AMERICA'S ENERGY FUTURE

THE NATIONAL ACADEMIES REPORT IN BRIEF

Electricity from Renewable Sources

Status, Prospects, and Impediments

This report from the National Academy of Sciences and the National Academy of Engineering explores the potential for and barriers to developing wind, solar, geothermal, and biopower technologies for electric power generation. It concludes that with an accelerated deployment effort, non-hydropower renewable sources could provide 10 percent or more of the nation's electricity by 2020 and 20 percent or more by 2035. However, for these sources to supply more than 50 percent of America's electricity, new scientific advances and dramatic changes in how we generate, transmit, and use electricity are needed.

Solar, wind, geothermal, and biomass—all renewable sources of energy—offer a variety of benefits compared to fossil fuels, which currently supply 67 percent of America's electricity. Over their lifecycle, renewable sources produce far less carbon dioxide (CO_2) emissions, use less water, and emit lower amounts of pollutants, such as sulfur dioxide, nitrogen oxides, and mercury. By definition, renewable energy sources are sustainable. Because of these advantages and a host of policy initiatives, private investments in renewable technologies rose by more than 40 times from 2001 to 2007 (see Figure 1).

However, non-hydropower[1] renewables still contribute only 2.5 percent of America's electricity. Realizing the potential of renewable energy sources will require meeting many challenges before they can become cost-competitive with non-renewable sources. This report focuses mainly on the potential of wind, solar, geothermal, and biopower technologies, which collectively show promise for substantially increased deployment within the next decade.

[1]Although hydropower supplies 6 to 10 percent of electricity, depending on hydrological conditions, its generating capacity is unlikely to greatly expand because of ecological and environmental concerns around large dams.

Wind Power

From 1997 to 2006, the wind power industry experienced a 20 percent compound annual growth rate. Wind turbine technology is fairly mature and turbines are able to produce the amount of energy used in their manufacturing and installation in less than half a year. This "energy payback period" is only expected to improve as turbines' towers and rotors become larger and more efficient. Without any radically new technology, wind power has the potential to supply 10 to 20 percent of electricity demand by 2030. *Electricity from Renewable Sources* determined that a U.S. Department of Energy scenario involving installation of 300 GW of wind capacity by 2030 (which would be

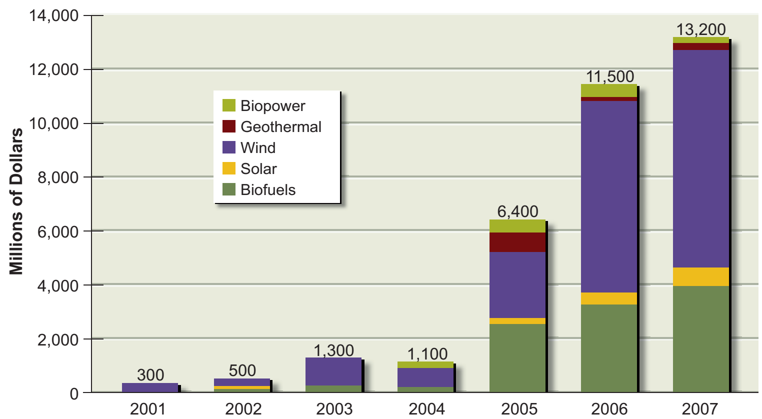

Figure 1: Private investments in renewable sources have risen dramatically since 2001. Source: DOE/EERE (2008).

sufficient to provide 20 percent of total electricity generation) would be possible but very challenging. Such a scenario would require a huge expansion of manufacturing, materials, and installation, and require up to $100 billion in capital costs and transmission upgrades more than a no-new-wind scenario. However, it would provide 140,000 jobs and reduce CO_2 emissions by 800 million tons/year.

Solar Power

There are two main types of solar power generation: photovoltaic (PV) and concentrating solar power. In PV solar, sunlight strikes the surface of a cell made of a light absorbing material. These materials include silicon or thin films of inorganic materials, such as cadmium telluride, that have absorption properties well matched to capture the solar spectrum. PV solar is useful for providing power at times of peak usage and has a very high resource potential in a number of U.S. regions. In the United States, about 22 percent of residential and 65 percent of commercial rooftop space is appropriate for PV cells. Based on available rooftops alone, PV could potentially supply more electricity than the United States consumed in 2008. Worldwide production of PV modules is increasing rapidly, but from a very small base.

Electricity from Renewable Sources describes one scenario involving installation of 100 to 200 GW of PV capacity (which would be sufficient to meet 10 to 15 percent of total electricity usage) by 2030 that would be very expensive but possible. It would also create 120,000 to 260,000 jobs and reduce CO_2 emissions by 70 to 100 million tons per year. Unfortunately, the production of solar cells is currently very expensive; less expensive thin-film cells exist but are less efficient. Also, because its manufacturing is extremely energy intensive, PV has the longest energy payback period (1 to 7.5 years) of any renewable source.

Concentrating solar power (CSP)—which uses lenses or mirrors to focus the sun's energy—offers promise. But it requires high quality solar resources and will only be cost-effective in the Southwest. CSP heats a liquid working fluid such as oil or molten salt that is then used to generate steam to power an electric turbine-generator. The basic technology is fairly mature, with one plant in the California desert operating successfully for over 20 years. In the future, this technology could be used to produce fuels that would store energy.

Geothermal Electric Power

Geothermal power is generated from heat stored in the earth, especially when underground reservoirs carry the Earth's heat toward the surface by convective circulation of water or steam. Where such resources exist, hydrothermal power plants use hot water or steam found 3 km or less from the surface to turn a turbine. In suitable resource areas, such turbines operate between 90 and 98 percent of the time and can be used as a source of reliable, steady (baseload) power generation.

Hydrothermal resources could experience moderate growth in the United States and contribute 5 to 10 GW of power generation capacity in the West by 2015. In known geothermal resource areas where no water aquifer exists, enhanced geothermal power may be possible. This technology involves producing an artificial water aquifer to bring geothermal heat at depths of 3 to 10 km to the surface to generate electricity. Enhanced geothermal technology is not sufficiently developed to contribute substantially to power generation in the United States by 2035. But with continued development, the technology could contribute beyond 2035.

Biopower

Wood or plant waste, municipal solid or gaseous waste, and crops grown to produce energy are the three main biopower feedstocks. Biopower is currently the second most common renewable source for generating electricity after hydropower, but most is generated by burning wood waste. However, some energy crops, such as switchgrass, may require using fossil fuels for production. This production would result in biopower having higher greenhouse gas emissions per kWh than most other renewable sources. Although biopower can provide baseload energy, limits on crop growth, land requirements, and competition for feedstock with renewable liquid fuels may constrain its potential.

Estimates of the amount of biomass potentially available vary widely. A joint U.S. Department of Agriculture/U.S. Department of Energy study concluded that, three to four decades into the future, using 57 percent of the continental United States, American farms could produce up to 1.3 billion dry tonnes/year of feedstock. A recent study by the America's Energy Future Panel on Alternative Liquid Transportation Fuels estimated that an annual supply of 550 million dry tons of cellulosic biomass could be produced sustainably per year by 2020. If 250 million tonnes were used to generate electricity, biopower could produce 0.416 million GWh/year, or 10 percent of the 2007 U.S. electricity consumption.

Transmission and Storage Requirements

From the level of deployment now until the level expected in 2020, there are no technological issues constraining deployment of wind, solar, conventional geothermal, and biopower technologies. However, a substantial fraction of new renewable electricity generation capacity would come from intermittent (wind and solar) and/or distant sources. As a result, increases in transmission capacity and other grid improvements are critical for significant penetration of renewable electricity sources. Co-location of renewable energy generation with fast-responding fossil fuel-fired generation, such as natural gas combustion turbines, can increase consistency and the value of building transmission lines. Further, for renewable power to produce more than 20 percent of total power generation, many local and regional electrical systems would require storage technologies to integrate these intermittent resources. Options include pumped hydropower, batteries, compressed air energy storage, or conversion of excess generated electricity to chemical fuels. Achieving a predominant (i.e., more than 50 percent) level of renewable electricity penetration would require storage technologies, as well as other scientific advances and dramatic changes in how we generate, transmit, and use electricity.

Capital and Economic Requirements

One of the primary barriers to the development of renewable electricity sources has been the inability to be cost-competitive with conventional sources. If future prices do not reflect costs of carbon emissions and other externalities, high costs will continue to be a barrier. The manufacturing and installation of renewable technologies are generally more expensive than building conventional power plants. However, many types of renewable electricity-generating technologies can be developed and deployed in smaller increments, and constructed more rapidly, than large-scale fossil- or nuclear-based generation systems. This speed allows faster returns on capital investments. When deciding whether or not to invest, businesses weigh these capital costs against the risk of potential increases in fossil fuel prices and possible CO_2 emissions limits. Because electricity prices are difficult to predict and the market is well-established and highly regulated in many states, most utilities have not taken this risk. Substantial infusions of capital, particularly between technology creation and early commercialization, are needed to fulfill renewable sources' potential. Accelerated deployment of renewables requires significant expansion of manufacturing capacity, installation, and trained workers. Limited amounts of key basic materials may also curb some technologies' growth.

Potential Policies and Incentives

The production tax credit (PTC), which allows renewable-electricity generators to offset their taxes proportional to production, has been one of the federal government's main tools to encourage investment. The main beneficiary has been wind power. The PTC for wind power began in 1992, but has lapsed three times since then (see Figure 2). However, from now until 2012, the PTC for wind power will provide a 2.1 cent tax credit for every kWh generated during a plant's first decade. Studies predict that extending the credit indefinitely would stimulate wind production to

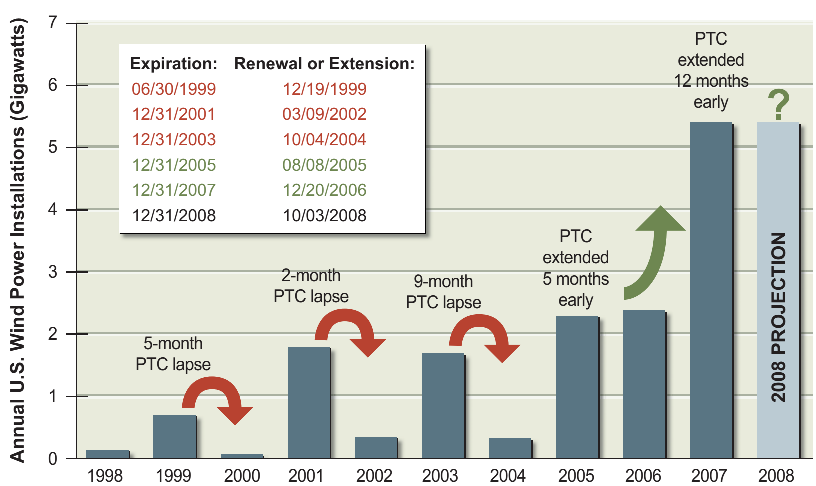

Figure 2: This graph illustrates the increases and decreases in wind power investment when the production tax credit expired and was extended. Source: Lawrence Berkeley National Laboratory; presented in Wiser (2008).

have twice the capacity by 2020 and three times the capacity by 2030 than it would otherwise.

Renewable portfolio standards, adopted by 27 states and the District of Columbia, require that renewable sources supply a certain percentage of the electricity sold in a state. According to an Energy Information Agency study, a federal portfolio standard that required 25 percent of power generation from renewable resources would result in 20 percent lower CO_2 emissions from electricity in 2030 than otherwise. For a standard of up to 15 percent renewable generation, renewable portfolio standards may encourage renewable growth more cost-effectively than either production tax credits or cap-and-trade policies designed to control CO_2 emissions, according to a Resources for the Future study.

A feed-in tariff is an incentive structure to encourage the adoption of renewable energy by requiring electric utilities to buy renewable electricity at above-market rates set by the government. It is a very popular policy option in Europe. Under such tariffs, renewable energy generators are paid a predetermined price for their power for a set period of time. Each technology is calculated individually, so that all renewables can be profitable compared to conventional sources.

Although neither **greenhouse gas emissions limits** nor **permitting policies** focus on renewable sources, these policies can influence their deployment. The Lieberman-Warner climate change bill, which proposed placing a $48/ton price on CO_2 by 2025, would have motivated non-hydropower renewables to increase to 13 percent of the sector by 2025. In contrast, permitting issues may delay projects. Although land occupied by renewable sources can often accommodate multiple uses, local communities sometimes have concerns about land use and ecological damage. Industry groups and the federal government are developing guidelines to minimize local impacts and streamline the permitting process.

In general, policies encouraging the development of renewable sources are more effective when they are stable and predictable. If recent policy initiatives continue, wind power is expected to grow rapidly. The 2.1 cent tax credit in place until 2012 has recently brought the price of wind power down to a point where it is competitive with that of conventional natural gas plants. As other renewable technologies are less financially favorable, additional clear, consistent policies will be needed to achieve greater penetration, accelerate production scale, and lower costs.

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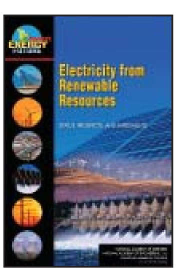
This report brief was prepared by the National Research Council (NRC) based on the committee's report. The NRC appointed the above panel of experts, who volunteered their time for this activity. The NRC study was initiated by the National Academy of Sciences and the National Academy of Engineering and subsequently endorsed by a request from Congress. The committee's report is peer-reviewed and signed off by both the committee members and the NRC.



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