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Renewable Energy: Considerations for the Transition

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: December 14, 2004

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Introduction

Energy is needed by every living thing. Plants derive their energy from the sun through the process of photosynthesis, animals from plants or from other animals. This is also true for humans, but with *Homo sapiens* comes another need for energy: Technology. Technology has created a need for energy outside of natural means, and has become nearly essential to our survival. There are many forms of energy; oil, wind, or electricity, to name a few. Electricity is the preferred form for many applications because of its ease of distribution, scalability, and ability to be created from other forms of energy. For example, gasoline can be burned in an internal combustion engine which turns an alternator allowing a stereo to turn on. In each transition, energy is lost, and each preceding form of energy in this series can be said to be of a "higher" form containing more energy than the forms after it. With the use of technology, there comes the need for electricity production. With electricity production comes several questions: From where? What by-products are generated? How much is it going to cost? The answers to these questions have shaped our energy production methods since the harnessing of fire by man. This paper will attempt to outline a brief history of energy use and production, explain the various means of electricity generation and their inherent positives and negatives, and explain the many considerations affecting *The Transition* to renewable and sustainable forms of energy. As with any transition, overwhelming public support is needed. The essential question arises: does society have sufficient knowledge about energy issues to make an informed decision about future energy needs.

Electricity

In 2001, the United States consumed more electricity than any other country in the world, using 3.6 trillion kWh. This is by far the most electricity consumed by any country (Appendix A, Table 1). However, if you consider the populations of each country, a slightly different picture appears (Appendix A, Table 2). It may be helpful to note that the top countries on this list have primarily cold climates, and many of the residents use electricity for their home heating.

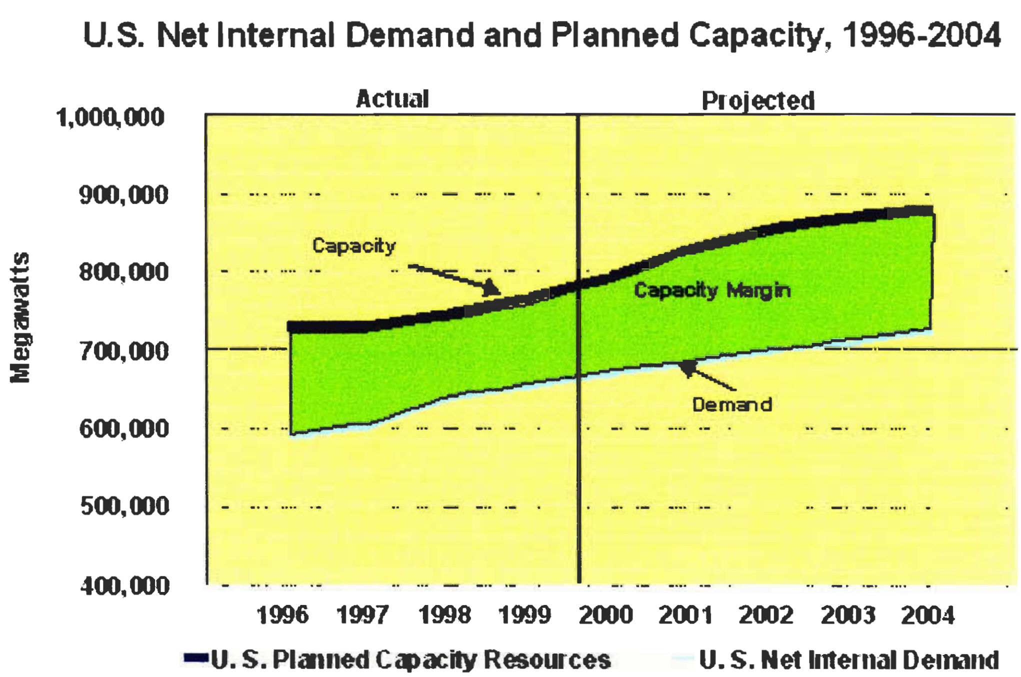
Technology in the United States has driven our electricity demand to nearly 3 times that of the second largest user. Electricity is used for millions of household appliances, computers, heat, and thousands of other applications. Until recently, there seemed to be an abundance of electricity on the consumer end. This apparent abundance of electricity, combined with a sense of detachment from where it comes from, how it is generated, or the need for conservation, has perhaps become one of the largest problems society will face in the very near future.

The United States' demand for electricity is constantly growing and over the past 26 years our capacity margin has decreased from 25-30% in 1978 to about 15% in 2001. However, in 2001, the trend was expected to reverse with the expansion of the overall capacity of U.S. power generation. However, from 2000 to 2003, 200,668 MW from 1862 power generating units of capacity were installed, doubling the projected increase in the graph below over the same time period. A large majority of these new power plants use natural gas as their primary energy source. Natural gas plants require immense infrastructure for delivering the gas to its intended destination. The distribution of energy sources can be seen below. Also noteworthy is the relatively small percentage of combined renewable energy sources. (1)

Figure 1:

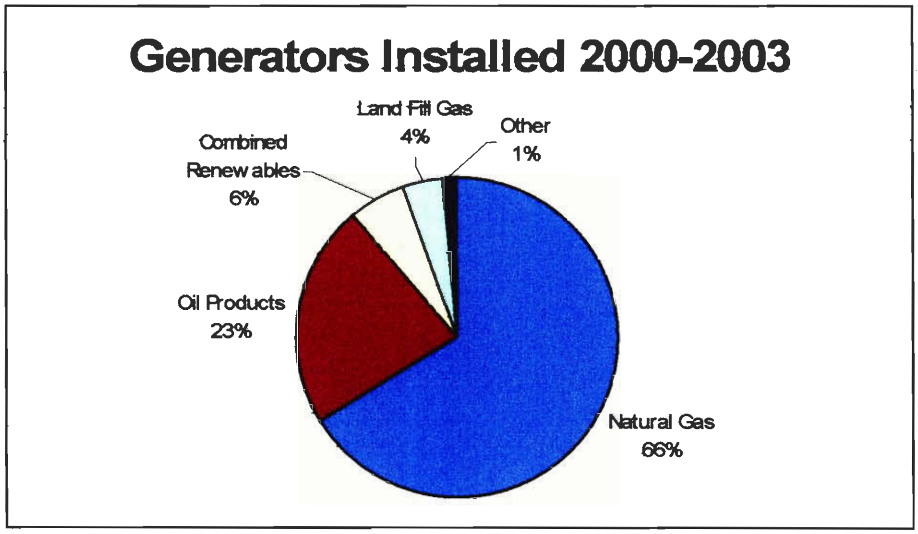
U.S. Capacity Margins, 2001				
	Eastern Grid	Texas Grid	Western Grid	U.S. Total
Demand (Megawatts)	501,405	53,414	114,830	669,649
Supply (Megawatts)	582,223	69,769	141,068	793,060
Capacity Margins (Percent)	13.9	23.4	18.6	15.6

Figure 2:



(Source: EIA http://www.eia.doe.gov/cneaf/electricity/page/fact_sheets/supply&demand.html, 2004)

Figure 3:



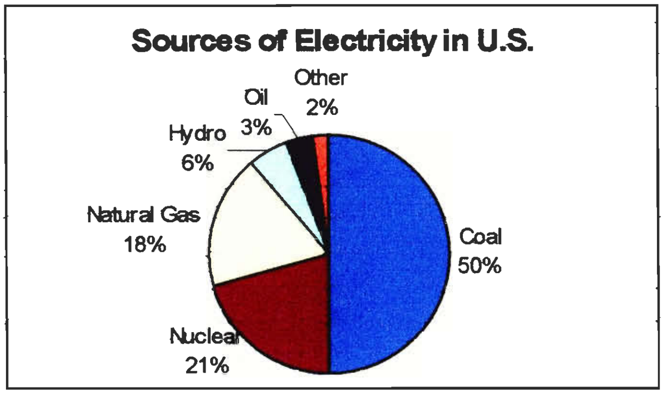
Electricity is not free. It is a form of energy, and at least according to the first law of thermodynamics, energy can neither be created nor destroyed. The sources of energy for electricity production can be arranged in two major categories; renewable and non-renewable. A renewable source of energy is one that is abundant enough to be considered inexhaustible, and a non-renewable type would be the opposite. An example of each would be wind used to turn a generator and burning oil to turn a generator, respectively. Currently, a vast majority of our electricity is derived from sources that are non-renewable. This poses an almost obvious question: In the years ahead, how will our choices affect our country's future?

Electricity generation

Of the electricity the United States uses, 71.4% of is produced from fossil fuels.

20.7% is from nuclear, 5.6% from hydro, 2.3% is from other sources such as wind and solar power (2). The fossil fuel burning power plants in the United States use coal, oil, or natural gas as their sources.

Figure 4:



Non-Renewable Energy

Non-renewable energy is energy derived from a source that is considered finite. Supply and demand play an important role in non-renewable energy, due to this particular property. The demand for energy is always increasing, and the supply always decreasing. Reliance on these usually foreign sources is somewhat like renting our power. With the exception of coal, much of our energy is imported as either oil or natural gas. This dependence can also be seen in the area of politics, such as the war in Iraq. These sources also invariably pollute more than renewable sources, causing much concern over emissions and global warming.

Coal

Coal burning power plants are the most widely used type of electricity generation in the United States, comprising just over half, (50.1%) of the total supply (1). The top twenty coal consuming countries are shown in Table 3 of Appendix A.

The process for electricity generation from coal is fairly simple. After mining, the coal is often cleansed of impurities through various means and then is transported to the generation facility. The coal is burned after being crushed into a fine powder, producing heat that is fed through pipes that are submerged in water, which produces steam. Through the pressure of the steam generation a turbine is spun to create electricity.

Coal is relatively abundant in the United States, with its reserves at approximately 266 billion tons, according to the Energy Information Agency. In 2000, the U.S. used about 1 billion tons for producing electricity (1). There is little fear of running out of coal any time soon, and we have little need to import coal, because of our extensive reserves. Hence, coal does not significantly factor into international relations.

With the abundance of coal, it would seem a likely candidate for a primary source of electricity generation, but with the use of fossil fuels comes quite a few negative factors. When any fossil fuel is burned, there are three major pollutants recognized by the Environmental Protection Agency as harmful that are released into the surrounding atmosphere: carbon dioxide, sulfur dioxide, and nitrogen oxides. In addition to these pollutants, mercury, methane and some radioactive elements are also released when these fuels are burned (3). Coal produces the most pollutants of the three major fossil fuels, followed by oil natural gas.

Natural Gas

Natural gas is the second largest non-renewable source for electricity production in the United States. In 2002, about eighteen percent of the United States' electricity supply came from this source. The process for converting this energy to electricity is achieved by either directly combusting the natural gas in a combustion turbine, or through a process involving steam similar to the coal process. Some newer plants combine the two methods, using the residual heat from the combustion turbine to heat water and turn another turbine powered by steam. These next generation power plants, called "combined cycle" plants, can achieve upwards of 60% efficiency, doubling the previous natural gas power plant standard of about 30%. (4)

The United States has an estimated 1037 trillion cubic feet of natural gas and about 29.3 billion barrels of liquid natural gases (5). Approximately 17.4% of our natural gas consumption is imported, and our total consumption annually is about 23 trillion cubic feet (1). The low percentage of total natural gas use that is imported has not made this resource a significant international relations issue. The majority of our imported natural gas comes from Canada, except for liquefied natural gas, which primarily comes from Trinidad and Algeria. (6)

Natural gas is the cleanest of the fossil fuels, emitting the least amount of pollutants. The average emission rates of the top three air-borne pollutants per megawatt/hour of electricity produced are the following: 1135 lbs of carbon dioxide, .1 lbs of sulfur dioxide, and 1.7 lbs of nitrogen oxides. (3)

Oil

In comparison to the other fossil fuels, oil is used the least in the generation of electricity, comprising only about three percent of our total production. This three percent can be produced in multiple ways. One such method is similar to the method employed by coal plants, another by directly injecting the oil into combustion turbines, and still another would be to use combined-cycle technology. Oil is the crude form of many other products. Familiar products such as gasoline, kerosene, propane, and diesel fuel all originate from oil. There are many chemical by-products of oil refining as well; chemicals essential in the production of grease, plastic, farming chemicals, and man-made fibers, such as nylon. The separation of oil into its many useful forms is accomplished at refineries by distillation processes; hence the general term for many of the resulting chemicals is distillates.

The United States is the largest consumer of oil in the world, consuming over twenty million barrels every day (Appendix A, Table 4). The primary uses of oil are for transportation and home heating. Sixty-eight percent of our total consumption is used for transportation (1). This is an astonishing statistic, which will be elaborated upon in a later section. Our proven domestic reserve of oil is 22.7 billion barrels, enough to supply the United States for about three years. Over fifty-six percent of the oil we consume is imported. This is a very unhealthy situation, both politically and economically, as we are heavily dependant on other countries for a resource our country cannot function without. The effects of this relationship have been apparent for some time, due to increasing involvement in foreign affairs of the Middle East and elsewhere.

The combustion of oil to generate electricity produces many of the same pollutants as coal. The average emission rates of the top three air-borne pollutants per megawatt/hour of electricity produced are the following: 1672 lbs of carbon dioxide, 12 lbs of sulfur dioxide, and 4 lbs of nitrogen oxides. (3)

There is another matter concerning oil, and that is there is essentially a finite supply. It takes millions of years for organic matters to be turned into oil. The rate at which the earth is producing oil is far, far less then the rate with which we are consuming it. The U.S. Geological Survey estimates that the Earth could hold as much as 2.3 trillion barrels of crude oil. Of this, the United States contains 113 billion barrels (5). Currently, the world's demand for oil is about 77 million barrels each day, and is expected to grow to 121 million barrels per day by 2025 (1). This would be enough to supply the world with oil for the next 63 to 95 years if the current trend in oil demand holds (5). While this may seem like a long time, and there may not be a need to start investing in new technologies just yet, the supply and demand aspect of fossil fuels must be considered. Demand for oil is ever increasing, and the supply is dwindling. Supply and demand economics dictate an increase in price at an alarming rate.

Gasoline

Gasoline usage is a heavy burden in the United States. According to the latest figures from the United States census bureau, 76% of commuting workers drove alone to work. A mere 12% car-pooled and 4.7% used public transportation (7). In the past year alone, the average price per gallon of gasoline has increased from $1.56 to $2.00. This corresponds to a 28% increase in a single year. Granted, there has been a United States-led war in the Middle East, but President Bush's plan to increase stability has thus-far not been as successful as his administration had planned. Another interesting figure is the average price versus the peak price of gasoline. In 2003, gasoline prices in California averaged $1.83 per gallon, but the peak was $2.14. These numbers can give an idea of the instability of the price of oil, obviously affected by any political instability. These are a few of the factors that make the price of oil inherently unpredictable, and make our country vulnerable in world politics. Our dependence may one day be our downfall, but there is hope. The need for *The Transition* to renewable energy is upon us.

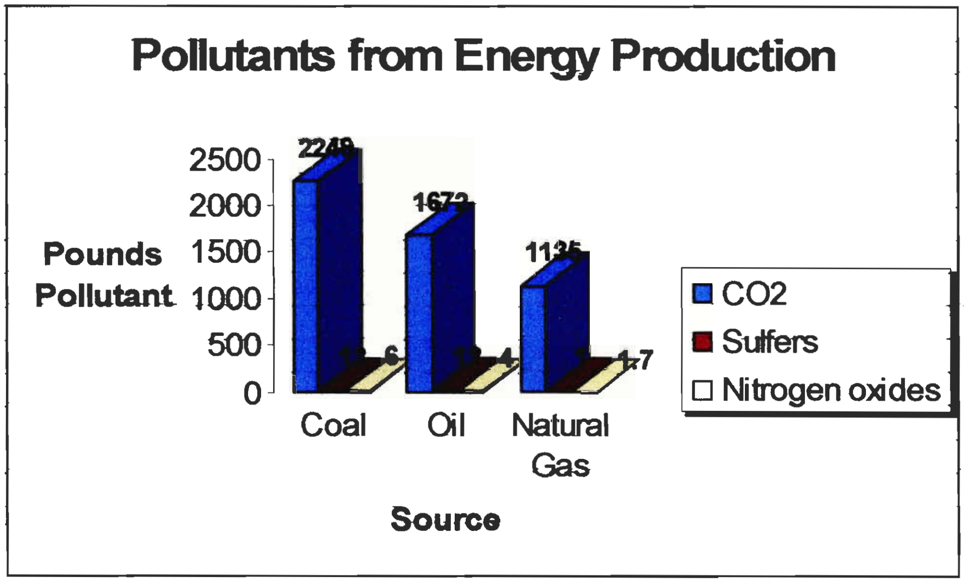
Fossil Fuel Summary

The average emission rates of the top three air-borne pollutants per megawatt/hour of electricity produced are the following: 1,685 lbs of carbon dioxide, 8.7 lbs of sulfur dioxide, and 2.9 lbs of nitrogen oxides. This amounts to about 4.05 billion tons of carbon dioxide produced from electricity each year, and 23 billion pounds of sulfur dioxide, and 10.8 billion pounds of nitrogen oxides (3). The total CO_2 emission from burning fossil fuels in the United States is about 5.76 trillion metric tons each year.

Throughout the world, fossil fuels are used as the only source of electricity production. There are currently 64 countries that are in this situation. The world average percentage of electricity production from fossil fuels is about 67%. (2)

The amount of pollutants for each fossil fuel source is shown below. The amount of these pollutants emitted by various countries can be seen in Appendix B

Figure 5:



Nuclear Energy

There is another energy source that is widely used to create electricity. It does not, however, easily fall into the two major categories. Some power plants use nuclear fuels, such as uranium. Uranium-238 is the most common form of the element, comprising ninety-nine percent of earths total. Uranium-235 (U235), which makes up .7% of total Uranium, or Uranium-239 (U239) are two radioactive isotopes that can be used as nuclear fuel. The latter is not a naturally occurring isotope but can be made relatively easily by bombardment of a U238 atom with neutrons (8). The enrichment to higher concentrations of U235 can be made by various methods such as diffusion, centrifugation, and electromagnetic filtration (9). U235 is used in concentrations of about three percent for power generation, and about ninety percent for nuclear weapons.

The radioactive isotopes of Uranium have the desirable trait of ability to undergo induced fission. Induced fission is the process started when an atom is hit by a projected neutron and spontaneously splits into two or more atoms and potentially several more neutrons. These excess neutrons then go on to start new fissions. The reaction can be controlled through the use of what are called control rods. These rods are made of a material (commonly graphite or carbon) that absorbs free neutrons readily. By inserting the rod into a reaction chamber, the breakdown of radioactive isotopes slows, and will eventually cease were the rod left in the chamber. This fission is extremely exothermic and can be used to heat water for steam generation. The steam can then be piped to power a steam turbine that produces electricity. From this point on, a nuclear reactor resembles an oil, coal, or natural gas power plant. (8)

This form of power is quite remarkable, in that we can generate an enormous amount of energy from a very small amount of material. The splitting of a U235 atom releases approximately two hundred million electron-volts of energy. This is to say that a one pound sphere of U235 contains the same amount of energy as one million gallons of gasoline. (8)

There are few air quality issues or pollutants produced in this process. There is however, an enormous amount of heat generated and what little waste there is can be extremely toxic. The Nuclear Regulatory Commission (NRC) has categorized all radioactive waste into two groups; high-level and low level. High-level radioactive waste results primarily from the fuel used by reactors to produce electricity. Low-level radioactive waste is generally produced from reactor operations and from medical, academic, industrial, and other commercial uses (10). The half-lives of the most common radioactive byproducts, cesium-137 and strontium-90, are about thirty years. A rarer, but more persistent waste element is plutonium-239, which has a half-life of 24,000 years.

Ten years after deactivation the radiation emitted from spent reactor fuel is approximately 10,000 rems/hour. A typical lethal dose of radiation is 500 rems. Hence, about three minutes of direct exposure to spent fuel would kill the average person. However, a potentially more dangerous situation would be radiation leaking into ground water supplies and radiating large populations of people. Over time, this indirect exposure can lead to mutations, cancers, and birth defects (11). This may sound horrible, but it may need a bit of perspective.

The earth's crust contains about 1 part per million of uranium and 3.5 parts per million thorium, both radioactive elements (12). Assuming a 4 miles thick crust, and an average density of 2.5g/cm3 (density of the crust's most abundant material: SiO_2), and an area of 18"x18", you are sitting on approximately 369 pounds of radioactive material. Organisms on the Earths surface are protected from this radiation by the crust itself.
The United States produces about 2000 metric tons of spent nuclear fuel per year (13). Currently, the United States is preparing a nuclear waste depository at Yucca Mountain in Nevada. Studies of this site have been ongoing since 1978. The objective of the project is to create a single place to store all of the United State's spent nuclear fuels. Currently, the spent fuel is spread out in 131 places throughout the United States.

About 21% of the United States' electricity comes from nuclear sources, which is low compared to many other developed countries (Appendix A, Table 7). However, the U.S. has very efficient nuclear facilities in comparison to other countries based on heavy metal waste generated per unit of electricity produced. (Appendix A, Table 8)

A quick comparison

According to the DOE in 1999, 50.6% of our electricity comes from coal powered plants. The total amount of coal burned to generate this amount of electricity was 796,733,000 metric tons (6). A simplified calculation that involves the empirical formula $C+O_2=CO_2$ and the molecular weights of each component shows that about 2.9 billion tons of CO_2 is generated from this source of energy per year. Also, according to the United States Geological Survey, the same amount of radioactive materials is contained in coal as in bedrock (5). When burned, this radioactive material is released into the surrounding atmosphere. Using the previous concentrations of naturally occurring radioactive materials, this means that about 3500 tons of radioactive heavy metals are released per year through the combustion of coal alone. These numbers do not reflect the amounts given off by oil or natural gas plants. Each of these other sources contains similar amounts of the radioactive material.

An obvious question to ask might be; "Which do we prefer, 3500 tons of radioactive waste in the atmosphere along with 2.9 billion tons of CO_2 emitted (not to mention the sulfur containing compounds and other harmful agents), or the equivalent nuclear generation by-product of 6325 tons solid radioactive waste that can be deeply buried in shielded containers inside the earth? This particular scenario is at hand, in the previously mentioned Yucca Mountain Project.

The cost of the Yucca mountain project is approximately 57.6 billion dollars, has been approved, and is currently underway. The excavated shaft within the mountain would have a useable area of 1,200 acres and would hold up to 150,000 metric tons. With this capacity, the repository would be approximately 1/3 full after all of the United

States' 52,000 metric tons of current nuclear waste is deposited. The large capacity of Yucca depository would allow scientists to delay the need for another such facility for at least 50 years under current waste production rates. (6)

Renewable sources

In comparison to fossil fuels, only a small fraction of our nation's electricity comes from renewable sources. The majority of which is essentially old technology, and having mostly to do with hydroelectricity. This is all changing, however, as industrialized nations are looking for ways to become less dependent on other countries for energy. The Netherlands, Germany, Spain, and Ireland are just a few of the European nations that have advanced renewable energy programs. The percentage of electricity production from renewable sources by the top 25 countries can be seen in Appendix A, Table 5.

Hydroelectricity

The largest portion of renewable power in the United States is that of hydro-electricity. The technology has been available since the early 1800's, and was first utilized in the United States in 1880. Shortly thereafter, the first hydroelectric plant was made near the same location. Until that time only coal was used for electricity production. Currently, 7% of the nation's electricity is produced through the power of water. The electricity generation works on the same turbine principle as most other generation methods, except that instead of combustion or heat driving steam, water pressure from a dam or from a river is used to directly spin the turbine. The largest hydro-electric plant in the United States is the Grand Coulee Dam, in Washington state, which generates about 27% of the hydro-electric power in the United States. Other dams, such as the Hoover dam are used throughout the country. The energy of falling water may also be used, as in the example of Niagara Falls in New York. The United States' facility on the falls has an output capacity of about 2.6MWh.

Hydroelectricity is one of the most environmentally sound choices when it comes to generating electricity. It produces no pollutants and requires little to no fuel or input, making the electricity essentially "free" after the facility is built. The only costs after the initial plant is constructed, is simply maintaining the plant. The reservoirs of such systems however, are usually made by flooding large areas of land. Lakes as long as 110 miles have been created by damming. This flooding can devastate the populations of local wildlife, and completely alter the ecosystem. Often, the reservoirs are used for recreation, drinking water, and sometimes even tourism. The world wide percentages for hydro-power can be seen in Table 6 of Appendix A.

Solar

The power of the sun is all around us. Most scientists would probably agree that life would not exist without it. It emits various types of radiation that in turn can heat the earth and its atmosphere, generating wind, which in turn can generate waves. Mankind has developed methods to harness the energy in all of these forms and convert them to electricity.

Photoelectric Cells

An energy collection method that has been widely used for decades now is the photoelectric, or solar, cell. Photoelectric, or photovoltaic, cells work on the basis of capturing certain bandwidths of energy emitted by the sun. The device is constructed two silicon layers, each imbedded, or doped, with impurities so as to either have an excess of electrons or a lack of them. Placed next to each other, the layers will allow electrons to flow freely from one side, but not pass back to the original side. This is the basic principle of a diode. If a path from one side to the other is made of a conductive material, a current can be generated.

Efficiencies for this technology have reached about 15%, meaning 15% of the energy being put in is converted to electricity. However, the cost of solar cells is fairly high compared to the price of utilities, and therefore there exists little demand. Without this demand there is not much hope of developing solar cells to their full potential. Another somewhat often overlooked issue with photovoltaic cells is that large amounts of harmful pollutants are generated in the production of the cells. Cesium, cadmium and arsenic and many other toxic substances are generated when making a photovoltaic cell. Of course, this is a one-time pollutant, and the benefits of having clean power might be considered greater than the downfalls of production byproducts.

The use of solar cells is consequently currently limited to such applications as mobile road signs, very small electronic devices, and NASA projects.

Wind

Wind is the fastest growing renewable energy source, with an annual growth rate exceeding 20% each year over the last five years. In 2003, 6,374 megawatts of electricity were produced in the United States. This is enough electricity to power about 1.6 million average American homes. This ranks as the second highest total wind power capacity in the world, behind Germany. The U.S. Department of Energy has set a goal to increase the wind generated electricity to 5% of the total electricity production by 2020. At the current growth rate of the wind industry, this goal will be just exceeded, to 6%.

The first off-shore wind farm in the United States is currently being planned and has gotten the approval of the Army Corps of Engineers. The farm, dubbed "Cape Wind" will be off the coast of Massachusetts, and provide about 420 megawatts of clean electricity to the residents of the area.

Wave and Tidal

Wave power is a relative newcomer to the energy conversion arena. There are many designs currently under development, in many different countries. This conversion process can be accomplished by many methods. There is considerable interest in making one of them economically feasible. In June of 2004, an assessment was done of all of the currently available devices and projections and calculations done for a pilot plant of several capacities for each device. The assessment was carried out for a collaborative of government, industry, public and private interests. Of the eight available devices, only one met all of the testing and cost criteria for consideration for a pilot plant. Three others were close, but had several issues that needed to be resolved or tested. The remaining four are still in the research and development stages. For the most part, the technology has been proven to work for each design, refining the mechanisms to make them cost-effective is the main obstacle that needs to be overcome. This shows that much more research needs to be done in this field, as the potential electricity generation from wave power is tremendous.

Of the projects that are underway, the expected efficiencies, power generation and cost of each type of unit appear in Appendix C.

Recent Policy

In May 2001, The National Energy Policy Development Group (NEPDG), headed by Vice President Dick Cheney, proposed a set of recommendations to President Bush regarding national energy policy. The NEPDG report outlines the steps that the United States should take to meet the ever increasing demand for energy. The report clearly states that the goal of the national energy policy is to "help bring together business, government, local communities, and citizens to promote dependable, affordable, and environmentally sound energy for the future." The report focuses on five main points; protecting the environment, increasing domestic supplies, improving infrastructure, strengthening global alliances, and conserving energy. Since the report was issued before the September 11 attack on the World Trade Center, and before the US led war in Iraq, some of the recommendations may no longer be feasible, or may have been de-prioritized to in order to address more immediate concerns. The following sections address these recommendations in the context of the future energy needs of the United States.

Protecting the Environment

As described previously, the processes that are used to turn raw materials into energy inherently produce harmful byproducts, which threaten the existence of humans and wildlife alike. One of the primary considerations in the NEPDG report is the effect of achieving energy policy goals while doing so in an environmentally sound way.

In order to reduce environmental damage, the group proposes a multi-pollutant legislation which focuses on *market incentives for power plants*. The key pollutants that are mentioned are Sulfur Dioxide, Nitrogen Oxides, and Mercury. In the report, the group recommends establishing reduction targets for emissions of these three chemicals. The report however does not mention establishing reduction targets for the fourth major pollutant emitted from fossil fuel burning power plants, CO_2, which accounts for 40% of the total US CO_2 output. The amount of CO_2 emitted yearly from US (pop. 290 million) power plants (4.0 billion tons) is higher than the *total* amount emitted yearly (2.5 billion tons) by Germany (pop. 82.4 million), Italy(pop. 58 million), and India (pop. 1.05 billion) *combined*.

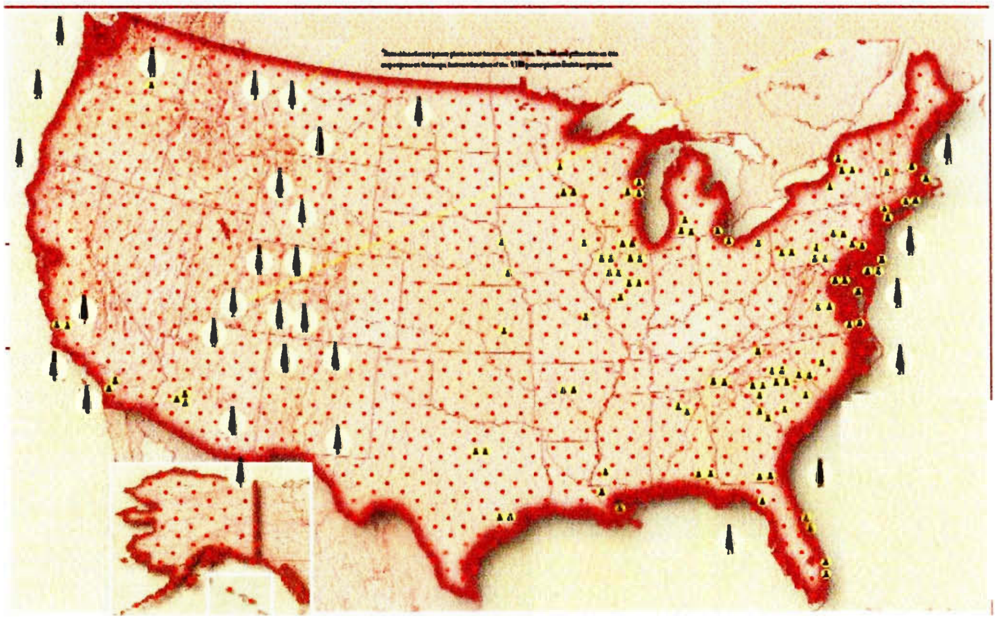
The NEPDG uses the so-called greenhouse gas intensity, which is the amount of greenhouse gas emission per dollar of gross domestic product, as a measure of efficiency. The idea behind this measure is that if the nation experiences economic growth, obviously more energy will be used in the process and hence more greenhouse gasses will be emitted. The problem with this measure is that the global environment does not benefit from a higher GDP. Greenhouse emissions must be measured on an absolute scale in order for it to achieve environmental goals and not just economic goals.

According to the NEPDG, market incentives are the best way to promote lowering emissions of harmful pollutants. The group recommends the use of tradable discharge permits (TDP) as a method of encouraging polluters to reduce their emissions. The idea behind TDP is that if a company emits less than a predetermined amount of pollutants, the company can trade discharge credits to other companies. Although this method will make the first company reduce its emissions, it simply displaces those emissions to the other company. This method does not decrease the total amount of emissions, but instead it effectively fixes the total amount of emissions from all power plants allowing credit to flow from company to company. TDP's provide flexibility for times when companies need to generate power but they have exceeded their emission cap. In such a case, the options are to generate more power and exceed the limit for emissions or to not generate power (not really an option). The TDP system introduces a way out of this predicament, but it is still a "quick fix," in the context of a comprehensive energy policy. Although TDP have in practice successfully reduced harmful emissions, they are certainly not a long term substitution for careful regulation and grid flexibility.

Increasing Domestic Supply

The NEPDG report estimates that, over the next 15-20 years, the United States will need to increase its electricity generation by 393,000 MW, which means building 1,300 to 1,900 new power plants. The report indicates that the most viable solution is to build power plants which employ the latest technology to increase efficiency while reducing emissions. Specifically, due to the abundant reserves of coal in the United States, the report emphasizes the use of new high efficiency coal power plants. The map of the United States below shows 1,300 power plant locations (red dots) distributed uniformly across the country. The wells on the map below indicate new oil drilling sites, and the small yellow dots represent new natural gas drilling sites, each as proposed under the NEPDG report.

Figure 6:



(http://www.sierraclub.org/wildlands/energymap/energymap.pdf, 2001)

Reliance on Coal and Fossil Fuels

Clean Coal Technology refers to technology which allows coal to be used for producing electricity while reducing emissions of key pollutants. The most prominent example of clean coal technology is gasification, in which coal is turned into a gas which is burned to produce electricity. Power plants that use the gasification process can produce electricity approximately 20 % more efficiently than traditional coal fired power plants. Although 20 % seems like a significant increase in efficiency, this figure is offset by the sheer number of coal power plants. In addition, these plants are still much dirtier than alternatives such as gas fired power plants. The gasification plant at Polk Station, Fort Lonesome, Florida, which at the time of construction was "the world's most advanced coal combustion power plant" emits seven times more smog-forming gasses than a similarly sized gas-fired plant.

Expanded Drilling Operations:

As of the year 2000, 52 % of the oil that is used in the US comes from overseas suppliers. The NEPDG plan aims to decrease the US dependence on foreign oil by increasing the drilling capacity of the nation. In order to do this, the nation also must increase refining capacity. According to the report, at peak consumption, the nation's oil refineries must operate at close to full capacity.

The NEPDG recommends leasing new drilling sites in the Arctic National Wildlife Refuge (ANWR), which lies on the north shore of Alaska. This area is already home to a number of drilling operations. According to the National Geological Survey, the economically recoverable amount of crude oil underneath the undeveloped part of the refuge is estimated to be between 7 and 16 billion barrels with an average estimate of about 10 billion barrels. Although more oil may be accessible, a drilling company must be able to recover it such that the cost of recovery will not surpass the current market price. Since the ANWR is an environment rich with wildlife, the idea of leasing more land to oil companies faced much opposition.

Opponents of the proposed legislation argue that the recoverable oil amounts to only a 6 month supply at the current rate of US consumption. In addition, the oil would not be available for 15 to 20 years, during which time consumption will have increased, therefore making the recoverable amount even less significant. The reason that oil companies would prefer to drill at the present time is because they can make more money later for oil that is claimed now. According to the US Geological Survey, opening the land to new drilling operations would possibly disturb the mating habits of Caribou in the region, which often flock to the coastal area to give birth to their young. In addition, the migratory patterns of over 160 species of birds could be disrupted. (14)

Proponents of drilling in the ANWR argue that environmentalists are the cause of high prices at the gas pump, and opening the refuge to oil companies will alleviate some of the burden of dependence on foreign oil. In addition, they claim that the only way to know the actual amount of recoverable oil is to begin exploratory drilling operations. The NEPDG report indicates that advancements in drilling technology allow the oil to be harvested without adversely affecting the wildlife. According to the NEPDG, the drilling platforms of today take up only 20 % of the space that older platforms take, therefore maintaining a small footprint. In addition, older rigs could only drill straight down, but recent advances in drilling technology allow horizontal drilling which could provide access to the reserves underneath sensitive areas.

This ideology does not account for the inevitable spillage, or the roads that must be constructed throughout the region. Also, even if drilling rigs take up 20 % of the space that they used to, wildlife will be affected in the same way, unless animals can somehow use the extra space directly adjacent to a drilling rig. Smaller footprint simply means that more rigs can be placed in a smaller area, which means that the oil can be harvested at a faster rate.

Recently, the US Department of Interior gave the final approval for two companies to begin development of the north eastern corner of the reserve. The two companies, Conoco-Phillips and Anadarko Petroleum are slated to develop five access routes to the area, for exploratory operations. The company's plans were rejected during the Clinton administration, but with recent alterations in the political environment they were able to move forward. The companies claim that the alterations were in the interest of protecting the wildlife population in the area.

Oil Lobby

A major factor in decisions regarding drilling and various other aspects of the oil industry is the oil lobby. In the United States, it is perfectly legal for companies to fund politicians so that the companies' goals, wants, and needs are fulfilled. This is no more apparent than in the case of drilling in the ANWR, but this trend of "dirty money making dirty policy" is not only limited to this instance. It permeates the entire government.

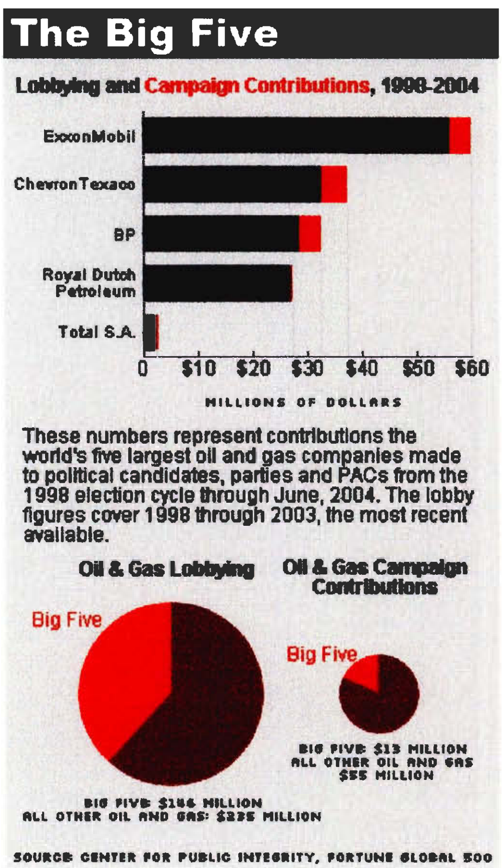
The U.S. Public Interest Research Group, a non-profit, Washington D.C.-based government and corporate watchdog, found that those who voted for ANWR drilling received almost six times more money in contributions from the four major oil companies, on average, than House members who supported ANWR's protection. The four oil companies lobbying to drill in ANWR are BP Amoco (ticker: BP), Chevron (CHV), Exxon-Mobil (XOM) and Phillips Petroleum (P). In total, BP Amoco, Chevron, Exxon-Mobil and Phillips Petroleum gave $752,038 to House members during the 1999-2000 election cycle. More than 86 percent of this money, $647,038, went to members who voted to drill in ANWR. Members of the Senate were also under the oil companies spell, accepting $242,950 from these corporations during the same time period.

Alison Cassady of U.S. PIRG has estimated that spread out over ten years, the House energy bills give $27 billion in tax breaks and $11 billion in subsidies to polluting industries. That is a total of $38 billion – not a bad return on an $18.4 million investment by oil, electric, automotive, and mining industries.

According to the Center for Public Integrity (CPI), the oil industry has lavished more than $440 million over the past six years on politicians, political parties and lobbyists. This breaks down to about $381 million in lobbying, and about $67 million in campaign contributions. The world's largest oil company and third largest company of any kind, Exxon-Mobil, was the industry's leader in lobbying expenditures, spending $55 million to plead its case with official Washington over the past six years. Other big spenders included Chevron-Texaco ($32 million), Marathon Oil ($29 million), British oil giant BP ($28 million), and British/Dutch behemoth Royal Dutch/Shell Group ($27 million). Other noteworthy entries on the list include the top industry group, the American Petroleum Institute ($20 million), and Occidental Petroleum ($12 million). Some more notorious names on the list include scandal-plagued Enron Corporation ($16 million), and Vice President Dick Cheney's former employer, Halliburton Corp. ($3 million), which is currently the subject of government investigations over its contract work in Iraq and alleged bribes paid in connection with a natural gas project in Nigeria.

The largest single recipient of this "dirty money" was former Texas oilman George W. Bush. The president has received $1.7 million in campaign cash from the oil and gas industry. Of all the contributions, over 73% of the monies were given to republicans. Money is not the only form of power, and the oil industry uses its influence in other ways, such as appointing members of the National Petroleum Council, a board that advises the energy secretary on policy and tax changes. In addition, U.S.-based oil and gas companies have nearly 900 subsidiaries located in tax haven countries, such as the Cayman Islands and Bermuda. This exempts them from paying billions in taxes.

Figures 7 and 8:



(Source: Center for Public Integrity, http://www.publicintegrity.org/oil/printer-friendly.aspx?aid=345 , 2004)

Nuclear Power

Another way to increase the US energy supply is by expanded use of nuclear power. Today, nuclear power plants provide roughly 20 % of the electricity in the United States. The NEPDG report estimates that usage of nuclear plants will decline over the next fifteen to twenty years. This is mainly due to the fact that as many nuclear plants are decommissioned, new plants may not be built to replace them. The reason for this lack of activity is due to the high price of constructing a nuclear plant, as well as the inherent safety concerns that go along with nuclear power. Most nuclear power plants cannot afford to independently provide the necessary amount of insurance in the case of a nuclear disaster. In all cases, the government subsidizes the cost of insurance through the Price-Anderson act and implements liability caps in the case of a nuclear disaster. The Price-Anderson act was first passed through congress in 1957 (15), and was renewed in 1988. The problem with the Price-Anderson legislation is that some amount of accountability is removed from the nuclear industry. If the government is allowed to subsidize insurance for a nuclear power facility, the administration of the facility has less incentive to provide necessary maintenance. This also means that the funding for the Price-Anderson act is provided by American taxpayers. In addition, the Price-Anderson act considers all nuclear reactors on the same level, although newer nuclear reactors are much less prone to disaster. In 1982, Sandia National Labs leaked an assessment tabulating the estimated cost of nuclear disaster. Private insurance under the Price Anderson Act covers less than 2% of the cost ($313 billion at that time).

As mentioned previously, the amount of nuclear waste generated by nuclear power plants has been a topic of controversy. As compared to the amount of power generated by such a plant, the amount of nuclear waste is manageable, especially considering that the emissions from a typical coal fired plant contain about half as much radioactive material per amount of energy generated as those of a nuclear plant. In addition, the nuclear plant does not emit any the other pollutants associated with coal fired power plants. The only remaining problems with storing radioactive material are the risk of a terrorist attack on the storage site, theft of the radioactive material, and processing of radioactive material.

Improving Infrastructure

One of the most important aspects of preparing for the increased energy demand that the United States is facing in the next few decades is upgrading out-of-date infrastructure. In addition to improving transmission reliability, modernizing the national power grid would make it easier to integrate renewable energy into the system. The largest problem with current renewable energy technology is that it relies on nature to produce the power, which tends to lack the reliability of generation methods. If the power grid were made to be more flexible, the capacity for dealing with loss-of-load due to renewable energy could be dealt with in a more efficient way.

One class of technology, called Flexible AC Transmission systems (FACTS), focus on optimizing control of the power grid. These technologies include smart switching devices and load sharing devices which allow the flexibility to reduce load loss and increase efficiency, potentially preventing large problems.

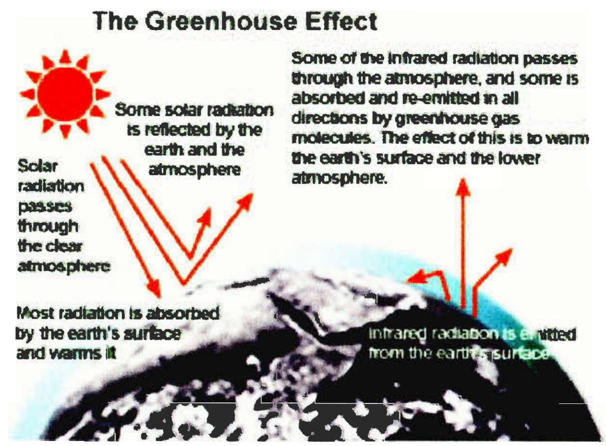
Conserving Energy

Another conservation step recommended by the NEPDG is increasing the Energy Star labeling program to include industrial and governmental sectors. The Energy Star program is a system which rates similar devices, like refrigerators, according to their efficiency. The idea behind such a system is that most consumers do not comprehend the meaning of the typical units used for measuring power consumption of household devices. The Energy Star labeling system places all similar appliances on a level playing field so that the consumer can make a direct comparison between two appliances and their relative efficiencies. According to the NRDC, up to 60% of the increase in demand could be met with efficiency measures, thereby eliminating the need for approximately 610 of the coal power plants proposed by the Bush plan. It is clear that the Bush administration does not consider conservation as a key factor in the quest for environmentally safe and affordable energy. Vice President Dick Cheney said during a press conference that "Conservation may be a sign of personal virtue, but it is not a sufficient basis for sound, comprehensive energy policy" (17)

Global Warming

Global warming is no longer considered to be a natural occurrence, at least according to the EPA, Scientific American, Science, and National Geographic (18). A Since the industrial revolution, the concentration of greenhouse gases has risen sharply. Carbon dioxide, the principle pollutant from combustion processes, is considered to be the largest contributor to the greenhouse effect. The greenhouse effect occurs when an increase in concentration of gases that have a higher capacity for heat than normal air is in the atmosphere. These gases trap energy both from the sun directly, and from radiant heat reflected by earth.

Figure 9:



(Source: EPA, http://yosemite.epa.gov/oar/globalwarming.nsf/content/climate.html, 2000)

As previously mentioned, the United States produces about 5.76 Trillion tons of CO_2 annually. For a world-wide comparison, below is a table that shows the CO_2 production of the top twenty emitters.

Figure 10:

Total Carbon Dioxide Emissions

	Country	Description (1000 metric tons)	Amount
1	United States	5,762,054.00	
2	China	3,473,597.30	
3	Russia	1,540,365.00	
4	Japan	1,224,737.40	
5	India	1,007,978.90	
6	Germany	837,424.80	
7	United Kingdom	558,225.10	
8	Canada	521,404.40	
9	Italy	446,596.50	
10	Mexico	385,075.00	
11	France	363,484.20	
12	Ukraine	348,356.60	
13	South Africa	344,590.40	
14	Australia	332,377.20	
15	Brazil	327,857.70	
16	Spain	304,882.50	

17	Poland		303,777.50	
18	Indonesia		286,027.20	
19	Saudi Arabia		266,083.00	
20	Turkey		223,861.60	
	Total	18.86 million		
	Weighted Average	2 million		

Source: World Resources Institute. 2003. Carbon Emissions from energy use and cement manufacturing, 1850 to 2000. Available on-line through the Climate Analysis Indicators Tool (CAIT) at Washington, DC: World Resources Institute.

The first chart shows the United States well in the lead in total CO_2 emissions. However, if you consider the populations of the countries in question, the discrepancy is not as dramatic.

Figure 11:

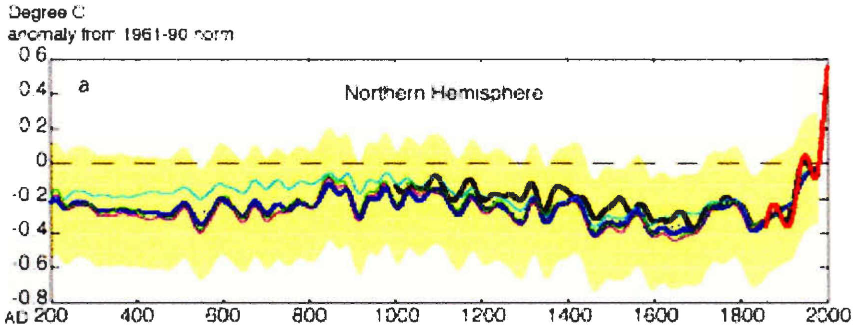
Total Carbon Dioxide Emissions per Capita

	Country	Description (1000 metric tons)	Amount
1	Qatar	42.96 per 1000 people	
2	United Arab Emirates	29.10 per 1000 people	
3	Kuwait	26.80 per 1000 people	
4	Bahrain	20.65 per 1000 people	
5	United States	19.84 per 1000 people	
6	Luxembourg	18.54 per 1000 people	
7	Australia	16.84 per 1000 people	
8	Trinidad and Tobago	16.38 per 1000 people	
9	Canada	16.18 per 1000 people	
10	Singapore	13.26 per 1000 people	
11	Palau	12.26 per 1000 people	
12	Belgium	12.15 per 1000 people	
13	Czech Republic	12.10 per 1000 people	
14	Saudi Arabia	10.95 per 1000 people	
15	Ireland	10.91 per 1000 people	
16	Finland	10.90 per 1000 people	
17	Netherlands	10.82 per 1000 people	
18	Nauru	10.78 per 1000 people	
19	Russia	10.65 per 1000 people	
20	Estonia	10.56 per 1000 people	
	Weighted Average	16.17 per 1000 people	

Source: World Resources Institute. 2003. Carbon Emissions from energy use and cement manufacturing, 1850 to 2000. Available on-line through the Climate Analysis Indicators Tool (CAIT) at Washington, DC: World Resources Institute.

The fact that our planet is getting hotter is a proven scientific fact. As shown in a recent article from *Geophysics* (Mann & Jones, Geophys. Research Letters, 2003) there has been a sharp increase in temperature since the industrial revolution, as compared to the past 1800 years.

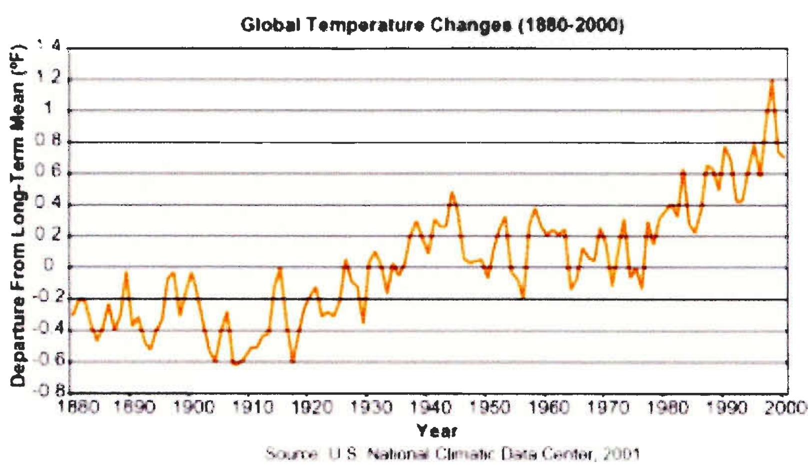
Figure 12:



Temperatures AD 200-2000, from proxy temperature indicators and direct measurement (red) showing rise from from long-term cooling trend. Mann & Jones, Geophys. Research Letters, 2003.

According to the EPA, the concentration of CO_2 in the atmosphere has increased 30% since the industrial revolution. Methane and Nitrous Oxides have also increased dramatically, methane more than doubling and NOs up 15%.

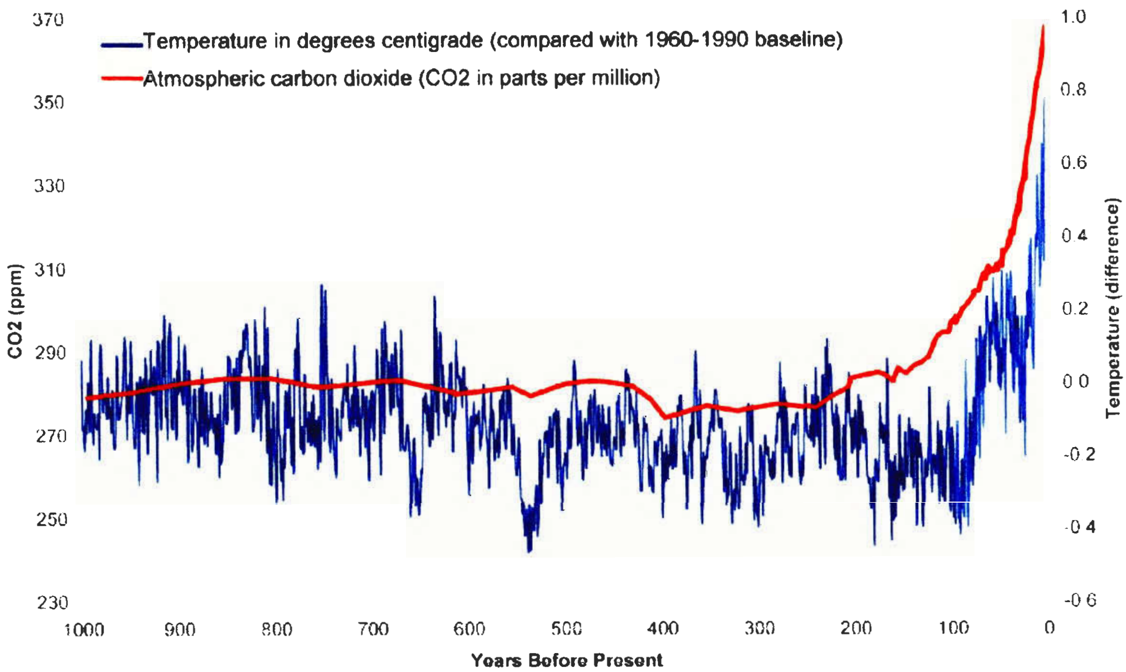
Figure 13:



(Source: EPA, http://yosemite.epa.gov/oar/globalwarming.nsf/content/climate.html, 2000)

Further analysis of these readings; overlaying the concentrations of CO_2 measured in the atmosphere at Mauna Loa, Hawaii during the period of sharp increase shows a disturbing trend.

Figure 14:



(Source: http://www.brighton73.freeserve.co.uk/gw/paleo/millenniumCO2.htm, 2003)

The repercussions of the temperature increase in the figure above are apparent on every continent, and with the accelerating temperatures, it is only going to get worse.

An excerpt from the EPA's website:

"Global mean surface temperatures have increased 0.5-1.0°F since the late 19th century. The 20th century's 10 warmest years all occurred in the last 15 years of the century. Of these, 1998 was the warmest year on record. The snow cover in the Northern Hemisphere and floating ice in the Arctic Ocean have decreased. Globally, sea level has risen 4-8 inches over the past century. Worldwide precipitation over land has increased by about one percent. The frequency of extreme rainfall events has increased throughout much of the United States. Increasing concentrations of greenhouse gases are likely to accelerate the rate of climate change. Scientists expect that the average global surface temperature could rise 1-4.5°F (0.6-2.5°C) in the next fifty years, and 2.2-10°F (1.4-5.8°C) in the next century, with significant regional variation. Evaporation will increase as the climate warms, which will increase average global precipitation. Soil moisture is likely to decline in many regions, and intense rainstorms are likely to become more frequent. Sea level is likely to rise two feet along most of the U.S. coast."

These impacts are already becoming very apparent for some people in the world, as the rise in sea level has affected thousands of island-dwellers. The effects can be seen from the polar regions of earth to the greatest of forests and deserts. Entire books have been written on these effects in every type of environment, and thus the scope of the problem is outside of this paper. It should suffice to say that the delicate balance of the world's ecosystem has already been tipped heavily to one side, with no signs of a possible reversal in this trend.

Despite the overwhelming evidence, and the extremely serious predicament our planet is in, the current administration has refused to acknowledge the potential deadly impacts of these trends. In June of 2004, the President of the United States, George W. Bush, dismissed the EPA's most recent report that human activities have caused the warming trend. In October of 2004, NASA scientist James Hansen stated that not only was the president ignoring the evidence, but that "In my more than three decades in government, I have never seen anything approaching the degree to which information flow from scientists to the public has been screened and controlled as it is now," adding "This, I believe, is a recipe for environmental disaster." Hansen is director of the NASA Goddard Institute for Space Studies in New York and has twice briefed a task force headed by Vice President Dick Cheney on global warming.

Hundreds of politicians, both from the United States and from various other countries have pleaded with the administration to do something about global warming, but the effects of the pleading have amounted to nothing more than a generic speech from the president, available at the White House website.

Bush, in his speech talks about the report from the "Respected National Academy of Sciences", a government assigned panel of 11 scientists. Their "report" was 24 pages long and took less than a month to complete. A scientist who reviewed the draft for the New York Times said that the quick response of the presidential query should not come as a surprise, because the questions asked by the administration were obsolete and "might have been relevant in 1990."

In concluding his review, the anonymous scientist asked "Where have you been the last decade?" (16)

The ambivalence of the current administration is an issue that has come up recently in light of the Kyoto Protocol treaty. The treaty is the first of its kind, calling on all developed nations to regulate CO_2 emissions. Essentially, the United States' refusal to sign the treaty makes the efforts of other countries negligible, and dooms the treaty for failure. However, despite harsh criticism from the environmental community, Bush's reasoning for not signing the treaty actually makes some sense. The Kyoto protocol is flawed in several ways. For one, the treaty fails to include China, which in the next 9-10 years is predicted to surpass the United States in CO_2 emissions from power plants. In addition, China is expected to surpass the United States' in total CO_2 contributions by 2050. The regulations provide China and other countries, the ability to expand their economies at a much higher rate than the countries listed in the protocol. Another issue with the treaty is that the numbers and dates proposed were chosen without data to legitimatize the regulations. The protocol calls for all signed countries to reduce their emissions to below 1990's levels. This gives European nations a huge economic advantage, for several reasons; First, the recent discovery of Natural Gas in the North Sea has led to the dismantling of the coal industry in the U.K., Second, the reunification of Germany has led to a mass deconstruction of old dirty power plants, and reduced their CO_2 emissions significantly. These factors alone would not be sufficient to give an economic advantage, but the protocol allows credit to be transferred from country to country within the European Union, which give EU countries the ability to pass off pollution credit to other EU counties. In effect, little would have to be done to comply with the Kyoto Protocol in Europe. The United States does not have this trading ability, and would be held to comply with the regulations on its own. This would be extremely detrimental to the economy in the U.S., according to several Harvard economists.

One more aspect of the treaty which should get some attention is the timeframe within which the countries would need to comply. The protocol calls for all regulations to be met by 2008. The average lifespan of a power plant is 30 years, and the average automobile is about 12 years. Decommissioning or spending large quantities of money to update all of this current economically productive equipment in such a short time would again have severe consequences to the U.S. economy.

Lastly, the protocol will actually be essentially ineffective. With developing countries omitted, the real problem – CO_2 concentration in the atmosphere, is not even addressed (at least not directly, see below), and will still be on the increase over the timeframe of the protocol. The only measure that is taken to reduce atmospheric carbon dioxide is what is called carbon sequestration.

Carbon sequestration refers to the capturing of carbon dioxide through various means, either by directly capturing it and filling former oil cavities, or by planting large areas of forest. The planting of forests, however, may not be as effective as once thought, as much of the planting actually destroys natural ecosystems, namely, wetland regions, which are a major natural resource for natural carbon sequestration.

Survey

During the course of this project, it has become overwhelmingly apparent that there is indeed a necessity to start *The Transition* to renewable energy immediately. Unfortunately, this is easier said than done, and without significant popular demand, the current administration will not initiate this endeavor. To determine the level of awareness of renewable resources among the general population, and the demand for renewable energies within the population, a survey was conducted consisting of ten simple questions, and a website was created to host the survey. The survey is shown in Appendix D. This method, combined with handing surveys out in person allowed a much more diverse sampling. In total, there were about 75 respondents, of ages ranging from 18-50. A majority of these responses (about 60%) were received through an internet survey, which may indicate a higher-than-average income level.

In the following section, each question will be addressed, and the results given some attention and analysis.

Questions 1:

The questions in general were aimed at trying to poll a sample population and determine the knowledge of the number of different sources of energy and their relative usage.

Figure 15:

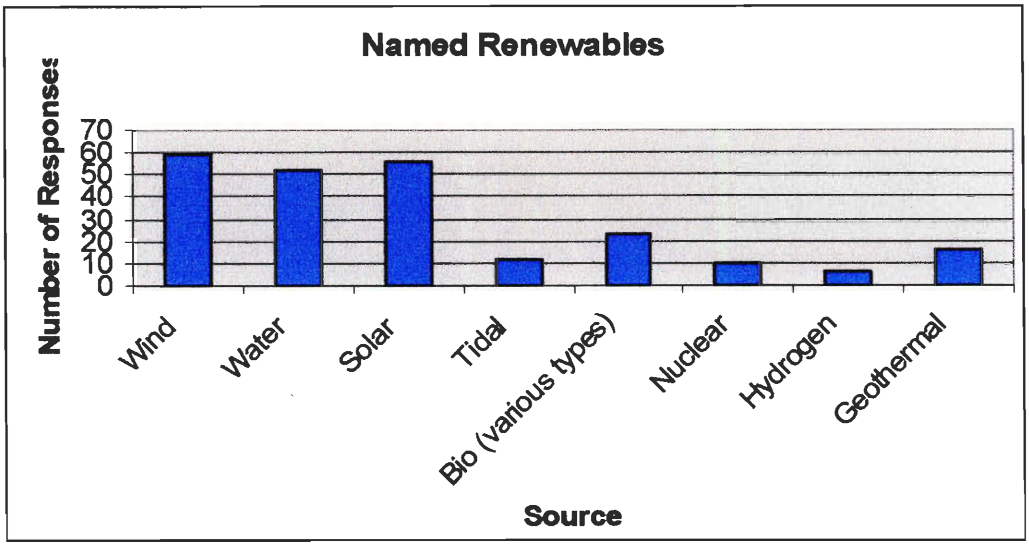
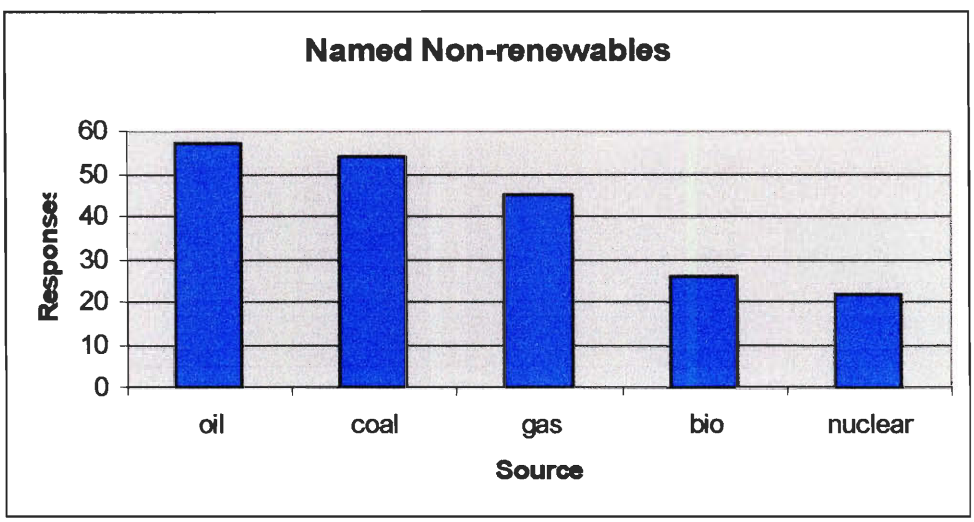
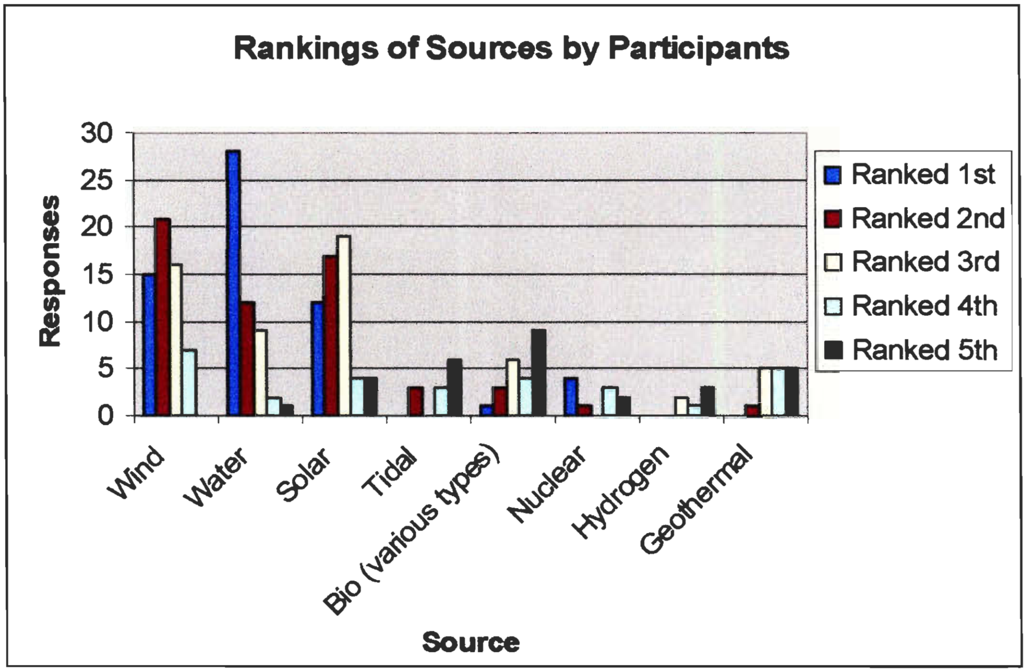


Figure 16:



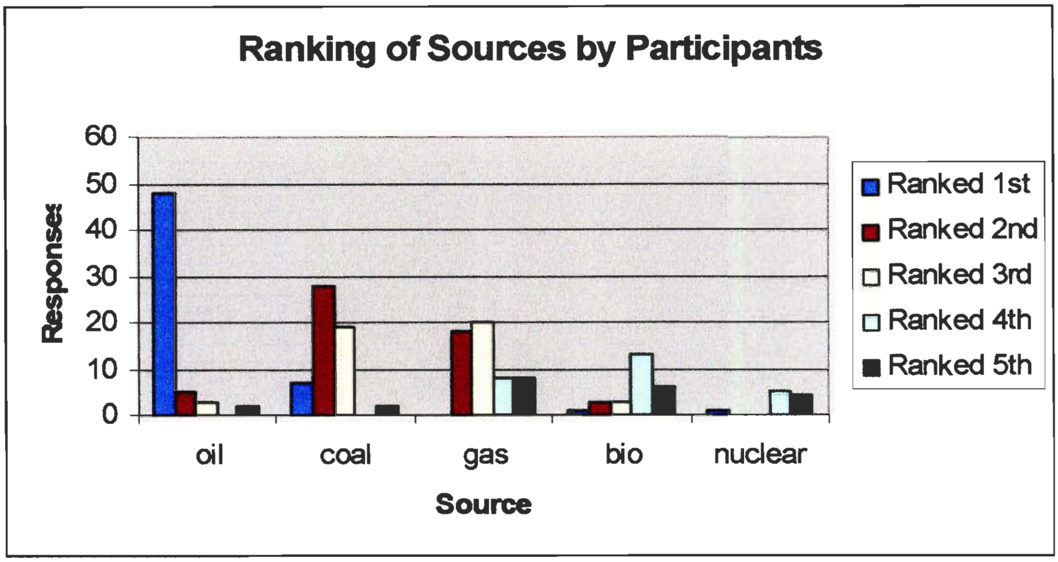
According to the results, the vast majority of the population is aware of the "Big Three", wind, water, and solar. Surprisingly, biological sources, such as ethanol, or vegetable oil came in as the fourth most known renewable energy source. Most of the respondents knew of the major non-renewable sources as well. The participants were also asked to rank them in the order in which they thought they were currently used the most.

Figure 17:



Rankings of Sources by Participants
Responses
30
25
20
15
10
5
0
Ranked 1st
Ranked 2nd
Ranked 3rd
Ranked 4th
Ranked 5th
Wind
Water
Solar
Tidal
Bio (various types)
Nuclear
Hydrogen
Geothermal
Source

Figure 18:

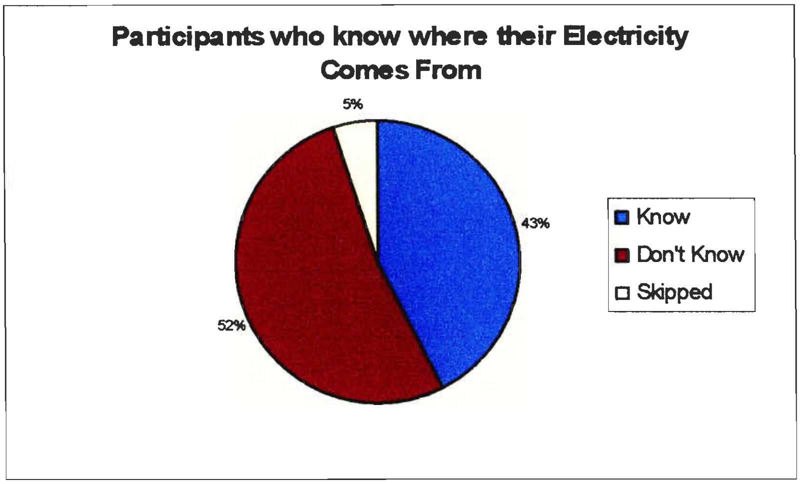


In Figures 17 and 18, the sample population shows that they are aware of the relative usage of these renewable sources, with the exception of nuclear power (which doesn't easily fall into either category), the responses were very close to the relative actual usage. This trend actually continues through non-renewable sources as well, indicating the public does actually know what is being used. However, as will be seen in the next question, the source of their electricity is barely known.

Question 2:

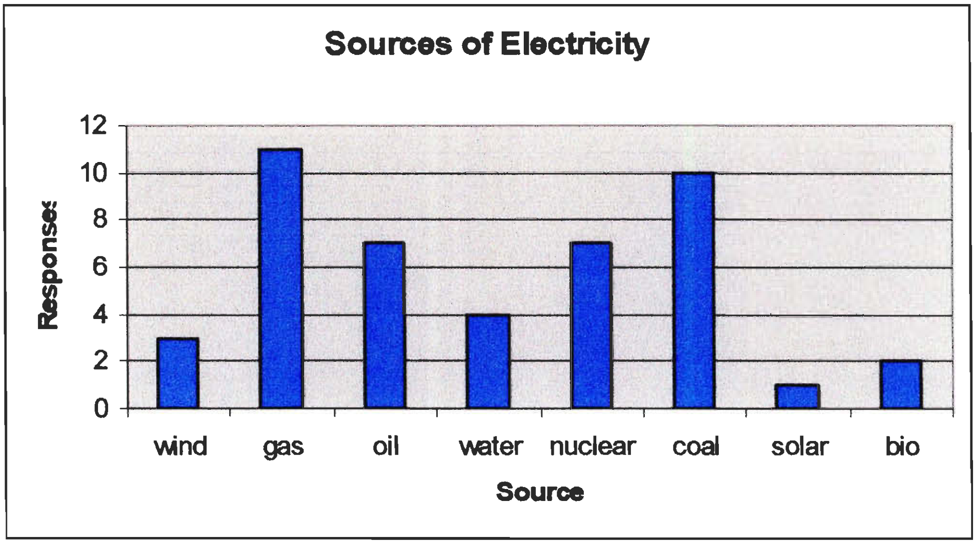
These questions were to find out if the participants knew where their own electricity comes from. If they answered "Yes", they were asked from which source they thought it was from.

Figure 19:



As can be seen in the above graph, less than half (42%), of the participants said they knew where their electricity comes from. This detachment from the relationship between energy sources and home electricity use may be a significant factor in the public's role in energy policy. Even of the people who said they knew, the majority of the responses were inaccurate, given the distribution of sources on the U.S. power grid.

Figure 20:

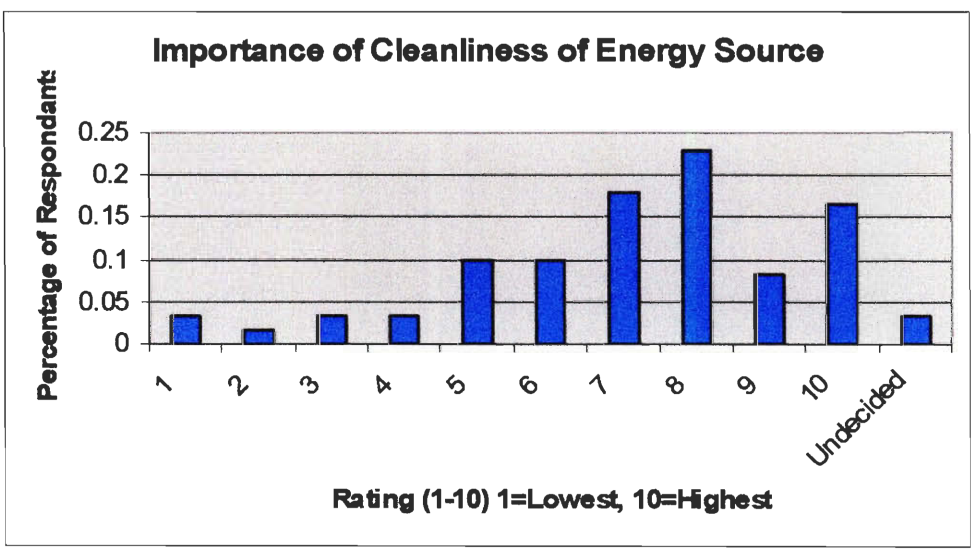


The result that the majority of people have no idea where their electricity comes from is a fairly disturbing thought. Education of the public is one of the easiest ways to instill energy saving mentality, and informed consumer decisions on purchases that will require electricity. Unfortunately, ignorance toward energy issues in general is the best way to maintain the status quo and prevent or at least delay significant change. Considering the fact that education is supposedly 1/3 of the "Three-pronged-attack" of the U.S. energy plan, it doesn't seem as though this part of the plan is being fulfilled, thereby making the plan partially ineffective.

Question 3:

To determine some how much the population cares about the cleanliness of their energy source, participants were asked to rank how important this is to them.

Figure 21:

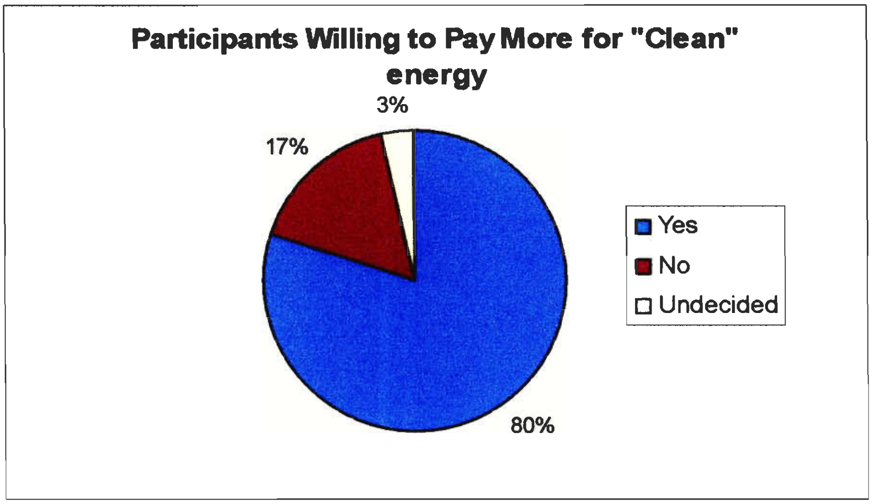


These results show that the average ranking was about 7.1, with 8 bringing in the highest percentage, with 23% of the total participants. About 70% of the respondents ranked importance of clean energy as a 7 or above, showing that this is obviously a concern among the participants. The skewed distribution in this regard can be seen in the chart above.

Question 4:

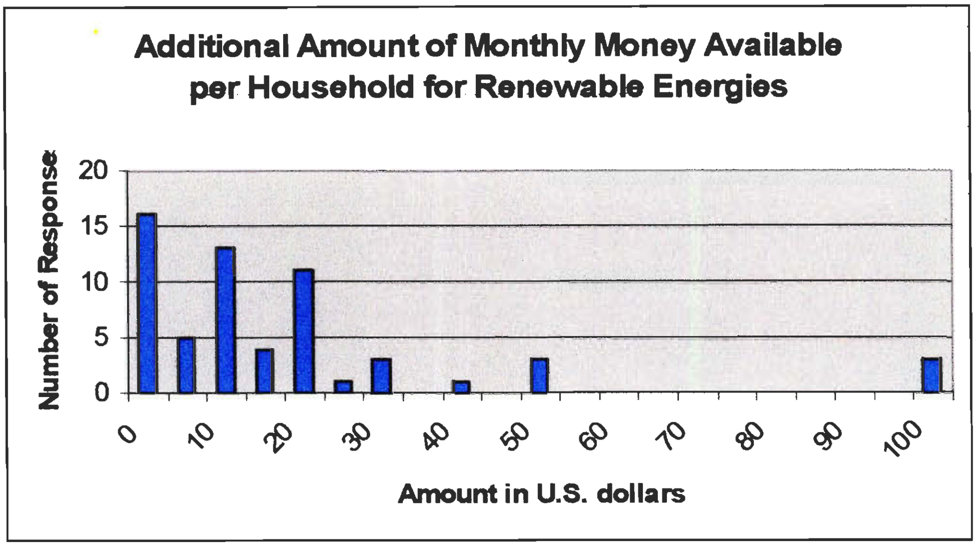
The next question was an attempt at determining just how much people were concerned, using cost as a more statistically relevant scale.

Figure 22:



The results from this question show an overwhelming willingness to pay more for cleaner energy. This should not come as a shock based on the results from the previous question. Interestingly, the 80% that responded "Yes" to this question corresponds to the total that ranked the previous question about 5 or higher. The large majority of the sample that said they would pay more for cleaner energy were then asked how much more they would be willing to pay. This data could be extrapolated to determine the economic feasibility of a particular energy source, although the scale will probably not be applicable to a nationwide survey of similar questions. The second part of this question was: How much more are you willing to pay for cleaner electricity?

Figure 23:

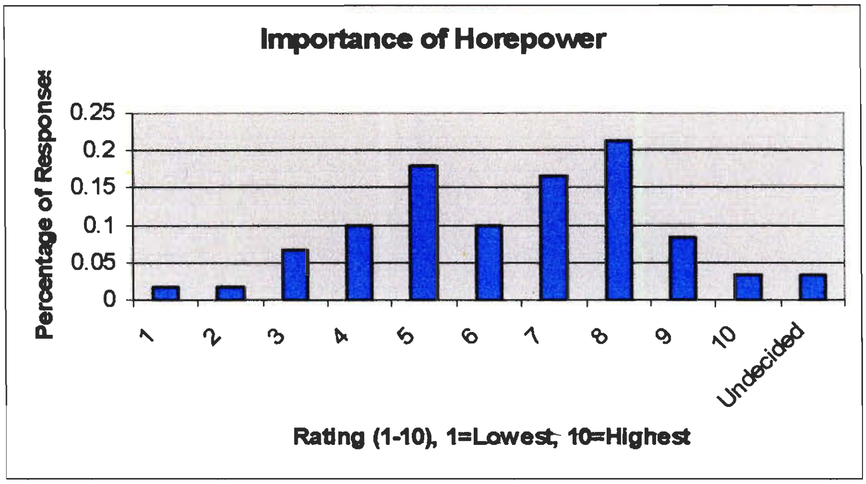


Of the participants that answered yes to the previous question the average amount they would be willing to pay was $17.33 per month. Some respondents answered in terms of a percentage. Taking the average household electric bill of about $100, (actual is $96) and applying the average percent increase they were willing to pay, the amount was in line with the respondents who specified a dollar amount. This amount, multiplied by the number of households in the United States (105.5 million, US Census, 2000) gives a total of $1.83 billion dollars in additional monies available for companies to compete for in the renewable energy market on a monthly basis or $21.9 billion annually. This is an astonishing statistic if it can be applied on a nationwide scale.

Question 5:

As previously mentioned, one of the largest contributors to pollution in the United States is the automobile. A not so significant increase in efficiency of internal combustion engines would yield an enormous savings in gasoline usage, based on the large distances driven by Americans. To determine how the population feels about two factors that are somewhat of a balancing act in the purchasing of a new automobile, we asked the following two questions: How important is horsepower? How important is gas mileage?

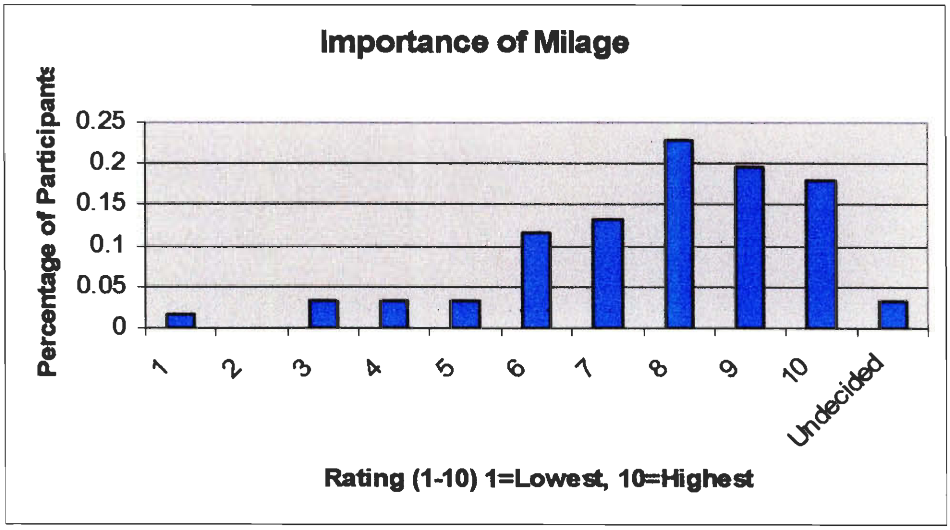
Figure 24:



The average rating of the importance of horsepower was 6.25. The distribution is much more even for this question, indicating that horsepower is certainly a factor, but not a largely significant one.

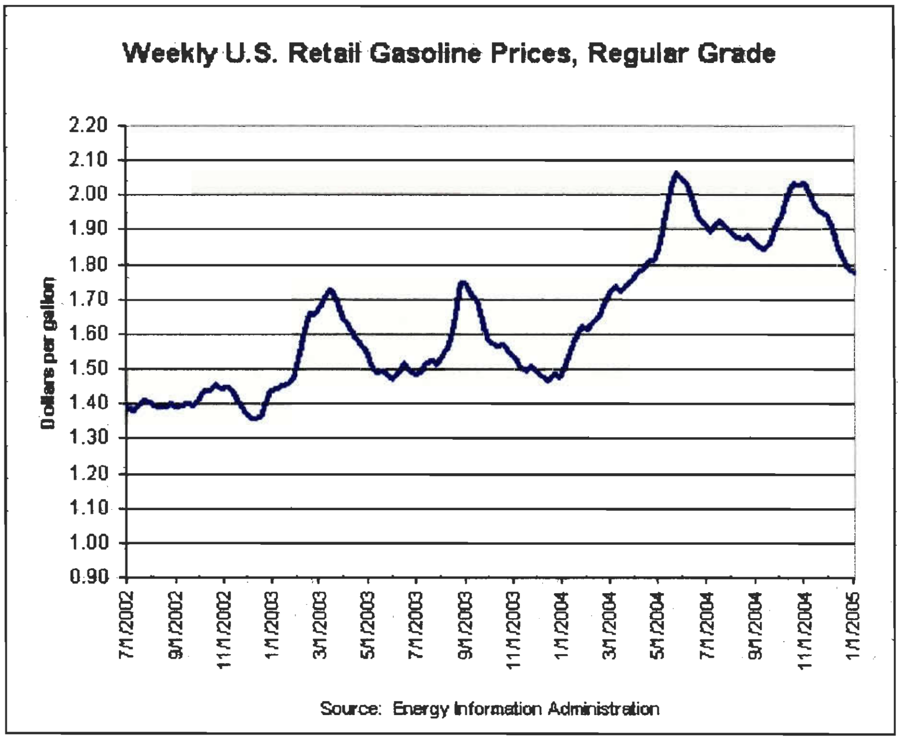
In contrast, the results for the next part of this question relating to mileage were heavily skewed towards favoring mileage.

Figure 25:



The average rating of gas mileage was 7.7 (out of 10), the highest ranking of any in the survey. This is obviously a very important aspect of purchasing a new car, very likely due to the instability of gasoline prices, and the increase of the average price of gasoline jumping nearly $0.60 per gallon since the start of the Iraq War. Both of these effects can be seen below.

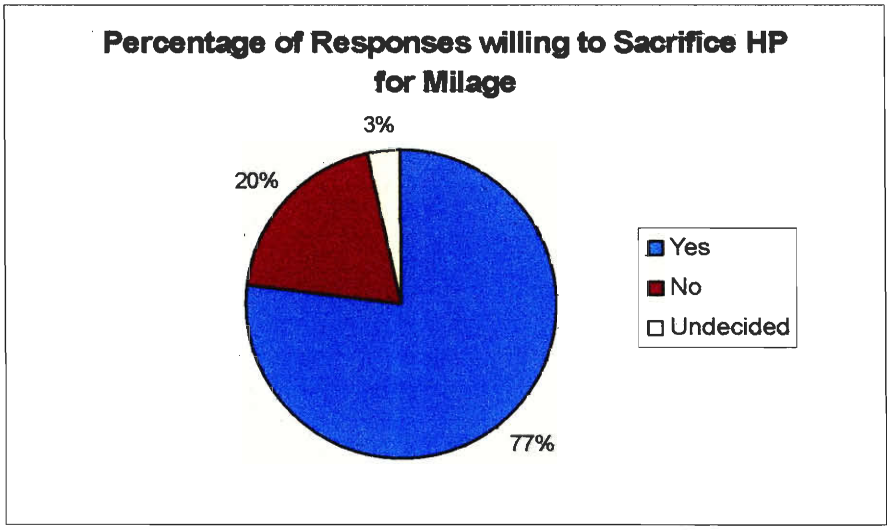
Figure 26:



This is a 43% increase in end-user cost of gasoline (EIA). In a way, the war in Iraq may inadvertently start a popular movement towards renewable energy sources, if the current trends continue.

The final part of this question was asked to determine whether the two previous questions could be correlated to show that there is a demand for more efficient automobiles, as opposed to more powerful ones.

Figure 27:



As may have been concluded from the previous questions, the results show that a vast majority of people are willing, and in fact probably prefer more efficient vehicles over more powerful ones. This correlation has been shown to be an almost obvious market that automobile manufacturers could and should tap into. If 77% of the actual population would be willing to sacrifice horsepower for gas mileage, than feats such as a national average of 40mpg could almost certainly be attained. This small increase in mileage would equate to about 255 billion barrels of oil over 50 years, which does not include further advancement in engine efficiency. (NRDC, USGS)

Conclusions

In light of the recent policies and energy trends, it is clear that the plans of the Bush administration are not in the long-term best interests of the US or the global community. Increasing reliance on coal, does not amount to a feasible long-term solution. Relying on clean coal and increasing the supply of power generated from clean coal technologies simply pushes the burden of dealing with the real problem into the future. According to the Bush Administration, clean coal technologies will help reduce the United States' dependence on foreign oil, but in reality only a small percentage of electricity is generated through burning oil. A greater reduction would come from imposing stricter mileage regulations for SUVs. As mentioned previously, 40 mpg average standard for automobiles would save 15 times the amount of oil that is recoverable from the Arctic National Wildlife Refuge over the next 50 years. This is the same timeframe that, according to the US Geological Survey, it would take to harvest the oil in the Arctic National Wildlife Refuge. The current allotment of $2 billion for research into clean coal technologies would be better spent on renewable energy research.

As the survey results show, there is public interest in cleaner energy, even if it comes at a slightly higher cost. On average, people would be willing to pay an additional $17.33 per month for energy if it came from a renewable source such as wind power. In addition, the survey indicates that people are interested in more efficient automobiles. One of the major roadblocks to renewable energy integration seems to be lack of public knowledge about where energy comes from and the alternatives that already exist. The sample population of the survey consisted of mostly students, which makes the results even more shocking, mainly because the sample population has an education level higher than that of the average American.

A farsighted plan to deal with the upcoming increase in energy demand should include measures which seek to reduce the demand rather than ramping up supply to meet an unchecked demand. The United States has an obligation to the global community to conserve energy to ensure the well-being of our planet. Technology allows us to implement more complex systems to regulate usage, manage information, and recognize problems so that we can make the most informed decisions. The problems that we face cannot be solved in the near future and require careful planning to ensure success. For this reason, we need to develop a short-term solution that leads to a long-term solution involving rigorous conservation and renewable energy integration. The short term solution amounts to meeting the increase in demand with current technology, both renewable and non-renewable, as we develop new technology and policy for conservation and renewable energy.

Although nuclear power is sometimes regarded as being unsafe, the energy yields of nuclear fission offset the effects of containing the byproducts of the process. As a short term solution during the period of renewable energy development, nuclear power can stifle the demand and can eventually be replaced with renewable supplies. The main issues surrounding nuclear energy are the lack of interest due to liability and concerns about safety. It is however true that the newest nuclear fission technologies are much safer than those of the 1950's. The Price-Anderson Act does not account for these differences, which themselves make a large difference in the probability of a nuclear accident. Revising the Price-Anderson act to account for newer technologies could stimulate growth in the nuclear industry. In addition, the ongoing Yucca Mountain project could contain the waste of 50 years of nuclear production at our current pace. Assuming that we increased our nuclear production to 1.5 times its capacity, we could still contain the waste for approximately 30 years.

This would probably be the best long term solution, maintaining our supply with nuclear power, while keeping up with the increase in demand with newer technologies. An eventual phasing out of old technologies as new technologies are developed is essential for accomplishing our long term goals. Recognizing the limits of various types of energy sources should also be a priority, as opposed to refining current techniques for electricity production.

Of all the of sources energy, it is apparent that renewable sources are strongly preferred. Renewable energies are not only much cleaner, the energy supplies are considered infinite. If the electricity generated from renewable sources is made in the U.S., it would allow us to be less reliant on other countries. The implications of our dependence on foreign oil should especially be considered. However, bear in mind that this dependence is perpetuated by the enormous oil industry lobby.

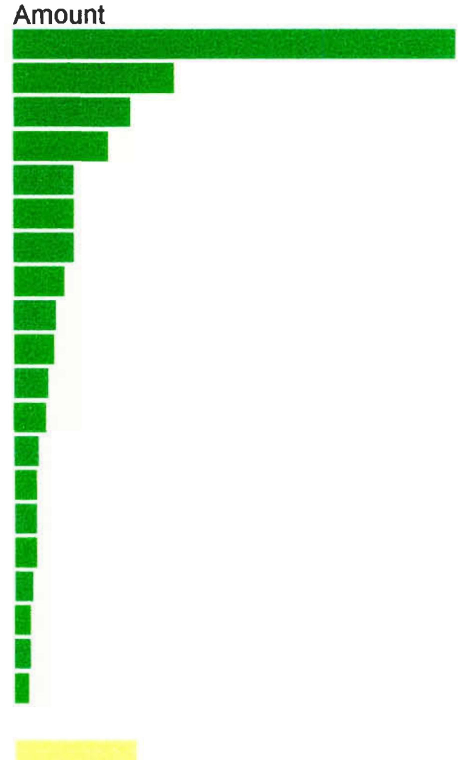
Global Warming is something that needs to be addressed immediately, focusing on total CO_2 concentration in the atmosphere, not on a country by country output strategy. This is serious concern of thousands of scientists, and their views are being kept from the populations. It is fairly apparent that the current administration is more concerned with keeping the public un-informed and maintaining the status quo for current economic powers. In turn, these economic powers fund political allies, perpetuating the cycle of funding for old technology (non-renewable sources).

APPENDIX A: World Energy Statistics

Table 1:

Annual Total Electricity Consumption

	Country	Description	Amount
1	United States	3.602 trillion kWh (2001)	
2	China	1.312 trillion kWh (2001)	
3	Japan	964.2 billion kWh (2001)	
4	Russia	773 billion kWh (2001)	
5	Germany	506.8 billion kWh (2001)	
6	Canada	504.4 billion kWh (2001)	
7	India	497.2 billion kWh (2001)	
8	France	415.3 billion kWh (2001)	
9	United Kingdom	346.1 billion kWh (2001)	
10	Brazil	335.9 billion kWh (2001)	
11	Italy	289.1 billion kWh (2001)	
12	Korea, South	270.3 billion kWh (2001)	
13	Spain	210.4 billion kWh (2001)	
14	Mexico	186.7 billion kWh (2001)	
15	Australia	184.4 billion kWh (2001)	
16	South Africa	181.2 billion kWh (2001)	
17	Ukraine	152.4 billion kWh (2001)	
18	Taiwan	140.5 billion kWh (2001)	
19	Sweden	134.9 billion kWh (2001)	
20	Poland	118.8 billion kWh (2001)	
	Total	11.13 trillion kWh	
	Weighted Average	998.23 billion kWh	

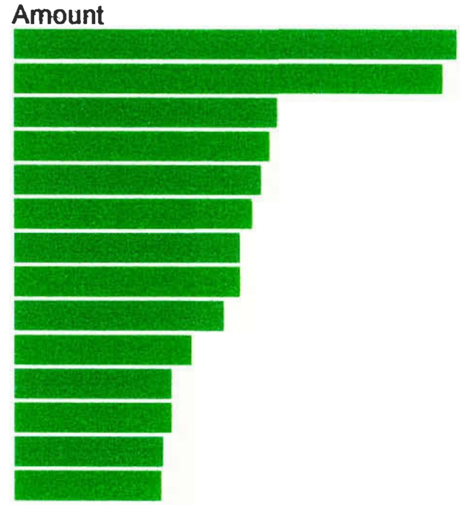


Source: CIA World Factbook, December 2003

Table 2:

Annual Electricity Consumption per Capita

	Country	Description	Amount
1	Iceland	26143.34 kWh per person	
2	Norway	25362.27 kWh per person	
3	Canada	15661.13 kWh per person	
4	Sweden	15194.71 kWh per person	
5	Finland	14676.00 kWh per person	
6	United Arab Emirates	14125.78 kWh per person	
7	Kuwait	13416.32 kWh per person	
8	Luxembourg	13365.42 kWh per person	
9	United States	12406.03 kWh per person	
10	Qatar	10545.22 kWh per person	
11	Australia	9345.23 kWh per person	
12	Bermuda	9283.21 kWh per person	
13	New Zealand	8827.45 kWh per person	
14	Bahrain	8721.02 kWh per person	



15	Cayman Islands	8470.45 kWh per person	
16	Virgin Islands	7676.83 kWh per person	
17	Belgium	7598.34 kWh per person	
18	Japan	7579.32 kWh per person	
19	Switzerland	7300.53 kWh per person	
20	Slovenia	7144.78 kWh per person	
	Weighted Average	11,288.92 kWh per person	

Source: CIA World Factbook, December 2003

Table 3:

	Total Coal Consumption Country	Description	Amount
1	China	1.31 billion short tons (2000E)	
2	United States	1,060 million short tons (2001E)	
3	India	339 million short tons (2001E)	
4	Russia	298 million short tons (2000E)	
5	Germany	265 million short tons (2001E)	
6	South Africa	170.5 million short tons (domestic sales) (2000E)	
7	Japan	149.5 million short tons (1999E)	
8	Australia	144.17 million short tons (2000E)	
9	Korea, North	103.6 million short tons (2000E)	
10	Ukraine	97.2 million short tons (2000E)	
11	Turkey	81.1 million short tons (2001E)	
12	Korea, South	71.7 million short tons (2000E)	
13	Greece	70.5 million short tons (2000E)	
14	Canada	67 million short tons (2000)	
15	United Kingdom	66.1 million short tons (2000E)	
16	Taiwan	52.9 million short tons (2001E)	
17	Spain	45.19 million short tons (2001E)	
18	Thailand	24.9 million short tons (2000E)	
19	Brazil	23.5 million short tons (2000E)	
20	Italy	22.4 million short tons (2001E)	
	Total	4.46 billion	
	Weighted Average	669.25 million	

Source: Energy Information Administration, US Department of Energy

Table 4:

	Total Oil Consumption Country	Description	Amount
1	United States	19.7 million barrels per day (2002E)	
2	Japan	5.4 million barrels per day (2002E)	
3	China	4.9 million barrels per day (2001E)	

4	Germany	2.71 million barrels per day (2002E)
5	Russia	2.38 million barrels per day; (2001E)
6	Brazil	2.2 million barrels per day (2001E)
7	India	2.0 million barrels per day (2002E)
8	Canada	2.0 million barrels per day (2002E)
9	France	1.96 million barrels per day (2002E)
10	Mexico	1.93 million barrels per day (2002E)
11	Italy	1.87 million barrels per day (2002E)
12	United Kingdom	1.7 million barrels per day (2002E)
13	Spain	1.5 million barrels per day (2002E)
14	Saudi Arabia	1.36 million barrels per day (2002E)
15	Indonesia	1,022,000 barrels per day (2001E)
16	Taiwan	985,000 barrels per day (2002E)
17	Australia	872,000 barrels per day (2001E)
18	Singapore	722,000 barrels per day (all imported) (2002E)
19	Thailand	715,000 barrels per day (2001E)
20	Turkey	635,000 barrels per day (2002E)
	Total	56.56 million barrels per day
	Weighted Average	4.26 million barrels per day

Source: Energy Information Administration, US Department of Energy

Table 5:

Percent Electricity from Renewable Sources

	Country	Description	Amount
1	Philippines	26.9% (2001)	
2	El Salvador	25.1% (2001)	
3	Iceland	17.5% (2001)	
4	Luxembourg	17.5% (2001)	
5	Denmark	17.3% (2001)	
6	Costa Rica	16.6% (2001)	
7	Guatemala	12.9% (2001)	
8	Finland	11.8% (2001)	
9	Kenya	11.3% (2001)	
10	New Zealand	10.7% (2001)	
11	Nicaragua	8.4% (2001)	
12	Netherlands	5.7% (2001)	
13	Cuba	5.4% (2001)	
14	Brazil	4.6% (2001)	
15	Germany	4.1% (2001)	
16	Portugal	4.1% (2001)	
17	Spain	4.1% (2001)	
18	Austria	3.5% (2001)	
19	Italy	3% (2001)	
20	Mexico	2.9% (2001)	
21	Indonesia	2.5% (2001)	
22	Thailand	2.4% (2001)	

23	Sweden	2.3% (2001)	
24	United States	2.3% (2001)	
25	Switzerland	2% (2001)	

Source: CIA World Factbook, December 2003

Table 6:

Total Hydro-Electricity

	Country	Description	Amount
1	Canada	347.3 terawatt-hours	
2	Brazil	284.5 terawatt-hours	
3	United States	257.4 terawatt-hours	
4	China	246.5 terawatt-hours	
5		229.6 terawatt-hours	
6	Russia	164.3 terawatt-hours	
7	Norway	129.7 terawatt-hours	
8	Japan	90.7 terawatt-hours	
9	India	74.5 terawatt-hours	
10	Sweden	66.7 terawatt-hours	
11	France	66.4 terawatt-hours	
12	Venezuela	61.9 terawatt-hours	
13	Italy	48.1 terawatt-hours	
14	Austria	39.3 terawatt-hours	
15	Switzerland	36.9 terawatt-hours	
16	Colombia	33.7 terawatt-hours	
17	Argentina	33.6 terawatt-hours	
18	Spain	27.0 terawatt-hours	
19	Germany	26.0 terawatt-hours	
20	Mexico	24.9 terawatt-hours	

Source: BP

Table 7:

Percent Electricity from Nuclear Power

	Country	Description	Amount
1	Lithuania	77.70%	
2	France	77.10%	
3	Belgium	59.30%	
4	Slovakia	53.60%	
5	Bulgaria	44.10%	
6	Ukraine	43.50%	
7	Sweden	43%	
8	Hungary	39%	
9	Switzerland	37.10%	
10	Slovenia	36.80%	
11	Korea, South	36.60%	

12	Armenia	30.70%
13	Finland	30.40%
14	Germany	29.90%
15	Japan	29.80%
16	Spain	27.20%
17	United Kingdom	23.70%
18	Taiwan	22.60%
19	United States	20.70%
20	Czech Republic	20%

Source: CIA World Factbook, December 2003

Table 8:

	Nuclear Efficiency Country	Description
1	Canada	6.5
2	France	4.6
3	Sweden	4.5
4	United Kingdom	3.7
5	Hungary	3.2
6	Belgium	2.8
7	Switzerland	2.4
8	Korea, South	2.3
9	Finland	2.2
10	Japan	1.8
11	Germany	1.3
12	Czech Republic	1
13	United States	0.9
14	Spain	0.9
15	Netherlands	0.2
16	Mexico	0.1
	Weighted Average	1.76

Source: Organization for Economic Cooperation and Development, Paris, France, OECD Environmental Data Compendium, 1999

APPENDIX B: Pollutants Emitted

CO_2

Total Carbon Dioxide Emissions

	Country	Description (1000 metric tons)		Amount
1	United States		5,762,054.00	
2	China		3,473,597.30	
3	Russia		1,540,365.00	
4	Japan		1,224,737.40	
5	India		1,007,978.90	
6	Germany		837,424.80	
7	United Kingdom		558,225.10	
8	Canada		521,404.40	
9	Italy		446,596.50	
10	Mexico		385,075.00	
11	France		363,484.20	
12	Ukraine		348,356.60	
13	South Africa		344,590.40	
14	Australia		332,377.20	
15	Brazil		327,857.70	
16	Spain		304,882.50	
17	Poland		303,777.50	
18	Indonesia		286,027.20	
19	Saudi Arabia		266,083.00	
20	Turkey		223,861.60	
	Total	18.86 million		
	Weighted Average	2 million		

Source: World Resources Institute. 2003. Carbon Emissions from energy use and cement manufacturing, 1850 to 2000. Available on-line through the Climate Analysis Indicators Tool (CAIT) at Washington, DC: World Resources Institute.

Total Carbon Dioxide Emissions per Capita

	Country	Description (1000 metric tons)	Amount
1	Qatar	42.96 per 1000 people	
2	United Arab Emirates	29.10 per 1000 people	
3	Kuwait	26.80 per 1000 people	
4	Bahrain	20.65 per 1000 people	
5	United States	19.84 per 1000 people	
6	Luxembourg	18.54 per 1000 people	
7	Australia	16.84 per 1000 people	
8	Trinidad and Tobago	16.38 per 1000 people	
9	Canada	16.18 per 1000 people	
10	Singapore	13.26 per 1000 people	
11	Palau	12.26 per 1000 people	
12	Belgium	12.15 per 1000 people	
13	Czech Republic	12.10 per 1000 people	

14	Saudi Arabia	10.95 per 1000 people
15	Ireland	10.91 per 1000 people
16	Finland	10.90 per 1000 people
17	Netherlands	10.82 per 1000 people
18	Nauru	10.78 per 1000 people
19	Russia	10.65 per 1000 people
20	Estonia	10.56 per 1000 people
	Weighted Average	16.17 per 1000 people

Source: World Resources Institute. 2003. Carbon Emissions from energy use and cement manufacturing, 1850 to 2000. Available on-line through the Climate Analysis Indicators Tool (CAIT) at Washington, DC: World Resources Institute.

NOs

Nitogen Oxides per Capita

	Country	Description (Kg)	Amount
1	Australia		118
2	Iceland		106
3	United States		80
4	Canada		68
5	Finland		51
6	Norway		51
7	Denmark		47
8	New Zealand		46
9	Czech Republic		41
10	Luxembourg		40
11	Sweden		38
12	Portugal		37
13	Greece		35
14	United Kingdom		35
15	Ireland		34
16	Belgium		33
17	Spain		32
18	Italy		31
19	Poland		30
20	France		29
	Weighted Average		57.62

Source: Organization for Economic Cooperation and Development, Paris, France, OECD Environmental Data Compendium,

APPENDIX C: Compiled Wave Device Data

Device	Cost/Unit ($)	Ave Annual Wave Power (kW/m)	Annual Electricity Produced (MWh)	Rating	Assumed Capacity	Install cost/MWh
Bouy	750000	12.4	102.5	250kW	40%	3M
		15.2	134.5			
		21.2	145.5			
		26.5	153			
OWC	2000000	12.4	1631	1.25MW	33%	1.6M
		15.2	1631			
		21.2	2275			
		26.5	2844			
Pelamis	2500000	12.4	1076	750kW	40%	3.3M
		15.2	1143			
		21.2	1337			
		26.5	1587			
SeaDog	3000000	12.4	117	750kW	40%	4M
		15.2	125			
		21.2	139			
		26.5	167			
MRC1000	3000000	12.4	2782	1000kW	50%	3M
		15.2	4488			
		21.2	4661			
		26.5	4915			
WaveSwing	5000000	12.4	1209	4MW	20%	1.25M
		15.2	1564			
		21.2	3078			
		26.5	2653			
WaveBob	?	12.4	523	1000kW	40%	
		15.2	726			
		21.2	1147			
		26.5	1271			
WaveDragon	11000000	12.4	7038	4MW	34%	2.75M
		15.2	7240			
		21.2	10938			
		26.5	12302			

APPENDIX D: Survey (Hosted by www.surveymonkey.com)

Terms:
renewable energy – energy that is generated from sources that are essentially inexhaustible, such as wind power
non-renewable energy – energy produced from exhaustible sources, such as oil

1. Please list up to five renewable and non-renewable sources of energy, in the order you think they are most used:

Renewable	Non-renewable
________________	________________
________________	________________
________________	________________
________________	________________
________________	________________

2. Do you know what specific type of energy source your electricity comes from? If so which type (s)?

3. On a scale of 0-10, 10 being of utmost importance, how important is the cleanliness of an energy source to you?

0	1	2	3	4	5	6	7	8	9	10
Least										Most

4. Would you being willing to pay more for "cleaner" energy, for example wind power? If so, how much more per month?

   Yes ☐ $ ______________ per month
   No ☐

5. If you were to purchase an automobile;
   a) How important is horsepower on a scale of 0-10?

0	1	2	3	4	5	6	7	8	9	10
Least										Most

   b) How important is gas mileage?

0	1	2	3	4	5	6	7	8	9	10
Least										Most

   c) Would you consider sacrificing horsepower for gas mileage?

   Yes ☐ No ☐

APPENDIX E: Survey fact sheet shown to all survey participants

Interesting Energy Facts:

Where electricity comes from in the U.S.:

Coal	50.1%
Nuclear	20%
Gas (various)	18%
Hydro	7%
Oil	2%
Other	2%

The average residence in the United States uses 907 kWh per month. This amounts to just over one ton of CO_2 (2040lbs) from electricity generation for every residence. The volume of this gas is at STP is 16652ft3, or enough to fill two Olympic sized swimming pools every year, from every residence.

Annually, CO_2 emissions measure about 4.05 trillion pounds in the U.S.

Texas is the 5th largest producer of CO_2 in the World, behind China, Russia, Japan, and India. Texas alone produces more CO_2 than any European nation.

CO_2 is not recognized as a pollutant under current U.S. energy policy, despite world-wide global warming concerns.

The United States has 5% of the world's population, yet consumes 25% of the world's oil. The U.S. has only enough oil in reserve for about 3 years. 56.1% of its petroleum products are imported.

A 40mpg average standard for automobiles would save 15 times the oil that is recoverable from the Arctic National Wildlife Refuge over the next 50 years, the same timeframe the ANWR will be drilled.

Bibliography

1. United States Energy Information Agency (EIA), http://www.eia.doe.gov/ 2004
2. CIA World Fact Book (CIA), http://www.cia.gov/cia/publications/factbook/, Dec 2003
3. United States Environmental Protection Agency (EPA), http://www.epa.gov/, 2004
4. DeMorgan Industries Corporation, http://www.powerfrontiers.com/, 2003
5. United States Geological Survey (USGS), http://www.usgs.gov/, 2004
6. United States Department of Energy (DOE), http://www.energy.gov/engine/content.do, 2004
7. United States Census Bureau http://www.census.gov/, 2004
8. How Stuff Works http://www.howstuffworks.com/nuclear-power.htm
9. Wikipedia, http://en.wikipedia.org/wiki/, Uranium, 2004
10. Nuclear Regulatory Commission (NRC), http://www.nrc.gov/, 2004
11. Washington State Department of Health, http://www.doh.wa.gov/, 2004
12. Taylor, S.R. and S.M. McLennan, 1985. *The Continetnal Crust: its composition and evolution.* Blackwell Scientific Publishers, Oxford; Taylor, S.R. and S.M. McLennan. 1995. *Rev. Geophys.* 33:241-265
13. Congressional Research Report by Mark Holt, Resources, Science, and Industry Division, April 23, 2001.
14. Natural Resources Defense Council (NRDC), http://www.nrdc.org/, 2001
15. Public Citizen http://www.citizen.org/cmep/energy_enviro_nuclearelectricity/P_Anderson/, 2004
16. British Broadcasting Corporation (BBC), http://www.bbc.co.uk/, 2004
17. The Whitehouse http://www.whitehouse.gov/vicepresident/newsspeeches/speeches/vp20010430.html, 2004
18. Apeenzeller, Tim and Robert Dimick, (2004, September), *National Geographic*