Project Number: MH 0712

US ENERGY GOALS AND POLICY

A Critical Look at Existing Energy and Sustainable Energy for the Future

An Interactive Qualifying Project Report

submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

by

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Date: March 6, 2007

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Abstract

The project developed a viable, comprehensive, energy plan for the United States with the intent to drastically reduce the dependence on foreign oil over the next 20 years. To this end a pragmatic and comprehensive evaluation of various energy technologies was made. The intent is to encourage widespread adoption of solar and wind energy technologies in the US before there is an energy crisis as transition after that point becomes problematic.

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Executive Summary

Current energy polices are not sustainable in the long term due to increasing domestic and global demand that is outpacing supply and environmental concerns causes by traditional energy sources. If a crash transition to sustainable energy occurs as a result of high energy prices the change process will be much more destabilizing on the economy and expensive.

Oil and coal are currently the most widely used forms of domestic power in the US, but they have numerous externalized costs that hide their true price. While power plants using these types of fuels are cheap to construct, the long term health impacts of the emissions are highly expensive. Supplies of the feed-stocks for these plants are limited and demand is ever increasing, thus necessitating an eventual transition.

In contrast, clean renewable energy sources such as solar and wind energy have high initial costs for the construction of the energy generating device, but minimal long term operating costs or pollution. Advances in technology are rendering wind energy more economically competitive, but it is not directly competitive with existing technology yet. We expect widespread wind adoption will drastically reduce oil consumption by roughly 50% within the next 20 years as oil prices rise and wind becomes more cost effective.

Europe has achieved widespread adoption of sustainable energy sources through a variety of polices ranging from ones aiming at reducing the initial investment to ones that guarantee prices on the output in order to reduce the risks involved. It is recommended that the United States take a more proactive approach in encouraging these technologies to become independently viable leading to a production shift to sustainable power sources.

Introduction

The problem of sustainable energy resources for our society is of paramount importance and extreme relevance. Without adequate energy electricity, heat, food, finished goods, and communication would be impossible to provide for society as a whole, now and in the future. The relative lack of focus on this issue combines with the far reaching implications of an energy shortage to make this topic of interest to students in diverse majors and the solution to it is essential to ensuring that our varied career paths are able to be followed. As engineers, we essentially design solutions to important problems, clearly this fits within that criteria.

The goal for this project is to provide the nation better and/or more efficient ways to use the current resources available to us. This will benefit society because at our current pace, which is going to increase as the rest of the world matches our level of technology, existing resources are clearly limited. In order to make better use of our available resources we have to either find alternatives sources of energy, or get more energy out of the current ones.

This project is qualified as worthy of an IQP both by the importance of a comprehensive investigation with the aim of developing possible solutions to the pending energy crisis and the scientific nature of that investigation. It is an interactive project in that it is a group of people working together on a real issue to solve a problem in society. We will be using what we have learned at WPI in math and science courses on a real world project not on abstract problems in a textbook.

If original insight is developed that is worthy of scholastic dissemination, the findings of this project could be submitted to the appropriate journal for review and perhaps publication in order to share what may be a viable solution to an essential problem with other people to evaluate and perhaps implement parts of it. In the true spirit of an IQP, publication for publications sake is not anywhere near as rewarding as active interest leading to implementation of ideas in real world problem solving.

Evaluation of Current Technology

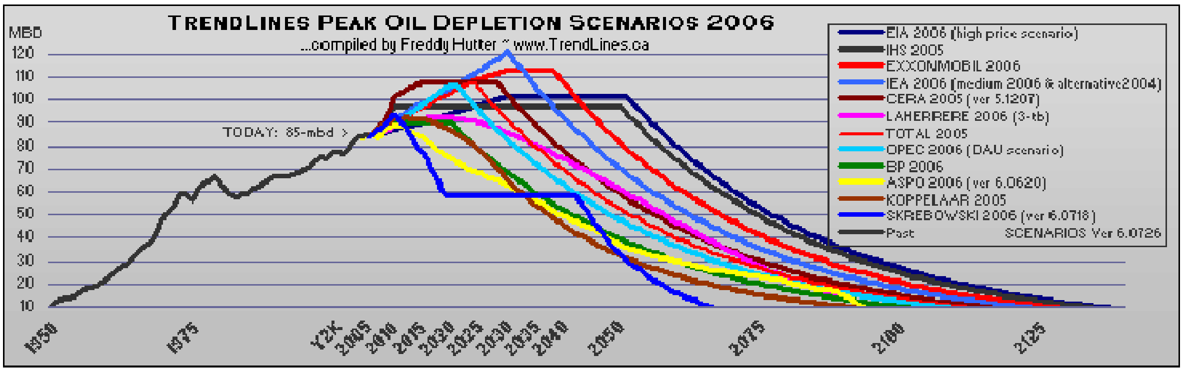
Oil

In terms of social issues that are dismissed by the general population, the fundamental problems with an oil based economy rank near the top. The global oil supply is a finite quantity with production increases expected to peak somewhere between the years 2002 and 2008, a problem that was not mentioned in the last major contested election in 2000[1]. After this peak, an oil shortage will exist and unlike the shortage of

1973 it "will not be artificial and it will not be temporary" in that demand will outpace production at ever increasing rates[2]. How an economy and the accompanying society deal with this problem is a pressing concern and a valid subject for serious inquiry.

Global oil production rates can be thought of as a bell curve increasing up to a certain point, known as Hubbert's Peak after the correct prediction of American Geophysicist M. King Hubbert in 1956 that domestic oil production would peak in early 1970s, and then decrease after that point[3]. The gap between global supply and demand can be projected to occur at the same rate as the growth on upward side of the peak roughly "5 percent per year" thus requiring "a substitute for something like ten billion to fifteen billion barrels per year"[4]. This demand estimation is modest and does not take into account the explosive growth that can be expected to occur as India and China bring petroleum based economies online. "Americans consume fuel at five times the average per capita rate of the rest of the world" and as the rest of the world develops further there will be even more demand for oil[5]. Yet despite the increased demand "the finite supply of world oil is…written in stone. It's not engraved on the façade of the Treasury Building. It's written in the reservoir rocks, in the source rocks, and in the cap rocks" and "no amount of [innovation in drilling] is going to satisfy our appetite for oil" showing that after a point oil can no longer sustain a society[6]. The question lies in how a society departs from the unsustainable oil based system.

It is vital that plans are made to facilitate the switchover and do not rely on rising oil prices to render "other fuels economically competitive" as a means of leading to the introduction of viable alternatives, as the time for these alternatives to develop is such that it would destabilize the economy if the transition occurred as a result of necessity rather than planning[7]. Furthermore, the resources required to transition an economy are such that it may not be possible after an energy crisis to gather enough resources to fix the problem. With that said, "it has traditionally taken society 50 years to make the transition from one dominant energy source to another"[8]. The immediacy of the Hubbert's Peak for the global oil production demonstrates that this traditional, free market transition is no longer feasible given the existing time constraints.



As the graph[9] above demonstrates the problem will occur within the next 25 years as global production is unable to meet demand under various forecasting scenarios. The issue of when oil runs out as a resource is not particularly meaningful as a once it becomes scarce it will cease being a viable source of energy.

There are a wide variety of ways of generating energy that are not based on crude oil, and a systematic inquiry into the characteristics, development required to achieve implementation, and long term sustainability of each will be used to attempt to suggest a solution to the problem of the pending oil production gap and subsequent shortage.

Indirect Problems of Petroleum Energy

Particulates from gasoline are a social problem for the world because chemicals such as BTEX (benzene, toluene, ethyl benzene, and xylene) cause respiratory irritation. Side effects of particulates are: headaches, dizziness, sleepiness, nausea, irritated eyes, breathing difficulties, and respiratory problems.[10]

Other well known particulates are sulfur oxides. Patients who already suffer from chronic bronchitis have shown an increase in respiratory symptoms when the TSP (Total Suspended Particulates) levels exceed 350 micrograms per cubic meter. Studies in Holland have showed that as the SO_2 and the TSP levels dropped the patient's condition improved respectively.[11] While the particulate level in normal gasoline is low, diesel has a much higher level of the particulates.[12] Although normal gasoline release a small amount of particulates into the atmosphere, with the amount of cars in the world now, carbons ppm (parts per million) in the air is increasing. Diesel contribution to the pollution is even greater.

The most general problems that gasoline causes are increase exposure to nitrogen oxides, carbon monoxide, and unburned hydrocarbons. The potential threat of unburned hydrocarbons is that they will create more carbon monoxide which is a poisonous gas.

Smog

The two most prevalent contaminants from the combustion of fossil fuels that form smog are nitrogen oxides (NO_x) and volatile organic compounds (VOC). Because volatile organic compounds also come in large quantities from non-vehicular activities and the formation of nitrogen oxides results mainly from high-temperature combustion of fuel, it will be instructive to focus on the nature of NO_x in urban air pollution. [13]

In the natural state of normal dry air, the concentration of nitrogen dioxide (NO) ranges from 0.25 to 0.5 parts per million (ppm) and the concentration of nitrogen dioxide (NO_2) ranges from .001 to .002 ppm. Nitrogen oxide most commonly occurs in air by nitrogen "fixation," which is the reaction of air nitrogen and oxygen by[14]:

$$N_2 + O_2 \rightarrow 2NO$$

At high-temperature combustion:

$$N + O \rightarrow NO$$

The formation of nitrogen oxide results from the oxidation of NO by both a slow reaction with oxygen:

$$2NO + O_2 \rightarrow 2NO_2$$

Fast reaction with ozone:

$$NO + O_3 \rightarrow NO_2 + O_2$$

Smog is formed by photochemical reaction with nitrogen dioxide, producing a chain reaction with atomic oxygen and VOC hydrocarbons that results in the formation of chemically reactive free radicals (R• and OH•) by the transfer of a hydrogen atom from the VOC to the oxygen atom[15]:

$$NO_2 + hv \rightarrow NO + O$$

$$O + RH \rightarrow R\bullet + OH\bullet$$

$$OH\bullet + RH \rightarrow R\bullet + H_2O$$

Notes: hv= photons of ultraviolet light (from sunshine)

RH= hydrocarbons (from VOCs)

Distribution of air pollutants by source for 1970 compared with 1998[16]

Source	CO		SO_x		SPM*		VOC		NO_x	
	1970	1998	1970	1998	1970	1998	1970	1998	1970	1998
Transportation	111.0	70.2	1.0	0.4	0.7	0.7	19.5	7.8	11.7	13.0
Electric Power	0.8	5.4	26.5	16.7	6.8	1.1	0.6	0.9	10.0	10.2
Industry	11.4	3.6	6.0	1.5	13.1	0.6	2.0	1.4	0.2	0.8
Solid Waste	7.2	1.2	0.1	0.1	1.4	0.3	7.1	0.4	0.4	0.1
Other	16.8	9.1	0.3	0.9	3.4	32.0	7.1	7.4	0.4	0.3
Total	147.2	89.5	33.9	19.6	25.4	34.7	34.7	17.9	22.7	24.4

*suspended particulate matter

Air pollution emissions in the U.S. 1940-1970[17]

Pollutant	Mass (in million tons)
CO	85-150
SO_x	22-34
SPM	25-27
VOC	19-35
NO_x	7-23

Typical concentration of gases in photochemical smog[18]

	Component	Concentration (ppm)
Major Gases	H_2O	$2x10^6$
	CO_2	$4x10^4$
	CO	$4x10^3$
	CH_4	250
Smog Gases	NO_X	20
	O_3	50
	VOC	10-60

The chart above shows the magnitude of NO_X emissions in the United States. In 1970 the fractional emissions was 51.5% from transportation and 44% from electric power plants. In 1998, NO_X emission was 53.3% transportation and 41.8% electric power plants. From these figures we can conclude that as total energy consumption increases, the smog problem will not lessen greatly if the transportation sector continues to uses fossil fuels.[19]

These various types of air pollutants cause health problems such as "cancer, neurological, cardiovascular, and respiratory effects, effects on the liver, kidney, immune system and reproductive system, and effects on fetal and child development."[20]

NO_X[21]

NO_X can cause a wide variety of health and environmental changes because of various compounds and derivatives in the group of nitrogen oxides, including nitrogen dioxide, nitric acid, nitrous oxide, nitrates, and nitric oxide.

Affects ground-level Ozone (smog)

Smog is formed when NO_X and volatile organic compounds (VOCs) react in the presence of sunlight. People with asthma and people who work or exercise outside are susceptible to adverse effects such as damage to lung tissue and reduction in lung function. The ozone is also never stationary. A strong wind current can transport the smog miles away, which cause health impacts far from the original source. Other impacts ozone has is damaging the vegetation and reducing crop yields.

Acid Rain

NO_X and sulfur dioxide (SO_2) react with other substances in the air to form acids which fall to earth as rain, fog, snow or dry particles. Acid rain is devastating to the environment. It can cause deterioration of cars, building and historical monuments, and cause lakes and streams to become acidic and inhabitable for many fish.

Particles

NO_X reacts with such material as ammonia, moisture, and other compounds to for nitric acid and related particles. This is a concern to human health because it affects the respiratory system. If enough is inhaled, damaged to the lung tissue and premature death is possible. Small particles penetrate deeply into sensitive parts of the lungs and can cause or worsen respiratory disease such as emphysema and bronchitis, and aggravate existing heart disease.

Water Quality Deterioration

Increased nitrogen loading in water bodies, particularly coastal estuaries, upsets the chemical balance of nutrients used by aquatic plants and animals. Additional nitrogen accelerates "eutrophication," which leads to oxygen depletion and reduces fish and shellfish populations. NOx emissions in the air are one of the largest sources of nitrogen pollution in the Chesapeake Bay.

Climate Change

Of the NO_X group, nitrous oxide (N_2O) is a greenhouse gas. It accumulates in the atmosphere with other greenhouse gasses causing a gradual rise in the earth's temperature. One of the effects from the increase in temperature is the rise in sea level and adverse changes to plant and animal habitats.

Toxic Chemicals

When NO_X is in the air, it reacts readily with common organic chemicals and even ozone, to form a wide variety of toxic products. Some of these are so dangerous that they could cause biological mutations. An example of this would be nitrate radicals, such as nitroarenes, and nitrosamines

Visibility Impairment

Nitrate particles and nitrogen dioxide (NO_2) have the possibility to block transmission of light, reducing visibility in urban areas such as national parks and historical land marks. During daylight NO and NO_2 are in equilibrium with the ratio NO/NO_2 determined by the intensity of sunshine (which converts NO_2 to NO) and ozone (which reacts with NO to give back NO_2). NO and NO_2 are also central to the formation of tropospheric ozone.[22]

Particulate Matter (pm, or pp [particle pollution])[23]

This term is for a mixture of solid particles and liquid droplets found in the air. This includes dust, dirt, soot, smoke; which are large and dark enough to see with the naked eye. These particulate matter contains microscopic solids or liquid droplets that are so small that they can get deep into the lungs and cause serious health problems.

Particles smaller then 10 micrometers (mm) pose the greatest threat. Particles of this size can access the lungs easily and cause severe damage; particles of this stature can also enter the bloodstream. Particles this big is the major cause of reduced visibility.

CO[24]

Cardiovascular Effects

Carbon monoxide affects people with heart disease, angina, clogged arteries or congestive heart failure. A person with heart disease, with just a single exposure to CO at low levels may cause chest pain and reduce that person's ability to exercise. Having exposure multiple times could contribute to other cardiovascular effects.

Central Nervous System Effects

No one is safe from high levels of CO exposure. People who inhale high levels of CO can develop vision problems, reduced ability to work or learn, reduced manual dexterity, and difficulty performing complex tasks. At high concentrations of carbon monoxide is poisonous and can cause death.

Smog

Carbon monoxide contributes to the formation of smog at ground-level ozone.

SO_X[25]

Respiratory Effects from Gaseous SO_2

High levels of SO_2 in the air can cause temporary breathing difficulty for people with asthma who are active outside. Long-term exposure to high levels of SO_2 gas and particles cause respiratory illness and aggravate existing heart disease.

Respiratory Effects from Sulfate Particles

SO_2 reacts with other chemicals in the air to form tiny sulfate particles. When these are inhaled, they gather in the lungs and are associated with increase respiratory symptoms and disease, difficulty in breathing, and premature death.

Visibility Impairment

Just like with NO_X, haze occurs when light is scattered or absorbed by particles and gases in the air. Sulfate particles are one of the leading causing of reduced visibility in many parts of the United States.

Acid Rain

Sulfur dioxide and nitrogen dioxide react with other substances in the air to form acids, which fall to earth in many different forms (i.e. rain, fog, snow, or dry particles). Some of these particles can be carried by the wind for hundreds of miles damaging other areas.

Plant and Water Damage

Acid rain also damaged forest and crops, changes the makeup of soil, and makes lakes and streams acidic and inhabitable for fish. Continue exposure over a long period of time could change the natural variety of plants and animals in the ecosystem.

Aesthetic Damage

SO_2 accelerates the decay of building materials and paints. This includes monuments, statues, sculptures that are part of nation's cultural heritage that would require additional money to fix.

Coal: Cheap in the Short Term

Since the 1700s coal has been burned as a source of energy.[26] Currently coal is still used to generate electricity for the majority of consumption in the United States. "Electricity generation is the single largest use of coal in the United States. Electric utilities consumed 87.4 percent of the total 1992 coal consumption of 892 million tons"[27] This consumption translates to just over half of the electricity production of the United States. Many states, especially in the coal-producing regions, get virtually all their electricity from coal; others, especially on the West Coast and in New England, burn next to none.[28]

The current coal production and consumption in North America has remained steady for the pass ten years. That decade, the increase of coal production went up 3.29% while the consumption rose 14.4%. In other continents such as Asia, the production rate of coal increased by 61.9% and consumption by 56.1%. Compared to the North American statistics these numbers are much more drastic. Unlike North America, Asia is even more dependent on coal and is increasing its output of it as well. The world's overall production of coal is up 28.1% and its consumption is up 28.4%. Globally, the world hasn't given up on this resource since the numbers not decreasing at any rate. In 2005, the world produced 2887.2 million metric tons of coal while consuming 2929.8 million metric tons. From 2004 to 2005, North America's change in the production of coal was increased by 1.6% and its consumption by 2.0%.[29] Even though North America is keeping good pace with the consumption of coal, it is still depleting the level of coal reserve on earth.

While the world is consuming more coal then its producing, there are still great amounts of coal reserves around the world. In North America alone there is 254.4 billion metric tons of reserved coal.[30] While in the rest of the world, there is a coal reserve of 654.6 billion metric tons.[31] Even if the rates of coal consumption increase in as it is now

Environmental Concerns

One of the main reasons that the coal production has remained steady in North America for the pass ten years may mostly because of the environmental awareness around the country. As more coal is used, the pollutants in the air also grow. "Coal use in the United States can't remain invisible for much longer, though. It is increasingly under attack on environmental grounds, and objections are coming both from home and abroad. Even after decades of regulation, an astounding proportion of the most serious pollution problems in the United States are still caused by coal and the threat of global climate change-something U.S. laws have yet to touch is a matter of increasing international urgency."[32] Coal has caused environment harm such as acid rain that damages the plants and animals that may make it difficult for them to live in their current environment.[33]

In places such as the United States are regulating the amount of coal being used and produced. With these regulations, the amount of change on a world scale is very subtle. But since coal isn't an unlimited resource, the world needs to find a better way to converse it. As seen on table 10-1, there are new technological breakthroughs that will increase the efficiency of coal. Efficiency is the ratio of the amount of energy created to the energy supplied by the source.

As of now, coal's efficiency level is about 38-42%.[34] The energy density of coal is about 6.67 kW*hours/kg, however coals average efficiency level is only about 30-40% which only produces about 2.33 kW*hours/kg.[35] With new machines the amount of energy extracted from coal can be increased up to 60% efficiency, which almost doubles the expectancy of the world's coal reserve.

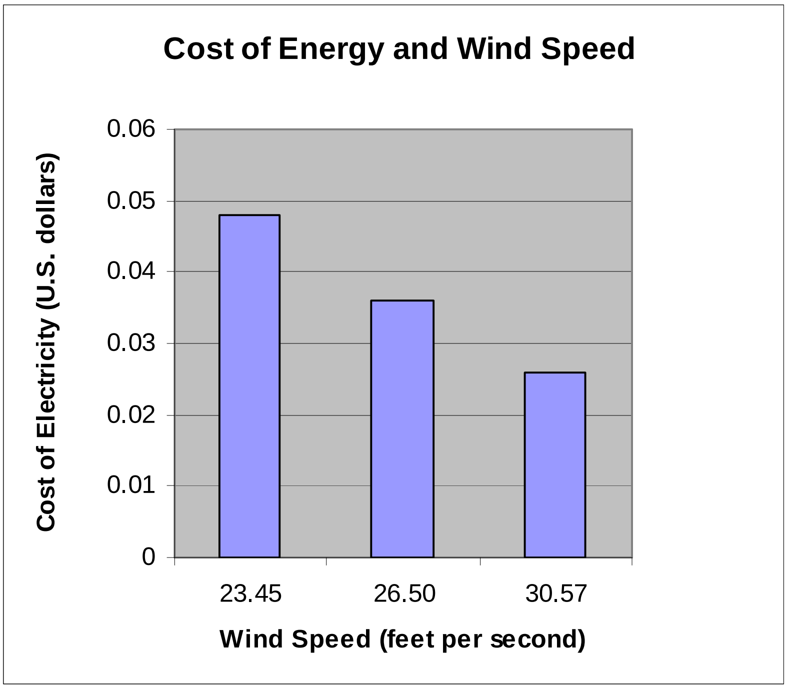
As soon as 2010 there could be a new machine that will increase that efficiency of 60% or more.[36] As long there are advancements in technology for coal in the future, the amount of coal reserve may not be a concern.

Wind Energy: The Untapped Resource

In the United States, the expected value of energy that will be generated by wind is 24.8 billion kWh of electricity. It has been estimated that the total potential of wind energy could go up as much as 10,777 billion kWh annually, which is three times the electricity the United States generates today.[37] As of July 31, 2006, the total installed U.S. wind energy capacity was 10,039 MW.[38] This represents a 10% increase from a total capacity at the end of 2005 of 9,149 megawatts[39] . The major limiting factor on capacity increases is not market interest or even cost incentives, but availability of turbines. As of March 2006, General Electric, the supplier for roughly 60% of US wind turbines was sold out until 2007[40]. Other smaller manufacturers are recognizing the market demands and coming online with production capacity slowly, however the technological complexity and high degree of precision needed to construct highly efficient turbines is fairly high.

Wind Energy Prices

A major driver of increased interest at all levels in wind power, is that in the past 20 years, the cost of wind energy per kilowatt hour has dropped roughly 90% "from 38 cents in the early 1980s to between three and six cents in 2004"[41]. In comparison, according to the US Department of energy the average price per kilowatt hour of standard electricity is roughly $.075[42]. The factors that affect the cost of wind energy have changed drastically and will continue to decline as the industry grows and matures. One of the major factors that determines the cost to produce wind energy at a given site project site is wind speed. From chart A-1, you can see a noticeable improvement in price efficiency as the wind speed increases.[43]



[44]

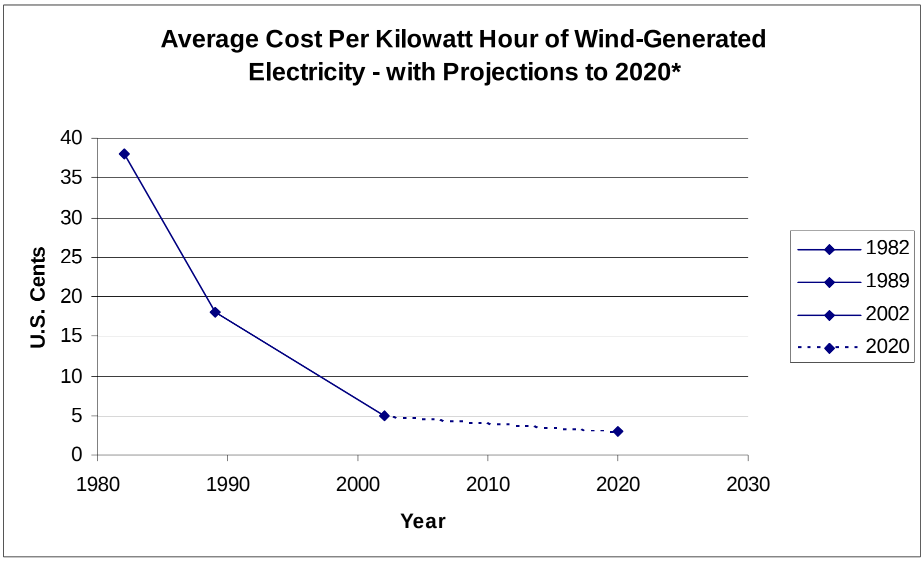
The further above the ground the turbine is and the larger the surface area swept by the blades, the more powerful and productive the turbine. "The swept area of a turbine rotor (a circle) is a function of the square of the blade length (the circle's radius)." In other words, if you have a 20m it would have a 100 kW turbine. Unlike in the 1980's, where they were only capable of producing 10m diameter blades, today we can construct blades over 50 meters. Since wind speeds increase with distance from the ground, new higher wind turbines are a vast improvement.[45]

Compared to 1981, the price per kW has greatly improved throughout the past 25 years. The increased rotor diameter has contributed greatly to this increase in price efficiency.[46]

Improvements in Wind Turbines 1981-2000[47]

	1981	2000
Rated Capacity	25 kW	1650 kW
Rotor Diameter (meters)	10 m	71 m
Total Cost ($)	$65	$1,300
Cost per kW	$2,600	$790
Output, kWh/year	45,000	5.6 million

On the world standpoint, the United States has one of the largest wind-generating capacities. As more technology is developing to improve the use of wind turbines, there will also be an increase of the use of them. By 2020, the price per kilowatt of wind energy generated could be as low as 3 cents.



*In 1982 it was 38 cents, 1989:18 cents, 2002:5. In the next 20 years it is predicted that wind energy will go as low as 3 cents per kWh generated.[48]

Scale for Wind Turbines

It may still be too early to see small scale wind turbines for conventional use at high levels of efficiency, since the price is significantly different depending on the size of the turbine. "A 3–MW wind project delivers electricity at a cost of $0.059 per kWh and a 51-MW project delivers electricity at $0.036 per kWh—a drop in costs of $0.023, or nearly 40%." Also, larger installations have less operations and maintenance (O&M) costs per output.[49]

However with that said, there are certain applications where small scale wind turbines are being deployed with a great deal of success. In areas with long distances between consumers, local smaller power generation plants may be more cost effective to maintain as estimated costs to maintain rural power lines are around $500 per mile[50]. Local power generation would lead to more reliable power for isolated consumers as the reduced line lengths are also less likely to be broken by limbs or other weather related incidents as these incidents occur probalisticaly based on location and line length.

As a possible application of small scale wind power, the deployment of turbines to augment residential power needs and interconnect with the local electrical grid, selling excess power and buying needed power has several essential issues. In over half the United States, residential wind power that is connected to the grid often is sold to the power company for one rate that is drastically less than the price charged for power, creating a disincentive for larger more efficient power generation at the residential level as the spare power generated does not save a consumer much money[51]. To deal with this problem "twenty-two states in the United States permit net metering for wind turbines" where essentially power put into the grid comes off the power consumed on a 1:1 basis[52]. The typical limit on the size of this type of interconnect is "10 kW, though in some states the limit is higher; Minnesota, 40 kW; Massachusetts 30kW; New Mexico and North Dakota, 100 kW. There is no limit in Iowa" [53]. While useful in certain applications, these small scale wind turbines are unable to generate the same cost effectiveness as large wind farms, restricting their usefulness.

Wind Energy is increasingly becoming utilized globally and "Asia became the most dynamic world region in the year 2005, with a growth rate of 48 %, adding 2.263 MW, up to an overall capacity of 7.022 MW." In Asia, India and China are the major drivers in terms of installed capacity as well as in terms of manufacturing facilities. "The Asian leader continues to be India which overtook Denmark and ranks now at the fourth position both in terms of overall capacity (4.430 MW) as well as of added capacity (1.430 MW)."[54]

China which was once ranked tenth (with 764 MW) in wind energy is now ranked eighth (with 1,260 MW) in the world. In early 2005, the Chinese government adopted a renewable energy law and increased the official target for the year 2020 from 20 GW to 30 GW. With this change, it will create excellent growth perspectives, a policy the US government can look to.[55]

Europe is still the global leader in wind energy capacity (40.932 MW), representing about 55% of the added global capacity. The European market has shown a growth of 18%.[56]

Typical wind turbines, as installed in power plants around the world are usually around 750-kilowatt (kW), produce about 2 million kilo-watt-hours (kWh) of electricity annually

Global Installed Wind Capacity[57]

	installed capacity 2005 MW	2005 in %	installed capacity 2004 MW	2004 in %
Europe	40,392	69.4	34,758	72.9
Africa	252	0.4	240	0.5
America	10,036	17	7,367	15.5
Asia	7,022	11.9	4,759	10
Asia Pacific	740	1.3	547	1.1
World	58,982	100	47,671	100

Benefits of Wind Power

The major benefits of wind power are that it is growing to be cost effective and it is sustainable and green. Wind power is green in that it does not produce waste, any CO_2 or toxic emissions, in contrast to many of the traditional means of power generation. It also does not consume significant resources to maintain.

A typical 750-kilowatt turbine with reasonable wind speeds "can be expected to displace a total of 1,179 tons (2.36 million pounds) of carbon dioxide, 6.9 tons of sulfur dioxide, and 4.3 tons of nitrogen oxides" in one year in comparison to the general level of outputs from typical U.S. utility fuel power[58]. The average fuel mix emits 1.5 pounds CO_2 for every 1 kWh. Annual wind power energy production is currently around 2 million kWh of energy per year, which is a mitigation of 1,500 tons of CO_2 alone and proportionate levels of other toxins. "According to *Our Ecological Footprint*, a forest absorbs approximately 3 tons of CO_2 per acre of trees per year." To provide scale on this data, in California alone current energy productions is over 3 billion kWh a year, so if even half of California's energy needs could be met by wind farms that would prevent 2.25 billion tons of CO_2 from entering the air. [59]

In addition to no pollutant output, one of the other benefits of wind energy is that it uses very little water to maintain itself. Compared to other major energy sources like nuclear, coal, oil and combined cycle, wind only uses a small faction of what these sources uses. A material such as coal required a vast amount of water in order to derive usable energy from it as it needs to be cleaned and processed with water before it can be used properly. As seen on the table below, the amount of water that is required for wind is significantly less then the other resources accounted for. The main use for water with wind energy is to clean wind turbine rotor blades in arid climates (where rainfall does not keep the blades clean). Cleaning the blade is necessary to eliminate dust and insect buildup, which otherwise deforms the shape of the airfoil and degrades performance.[60]

Amount of Water Required to Process Each Resource[61]

Technology	Gallons/kWh	Liters/kWh
Nuclear	0.62	2.30
Coal	0.49	1.90
Oil	0.43	1.60
Combined cycle	0.25	0.95
Wind	**0.001**	**0.004**
PV (solar)	0.030	0.110

Commonly Held Objections to Wind Energy

There are several commonly raised perceived issues with wind power than hinder public acceptance; operating noise, raptor kills and perceived unreliability and thus a need for backup power,

Modern wind power does not cause high levels of noise pollution with a wind farm that is 750 ft away generating levels of noise at around 40-45 decibels, which is quieter than a typical conversation in a home[62].Wind mills do kill birds, but in statistically insignificant numbers compared to the total bird fatalities as a result of other technologies such as power lines. Roughly one out of every ten thousand bird deaths as a result of technology occur as a result of wind turbines whereas buildings and windows kill roughly 5,5000 per ten thousand[63].

When installed correctly in a windy area and as part of a distributed system wind turbines generate power about 65-80% of the time though not at maximum output, typical levels of output due to wind speed variations break down as follows “at full rated capacity about 10% of the time, and on average throughout the year the plant will generate 30% to 35% of its rated capacity" [64].These variations are not unpredictable and can be accurately forecasted allowing time to bring other power sources online. A major study "conducted in 2004 for the Minnesota Department of Commerce found that adding 1,500 megawatts…would require only an additional 8 MW of conventional generation to deal with added variability"[65]. As this demonstrates, when coupled with other forms of power that can be phased in and out to meet demand needs this is fine, and most systems have excess capacity built in. However, wind is not viable as a standalone solution to the pressing energy problem, but as part of a larger solution with other technologies it looks promising.

Solar Power Analysis

Solar power offers a potential solution to the pending energy crisis. However it currently suffers from prohibitively expensive material costs and space to power output issues. As an example, to have the same 1,000 megawatt output as a typical power plant "a solar or wind collector has to occupy five square miles" [66].

The major issues with using photovoltaic cells to harness solar power are cost, both in terms of efficiency and initial investment and energy storage for night utilization. The costs per kWh for solar power over a 40 year life have fallen from $0.18 in 2001 to roughly $0.15 as of February 2006. [67]This is higher than existing energy costs, but the advantage of solar, much like wind is that it requires minimal maintenance expenses.

In terms of ability to be implemented current solar cells have energy efficiencies of 8% while technology currently in development has a goal of 12% efficiency and levels of roughly 25% are needed to be viable and implemented on a wide scale[68]. Recent research in this area is promising with a recent development of a photo voltaic cell with "efficiencies of >32% in lab conditions"[69]. Along with efficiency issues the cost of producing the cells is also rather expensive. By looking at current online stores, it was determined that PV panels range from anywhere from $400-1,100 per panel. These panels were only available in the range of 85-270 watts capacity costing on average between 4 and5 dollars per watt generated.

Panel Size and Cost in Solar Cells[70]

20 years	2400 kWh	2200 kWh	2000 kWh	1800 kWh	1600 kWh	1400 kWh	1200 kWh	1000 kWh	800 kWh
200 $ / kWp	0.8	0.9	1.0	1.1	1.3	1.4	1.7	2.0	2.5
600 $ / kWp	2.5	2.7	3.0	3.3	3.8	4.3	5.0	6.0	7.5
1000 $ / kWp	4.2	4.5	5.0	5.6	6.3	7.1	8.3	10.0	12.5
1400 $ / kWp	5.8	6.4	7.0	7.8	8.8	10.0	11.7	14.0	17.5
1800 $ / kWp	7.5	8.2	9.0	10.0	11.3	12.9	15.0	18.0	22.5
2200 $ / kWp	9.2	10.0	11.0	12.2	13.8	15.7	18.3	22.0	27.5
2600 $ / kWp	10.8	11.8	13.0	14.4	16.3	18.6	21.7	26.0	32.5
3000 $ / kWp	12.5	13.6	15.0	16.7	18.8	21.4	25.0	30.0	37.5
3400 $ / kWp	14.2	15.5	17.0	18.9	21.3	24.3	28.3	34.0	42.5
3800 $ / kWp	15.8	17.3	19.0	21.1	23.8	27.1	31.7	38.0	47.5
4200 $ / kWp	17.5	19.1	21.0	23.3	26.3	30.0	35.0	42.0	52.5
4600 $ / kWp	19.2	20.9	23.0	25.6	28.8	32.9	38.3	46.0	57.5
5000 $ / kWp	20.8	22.7	25.0	27.8	31.3	35.7	41.7	50.0	62.5

"The table below shows the total cost in US cents per kWh of electricity generated by a photovoltaic system. The row headings on the left show the total cost, per peak kilowatt (kW_p), of a photovoltaic installation. The column headings across the top refer to the annual energy output expected from each installed kW_p. This varies by geographic region (mainly because of different levels of insulation) and the efficiency of the PV modules. The calculated values reflect the total cost in cents per kWh produced. They assume a 4% cost of capital, 1% operating and maintenance cost, and depreciating the capital outlay over 20 years. (Normally, photovoltaic modules have 25 years' warranty, but they should be fully functional even after 30-40 years.)"[71]

Manufacturing costs are dropping at 3 to 5% a year in recent years, expanding the range of cost-effective uses. From 1990 to 2005, the cost of retail photovoltaic panels dropped from $7.50 to about $4 per watt. With many jurisdictions now giving tax and rebate incentives, solar electric power can now pay for itself in five to ten years in most places. Grid-connected systems, a system with no battery that connects to the utility grid through a special inverter - now make up the largest part of the market.

The large initial investment required to harness the sun's energy makes it more expensive than other energy sources in the short run requiring longer to realize a return on investment. Existing battery technology is inadequate for storing energy for evening use as it grows inefficient with daily charging and discharging. Perhaps storing the energy in another form using a future technology as hydrogen fuel cells would also enable solar energy. With sufficient technological advances that lower costs and increase efficiency it would be possible for solar power to become a viable energy source for both grid power and charging batteries in transportation, as a reference statistic roughly "ten thousand times as much electric power as even Americans consume" falls on the US in the form of sunlight each year but it would be highly impractical to cover even one thousandth of the surface of the US in solar panels[72].

It is not the absolute cost of solar power to its output that makes it prohibitive but instead the cost compared to the current option, gasoline. Also, more realistic pricing on gas through the removal of subsidies will help tilt the scales in favor of implementation of solar power. While sustainable as long as sunlight reaches the earth and wind moves "renewable energy sources are also rate limited; they can flow forever, but only at a fixed rate. They cannot support an indefinitely large population and a capital plant growing at high rates[73]. Thus they are not a stand alone solution but a component of a system to replace the existing one. There must be major progress made on efficiency and material costs in the near future for photovoltaics to become a significant source of energy. Otherwise they will just used as support in an integrated system, perhaps with wind turbines.

Foreign Sustainable Energy Policies

Europe has enjoyed much greater success adopting and implementing sustainable alternative energy than the US to date and as resource for moving the US to sustainable energy the example of nations that have made the transition are viable areas for research. The three countries that are most effective in delivering wind energy are Denmark, Germany and Spain. The amount of taxes that Germany would apply would depend on the wind resources. France uses the same system. The main driver for investment in wind energy especially in Spain and Germany is the high level of feed-in tariffs.

A feed-in tariff essentially is the government mandating "The price per unit of electricity that a utility or supplier has to pay for renewable electricity from private generators"[74]. This is a vital policy that the US can and should emulate to increase market adoption and viability of wind turbines. Policies such as this would lower a major barrier to market entry of excess capacity is effectively wasted from the point of view of the owner of the grid connected turbine as it is bought for a fraction (generally 20%) of what it is sold back to the consumer for. This sort of tariff ensures someone who owns a turbine or a solar panel they will be able to get a stable, fixed price per kW/h and recover their investment. Additionally, by providing incentive to generate more power rather than minimum for personal use, this policy encourages the construction of larger more efficient turbines. An interesting issue is that feed-in tariffs work even with fairly low profit margins, as long as it is guaranteed.

In Denmark, the "feed-in tariff for wind power has historically been set at 85% of retail electricity prices…and – along with important companion policies including capital subsidies, tax incentives, low-cost financing, and R&D funding" has lead to Denmark's position as the world's foremost "industrial center for wind technology development and manufacturing"[75].

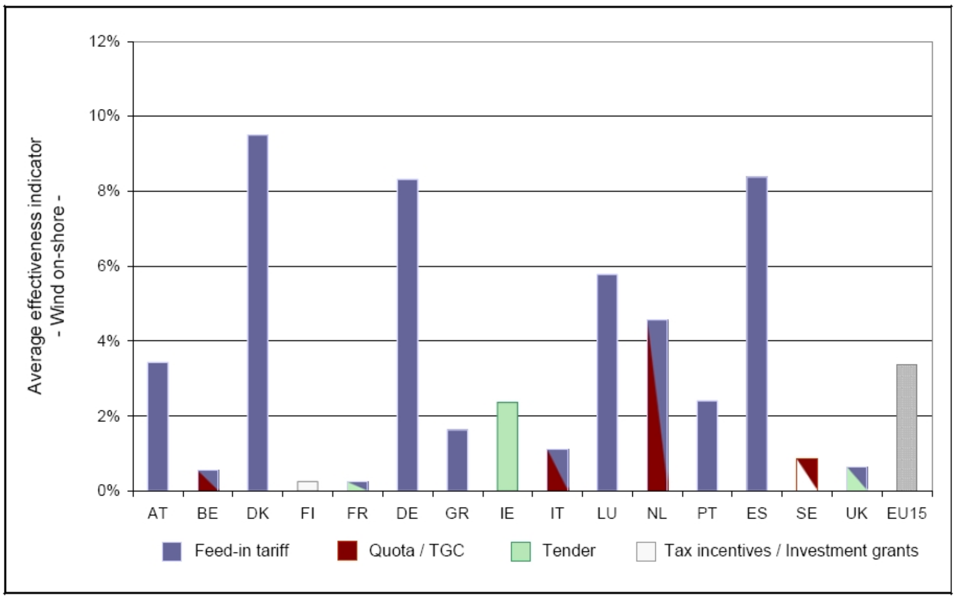
During the 1990s, "the German electricity feed-in law…required that wind power, solar, hydropower, and biomass receive 90% of the residential retail price of electricity (from 9.5 cents/kWh in 1991 to 8.8 cents/kWh in 1999)" providing a strong incentive for the creation of alternative power sources. This law has been revised and updated since then and while it has "frequently been protested by electric utilities…it has successfully launched the most sizable wind power market worldwide and Germany now represents one of the largest solar markets as well" [76]. Recently, Spain has drastically increased it's "installed wind power capacity, in large part as a result of an attractive feed-in tariff established in 1994" [77].

While feed-in laws are a viable solution in Europe they are not generally politically popular in US free market economics where the government seeks to minimize short term costs rather than optimize energy utilization and long term public costs benefits. Based on the success of the European nations in adopting alternative energy it is suggested that the US develop some sort of feed-in program to reduce risk and encourage investing in renewable energy.

In addition to feed-in tariffs, another major means of increasing alternative energy adoption is the establishment of a Renewable Portfolio Standard or RPS, policies mandating that utilities derive a certain percentage of their power from renewable energy sources. These include target dates and penalties for failure to comply with the RPS. "The RPS is an increasingly popular form of support for renewable energy, with several developed nations considering phasing out their feed-in tariffs in favor of an RPS-based mechanism" since it enables alternative energy adoption while still allowing the open market to control pricing[78]

While much more flexible and in tune with American ideology than feed-in tariffs, RPS still is not politically acceptable to the American Congress. In May of 2005 the “House Committee on Energy and Commerce, an amendment to add an RPS (1% in 2008, increasing by 1% annually through 2027) was rejected (17-30)” while a “Senate version had a 10% RPS provision” also was rejected [79]. The fundamental issue is that the American government is highly uncomfortable mandating anything to private utilities and is also too heavily influenced by petroleum lobbyists to enact any legislation that is against their interests but in the overall interest of the nation. This MUST change for a secure, sustainable, non-polluting American energy portfolio to develop.

Effectiveness Indicator for Wind Onshore Electricity (1998-2004)[80]



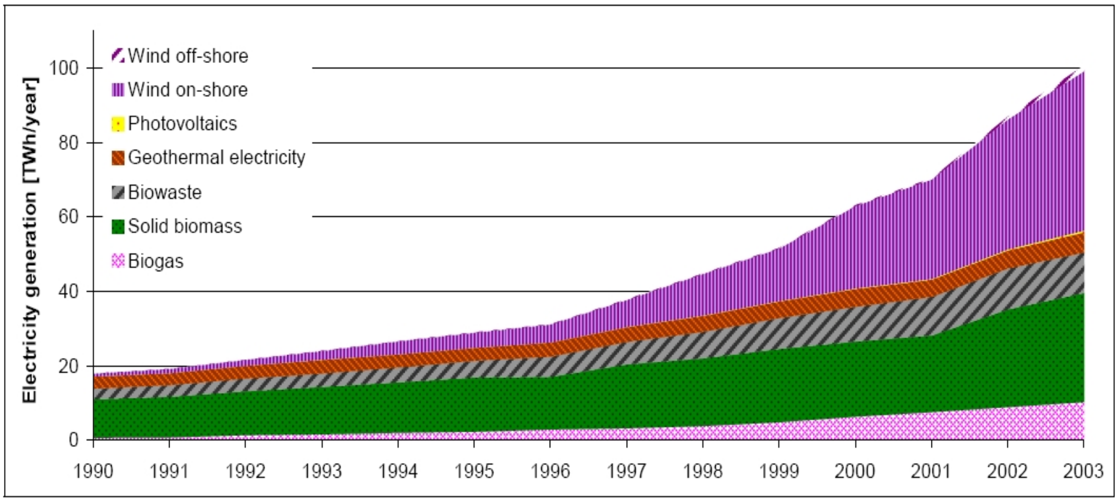
This data shows that development of wind generation capacity has been the most effective, by far in those nations with feed-in tariffs as the risk to investors is minimized, providing enough incentive to invest in the new technology. EU analysts have concluded “that, in a quarter of the Member States, support is too low for any takeoff. Another quarter provides enough support but still obtain mediocre results. This can be explained by the existence of grid and administrative barriers” [81]

Overview of the main policies for renewable electricity in EU-15[82]*

Country	Main electricity support schemes	Comments
Austria	Feed-in tariffs (now terminated) combined with regional investment incentives.	Feed-in tariffs have been guaranteed for 13 years. The instrument was only effective for new installations with permission until December 2004. The active period of the system has not been extended nor has the instrument been replaced by an alternative one.
Belgium	Quota obligation system / TGC27 combined with minimum prices for electricity from RES.	The Federal government has set minimum prices for electricity from RES. Flanders and Wallonia have introduced a quota obligation system (based on TGCs) with the obligation on electricity suppliers. In Brussels no support scheme has been implemented yet. Wind offshore is supported at federal level.
Denmark	Premium feed-in tariffs (environmental adder) and tender schemes for wind offshore.	Settlement prices are valid for 10 years. The tariff level is generally rather low compared to the previously high feed-in tariffs.
Finland	Energy tax exemption combined with investment incentives.	Tax refund and investment incentives of up to 40% for wind, and up to 30% for electricity generation from other RES.
France	Feed-in tariffs.	For power plants < 12 MW feed-in tariffs are guaranteed for 15 years or 20 years (hydro and PV). For power plants > 12 MW a tendering scheme is in place.
Germany	Feed-in tariffs.	Feed-in tariffs are guaranteed for 20 years (Renewable Energy Act). Furthermore soft loans and tax incentives are available.
Greece	Feed-in tariffs combined with investment incentives.	Feed-in tariffs are guaranteed for 10 years. Investment incentives up to 40%.
Ireland	Tendering scheme. It has been announced that the tendering scheme will be replaced by a feed-in tariff scheme.	Tendering schemes with technology bands and price caps. Also tax incentives for investment in electricity from RES.
Italy	Quota obligation system / TGC. A new feed-in tariff system for photovoltaic valid since 5th August 2005.	Obligation (based on TGCs) on electricity suppliers. Certificates are only issued for new RES-E capacity during the first eight years of operation.
Luxemburg	Feed-in tariffs.	Feed-in tariffs guaranteed for 10 years (for PV for 20 years). Investment incentives also available.
Netherlands	Feed-in tariffs.	Feed-in tariffs guaranteed for 10 years. Fiscal incentives for investment in RES are available. The energy tax exemption on electricity from RES ended on 1 January 2005.
Portugal	Feed-in tariffs combined with investment incentives.	Investment incentives up to 40%.
Spain	Feed-in tariffs.	Electricity producers can choose between a fixed feed-in tariff or a premium on top of the conventional electricity price, both are available over the entire lifetime of a RES power plant. Soft loans, tax incentives and regional investment incentives are available.
Sweden	Quota obligation system / TGC.	Obligation (based on TGCs) on electricity consumers. For wind energy, investment incentives and a small environmental bonus are available.
United Kingdom	Quota obligation system / TGC.	Obligation (based on TGCs) on electricity suppliers. Electricity companies which do not comply with the obligation have to pay a buyout penalty. A tax exemption for electricity generated from RES is available (Levy Exemption Certificates which give exemption from the Climate Change Levy).

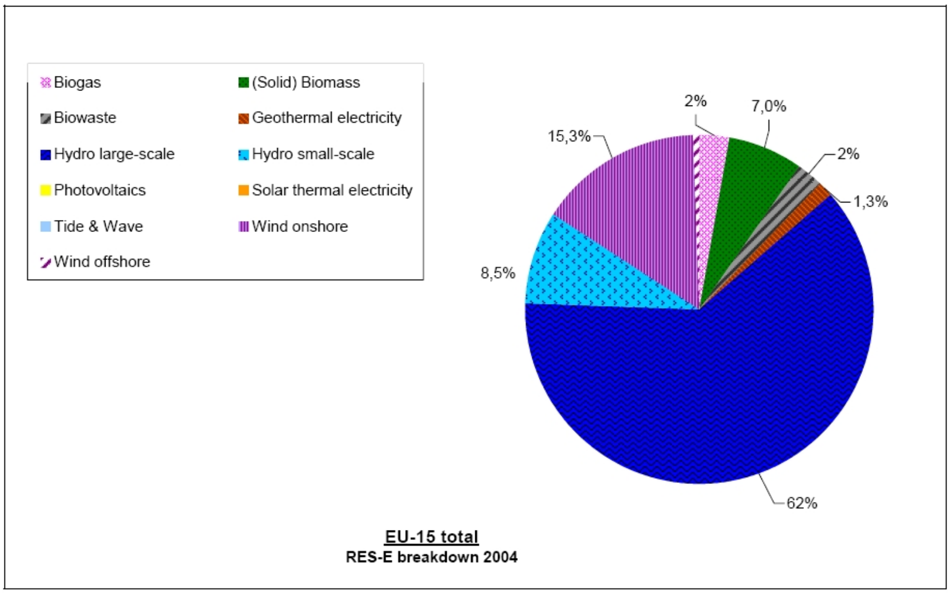
*TGC = tradable green certificates.

Historical Development of Electricity Generation from 'New' RES-E in the European Union (EU-25) from 1990 to 2003.[83]



As the graph above shows, the adoption of alternative energy sources has been increasing in recent years. Wind energy both on shore and off has shown both the greatest relative increase and real increase in output from 1990-2003 of the sources examined here.

RES-E as a Share of the Total Achieved Potential in 2004 for the EU-15[84]*



*EU-15: Consist of the following countries. Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Portugal, Spain, Sweden, United Kingdom.

In terms of renewable energy sources in Europe far and away hydropower provides the most energy, and then wind is a distinct second.

Policy Analysis and Suggestions for the Future

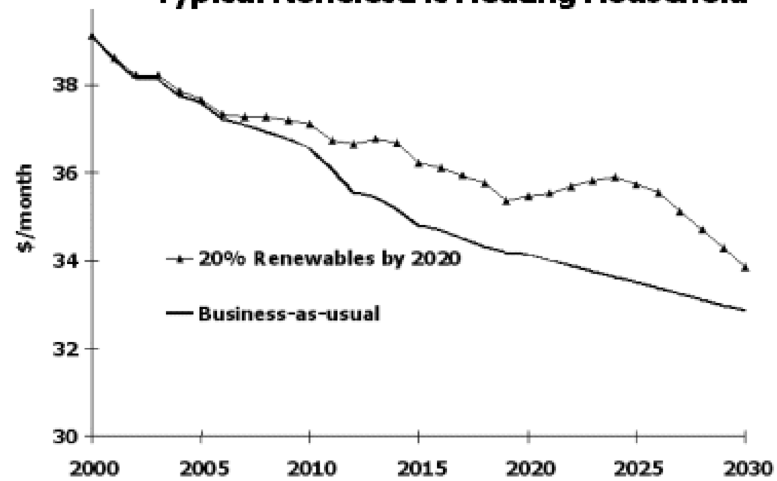
Ideally "by 2025 we can cut our oil consumption in half. This would slash our reliance on electricity-producing fossil fuels like coal and natural gas almost entirely".

Utilizing sustainable "energy sources we can virtually eliminate our need to rely on greenhouse-gas-producing fuels" a major benefit both in terms of decreasing our political reliance on foreign nations and our pollution levels.[85] This goal for the US is not overly ambitious in the global scale as by "2020 Sweden wants to become fossil-fuel dependency free" and "only using 35% of its total energy from oil, gas, and coal. [In contrast] fossil fuels satisfy 86% of the United States demands"[86]. We are far behind Europe in adoption of alternative energy where Denmark is able to currently meet a fifth of its energy needs with wind power and plans to increase that to a quarter in 2008 "and by 2030 40%. While in the United States, only 0.4% of energy demand is satisfied by wind turbines"[87].

Reducing CO_2 emissions or at least keeping them constant at 2000 levels is also a reasonable policy goal. Under current projections "Carbon dioxide emissions from energy use are projected to increase at an average rate of 1.4 percent per year from 1,511 to 2,041 million metric tons carbon equivalent between 1999 and 2020"[88]. If we are able to achieve a standard of having 20% of all energy in the US come from renewable sources in "2020 [it] would freeze electricity-sector carbon dioxide emissions at year 2000 levels through 2020 at a modest cost of $18 per ton reduced" [89]. If nothing is done the CO_2 levels will grow by 24%. [90]

Keeping total energy costs low for consumers is an essential goal of any energy policy. Maintaining inflation linked energy costs at in constant dollars is essential to keeping the economy running smoothly. A US government study found that "RPS proposals" will save consumers less than higher polluting, non renewable policies, "but in every RPS proposal, customers would still be paying less for electricity than they are today. Even under the more aggressive 20 percent RPS, average consumer electricity prices were projected to fall 13 percent between 1997 and 2020, compared with 18 percent without an RPS" [91]. As seen in the graph below, this will result in a "average electric bill savings of $5.90 per month between 1998 and 2020 under business as usual by $1.33." for a typical household[92].

Figure 10. Average Monthly Electricity Bill for a Typical Nonelectric Heating Household



Source: Steven Clemmer, Alan Nogee, and Michael Brower, *A Powerful Opportunity: Making Renewable Electricity the Standard*, Union of Concerned Scientists, January, 1999.

Strategies to Overcome Barriers

In order to realize this vision it essential to overcome the political and inertial entrenchment of the existing power ideologies. Sustainable power is on the cusp of being viable, with support the entry barriers to the markets will be lifted, ushering in a new age of "reduce[d] trade deficits, enhance[d] national security, and …millions of non-exportable jobs".93 As seen in the analysis of existing technologies combined with the long term trending below, alternative energy will be increasingly economically feasible as the price of conventional energy increases. Increased attention to the externalized costs of conventional power generation will also tilt public opinion towards green energy. Mercury pollution and ozone are seen as general social ills, rather than specific outputs from certain industries. As this perception changes so to will the preference towards willing to absorb higher monetary costs for clean energy?

Some policy options to facilitate the transition include RPS and feed-in tariffs as seen in Europe. Renewable energy sources currently provide 6% of all energy in the US. If this number is to reach 20%, government policy must make reasonable efforts to increase the viability of alternative energy. Wind is proving itself economically viable in both the long and short term as compared with the projected price for a traditional energy mix rising to 6.71 cents per kWh while wind will only cost roughly 3 cents. The major issue is the high initial cost of constructing the turbines as seen in the technical analysis of the technology. RPS strategies to encourage adoption will further facilitate the transition. Feed-in tariffs as seen in Europe for the transitory period will also be helpful. Guaranteeing that the investment will provide a certain rate of return will make the initial capital investments much more forthcoming and help cause utilities to favor the construction of a new wind farm rather than a coal plant to handle increased consumption. Given enough time and the gap in petroleum demand and supply it is likely that alternative energy will be economically competitive with traditional energy sources as demonstrated below.

Total Energy Consumption – U.S. 2000-2004(in QuadBtus)94

Energy Source	2000	2001	2002	2003	2004[P]
Total [a]	**98.961**	**96.464**	**97.952**	**98.714**	**100.278**
Fossil Fuels	**84.965**	**83.176**	**84.070**	**84.889**	**86.186**
Coal	22.580	21.952	21.980	22.713	22.918
Coal Coke Net Imports	0.065	0.029	0.061	0.051	0.138
Natural Gas[b]	23.916	22.861	23.628	23.069	23.000
Petroleum[c]	38.404	38.333	38.401	39.047	40.130
Electricity Net Imports	**0.115**	**0.075**	**0.078**	**0.022**	**0.039**
Nuclear Electric Power	**7.862**	**8.033**	**8.143**	**7.959**	**8.232**
Renewable Energy	**6.158**	**5.328**	**5.835**	**6.082**	**6.117**
Conventional Hydroelectric	2.811	2.242	2.689	2.825	2.725
Geothermal Energy	0.317	0.311	0.328	0.339	0.340
Biomass[d]	2.907	2.640	2.648	2.740	2.845
Solar Energy	0.066	0.065	0.064	0.064	0.063
Wind Energy	0.057	0.070	0.105	0.115	0.143

[a] Ethanol blended into motor gasoline is included in both "Petroleum" and "Biomass," but is counted only once in total consumption.
[b] Includes supplemental gaseous fuels.
[c] Petroleum products supplied, including natural gas plant liquids and crude oil burned as fuel.
[d] Biomass includes: black liquor, wood/wood waste liquids, wood/wood waste solids, municipal solid waste (MSW), landfill gas, agriculture byproducts/crops, sludge waste, tires, alcohol fuels (primarily ethanol derived from corn and blended into motor gasoline) and other biomass solids, liquids and gases.
[P] = Preliminary
Note: Data revisions are discussed in Highlights section. Totals may not equal sum of components due to independent rounding.
Sources: Non-renewable energy: Energy Information Administration (EIA), Monthly Energy Review (MER) March 2005, DOE/EIA-0035 (2005/03) (Washington, DC, March 2005,) Tables 1.3 and 1.4. Renewable Energy: Table 2 of this report. As a result totals in this table do not match the March MER.

Solar energies rate of change per year is about -1.2%. Solar energy is losing its popularity in the United States. If this decrease continues, the amount of solar energy consumed will only be 1.24 mtoe. Solar energy will require large amounts of advertising and subsidizing to rebound from its slumps of the past.

Wind on the other hand is doing very well in the past few years, reaching an average increase of about 26.45%. In twenty years, wind energy consumption could be as much as 393.6 mtoe. If this remains true, wind energy will have a 14% share of the amount of total energy consumed. This represents a very large jump from its tenth of a percent before and is independent of any policy actions.

Recommendations for Future Research

Future IQPs in this topical area would do well to examine in detail how solar and wind energy are progressing at a technical level as there are varying statistics for the efficiency and costs associated with each. In particular there are several cutting edge advances in solar cell design such as quantum dots that project high enough efficiencies that it may become a viable technology. We did not examine nuclear fission or fusion as the former was deemed too polluting to be considered truly sustainable and the later as it is too theoretical and distant to be incorporated into energy policy decision making within the next 20 years. Biomass is an interesting area to examine, but from our initial research the process of growing crops to burn for energy isn't terribly energy efficient or cost effective when all external factors are considered. Geothermal and tidal power are potentially beneficial for certain energy markets with an abundance of the needed resources, but neither is particularly prevalent in the US. A political power analysis of the changing impact on global politics under various energy situation scenarios is also relevant for future policy planning.

Conclusion

Widespread voluntary adoption of long-term viable energy technologies such as wind energy is likely to occur with minimal government intervention as prices drive usage and wind energy is starting to become economically competitive with other sources, particularly when externalized costs are calculated. This is an interesting trend as until recently, wind energy was not economically viable. As seen in Europe, it is conceivable that with immediate and major effort the US economy can transition from the current unsustainable oil based economy to one based on renewable resources with long term sustainability. While "there is no [single] existing technology capable of replacing the oil we will soon be without, nor is there any on the horizon that we can depend on to replace the remaining fossil fuels when they are exhausted" it is possible through innovative and sweeping actions[95]. By transitioning from the existing system to one with an interconnected system of sustainable stationary power generation in the form of solar, wind, with minor traditional energy for backup to generate electricity for general use it is likely to be financially viable and environmentally sound. To bring about these innovations requires a massive social commitment to future research to prevent catastrophic problems that will be insolvable in the short term if allowed to develop.

The current administration is failing to address this pressing concern in an adequate manner given the peak global oil production may have occurred and is expected to occur by 2008. Reassuring statements by the administration such as “more money is being spent on energy efficiency research today than ever before” fail to mention that the funding is miniscule when the scope and urgency of the problem are taken into account [96]. As an additional shortcoming, the administration suffers from a time frame issue in that it is responding to urgent problems both too far into the future and by using a short term basis to its long term thinking. It is only through the development of a system of viable sustainable alternative energy source will the economy be able to insulate itself from the peaking of oil production and ensuing supply gap and continue on into the future.

By mandating phased implementation of various energy technologies into existing energy portfolios and creating feed-in tariffs to guarantee a fixed rate on the power produced, widespread adoption of wind and solar power will be vastly increased. By providing assistance in the short term with recovering the initial investment, the government would enable profit driven companies to look to the long term and realize significant savings both internally and in reduced externalized costs. With even modest policies utilities should begin to favor the construction of a new wind farm rather than a coal plant to handle increased consumption as traditional energy prices rise renewable energy appears more attractive. With the modest government incentive policies outlined in this paper, it is highly likely that sustainable energy systems can be implemented before oil prices reach crippling levels.

Appendix

Plentiful Energy

Fuel cost:

<Pros> With plentiful amounts of energy, space research and travel both for business and pleasure will experience significant growth. With low fuel costs the likelihood of violent conflict due to resources disputes will decrease significantly. Personal comfort will increase significantly as people are able to affordably control their living temperature via heat and air conditioning. Overall low fuel costs facilitate economic growth.

<Cons> When fuel costs are low there is less incentive to conserve energy and find new ways to generate it. Pollution may passively increase because companies will no longer need to worry about conserving energy. This would lead to higher carbon dioxide emission levels and the possibility of an energy shortage as the growing economy consumes increasing amounts of resources.

Technology:

<Pros> With enough low cost energy, portable devices and various units will be improved at a faster rate. A major limiting factor in the portable electronics market, portable energy would be solved by low cost solutions to charging portable energy storage systems. The development of high capacity batteries to store more energy will occur in tandem.

Transportation:

<Pros> All forms of transportation will be used more frequently. Travel will be encouraged. World travel will take place more often, which will lead to better understanding of other countries. People will be able to experience more unique places

Scarce Energy

Fuel cost:

<Pros> High fuel prices drive interest in alternative energy development. Pollution will passively decrease as fossil fuels will likely be a rare commodity. This will also decrease the carbon dioxide emission levels.

<Cons> Shortage or depletion of a resource would have severe, possibly destabilizing impact of the economy. Means of transportation will be more expensive and difficult to find crippling the economy. Personal comfort will decrease drastically as well as health as people are unable to regulate their living conditions comfortably.

Technology:

<Cons> Many forms of research will be differed due to lack of funds and energy.

Transportation:

<Pros> Since transportation will be expensive, there will be an incentive for alternative forms of transportation be it man power or simply efficient mass transit. Efficiency will become more important in vehicular technology.

<Cons> Train, bus, taxi, and car fees will all increase as a result of fuel prices, people may not be able to afford to travel beyond their immediate local. A significant economic downturn may occur as people attempt to sell personal automobiles due to fuel costs and there are not enough interested buyers leading to a massive equity loss.

Space:

<Con> Any further space travel research may not be feasible, as public interest is only prevalent in good economic times.

leading to overall increases in happiness as well as economic growth due to tourism.

<Cons> All forms of transportation use will increase. Pollution will become even more of an issue as the most popular domestic form of transportation, the personal automobile generates a high amount of pollution per person served. Cheap energy will make the pollution issues less important to consumers.

Space:
<Pros> More space programs will be launched as the economic growth fuels research. This will lead to even more technological advances as seen in the past. With enough space research many breakthroughs such as the discovery of other habitable planets are possible.

Foreign Policy:
<Pros> With plentiful energy the dependence on foreign nations for resources will decrease reducing the vulnerability to "resource blackmail". From the United States perspective this is a valuable policy change as we import more energy resources than we export.

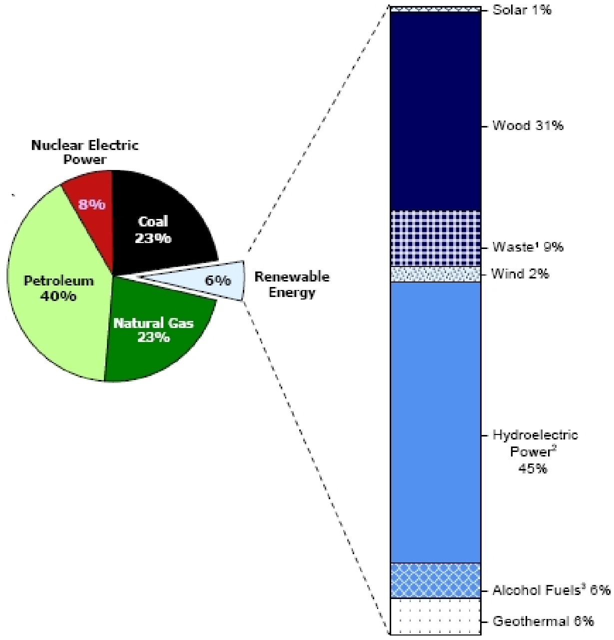
<Cons> It is possible that with less economic influence the Arab nations may turn to more radical means of impacting global politics. Reduced energy prices will reduce the clout of resource trading on the political sphere.

Foreign Policy:

<Pros> High amounts of profit will be made in trading scarce energy resources. This may lead to global partnerships for energy distribution across political lines.

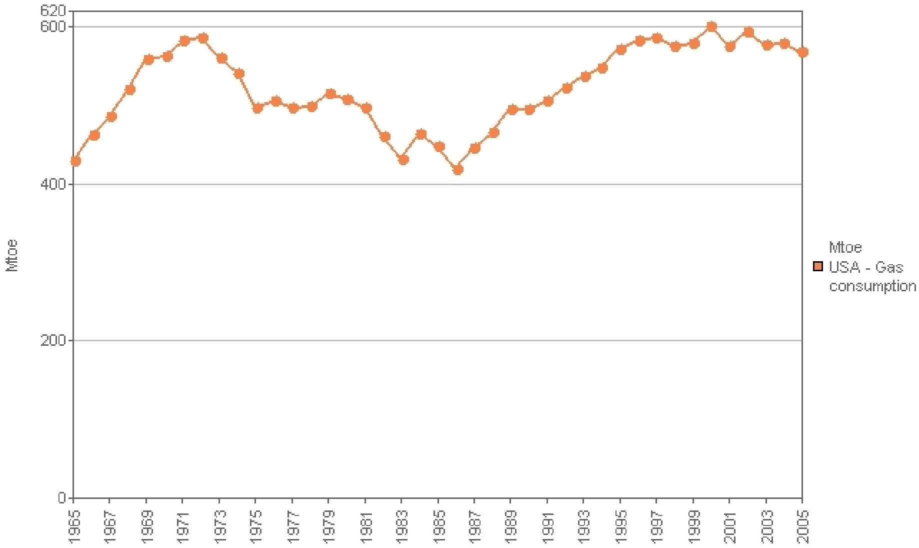
<Cons> Most likely, nations with rare resources will further inflame the problem by restricting the supply to artificially inflate prices and line their own pockets. The Arab nations will develop even more political clout and be able to blackmail most governments with impunity. If the shortages of certain resources becomes severe, it is not unlikely that war could break out for control of the needed resources

Renewable Energy Consumption by Major Sources - 2005[97]



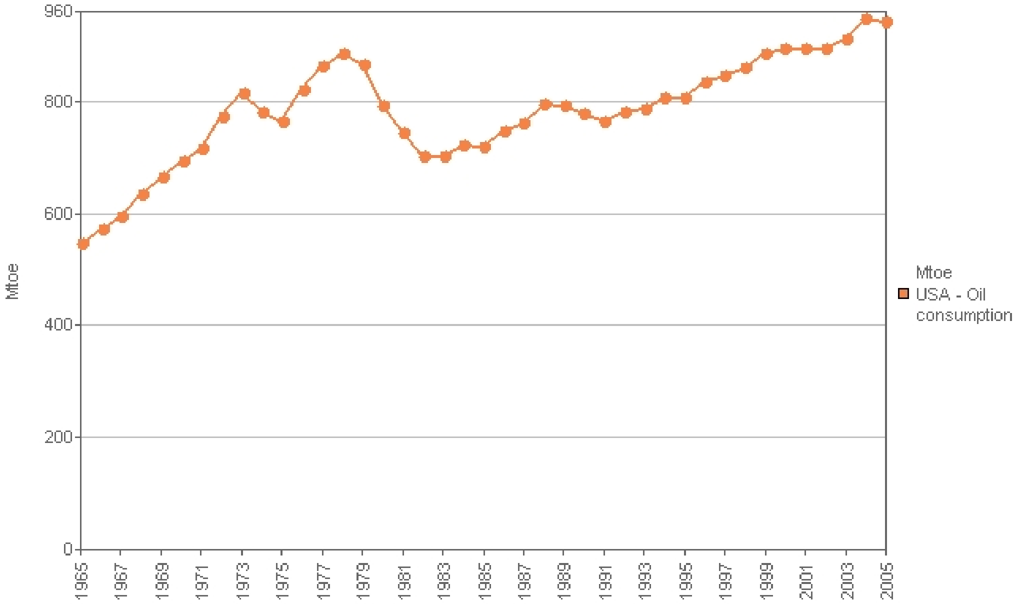
Consumption Statistics

US Gas Consumption[98]



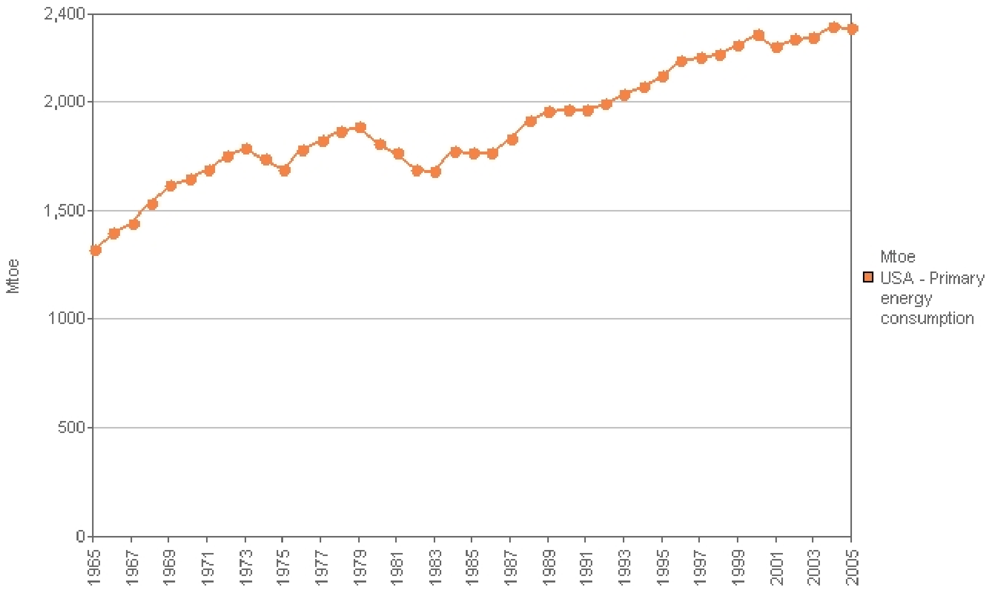
Unlike the other energy resources, gas in the United States is going down annually at about -.3% a year. In twenty years from now it may be likely that the gas consumption will be around 536.8 mtoe. If solar and wind energy want to dominant the energy market, this maybe an excellent area to start. With the decrease in demand for gas, it is possible for renewable energies to step in and slowly replace it.

US Oil Consumption[99]



Surprisingly, the United States average annual growth is only 1.31% in the oil sector. Twenty years from now the United States will be consuming roughly 1225.4 mtoe.

Total Energy Consumption - US[100]



Total energy consumption by the United States is only going up 1.04% a year. By 2026, the amount of consumed energy will be about 2873 mtoe.

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[1] Deffeyes, Kenneth S. Hubbert's Peak: The Impending World Oil Shortage. Princeton: Princeton University Press, 2003.pgs 7, 146-149.

[2] Goodstein, David L. Out of Gas: the End of the Age of Oil. New York: W.W> Norton & Company, Inc., 2004. pg 17.

[3] Deffeyes, Kenneth S. Hubbert's Peak: The Impending World Oil Shortage. Princeton: Princeton University Press, 2003.

[4] Goodstein, David L. Out of Gas: the End of the Age of Oil. New York: W.W> Norton & Company, Inc., 2004. pg 36.

[5] Ibid 46.

[6] Deffeyes, Kenneth S. Hubbert's Peak: The Impending World Oil Shortage. Princeton: Princeton University Press, 2003.pg 175.

[7] Goodstein, David L. Out of Gas: the End of the Age of Oil. New York: W.W> Norton & Company, Inc., 2004. pg 18.

[8] Meadows, Donnella, Jorgen Randers, and Dennis Meadows. The Limits to Growth. White River, VT: Chelsea Green Publishing Company, 2004. pg 90.

[9] ,www.trendlines.ca/economic.htm

[10] Combustion Pollutants March 2002.
Utah State University Extension. 20 September 2006
<http://extension.usu.edu/files/homipubs/hh03.pdf#search=%22pollutants%20from%20combustion%22>

[11] Davis, Mackenzie, Masten, Susan. Principles of Environmental Engineering and Science. New York: McGraw Hill, 2004. 435-446 p.

[12] How Clean is Clean? November 1999.
Ward's Auto World 20 September 2006.
<http://findarticles.com/p/articles/mi_m3165/is_1999_Nov/ai_57165220>

[13] Kruger, Paul. Alternative Energy Resources: The Quest for Sustainable Energy.
Hoboken, New Jersey: John Wiley & Sons, Inc., 2006. Page 7

[14] Ibid.

[15] Ibid.

[16] Ibid.

[17] Ibid.

[18] Ibid.

[19] Ibid.

[20] Ibid.

[21] Basic Information | Particulate Matter |. 20 Nov. 2006.
Environmental Protection Agency. 26 January 2007.
<http://www.epa.gov/air/urbanair/nox/hlth.html>

[22] Nitrogen oxide. 19 Jan. 2007
Wikipedia. 26 January 2007.
< http://en.wikipedia.org/wiki/Nitrogen_oxide>

[23] EPA Air and Radiation Basic Information. 27 Sept. 2006.
Environmental Protection Agency. 26 January 2007.
<http://www.epa.gov/air/particles/basic.html>

[24] EPA Air and Radiation Basic Information. 20 Nov. 2006.
Environmental Protection Agency. 26 January 2007.
<http://www.epa.gov/air/urbanair/co/hlth1.html>

[25] EPA Air and Radiation Basic Information. 20 Nov. 2006.
Environmental Protection Agency. 26 January 2007.
< http://www.epa.gov/air/urbanair/so2/hlth1.html>

[26] DOE – Fossil Energy: A Brief History of Coal Use in the United States. 17 Dec. 2005. U.S Department of Energy. September 7, 2006 <http://www.fossil.energy.gov/education/energylessons/coal/coal_history.html>

[27] National Research Council. Coal: Energy for the Future. Washington D.C.: National Academy Press, 1995. 19 p.

[28] Ibid. 177 p.

[29] BP Global – Reports and publications – Coal Production. 2006. BP Global. September 6, 2006 <http://www.bp.com/sectiongenericarticle.do?categoryId=9009510&contentId=7017942>
BP Global – Reports and publications – Coal Consumption. 2006. BP Global. September 6, 2006 <http://www.bp.com/sectiongenericarticle.do?categoryId=9009511&contentId=7017940>

[30] *BP Global – Reports and publications – Coal Reserve. 2006. BP Global. September 6, 2006 <http://www.bp.com/sectiongenericarticle.do?categoryId=9009509&contentId=7017943>*
[31] Ibid.
[32] Freese, Barbara. Coal: A Human History. Massachusetts: Perseus Publishing, 2003.166 p.
[33] Ibid. 186 p.
[34] *National Research Council. Coal: Energy for the Future. Washington D.C.: National Academy Press, 1995. 184-185 p.*
[35] Coal – Wikipedia. 5 September 2006. en.Wikipedia.org. 7 September 2006. <http://en.wikipedia.org/wiki/Coal>
[36]*National Research Council. Coal: Energy for the Future. Washington D.C.: National Academy Press, 1995. 184-185 p.*
[37]Wind Energy An Untapped Resource. 2006
American Wind Energy Association (AWEA). 26 September 2006
< http://www.awea.org/pubs/factsheets/Wind_Energy_An_Untapped_Resource.pdf>
[38] Wind Energy Projects in the U.S. 2006
American Wind Energy Association (AWEA). 28 September 2006
<http://www.awea.org/projects>
[39] *WIND ENERGY DEMAND BOOMING. Mar 22, 2006*
Earth Policy Institute. 25 September 2006
<http://www.earth-policy.org/Updates/2006/Update52.htm>
[40] *Ibid.*
[41] Price of Wind-Generated Electricity Plummeting. Mar 23, 2006
VOA News. 25 September 2006
< http://www.digitaljournal.com/news/?articleID=4554>.
[42] Ibid.
[43]*EconomicsOfWind-Feb2005.pdf 2006*
American Wind Energy Association (AWEA). 28 September 2006
<http://www.awea.org/pubs/factsheets/EconomicsOfWind-Feb2005.pdf>
[44] Ibid.
[45] Ibid.
[46] Ibid.
[47] Ibid.
[48]*March 22, 2006 Wind Energy Demand Booming Cost Dropping Below Conventional Sources Marks Key Milestone in U.S. Shift to Renewable Energy – Data.*
Earth Policy Institute. November 1, 2006.
<http://www.earth-policy.org/Updates/2006/Update52_data.htm>

[49] Ibid.
[50] Gipe, Paul. Wind Energy Basics: a Guide to Small and Micro Wind Systems. White River Junction: Chelsea Green, 1999. pg 103
[51] Ibid 66.
[52] Ibid. 67
[53] Ibid. 67
[54] *Statistics March 2006. 2006*
World Wind Energy Association. 28 September 2006
<http://www.wwindea.org/home/index.php?option=com_content&task=view&id=88&Itemid=43 >
[55] Ibid.
[56] Ibid.
[57] Ibid.
[58] http://awea.org/pubs/factsheets/wetoday.pdf
[59]Wind and CO_2. 2006
American Wind Energy Association (AWEA). 26 September 2006
<http://www.awea.org/faq/co2trees.html>
[60]*Turbine Water Usage Comparison. 2006*

American Wind Energy Association (AWEA). 26 September 2006
<http://www.awea.org/faq/water.html>

[61] Ibid.

[62] *Wind Power Myths vs. Facts. 2006*
American Wind Energy Association (AWEA). 26 September 2006
< http://www.ifnotwind.org/pdf/Myths%20&%20Facts.pdf>

[63] Ibid.

[64] Ibid.

[65] Ibid.

[66] Deffeyes, Kenneth S. Hubbert's Peak: The Impending World Oil Shortage.
Princeton: Princeton University Press, 2003. pg 183

[67] Home PV Solar Energy Systems: Cost and Benefits 2001
Franklin Energy Services, Inc. October 5, 2006
<http://energymatch.com/features/article.asp?articleid=20>

[68] Takatsuka, Hiromu, Matsuhei Noda, Yoshimichi Yonekura, et al. "Development of high efficiency large area silicon thin film modules using VHF-PECVD." Solar Energy 77.6 (Dec. 2004): 951-960. ScienceDirect. WPI, Worcester, MA. 6 Oct. 2005
<http://www.sciencedirect.com/science?_ob=ArticleURL&_aset=V-WA-A-W-CV-MsSAYZW-UUA-U-AABAWBWAZV-AAWYYAWEZV-BYDEAAAUE-CV-U&_rdoc=3&_fmt=full&_udi=B6V50-4D13868-1&_coverDate=12%2F01%2F2004&_cdi=5772&_orig=search&_st=13&_sort=d&view=c&_acct=C000005878&_version=1&_urlVersion=0&_userid=74021&md5=3b7965cf948c0938296d9cabfdfc2751>.

[69] Tester, Jefferson W, Elisabeth M. Drake, Michael J. Driscoll, et al. Sustainable Energy: Choosing Among Options. Ed. Jefferson W. Tester. Cambridge: MIT Press, n.d. Pg 582.

[70] Photovoltaics 2006
Wikipedia.org. October 5,2006
<http://en.wikipedia.org/wiki/Photovoltaic>

[71] Ibid.

[72] Goodstein, David L. Out of Gas: the End of the Age of Oil. New York:
W.W Norton & Company, Inc., 2004. pg 40

[73] Meadows, Donnella, Jorgen Randers, and Dennis Meadows. The Limits to Growth.
White River, VT: Chelsea Green Publishing Company, 2004. pg 96

[74] http://glossary.eea.europa.eu/EEAGlossary/F/feed-in_tariff

[75] http://www.usembassy.it/pdf/other/IB10041.pdf

[76] Ibid.

[77] Ibid.

[78] Ibid.

[79] Ibid.

[80] 2005_12_07_comm_biomass_electricity_en.pdf. December 7, 2005.
Commission of the European Communities. November 9, 2006
<http://ec.europa.eu/energy/res/biomass_action_plan/doc/2005_12_07_comm_biomass_electricity_en.pdf>.

[81] Ibid.

[82] Ibid.

[83] Ibid.

[84] Ibid.

[85] Step 1: Harness the Wind. July 2006.
Popular Science. November 1, 2006
< http://www.popsci.com/popsci/energy/062f2ec75919b010vgnvcm1000004eecbccdrcrd.html>

[86] http://www.popsci.com/popsci/flash/gatefold_rev.swf

[87] Ibid

[88] http://www.usembassy.it/file2000_11/alia/a0112811.htm

[89] Ibid.

[90] Ibid

[91] http://www.ucsusa.org/clean_energy/renewable_energy_basics/increasing-renewables-costs-and-benefits.html

[92] Ibid

[93] Step 1: Harness the Wind. July 2006.
Popular Science. November 1, 2006
< http://www.popsci.com/popsci/energy/062f2ec75919b010vgnvcm1000004eecbccdrcrd.html>

[94] *Renewable Energy Trends 2004. 2004*
Energy Information Administration. November 15, 2006
<http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/table1.html>

[95] Goodstein, David L. Out of Gas: the End of the Age of Oil. New York:
W.W Norton & Company, Inc., 2004. pg 115

[96] *Office of the Press Secretary, President Bush Signs Into Law a National Energy Plan. 8 Aug. 2005. 6 Oct. 2005. <http://www.whitehouse.gov/news/releases/2005/08/20050808-4.html>.*

[97] *Sec10_2.pdf. 2005.*
Energy Information Administration. November 15, 2006
<http://www.eia.doe.gov/emeu/aer/pdf/pages/sec10_2.pdf>

[98] Ibid.

[99] Ibid.

[100] Ibid.