Case Study of Current Domestic Energy Deficit in the United States and Simulated Solutions for Filling the Deficit by Utilizing Renewable Resources and Other New Technologies

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Overview

As the world moves into the future, we must look to new ways of creating energy for the population. This report about energy and its sources was written for several reasons:

- **Identify current energy production and consumption data in the United States.**
    - Equate all energy sources to quadrillion Btu for direct comparison and addition of the sources.
    - Spatially represent a geographic distribution of energy production in the U.S. Energy production is broken into different source categories including coal, petroleum, natural gas, nuclear energy and renewable energies being produced in each state as of 2003.
    - Spatially represent 2003 energy consumption data for each state.
    - Compare production to consumption on a state by state scale and a national scale to establish the 2003 domestic shortage.
- **Identify renewable energy resources in the United States.**
    - Discuss basic technologies available for energy production and which ones could be expanded in the future.
- **Create a hypothetical scenario of energy self adequacy for the United States.**
    - Assume the existing deficit of 27 quadrillion Btu, currently filled by imported energy sources, to be the deficit that needs to be made up domestically.

    - Assume no new petroleum drilling advances.
    - Even though the imported energy is mostly crude oil for gasoline, we will assume that the deficit can be filled with electric power.
    - Assume that nuclear power generation will be doubled to fill some of the deficit.
    - Illustrate land usage and potential cost of renewable energy sources needed to generate enough energy to fill the hypothetical domestic shortage.
    - Study each of the three popular renewable sources: wind, solar and biomass as individual solutions to the deficit.
- **Discuss some technological advances that could change the face of energy consumption and production in the future.**
    - Discuss clean coal technology and its possible impact on future energy generation.
    - Discuss some of the known difficulties with current electric transmission lines in the U.S. and identify the severity of the problem with lines already operating at capacity.
- **Discuss why Wyoming is so important to the future of the nation.**

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I. Introduction to the Issues

All data is current for the year 2003 except where noted. Resources for the raw data are listed at the end of this document.

The global climate of energy consumption is changing from what it once was. Demand is increasing for non-renewable fuel resources in developing countries, and the U.S. may face more competition for energy sources in the future[17]. In the future, the U.S. may have to consider energy self-sufficiency- making it an important topic to discuss. One solution to potential energy supply issue is to phase out imported energy sources and become more independent in tomorrow's energy driven world. This is not an easy problem to address.

Scope:

This report will look at energy resources available to the United States. It will analyze current domestic resources as well as current imported energy. The report will also discuss hypothetical situations were renewable energies are used to supplement the U.S. energy supply. The supplemental energy from the renewables is not necessarily to replace the functions of petroleum in this report. Replacing the use of petroleum is beyond the scope of the report. The situations look to fill a deficit regardless of which energy sector would actually see a decrease in energy supply if imported energy were not available.

A. History

Historically the U.S. has gone through periods of energy deficit followed by advances in technology. One particular period of energy deficit was during the OPEC oil embargo and resultant energy crisis during the 1970's. The dramatic increase in the cost of energy fuels and the consequent thrust of the nuclear age had the country in an upheaval. One side of the story was the immediate need for fossil fuel energy, and another side was the continued growth of demand for energy. The country entered the nuclear age hoping to address long term energy demands, but unfortunately it came and went very quickly. The uranium industry was in full swing with exploration and production, but discoveries of new petroleum reserves and the end of the embargo caused the country's focus on conservation and nuclear development to revert. Fear of nuclear accidents like the one at Three Mile Island was simply another reason that further swayed the country back toward fossil fuels as a means of energy resource for the future. Any advances that the country developed during the embargo were placed on the back burner while the country went back to using what were already available, fossil fuels. This almost put us back to square one in development of non-fossil fuel energy sources.

Energy prices are soaring to record levels thirty years later, and as a result many are looking to developing alternative energies again. Today many economic analysts, scientists, and even the current administration are looking to alternative energy sources to help bridge the gap between the fossil energy age and the proposed “hydrogen economy”. However, in the time since the OPEC crisis, several factors have changed- the country is more populated, more industrialized, and has an even bigger need for energy. Over the last 30 years, the U.S. has subtly and quietly increased our net import of foreign energy; in fact the net energy deficit has exceeded 27 quadrillion Btu[38]. Increased energy costs are currently driving the increase in funding, research, and development on the economic viability of alternate energy sources which include renewable resources like wind and solar power.

B. Current Production and Consumption

This research was done in an effort to try to put potential solutions to the energy deficit into perspective for everyone. First, we look internally at where the U.S. already has resources- which states are the major producers and which are the major consumers. Production in the U.S. is an important factor to consider in the search for energy independence from foreign imports. Several states lead the production of fossil fuels while others with more limited fossil energy resources are leading the way with renewable energies. However some states are totally dependent upon others to receive the energy sources that fuel their economies.

The U.S. consumes almost twice the energy as any other country in the world. In 2002, the U.S. consumed more than all of Western Europe combined[17]. Energy may be used in the form of electric power, fuel for transportation and heating, or gas for heating or electricity. There are also many other uses for energy in private, commercial, governmental, and industrial sectors. The U.S. is a nation that heats, cools, uses electronic devices in almost everything we do, and drives a lot.

In order to compare the different sources of energy to each other, the energy is equated in British thermal units (Btu), which is the amount of energy required to raise the temperature of one pound of pure water one degree Fahrenheit at mean sea level. To quantify energy at a national level requires use of the prefix quadrillion. A quadrillion Btu is equivalent to

1,000,000,000,000,000 Btu. The average U.S. household in 1997 used 101 million Btu or 10^{-7} quadrillion Btu[30].

The pie chart in Figure 1 represents the total production of the various energy sources in the U.S. as of 2003[38]. Federal Offshore includes both the natural gas production and crude oil production that is credited to the U.S. as a whole as opposed to an individual state.

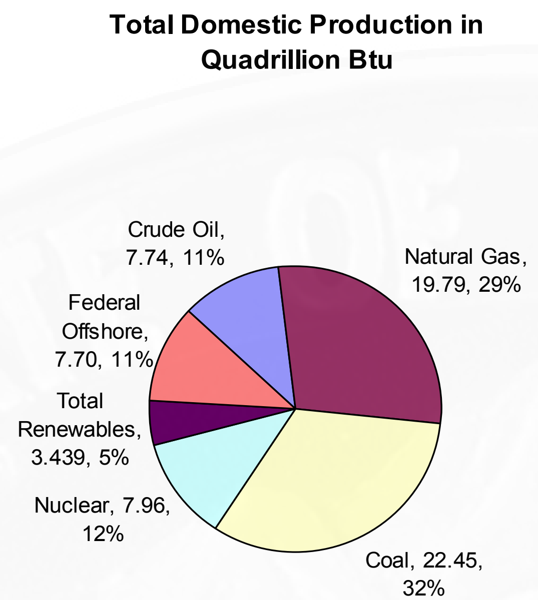


Figure 1 Total Domestic Production

Federal Off Shore in Quadrillion Btu	
Crude Oil	**3.15**
Natural Gas	**4.56**

Currently the U.S. imports 28% of the total products needed to meet energy consumption demands. The total energy supply for the U.S. is shown in Figure 2.

Imports in Quadrillion Btu	
Coal	**-0.49**
Natural Gas	**3.39**
Crude Oil	**21.06**
Petroleum Products	**2.74**
Electricity	**0.02**
Coal Coke	**0.05**

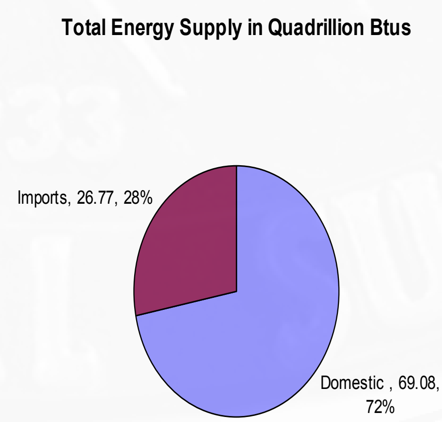


Figure 2: Total Energy Supply

The U.S. consumes more energy than it produces domestically, and the energy required to meet the balance must be imported to meet the ever growing demand. In 2003 the reported total consumption for the U.S. was 98.2 quadrillion Btu[17]. The total amount of energy produced or supplied to the U.S. was calculated by the authors to be around 95.85 quadrillion Btu[38]. Comparing these two numbers we see the following:

Total Production, Imports, QBtu
95.85

Total Consumption, QBtu
98.23

Extra Consumption
-2.38

% Under estimation
-2.42

The percent underestimation of total production can be due to several factors. The numbers supplied by the Energy Information Administration (EIA) are provided and rounded by individual sources, and thermal conversion rates may vary from the rates utilized in this study. These combined errors may have caused the 2.42% error between consumption and production.

C. Future Projections

A major goal of U.S. energy policy is to become more self-sufficient. The U.S. is facing increased competition for energy with other quickly developing countries. Currently, developing countries use about 66% of the amount of oil that an industrialized country does, but these developing countries are expected to be using 94% of what the industrialized countries are using by the year 2025 [16] . “China accounted for 40% of total growth in world oil demand during 2000-04, said Cambridge Energy Research Associates (CERA) in a report on China energy” [27].

The entire world is dramatically increasing energy consumption. World energy consumption is projected to increase by 54% from 2001 to 2025, or grow from 404 quadrillion Btu to 623 quadrillion Btu in 2025

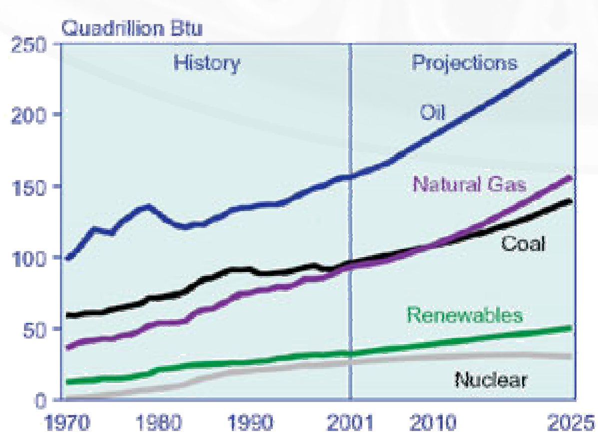


Figure 3: World Marketed Energy Consumption by Energy Source, 1970-2025 Courtesy of DOE/EIA, International Energy Outlook 2004

Again, the fastest of this growth can be attributed to the nations of China and India where gross domestic product is increasing by an average annual rate of 5.1% [17]. Since the populous of both India and China are moving into more industrialized economies, their lifestyles are starting to become more like the ones we currently enjoy in the U.S. This puts a tremendous strain on the fossil fuel resources of the earth. More and more people are demanding a fuel supply that is becoming smaller and smaller each day.

D. Energy Resources

An energy supply that will be under especial demand is crude oil. In 2003 the U.S. imported 21.06 quadrillion Btu of crude oil, or 4,011,428,571 barrels of oil[5]. The amount imported is almost three times what is produced domestically. Basic application of the supply and demand rule could predict a future where the country that pays the most per barrel will get that oil. This will have a tremendous impact on transportation and electric power generation in the U.S. The price per barrel is already high when compared to historic prices and will continue to climb.

Coal production has continued to increase at an incredible rate since the energy crisis of the 1970's. Domestically produced coal will remain an integral part of the energy consumption fuel at around 23% in the year 2025[17]. A major producer of U.S. coal is the Powder River Basin coal fields in northeast Wyoming. Coal can be used in a variety of industrial applications, but most of the coal is mined to be used to generate steam for electric power plants. Electricity generated from coal-fired plants accounts for roughly 50% of the national steam-power generation[4]. Coal also may be a flexible energy resource in the future. Coal derived fuels in combination with upgraded power facilities are shown to run at higher levels of efficiency and with lower net emissions. Coal conversion technologies such as gasification and liquefaction may eventually pave the way to energy fuels derived from coal. Overall coal is a tremendous resource for the U.S.

Natural gas fired plants and nuclear power plants also contribute to electricity generation. Nuclear and gas-fired plants may have lower net emissions, but enhanced coal firing and clean coal technologies show great potential for increased efficiency. In contrast to the U.S., international power generation is expected to be generated primarily from nuclear power facilities, and this power source expected to be especially prominent in the developing regions of the world[17]. However, China is developing many coal fired power plants to serve their developing country. Natural gas can be used for home heating. This energy resource is expected to be in high demand in the eastern U.S. in the winter of 2005[26]. Most natural gas occurs with petroleum reserves, but coal bed natural gas is gaining popularity as more and more wells are emplaced and begin producing.

E. Energy Infrastructure

In light of the necessary increase in domestic power production, a key issue pertaining to any type of power generation is conveyance. The need for improved and more efficient electrical transmission infrastructure in the U.S. is critical, "Everyone wants electricity at reasonable prices, reliable electricity, nobody wants transmission lines"[16] as stated by Harold Kitching of the Tri Valley Central is a forewarning of a real problem. Sighting transmission lines is becoming increasingly difficult because property owners and real estate developers do not want the lines on their land, but along with the rest of the country they create the demand for the electricity. Also many of the existing lines are aging and could be replaced with higher voltage transmission serving more people with the same number of lines. Enhanced and efficient power transmission infrastructure is necessary in order to allow increased power transmission on the grid to meet future demand.

In order to move forward in the U.S.'s effort to reduce dependency on foreign energy resources, several compromises and sacrifices will have to be made. This includes everything from additional power lines, more wind turbines, more and or upgraded and higher efficiency power plants, increased mining and drilling production, and more rail lines and roads to service it all. Large areas of land and major investment will be needed to move the U.S. energy resources and production into the future.

II. Production of Energy in the U.S.

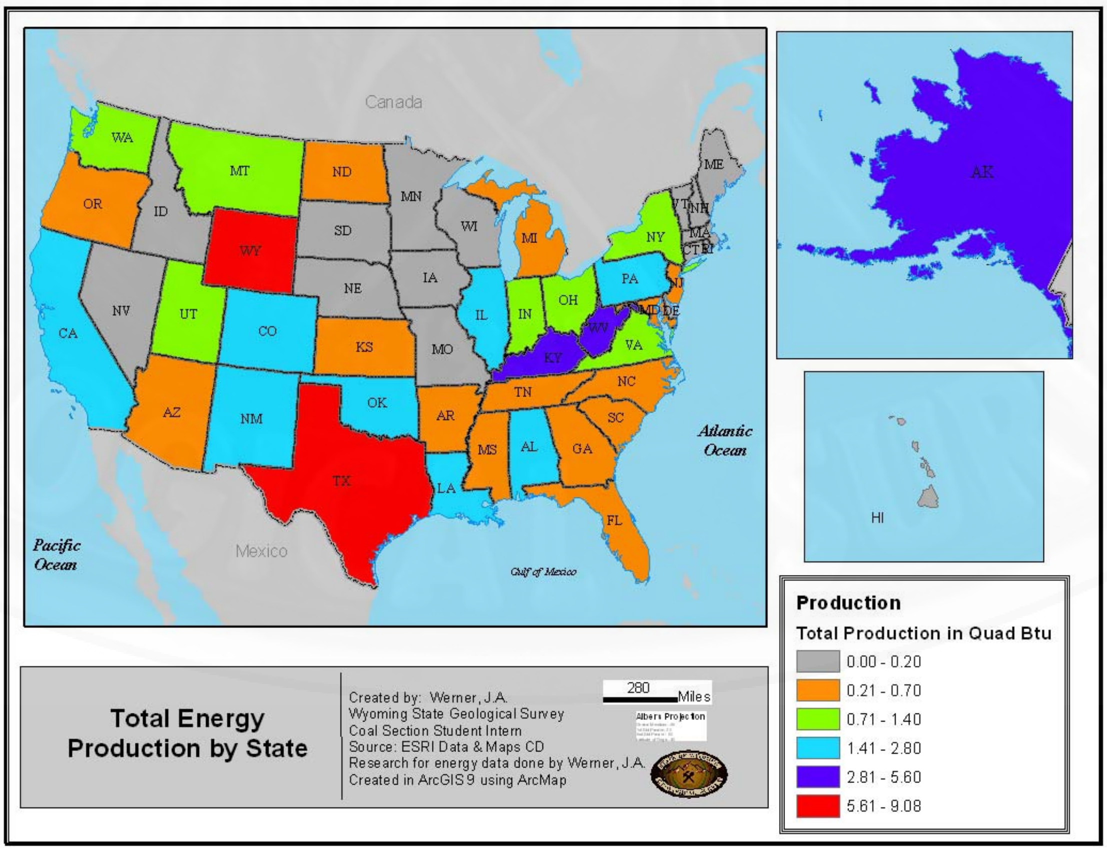
A. All Resources Combined

The U.S. has a variety of energy resources available. The country is endowed with non-renewable fossil energy resources, and also has the capacity to increase renewable energy production and upgrade the existing power plants, whether its hydro-electric, steam, gas, wind, solar, or even biomass. Values are shown in quadrillion Btu as a common unit to allow the total to be added and the different sources compared. It is much easier to compare quadrillion Btu than barrels to short tons. Quadrillion Btu are found utilizing a variety of different heating values. The heating value is how many Btu are released for every pound, ton, barrel, etc of the source. The conversions used in this research supplied by Bob Lyman of the WSGS are:

- Crude oil is 1 barrel = 5.25 million Btu
- Natural gas is 1 cubic foot = 1012 Btu
- Coal heating values are estimated by the WSGS for each state due to different coal qualities, but an average value would be 21,000,000 Btu per short ton (2000 pounds)
- Nuclear and renewable power is estimated at 10,421 Btu per kilowatt hour produced

The raw data for the maps created for this report was calculated by the WSGS using many of the resources found at the end of this report. Please contact the coal section at the WSGS for more information.

Map 1 shows the total production of energy in quadrillion Btu for each state.

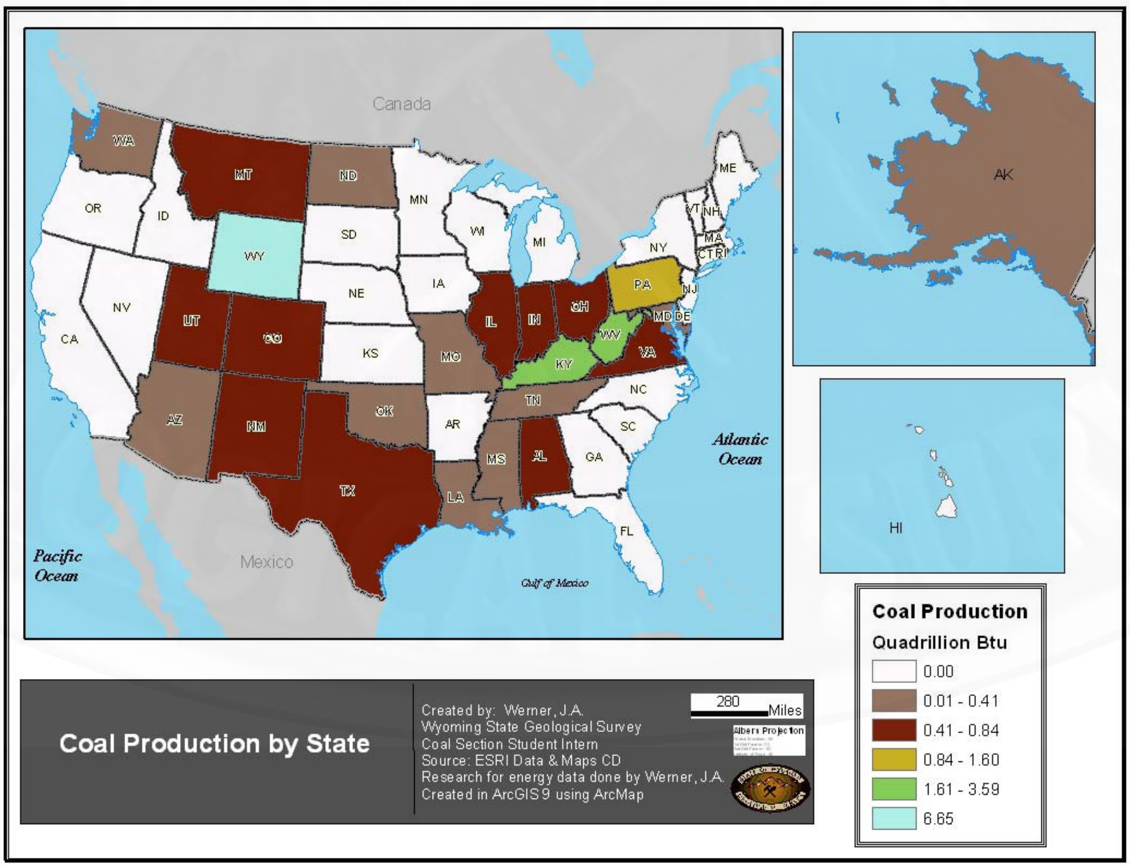


Map 1: Total Energy Production by State

Map 1 includes both non-renewable and renewable energy sources. The fossil fuels produced are credited to the state where the production occurs. Nuclear power generation is also included, but in contrast is credited to the state where the reactor is located as opposed to where the uranium is produced. Map 1 does not include federal offshore production but does include any state offshore production of crude oil and natural gas. Several states produce little energy on a national scale. A quadrillion Btu is an enormous quantity, so these states are not necessarily non-producers though their production is low enough not to make a large difference on the national scale.

Maps 2 thru 10 put the roles that each renewable and non-renewable resource plays in national energy production into perspective.

B. Domestic Coal Production



Map 2: Coal Production by State

Coal production in the U.S. currently accounts for 22.45 quadrillion Btu of the total energy produced, or roughly 32% of the domestic market. Approximately 30% of this is produced in Wyoming, and it comes from the surface mines in the Powder River Basin and the Green River Basin. Wyoming is home to the top 10 coal producing mines in the nation[37]. The coal is produced mainly through surface strip mining as can be seen in Figure 4.

Figure 4: Surface Mining in Wyoming, Courtesy WSGS

Roughly 94% of coal produced in Wyoming is subbituminous in rank. This type of coal has about 66% of the heating value of higher ranked eastern coals. Wyoming subbituminous coal runs about 20% higher moisture content than eastern coals, but the low sulfur content of Wyoming coal makes it a good choice for electric power production. When coal is burned to create heat, chemicals from the coal are released. If a plant has less sulfur in the coal at the beginning, they have less sulfur to control during and after combustion saving them money and reducing harmful air pollution. Sulfur in the air can irritate the nose and lungs, and it can contribute to acid rain.

Lately there has been much interest in possibly converting Wyoming coal to a liquid diesel fuel. This technology is anticipated to alleviate some of the burden on conventional diesel used for transportation fuel. Most Wyoming coal has a moisture content higher than optimal for these technologies because the gasification processes do not operate as well in high moisture. Nonetheless, Wyoming is the largest single coal producer, thus making it a good candidate based on location of the feed stock to the plant for the conversion of coal derived fuels. Coal will become an invaluable energy resource if all the proposed technological advances in utilizing it are fulfilled.

Coal is also a source of natural gas. Coal bed natural gas, methane, is drawn from the coal seams by creating a change in pressure in the coal. Once the water pressure is dropped in the coal the gas will migrate toward the well and then come up to the surface. Coal bed natural gas wells can tap energy from coals much too deep underground to mine at the current technology levels. Coal bed natural gas is utilized the same way that conventional natural gas is used.

C. Domestic Natural Gas Production

Natural gas is collected from the earth and is a hydrocarbon mixture composed mainly of methane. Natural gas is known as a clean burning fuel and has many applications like direct heat and electricity generation. Natural gas is generated in one of two ways, biogenic or thermogenetic. Gas occurrence in coal seams was generated biogenetically, microbes in the peat that became the coal produced methane gas as a byproduct. New research has found that the economically recoverable resources of coal bed natural gas is around 100 trillion cubic feet, more than half of the U.S.'s total proven natural gas reserves[26]. Deeper occurrences like those found in basin centers have been made through thermogenetic processes. These reserves are formed as a result of intense heat, pressure and thermal chemical conversions. Figure 6 is a diagram of a petroleum trap, one of the places thermogenetic natural gas can be found. Natural gas also can also be found in unconventional places such as sandstones adjacent to coal deposits and in deeper than once thought natural gas reserves[26].

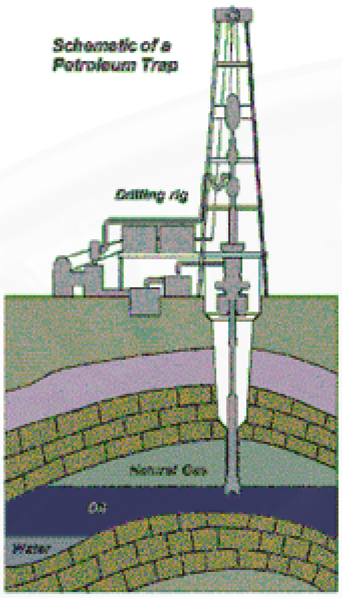
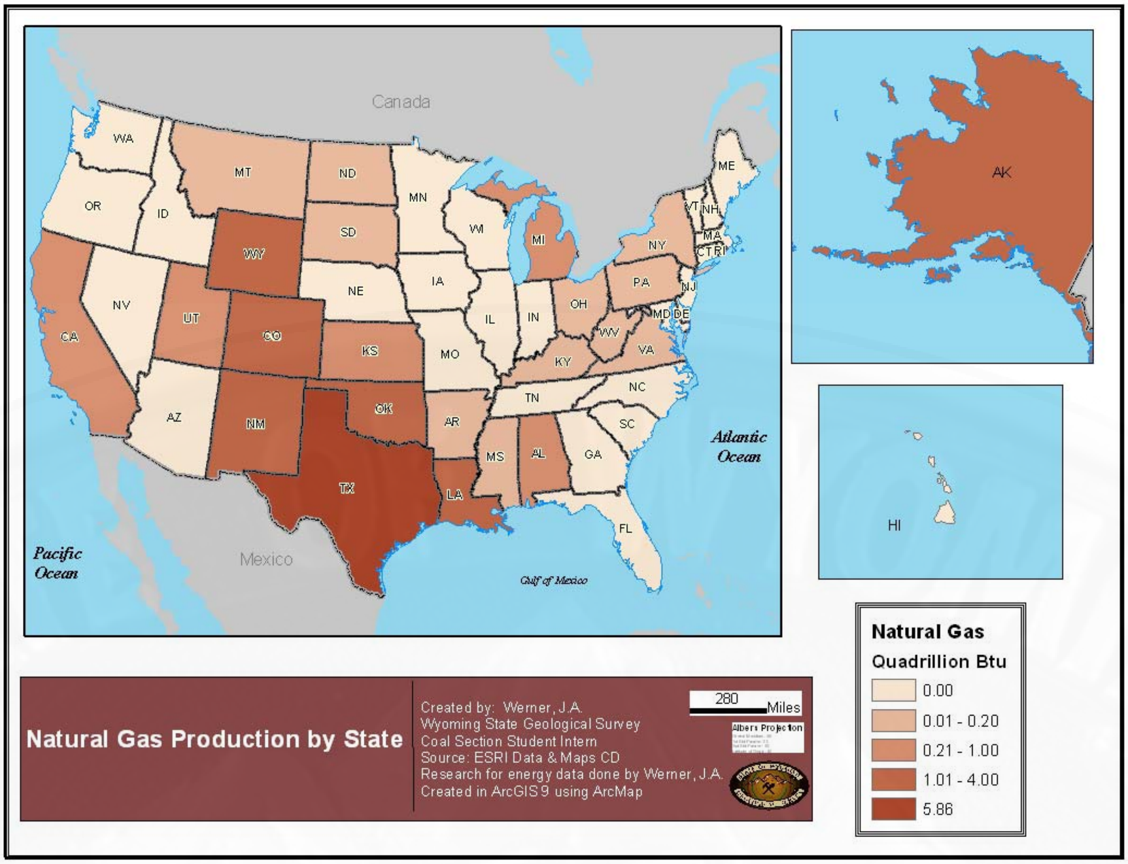


Figure 5: Thermogenetic Natural Gas, Courtesy of U.S. Energy Information Administration

Texas and Alaska are the major producers of conventional off-shore natural gas in the U.S. Natural gas currently constitutes 19% of total domestic energy production. Natural gas is also an import for the U.S. at 3.39 quadrillion Btu. State leaders in any kind of natural gas production are Wyoming, Colorado and New Mexico where coal bed natural gas makes up a good portion the gas production. Map 3 illustrates the distribution of natural gas production in the U.S.



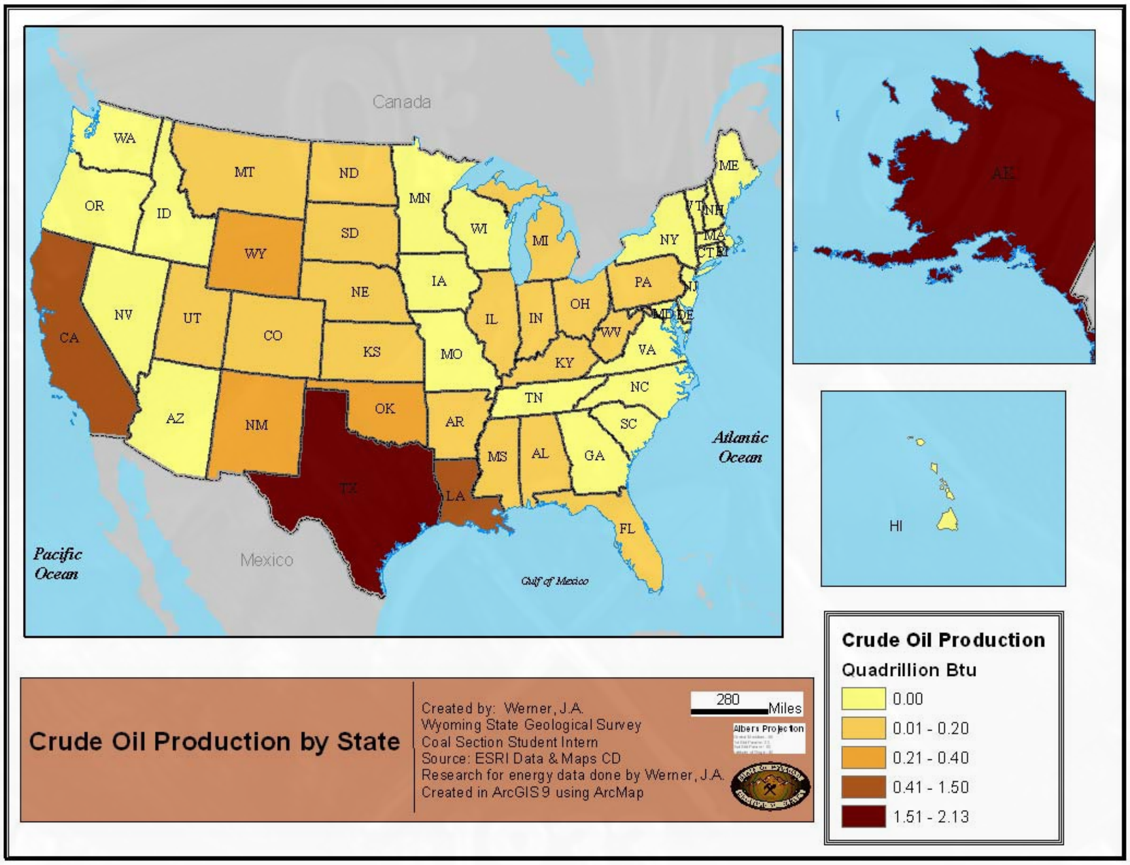
Map 3: Natural Gas Production by State

C. Domestic Crude Oil Production (Petroleum)

Crude oil is produced at oil fields around the country and offshore. It often occurs with natural gas in a petroleum trap that was shown in Figure 6. The oil is drilled for then pumped to be shipped to refineries to make gasoline or used for another application. Known petroleum reserves currently are not as large as documented coal reserves. Many potential drilling sites have many environmental, health and safety concerns to address before any drilling can occur, so recovery of these resources takes lots of time and money. Many analysts have been talking about when the petroleum reserve will run out since it is a limited resource. Crude oil is globally one of the most politically tied energy resources.

Figure 6: Offshore rig, Courtesy of www.oil-rig-jobs.com

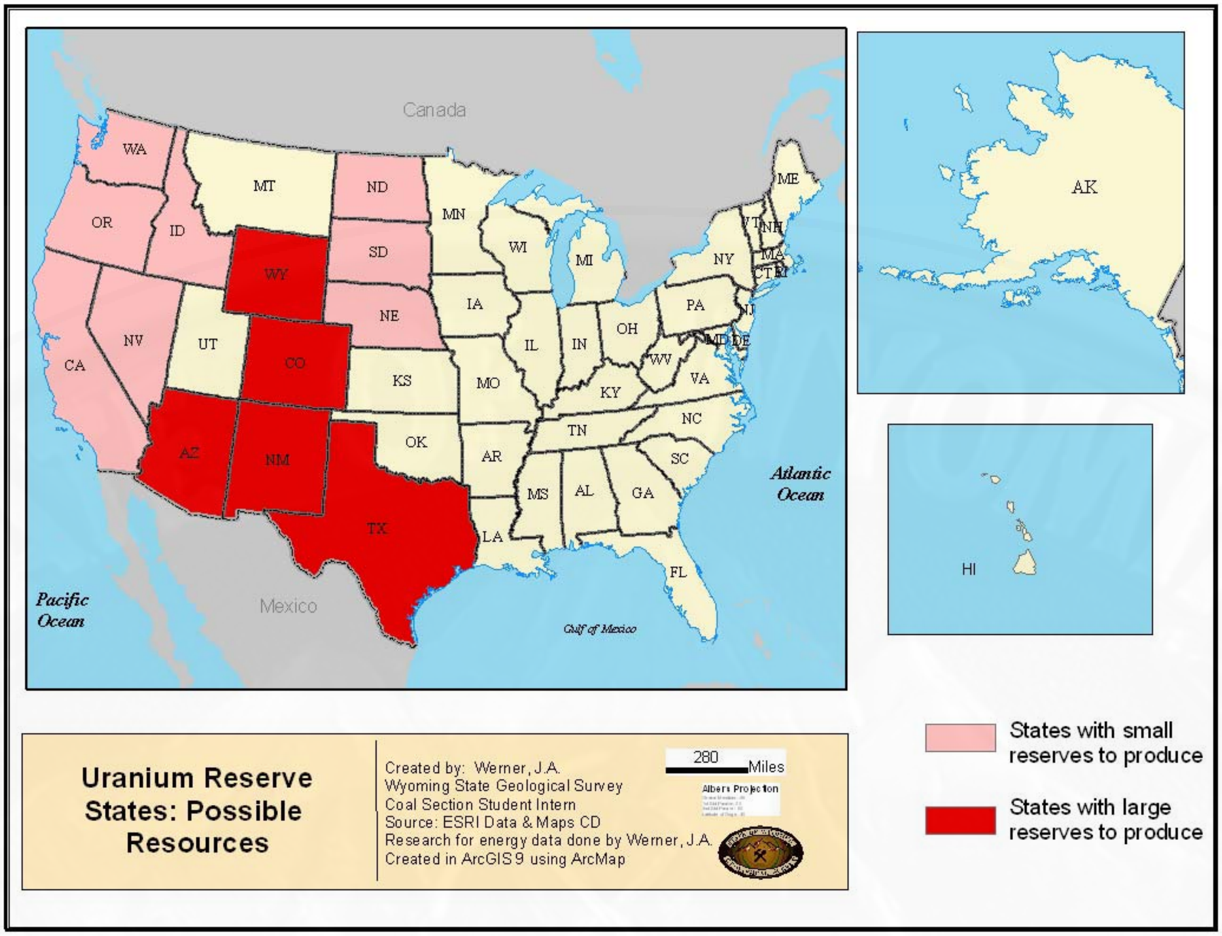
In the U.S. crude oil production is limited to only a few states. Texas and Alaska are dominant players in the oil market and both states have offshore drilling sites. The U.S. as a whole is the second largest oil producer in the world, but also the largest importer [17]. The oil produced by the nation is not enough to fuel the country. Crude oil constitutes 8% of the national total energy resource production as well as 79% of imported energy supply[38]. If we directly compare the amount of energy produced with our crude oil resources to our coal resources, the quadrillion Btu produced by the largest crude oil state are 70% less energy than the quadrillion Btus of energy produced in the largest coal state. Map 4 shows the distribution of petroleum resource production.



Map 4: Crude Oil Production by State

D. Domestic Nuclear Power

Nuclear power is created by using radioactive compounds to heat water and make steam for electricity generation. Uranium is a common fuel source for nuclear power plants, and it is mined in the western states. Several states in the southern Rocky Mountain region have been estimated to have large numbers of uranium reserves. Map 5 shows the states where large uranium reserves are.



Map 5: Uranium Reserve States

Much of the uranium mined in these states is exported out of the state or country. However, these states do not all have working nuclear reactors. Figure 7 is a good representation of a nuclear reactor in service. Nuclear power generation is regulated by the state in which the reactor resides, so the energy production is credited to the state where the reactor is located as opposed to where the uranium is produced. The major reserve states are highlighted in red. Wyoming, New Mexico, and Colorado have no nuclear reactors operating in state and they only export uranium. These states all have the potential to become a source for the uranium needed to produce power, so if nuclear power production was to rise the resources are available domestically.

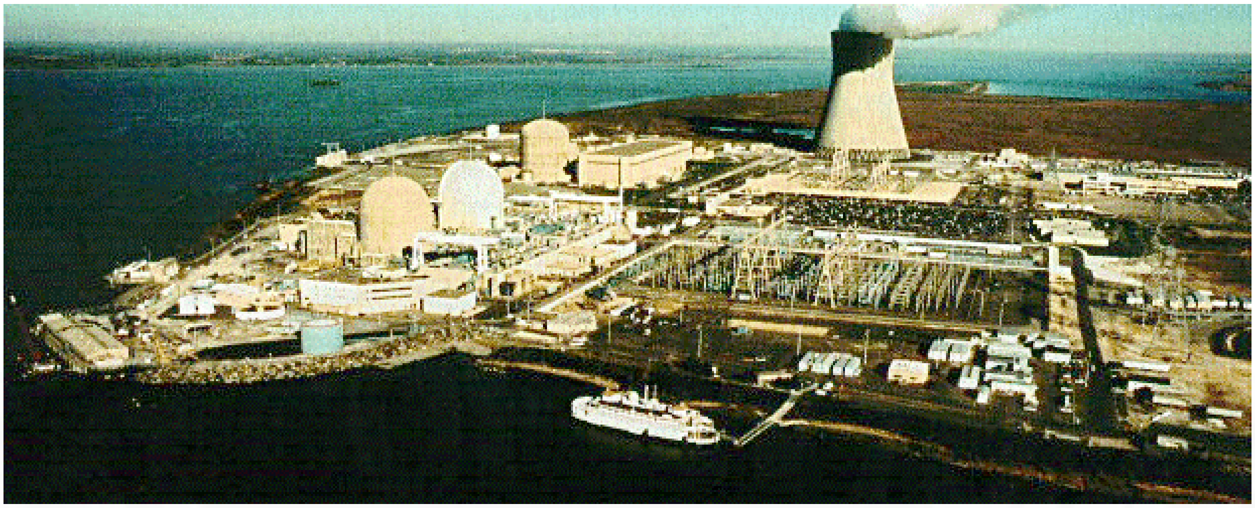
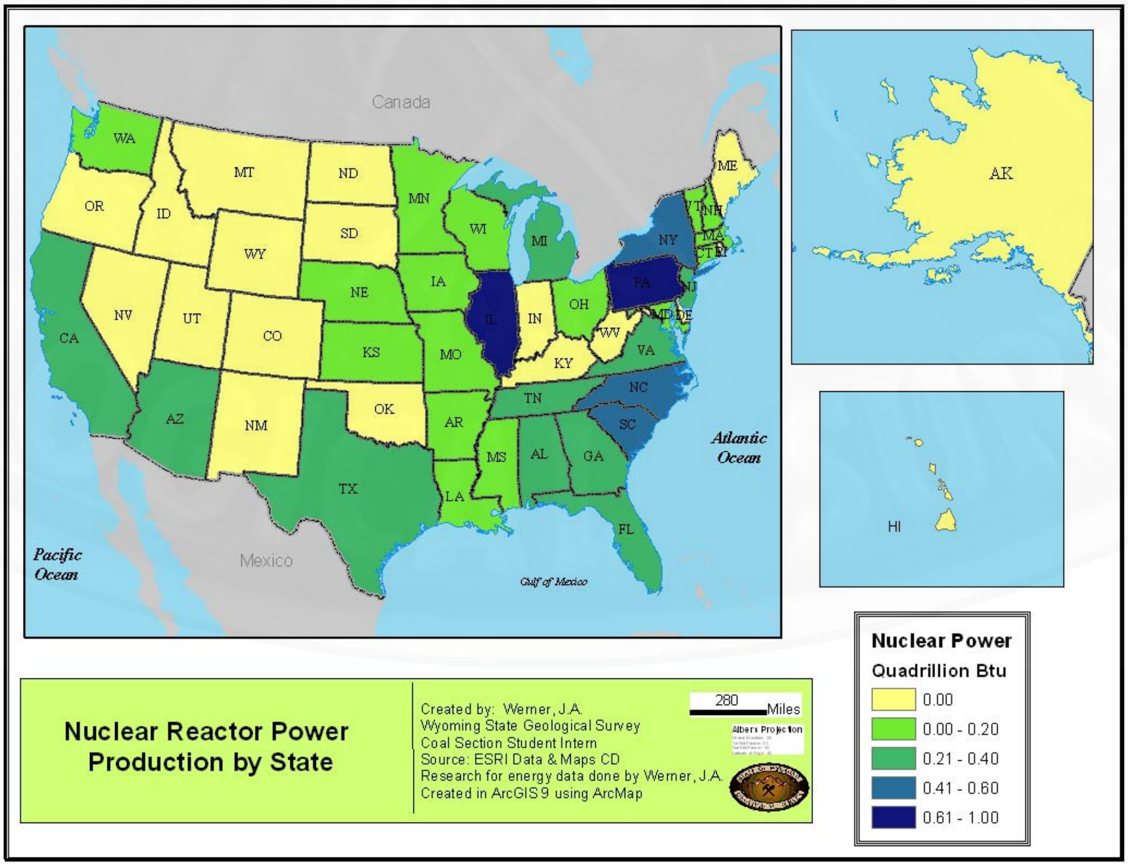


Figure 6: Working Nuclear Reactor, Courtesy of Sargent & Lundy/Power Engineering Salem and Hope Creek New Jersey

Currently, nuclear energy sources comprise only 8% of the total energy supply in the U.S[38]. Map 6 shows states that produce power from working nuclear reactors within state lines.



Map 6: Nuclear Reactor Power Production by State

Nuclear energy is a low emission power source, but there is concern over the disposal of spent nuclear fuel. Nuclear power plants generally use fuel rods that contain the radioactive compounds. Once these rods are used they still remain radioactive and have to be disposed of in a special way. The U.S. was proposing to store the spent fuel rods in Yucca Mountain, Nevada, but progress has been slow in actually using the site for storage. Yucca Mountain would be a deep geological storage tool. Radioactive wastes often stay dangerous for over 10,000 years so safe storage is an important issue.

E. Renewable Energies Currently Utilized

**The data used for all renewable energies is from the year 2002 as opposed to 2003. All other production, supply, and consumption data are from the year 2003. It was assumed renewable production data for 2003 would not differ significantly from the 2002 data. Data for the year 2003 will be available late 2005. **

Renewable energy sources currently play a small part in the national energy scheme, but almost all states participate in the exploration of renewable energies[29]. Renewable energy currently accounts for only 4% of the total national production, and the total can be further broken into each individual type of renewable.

Figure 8 shows a graphical representation of the breakdown. Hydroelectric produced the majority of the renewable energy at 79%. The next largest source is geothermal energy. Landfill gas, another source for methane gas is the third largest contributor.

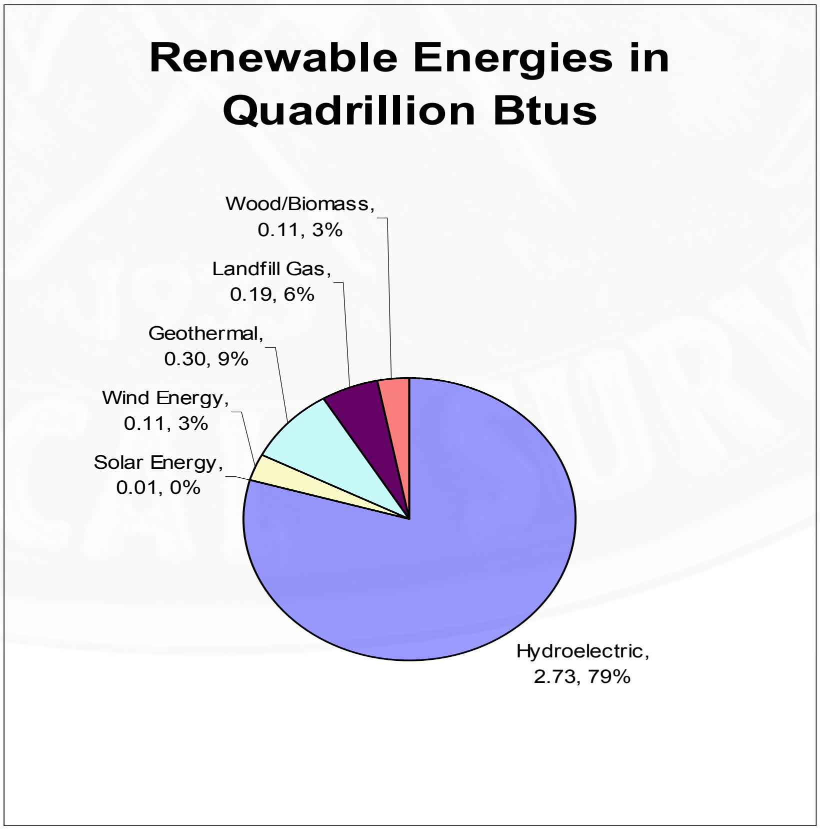
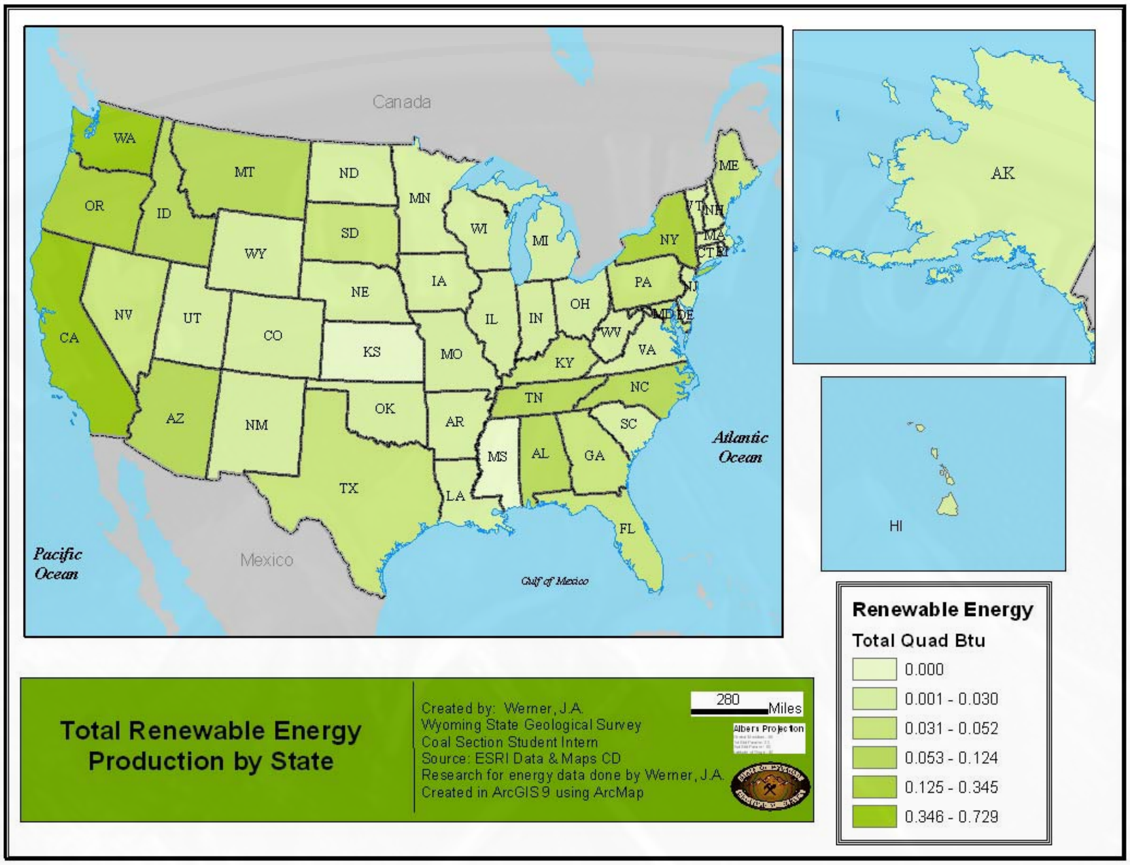


Figure 7: Renewable Energies Distribution

Map 7 illustrates the total amount of renewable energy produced in each state. These energy sources are also broken down into each type listed in Figure 8. They are represented on Maps 8 – 10.



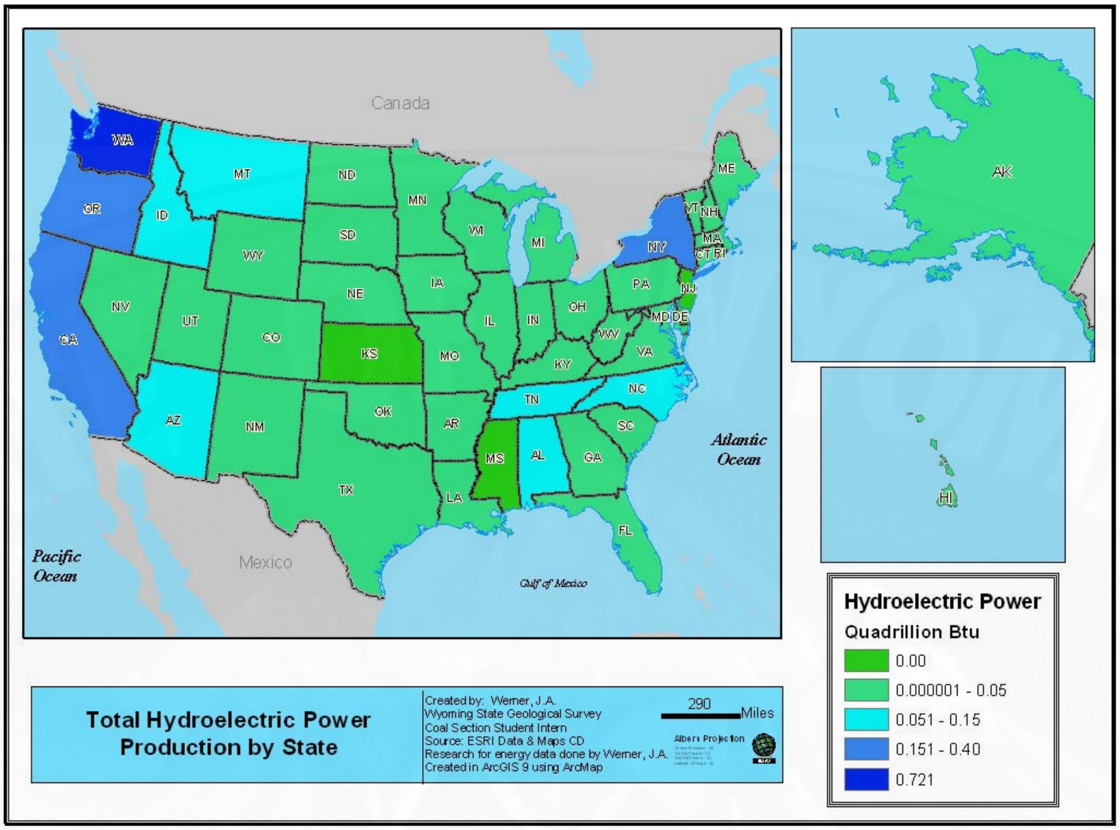
Map 7: Total Renewable Energy Production by State

Hydroelectric Power

Hydroelectric power is the most productive type of renewable power used today. A common type of hydroelectric power plant utilizes a dam on a river to capture water in a reservoir. The water released from that reservoir then flows through a turbine and spins it to generate power. The state of Washington is the largest producer of hydroelectric power.

Figure 8: Hydroelectric power generation dam, Courtesy of Army Corps of Engineers

Map 6 shows the national view of hydroelectric power production.

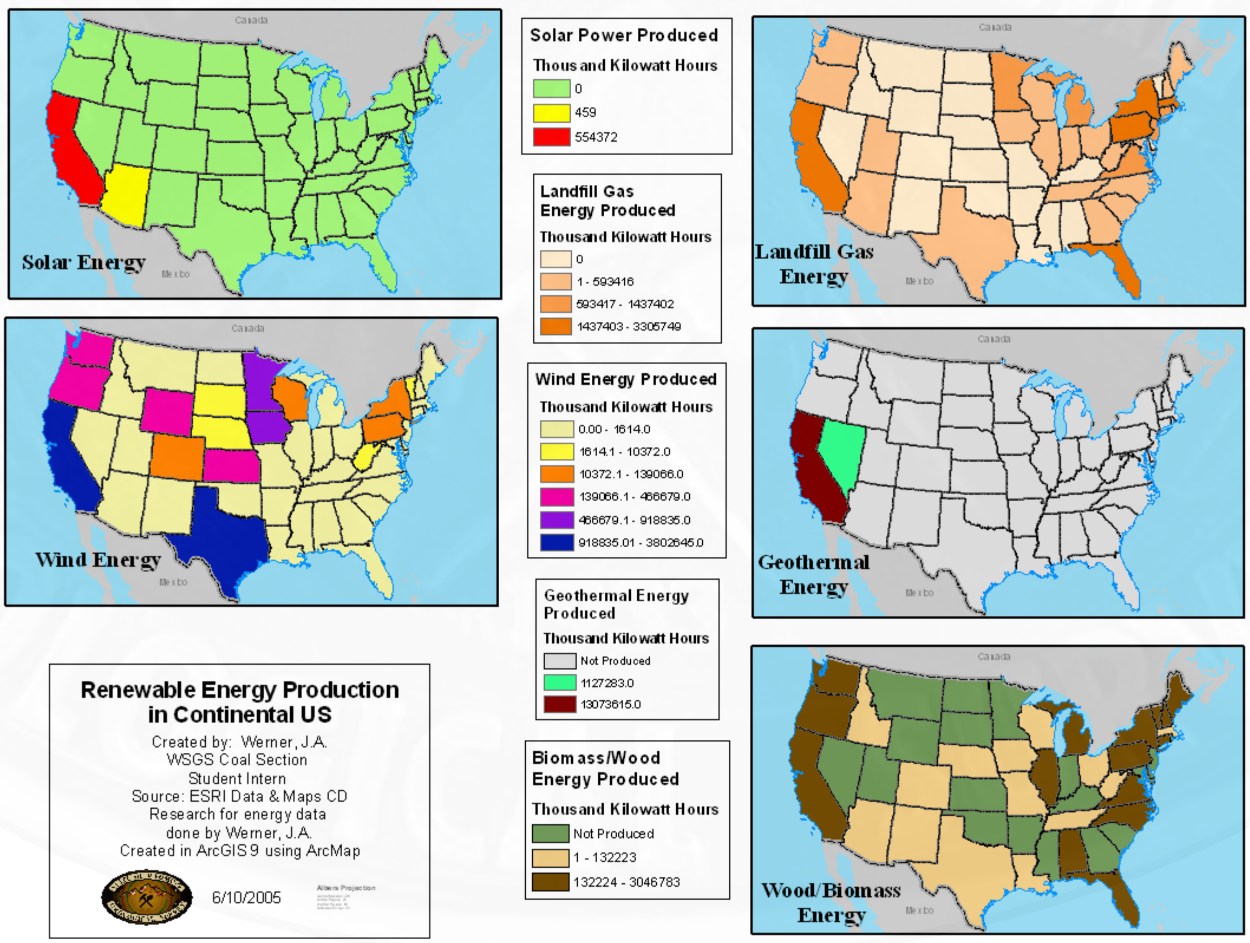


Map 8: Total Hydroelectric Power Production by State

Hydroelectric power is limited by geographic extent. Regions where it is not feasible to dam rivers or utilize tidal fluctuations have little to no potential growth in hydroelectric power.

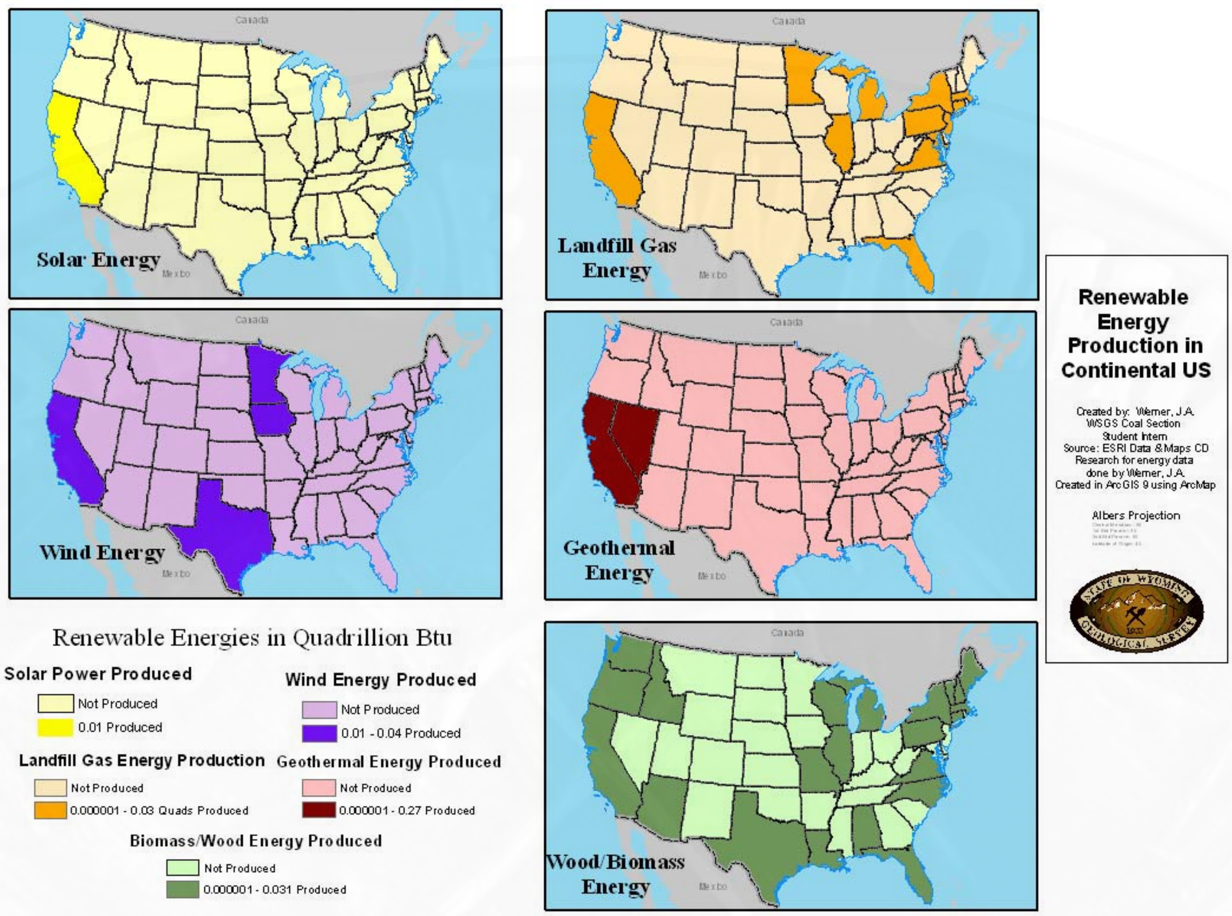
Current Solar, Wind, and Other Renewable Energies

Popular renewable energies include the use of solar cells to capture sunlight for power, wind turbines to create mechanical energy and the age old practice of burning wood for heat. These renewables can be very popular in parts of the U.S., but they are not feasible in other parts. The sun does not shine and the wind does not blow the same everywhere. Unfortunately, one of the major difficulties in the widespread implementation of renewables, like wind energy and solar energy, is the undependable resources needed. Cost of these technologies is another issue that needs to be addressed when considering renewable energy development. These energies are an important part of the solution for tomorrow's energy needs, but they alone will not solve the problem. Houses and companies that depend on these energies still have to have a backup power source if they need to have power all the time, especially during inclement weather. A day that has 20% cloud cover can result in only 50% of the normal power generation of a solar power cell[33]. These limitations mean that like any other energy source, renewables are not found in a usable amount everywhere. Since renewables are such a small contributor in many states it is valid to look at the quantity in both quadrillion Btu and in kilowatt-hrs. A kilowatt- hr is a common unit to measure consumption of electricity in. Many appliances say they will use x number of kilowatt-hrs, and chances are your electricity bill is measures in kilowatt-hrs. Map 8 shows the states involved in producing any measurable power from renewables in kilowatt–hrs.



Map 9: Renewable Energy Production in Continental U.S. in kilowatt-hours

Map 8 highlights only those states that produce a more substantial amount of renewable energy. These amounts are measured in quadrillion Btu.



Map 10: Renewable Energy Production in Continental U.S. in quadrillion Btus

California is a leader in producing energy from all five energy groups: Solar, Wind, Landfill gas, Geothermal, and Wood/Biomass sources. Unfortunately, the amount of quadrillion Btu produced in any state barely reaches an eighth of a quadrillion. We will now take a closer look at each of the renewable energies mentioned.

Solar

Solar energy is essentially capturing power from the sun that shines on the earth everyday. Panels made of special material, often silicon, are positioned so that they can capture the sunshine and convert that energy into power for us to use. Popular uses of solar energy are heating of residential homes and water heating. We have been using the sun's energy to heat long before solar panels were introduced by designing buildings to gain heat from the sunshine through the windows. Solar panels can be used in remote locations to supply a power source. Often solar panels are used in conjunction with batteries that store the energy to be used when the sun is not out. While the sun is a great source of energy, but technology used to capture that energy has low efficiency when it comes to saving that energy for us to use. Efficiency on most photovoltaic, sun capturing, cells is less than 10%[9]. A photovoltaic cell is shown in Figure 9. Solar energy is then only feasible in areas where the sun shines abundantly and where the solar cells won't be in the shadows of buildings. Some solar cells have the ability to rotate with the sun, always capturing as many rays as possible. Solar cells are expensive and installation should be done professionally to insure as much efficiency as possible.

Figure 9: Courtesy of Robb Williamson, Photovoltaic cell at Oberlin College [23]

Wind Power

Wind turbines look like large streamlined windmills. They create energy by turning in the wind. When the propellers turn, mechanical energy is created. This energy can then be harnessed and sent on power lines to be electricity for cities and towns. The wind has to be blowing within certain speeds for the turbines to work. Not all places see wind frequently enough to harness the power economically and with dependability. Wyoming is a state where wind farms are feasible, and we have several operating wind farms. AES SeaWest Inc. operates a large wind farm facility know as Foote Creek Rim near Arlington. The wind turbines all face west towards Elk Mountain, where Native American legend believes that all the wind in the world originates[19]. Figure 10 shows some of the wind turbines on the site.

Figure 10: Wind Turbines at AES SeaWest Inc. Facility in Arlington, WY July 21, 2005 Picture by Nick Jones, WSGS

According to Gary McCarty from AES SeaWest Inc. the facility has 183 turbines that altogether have a capacity of 134.5 MW. The turbines have a minimum operating wind speed of about 4-5 mph and a cut off speed at gusts of around 65 mph depending on the model of turbine. The facility runs at an average of 35% efficiency and moves power to a 600 kV substation where it is distributed from[19]. Even with all of the turbines and transfer boxes around, wildlife and livestock continue to use the land around the turbines. Figure 11 shows a rabbit enjoying the shade from a transfer box on a hot summer day.

Figure 11: Rabbit enjoying the shade from a wind turbine power transfer box, Photo: J.A. Werner

The facility may someday expand to create even more power, but it is currently limited due to the lack of adequate sized transmission lines[19]. The lack of ample transmission line capacity and efficiency is a major downfall for development in all energy sectors around the U.S. However, these renewable energies are still being explored for supplemental use in many states because in a crisis every little bit helps.

Other energies: Landfill gas, Wood/Biomass energy and Geothermal energy

Other energy sources listed in Maps 9 and 10 include landfill gas, wood/biomass energy, and geothermal energy. These energies themselves make up a very small percentage of the total renewable energy supply. Landfill gas is cultivated by capturing it as it is released from the landfill. This gas is produced as a result of biodegradation of material disposed of in the landfill. Wells are put in the landfill so that the methane gas can be collected and brought to the surface.

Wood/biomass energy is utilized by either direct burning or conversion of the biomass into other fuel forms. Wood utilized for individual home heating is not recorded or reported. Wood and biomass can be burned in conjunction with coal for power generation. Biomass is predominately utilized for thermal output as opposed to electricity generation, but 96 U.S. electricity generation plants used both biomass and coal in a co-firing or dual-firing plant that consume the fuel based upon availability[29]. Conversion technologies are in development and include conversion of biomass to fuel ethanol.

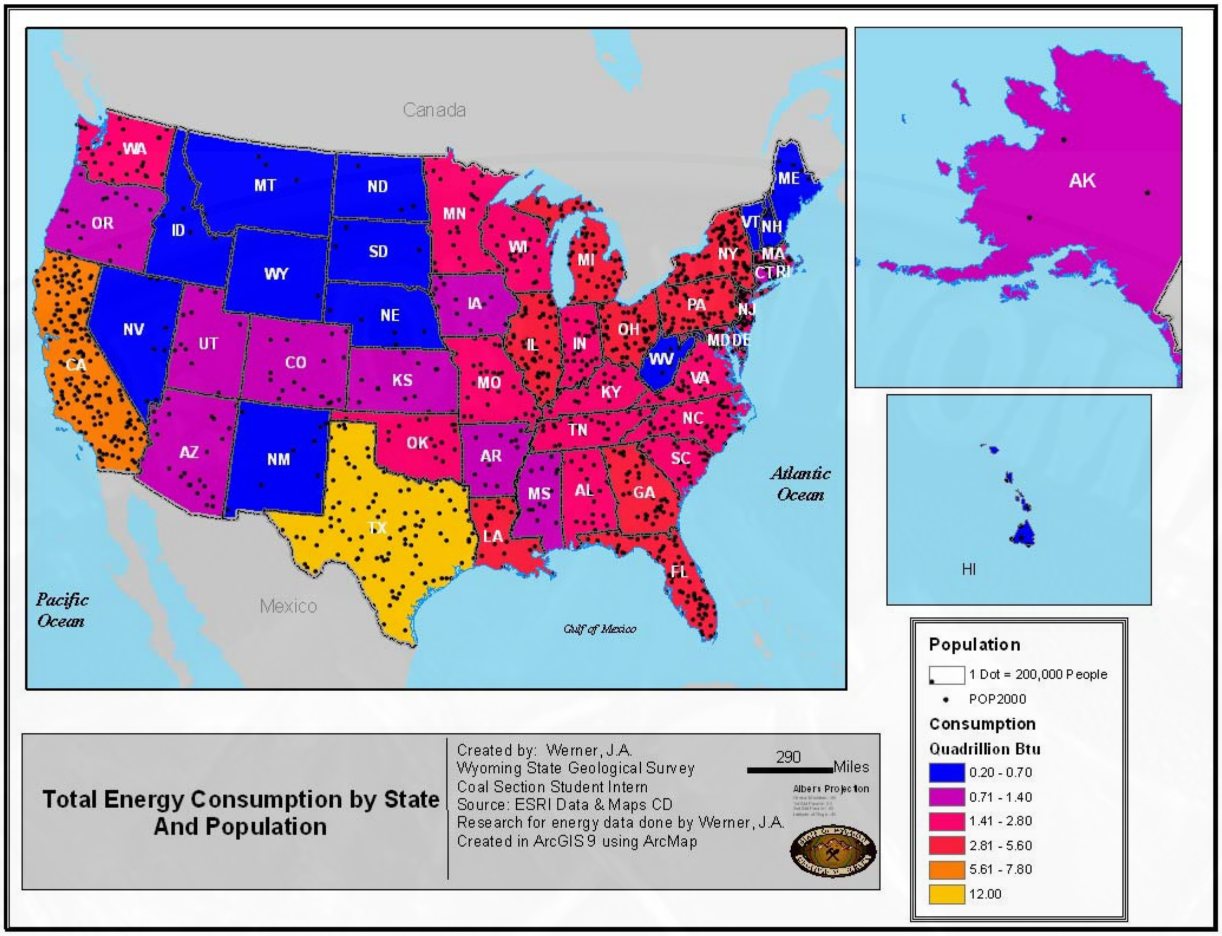
Geothermal energy technologies use the heat of the earth for many applications[15]. This heat is collected through geothermal vents. Direct-use applications, geothermal heat pumps, and electrical power production can all be uses of geothermal energy.

It has been estimated by many experts that the renewable energies will continue to play a small role in energy production. Electric companies will continue to utilize solar and wind farms as subsidiaries but not major producers. These renewable alternatives may have more of an impact on rural communities and vacation homes where they can aid in getting power to these places and save the land owners the costs of connecting lines to the grid.

III. Consumption of Energy in the U.S.

***For the purpose of this study, historical data has been graphed and analyzed to estimate the 2003 consumption values for each state.*[38] **

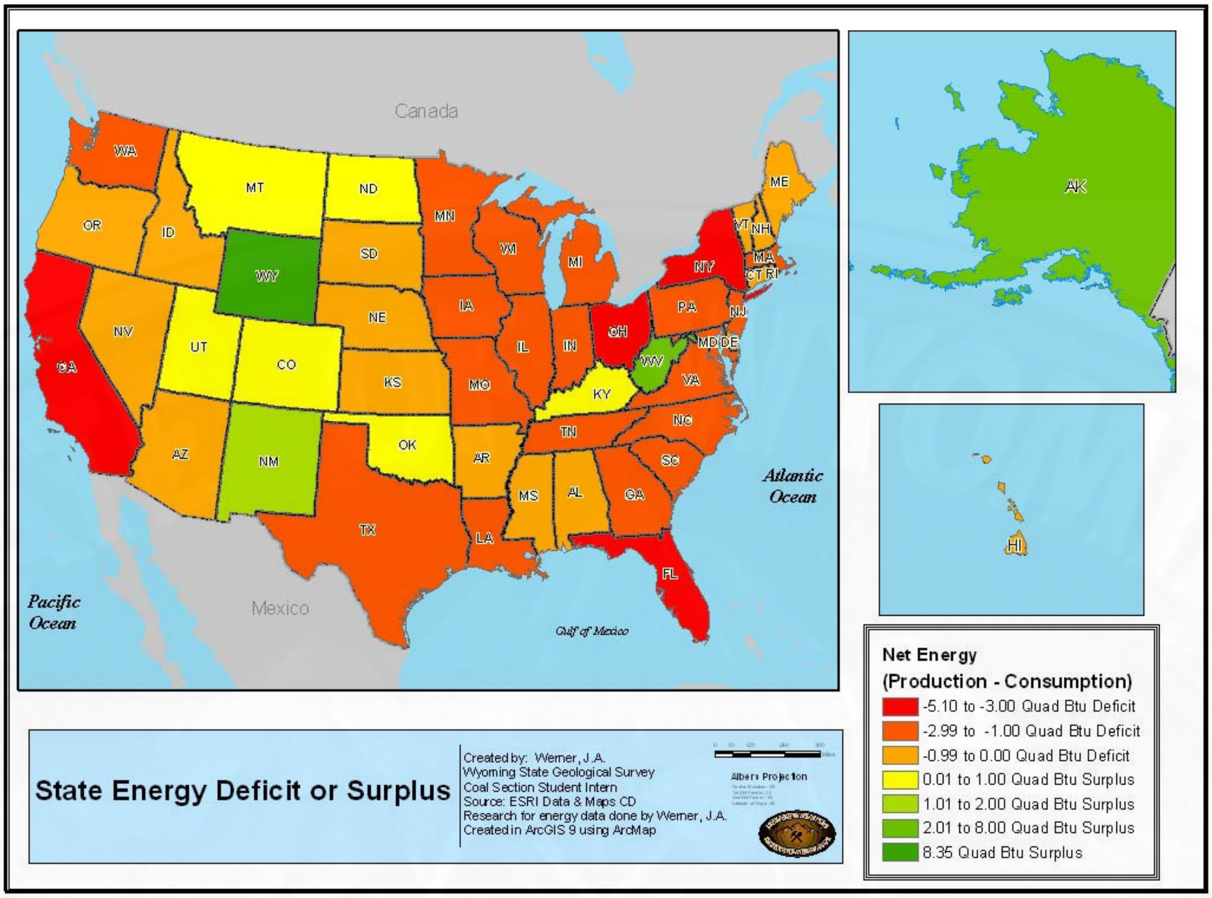
The U.S. as a whole has been slowly increasing its energy usage almost every year. For example the U.S. consumed 87.58 quadrillion Btus in 1993 and 96.38 quadrillion Btus in 2001[34]. In 2003 the nation as a whole consumed an estimated 98.2 quadrillion Btus[38]. The estimated state consumption is represented in Map 11. Population density dots are shown to emphasize that energy consumption is often a function of how many people are living in the state.



Map 11: Total Energy Consumption by State

A. Production versus Consumption

Next, production can be compared to consumption. The deficit or surplus of a state is found by taking the difference between the state energy consumption and energy production. Energy production by state was detailed in Map 1 on page 11. From Map 12 it is concluded that most states use imported energy like coal or natural gas from other states. Most states east of the Mississippi River have a negative number for a deficit. That means that they import energy from out of state.



Map 12: State Energy Deficit or Surplus

Wyoming has the largest surplus at over 8 quadrillion Btus of energy. This surplus is a result of low consumption as well as robust coal, oil and natural gas industries. Other states like Florida and most of the Eastern seaboard have a deficit of energy supplies in state compared to how many people they have. In total, the entire nation is lacking over 26 quadrillion Btus. This deficit is currently met with imported energy sources.

IV. Possible New Energy Technology Solutions to Gain Self Sufficiency

One of the current attitudes about further development of surface mines, oil and gas fields, dams, nuclear power plants, and transmission lines is that these resources will take up land and take away open areas. However, renewable energies also make a large foot print on the ground. As mentioned earlier, sacrifices and compromises will need to be made in an effort to move the U.S. toward self reliance in energy production, pertaining to land use and permitting issues. Again, regardless of the energy sector, and whether it is non-renewable or renewable, both a tremendous capital investment and land use allocation is critical in order to wean the U.S. off of imported energy sources. These simulations were done to examine the land area usage of some of the renewable resources.

The investigation is looking at what would happen right now if the U.S. had to become energy independent virtually overnight. What would we do? The proposed solutions have the following assumptions:

- Start with the assumption that nuclear power will double, supplying the nation with a 17% nuclear power supply as opposed to the 8% being supplied in 2003. This part of the simulated solution would take many years to implement and permit, but all of the possible solutions presented here it will take time to be in service. Simply put, doubling nuclear power generation would be a logical first step assuming that existing facilities could double the number of reactors without having to develop and build additional nuclear facilities elsewhere. This would be a large capital expenditure.
- If the nuclear power is doubled, the deficit would decrease to 19 quadrillion Btus, or 20% of what is needed by the U.S. as of 2003[38]. This deficit is what remains of the imported quadrillion Btus, which is mostly crude oil.
- We are assuming a simplified solution by considering each renewable energy source independently.
- The replacement of the 19 quadrillion Btu deficit will more realistically be a consortium of increased petroleum exploration and production, upgrading of existing power plant capacity, increased coal production, accommodation of coal conversion facilities, upgraded hydro-electric power stations and an increase in the development and use of other existing renewable energies such as solar, wind and biomass.
- Since no new petroleum reserves are being considered in the simulated solutions, the transportation sector would theoretically see a redistribution of fossil fuel that was once used for other things now allocated to the transportation sector.
- Transmission lines would have to be upgraded no matter the electricity source.

- Remember this is only a hypothetical situation with limited scope that is looking mainly at replacing quadrillion Btu values with no real implication of which energy sector that the energy is going to.

The energy distribution for this simulated situation is illustrated in Figure 12. The deficit (20%) to be made up will be our focus.

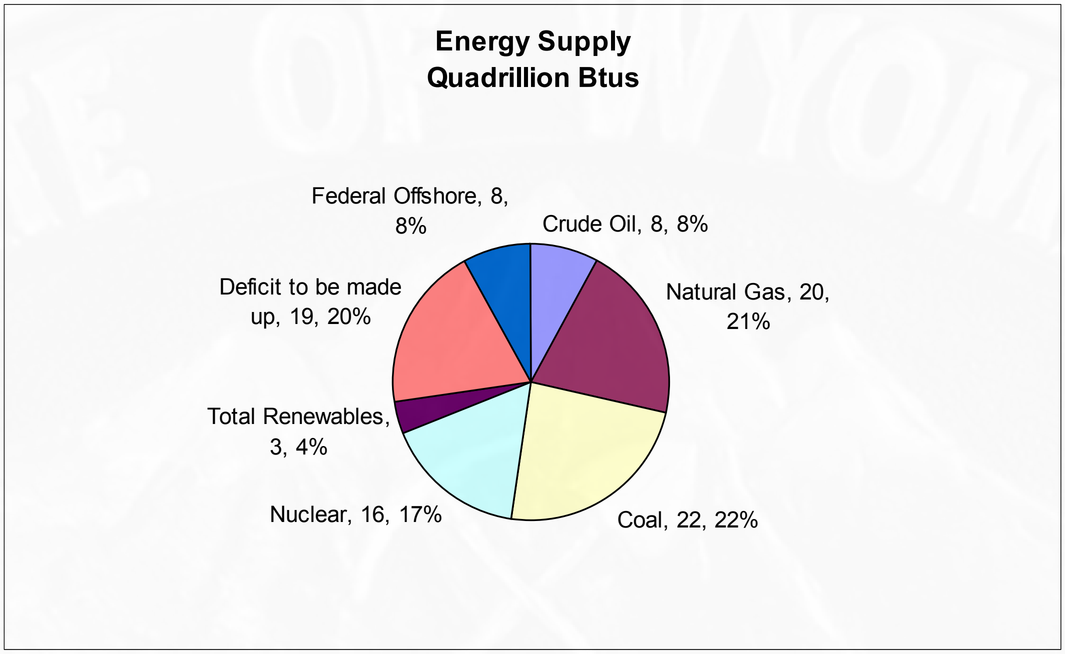


Figure 12: Energy Supply in Quadrillion Btus

This deficit will be filled with one of three possibilities considered: wind, solar or biomass in the form of switchgrass crops. Renewable energy solutions are known to have low or no pollution outputs and that makes them appealing, but they come at a high initial cost and with a tremendous need for large parcels of land. We will try to determine just how much land is needed if each energy source was used individually.

Some possible solutions that will not be studied in detail include:

- Further development of more landfill gas, which is limited by climate and region. In drier regions, landfill materials can remain unchanged for many decades. There is not enough moisture in the landfill for microbial growth which is required for the production of methane gas. Often landfill gas comes from closed landfills, and because not all areas are to the point yet of closing their landfill, the gas is a limited resource.

- Hydroelectric power will improve only with upgrades; no new facilities are expected to be constructed. Hydroelectricity generating plants on rivers are facing adversity because of both endangerment to fish life and the lowering of water quality downstream of the dam. These environmental and preservation issues would make the permitting and building of new hydroelectricity plants a more difficult process than it once was.
- Geothermal energy is geologically and geographically limited. Currently the only two states that utilize geothermal energy on a large scale, Nevada and California, are likely the only states that ever will use the energy. This is assumed correct for the purposes of this hypothetical situation.

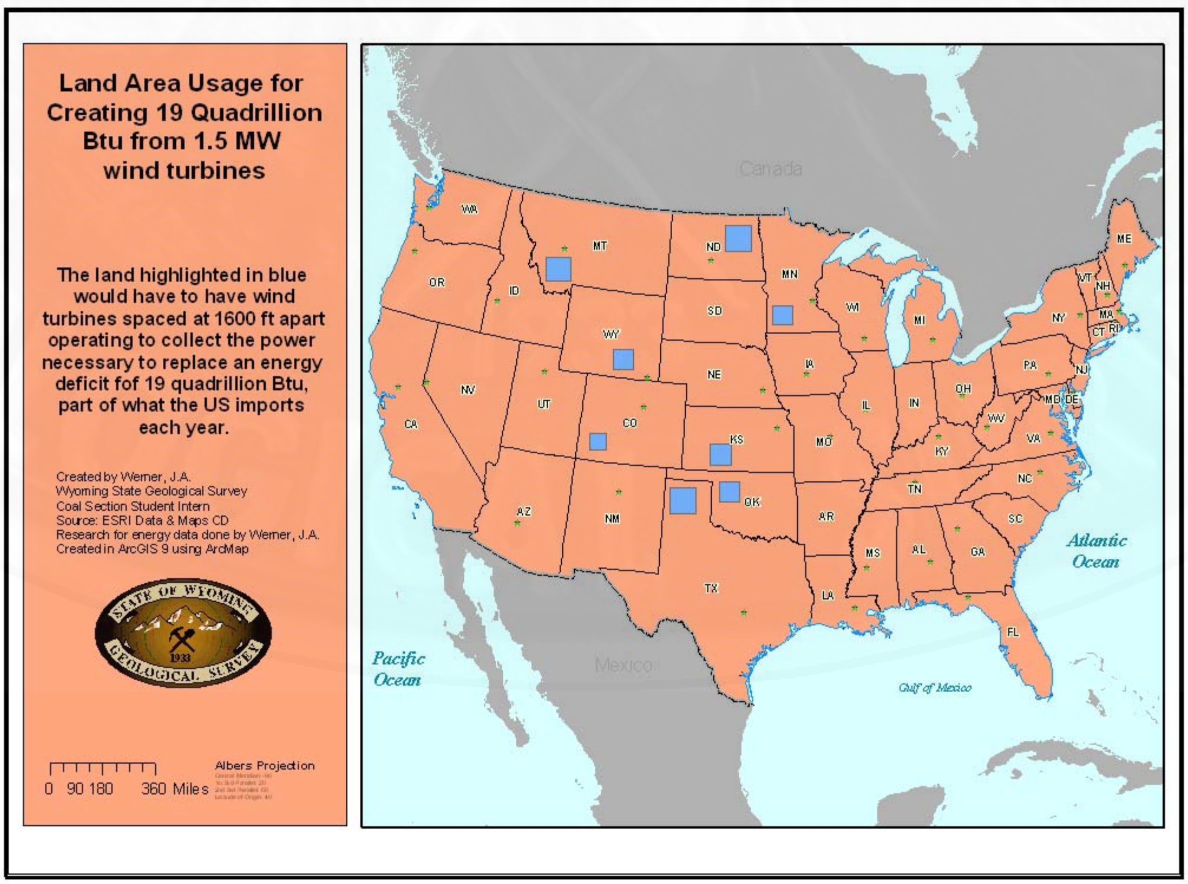
A. Wind Energy Scenario

The implementation of more large wind farms is one possible solution to fulfill a 19 quadrillion Btu deficit. These farms would consist of utility scale horizontal axis wind turbines. Large turbines that have a 77 meter rotor blade diameter and a capacity of 1.5 MW could be used on suitable land, and 19 quadrillion Btus could be generated. General Electric's 1.5sle wind turbine was chosen, as it is a popular wind turbine for utility electricity generation around the world[1]. The turbines would operate at wind speeds of 3.5 m/s (7.8 mph) to 25 m/s (55.9 mph)[1]. [The turbines utilized for this estimation are in no way endorsed by the WSGS, they are simply an example of a popular wind turbine.]

The total number of new turbines required to produce the 19 quadrillion Btus (1,855,287,570 megawatts) needed would be roughly half a million (515,358 turbines). It is estimated that the wind energy project would cost about $773 billion dollars to manufacture based on the current asking price of $1000 per kilowatt capacity, and this figure does not include cost of construction and or the construction of additional power lines, which is beyond the scope of this study[3]. Remember the idea is to not replace existing electrical power generating facilities, but to build more, so the need for additional conveyance would still be a major factor.

Not only will the need for additional power transmission lines be a factor, but finding an adequate location for all of these turbines and acquiring all the land necessary would require additional time and money. An average lease on a farmland is $55 per acre per month to each farmer or rancher[3], and the total area of land required is 68,313,139 acres or 106,743 square miles. The total area was found assuming spacing between turbines of 1600 feet apart in rows 1600 feet apart. The turbines are spaced this far apart to allow for a safe distance between moving rotors and to prevent wind shadowing. If all the necessary land was leased, the lease payments on the 69 million acres would cost $45 billion per year.

Due to the large land area necessary and the fact that some of the best wind areas are also agricultural areas, the spacing between turbines allows for continued agricultural use. Also many states will be needed to create the best circumstances for the wind turbines. The wind farm would have to be spread around the nation because any given state only has a limited wind potential. All states that are chosen in Map 13 for probable wind farm sites have been shown in a study by Elliot et. al. in the "Wind Energy Resource Atlas of the United States" to be some of the best sites for possible generation of wind electricity[13]. Map 13 was created to give a general impression of the land area usage needed for a project of this magnitude.



Map 13: Wind Turbine Possible Sites and Land Areas

It is concluded then that while it may be possible to invest this much time, space, and money into a wind farm project, it is highly improbable to do it all at once. Overall, wind energy will be a component of the solution, but on its own is an impractical solution to the overall issue. In all reality, additional wind energy projects could potentially contribute double the energy they produce today, however that total would only amount to 0.22 quadrillion Btu, a far cry from the proposed needed 19 quadrillion Btu.

At a much smaller scale, individual utilization of wind energy is much more practical than commercial utilization. Incentives and tax credits to small businesses and homeowners who incorporate wind or solar derived energy will help tremendously to spread the burden of cost. At the scale of the individual, homeowners can take it upon themselves to implement these energy options and inevitably help with the issue. Today, costs for converting a residential home to renewable self generated power can run from 15 to 20 thousand dollars to use wind and solar power. However, storage of the produced power remains the biggest issue and since the wind might not always blow or the sun shine homes will still require some means of back-up power.

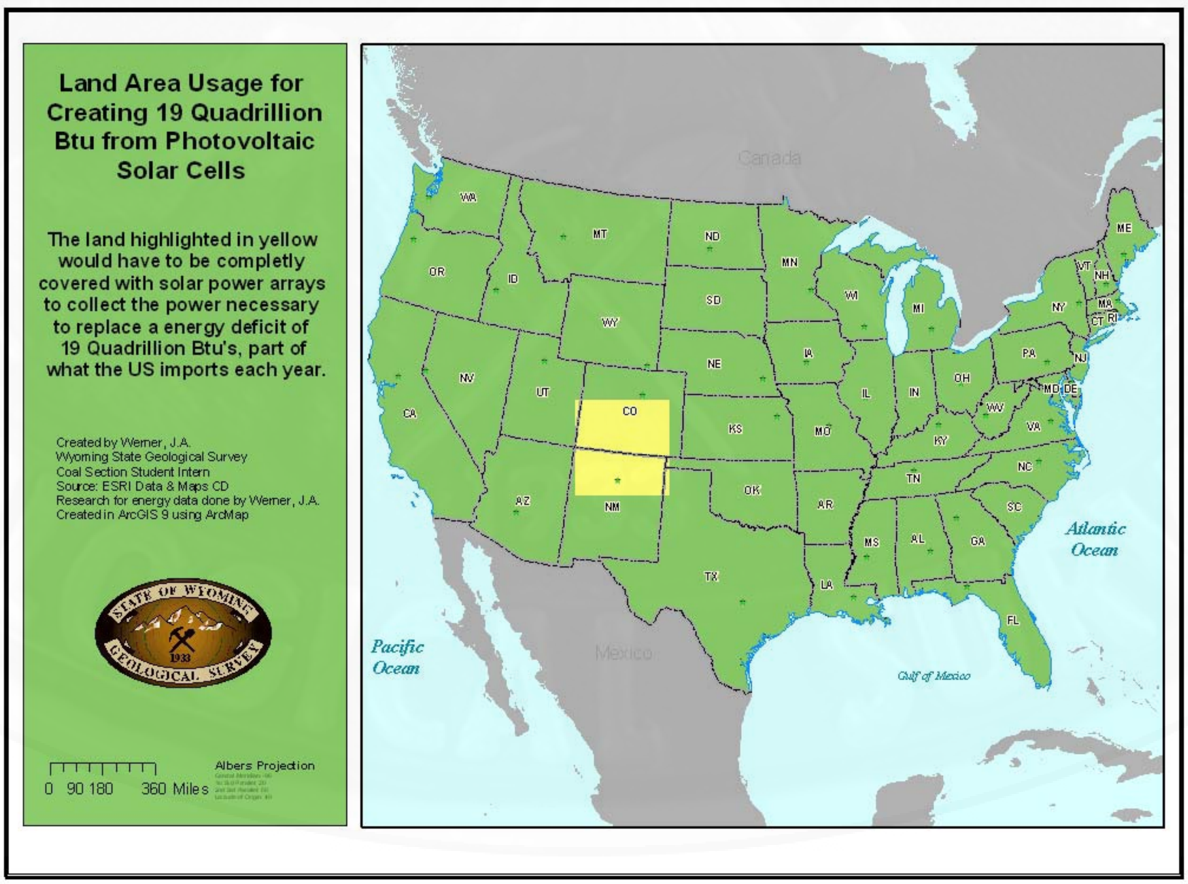
B. Solar Energy Scenario

The next scenario to consider is the completion of gigantic fields of solar panels. Sunshine is a powerful energy resource. The Union of Concerned Scientists has stated that "all the energy stored in the earth's reserves of coal, oil and natural gas is matched by the energy from 20 days of sunshine" around the world [9].

The solar panels chosen for this example are standard amorphous silicon (a-Si) photo-voltaic cell panels[18]. These panels are not overly expensive to manufacture, but still have a decent efficiency. The major problem with solar energy is that the current technology available to capture the sun's rays does so with little efficiency. A typical solar collector is about 2-10% efficient[24]. The mass majority of the energy that rains on the earth each day from the sun is lost.

The Solar Radiation Research Lab (SRRL) has a large project in Golden, Colorado set up to study solar energy collection. Different areas of the country have different irradiances, or how strong the sun's energy is. This study is based on the irradiance that could be expected in or around Colorado. The SRRL has found that the global monthly mean daily total sunlight irradiance is about 4600 watt-hours per square meter per day[24]. If the solar panel has an efficiency of 6%, the collected energy is only 100.74 kWh per square meter of panel. In order to create enough energy to account for 19 quadrillion Btus, 7111 square miles of solar panel is needed. These panels would all have to be southerly facing and be in direct sunlight. They have to be spaced as to not shadow each other, even at the lowest sun position. A 1 meter high stick will cast a shadow 11.43 meters as the sun is at its lowest point or the solar panels have to be spaced at a ration of 11:1 space: height[2].

Map 14 is a rough representation of how much land area would be needed for the solar panels if they were on posts and turned to the south. The panels would be in sets of two 3-square-meter panels with 1 meter side spacing for maintenance purposes. There are mountain ranges and communities in Colorado and New Mexico that would make this actual placement in some areas impossible, but the land highlighted in Map 14 is only meant to represent land area, not necessarily actual placement.



Map 14: Solar Energy Solution

Developers for a solar energy farm would have to find publicly acceptable sites with good resources and access to transmission lines. Potential sites can require several years of monitoring to determine whether they are suitable[23]. If the example area in Map 14 was actually chosen, everyone in southern Colorado and northern New Mexico would be displaced. Another deterrent of changing the U.S. over to solar power may be the price tag. In 1995, the cost of the a-Si (amorphous-silicon, a common material used for solar cells) cells was around \$7 per watt[18]. Inflation gives us a value of 2003 dollars of \$8.2 per watt[31]. For just the solar cells alone the cost of the project would total just over \$15 quadrillion. Solar panel fields at the current technology and price are not the answer for creating a lot of electricity for the U.S. If solar panel installation for power generation became the responsibility of individual home owners, over 613 million homes or buildings would have to participate to create the 19 quadrillion Btu needed to fill the domestic deficit of 2003. The maximum estimation of the number of suitable homes that satisfy the necessary criteria is around 50 million, which would only fix 8% of the energy deficit.

Solar energy is an expensive simulated solution. The photovoltaic cells utilized in this simulation have a low efficiency, as do all of the currently available technologies. This simulated solution also depends entirely on the fact that the sun will shine a good portion of the year. Climatologically, this assumption can not be proven concretely. Solar energy would also require a lot of land, some which may be difficult to establish up front. The solar energy simulated solution would also require several years for all the panels to be installed and come online. Utilizing solar panels on an individual home scale is a viable option, but considering land usage, citing restrictions, storage, and capital investment, it is less likely that large scale solar farms will be the ultimate solution.

C. Biomass Energy Scenario

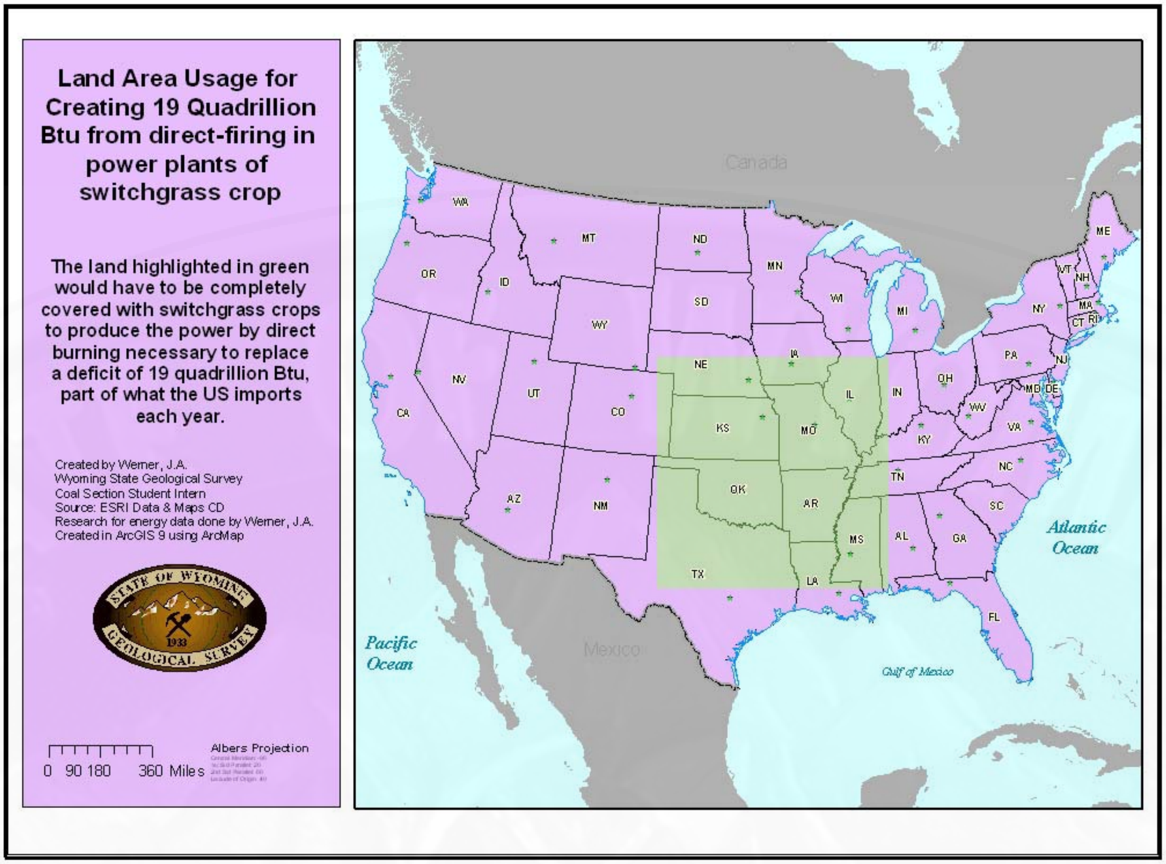
The last solution considered was the possibility of growing a grass crop called switchgrass for use in either power plants or for conversion to ethanol as a fuel. Switchgrass is a fast growing, thick grass that does not wear out the soil. It protects the soil from erosion and is a CO_2 recycling crop. It is expected that the CO_2 produced from burning the switchgrass is absorbed over the lifetime of the growing switchgrass[7]. The use

Figure 13: Measuring Switch Grass Growth, Courtesy Oak Ridge National Laboratory

of the biofuel, switchgrass, for power generation is already being studied across the Midwest. Switchgrass also has a relatively high heating value of 17.4 million Btu per 1000 kg, as found in the United Kingdom[7]. Based on this heating value, the amount of switchgrass that would have to be direct fired at a 100% efficiency plant would be 1.2 billion tons to create 19 quadrillion Btu. Experiments conducted by farmers indicate that the yield of a switchgrass crop can upwards of 4 tons per acre of land. Oak Ridge National Laboratories had a crop yield 15 tons per acre, but this is unlikely to be the case for the many diversified farmlands and growing conditions.

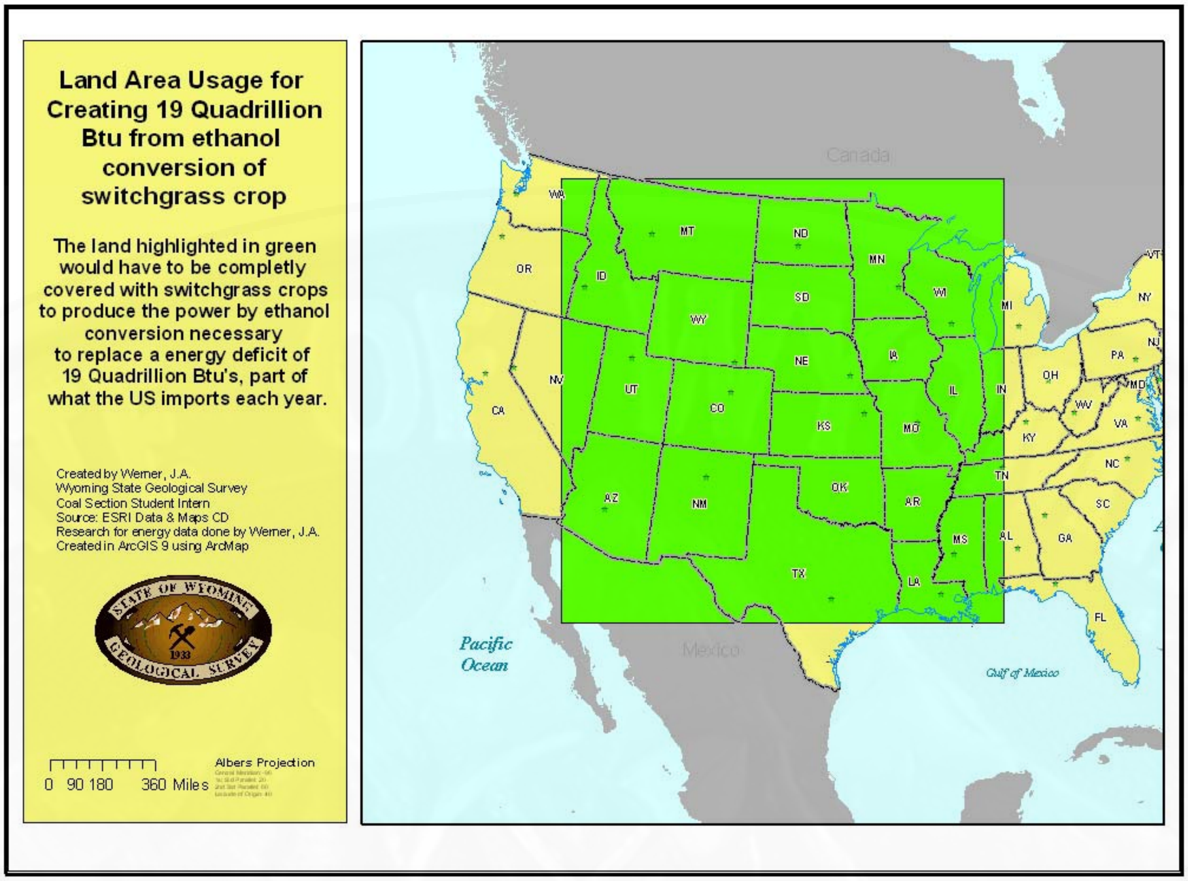
The first usage of the switchgrass studied is direct fire for electricity. The switchgrass would be harvested, dried and burned much like coal is now. Crops would have to be robust enough during the growing season to supply the power plants all year. Calculating the land needed at an average of 9 tons per acre to create the 19 quadrillion Btus needed gives a value of 658,458 square miles of land. Essentially the entire interior continental U.S. would need to be converted to one large field with service roads. Map 15 is an illustration of the land area that would have to be converted into switchgrass crop.

Map 15: Switchgrass Crop Area for Direct Fire Power Plant



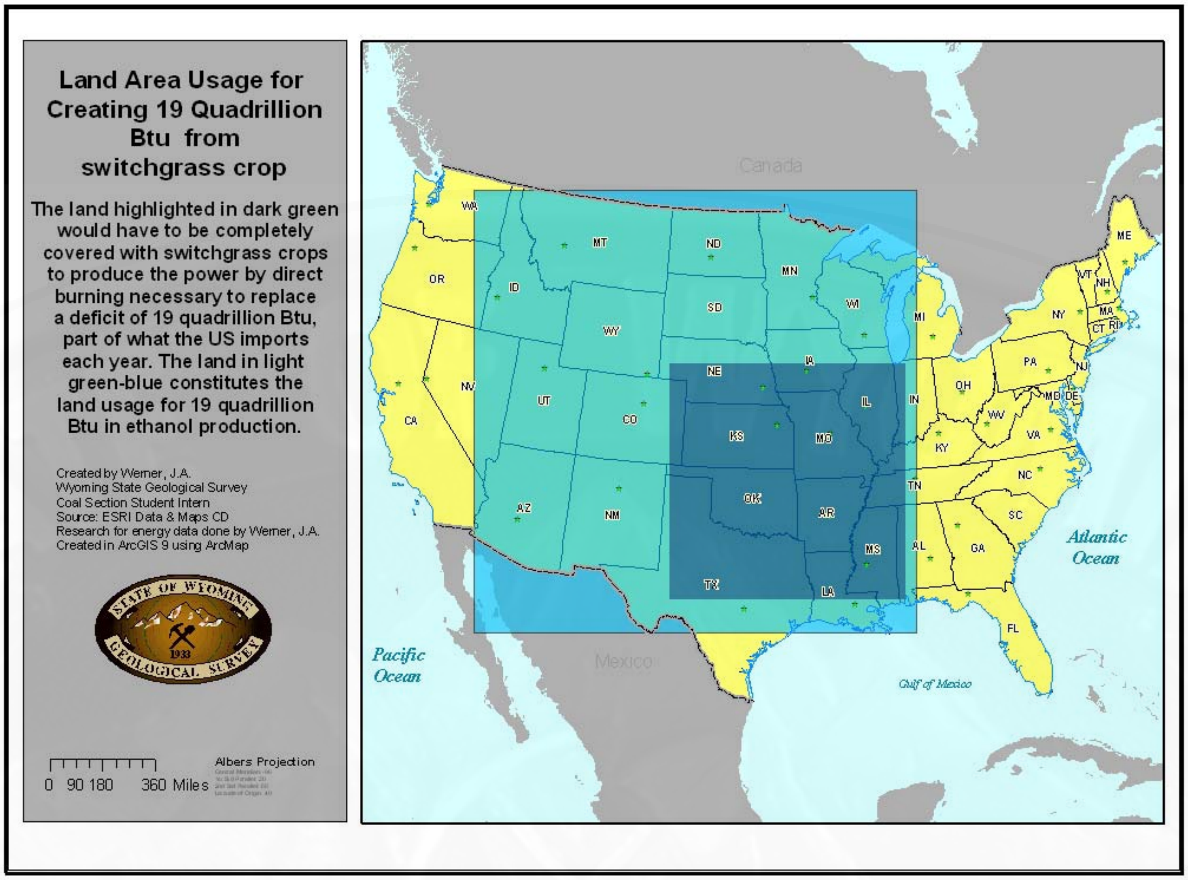
The part of the U.S. highlighted in green in Map 15 is the theoretical representation of a switchgrass crop and this region is where the best growing conditions for switchgrass are. No matter what the cost per ton of the switchgrass, it is unfeasible to convert this much of the U.S. to nothing but grass fields.

There is also the prospect of converting switchgrass to ethanol using advanced chemical conversion technologies. If a crop is converted directly to 19 quadrillion Btu of ethanol for fuel use, it would take about 4 billion tons of switchgrass to produce roughly 338 billion gallons of ethanol at a heating value of 83,961 Btus per gallon[7]. Conversion of the switchgrass to ethanol also takes energy to do, and this extra energy required above fulfilling the deficit was not accounted for in the calculation of land area needed. Map 16 illustrates the land area needed to produce 4 billion tons of switchgrass in a year.



Map 16: Switchgrass Crop Area for Ethanol Conversion

As it can be seen from Map 16, there is not enough land in the U.S., let alone suitable land, to produce the switchgrass needed. It would do no good to have fuel but no highways or towns to use the fuel in. Map 17 compares the land use areas from both possible uses of switchgrass. The direct fire use of the switchgrass in electricity production is the better option in terms of land use, but it still is not a feasible choice. Growing the switchgrass crops is not guaranteed and depends on many environmental factors. If a drought or other adverse growing condition is present in any given year, the energy supply would be significantly crippled.



Map 17: Comparison of Possible Switchgrass Solutions

D. Clean Coal Technology

The nation still has many opportunities by looking at the resources we have, like large coal reserves, and thinking of new ways to use them to create more energy. Currently coal constitutes 56% of the electricity sector's energy source use, and electricity generation is one of the main uses of coal[8]. Coal is a carbon intensive fossil fuel that emits pollutants like carbon dioxide (CO_2), sulfur dioxide (SO_2), particulate matter and mercury into the air when burned uncontrolled[8]. CO_2 is classified as a green house gas which is a group of air pollutants said to contribute to global warning. To increase the use of coal for electricity generation, new technologies for the capture of these pollutants are needed to keep the earth safe.

Instead of just capturing more pollutants and using the same technologies to convert coal to energy, new coal conversion technologies can be developed. Coal will continue to be a valuable and potentially cleaner energy source. Carbon capture and sequestration technologies can be used to generate electricity, enhance oil and gas recovery, and produce hydrogen as a byproduct[8]. Right now these technologies are on the drawing board. Existing power plants will need significant upgrades or replacement to boost efficiency and meet proposed air quality restrictions[8]. More research and development must be done on new technologies and incentives and policies from the government may help this along.

Clean Coal Technology projects receive funding from the Department of Energy, and many individual firms are working on other technologies for the cleaner and more efficient use of coal. Coal producing states have already been approached by different companies wanting to begin implementing clean coal technologies. These technologies could come in a variety of ways from proposed plants that would convert coal to cleaner burning diesel fuel to incorporated electrical power generating units. It is estimated that three barrels of diesel fuel can be generated per ton of coal[8]. This process thereby increases the value of coal and further satisfies environmental and future energy concerns. FutureGen is a recent initiative by the Depart of Energy and the current administration which entails the development and implementation of clean coal technologies[8]. Coal liquefaction and gasification technologies are not new; in fact they were developed during the 1930's and 1940's and later used by South Africa during the Apartheid. However, in the U.S. these are new ideas, and as a result investors do not have any tangible projects to relate too. In essence concepts such as FutureGen incorporate into one facility:

- mining
- coal conversion
- syn-gas (recycling gases after combustion to use for other energy sources)
- liquefaction
- electrical power production
- fertilizer manufacturing
- hydrogen production
- CO_2 production

Much like many alternatives to create new and better uses of the energy sources available to the U.S., utilizing clean coal technology will take capital investment and time to implement. Clean coal technologies would use a source of energy that will not run out in the near future unlike oil reserves. Coal is also a more dependable energy source as it does not rely directly on the current climate. Wyoming is an excellent source of low sulfur coal, and the state has land area available for new plants. The Powder River Basing in Wyoming is already and invaluable energy resource of the U.S., and other coal fields in the state are great candidates for coal conversion technology as well.

E. Electricity Transmission Lines

Electricity transmission lines in the U.S. need to be overhauled for the new millennia. Transmission lines transfer power in high voltage to reduce energy losses in the line. Most lines transfer power in 3-phase alternating current to the grid, but over long distances the power can be transmitted as high voltage direct current[12]. At the current technology used in the transmission lines, energy loss occurs between the place of generation and the user. If the transmission lines were made more efficient, less energy loss would occur and we would not be wasting energy that we may so desperately need. Also transmission lines were not designed to carry as much capacity as they can be carrying now. This would serve more people with the same amount of line as before. Installing additional transmission line is a detailed process that is also expensive. Concerns that must be addressed with transmission lines include efficiency, citing, easements, permits, environmental impacts, and capital costs. The Federal Energy Regulatory Commission (FERC) recently gave preliminary approval for a $300 million transmission line for 400 MW of additional capacity in California[14].

Developing more renewable resources will do no good if the power can not be transmitted to the people. As the lines are constructed today, many of them can not carry any additional power then they already are. This means that renewable resources may not have room available for them to be transmitted on the grid. We can use the cost of updating the California transmission line as an estimate of cost for adding additional capacity to the current lines. The cost to upgrade the power lines for to carry an additional 19 quadrillion Btu is around $158 trillion dollars another cost to consider.

F. Working Together for Tomorrow

As illustrated in Maps 13-17, no renewable energy can alone close the gap between domestically produced energy and consumed energy. There are many reasons why it does not make sense to put all our faith in renewable energy to bridge the gap. All of the renewable energy sources are highly dependant on the climate which the U.S. can exert no control over. Implementation of large scale renewable "farms" may be a large risk of capital investment due to the variability of the climate. Also, the duration of the mark on the land of these renewables would be a permanent. Mining operations are temporary (30-50 years), and after operations are complete the areas are reclaimed, and in many cases are more productive than they were prior to mining. The structures for solar and wind energy generation would become a permanent part of the landscape.

Renewable energies still can be an important component to the future of energy generation in the U.S. These technologies are great to use in remote locations where it is not feasible to run power lines too. The renewable technologies can bring choice to the electric consumer of which kind of generated energy to buy. Also the renewable energies can work right along side nuclear power plants and enhanced coal usage. One such distribution of new technologies is illustrated in Figure 14.

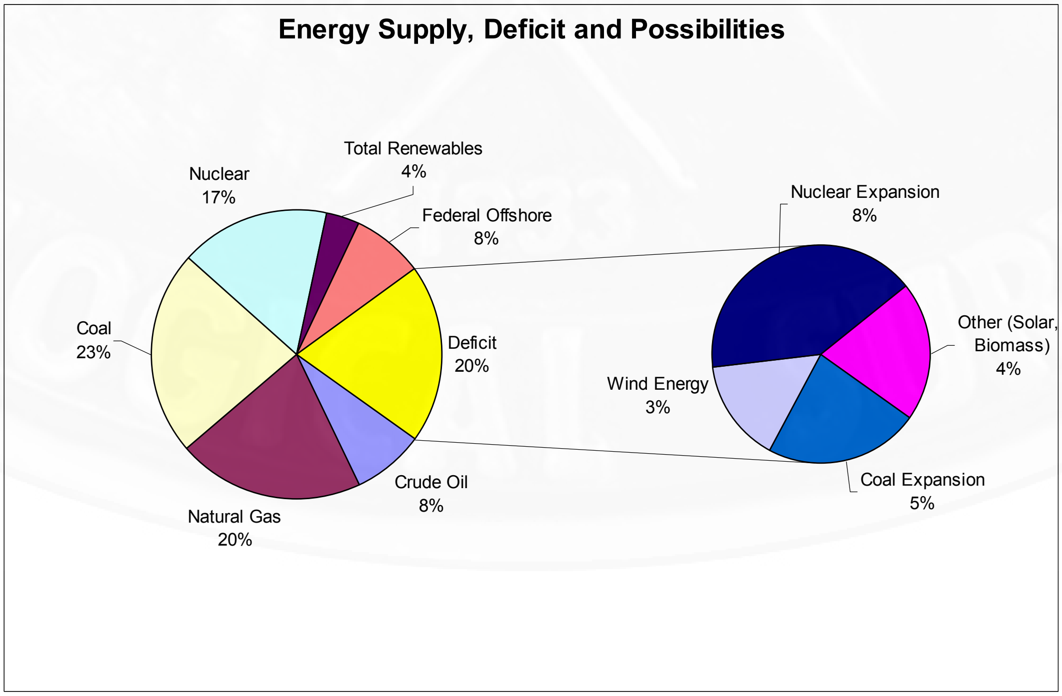


Figure 14: Energy Supply, Deficit and Possibilities

There are many combinations that new technologies can be arranged in to meet the energy demands of the nation. The important thing is that these technologies are developed and improved so that when it is time for them to step up to the plate they can.

Wyoming will be a very important energy supplier for the nation. The state has the possibility of having a good deal of energy from renewables such as wind and solar, and it has large reserves of coal bed natural gas and coal. Wyoming coal could be a good source for proposed coal to diesel plants, and the state has room to accommodate these facilities near mines to eliminate the transportation expense. Overall the state of Wyoming has everything needed to build a strong energy source for the U.S. to depend on.

V. Conclusion

The U.S. has a growing domestic energy deficit because population and industries are utilizing more energy than what can be produced inside the country. Imported energy in various forms like petroleum and natural gas currently fill this deficit. If the U.S. is moving toward having enough energy resources to supply the country, renewable energies will play a role. However, renewables will only be part of the solution. Factors such as reliable generation, cost, energy storage, transmission, and efficiency are all things that must be considered when studying the feasibility of implementing large scale renewable energy generation.

Large commercial-scale development of renewables is unworkable in terms of equipment, and also not viable in terms of land area availability. Farmers and landowners may not want thousands of wind turbines to dot their land. Residents of certain states will most likely not want to be kicked out of their homes and recreation areas so that massive fields of solar panels can be constructed. Rural and vacation homes may be able to utilize these renewables in an economic way, but the nation as a whole needs to invest in a diverse energy portfolio.

The nation must look at viable economic solutions. Renewable energies will be an important subsidiary piece of the solution, but so will other technologies like the further development of coal-conversion for both fuel and electricity. Coal is one of America's greatest resources, and has been shown to be flexible enough to satisfy many forms of energy that Americans consume. Coal bed natural gas, once a wasted source of methane gas, is now used by the nation for heat and electrical generation. Coal can be converted to diesel fuel for transportation. The feasibility of the implementation of new technologies for clean coal use is much better than converting the entire country to renewables.

There are many possible combinations that could fill the deficit. Additional coal and nuclear energy sources are major. Advances in energy production technology and future legislation will play key roles in the solution to eliminate our foreign energy dependence. Economics are a prominent in the decision making process for deciding what type of energy resource to use. Some solutions are more economic than others making them a better choice for further examination. The current government energy bills include tax breaks and credits for renewable energies and conservation efforts, but only time will tell if any of these bills will have a major impact on energy resources in the U.S. The tremendous overall cost of development of new technologies and improvement of old technologies will be necessary in order for the nation to continue the lifestyle it enjoys today.

The U.S. is facing major decisions in energy supply. There is no easy and quick answer, nor is there an inexpensive answer. The nation has a need for more energy resources and time and money will be required to study the feasibility of these resources. A delicate balance will be formed with environmental concerns and economic development. In conclusion, the road to our energy independence will require diligence, foresight, creative thinking and tremendous effort. It will involve land developers, scientists, industrialists, engineers, manufacturers, suppliers, and everyone in between. The future will see more conservation, increased efficiency, enhanced storage and better conveyance of all energy resources.

VI. Updates

On July 29th, 2005 the Senate passed the Energy Policy Act of 2005 by majority vote. The bill includes tax breaks for the oil and gas industry as well as raising the renewable energy bar standard by requiring at least 7.5 billion gallons of ethanol and biodiesel to be used in the motor fuel supply by 2012 [22]. The bill also contains legislation that will promote energy conservation and efficiency and improved energy transmission and distribution while helping promote new technologies that promise greater efficiency and environmental protection[20]. Secretary of Energy Samuel W. Bodman also says "By encouraging greater efficiency, increased energy production in an environmentally responsible way and encouraging investment in our nation’s outdated energy infrastructure, this bill takes a balanced approach and embodies the right priorities for the American people." Overall if this new bill is signed by President Bush the U.S. will be on its way to finding new energy solutions for the world of tomorrow.

Hurricane Katrina in August of 2005 has brought to the fore front of everyone’s mind the effect on the U.S. that a shortage of petroleum has. The hurricane destroyed several oil drilling rigs and transmission pipelines. The time has come for the nation to put more attention into conserving gasoline and eventually replacing it in the nation’s economy.

References

1. "1.5sle/1.5sl/1.5s/1.5se wind turbines." 1.5 MW Wind Turbine Technical Specifications. General Electric. 08 Jul. 2005 <http://www.gepower.com/prod_serv/products/wind_turbines/en/15mw/specs.htm>.

2. Adkins, Jeff. "Shadow Stick Project on March 20" 13 Mar 2005. Astronomy and Space Science: Blog for Jeff Adkins' Astronomy Classes. 28 May, 2005 <http://astronomyteacher.blogspot.com/2005_03_13_astronomyteacher_archive.html>

3. American Wind Energy Association "Frequently Asked Questions", 13 Jun, 2005 <http://www.awea.org>

4. "Annual Coal Report 2003." DEO/EIA-0584 (2003). DOE/EIA. 26 May. 2005 <http://www.eia.doe.gov/cneaf/coal/page/acr/acr.pdf>.

5. "Annual Energy Outlook 2005." DOE/EIA. January 2005. 24 May 2005 <http://www.eia.doe.gov/oiaf/aeo/forecast.html>.

6. "Approximate Heat Rates for Electricity." DOE/EIA. 26 May. 2005 <http://www.eia.doe.gov/emeu/mer/pdf/pages/sec12_6.pdf>.

7. "Biofuels from Switchgrass: Greener Energy Pastures" Oak Ridge National Laboratory (ORNL) Sept. 1998, 2 Jun 2005. <ftp://bioenergy.ornl.gov/pub/pdfs/biofuels-switchgrass.pdf>

8. "Challenge and Opportunity: Charting a New Energy Future." Future of Coal Working Group. Energy Future Coalition. 02 Aug. 2005 <http://www.energyfuturecoalition.org/preview.cfm?catID=67>.

9. "Clean Energy Backgrounder: How Solar Energy Works." 12 2004. Union of Concerned Scientists. 16 Jun. 2005 <http://www.ucsusa.org/clean_energy/renewable_energy/page.cfm?pageID=79>.

10. Craig, Stevens. Secretary of Energy's Statement on the Senate Passage of the Energy Bill. 29 Jul. 2005. Department of Energy. 02 Aug. 2005 <http://www.energy.gov/engine/content.do?PUBLIC_ID=18403&BT_CODE=PR_PRESSRELEASES&TT_CODE=PRESSRELEASE>.

11. "Electric Power Monthly March 2004 With Data for December 2003." DOE/EIA-0226 (2004/03). DOE/EIA. 26 May. 2005 <http://tonto.eia.doe.gov/ftproot/electricity/epm/02260403.pdf>.

12. "Electric power transmission." Wikipedia. CD_ROM. ed. 2002.

13. Elliot, D.L., C.G. Holladay, W.R. Barchet, and H.P. Foote. "Wind Energy Resource Atlas of the United States." Oct 1986. 15 Jun 2005 <http://rredc.nrel.gov/wind/pubs/atlas/titlepg.html>.

14. Federal Energy Regulatory Commission, . "FERC Accepts Rate Principles Proposal for San Francisco Bay Transmission Line." Transmission and Distribution World 21 Jul 2005. 01 Aug 2005 <http://tdworld.com/news/FERC-San-Francisco/>.

15. "Geothermal Topics" Energy Efficiency and Renewable Energy (EERE)/DOE. 14 Jun, 2005 <http://www.eere24.energy.gov/RE/geothermal.html>

16. Kitching,Harold. "Commissioner: Line decisions reach way into an area's future." Tri Valley Central 28 Jul 2005. 01 Aug 2005 <http://www.zwire.com/site/news.cfm?newsid=14941990&BRD=1817&PAG=461&dept_id=68561&rfi=6>

17. "International Energy Outlook 2004." DOE/EIA -0484(2004) 13 Jun, 2005 <http://www.eia.doe.gov/oiaf/ieo/index.html>

18. Mah, Olivia. "Fundamentals of Photovolatic Materials." National Solar Power Research Institute, Inc. 21 Dec 1998. 16 Jun 2005 <http://userwww.sfsu.edu/~ciotola/solar/pv.pdf>.

19. McCarty, Gary. Personal Interview. 21 Jul. 2005

20. Montague,Jim. "NEMA hails passage of U.S. comprehensive energy bill." Control Engineering 02 Aug 2005. 02 Aug 2005 <http://www.manufacturing.net/ctl/article/CA631024?spacedesc=latestNews>.

21. "Monthly Nuclear Utility Generation by State, 2003." 2 April 2004. DOE/EIA. 26 May. 2005 <http://www.eia.doe.gov/cneaf/nuclear/page/nuc_generation/usreact03.xls>.

22. "Nelson: Passage of Energy Bill is a Win-Win-Win for Nebraska." Southwest Nebraska News 1 Aug 2005. 02 Aug 2005 <http://www.swnebr.net/newspaper/cgi-bin/articles/articlearchiver.pl?157695>

23. Nogee, Alan, Steven Clemmer, Bentham Paulos, and Brent Haddad. "Powerful Solutions: 7 Ways to Switch America to Renewable Electricity." Jan 1999. 27 May 2005 <http://www.ucsusa.org/documents/psfront.pdf>.

24. NREL, "About solar energy." Clean Energy Basics. 13 Jun, 2005 <http://www.nrel.gov/clean_energy/solar.html>

25. NREL, “Introduction to hydroelectric power.” Clean Energy Basics. 13 Jun, 2005 <http://www.nrel.gov/clean_energy/hydroelectric_power.html>

26. “Overview of Natural Gas.” NaturalGas.org. 13 Jun, 2005. <http://www.naturalgas.org/overview/background.asp>

27. "Overview: Thursday July 28." Natural Gas Weekly Update (2005). EIA/DOE. 01 Aug 2005 <http://tonto.eia.doe.gov/oog/info/ngw/ngupdate.asp>.

28. PennWell Corporation. "News & Trends: E and SE Asia." Alexander's Gas and Oil Connections (2004) 13 Jun 2005 <http://www.gasandoil.com/goc/news/nts42272.htm>.

29. “Renewable Energy Trends 2003 With Preliminary Data for 2003." DOE/EIA. July 2004. 26 May 2005 <http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/trends.pdf>.

30. “Residential Energy Usage by Origin of Householder." 06 Mar. 2002. DOE/EIA. 20 Jun. 2005 <http://www.eia.doe.gov/emeu/recs/origin/origin_householder.html>.

31. Sahr, Robert. “Inflation Conversion Factors For Dollars 1665 to Estimated 2015.” Oregon State University. 19 Jan. 2005. 1 Jun, 2005 <http://oregonstate.edu/Dept/pol_sci/fac/sahr/infcf16652005.pdf>

32. “State Consumption Data." 14 Feb. 2005. DOE/EIA. 26 May. 2005 <http://www.eia.doe.gov/emeu/states/_use_multistate.html>.

33. Stoffel, Tom. "20 Years of Solar Measurements: The Solar Radiation Research Laboratory (SRRL) at NREL." 6 April 2005. 27 May 2005 <http://www.nrel.gov/srrl/history.pdf>.

34. “Table 11.3 World Primary Energy Consumption by Region, 1993-2002” Annual Energy Review 2003. DOE/EIA. 16 Jun 2005 < >

35. “Table 14. Production of Crude Oil by PAD District and State, 2003." Petroleum Supply Annual 2003. DOE/EIA. 26 May. 2005 <http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/petroleum_supply_annual/psa_volume1/current/pdf/table_14.pdf>.

36. “Table 3. Gross Withdrawals and Marketed Production of Natural Gas by State and the Gulf Of Mexico, 1999-2003." Natural Gas Annual 2003. DOE/EIA. 26 May. 2005

<http://www.eia.doe.gov/pub/oil_gas/natural_gas/data_publications/natural_gas_annual/current/pdf/table_003.pdf>.

37. ""Top 10" Lists and Rankings". DOE/EIA. 15 Jun 2005 <http://www.eia.doe.gov/neic/rankings/rankindex.htm >

38. Werner, Julie A., Lyman, R.M., Jones N.R. Wyoming State Geological Survey. "Quadrillion Btu Study". June 2005

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