20% Wind Energy by 2030: Wind, Backup Power, and Emissions

20% Wind Energy and Climate Change

As America and the world grapple with the immense problem of climate change, one energy source stands out as an abundant, affordable and readily available supply option: wind power. The U.S. Department of Energy's *20% Wind Energy by 2030 Technical Report* (www.20percentwind.org) finds that wind power can supply 20 percent of America's electricity by 2030 and reduce projected emissions of carbon dioxide (CO_2), the leading greenhouse gas, by 25 percent.

This fact sheet is one in a series aimed at informing decision-makers and the public about this critically important option for America's energy future and countering persistent myths about wind energy.

AWEA contact

Michael Goggin
Electric Industry Analyst
mgoggin@awea.org
202-383-2531

Other resources:

www.awea.org

European Wind Energy Association, www.ewea.org

Utility Wind Integration Group, www.uwig.org

National Renewable Energy Laboratory, www.nrel.gov/wind/

The "no reduction in emissions" myth

Wind opponents sometimes argue that wind energy doesn't actually reduce the fuel use or harmful emissions of other power plants. On its face, this claim does not make sense: utility system operators must precisely balance the total supply of electricity with the total demand for electricity at all times, so the electricity produced by a wind plant must be matched by an equivalent decrease in electricity production at another plant.

When it is available, system operators use wind energy to reduce the output of the power plants that are the most expensive to operate, which are almost always natural gas or coal power plants because of their high fuel costs. Wind energy is also occasionally used to reduce the output of hydroelectric dams, which can store water to be used later to replace more expensive fossil fuel generation.

By directly reducing the use of fossil fuels, wind energy significantly reduces emissions of the greenhouse gas carbon dioxide (CO_2) and other harmful pollutants. A number of detailed power system studies, as well as real-world experience with wind plants, have demonstrated that wind energy significantly reduces fossil fuel use and emissions:

- In 2007, wind energy in the U.S. reduced CO_2 emissions by over 28 million tons, equivalent to taking almost 5 million cars off the road. On average, each Megawatt-hour (MWh) of wind energy – the amount produced by two typical modern wind turbines in an average hour – reduces CO_2 emissions by 1,200 pounds.
- The U.S. Department of Energy's (DOE) *20% Wind Energy by 2030 Technical Report* calculated that obtaining 20% of our electricity from wind energy by 2030 would cut cumulative CO_2 emissions by over 7.6 billion tons.[1]
- The DOE report found CO_2 emissions would be reduced by over 825 million tons in the year 2030 alone, an amount equal to 25% of all electric sector carbon dioxide emissions in that year--the equivalent of taking 140 million cars off the road.
- The DOE study also found that wind energy would cut the amount of natural gas used for electricity generation by 50% in 2030.
- A study by the grid operator in Texas found similar results, concluding that adding 3,000 megawatts (MW) of wind energy to the state's grid would reduce CO2 emissions by about 5.5 million tons per year, sulfur dioxide emissions by about 4,000 tons per year, and nitrogen oxide emissions by about 2,000 tons per year.[2]
- In regions where a large share of electricity comes from coal power, the emissions savings of wind energy can be even larger. A DOE analysis found that Indiana could reduce CO2 emissions by 3.1 million tons per year by adding 1,000 MW of wind power.[3]
- The 30 MW Kaheawa wind plant in Hawaii directly offsets power from oil-burning power plants, reducing oil imports by almost 10 million gallons per year.[4]

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The "backup power" myth

Sometimes wind opponents claim that because wind energy output varies with the wind speed, wind plants require an equivalent amount of "backup power" provided by fossil fuel plants, negating the environmental and fuel savings benefits of wind energy. Understanding why this myth is false requires some explanation of how the electric utility system operates.

Overview of Power Grid Operations

System operators always maintain significant "operating reserves," typically equal to 5-7% or more of total generation. These reserves are used to deal with the rapid and unpredictable changes in electricity demand that occur as people turn appliances on and off, as well as the very large changes in electricity supply that can occur in a fraction of a second if a large power plant suffers an unexpected outage. Instead of backing up each power plant with a second power plant in case the first plant suddenly fails, grid operators pool reserves for the whole system to allow them to respond to a variety of potential unexpected events.

System operators use two main types of generation reserves: "spinning reserves," (regulation reserves plus contingency spinning reserves) which can be activated quickly to respond to abrupt changes in electricity supply and demand, and "non-spinning reserves," (including supplemental reserves) which are used to respond to slower changes. **Spinning reserves** are typically operating power plants that are held below their maximum output level so that they can rapidly increase or decrease their output as needed. Hydroelectric plants are typically the first choice of system operators for spinning reserves, because their output can be changed rapidly without any fuel use. When hydroelectric plants are not available, natural gas plants can also be used to provide spinning reserves because they can quickly increase and decrease their generation with only a slight loss of efficiency. Studies show that using natural gas plants or even coal plants as spinning reserves increases emissions and fuel use by only 0.5% to 1.5% above what it would be if the plants were generating power normally.[5]

Non-spinning reserves are inactive power plants that can start up within a short period of time (typically 10-30 minutes) if needed. Hydroelectric plants are frequently the top choice for this type of reserve as well because of their speedy response capabilities, followed by natural gas plants. The vast majority of the time non-spinning reserves that are made available are not actually used, as they only operate if there is a large and unexpected change in electricity supply or demand. As a result, the emissions and fuel use of non-spinning reserves are very low, given that they only rarely run, the fact that hydroelectric plants (which have zero emissions and fuel use) often serve as non-spinning reserves, and the very modest efficiency penalty that applies when reserve natural gas plants actually operate.

Accommodating Wind Energy

Fortunately, the same tools that utility system operators use every day to deal with variations in electricity supply and demand can readily be used to accommodate the variability of wind energy. In contrast to the rapid power fluctuations that occur when a large power plant suddenly experiences an outage or when millions of people turn on their air conditioners on a hot day, changes in the total energy output from wind turbines spread over a reasonably large area tend to occur very slowly.

While occasionally the wind may suddenly slow down at one location and cause the output from a single turbine to decrease, regions with high penetrations of wind energy tend to have hundreds or even thousands of turbines spread over hundreds of miles. As a result, it typically takes many minutes or even hours for the total wind energy output of a region to change significantly. This makes it relatively easy for utility system operators to accommodate these changes without relying on reserves. This task can be made even easier with the use of wind energy forecasting, which allows system operators to predict changes in wind output hours or even days in advance with a high degree of accuracy.

Moreover, changes in aggregate wind generation often cancel out opposite changes in electricity demand, so the increase in total variability caused by adding wind to the system is often very low. As a result, it is usually possible to add a significant amount of wind energy without causing a significant increase in the use of reserves, and even when large amounts of wind are added, the increase in the use of reserves is typically very small.

The conclusion that large amounts of wind energy can be added to the grid with only minimal increases in the use of reserves is supported by the experience of grid operators in European countries with large amounts of wind energy, as well as the results of a number of wind integration studies in the U.S. The table below summarizes the results of some of these studies.

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Variability added by wind energy over various time periods

Study	Wind Penetration Studied	1 minute	5 minute	1 hour
Texas 2008[6]	15,000 MW	6.5 MW	30 MW	328 MW
California 2007[7]	2,100 MW, plus 330 MW solar	0.1 MW	0.3 MW	15 MW
	7,500 MW, plus 1,900 MW solar	1.6 MW	7 MW	48 MW
	12,500 MW, plus 2,600 MW solar	3.3 MW	14.2 MW	129 MW
New York 2005[8]	3,300 MW	- -	1.8 MW	52 MW

Because wind energy output adds almost no variability on the minute-to-minute time scale, very large amounts of wind energy can be added to the grid with virtually no impact on the use of spinning reserves. While modest amounts of wind energy have very little impact on the system's hour-to-hour variability, as the amount of wind increases, it may be necessary to add non-spinning reserves to accommodate the more gradual changes in electricity supply caused by wind energy. Fortunately, as explained above, non-spinning reserves produce far fewer emissions than spinning reserves.

The following example further illustrates that the net emissions effect of any additional reserves to accommodate wind energy is inconsequential:

> On average, adding 3 MW of wind energy to the U.S. electric grid would reduce the emissions from fossil power plants by 1,200 pounds of CO_2 per hour. Adding this amount of wind would at most require anywhere from 0 to 0.01 MW of additional spinning reserves, and 0 to 0.07 MW of non-spinning reserves. It is likely that these reserves would be provided by zero-emission hydroelectric resources, but even under the worst-case scenario that an inflexible fossil fuel plant with an efficiency penalty of 1.5% must be used for reserves and that all of the non-spinning reserves would actually be activated, the increase in emissions would still be less than 1 pound of CO_2.[9] Even under this worst-case scenario, the emissions savings of wind energy (1,200 pounds) would outweigh the added emissions (less than 1 pound) by a factor of 1,000.

For Further Reading

- National Renewable Energy Laboratory, "Wind Energy and Air Emission Reduction Benefits: A Primer," February 2008: http://www.eere.energy.gov/windandhydro/windpoweringamerica/pdfs/policy/wind_air_emissions.pdf
- Utility Wind Integration Group, American Public Power Association, Edison Electric Institute, and National Rural Electric Cooperative Association, "Utility Wind Integration State of the Art," May 2006: http://www.uwig.org/UWIGIntSummary.pdf
- The Utility Wind Integration Group's library of wind integration studies: http://www.uwig.org/opimpactsdocs.html

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