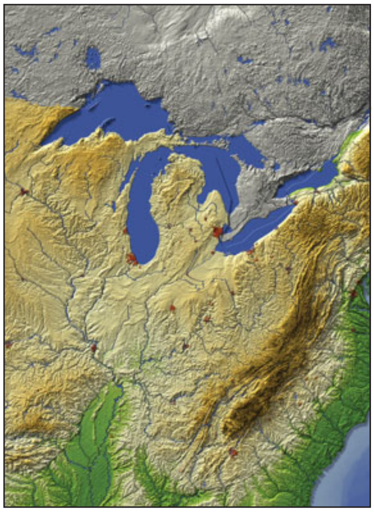

Wind on the Lakes

Philip Ball

Since wind power must go where the wind is, much attention so far in the United States has focused on the Great Plains. But the nation's highest winds are not on the Plains; they are over shallow waters all around the coast and on the Great Lakes.

There is currently no operating offshore U.S. wind farm. But the technology is proven. By the end of 2009, 2 GW of power was being generated by offshore wind worldwide, largely in Denmark. This is predicted to increase to approximately 20 GW by 2015 and to 100 GW by 2025. China, Sweden, Belgium, the Netherlands, Germany, and the United Kingdom have also built offshore wind turbines, and several manufacturers now sell turbines specifically for this market.

Although some plans for U.S. marine coastal wind power are close to being realized, using this technology in the Great Lakes has not yet been afforded the attention it is due. With technical, legal, and environmental challenges still blocking the way, it is not clear that this will change soon. But the arguments in favor are becoming harder to ignore.

Why the lakes?

Recent requirements for siting turbines farther from residences are reducing the number of available sites for land-based wind farms. Offshore wind farms, meanwhile, can be closer to coastal urban regions: about 26 million people live in the U.S. coastal counties around the shores of the Great Lakes. Such installations can still be far enough from the shoreline to lessen the aesthetic and noise objections that plague wind farms in the countryside. All the same, the high premium that shoreline property-owners pay for their view means that objections to turbines even on the distant horizon have killed some proposals on the Great Lakes.

Another advantage to offshore wind farms is the ease of water transportation: the size of components for onshore turbines is limited by what roads can carry. And on the Great Lakes, the problem of salt corrosion that bedevils marine installations is absent. The energy potential of Great Lakes winds is particularly strong for a state like Michigan with lots of shoreline. The net summer capacity of all Michigan powerplants is about 30 GW, of which just 4% currently comes from renewable sources. Yet the state has potential resources of around 44 GW of nearshore wind-generating capacity. In May 2008, the U.S. Department of Energy (DOE) claimed that offshore wind could provide a much greater resource for the entire country.

Wind-generated electricity is still expensive compared with that from other common sources, and mostly rely on subsidies and incentives. And because access is harder, installation and maintenance costs are generally higher for offshore than onshore.

One of the big uncertainties for offshore wind farms is their possible impact on the local ecosystems: fisheries, birds, and habitats. It has been suggested that the strong electromagnetic fields might disrupt navigation systems of fish and mammals that use geomagnetic sensing.

While turbines on the Great Lakes would not suffer salt corrosion, they confront another challenge: much of the nearshore lake surface is icebound in winter. Ice accumulating on a turbine can add enormous weight, while the structures can receive dangerous impacts from wave-tossed ice in winter storms. "Icing could definitely determine whether the various Great Lakes wind projects succeed or fail," said Guy Meadows of the University of Michigan, who is attempting to understand these loading mechanisms with funding from DOE. But "ice is not a deal breaker," according to Donny Davis of the Lake Erie Energy Development Corporation (LEEDCo). A wind farm in Lake Vanern in Sweden, which freezes in the winter, began operation in May 2010 with turbines about 7 km from the shore.

Making wind work

Most turbines consist of a tall (80–100 m) tubular steel tower with a three-blade rotor mounted on top, attached to a nacelle, a hollow shell of fiberglass or steel that contains the inner workings of the machine. Offshore turbines typically have a capacity of 3–5 MW, although Vestas and Siemens are developing 5–7 MW machines, and 20 MW is thought to be feasible. The bigger the machine, potentially the cheaper the power it produces.

Most of the experimentation with new materials focuses on the blades. They usually have a skin of fiberglass or carbon-fiber-reinforced plastic surrounding a core that is either hollow or filled with plastic foam or balsa wood. The rotors have typical diameters of about 80 m; General Electric's latest 3.6 MW turbines have a 110-m span, while that of the 7-MW turbines under development at Vestas is 164 m (hence the model name V164), with tip speeds of around 200 mph.

Fiber-reinforced plastic blades are plagued by various defects, such as delamination of fiber and resin, wrinkles, and misaligned fibers. Some of these can be taken into consideration in the design's safety margins, but they can be the most serious factors limiting a turbine's lifetime. There is still room for new materials, since laminated fiber-reinforced plastics can have low tensile and shear strength for out-of-plane deformations and cannot be recycled.

Although 20-MW turbines are often discussed, making them will be hugely challenging. As the blades get bigger, they need to be stiffer so that high winds do not bend them back so far that

https://doi.org/10.1557/mrs.2011.308 Published online by Cambridge University Press

they strike the tower. The weight of the blades could be reduced by optimizing the flexibility and microstructure of the constituent materials. Fatigue-inducing loads can also be reduced by using active control of the blade shape and aerodynamic properties, which could involve piezoelectrically deformable materials and shape-memory alloys.

Most commercial turbines use gears: the blade rotation speed is different from that of the generator rotors. But gearing mechanisms have drawbacks. Toothed gears increase vibration, while direct-drive turbines have a lower rotation speed, reducing wear. Gearboxes have tended to be the most maintenance-intensive components in current models. There is still no consensus on whether the larger turbines under development should be geared or not. The Vestas V164 has gears, whereas Siemens' 6-MW and GE's 10–15 MW prototypes are direct-drive.

There is room for improvement in the energy-generating and transmitting technologies too. The generators generally use rare-earth permanent magnets, the future costs of which may be held hostage to the uncertain rare-earth market: presently, this is mostly controlled by China, which has recently threatened to severely restrict its export quotas. GE's 10–15 MW prototype turbines replace these conventional magnets with superconducting electromagnets, which are smaller and lighter and can generate higher magnetic fields. This means that the rotation speed can be less, removing the need for gearing.

Some prototype designs also replace the generator rotor's copper wires with superconducting ones. American Superconductor Corporation's SeaTitan 10-MW turbine uses wires of the high-temperature superconductor yttrium barium copper oxide deposited on a nickel tungsten substrate, which incur less than half the electrical losses of existing turbine generators. They are also less noisy, and they too can dispense with gearing. Superconducting systems, however, need cryogenic cooling, which may be challenging for offshore installations.

What's happening?

The Great Lakes states are all exploring offshore installations, although none looks imminent. The prospects in Ohio are among the more favorable. LEEDCo's project offshore of Cleveland is being developed in partnership with GE, and is aiming for 20–30 MW capacity using 5–8 of GE's 4-MW turbines. It is expected to be complete by the end of 2012. Davis said that the lack of local opposition is partly because LEEDCo is not a private developer but a regional nonprofit organization dedicated to transparency. It is also of very modest scale. "We didn't want Northeast Ohio to wake up one day and read in the newspaper about a 130-turbine project headed for the lake," Davis said.

Evanston, Illinois, meanwhile, has taken a grassroots approach to offshore wind, with the community-based Renewable Energy Task Force for Citizens Greener Evanston (RETF/CGE) setting out to attract potential developers. One proposal is for a 200-MW wind farm 7 miles offshore just east of Northwestern University, which would provide enough power for around 60,000–80,000 homes—at least twice the number in Evanston. There are plenty of legal hurdles still to clear, but Nathan Kipnis, co-chair of RETF/CGE, hopes that construction might be ready to begin in 2017 and be completed by 2019.

Developers and campaigners are watching what could become the first U.S. offshore wind farm, in the marine setting of Horseshoe Shoal in Nantucket Sound, five miles off the Cape Cod shoreline in Massachusetts. The developers, Cape Wind Associates, plan for 130 turbines producing 420 MW at a cost of $2.5 billion. But the project has been dogged by controversy all the way; advocates regard the objections as the coastal equivalent of the "nimby" ("not in my back yard") resistance to land wind farms: "not near my beach."

Despite setbacks, the major federal approvals for the Cape Wind project were granted in May 2010. At first, its electricity is likely to cost twice as much as that from conventional sources. But the first projects will inevitably be the most expensive. With the benefits of experience, technological advance and economies of scale, offshore wind power should eventually make economic as well as environmental sense.

Nathan Kipnis of Kipnis Architecture + Planning served as Feature Editor for this article.

https://doi.org/10.1557/mrs.2011.308 Published online by Cambridge University Press