The Energy-Climate Crisis is Your Business

Part VII: Winds of Change–Energy, Jobs, and Economic Opportunity[1]

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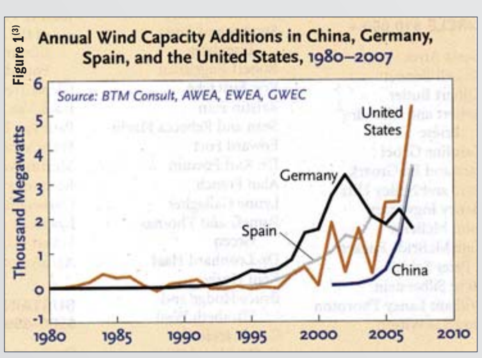
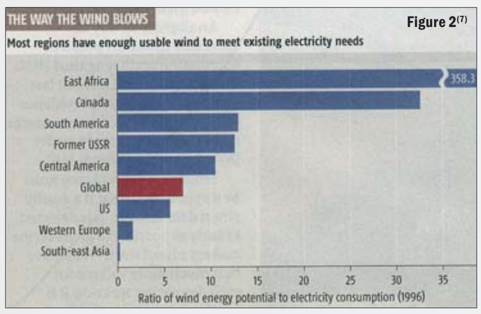
"The answer my friend is blowing in the wind."
Bob Dylan

In 1888, Charles Francis Brush, an inventor and entrepreneur, built a large wind turbine in his backyard to generate electricity for his home in Cleveland, Ohio. Mr. Brush's company, Brush Electric eventually merged with Thomas Edison's company, Edison Electric to form General Electric[1]. Wind power has come quite a way since then.

Wind is the most developed of all renewable-energy technologies and is now the fastest-growing form of electricity generation in the world, employing more than 350,000 workers. There are 9,000 large-scale turbines in some 60 countries. Wind power grew by more than 30 % in 2007, reaching over 100,000 megawatts of installed power by April 2008, the equivalent to the installed power of more than 100 large coal-fired plants, or a similar number of nuclear plants.

The U.S. leads in annual wind power growth, although surprisingly, China is close behind (see **Figure 1**)[3]. In Europe, wind provides a respectable level of total electricity in several countries – 20% in Denmark, 10% in Spain and 7% in Germany. Czech Power Group (CEZ) plans to build a 600 megawatt wind power park in Romania, which would be the biggest onshore wind power park in all of Europe[3]. With no significant change in power-generation strategies, wind power is expected to nearly triple in global capacity by 2012 to 290,000 megawatts. At that point wind will account for nearly 3% of world electricity generation, and by 2017, it could be nearly 6%[4].





Although wind energy currently supplies 1 % of U.S. power, a U.S. Department of Energy study found that wind energy could readily supply 20 % of U.S. electricity requirements by 2030. With no significant improvements in technology this would cost a mere 2 % more than staying with the current energy mix. This 2 % increase in cost would be more than compensated for by modest tax incentives, and this expansion would create more than 500,000 new jobs. This growth in zero-emissions wind energy by 2030 would nearly eliminate the projected increases in greenhouse gas emissions from U.S. power plants between now and 2030. It would also eliminate the consumption of 4 trillion gallons of water, an increasingly precious-commodity[5].

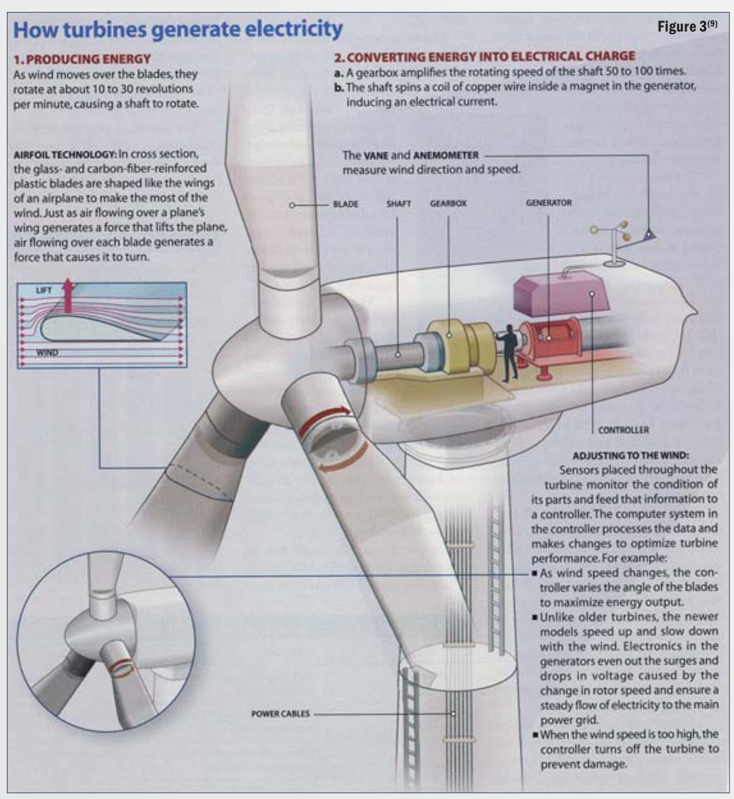
Wind power is attractive because it is available nearly everywhere, and is a renewable source of energy, producing neither pollution, nor climate-changing greenhouse gases (see **Figure 2**)[7].

The World Energy Council estimates that more than 80 % of the Earth's surface has wind speeds suitable for capturing energy. By exploiting just 10 % of the global wind resources, the world's entire electricity requirements could be met in a carbon-free future.

The cost to generate wind energy has decreased significantly, from more than 30 cents/kwh (cents per kilowatt-hour) in the 1980s to less than 10 cents/kwh today. When tax credits and feed-in tariffs are factored in, wind power is already cost-competitive with electricity generated from the most efficient gas-, coal- or nuclear-power plants. With a modest carbon tax of $30 per ton of CO_2, subsidies would not even be required and wind power would compete with all other power sources, globally[7].

Modern wind turbines are very efficient, extracting around 50 % of the energy of the impinging wind-close to the 59.3% theoretical limit. The newest turbines are built with light-weight, graphite-fiber-reinforced blades and are computer controlled so that the blade pitch can be adapted to wind speed fo-r optimum energy generation (see **Figure 3**)[9].

Currently, 99 % of all wind turbines are located onshore because they cost 40 % less to build and install



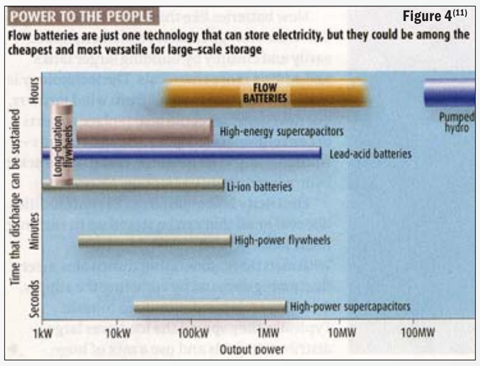


Figure 4[11]

than offshore turbines. However, as the technology is further developed, more turbines will move offshore. There are a number of advantages. Offshore winds have much greater speed and are less intermittent than winds over land. Offshore machines are also easily positioned near highly populated areas, where power is most needed. They can be built sufficiently offshore to be out of sight, and not heard, appealing to those who oppose wind power for those reasons.

The two most significant challenges for wind power are wind variability and ineffectiveness of the current global power grid. As for variability, it is now possible to forecast wind speed over a 24-hour period with good accuracy, making it possible to schedule wind power just as fossil power sources are planned. However, unlike electricity from conventional sources, wind power is not always available on demand. Utility operators must ensure that reserve sources of power are available in case the wind is not blowing at sufficient speed. But because wind power generation and electricity demand both vary, the extra capacity required to reach a 20% share of power by wind is quite small, just a few percent of the total installed wind capacity, and it can come from other existing power sources[9].

To exceed 20% power provided by wind, will require a means of storing electricity that is generated during low demand periods for use when demand is high. Several technologies have been developed to address this issue. These include pumping water uphill and discharging it through turbine generators during high-demand periods; super-capacitors for electrical discharge when extra power is required; high-power flywheels that store energy mechanically for conversion back to electricity; high-capacity lithium ion batteries; and flow batteries (see **Figure 4**)[11].

Flow battery technology is particularly promising. When excess electricity is generated by the wind turbines, it is used to convert a water solution of vanadium 5^+ ions to vanadium 2^+ ions. This means that each vanadium 5^+ ion captures 3 negative electrons and forms vanadium 2^+ ions. The vanadium 2^+ solution is stored in a tank, and when electricity is in high demand, this solution is run through an ion-exchange battery and the vanadium 2^+ ions give up their electrons which flow as electricity to the grid, giving back vanadium 5^+ ions, and the system is recycled again as needed (see **Figure 5**)[12]. This flow battery system can also be used for solar power, providing a means of storing electricity for distribution at night.

The most significant challenge for wind power, as well as other renewable power sources such as solar energy, is the current ineffective global grid system. Though more complex and larger in size, the global grid is not much different than the original one constructed in 1882 by Thomas Edison to serve 59 customers in lower Manhattan. A key challenge is that power transmission lines are not optimally located. For example, in the U.S. the gusty plains in the Midwest, an area that could supply the entire nation with wind power, are far removed from major electrical arteries that supply major metropolitan areas such as Chicago, New York or Los Angeles. Using current technology to reach 20% wind power installation in the U.S. by 2030 would require a $60 billion investment in 12,650 miles of new transmission lines[12]. However, this would more than pay for itself in a short period of time in fossil fuel saved and carbon credits.

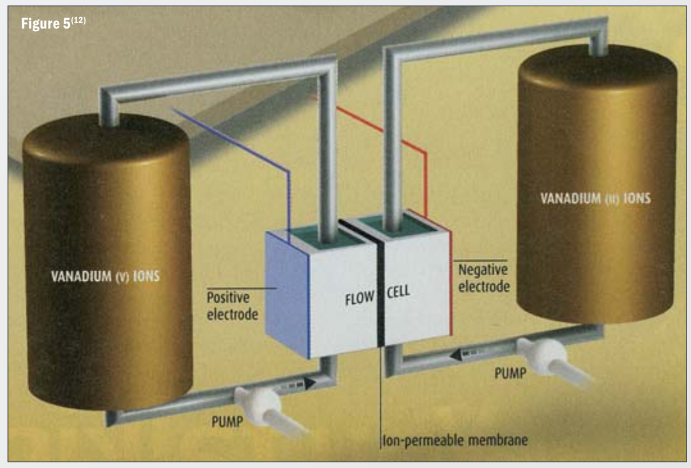


Figure 5[12]

A second issue is that the current grid lacks the electrical storage capacity to deal with power variability. This could be addressed by the storage technologies listed in **Figure 4**.

And finally, power flow is currently managed by human beings in a control room. Compared with other mechanized systems used in our modern world, the grid is quite "dumb." For example, in many instances if the power goes down in your neighborhood, the utility company will not be aware of this unless you or one of your neighbors calls them. In a smart grid system there is a seamless two-way connection with every user of electricity (see **Figure 6**)[14]. During a power demand surge, a signal goes out to meters in homes, factories and offices of customers who have agreed in exchange for rate reductions, to let the utility control the power to certain appliances, e.g. water heaters[14]. The technology exists to create a "smart" grid and is being implemented in a limited number of areas throughout the world. But much broader investment will be necessary to tap into the great potential of variably available power sources such as wind and solar energy.

Over 100 years have passed since Mr. Brush built the first wind turbine to generate electricity for his home. Wind power may never supply all of our global power needs, but it could supply a meaningful fraction. Indeed, it has already demonstrated that it has great potential to address simultaneously both energy security and climate change.

Victor Abate, Vice President of Renewables for GE Energy sums it up this way, "From a zero-fuel-cost and zero-carbon perspective, wind power is currently the most cost-effective and scalable technology available to mankind."

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[2] Janet L. Sawin, World Watch, July/August 2008, p. 35.
[3] Jana Mlcochova, "CEZ to Build Biggest Onshore Wind Park in Europe," Reuters Business & Finance, August, 27, 2008.
[4] "Wind of Change," The Economist Technology Quarterly, December 6, 2008, p. 21.
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[12] David Talbot, "Lifeline for Renewable Power," Technology Review, January/February 2009, p. 44.
[13] Emma Marris, Nature, Vol. 454, July 31, 2008, p. 572.
[14] Ibid

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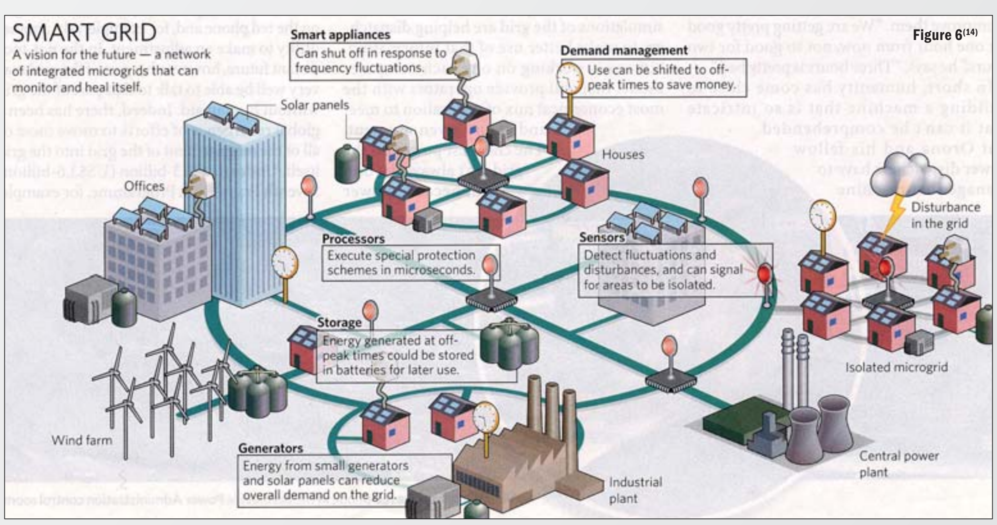

Figure 6[14]