RENEWABLES: an Inconvenient Energy Reality

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Global warming is a political reality in the United States today. The actual impact of the continued utilization of fossil fuels is not known and is open to debate. However, the growing concern about the continued use of these fuels is problematic. There are technologies available to us today that would permit America to meet its future energy demand and not contribute to global warming. The inconvenient reality is that fossil fuels cannot completely be replaced with energy conservation and the use of wind, solar, hydroelectric, geothermal and nuclear energy. The connection between the greenhouse effect and global climate change was first identified by physicist John Tyndall in the 1860s. To prove the greenhouse hypothesis, Roger Revelle and his research team started measuring carbon dioxide concentrations in the earth's atmosphere in the early 1960s (Becker, 2007). With the rising concern about global warming, scientists throughout the world have been obtaining surface and air temperature data. Scientists have also been comparing CO2 concentrations found in glaciers throughout the world with theorized annual temperatures. Data for both dates back 1,000 years. Armed with this data, many nations of the world and the United Nations Intergovernmental Panel on Climate Change (IPCC) have concluded that climate change is a reality. The IPCC also concluded that this climate change is the result of mankind's consumption of fossil fuels and that catastrophic consequences will occur on a global scale if nothing is done (Becker, 2007).

Former United States Vice President Al Gore has been the most outspoken advocate of global warming due to the use of fossil fuels and the serious global consequences that he believes are starting to occur. His book, An Inconvenient Truth, his Academy Award for the documentary film of the same name and his Nobel Peace Prize (shared with the IPCC) have raised the environmental conscience of citizens throughout the world.

On the other hand, there are many scientists throughout the world who do not believe that fossil fuels are the only or main culprit affecting global warming. They also have historical data and theories that prove their contention that global warming (and cooling) is a natural occurring phenomenon and that this latest global warming is being caused by many different factors. However, their message has, for the most part, been drowned out and made irrelevant by the weight of world opinion in favor of fossil fuel- induced global warming.

Armed with Gore's message and the IPCC report, many environmental organizations in the United States are seizing the opportunity by working collectively to prohibit the use of fossil fuel energy. Most notably, the Sierra Club and the Natural Resources Defense Council (NRDC) are advocating a moratorium on the construction of new fossil fuel power generating plants. They also want more emphasis placed on energy conservation and a much greater use of renewable or clean energy to power America's energy requirements.

Global warming is occurring in the world today and that fossil fuels are to be blamed is a political reality. The actual impact of the continued use of fossil fuels is not known and is open to debate. However, the growing concern about the continued use of these fuels is problematic. The environmental community also believes that the contribution to global warming from the residential, commercial, industrial and transportation sectors is significant. The transportation sector is not discussed here due to its international scope. The residential, commercial and industrial sectors will not be discussed due the lack of information on its impact. This article identifies the projected energy demand for America, the future contribution of renewable energy to this demand and answers the question of whether renewable energy can replace fossil fuel energy.

Discussion

The U.S. Energy Information Administration (EIA), a section of the U.S. Department of Energy (DOE), was created by Congress in 1977. Its mission is to provide statistical "policy-independent data forecasts, and analyses to promote sound policy making, efficient markets and public understanding regarding energy and its interaction with the economy and the environment." The EIA recently published its Annual Energy Outlook for 2008 in which electric power generation in the United States is expected to rise 0.9 percent per year to 2030. This translates into an increase of 197 GW over the 955 GW of electric generating capacity in 2006 to 1,152 GW of capacity in 2030. Figure 1 shows the Electric Power sector Capacity by Fuel Technology in GW from 2000 to 2030. To meet this increased demand, the EIA projects that coal-fired generating capacity will increase 96 GW, oil and natural gas increases 50 GW, nuclear increases 15 GW and renewables will increase 36 GW (Energy Information Administration, 2008).

The mission of the North American Electric Reliability Corp. (NERC), a self-regulated, nonprofit organization, "is to improve the reliability and security of the bulk power system in North America." To achieve its mission, "NERC develops and enforces reliability standards; monitors the bulk power system; assesses future adequacy; audits owners, operators and users for preparedness and educates and trains industry personnel."

In June 2007, the US. Federal Energy Regulatory Commission (FERC) conveyed upon NERC the legal authority to make its reliability standards mandatory and the right to enforce those standards. (North American Electric Reliability Corp., 2007) NERC has broken the United States and Canada into eight regional areas as shown in Fig. 2. The boxes indicating the name of each region also contains the year when each region's resources falls below its target capacity margin level. This is based on summer peak loads. The box also contains the year when each region's uncommitted resources fall below target capacity margin levels. Committed capacity resources include existing generating capacity, resources that are under construction and resources that are planned and committed.

Uncommitted capacity resources are, basically, those resources that do not have a contractual obligation to deliver and/or firm transmission capabilities in which to deliver.

The NERC Reliability Assessment runs from 2007 through 2016 and the SERC and FRCC regions are not scheduled to fall below their target capacity margin levels within that period of time.

Based on the EIA 2008 Energy Outlook, at least 66 GW of new electrical energy will be required by the year 2016. The Sierra Club, NRDC and other environmental organizations are advocating a moratorium on the construction of new fossil fuel power generating plants. Through the intense lobbying of federal and state regulators, select lawsuits and administrative appeals throughout the country, their coordinated offensive has been successful. As of Jan. 1, 2008, 74 commercial coal plants, 141 natural gas plants and 11 petroleum plants have been canceled. These represent a total of 100 GW. Thirty-four coal plants, 50 natural gas plants and one petroleum plant have been postponed, representing and additional 37.6 GW. This leaves 46 coal plants, 79 natural gas plants and three petroleum plants under construction, representing a total of 32.4 GW planned to come online by 2012 (Edison Electric Institute, 2008).

If an additional 33.6 GW (66 GW-32.4 GW) of electrical power is not constructed and brought on line during the next eight years, then the unintended consequences of canceling fossil fuel power plants to reduce greenhouse gases means that at least six out of the eight regional areas could be adversely affected. There is a high probability that a large segment of the United States could experience electrical power interruptions within the next eight years.

Environmental organizations are stating that fossil fuel electrical power can be replaced with energy conservation, renewable and clean energy. The following energies are considered renewable: wind, solar, hydro, geothermal and municipal waste/wood/biomass. Nuclear, in this article, is considered to be a clean energy. From recent news articles throughout the U.S., it appears that this environmental vision is supported by many state and federal elected officials and regulators, industry, some electrical power companies and the general public. Many major businesses have formed an alliance with environmental groups to form the U.S. Climate Action Partnership with the stated goal of encouraging federal agencies to reduce greenhouse gas (GHG) emissions.

Energy conservation and energy efficiency

Energy conservation and improved energy efficiency are important programs that America has been working on since the late 1970s as a result of the first oil embargo. Great advances have been made and more can be accomplished. Figure 3 is a graphic representation of how the NRDC recommends solving global warming (Natural Resources Defense Council, 2008).

Gore has a similar graphic representation based upon the Socolow/ Pacala study in his book An Inconvenient Truth (Gore, 2006).

Although there are numerous plans for energy conservation and energy efficiency programs, this author could not find specific details or actual projections of the electrical energy saved from these two programs. For these programs to work, citizens, industry and the government need to be educated and committed to the task and tax incentives need to be in place. The benefit from these two programs is long range in scope. Therefore, they will not substantially assist in replacing the fossil fuel power generation recently canceled.

Wind energy

The United States has tremendous wind energy potential and is starting to take advantage of this valuable resource. As of Dec. 31, 2007 there was a total of 16.8 GW of installed wind generation operating in 34 states (American Wind Energy Association, 2007). Figure 4 illustrates that all states are not created equal. By the year 2030, the National Renewable Energy Laboratory (NREL) projects that the U.S. will have 100 GW of installed wind generation (National Renewable Energy Laboratory, 2008). This is a six-fold increase in this important renewable energy resource. However, wind energy is not a base load similar to fossil fuel power plants.

Each wind generation site has its own unique operating conditions that determine the capacity factor for each wind generator. Capacity factors can range from a low of 5 percent to a high of 40 percent of nameplate generating capacity for the generator. However, wind farms installed in 2007 are averaging a 36 percent capacity factor. This means that a 100-MW wind farm with a capacity factor of 36 percent can be considered to contribute 36 MW to the power grid as a base load. Site factors are determined by meteorological conditions and include high, low and average wind velocities plus other weather conditions. Large utility-scale wind turbines cannot operate in wind velocities lower than 5 m/sec (11.2 mph) and in wind velocities greater than 27 m/sec (60.4 mph). Most utility-scale wind turbines have a nameplate generation capacity of 1.5 to 2.2 MW, will be mounted on 80-m (262.5 ft) towers and have 40-m (131.25-ft) blades.

Even with the tremendous energy potential of wind, there are socioeconomic problems with this resource. A large proposed wind farm to be located in Nantucket Sound just off Hyannis, MA and another large wind farm to be located in northern Montana next to a wilderness area have been canceled due to negative view-shed considerations. Most wind farms will be located in remote rural areas that do not have electrical transmission Unes nearby and the requirements of permitting new transmission corridors are arduous and time consuming. Then there are the avian concerns. Whether these problems can be mitigated depends on public awareness and acceptance and a commitment from state and federal regulators to move the permitting process forward.

Solar energy

Solar energy's potential is unlimited. How this energy is harvested will depend on how much land is dedicated to solar panels and heating troughs and how much money is dedicated to paying to develop this resource. The technology is ready to be applied. Commercial solar systems used to generate electricity are broken into photovoltaic and concentrating solar power technologies (National Renewable Energy Laboratory, 2007).

Photovoltaic systems convert sunlight directly into electricity by using semiconducting materials. These allow solar energy to move electrons through the material to produce electricity. Since solar photovoltaic cells have an efficiency of 15 percent, large areas are required to generate commercial amounts of power. Concentrating solar power systems are broken into three main types: parabolic- trough, dish/engine and power tower. All three use mirrors to concentrate the sun's energy onto collectors containing a heat transfer medium that boils water to run a steam generator.

There are approximately 420 MW of photovoltaic commercial power systems operating in the U.S. today. These systems have an estimated 30 percent capacity factor. There is only 64 MW of concentrating solar, a parabolictrough system, operating in Nevada today. These systems have an estimated 40 percent capacity factor.

Although solar power appears to be in its infancy of development, it is projected that concentrating solar power systems will contribute 30 GW of energy by the year 2030 (National Renewable Energy Laboratory, 2007).

However, authors Zweibel, Mason and Fthenakis are more bullish on solar power in their December 2007 Scientific American article. The authors present a Solar Grand Plan that will provide 69 percent of America's electrical energy by the year 2050. To provide this amount of electrical energy using both photovoltaic and concentrating solar power will require an estimated 119,140 km? (46,000 sq miles) of land located principally in the Southwest. Imagine an area roughly the size of the state of Mississippi. The authors plan on moving this electrical energy to other parts of the U.S. by high-voltage dc power lines. To pay for this plan, they suggest a carbon tax on coal of $36/t to $82/t ($40/stto$90/st). Permitting 119,140 km2 (46,000 sq miles) of land for this energy resource is highly problematic considering that the flora and fauna would be completely displaced.

Hydropower

Hydropower is an ancient clean source of energy that has served mankind for thousands of years and will do so in the future. Hydroelectricity is produced at about 2,181 locations in the U.S. and produces 80 GW of power. However, it is estimated to drop from 8 percent of America's generating capacity today to 6 percent by the year 2020 (Energy Efficiency and Renewable Energy Programs, 2008). Hydroelectric dams are being decommissioned and removed today due to environmental considerations.

However, that does not mean that the use of hydropower is over, for there are other forms of this energy with great potential. Research is currently being conducted on ocean thermal energy conversion, ocean tidal power, ocean wave power and low-head run-of- river power. There is minimal installed commercial electrical power being produced from wave or tidal energy in the United States today. However, the Electric Power Research Institute (EPRI) estimates there will be 540 MW of installed wave energy power and 205 MW of tidal energy power installed by the year 2012. Depending on government regulatory barriers, public support, and tax incentives, EPRI predicts that wave energy could reach 10 GW of commercial plant capacity by the year 2025 (EPRI, 2007). Note that this form of energy has a 33-percent capacity factor.

Geothermal

Geothermal energy is present at varying depths everywhere beneath the earth's surface. However,the most desirable resources are located where hot or molten rock is located close to the surface. Today, principally in the southwestern United States, geothermal energy is being tapped to generate 2.9 GW of electrical power.

There are three basic types of power generation using this energy source: dry steam, flash steam and binary cycle. The generating method used depends mostly on the geology and thermal characteristics of the energy resource.

Dry steam plants were the first to generate electricity. They did so by using the steam coming directly from wells to run the turbine/ generator. Flash steam power generation plants, which are the most common in operation today, use high-pressure water pumped to the surface. The pressure of the water is suddenly reduced at the power plant allowing it to flash into steam where it then runs the turbine/ generator. Binary cycle power generation plants can use lower temperature water to heat, by means of a heat exchanger, a lower boiling point "working fluid," which then runs a turbine/generator (Idaho National Laboratory, 2007).

The Geothermal Task Force of the Western Gover-r nors' Association concluded from its research, that 13 GW of geothermal generated electrical power could be developed in a reasonable timeframe. (Western Governors' Association). This is consistent with INEL projections but is considered to be quite aggressive.

To more thoroughly use the geothermal resource, a study by the Massachusetts Institute of Technology (MIT) recommends using enhanced (or engineered) geothermal systems (EGS) to provide base- load electricity from geothermal resources located in low- permeability sediments and basement rock throughout the United States. EGS recovers geothermal heat contained in deep, 3 to 10 km (9,843 to 32,810 ft) basement rocks by drilling injection and recovery wells to an engineered reservoir, thus developing a closed loop system. Water is then pumped down the injection wells, circulated throughout open fractures and porous rock in the heat reservoir, and then returned to the surface to be used to generate electricity. The MIT study concludes that EGS could provide 100 GW of geothermal generated electrical power throughout the United States by the year 2050 (MIT, 2007). However, most experts on geothermal energy say this technology can only be developed after we perfect our knowledge of finding these deep geothermal resources.

Nuclear

The United States is the largest generator of commercial nuclear electrical power in the world today. There are 104 licensed and operating commercial plants generating 100.2 GW. The EIA projects that 14 to 15 new plants will be constructed and generating an additional 18.6 GW of electrical energy by the year 2030.

Boiling water reactors (BWR) and pressurized water reactors (PWR), called light-water reactors, are the two main types that are used in the U.S. today. Both use processed uranium fuel to heat ordinary water, which is removed from the reactor core either as steam in the BWR or as superheated water in the PWR. The steam produced in the BWR is used directly in the turbine/ generator, whereas the superheated water produced in the PWR transfers this heat to a

secondary loop that creates steam to run the turbine/ generator. Out of the 104 operating plants, there are 35 BWR and 69 PWR (Energy Information Administration, 2008). Nuclear energy is considered clean energy in terms of not generating GHG. However, the environmental community does not consider it a clean energy resource because of its high-level radioactive waste. The DOE has been researching Yucca Mountain, NV since 1978 to determine if this site would be suitable as a long-term nuclear waste repository. The site is located approximately 161 km (100 miles) northwest of Las Vegas in a remote desert within the borders of the Nevada test site.

Currently, the DOE is preparing to submit an application to the Nuclear Regulatory Commission for a license to commence construction of the repository (Office of Civilian Radioactive Waste Management, 2008). However, many politicians and environmental groups are opposing the licensing of this repository.

Even though a majority of Americans support the use of nuclear energy, future development of this important green energy source is problematic due to the lack of safe storage for nuclear waste. Today, there are at least 10 states that have restrictions on new nuclear plants until there is a central repository available. In the meantime, nuclear waste is stored locally at 126 sites around the nation.

Energy summary

Liberally calculating the proposed increase in renewable energy, as presented here to the year 2030, a total of 37 GW is obtained. Basically, this is the same amount that the EIA 2008 Annual Energy Outlook estimated. This means that the remaining 160 GW of additional energy needed by the year 2030 has to be made up with fossil fuel and nuclear energy. Renewable energy, therefore, cannot replace fossil fuel-generated energy between now and the year 2030. Nor can it replace the 759 GW already operating today.

Even if the maximum projected amount of renewable energy is developed by the year 2050, it cannot replace fossil fuel generated energy. This is the inconvenient reality. However, there is a solution. Clean fossil fuelgenerated electricity, along with renewable and clean energy resources, can and must be developed to reduce green house gases.

Clean coal

Integrated-gasification combined-cycle (IGCC) power plants burning coal to generate electrical energy have certainly been in the news. They are well known, especially following the recent announcement that the DOE canceled its support for the proposed 275- MW FutureGen IGCC project in Mattoon, IL. IGCC plants use mature coal gasification processes to convert pulverized coal into synthesis gas that is cleaned before it is used to run gas turbines to generate electricity. There are six operating IGCC plants worldwide with two operating in the U.S. (Power Magazine, 2007/ 2008).

IGCC plants are still being refined, and more research needs to be conducted before the process can be sold as viable on an economic, reliability, and performance basis, as well as its ability to remove CO2, NO^sub x^ and SO^sub 2^. Actual CO2 capture from the process is at least a decade away. However, IGCC plants hold the greatest promise of burning one of the world's most abundant resources, coal and at the same time, reducing the emission of GHG.

There are two emerging technologies that can be used at existing fossil fuel power plants to remove the CO2. One is being tested at an existing coal power plant in Ohio using an electro-catalytic oxidation (ECO/TECO^sub 2^) process to remove NO^sub x^, SO^sub 2^, CO2, paniculate matter and mercury. The other is being constructed at an existing coal power plant in Wisconsin. It uses a chilled ammonia CO2 capture process. Although these systems use a lot of energy to operate, they are showing promise in removing GHG pollutants from existing coal power plants (Power Magazine, 2007).

Running parallel to research on technologies that remove CO2 and other pollutants from coal power plants, research is being conducted on sequestering the CO2 once it has been removed. This research is concentrating on sequestering the CO2 in the following geologic formations: depleted oil and gas reservoirs, unminable coal seams, saline, shale and basalt formations. Research is also being conducted on the storage balance of produced and natural CO2 within terrestrial ecosystems. Of particular interest to researchers is how much CO2 can realistically be stored over time (National Energy Technology Laboratories).

Conclusions

Global warming is occurring in the world today and that fossil fuels are to be blamed is a political reality. The Sierra Club, NRDC and other environmental organizations are advocating a moratorium on the construction of fossil fuel power generating plants and their coordinated offensive has been successful. A total of 138 GW of fossil fuel electrical generation has been canceled or postponed at a time when America's need for electrical energy is continuing to grow.

At the same time that this electrical generation is being removed, the North American Electric Reliability Corp. warns that the United States will be dropping below its capacity margin levels within the next eight years unless more generating capacity is added. The unintended consequences of canceling fossil fuel plants to reduce greenhouse gases and not replacing this lost electrical energy immediately is that at least 35 states could experience electrical power interruptions within the next eight years.

Environmental organizations are stating that fossil fuel- generated electrical power can be replaced with energy conservation, renewable and clean forms of energy. This article has investigated this premise and has found that the U.S. can and should, indeed, increase its use of renewable and clean energy. But the inconvenient reality is that the nation cannot replace fossil fuel energy with renewable and clean energy. There are substantial environmental, technical, and political impediments to the future development of both renewable and clean fossil fuel-generated electrical energy. The American people have to be prepared to accept large areas of land dedicated to energy development and electrical transmission. They also have to be ready to pay more for this energy to reduce the generation of green house gases and, at the same time, to maintain the nation's economic vitality and our standard of living.

Recommendations

The executive and legislative branches of the federal government should have the same commitment to reducing America's carbon footprint as it had in constructing this country's interstate highway system or sending men to the moon. Both were technical and economic challenges and both succeeded.

Congress should not enact repressive tax laws to prohibit the use of fossil fuels or to pay for renewable energy development. It should support research and development of all forms of energy, proportional to the value of the energy based upon cost and environmental considerations.

The residential, commercial and industrial sectors of society can better use energy conservation and efficiency, resulting in substantial savings in electrical power. The environmental community needs to educate and lead in this area.

Industry needs to step forward and assist in the research and development of renewable and clean fossil fuel energy. (References available from the author.)

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