel supplies will be depleted, but with continued research towards renewable energy we can greatly increase the amount of time remaining.

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Chapter 1

Introduction

1.1 Choosing Energy Sources

When deciding which solutions to the energy crisis we would research, we took several properties of each energy source into account. These properties included cost, environmental impact, tangible amount of resource left in the world, etc. This led us to decide on three sources: wind energy, and solar energy. Although these two sources of energy were chosen as our top two, they both have drawbacks which will also be discussed.

One of our main objectives of the project is to research the development of wind and solar energy. Not only will we be trying to help develop these sources of energy, but also helping to ease the transportation of this energy from its origin to the consumers with the least amount of environmental harm possible. We will research many different ideas and formulate various hypotheses.

One of the biggest factors in dealing with the energy crisis is the social aspects. The thing is everyone uses energy, which means everyone has a choice of which types of energy they use. Many peoples' opinions are formulated around how environmentally safe the specific energy source is. Also many people are affected more than others due to their geographic location (proximity to a wind farm for example), which certainly plays a major role in the decisions of backing certain types of energy sources.

1.2 Personal Motivations

Mason Winner:

I chose this project because of its obvious impact on everyday life. I can not imagine what life or even school would be like if there was no fossil energy left in the world, but this is a problem that we grow closer and closer to facing everyday. The energy crisis becomes more and more of a problem with each new generation of people. I believe many of us attending colleges now will be working on some aspect of renewable energy at some point in our careers. Being a computer science major, I would not be surprised to see myself designing programs to test the efficiency of solar cells made of diamond film for example. Another motivation is the environmental aspects of the project. Something needs to be done about the tremendous toll that dangerous toxins resulting from used energy take on our environment. Everyone knows that one needs some form of energy to power their vehicles, electronics, etc., but they probably don't know how this energy is created and makes its way into their lives. I believe this project will be very interesting and the information gained from it, very useful. In taking on this project, I hope to ascertain that the human race will always keep the upper hand in this battle verse time and energy.

John Carnevale:

I was first informed about this IQP project my current group partner Mason Winner. I became immediately interested in the topic because of the many different problems which are arising in the hopes of conserving energy. It also seemed like a project which would desire a very concentrated group effort, while presenting a challenging problem which seemed would inevitable provide us with great new knowledge and new ideas to conserve our precious energy. I realize that there are many different ways to produce energy, but how many of these ways are environmentally safe and are of reasonable cost. Wind Energy could in fact be one of the cleanest ways to produce energy, but unfortunately it has many drawbacks. These drawbacks may have answers, but their solutions surely will not be easily acquired. This seems a great challenge and is most of the reason I was attracted to and chose to look further into this particular topic. One of the main reasons for my great interest in the Conservation of Energy IQP is that I am in the process of graduating as a Mechanical Engineer. Right now I am doing research about wind energy and much of my research shows that a lot of formulas and equations used for building wind turbines are from a mechanical point of view. I could certainly see myself working in the field of wind energy because of the many different challenges it puts forth. I'm sure in the upcoming years as wind energy is further explored, more and more mechanical engineers will have a part in designing many of the turbines.

Buddy Penny:

I wanted to do this IQP because conservation of energy sparked my interest. The project will hopefully be a meaningful and practical one, which will help a community. So not only are we doing the project as a requirement but also to help other people. I decided on fossil fuels simple because it seems most important to the energy crisis in the USA and I would also like to learn much more about it. Through learning about it, we are planning on using that knowledge to help with the conservation of energy crisis on Cape Cod.

This is an important project for my career because it will be done very professionally. I will hopefully gain numerous skills including: team problem solving skills, presentation skills, professional documentation skills, time management skills, hands on experience, and more. All these skills will be very useful in any field I end up in. I'm planning on graduating with a major in Biomedical Engineering with a concentration in mechanical. I also have a great interest in Civil Engineering. This project will give me the ability to take a problem, attack it from all possible sides, and come up with a reasonable, sensible solution. In any engineering job this is a very important concept.

Chapter 2

Literature Review

2.1 Researched IQPs

There have been a number of IQP projects done in the past at WPI that pertain to world energy concerns. The first thing our group decided to do was to research these projects to obtain good background material on our project topic. Most of the projects we researched had to do with the conservation of energy or alternative energy sources. This research helped us to acquire a general scope of the task we had to accomplish.

2.1.1 02C027I

Title: The Upcoming Energy Crisis

Author(s): Bowden, Scott
DeMars, Andrew
Alden, Justin

Advisor(s): Humi, Mayer

Year: 2002

This IQP dealt with finding a new energy policy. It researched present energy sources to see what will happen in the near future to the United States energy resources. They examined in-depth; oil, natural gas, coal, nuclear, wind, solar, hydroelectric, biomass, and geothermal energy sources. This helped them to understand the present energy concerns and helped facilitate the creation of there new energy policy. This new energy policy consisted of a combination of renewable and non-renewable energy sources to better compliment the use of energy in the US.

This helped with our project because it covered many of the same topics we researched. Although this project included hydroelectric, biomass, nuclear, and geothermal and ours did not, it was still a very useful source for background research.

2.1.2 01B027I

Title: The Upcoming Energy Crisis

Author(s): Harrington, Robert

Minka, Nicholas

Mulhall, Shamus

Advisor(s): Humi, Mayer

Year: 2001

Once again this project was done on the energy crisis approaching the US in the near future and concentrated on finding a new policy that would be economical and reasonable. This project was very helpful to our research in that it discussed the use of wind and solar energy in combination with fossil fuels to create a new energy policy. Before doing this they researched in detail, the present status of these different types of energy. Once they had a sufficient amount of information on wind, solar, and fossil fuels they discussed possible solutions to the upcoming crisis.

2.1.3 01C020I

Title: World Energy Use Virtual Exhibit

Author(s): Partridge, James

Pitreau, Brian

Proshchitskiy, Alex

Swick, Zachary

Advisor(s): Thompson, Robert

Menides, Laura

Year: 2001

The National Museum of Science in London was holding an energy gallery and sponsored this project to create exhibits related to world energy use. They had to research on all the different types of energy used in the world, along with museum exhibit design. The world energy use research done helped us to obtain more background information on fossil fuels, wind energy, and solar energy. The projected at least touched upon, if not elaborated on, each of these energy sources. Although our project concentrated on US energy use, we also needed to compare and contrast US to World energy. This project gave us abundant amounts of information on energy use on a global scale.

2.1.3 00D132I

Title: Alternative Energy Resources at Colegio Technologico

Author(s): Fontaine, Dan

Jacques, Dan

Troncoso, Antonio

Advisor(s): Woods, Douglas

Menides, Laura

Year: 2000

This project concentrated specifically on electrical power and was perform in San Juan. The objective was to come up with an alternative to purchasing electric power form a local utility. This project helped us to understand the basics of creating a new policy. It also made suggestions in the recommendations of was to use alternative energy resources effectively and cost efficiently. This project was also an excellent source for us to use as a reference for putting our formal written project together. It was very organized and well presented.

2.1.4 00D163I

Title: Siting Offshore Windfarms

Author(s): Berry, Anthony

Lamoureux, Joel

Staples, Todd

Advisor(s): Pierson, Steven

Carrera, Fabio

Year: 2000

This project researches the Ocean Ranch project that proposes two wind farm sites in Nantucket Sound. It investigated the important factors (water depths, avian issues, and visual impact) to determine whether the proposal was suitable for the locations selected. This project found that the sites were promising and so were some more nearby locations.

Wind energy was a main renewable energy source that we investigated in our project. This previously completed IQP helped us to better understand the dynamics of wind farms and wind farm locations. It served as a good source for background information on wind energy and how it works.

Chapter 3

Fossil Fuels

3.1 Background of Different Fuels

Energy is very important today in everything we do and everything around us. Without energy the world as we know it would not exist. Currently, we get most of our energy from "fossil fuels". Coal, oil, and natural gas make up the three main forms of fossil fuels. Other energy used that we will explore in this project are wind and solar energy. The future of fossil fuels is very important to our society's energy "crisis".

Before discussing the individual fossil fuels and the future of them we should first have a good understanding of what they are and where they originate from. When prehistoric plants and animals (that lived hundreds of millions of years ago) died, they decomposed and were heavily covered with rock and mud. The decomposing, in addition to the types of materials that were buried, how long it was buried, the temperature, and finally the pressure, all combine to create the different types of fossil fuels.

The most abundant fossil fuel that America has is coal. "The United States also has more coal reserves than any other single country in the world. (http://www.fe.doe.gov/education/)" All this coal is used primarily to generate electricity. Power plants in the U.S. generate more than half the energy we use by burning coal. The four different types of coal that we mine today are: lignite, subbituminous, bituminous, and anthracite. There is enough coal to be used as energy for about the next 200 to 300 years. There are imperfections to burning coal for energy.

These include sulfur and nitrogen trapped in side coal that mixes with water vapor to produce "acid rain". Also, when coal is burned, carbon combines with oxygen and forms carbon dioxide. This is a major contributor to the "greenhouse effect". The future of clean energy produced by coal depends on advances in technology to filter out the pollutants. "Many of these technologies belong to a family of energy systems called "clean coal technologies." Since the mid-1980s, the U.S. Government has invested more than $2 billion in developing and testing these processes in power plants and factories around the country" (http://www.fe.doe.gov/education/). Clean coal technologies can be new combustion processes - like fluidized bed combustion and low-NOx burners - that remove pollutants, or prevent them from forming, while the coal burns. Clean coal technologies can also be new pollution control devices - like advanced scrubbers - that clean pollutants from flue gases before they exit a plant's smokestack. Still other clean coal technologies can convert coal into fuel forms that can be cleaned before being burned. For example, a clean coal plant may convert coal into a gas that has the same environmental characteristics as clean-burning natural gas. (http://www.fe.doe.gov/coal_power/cct/).

Oil is another one of the fossil fuels mentioned above. The U.S. uses this form of energy more than any other country. "Oil supplies 40 percent of all the energy this country consumes" (http://www.fe.doe.gov/education/). A big problem with oil energy in the U.S. is that we can not produce enough oil to satisfy our demands. This is where

OPEC comes into play. OPEC is the Organization of the Petroleum Exporting Countries. These countries pump oil and sell it to other "in need" countries (like the U.S.). We measure oil in barrels (one barrel equals 42 U.S. gallons). "The world crude oil reserves are estimated to be more than 1012 billion barrels, of which the 11 OPEC member countries hold more than 75 percent. (http://www.kcpc.usyd.edu.au/discovery/9.2.2/9.2.2_OilReserves.html)" As of today the world produces 75 million barrels a day. If world economic growth continues the demand for oil will be much higher and will gradually increase. No one knows for sure how long the oil reserves will last. Some oil producers feel we will be fine for a long time to come, while others feel the reserves might last less than 20 years.

The final fossil fuel discussed is natural gas. This is made up primarily of methane. We burn this in homes for cooking, heating, and to fuel many other things. "Natural gas provides one-fifth of all the energy used in the United States" (http://www.fe.doe.gov/education/). There is plenty of natural gas in the U.S. but it is expensive and can be difficult to get to. We should have enough to last at least 60 year and probably a lot longer. The future of nature gas depends on finding newer, cheaper ways of obtaining it from the ground.

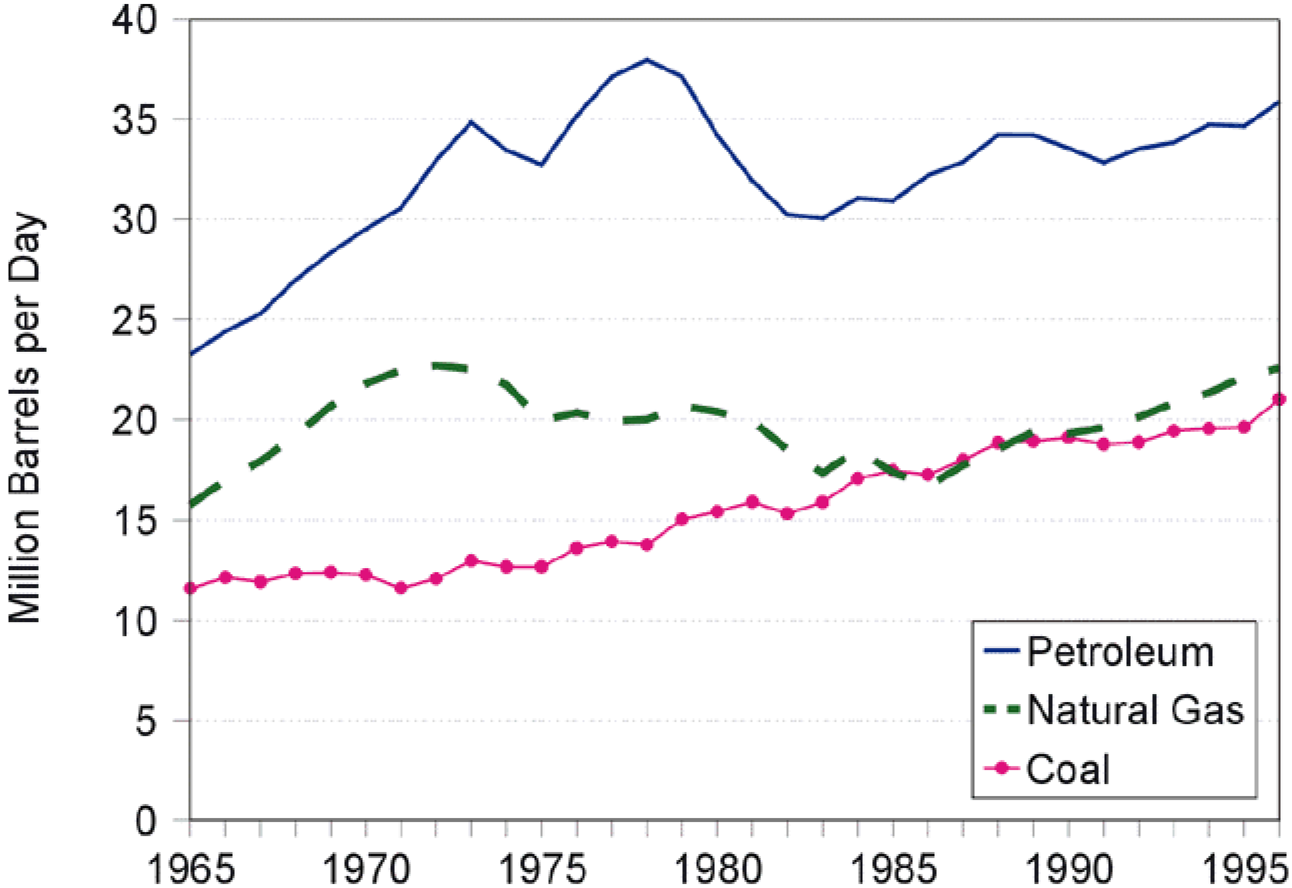
3.2 Consumption Rates and Projections

The consumption of fossil fuels is important to the future of energy sources in the U.S. The rate at which the U.S. uses these fuels is examined to give us some idea of how long we have left to use these types of energies. All three fossil fuels have different expected times of disappearance (when they're all used up).

The first graph illustrates just the three energy sources concentrated on in this project (fossil fuels: coal, oil, and natural gas). It displays the consumption rate of them from 1965 to 1995, a period of 30 years. You will notice that in this period of time their consumption seems to all be constantly increasing, with the exception of oil in 1977 when the rate drops because of higher prices. You see a more steady consumption rate of oil during 77-86, then the price collapsed and consumption rates have gradually been increasing since. Natural gas rates stay nearly flat because we can't produce enough of it anymore and we do not import it. It is said to run out in the next 50 years. Coal is the only one that we can count on for a long time to come. It makes up 97% of our fossil fuel reserves. "At the current usage, supplies will last 1500 years. At 5% growth rate, supply will last 86 years" (http://zebu.uoregon.edu/1999/ph161/l12.html). The number one reason for such a difference is due to exponential growth in demand for this fuel in the future.

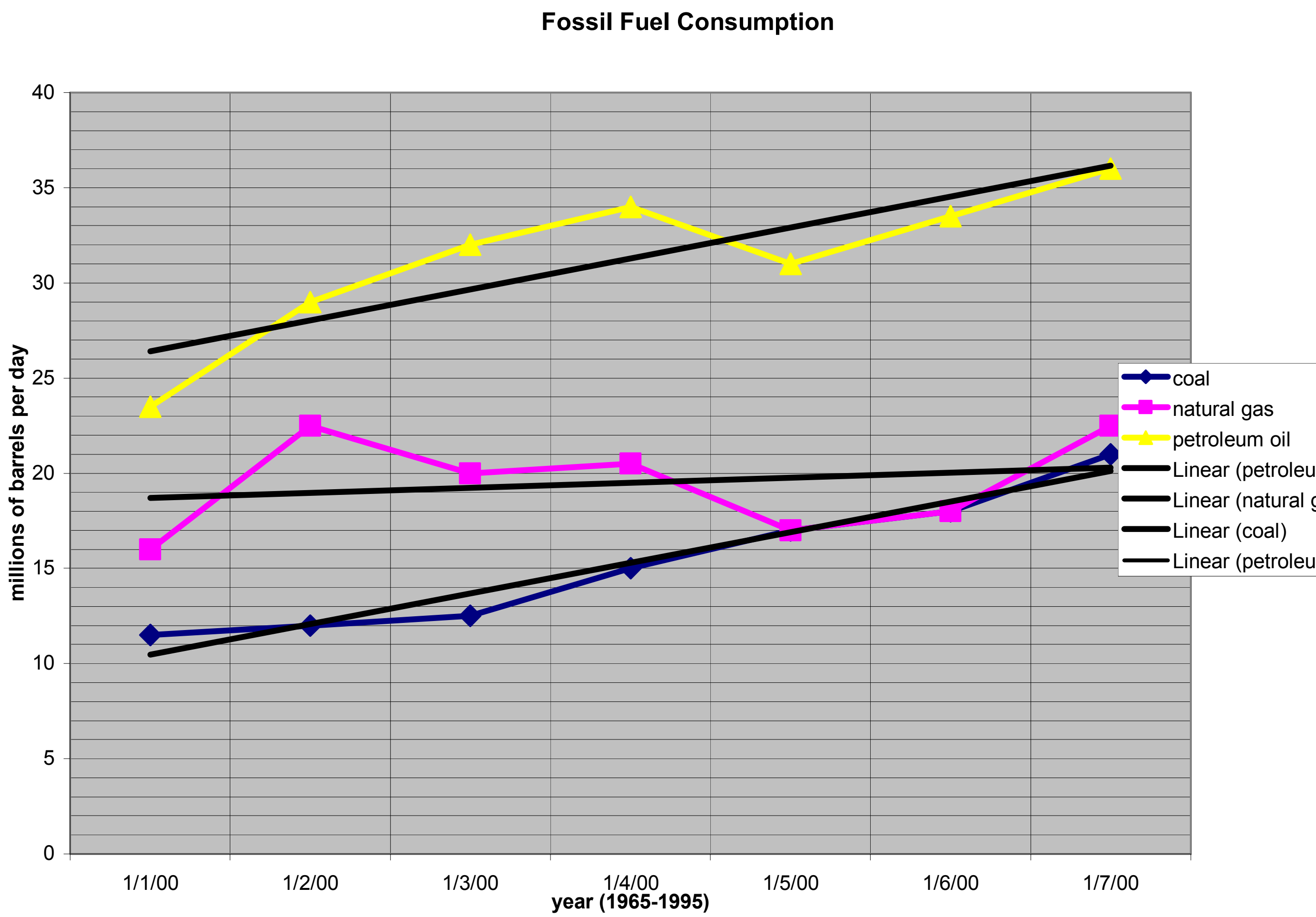
http://www.eia.doe.gov/cneaf/electricity/chg_str_fuel/html/fig20.html

Figure 20. U.S. Fossil Fuel Consumption, 1965-1996



Source: Energy Information Administration, *Annual Energy Review 1996*, DOE/EIA-0384(96) (Washington, DC, July 1997), Table 1.3.

To get a better idea of the future of fossil fuels I took this graph and plotted the best fit line to find the slope. Once this was obtained I could obtain a reasonable value of consumption for future years:



Slope= rise/run

Run = period = 1995-1965 = 30 years

For oil:

36 millions of barrels a day – 25.5 millions of barrels a day = 10.5 millions of barrels a day

slope = 10.5 millions of barrels a day / 30 years

= .35 millions of barrels a day/year

So in 2050 we can estimate the following:

30 years + 55 years = 85 years

.35 = x / 85 years

x = 29.75 millions of barrels a day

29.75 + 25.5 = 55.25 millions of barrels a day (in the year 2050)

For Natural Gas:

20.2 millions of barrels a day – 18.8 millions of barrels a day = 1.4 millions of barrels a day

slope = 1.4 millions of barrels a day / 30 years

= .04667 millions of barrels a day/year

So in 2050 we can estimate the following:

30 years + 55 years = 85 years

.04667 = x / 85 years

x = 3.97 millions of barrels a day

3.97 + 18.8 = 22.77 millions of barrels a day (in the year 2050)

For Coal:

20 millions of barrels a day – 10.5 millions of barrels a day = 9.5 millions of barrels a day

slope = 9.5 millions of barrels a day / 30 years

= .3167 millions of barrels a day/year

So in 2050 we can estimate the following:

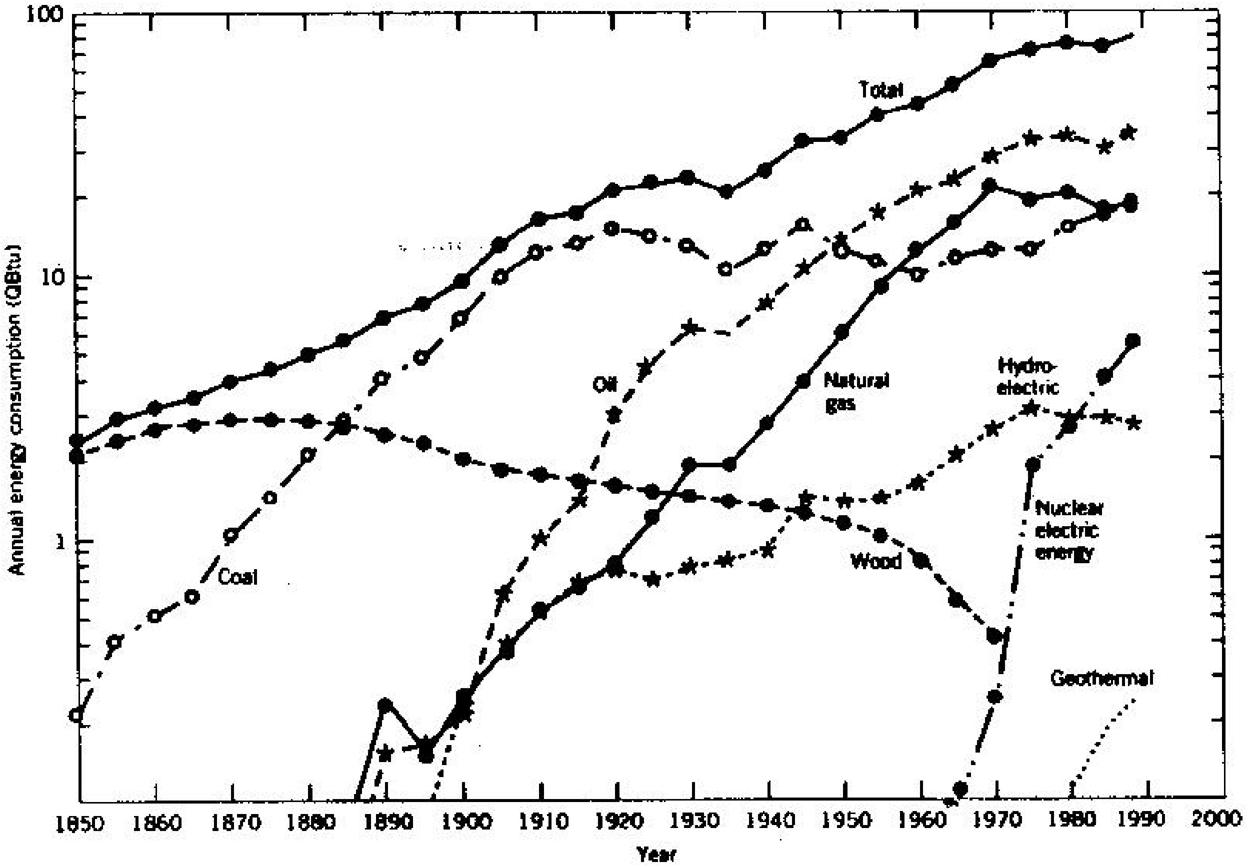
30 years + 55 years = 85 years

.3167 = x / 85 years

x = 26.9 millions of barrels a day

26.9 + 10.5 = 37.4 millions of barrels a day (in the year 2050)

This second graph shows a comparison of fossil fuel consumption to that of other types of energy. It illustrates the importance of finding alternative energy sources or discovering more fossil fuels. As you can see, the three fossil fuels top the charts for consumption in the U.S. If these rates continue to grow and production/import does not increase then we will soon run out of all of these (some quicker than others).

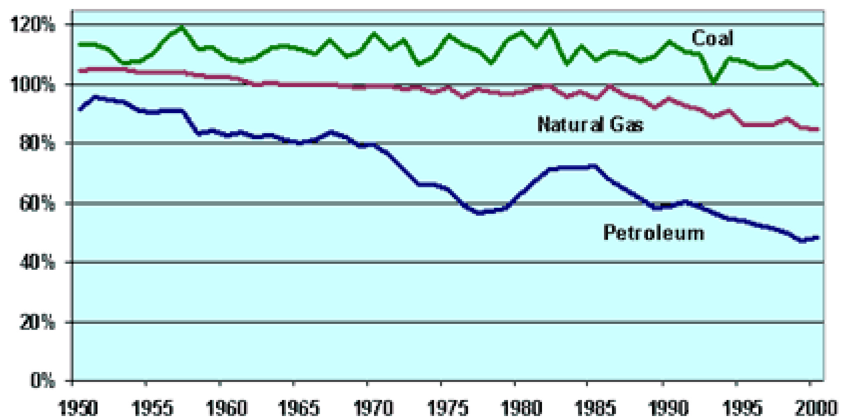


http://zebu.uoregon.edu/1999/images/econsum.gif

3.3 Production Rates and Projections

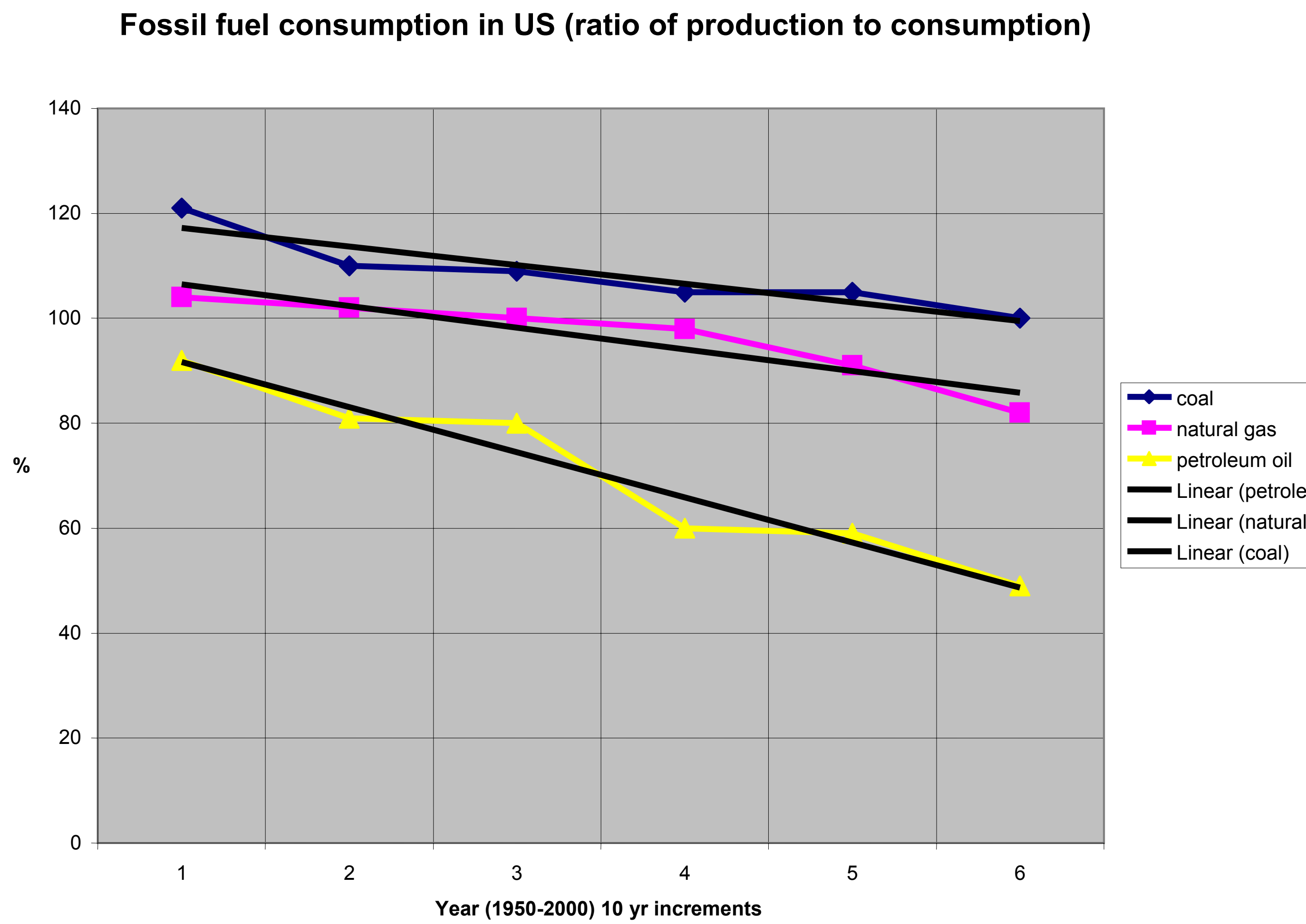
While examining the consumption rates, it is also important to compare that to the production rates of these fuels. This is how we know that we have enough coal and not enough oil. The U.S. has nearly always produced enough oil to fulfill its needs. Natural gas production in the U.S. has been lacking since 1967 and since then we have not imported much, but enough to meet our needs. Oil is a major import for the U.S. We import more than half the oil we consume each year. This is once again because our need far surpassed our domestic production. This important concept of fossil fuel production as a share of consumption is graphed below. Important facts from this graph include: we are comfortable with coal, and hurting for oil.

Fossil Fuel Production as a Share of Consumption in the USA



Source: Energy Information Administration, *Annual Energy Review 2000*, Tables 5.1, 6.1, and 7.1, DOE/EIA-0384(2000), August 2001. [Graph shown in EIA's *Energy Perspectives: Trends and Milestones 1949-2000*, DOE/EIA-X055, December 2001.] http://www.ott.doe.gov/facts/archives/fotw209.shtml

I did some calculations using the best fit line of the graph to obtain the slope again, and then determined an estimated time of complete depletion:



Slope= rise/run

Run = period = 2000-1950 = 50 years

% = (production / consumption) x 100

For oil:

91% - 50% = 41%

slope = 41% / 50 years

= .82%/year

So for complete depletion:

percentage would go to 0....... 120% -0% = 120%

.82 = 120% / x

x = 146 years

146 years – 50 years = 96 years (until we run out)

For Natural Gas:

107% - 87% = 20%

slope = 20% / 50 years

= .4%/year

So for complete depletion:

percentage would go to 0....... 120% -0% = 120%

.4 = 120% / x

x = 300 years

300 years – 50 years = 250 years (until we run out)

For Coal:

118% - 100% = 18%

slope = 18% / 50 years

= .36%/year

So for complete depletion:

percentage would go to 0....... 120% -0% = 120%

.36 = 120% / x

x = 333 years

333 years – 50 years = 283 years (until we run out)

The future of fossil fuels depends greatly on how we use them now and new ways we discover to find them. They are a non-renewable energy source, so we will eventually run out of all three (coal, gas, and oil). The only question is exactly when.

3.4 Problems with Fossil Fuels

One of the main concerns with fossil fuels is the air pollution it creates from burning the coal, oil, and natural gases. The chemicals in polluted air can cause cancer, brain and nerve damage, birth defects, lung injury, and breathing problems. Air pollution harms the environment, and the people, animals, forests, streams and lakes that reside within it. There are four main problems with fossil fuel energy.

The four big problems that fossil fuels create are:

3.4.1 Air pollution – driving cars burns gasoline, although car's catalytic converters are ideally made to filter out air pollutants they're not perfect. They create the following:

- Carbon monoxide, a poisonous gas
- Nitrogen oxides (urban smog)
- Unburned hydrocarbons (urban ozone)

Air pollution from cars and power plants is a real problem in big cities. The smoke that comes out of power plants smokestacks is formed from burning coal. There are tiny specks of minerals, including common dirt, mixed in coal. Some of the tiny particles get caught up in the swirling combustion gases and, along with water vapor, form this smoke.

. http://www.howstuffworks.com/hydrogen-economy1.htm

3.4.2 Environmental pollution – accidents that happen from transporting these fossil fuels greatly effects the environment. For example, oil tanker spills have continuously polluted our waters. Also pipeline explosion or well fires make big messes. The Exxon Valdez spill is the best known example of the problem, but minor spills happen constantly.

Another example of environmental pollution is "acid rain". "Trapped inside coal are traces of impurities like sulfur and nitrogen. When coal burns, these impurities are released into the air. While floating in the air, these substances can combine with water vapor (for example, in clouds) and form droplets that fall to earth as weak forms of sulfuric and nitric acid – scientists call it 'acid rain'" (http://www.fe.doe.gov/education/).

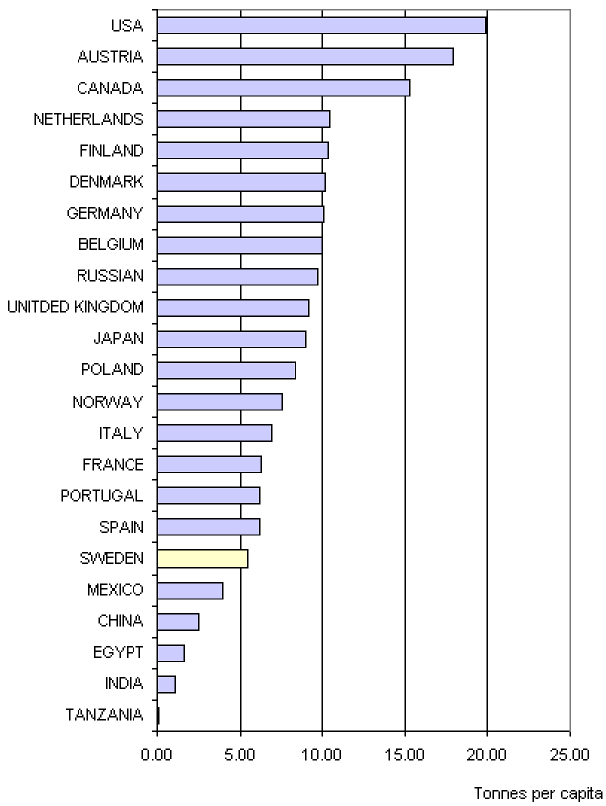
Supertankers being loaded with oil in Saudi Arabia

. http://www.howstuffworks.com/hydrogen-economy1.htm

3.4.3 Global warming - coal like all fossil fuels is formed out of carbon. When coal burns, its carbon combines with oxygen in the air and forms carbon dioxide. Carbon dioxide is a colorless, odorless gas, but in the atmosphere, it is one of several gases that can trap the earth's heat. "The largest single source of atmospheric carbon dioxide (CO_2) is the burning of fossil fuel (coal, oil and gas), which currently accounts for ~80% of the annual emission of CO_2 into the atmosphere" (http://www.giss.nasa.gov/research/intro/matthews_01/). "Total world carbon dioxide emissions from the consumption of petroleum, natural gas, and coal, and the flaring of natural gas increased from 5.873 billion metric tons of carbon equivalent in 1990 to 6.144 billion metric tons in 1999, or by 4.6%" (http://www.giss.nasa.gov/research/intro/matthews_01/). This emission is known as greenhouse gas and is slowly raising the temperature of the planet. The ultimate effects are unknown, but it is a strong possibility that, eventually, there will be dramatic climate changes that affect everyone on the planet.

The following bar chart displays CO_2 emissions from different fossil fuel burning countries.

http://www.scb.se/statistik/mi0102/mi0102dia2eng.asp



You can see here that the USA is the leader in emissions of this harmful pollutant. There is little to do now to prevent these emissions, but scientists are constantly working to improve how we burn this energy.

“The United States, China, Russia, Japan, and India produced 51% of the world's total carbon dioxide emissions from the consumption and flaring of fossil fuels in 1999. Germany, the United Kingdom, Canada, Italy, and France together produced 12%.

Petroleum accounted for 44% of the carbon dioxide emissions; coal, 35%; and natural gas, 21%" (http://www.infoplease.com/ipa/A0881748.html).

3.4.4 Dependence - The United States cannot produce enough oil to meet demand, so they import it from oil-rich countries (OPEC). That creates an economic dependence. When Middle East oil producers decide to raise the price of oil, the rest of the world has little choice but to pay the higher price.

There are many problems caused by the burning of fossil fuels. The main problem lies in the emission of the pollutant carbon dioxide which leads to global warming. This emphasizes the importance of finding ways to control these emissions and clean up the pollution.

3.5 Carbon Sequestration

We know now that carbon emissions, involved when burning fossil fuels, are a major health and environmental problem. There are two major ways discovered so far that attempt solutions to these problems. These solutions include; developing new technology, and, more temporary but effective, carbon sequestration. Many of these technologies belong to the family known as "clean coal technologies", previously discussed in this report.

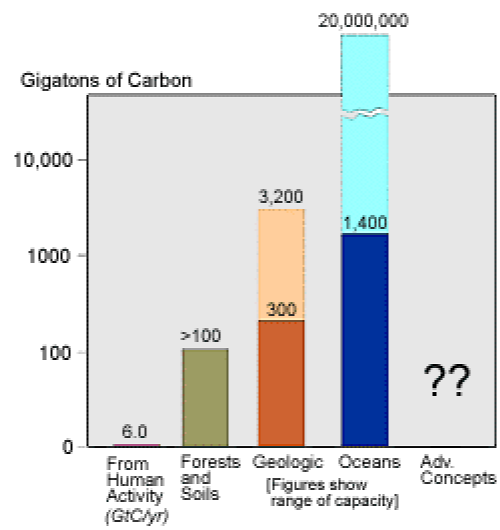
Ideally, the most effective way to reduce the pollution caused by burning fossil fuels would be to come up with extraordinary, alternative ways to produce energy. Today there are other energy sources: wind power, solar power, and nuclear fission. All these are better for the environment, but are too expensive (not cost effective) or still in a developmental stage.

In the last 20 years, scientists have developed ways to capture the pollutants trapped in coal before the impurities can escape into the atmosphere. “Today, we have technology that can filter out 99 percent of the tiny particles and remove more than 95 percent of the acid rain pollutants in coal.” (http://www.fe.doe.gov/education/) Another very promising approach is carbon sequestration. This process involves collecting and storing emitted carbon dioxide, from fossil fuels, in trees, oceans and other potential reservoirs. This will hopefully reduce the CO2 emissions into the atmosphere.

The Department of Energy’s office of Science is concentrating mainly on the following areas of sequestration: sequestering carbon in underground geologic repositories, enhancing the natural terrestrial cycle, and carbon sequestration in the oceans.

Although this process is still in its beginning stages the outcomes look very positive. “The President’s Committee of Advisors on Science and Technology recommended increasing the U.S. Department of Energy’s (DOE’s) research and development (R&D) for carbon sequestration. The report stated: ‘A much larger science-based CO2 sequestration program should be developed. The aim should be to provide a science-based assessment of the prospects and costs of CO2 sequestration. This is very high-risk, long-term R&D that will not be undertaken by industry alone without strong incentives or regulations, although industry experience and capabilities will be very useful.’” (http://www.fe.doe.gov/coal_power/sequestration/index.shtml)

Global Sequestration Capacity

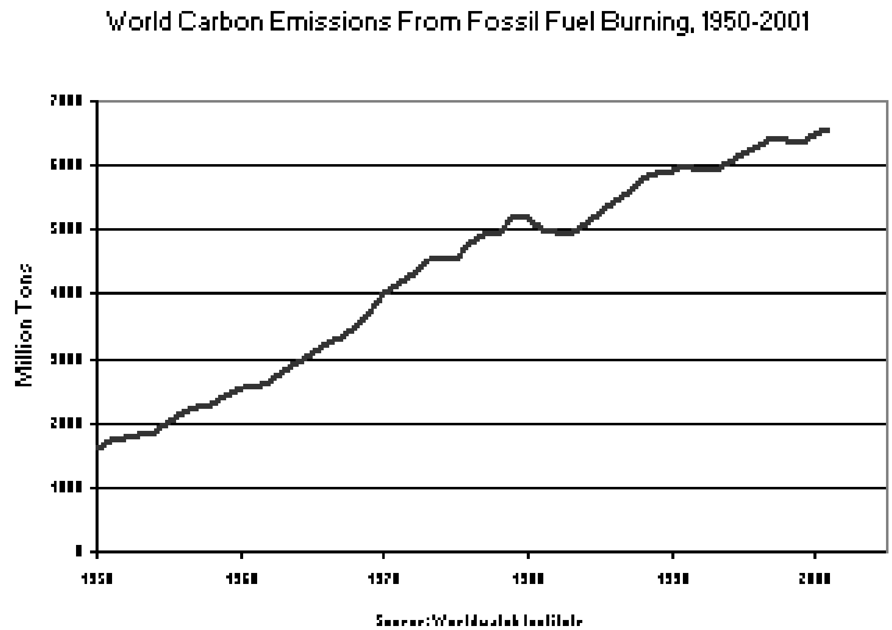


The graph above shows where we stand now as far as sequestered carbon and what we are capable of in the future. You can see that there is a lot of room to work with in this area. For this to be successful the sequestering process has to cost effective, provide long term storage, and be environmentally safe.

The efforts for cleaning up fossil fuels are evident and we can expect things will only get better. Carbon sequestration is a good method to use until our reserves run out. This is a reason why, ideally, the best solution is to come up with the most cost effective and environmentally safe combination of new ways to produce energy.

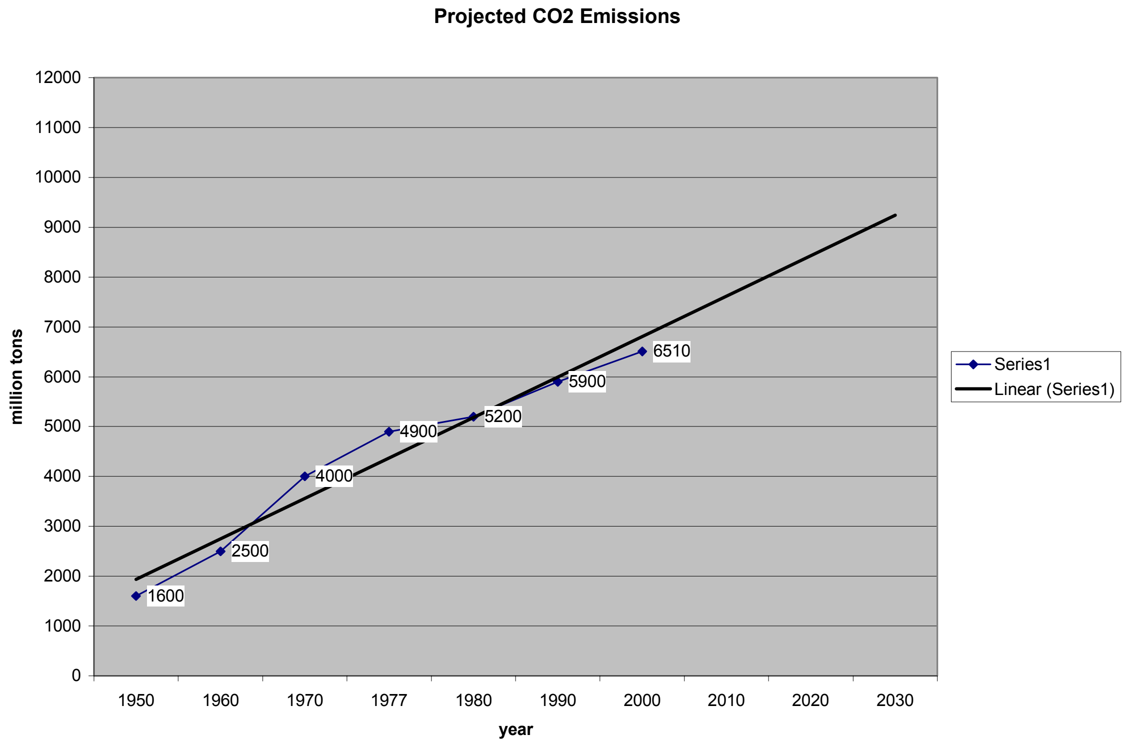
3.6 Projected CO2 Emissions

http://www.earth-policy.org/Indicators/indicator5_print.htm



This graph displays the CO2 emissions from burning fossil fuels over the past 50 years. You can see the gradual increase which shows a quadrupling in this 50 year span, from 1600 million tons in 1950, to 6500 million tons in 2000.

To project the possible future of CO2 emissions I used excel to plot the data from this chart. Once I produced a similar chart to the one above, I plotted a best fit line. Then I extended this line to see the emission level in the next 30 years. From this I found that CO2 emissions are estimated to be 9300 million tons in the year 2030.



This projection is definitely not 100% accurate because there are on going improvements concentrating on limiting CO_2 emissions. Also, the use of fossil fuels is expected to change in upcoming years. "Coal use is expected to increase by 45 percent, oil consumption by 58 percent, and natural gas by 93 percent, according to the U.S. Department of Energy"(http://www.earth-policy.org/Indicators/indicator5_print.htm). Coal is the major fossil fuel contributor to CO_2 emissions. Even though its use is expected to increase, it is still below its peak use in 1996. These factors make it hard to predict the future of CO_2 emissions, even if coal usage remains steady over the next 20 years, the current level of emissions from all fossil fuels is simply too high. The increasing use of fossil fuels will only exacerbate changes in global climate.

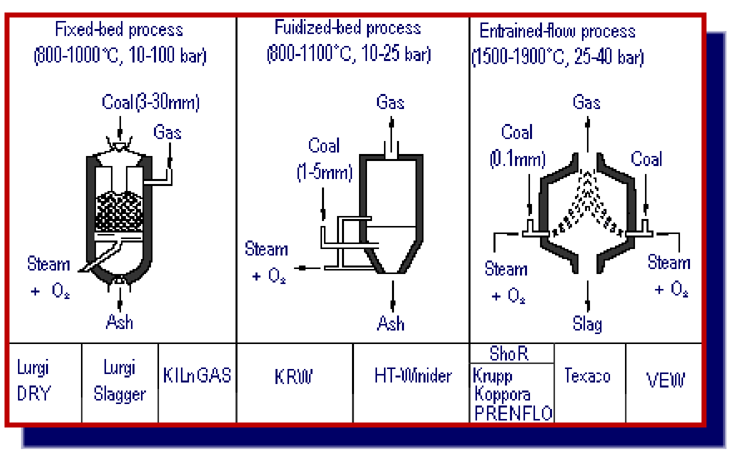
3.7 Coal Gasification

One of the most recent methods to cut down the emissions from burning coal is coal gasification. This does not only filter out many pollutants, it also proves to be much more efficient as well. This is still in its begin stages and many power plants are testing the process to see what the result will be.

Coal gasification reacts coal with steam and carefully controlled amounts of air or oxygen under high temperatures and pressures, rather than the conventional burning of coal. The heat and pressure during the gasification process break apart the chemical bonds in coal, setting into motion chemical reactions with the steam and oxygen. This usually forms hydrogen and carbon monoxide. At this stage in the process the impurities can be filtered out. As much as 99% of SO2 (sulfur), 50 ppm of NOx, and other pollutants can be removed. They can then be processed into commercial products such as chemicals and fertilizers.

There are several options for controlling the flow of coal in the gasification section. The three different ways that IGCC uses are below:

Generic Coal Gasification Reactors

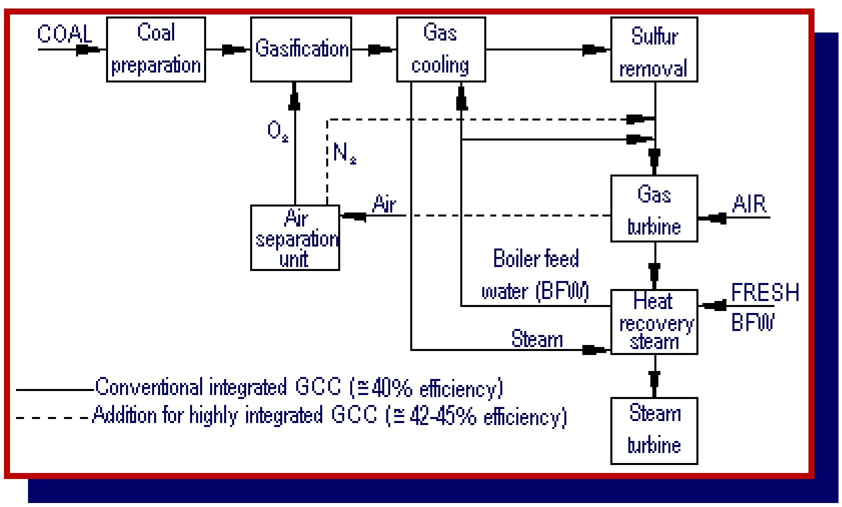


(http://www.f-u-s-s.org/coal_gasification.htm)

This shows the main three coal gasification processes: Left: fixed bed, center: fluidized-bed, and right: entrained flow.

To create a gasification power plant you must integrate these gasification processes into a highly complex, configured system. A basic power plant configuration would look like the following:

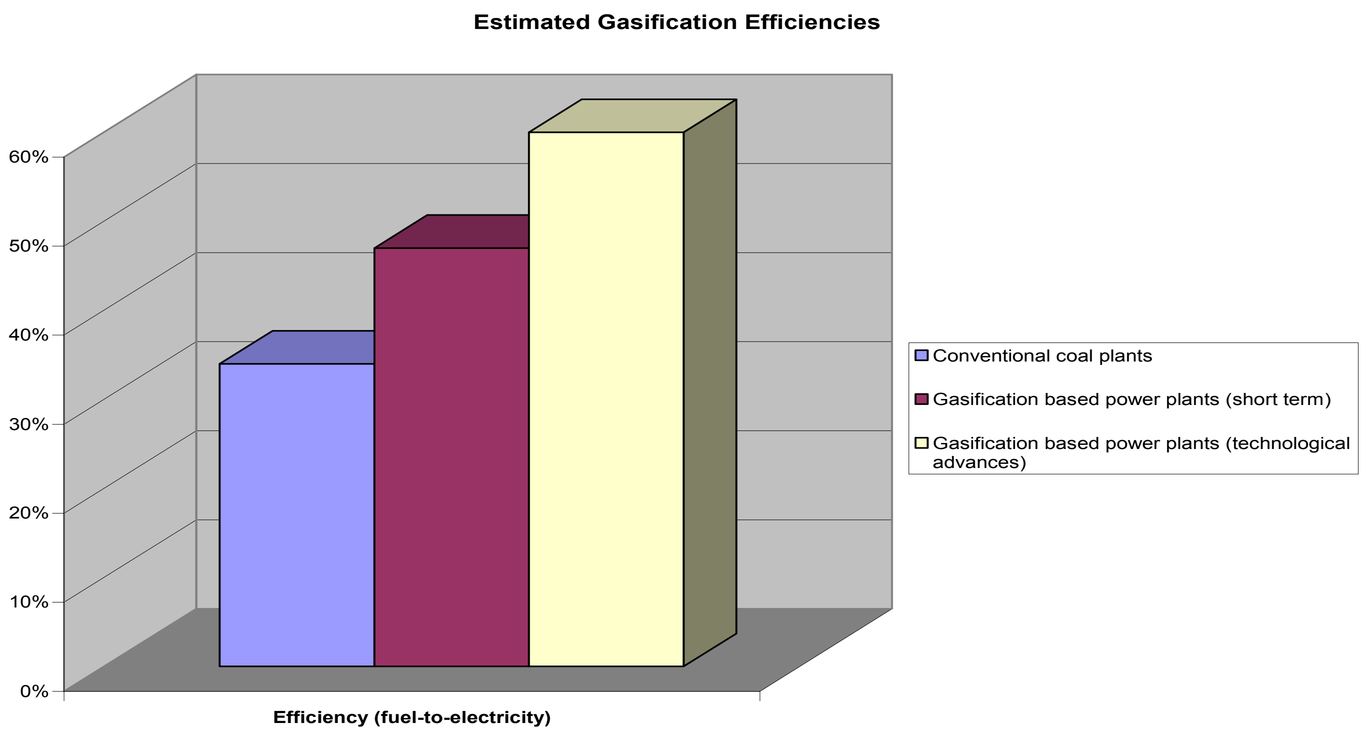
Highly Integrated Gasification Power Plant Configuration



(http://www.f-u-s-s.org/coal_gasification.htm)

One of main reasons the coal gasification process seems so promising is because it offers a much more efficient way to generate electricity than conventional coal-burning. A gasification-based power plant uses the hot, high pressure coal gases exiting a gasifier to power a gas turbine. Hot exhaust from the gas turbine is then fed into a conventional steam turbine, producing a second source of power. This dual, or "combined cycle," arrangement of turbines - a configuration not possible with conventional coal combustion - offers major improvements in power plant efficiencies. This improves upon a conventional plant which uses heat from the coal furnace to boil water, creating steam for a steam-turbine generator.

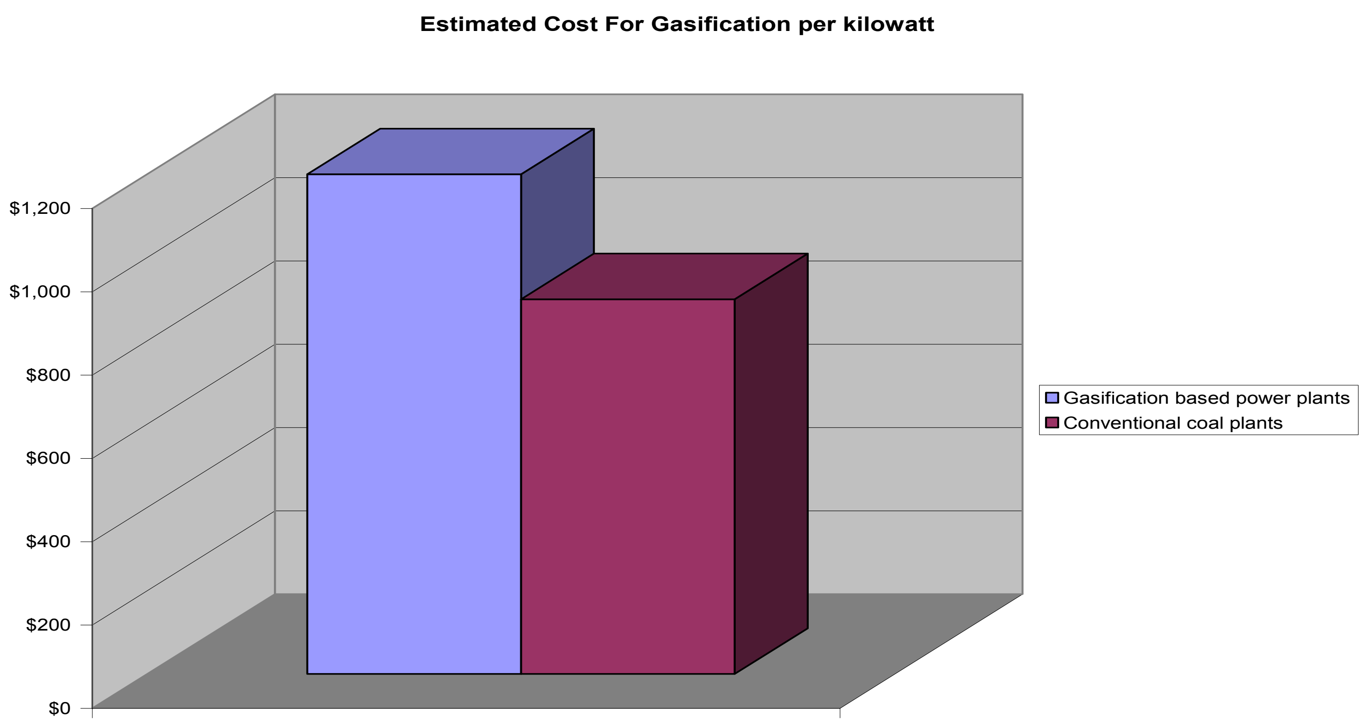
To compare the efficiencies I created a graph which juxtaposes conventional coal combustion with coal gasification in the near and far future. These higher efficiencies mean better economics and a great reduction in pollutants and greenhouse gases.



The coal gasification power plants are still in the elementary (testing) phase. "In DOE's original Clean Coal Technology Program, utilities built and operated two successful coal gasification power plants (near Tampa, FL, and West Terre Haute, IN)"(http://www.fe.doe.gov/coal_power/gasification/index .shtml). Other gasification program locations include Kentucky, Kingsport, TN, Wilsonville, AL, the National

Energy Technology Laboratory in West Virginia and Pennsylvania, and several other industry sites.

Cost is a major reason for not having more of these highly efficient power plants. To demonstrate the difference in cost of a conventional coal burning power plant to that of a coal gasification power plant I again created a graph.



From this you see that conventional methods are 25% cheaper than the gasification methods. For this reason and because environmental regulations in developing countries do not require the high SO_2 removal and low-NOx emissions we continue to use the conventional coal burning methods as our main source on coal energy.

There are many promising aspects of coal gasification. It is high efficient and will filter out a great percentage of emission pollutants. For the next paper I would like to research an existing gasification power plant and see the test they preformed and their results and compare that to others using this process also.

3.8 Cost Analysis

Ideally this project develops an energy policy that will be most effective and efficient, that will combine different types of energy sources. In order to do this, we must first divulge into the current prices and projected prices of these energies. Also, things that affect these prices become very important. The following section will discuss these price issues.

Oil Prices

The average world oil price in 2001 was $22.01 per barrel. Now at this present time (March. 20) its $23.20 but the average to date is $29.86 per barrel so far this year, then to decline to $23.27 per barrel in 2005. Rising prices are projected for the longer term, to roughly $25.50 in 2020 and roughly $26.50 in 2025 largely due to higher projected world oil demand. (http://www.bry.com/prices.htm)

World oil demand is projected to increase from 76.0 million barrels per day in 2001 to 112.0 million barrels per day in 2020 due to lower projected demand in the former Soviet Union and in developing nations, including China, India, Africa, and South and Central America. World oil demand grows to 123.2 million barrels per day by 2025. The slow increase in prices above is due to the growth in oil production in both OPEC and non-OPEC nations. OPEC conventional oil production is expected to reach 60.1

million barrels per day in 2025, more than double the 28.3 million barrels per day that it produces today. (http://www.eia.doe.gov/oiaf/aeo/)

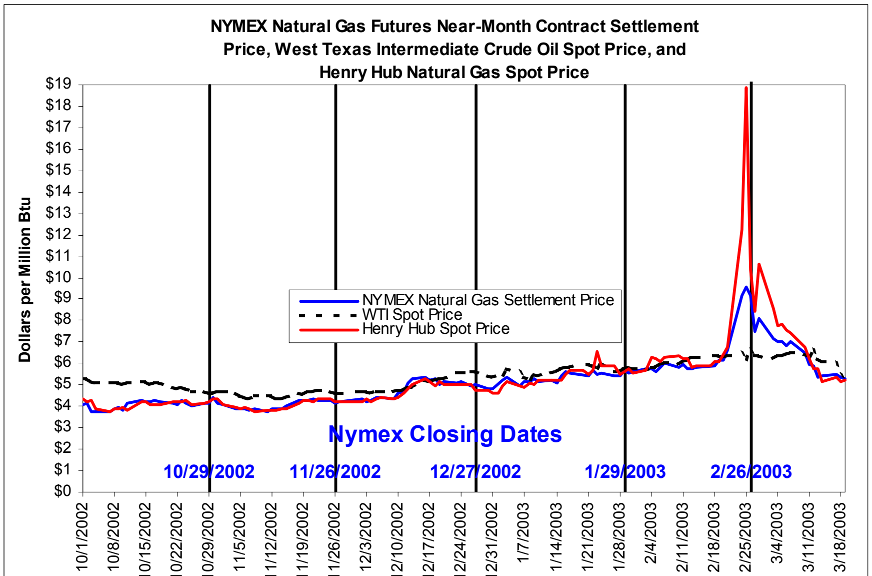
These crude oil prices are the unaffected prices in an ideal situation. There are things that affect these prices. One of those is war, which we are in the midst of in the US. "Using CRIEPI's World Energy Prices Model, we analyzed the effects that military action against Iraq would have on world oil prices and economic growth. The major results of the experiment revealed that the world oil price (Dubai crude oil) would rise by an average of 16% per year (about $4 per barrel), even if Saudi Arabia and other oil producing countries raised their levels of production" (http://criepi.denken.or.jp/eng/PR/Press/2002/20021204e.pdf).

So now that we have attacked Iraq, an entire year of Iraqi oil production is suspended, like was done during the Gulf War. This has a major impact because Iraq's daily production of 1.59 million barrels as of August 2002 is equivalent to about 2.4% of world production. Also, crude oil prices (Dubai crude) will rise 16% on average the following year, 2004, (equivalent to $4 per barrel).

This rise in the price of crude oil would have various effects on energy markets all over the world. "Global demand for crude oil would decline by about 1% (equivalent to 860 thousand barrels per day), as a result of the price rise and the resulting economic slowdown" (http://criepi.denken.or.jp/eng/PR/Press/2002/20021204e.pdf). The price increase would also result in an increase in crude oil production. OPEC nations would raise production by 500 thousand barrels per day, while non-OPEC nation's production would rise by 230 thousand barrels per day. These increases in production would still on be equivalent to about half of Iraq's total production. On the other hand, if OPEC nations did not increase production, the price of crude oil would rise by about 50%, to reach approximately $40 per barrel. From this you can see the extreme affects the war can and may have on oil prices. This greatly affects any energy policy we would create for the next couple of years.

Natural Gas Prices

http://tonto.eia.doe.gov/oog/info/ngw/ngupdate.asp



Note:The West Texas Intermediate crude oil price, in dollars per barrel, is converted to $/MMBtu using a conversion factor of 5.80 MMBtu per barrel. The dates marked by vertical lines are the NYMEX near-month contract settlement dates.
Source: NGI's *Daily Gas Price Index* (http://Intelligencepress.com)

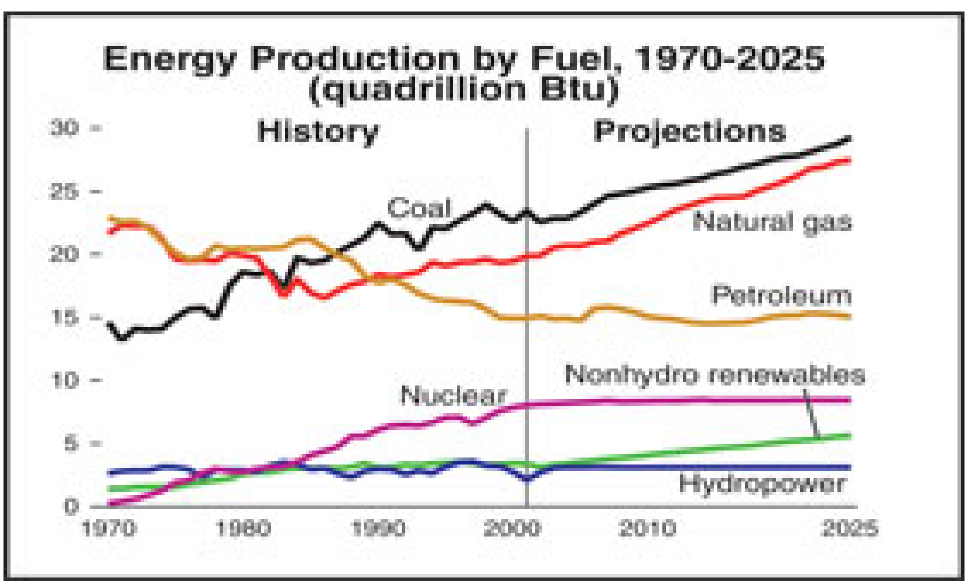
This graph displays the prices of natural gas from the key players in the US gas production. You can see that the average from the past year and a half has been consistently between $4-$6. This information was found on the DOE natural gas weekly page. This site gives up to the day reports on natural gas prices and other important aspects like gas storage information.

The current price of natural gas as of yesterday is $5.287 per MMBtu, but prices are projected to reach about $3.70 per thousand cubic feet by 2020 and $3.90 per thousand cubic feet by 2025 (equivalent to more than $7.00 per thousand cubic feet in nominal dollars). As demand for natural gas increases, technology is expected to improve, which will in turn make natural gas more efficient.

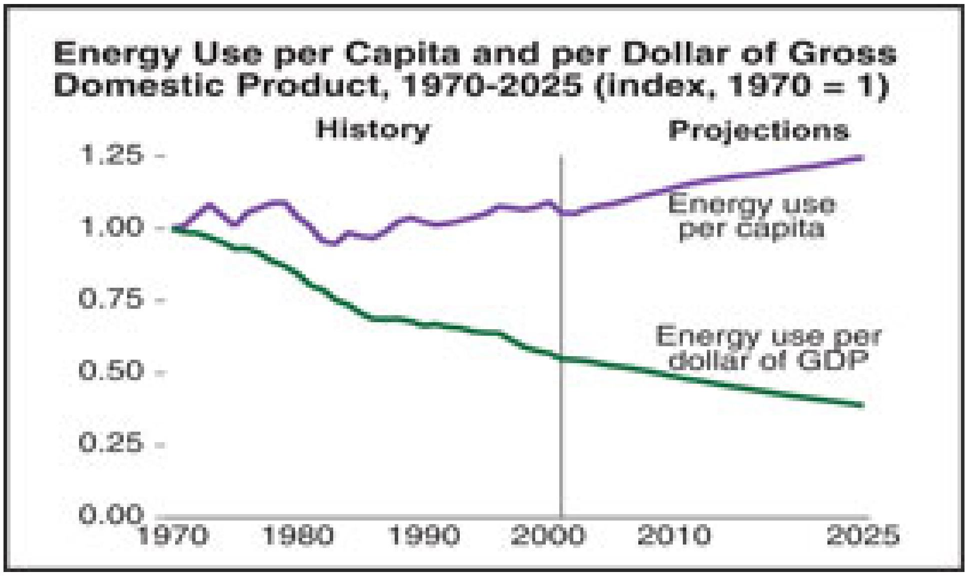
Coal Prices

The average mine mouth price of coal is presently about $17.59 per short ton and is projected to decline to about $14.40 per short ton in 2020 and sustaining that level through 2025. Prices decline because of increased mine productivity, a shift to western production, and competitive pressures on labor costs. This is a cheap resource for energy because we have plenty of coal it is just a matter of finding more economical ways of mining it. The most expensive aspect of coal is the labor used to mine it.

Overall Energy Production and Price Projections



The graph above displays all the sources of energy (except wind). Projections are made from 1970 to 2025 showing total energy production in quadrillion Btu.



This graph shows energy use per dollar projected to 2025. You can see that gross domestic production will decline significantly, whereas per capita energy consumption increases

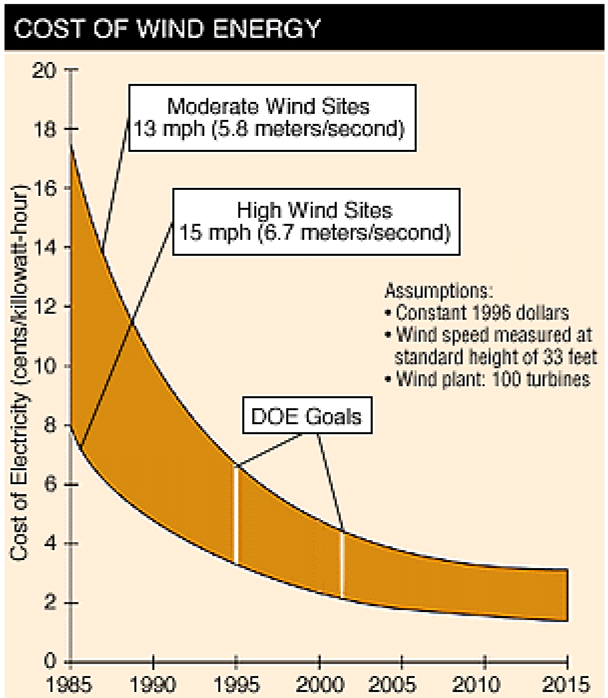
(http://www.eia.doe.gov/bookshelf/brochures/aeo2003/AEOBrochure.html)

Chapter 4

Wind Energy

4.1 Economics of Wind Energy

One of the major variables which are taken into account when deciding on a source of energy is the cost. The cost of generating electricity from wind systems had dropped about eighty percent over the past twenty years, thus putting wind energy in a category of great importance. An example of how much price has dropped, during the eighty's wind energy when the first wind turbines were installed, wind generated electricity cost as much as 30 cents per kilowatt-hour. Nowadays with much of the technology greatly improved, wind electricity can be produced as cheap as five cents per kilowatt-hour if the plant is at a good geographical site. These costs are not even being looked at as ones which can not be dropped. Actually predictions from AWEA(American Wind Energy Association) researchers show that as more plants are built and as technology continues to advance, costs of producing wind generated electricity are likely to fall even more.



Besides the benefits of cost, wind energy has many more economic benefits, one being a lesser dependence of fossil fuels. This is of great important because of the fact that fossil fuels are a non-renewable resource, meaning that once they are gone there is no getting them back. Another reason is because the use of fossil fuels tends to be associated with rapid price changes as well as supply problems and company shortages.

Another economic benefit of wind energy is that it greatly reduces environmental impacts, being compared to a normal power plant. This figure makes wind energy very likeable to many of the environmentalists who many are credited with stopping many energy sources from ever getting into production. When it comes to keeping our environment clean, wind energy may be one of the cleanest and safest resources that we have to choose from.

In order for an energy source to actually go into effect, it must be accepted by a various crowd. Wind energy could certainly help in our nations struggle to solve our nations unemployment problem. Wind energy would call for more jobs than would many other energy sources. Even attributes such as long term income would directly benefit ranchers and farmers who own land on which wind farms were built.

In terms of conserving our environment, wind energy certainly attracts many buyers. “The United States faces a formidable challenge in seeking to reduce its greenhouse gas emissions to 1990 levels by the year 2010” (http://www.awea.org/policy/ccwp.html). Wind energy has the power to produce electricity with almost no CO2 emissions, all the while being one of the most abundant energy resources. “The AWEA estimates that U.S. installed wind capacity can reach 30,000 megawatts in 2010(105 billion annually),….enough electricity to meet the needs of more than 10 million homes”.

From researching upon many of the economics benefits of wind energy, it seems that wind energy certainly holds many advantages compared to other energy sources from an economic standpoint. It is clear that from benefits such as providing more jobs, keeping our environment clean, and supplying another energy source to relieve our dependence on fossil fuels will grab many attentions and displays benefits which will not be easy to turn down.

4.2 Economics of Wind Turbines

One of the major questions asked before building a particular wind turbine is how much is it going to cost and is the size of the turbine going to affect the cost. Taking a look at the graph of Danish Wind Turbines of 1998, you can see prices vary for each generator size. The reasons for price fluctuations are because of the different tower heights, and different rotor diameters, not necessarily the actual size of the entire structure. A special low wind machine with a relative large rotor diameter will be more expensive than a high wind machine with a small rotor diameter.

As you move from a 150 kW machine to a 600 kW machine, prices will almost triple. The reason is the amount of manpower involved in building a 150 kW is not very different from what is required to build a 600 kW machine. Also the safety features, and the amount of electronics required to operate a small or a small or a large machine is roughly the same. Even if the prices are very similar in the range from 500 to 750 kW, you would not necessarily want to pick a machine with as large a generator as possible. A machine with a large 750kW generator may produce less electricity than a 450 kW if it is located in an area where the wind is not great enough to obtain the maximum potential of the generator.

Another factor which affects the cost is the installation of the actual turbines. Installation costs include formations, road constructions, telephone connection and surveillance of the turbine, and cabling costs. Other considerations would be the type of soil and also the equipment needed to clear the site for building.

4.3 How technology Innovations Lower the Cost of Wind Energy.

Since the 1940’s wind energy has become more and more of a valuable energy source to our ever changing environment. Around the 1940’s the cost of wind energy was about 50 cents per kilowatt-hour. At this price no one was willing to even give wind turbines a chance because of their financial expense. As time passed, modern wind energy prices have dropped down to about 5 cents per kWh. The major why these prices have plummeted so low is due to the innovations of wind turbines. The upcoming pagers will show how innovations mechanical improvements, turbine development, and resource assessment have all contributed to lowering the cost of wind energy.

The performance of a generator, the lifetime of a generator, and the reliability are three attributes a generator must have in order to be efficient. A factor which has seemed to assure the efficiency of the ideas is the mechanical improvements to wind generators. Today structural engineers are using materials which are lighter but much stronger, ultimately performing better but costing less. During the 1950's there was little known about the aerodynamics, and how much they could affect overall performance. Back then turbine blades were constructed using airfoil designs for airplanes, and of course this procedure did not guarantee the maximum potential wind which could be used. Also heavy gearboxes were mounted upon the turbines which simply led to higher costs and more maintenance.

The newer designs of wind turbines reduce stress by flexing, rather withstanding harmful loads caused from turbulence. Engineers have developed more flexible components, such as teetered hubs, which reduce the loads by allowing once pivoted rotors to pivot away and reduce stress from harmful winds. For the start of our new millennium three types of wind turbines will be looked upon the ones which will be used the most. Two of these machines are ones of vertical and horizontal axis. The first type is one of a lower risk design path of a conventional three-blade rotor. Some innovations are a larger rotor which uses advanced airfoils and trailing-edge flaps for over speed control. The second machine is one of higher risk, including a fifty meter diameter rotor, two bladed, teetered downwind rotor. These features better protect the structure and allow it to better use full gusts of wind. Also variable speed generators will allow increased energy capture over a broad range of wind speeds. The last type is a vertical axis wind turbine. This model's key is simplicity. This design can produce electricity as cheap as two cents per kilowatt-hour.

4.4 Smalls Wind Turbines

Before the 1930's, millions of farmers used small wind turbines to power their water pumps, lights, and radios. Today our society is looking to still use small wind turbines in many parts of the country, accept now it is hoped that with the growth of technology these small turbines will be able to power a lot more machinery. The upcoming pages will entail information of the new types of turbines, and the best and most often used. Also there will be a comparison of small turbines to large ones, in terms of which ones are more reliable and which one is more efficient.

In the past couple of decades the small wind turbine industry has sold about 60,000 of its turbines from hundreds of different companies. One of the fist things which must be determined before purchasing a turbine is if there is enough wind in your area to effectively reach the potential of your turbine. In general you will need an average of nine miles per hour for stand alone systems, and 10 miles per hour for grid connected systems, to economically generate electricity. Unfortunately, if you are to connect to a grid system and there is not one near your location the costs are very high because connection can then be only made through an expensive power line extension. Depending on the terrain, the cost of running a power line from a remote to an electricity grid can range anywhere from $15,000 to over $50,000 per mile.

The process of determining whether it is possible to run an efficient turbine for your home definitely takes some preparation and planning. After determining the wind speed in your area, the next step is to decide which type of turbine would best suit your home. One of the most popular choices is what they call a HAWT (horizontal wind axis turbine), shown in the picture below.

The picture is one of a larger HAWT, but is just a larger model from what the small one would be. The energy cost from theses will be on the level of $.35 per kWh at 3000 hours/year in average wind speed of 10m/s. The other small type of wind turbine is called the VAWT (vertical axis wind turbine). These turbines are not able to function reliably in icy climates due to the shape of its structure. A typical 10-kilowatt residential wind turbine on the grid system costs about 32,000 and takes about 15 years to pay for itself. Off-grid systems for a home typically cost from 5,000 all the way up to 50,000.

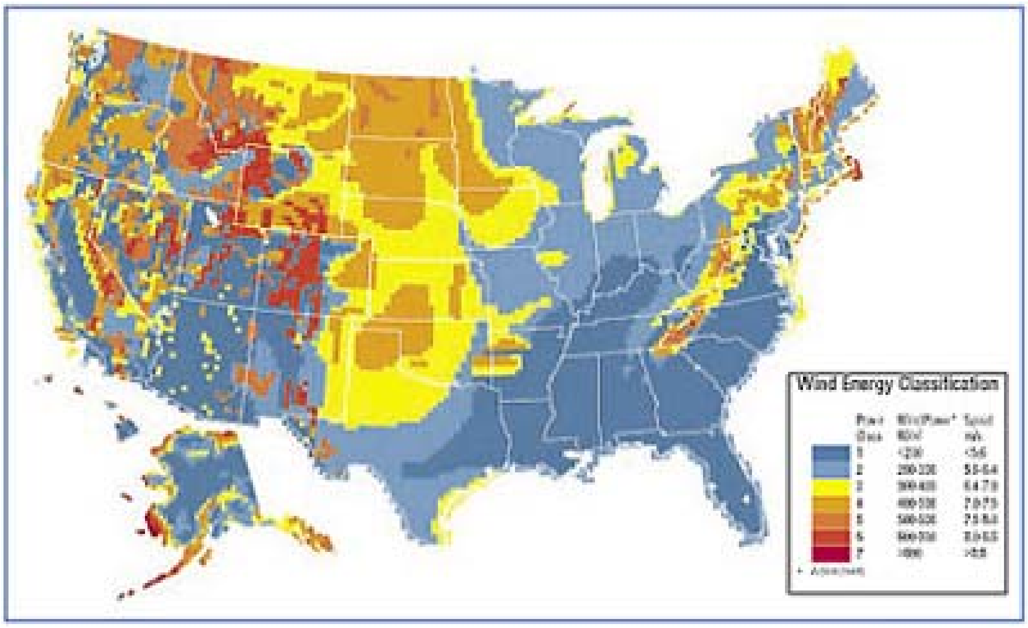
The make your decision on getting a home turbine more effective as well as reliable it would be a good idea to complement it with some type of solar energy system. "Wind and solar are often combined in a hybrid system because they reinforce each other on a daily and seasonal basis". Wind often blows when the sun is not shining and the sun often shines during periods of low wind.

If you were going to purchase a small wind system and wanted to do it affordable and through a well respected production company you could look to the ones which do not have batteries and they can not supply power during utility power outages. A typical 10 kW Bergey Gridtek home wind energy system will cost about 28,000 to 35,000 to install. Depending on the wind resource they will produce anywhere from 10,000-18,000 kWh per year. A home sized consists of a 23 foot blade diameter and an 80-120 foot tall tower. About an acre of land would be suitable for the construction of a turbine this size.

4.5 Areas of Wind Power in the United States

There are many factors which influence the decisions made on where to build a wind farm. One of the most important factors is to build it in a place where strong winds persist and are somewhat constant year around. With the advances in technology, scientists are now able to predict areas which comply with these attributes. The question remains where in the United States are these places and how much wind do they actually produce. The upcoming pages will display these facts through various graphs and charts of different geographic regions in the United States.

The first picture shows the United States annual average wind power. From observing the graph it is clear that most of our high class wind power in produced in the northwestern part of the United States. Major areas of the United States that have a potentially suitable wind energy resource include: much of the Great Plains from northwestern Texas and eastern New Mexico northward to Montana, North Dakota, and western Minnesota; and the Atlantic coast from North Carolina to Maine.



In the Great Plains, class 5 wind resources found over elevated areas of North Dakota, such as the Missouri escarpments and Turtle Mountains, and the hilltops and uplands of the Missouri Plateau in southwestern North Dakota and high plains in northwestern Montana. These areas are very suitable for more scientific research because they withhold the potential of becoming great spots for future wind farms.

Wind Power also varies over different types of the geographical features. In basins, valleys, and lowland plains throughout the mountainous regions, mean manual wind power is generally low. During the colder months, cold air often fills the basins and valleys, creating a temperature profile that frequently stable throughout the day because of low insulation. Under these stable surface conditions, “vertical mixing of the atmosphere is limited, and light surface winds usually persist in the lowland areas, even though winds may be strong on the nearby higher terrain. In the warmer months, although insulation and vertical mixing increase, mean wind speeds aloft are much lower than in colder months”.

The previous information certainly shows that wind power varies from season to season. This is a factor which scientists must take into account before deciding where to build a farm. In winter, the mean upper-air wind speeds are stronger than in any other season over most of the contiguous United States.

In spring, the mean upper air flow is weaker than in winter but remains quite strong over mot of the contiguous United States, although its strength decreases as spring progresses from March to May. Thus, in spring the wind resource is generally less energetic than in winter on mountain summits and ridge crests.

In summer months, wind speeds on average diminish, and average wind power is at its lowest over most of the United States. Although summer is the season of maximum wind energy in Hawaii, Puerto Rico, the Virgin Islands, parts of California, Oregon, and Washington.

In autumn, upper-air wind speeds increase as autumn progresses towards winter. Consequently, the mean wind power is considerably grater in November than in September in most of the country. Throughout much of the United States the mean autumn wind resource is less than that of spring and winter but greater in summer.

After viewing the wind power over the four seasons, it is clear to see why all of this data must be taken into account when deciding where to build a wind farm. Take for example an area such as the great lakes. Viewing its wind power from a winter perspective would portray that the area produced many class4+ wind speeds and would look like a great place to build a plant. But if you look at the same area in the summer season it only producing up to class 3 speeds which may not be sufficient for maximum benefits of a wind farm.

4.6 The Cape Cod Wind Energy Project

These next few months will hold great importance in the minds of many environmentalists, scientists, and engineers. The first offshore wind farm is in the process of being built off the shores of Cape Cod, Massachusetts. This project is looked at by many to be one which ultimately has many more positives than negatives, and could be a huge step supporting clean, renewable energy. Others oppose seeing hundreds of giant steel structures put a dismal, unnatural view to their beautiful waters. There are many complexities which if fact must be accounted for before this historical project sets sail. The upcoming pages will take a look at where the project is as of today, the positives and negatives from both arguing sides, and finally the chances of this project being successful put into affected in the near future..

A plan to build the United States' first offshore commercial wind-powered electricity generator in cape waters has sparked a fierce debate over nearly every aspect of the project. Supporters say the so-called wind farm would cut pollution while easing global warming and the country's reliance on foreign oil. This is a very attractive attribute which comes which the use of renewable energy, in that it takes pressure off the consumption of our other natural resources. Opponents say the project would hurt sea birds, scenic views and tourism, "the cape's key economic engine".

Cape Cod is one of the most profitable summer spots on the East Coast. It relies very much on its waters and beaches to draw tourists from all around the world. Many feel that if these turbines are built off the cape shores, its "picture-perfect" postcard views will certainly diminish thus driving tourists away and shattering its economic safety.

Tourists are not the only thing which opponents say they will be losing. The blades on these enormous turbines will act as a deadly vacuum to many birds in the area. "We feel this is going to endanger the environment and hurt both sea birds and mammals," said Isaac Rosen, of the Alliance to Protect Nantucket Sound.

There seems that there will be many benefits which the cape will endorse from this project:

-First the project will bring along more high-paying year around jobs, plus pending between corporate businesses and institutions.

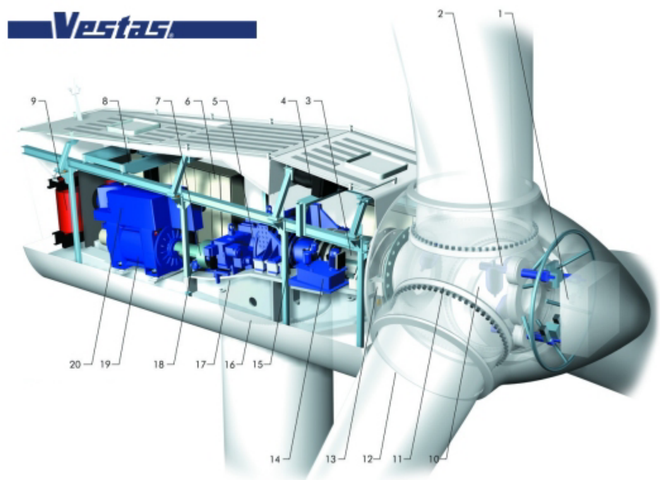
-The coast of Massachusetts has some of the best fishing grounds in the nation. The introduction of a wind park to Nantucket Sound will **not** diminish this valuable resource.

-the turbines are placed a third to a half mile apart, making them easily navigated by recreational boaters and fisherman, so the park will not impact public use of Nantucket Sound.

- Cape Wind is committed to preserving the natural beauty of the Cape while ensuring its economic future by providing clean energy to power the region.

If everything goes as planned the wind farm will inhabit the area of Nantucket Sound, but where will the project go if that site is turned down? The Army Corps of Engineers have about 14 different sites which are all being compared and contrasted on which ones would be most suitable and complementary to the structures of this unique wind farm. Some of the components which are being examined at the different sites is, is there access to New England power grid connections, including transmission and distribution lines, is there enough wind at the site, are water depths and soil conditions workable, and legal constraints involving any endangered species or struggling habitats, etc…Below is a graph or the most compelling site as of today, Nantucket Sound.

The types of turbines which are being planned to be used in the project are similar to the ones used in many other wind farms across the country and around the world, their main purpose being to convert kinetic energy from the wind that passes over the rotors into electricity. These wind turbines consist of four main components, the rotor, transmission system, generator, and yaw and control systems, each is designed to work together to reliably convert the motion of the wind into electricity. These components are fixed onto or inside the nacelle, which is mounted on the tower. The nacelle rotates according to the wind direction. The picture below displays an example of what many cape wind turbines would look like if the project was put into affect.



1. Hub controller
2. Pitch cylinder
3. Main shaft
4. Oil cooler
5. Gearbox
6. VMP-top controller
7. Parking brake
8. Service crane
9. Transformer
10. Blade hub
11. Blade bearing
12. Blade
13. Rotor lock system
14. Hydraulic unit
15. Hydraulic shrink disk
16. Yaw ring
17. Machine foundation
18. Yaw gears
19. Generator
20. Generator cooler

There seems to be much scientific research being put into this project. Already since this project had surfaced to the public about a year ago, scientists and engineers have found ways to cut the costs of this proposed wind farm by about 30 percent. Design advances would allow Cape Wind Associates to build 130 towers, not 170 as originally planned, but still produce the same amount of electricity with a lowered cost. The heights of the structures too, were decreased, from tallest at 246 feet above sea level, instead of 263 feet. Also the reduced number of turbines would push the wind farm farther from the shores of Cape Cod, Martha's Vineyard and Nantucket, which surely will calm tourists and cape residents of their feeling of their picture perfect views being ruined by technology. The structures are planned to be built 4.7 miles off the coast, probably only visible from shore on the clearest of days.

There are many factors yet to be discussed before the wind farm ever hits the cape waters. Probably the biggest question is will tourists and residents be able to accept this technology change, ultimately will Cape Cod still being as attractive as a tourist site as it is now? If certain groups can find ways to accept these reasonable changes, the Cape's offshore wind farm will undoubtedly bring with it many positives, with the biggest being the decrease in the use of fossil fuels in New England. "We see this as a very, very viable source of energy in the future," said Steve Zwolinski, president of GE Wind Energy.

4.7 Continued Cape Cod Wind Project

One of the most controversial matters in terms energy use lies in the Cape Cod Project. If this project is going to be a successful one, is its positives are going to outweigh its negatives. Another question is if this project goes as planned how much electricity or energy will the cape gain from the project? How many homes will be able to be run simply from this project alone? And what is the actual cost of electricity in Massachusetts right now? These are some of the questions being asked at this exact second to determine if this project will be worthwhile.

If the Cape Wind Project is successful it would produce about 1,491,384 megawatt-hours per year. The average Massachusetts household consumes about 6.45 megawatt-hours of electricity in one year. If it does that would mean that the project could fully provide two hundred and thirty thousand houses with electric power. Scientists and Engineers are still trying to find ways to reduce the cost of the project so that the final products seem even more appealing to government officials. No matter where the power goes though, the electricity produced on Cape Cod will help offset the power from dirty fossil fuel plants located in New England.

Putting aside the Cape Wind project, where is the cost of electricity today? In 1999, residential customers in Massachusetts paid an average of 10.09 cents per kWh, which was substantially above the national average of 8.16 cents per kWh for all residential customers. Industrial customers paid an average of 7.75 cents per kWh, which was also substantially higher than the national average of 4.43 cents per kWh for industrial customers. The graph shows how these prices have dropped over the past couple of years. Taking the average cost of these six major Massachusetts dealers we get an average cost of 4.89 cents per kilowatt-hour. (prices listed in cents/kwh)

	2003		
(1) Boston Edison Co.	4.95		
(2) Cambridge Electric Light Co.	4.7		
(3) Commonwealth Electric Co.	4.7		
(4) Fitchburg Gas and Electric Co.	5.36		
(5) Massachusetts Electric Co.	4.7		
(6) Western Massachusetts Electric	4.938		

From looking at all of this data, the Cape Wind project if put into affect will be able to provide for reasonable amount of Cape Cod. But will this project be able to keep up with our electricity needs if the future? Since 1970, the usage of electricity in New England has doubled. And by the end of the decade experts predict that New England will require 17% more electricity. The downfall with Massachusetts as of today is that most of its energy, actually about 94 percent, comes from sources which are not renewable. Government officials and environmentalists have given Massachusetts a challenge in the next decade of increasing its renewable resources by about 15-20 percent. If we take a look at some data displaying the dropping cost of wind energy and the average operating life of some of the turbines being used on the farm maybe this can help determine if the farm will fall to the growth of technology. Before 1975, the cost of electricity from wind energy was about .50-$1.00/kWh. The operating for these turbines was only 1-5years. Today that cost has dropped immensely. At the end of 2002, the cost dropped to about $.03-$.019, and the operating life increased to about 30 years. With the increase of the operating life, the cost of the actual turbine will drop as well, because there does not have to be as many repairs to the machinery. These attributes are giving engineers reasonable evidence the Cape Wind farm will be able to produce enough energy in the upcoming years to keep the Cape to its environmental goals.

Scientists and engineers are happy with the improvements that have been made to the project to further guarantee its success as a viable energy source. It has also been said that by the time the project goes into affect the yearly amount of electricity produced may go up close to 1,800,000 megawatt-hours per year. This means the project is able to provide for an extra seventy-seven thousand homes, all through clean and environmentally safe methods.

Chapter 5

Solar Energy

5.1 Photovoltaic Technology

The energy crisis facing the world today is much more than some mundane inconvenience which we can all sit back and watch fix itself. In fact, if nothing were done about it, we could expect complete depletion of all fossil fuels in the world within the next few hundred years. Though a heightened public awareness, we can conserve what fossil fuels remain while advancing our knowledge in alternative methods of obtaining energy. Results of a 1995 poll indicate that more than 70% of Americans recognize global warming or climate change as a threat and more than three quarters want to do something about U.S. dependency on foreign oil (American Solar Energy Society, 2002). Solar energy is a renewable and clean energy source that uses photovoltaic systems to convert some of the energy in sunlight directly into electricity. Research of solar energy has become more widespread as more people become aware of its capabilities.

Photovoltaic (PV) technology was created primarily to power satellites in space. Although in the last twenty years, with improvements of solid state semi-conductor technology used in transistors and computer chips, the cost of PV cells have come down over twenty-fold. Also, the efficiency of solar cells has made huge jumps from around 10% to over 60% by using different semiconductor materials in the solar cells. For example, research is being done on using diamond film rather than silicon in solar cells which could put the thermodynamic efficiency around 50%. Quantum dots which are very small granules of semiconductor material are another alternative being researched. These quantum dots are placed between the solar cell's normal p-type and n-type regions and form an intermediate band which allows for the absorption of more energy. This and the fact that energy from the sun results in none of the greenhouse or acid gas emissions generated by the combustion of fossil fuels makes solar energy one of the leading pioneers in alternative sources of energy (Energy Educators of Ontario, 1993).

5.1.1 Photovoltaic Cell

The basic building block of the PV effect is the photovoltaic cell. It is called a cell because it produces direct current (DC) electricity like a battery. In applications of photovoltaics, groups of cells are joined together to form a module. These modules can be wired into an array. Any quantity of electricity ranging from a few milliwatts (mW) to power a calculator to several megawatts (MW) which can provide electricity for a large power plant. PV cells are made primarily out of silicon. In the presence of sunlight, electrons are excited and move through the silicon causing the photovoltaic effect.

5.1.2 Photovoltaic Systems

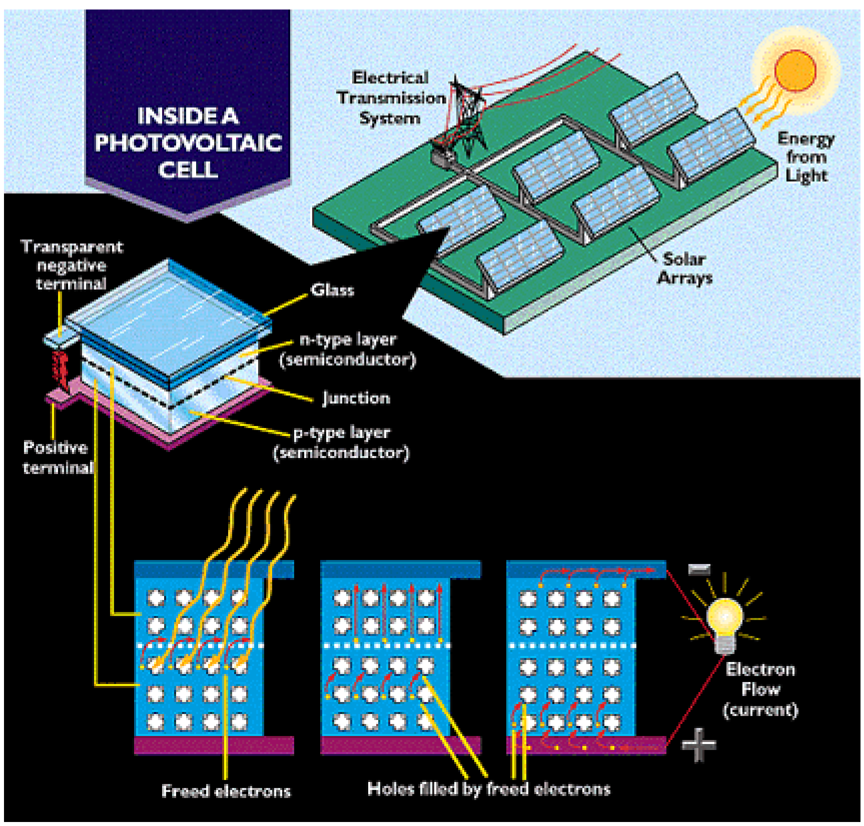
There are three basic types of PV systems: crystalline silicon flat plate collectors, thin film systems, and concentrators. Crystalline silicon flat plate collectors are the most common. The silicon is sliced into the desired cell size and then assembled onto a flat surface. With thin film systems we are able to create solar cells 100 times thinner than silicon cells. Thin film systems are also cheaper and can be processed at lower temperatures than crystalline silicon. They are made by placing a thin film of PV material on a surface such as glass or metal. This is the type of solar energy used in calculators and watches. Another advantage that thin film systems have over crystalline silicon is that with normal crystalline silicon cells, many single solar cells are connected to form a module so that their voltages can add up. However, with thin film systems this module connection is done in the initial manufacturing. As soon as the film is laid on a glass substrate surface, the metal oxide and silicon layers are cut into strips by a laser. These strips are then electrically connected in series (Dillinger, Renee Global Techno Scan). Concentrators are the least commonly used type of solar energy. It requires and lens to concentrate the sunlight, hence the name concentrators, and uses much less PV material than the other two methods. The reduced amount of PV material used in concentrators makes it less expensive, but it can only use direct sun so it will not work if it is cloudy (American Solar Energy Society, 2002).

5.1.3 PV Cell Efficiencies

Researchers studying PV reactions have made great strides with the efficiency of PV cells. In 1880, PV cells were made out of selenium and were able to convert light into electricity with 1% to 2% efficiency. During this time no one was sure how the light was able to be converted to electricity. It wasn't until Albert Einstein explained the "photoelectric effect" in the early 1900's when people started to understand that light was made up of particles called photons which each carried energy. We then found out that these photons would hit electrons in the atoms of the metal, selenium for example, and this would knock the electron out of the atom which could be used to create electricity.

When the first silicon PV cell was created in Bell Laboratories in 1954, it had 4% efficiency which later became 11%. Since 1993, crystalline silicon cells have been converting sunlight into electricity with 23% efficiency, while thin film cells have been converting at 12% efficiency, and concentrators were recorded to have 30% efficiency (Energy Educators of Ontario, 1993). Continued research will create even higher efficiency ratings

U.S. Department of Energy: Office of Energy Efficiency and Renewable Energy

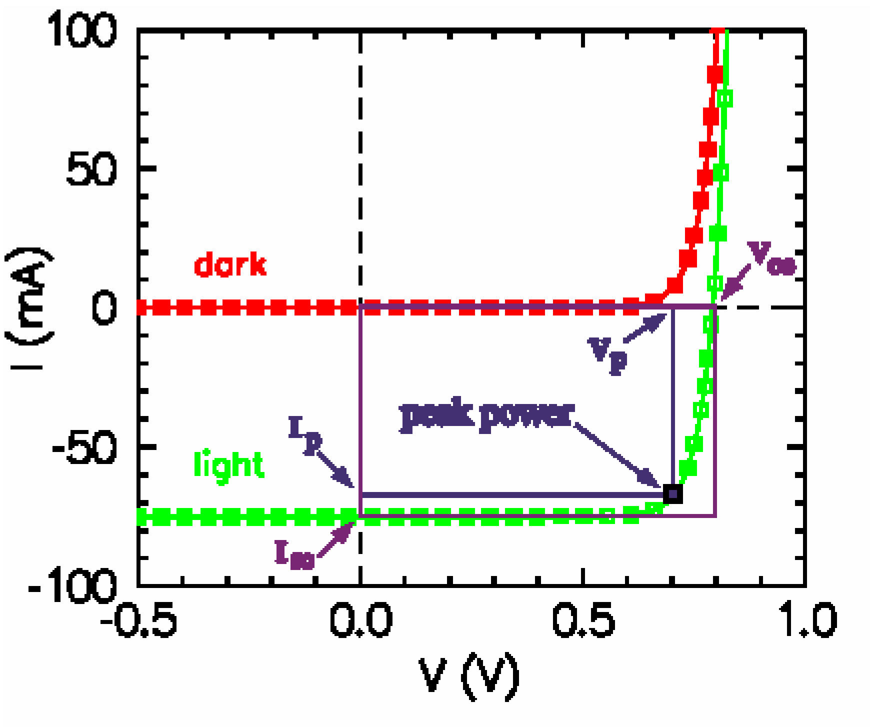


5.2 Energy Created From Solar Cell

Semiconductors offer a method for converting photon energy directly into electrical energy. If the photon energy in a semiconductor is greater than the bandgap energy, which is the energy needed to break the bond and allow the electron to leave the valence band and move to the conduction band. This creates and electron-hole (e-h) pair. From these holes, mobile charge carriers called photocarriers are produced. In a homogeneous semiconductor, thermal motion causes the electron and hole will move around and eventually recombine with each other or other electrons and holes in similar motion. This recombination emits a photon corresponding to the bandgap energy. Under certain conditions, the charge carriers can be collected before they recombine and form a photocurrent. This particular effect is what solar cells use to convert sunlight into electrical energy. This way energy can be extracted from photons having more energy than the bandgap of the semiconductor rather than from the work function (NREL, 1997). Depending on what material is being used, the bandgap energies range from a few tenths of an eV to several eV.

When exposed to sunlight, a solar cell behaves similar to a battery, although it is a not very ideal battery. Batteries use open-current voltage, V_{oc} and a short-circuit current, I_{sc}. Real batteries are modeled by a series combination of an ideal battery, E and an internal resistance, r. The voltage of an ideal battery is $E = V_{oc}$ and the internal resistance is $r = E/ I_{sc}$. In the dark a solar cell is just a diode with a current voltage (I-V) of $I = I_0\{e \wedge (qV/kT) - 1\}$, where $q = 1.6 \times 10^{-19}$ C which is the unit of charge k, which equals 1.38×10^{-23} J/K (Boltzmann's constant). T is the absolute temperature and I_0 is a device-dependent parameter known as the reverse saturation current (University of Orgeon Solar Energy Report, 2000).

data.solarquest.com/squire/scellgraph.asp



The graph above shows the I-V curves of a solar cell in the dark and under AM1.5 light. The AM1.5 light intensity is the spectral irradiance distribution used by the photovoltaic industry on solar cells. Current from the light causes the I-V values for the ideal solar cell to be lower than in the dark.

Quantum efficiency of a photon is the probability that the photon will give up an electron to the photocurrent. Photons that have energy less than the bandgap do not have enough energy to generate photocarriers. Sometimes even if the photon has enough energy it may not contribute to the photocurrent. The way we calculate the quantum efficiency (QE) is to illuminate the solar cell with a certain intensity of monochromatic radiation and then measure the short-circuit current. Using quantum efficiency we can find out exactly how much current we can get from a solar cell.

5.3 Photovoltaic PN Junctions

A typical photovoltaic cell is composed by two parts of silicon material in a pure electronic state. These two parts join together to form what is known as a PN junction. The difference in these two parts of silicon is that one part of silicon is of type *P* which has a deficiency of one electron and the other part of silicon is of type *N* which contains an extra electron. A material is p-type if it contains many holes (positive charge carriers) for electrons to jump into. N-type material is a good conductor because of the free electrons floating around creating an electric current to flow through the material. Whenever a photovoltaic cell is exposed to sunlight or another source of light, electrical current is produced by diffusion of electrons between the PN junction. The energy required to begin this type of diffusion comes from photons in the light. Photons are the discrete packets in electromagnetic fields which contain a particular amount of energy depending on its wavelength. If e is the amount of energy in Joules in a photon, then $e = hf$, where h is Planck's constant, 6.626×10^{-34} J-s, and f is the frequency of the electromagnetic field. When enough sunlight is exposed to PN junctions, about 0.5 volts of electricity is produced. In the same conditions, a typical commercial photovoltaic cell would produce about two amperes of electrical current. At peak performance, this combination of energy from the photons and from the photovoltaic cell produces about 1 watt of power. We always want to make sure that these values of electrical generation are at their highest which means that the solar cell is exposed to enough solar irradiation, usually between 800 watts/m^2 and 1000 watts/ m^2.

The solar cell is the fundamental device used to capture solar energy. A solar cell is made up of one *P*-type silicon block and one *N*-type silicon block. These solar cells are really just a special type of transistor. Transistors and solar cells are both PN junctions. Two other elements which are found in solar cells are phosphorous and boron. The phosphorous atom has an extra electron and the boron atom has a hole where it needs another electron. What takes place within a solar cell is the extra electron from the phosphorous atom leaves the phosphorous and goes to fill the empty hole in the boron atom. The path of the extra electron from phosphorus to the boron is the way that the sun's photon rays are converted to electrical energy. The photon comes from the sun and falls into the hole left by the phosphorus atom's escaped electron.

There is another type of solar cell called quantum dot (QD) solar cell. These cells have the potential to increase the maximum attainable conversion efficiency of light into energy up to about 66%. QD solar cells use hot photogenerated carriers which produce higher photovoltages or photocurrents.

In 1961 the maximum thermodynamic efficiency for conversion of unconcentrated solar irradiance into electrical energy was found to be about 31%. The main factor limiting these "cells to 31% efficiency is that the absorbed photon energy above the semiconductor bandgap is lost as heat through electron-phonon scattering and subsequent phonon emission, as the hot photogenerated carriers relax to their respective band edges." The main approach used to increase this efficiency has been to use a stack of multiple PN junctions with bandgaps better matched to the solar spectrum. "In the limit of an infinite stack of bandgaps perfectly matched to the solar spectrum, the ultimate conversion efficiency at one-sun intensity can increase to about 66%" (National

Renewable Energy Laboratory, Quantum Dot Solar Cells). Recently, photovoltaic effects have been reported in structures consisting of QD's forming junctions with organic-semiconductor polymers. (N.C. Greenham, X. Poeng, *Phys. Rev.* B 54, 1996) There is a variation of this configuration which will disperse the QD's into a blend of electron and hole-conducting polymers. Each type of carrier-transporting polymer would have a selective electrical contact to remove the respective charge carriers. Today's standard commercial solar cell efficiencies are about 10%, while "the best solar cells, which are very expensive semiconductor laminates, convert, at most, 35 percent of the sun's energy into electricity" (Sanders, Bob UCal Berkeley, 2002).

Source => http://www.nrel.gov/docs/fy02osti/31011.pdf

5.4 PV Systems Costs & Incentives

One of the main considerations for the relevance of alternative sources of energy, one of the main factors under consideration is cost. Renewable energy sources have obvious advantages over fossil fuels as being a clean energy which does not produce any pollutants and emits no greenhouse gases, helps to insulate against future energy cost increases, the ability to generate electricity at your own home rather than having it produced in another location and having to be transported to you, make no noise whilst in operation, utility discount rates, service revenues from PV manufacturing plants, etc. Some disadvantages of photovoltaics include a high initial cost of system, cost of electricity produced is usually higher than electricity produced by conventional power stations which use existing electricity grid networks, and energy output depends on sunlight levels on a day to day basis. Of course many of the initial costs of photovoltaic systems will decrease when they become more in demand. However, the purpose of this paper is to discuss long term costs of photovoltaics systems which will aid consumers in their decision on whether or not to invest in such a system.

One of the benefits being considered by many potential producers of solar and other renewable forms of energy is the Renewable Energy Production Incentive (REPI), which was included in the Energy Policy Act of 1992. The main goal of this program is to promote increases in the generation and utilization of electricity from renewable energy sources and to further the advances of renewable energy technologies (EERE, REPI article). This incentive also tries to promote public benefit such as reducing pollution and environmental costs, encourage competition in the electric industry and individual providers among sources of energy. It does this by providing financial incentive payments of 1.5 cents per kilowatt-hour for the first 10 years of the energy production. To qualify for the incentives, you must use solar, wind, geothermal, and/or biomass generation technologies.

Another technique being used help spark peoples' interest in producing renewable energy is a type of metering called net metering. This allows any business or consumer that produces his/her own electricity using a renewable energy generator to spin their existing electricity meter backwards for all of the excess electricity they produce. So renewable energy producers can sell back all of their excess energy to their local utility power plant at full retail value. Even places where net-metering is not allowed, renewable energy producers can still sell back excess electricity, but only at wholesale prices. This is called dual metering.

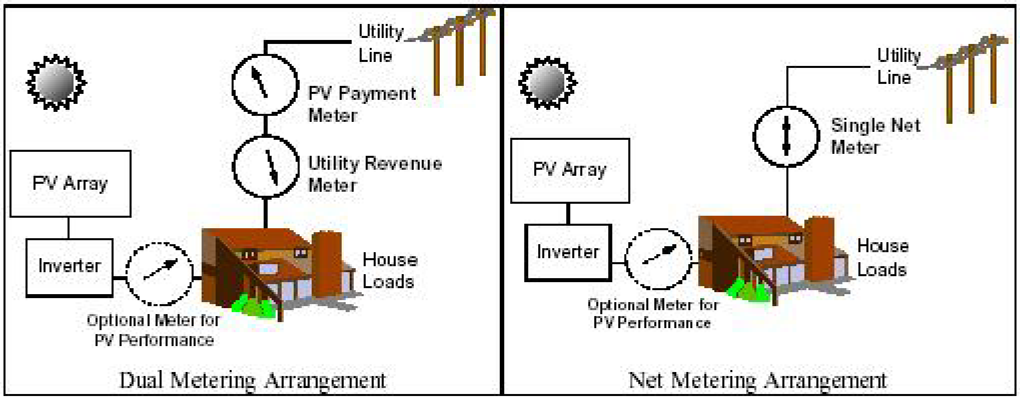


Figure 7-1. Metering arrangements for residential PV systems.

5.4.1 PV System Model

To model a PV system, we must make some assumptions about system size, type of metering scheme used, how much energy would be used/produced per month, and location. All of these factors play a part in cost and money saved using a PV system versus obtaining all electricity from local power plant. This model also assumes that the facility producing the electricity from the PV system uses the same amount of electricity each month of the year. This takes some efficiency away from the model, but it shows more clearly the potential money saved or spent which is the purpose of this paper. Also, this allows for surplus energy generated to be sold back to the electricity grid via metering.

For this example, a residential home in Sacramento, CA will be used as the location. This home consumes the average monthly amount of electricity as the current average per month for a residential home in Sacramento. The cost of generated electricity and buyback rates are based on a previous case study done by the California Photovoltaics for Utilities (PV4U).

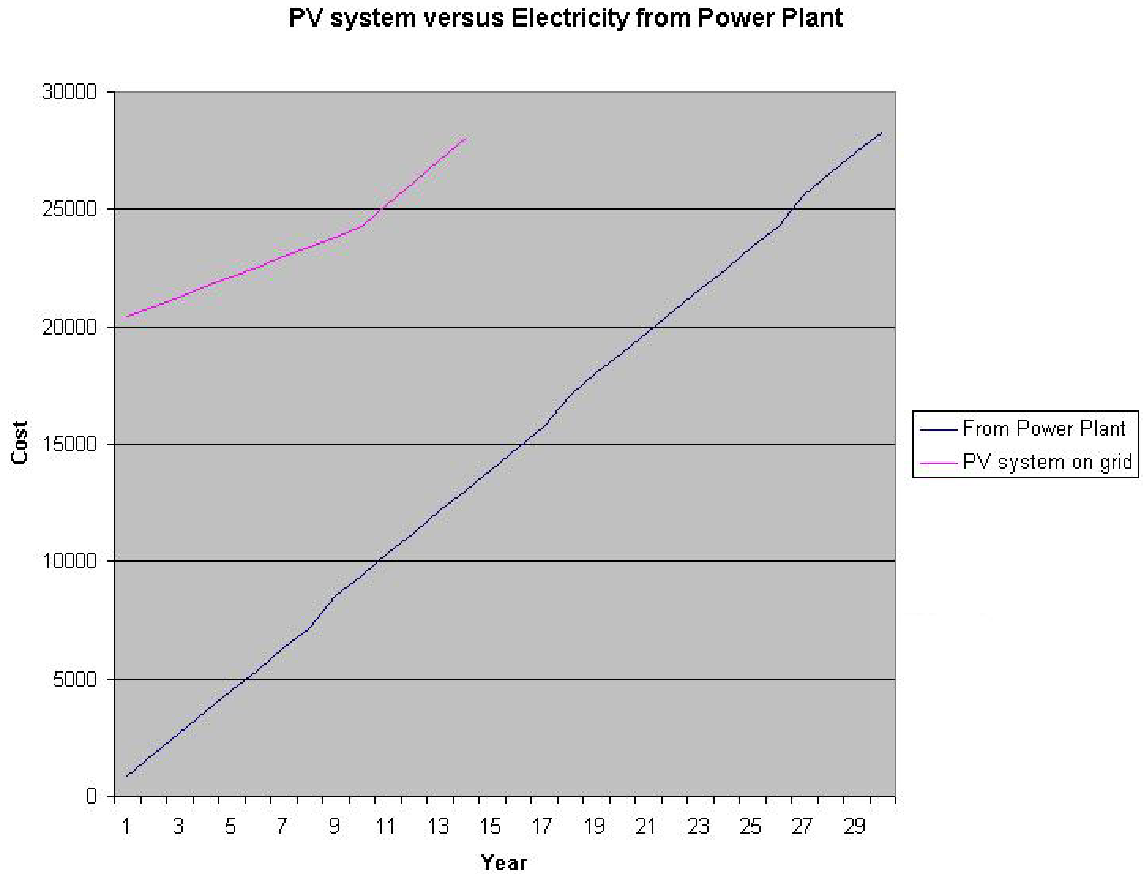
5.4.2 PV System Model 1

The first scenario for this model considers the residential home in Sacramento using only electricity from a local power plant and a gas water heater. The current rate for electricity from a power plant in Sacramento is 10 cents per kWh, and the annual average residential electric bill uses 750 kWh per month(Sacramento Municipal Utility District, SMUD). The average lifetime of a gas water heater based on industry statistics is 9 years. The range is from 5-14 years(EERE, Consumer Information). The choice for a water heater is important because depending on price, a typical water heater can have a much longer lifetime than normal and its energy efficiency will be resulted in one's monthly electric bill. For this model, I'm choosing $450 as the price for an average water heater. The cost graph below accounts for the monthly electric and gas bill as well as the maintenance cost for a water heater every 9 years.

5.4.3 PV System Model 2

The 2nd scenario considers the residential home in Sacramento using a PV system that is connected to the grid of a local power plant. Deciding on the right size for your PV system is one of the most important factors in potential gains/losses when investing in solar energy. Buying a system too large might never pay itself off, whereas a system too small might cost you more money to generate that it would be to obtain electricity solely off of the power plant grid. By investing in a PV system that fits one's budget, electricity needs, and long term goals, the system can become the net producer after only 3-4 years. One benefit of PV systems is the fact that you can start relatively small and use the money you saved on electricity to upgrade until you obtain the system size that you want.

For this model, the PV system will be a 2 kW system costing approximately $20,000. The annual average amount of sunshine in Sacramento is said to be between 2800 to 3200 hours. I will use 3000 hours of sunshine per year for this model. Typical maintenance costs on an average PV system is said to be about $12,000 over a 30 year period. Therefore a $400 maintenance cost per year is included in this model. This system of 2 kW can produce about 6000 kWh per year based on Sacramento's annual average amount of sunshine. The cost of electricity from photovoltaics is 30 cents per kWh, so if using net-metering this home owner could sell back any excess electricity at a lower rate. Since the average family uses 9000 kWh per year, 5500 kWh per year will have to be obtained from the local power plant grid. For this model I am using no metering so this home owner will have no excess electricity. This model does however, calculate the incentives from REPI which are 1.5 cents per kWh. In conclusion, the size of one's PV is one of the main factors and if chosen correctly it can be a great advantage to use solar energy over energy from local power plant.



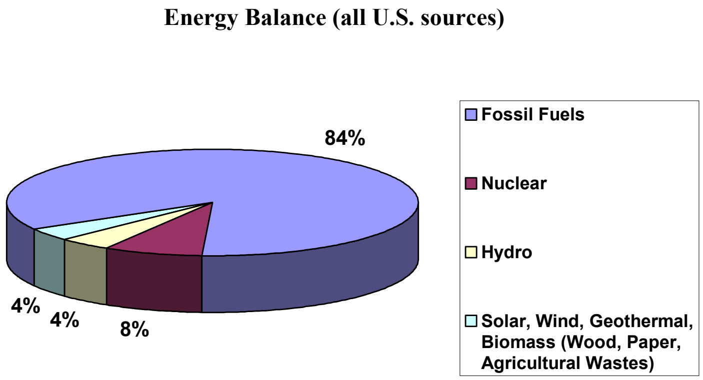
5.4.4 PV System Model Conclusion

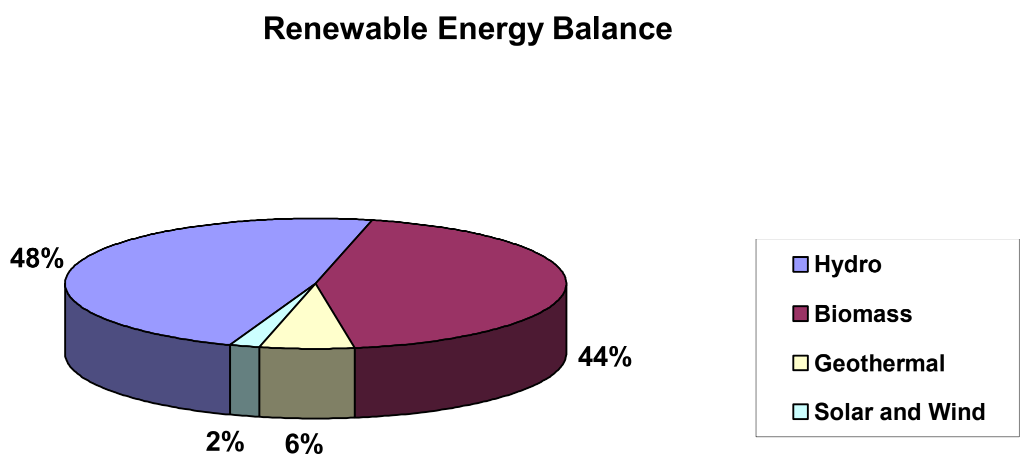
This graph shows that the system we bought being a 2 kW PV system will never really break even with the other graph before the 30 year presumed lifetime of the PV system. This means maybe we need to start with a different system, use some form of metering, or try a different location with lower electricity prices. However, you can tell in the first 10 years that the PV system graph was starting to head towards the power plant graph due to the incentives from REPI. These incentives are only for the 10 years though, which is why the PV graph started to rise higher after 10 years. Perhaps one thing to try would be to get a larger PV system so you can use less electricity from the power plant. These are all considerations one must make before investing in a PV system.

Chapter 6

Social Implications

6.1 Social Impact





These graphs illustrate the current percentage of energy use in the United States. The first takes into account all sources of energy and as you can see fossil fuels are responsible for the majority of the energy used in the U. S. From the first graph we observe that non-renewable are responsible for 8% of the total energy used.

Extrapolating even further we see that out of that 8% solar and wind is a very small portion (only 2% of all non-renewables, 2% of 8%).

For our policy we recommend that hydro, nuclear, and geothermal consumption percentages remain the same since we did not research them. Our most important recommendation is to significantly increase the percentage of use of wind and solar energy and more importantly decrease the use of fossil fuels.

One of the biggest factors that must be influenced in order to raise renewable energies is the people. By that we mean common households. Everyone needs to take part and one way to do that is to impose “net metering” for small renewable energy systems. “Under net metering, consumers feed excess electricity generated by their renewable energy systems back to the grid, in essence running their electric meter backwards”. What this means is that the consumer pays for the net amount of electricity supplied by their connected grid. So this would be an incentive for people to install small turbines or photovoltaic systems in their households.

Before we state our drawn up policy it must be made clear that these predictions and suggestions are our observations and there are still many difficulties and obstacles which must be overcome. Wind and solar energy certainly have the potential to relieve much of the pressure brought upon by the energy crisis. First and foremost these two forms of energy must be given much more of a dedicated and committed effort by our government as well as everyone beneath it. During the past 20 years, our strides taken to improve wind and solar efficiencies have been remarkable, but more must be done. Without government funding, many renewable energy sources which still have the potential to become more efficient and reliable will not. Areas such the lowering the cost of the materials used to make wind generators and photovoltaic systems, also having the money to hire more design engineers, maintenance workers, and innovators for both energy sources. These are only two of the many problems we will encounter on our way to better our environment, but they must be accounted for in order to sell these ideas to the people we need to use them. One way in which to bring down the cost of generating energy using renewable sources would be to create a greater consumer demand. This has been achieved to a certain extent with government incentives, subsidies, and tax cuts. Although, not only do consumers need incentives to invest in renewable energy, but more money out of state and federal budgets needs to be allocated to further development of these energy sources.

One of the most important questions is how do the structural attributes affect its neighboring viewers once they have been put together and are being put to use. First a look from the physical form of wind energy (by this meaning the generators and the actual turbines mounted on the ground). Using this form of energy does require that some sort of turbine be built. Many times these turbines can exceed heights over 100 ft tall, including the generally small wind turbines because of the height they are placed at to ensure the strongest wind gusts are being used. Many people are unhappy with the aesthetics of bulky wind turbines in their communities and towns, never mind their own backyards. Unfortunately this is a problem which people are going to have to deal with. Of course there is a possibility that someday a engineer will design a turbine which probably is undetectable to the human eye, but for now we need people in areas of high wind classes to consider purchasing a small turbine despite its mechanical, mostly unattractive appearance. Noise has also factor pushing people further from purchasing home neighboring wind farms. Again, this is a drawback that unfortunately comes with the energy source.

Chapter 7

Conclusions and Recommendations

7.1 New Policy

Over the past few decades or so, engineers and scientists have put they're best efforts forward on providing new innovations to our already known energy sources. Sources such as wind energy, and solar energy are getting to a point where there are being used enough and are taking some of the pressure off our consumption of fossil fuels. However scientists have not figured out the best combination at which these energies should be used.

There are many different roads we could take when making a new policy. Using the information that we have collected doing research on fossil fuels, wind energy, and solar energy, we have derived an energy policy of our own. Fossil fuels are a non-renewable source of energy and they will be exhausted in the near future. Wind and solar energy are renewable sources but are harder to use on an extensive scale and more expensive, respectively. Therefore, our energy policy is not easily obtain and requires a combination of both renewable and non-renewable energy sources. We did not research nuclear, geothermal, or hydroelectric energy sources, so our policy is bias to the three we researched. A more advance policy would possibly include combinations of all of these energy sources.

Fossil Fuels are the backbone of our energy policy because they currently account for most of the US's current energy, but are non-renewable so they're predicted to run out within the next couple hundred years. These facts prove that in our policy we can not be dependant on fossil fuels, but instead use them to help sustain proper energy levels using renewable energy sources. Our first recommendation is to not use fossil fuels as our primary energy source; instead we will use wind and solar energy.

The main fossil fuel that we will still use is coal because it is the most abundant of our fossil fuel reserves. The other two fossil fuels, oil and natural gas, will be almost completely discarded. The current policy, as of today, the US puts all its money towards domestic oil production and it does not support other energy technology research. We feel that this money and support should not be focused on oil at all and that the money could be better spent on other energy technologies. The reason for this being that oil can not be produced as fast as it is needed and the US is forced to import oil, making this an unreliable source of energy (especially now in our time of war). Natural gas will also not be used because it is very hard to find and getting rid of this would greatly reduce costs of trying to obtain it.

Besides using solar and wind energy we will still need to fill many of the gaps left from inadequacy using coal. There are many on going projects with coal to make it more efficient and environmentally safe. A major problem with burning coal is the CO2 emissions. We propose that research and development continue to be done for important coal burning aspects like coal gasification and carbon sequestration which will reduce these harmful emissions. These processes, in the future, can greatly extend the life of coal and make it a cleaner energy source as described previously in the project. Another recommendation for our policy would be to encourage more companies to get involved in these processes, possibly by offering some incentives or providing them with evidence that this will greatly affect the possible energy crisis.

Wind energy is a clean, abundant U.S. resource that produces electricity with virtually no CO2 emissions. Given strong policy support, the wind industry can build up production rapidly and can, through displacing emissions from coal, make a significant contribution to the 2010 goal. The American Wind Energy Association (AWEA) estimates that U.S. installed wind capacity can reach 30,000 megawatts in 2010 (compared to just 1,700 MW in 1998), generating 105 billion kWh annually. The question is, can these numbers actually be met? Upcoming are some of the policies which should be imposed in order to reach the maximum potential of wind energy.

One of the first policies which should be put to use a federal agency renewables purchase requirement, which steadily increasing over time. This is an immediate action the Energy Administration could take to demonstrate a serious commitment to reduce greenhouse gas emissions and also show people that it is taking huge steps to better our environment. By 2005, agencies should be required to obtain 10% of their electricity supply from nonhydro renewable resources.

The next step could be to apply a small wind turbine investment tax credit. This policy has been talked about over the past couple of years and I feel that it would be a good method of attracting small businesses to become small wind turbine users. This would be a huge step because many people take for granted how much small wind turbines positively affect our environment's pollution level if many are used.

Another crucial step the government and environmental agencies must take is to make "a federal commitment to multi-year spending of about $60 million annually for wind technology development. Over the past 16 years wind energy has dropped its production cost to more than 80 percent. The problem is that the DOE is always threatened by insufficient funds. This proposal would guarantee spending and the wind energy agencies would have the opportunity to further their innovations and hopefully make wind energy cheaper as well as more efficient. Researches from the AWEA feel this goal possible because they believe the cost of wind energy equipment can be reduced by another 40 percent.

Photovoltaic systems as well as other renewable energy sources could be a solution environmental, economic, and social problems going on in the world today. Some of these current problems include energy related greenhouse gases, rural families in developing countries, power outages due not having enough power plants to provide for the booming populations of the world, and etc. In developing countries alone, nearly two billion people still do not have grid electricity. Obviously, in order to begin the road to improvement, we must make policy changes to assist in dissemination of these renewable energy sources as quickly as possible.

Most small consumer PV systems generate modest amounts of electricity for lights, radio, television, and other small appliances. While photovoltaic markets are starting to develop in many countries, there are still many obstacles impeding this renewable energy source from reaching its full capabilities. Barriers include lack of information about these home systems and grid extension plans, lack of capital for businesses and consumer financing programs, lack of trained technicians, managers, and other human infrastructure needed for system delivery and maintenance. In many countries there are import duties oh small home PV system equipment as well as subsidies for kerosene. This is one of many of these difficulties in renewable energy dissemination. People in the world need to know about these types of backwards mandates in order to create the urgency that change is needed. International initiatives and country policies can help to remove these constraints, push PV systems markets, and ensure that the potential greenhouse gas mitigation and development benefits are realized.

In deciding on appropriate combinations of renewable energy sources to be used, we need to learn about the possible economic, social, and environmental benefits to be gained. It has been proven that have PV systems in a home can greatly increase the living conditions due to superior lighting from lamps powered by the PV systems. This is described at the most notable quality of life improvement which can be a great advantage for educational facilities. (IAEEL, Robert van der Plas) Socio-economic impact studies have found that a large percentage of small PV systems provide power and light for cottage industries, farm related activities, and rural stores. Another example is in the Dominican Republic where about 30% of the PV system support business activities, most of which are located in homes. (NREL.gov, *Solar Powered Clean Water in Dom. Rep.…*)

Once a workforce of trained technicians begin to gain more employment installing and maintaining these small PV systems around the world, the installation of more technically sophisticated PV systems will become possible for both business and community use.

Opponents of these renewable energy sources say, "Photovoltaics and wind-turbine devices are serious visual polluters, their real estate requirements are unreasonable, and their kilowatt-hour costs are too high (*Energy Barriers,* The Industrial Physicist, Laura Nader). Both Solar and Wind energy require existing base of conventional power to function. According to one journalist, without federal and state subsidies there would be no photovoltaic farms and no wind-turbine farms. Hopefully this is taken as a stimulus to push for further research and development rather than a reason to scratch these renewable energy sources.

In conclusion, no matter how many policy changes the world makes today, tomorrow, or next year even, it will take a good deal of time to reap the rewards we are hoping for. However, the longer we wait to begin this process of change, the deeper the hole that we are digging ourselves into grows. There are many more issues involved in renewable energy sources and creating policies to support their use. After all, these renewable energy sources are not just changing the way we obtain "energy", but rather, changing our whole economic, social, environmental outlook on life.

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