How far can wind power go toward reducing global carbon emissions from electricity production?

October 25 2011, by David L. Chandler

With the world's energy needs growing rapidly, can zero-carbon energy options be scaled up enough to make a significant difference? How much of a dent can these alternatives make in the world's total energy usage over the next half-century? As the MIT Energy Initiative approaches its fifth anniversary next month, this five-part series takes a broad view of the likely scalable energy candidates.

Of all the zero-carbon energy sources available, wind power is the only one that's truly cost-competitive today: A 2006 report by the U.S. Energy

Information Administration put the total cost for wind-produced electricity at an average of $55.80 per megawatt-hour, compared to $53.10 for coal, $52.50 for natural gas and $59.30 for nuclear power.

As a result, wind turbines are being deployed rapidly in many parts of the United States and around the world. And because of wind's proven record and its immediate and widespread availability, it's an energy source that's seen as having the potential to grow very rapidly.

"Wind is probably one of the most significant renewable energy sources, simply because the technology is mature," says Paul Sclavounos, an MIT professor of mechanical engineering and naval architecture. "There is no technological risk."

Globally, 2 percent of electricity now comes from wind, and in some places the rate is much higher: Denmark, the present world leader, gets more than 19 percent of its electricity from wind, and is aiming to boost that number to 50 percent. Some experts estimate wind power could account for 10 to 20 percent of world electricity generation over the next few decades.

Taking a longer-term view, a widely cited 2005 study by researchers at Stanford University projected that wind, if fully harnessed worldwide, could theoretically meet the world's present energy needs five times over. And a 2010 study by the National Renewable Energy Laboratory found that the United States could get more than 12 times its current electricity consumption from wind alone.

But impressive as these figures may sound, wind power still has a long way to go before it becomes a significant factor in reducing carbon emissions. The potential is there — with abundant wind available for harvesting both on land and, especially, over the oceans — but harnessing that power efficiently will require enormous investments in manufacturing and installation.

So far, installed wind power has the capacity to generate only about 0.2 terawatts (trillions of watts) of energy worldwide — a number that pales in comparison to an average world demand of 14 terawatts, expected to double by 2050. The World Wind Energy Association now projects global wind-power capacity of 1.9 terawatts by 2020.

But that's peak capacity, and even in the best locations the wind doesn't blow all the time. In fact, the world's wind farms operate at an average capacity factor (the percentage of their maximum power that is actually delivered) somewhere between 20 and 40 percent, depending on their location and the technology.

Some analysts are also concerned that widespread deployment of wind power, with its inherently unpredictable swings in output, could stress power grids, forcing the repeated startup and shutdown of other generators to compensate for wind's variability. Many of the best wind-harvesting sites are far from the areas that most need the power, necessitating significant investment in delivery infrastructure — but building wind farms closer to population centers is controversial because many people object to their appearance and their sounds.

One potential solution to these problems lies offshore. While many wind installations in Europe have been built within a few miles of shore, in shallow water, there is much greater potential more than 20 miles offshore, where winds blow faster and more reliably. Such sites, while still relatively close to consumers, are generally far enough away to be out of sight.

MIT's Sclavounos has been working on the design of wind turbines for installation far offshore, using floating platforms based on technology used in offshore oilrigs. Such installations along the Eastern Seaboard of the United States could theoretically provide most of the electricity needed for the eastern half of the country. And a study in California showed that platforms off the coast there could provide more than two-thirds of the state's electricity.

Such floating platforms will be essential if wind is to become a major contributor to reducing global greenhouse gas emissions, says research engineer Stephen Connors, director of the Analysis Group for Regional Energy Alternatives (AGREA) at the MIT Energy Initiative. Wind energy is "never going to get big if you're limited to relatively shallow, relatively close [offshore] sites," he says. "If you're going to have a large impact, you really need floating structures."

All of the technology needed to install hundreds of floating wind turbines is well established, both from existing near-shore wind farms and from offshore drilling installations. All that's needed is to put the pieces together in a way that works economically.

But deciding just how to do so is no trivial matter. Sclavounos and his students have been working to optimize designs, using computer simulations to test different combinations of platforms and mooring systems to see how they stand up to wind and waves — as well as how efficiently they can be assembled, transported and installed. One thing is clear: "It won't be one design for all sites," Sclavounos says.

In principle, floating structures should be much more economical than wind farms mounted on the seafloor, as in Europe, which require costly construction and assembly. By contrast, the floating platforms could be fully assembled at an onshore facility, then towed into position and anchored. What's more, the wind is much steadier far offshore: Whereas a really good land-based site can provide a 35 percent capacity factor, an offshore site can yield 45 percent — greatly improving the cost-effectiveness per unit.

There are also concerns about the effects of adding a large amount of intermittent energy production to the national supply. Ron Prinn, director of MIT's Joint Center for the Science and Policy of Global Change, says, "At large scale, there are issues regarding reliability of renewable but intermittent energy sources like wind that will require adding the costs of backup generation or energy storage."

Exactly how big is offshore wind power's potential? Nobody really knows for sure, since there's insufficient data on the strength and variability of offshore winds. "You need to know where and when it's windy — hour to hour, day to day, season to season and year to year," Connors says. While such data has been collected on land, there is much less information for points offshore. "It's a wholly answerable question, but you can't do it by just brainstorming."

And the answers might not be what wind power's advocates want to hear. Some analysts raise questions about how much difference wind power can make. MIT physicist Robert Jaffe says that wind is "excellent in certain niche locations, but overall it's too diffuse" — that is, too thinly spread out over the planet — to be the major greenhouse gas-curbing technology. "In the long term, solar is the best option" to be sufficiently scaled up to make a big difference, says Jaffe, the Otto (1939) and Jane Morningstar Professor of Physics.

Connors is confident that wind also has a role to play. "This planet is mostly ocean," he says, "and it's pretty windy out there."

This story is republished courtesy of MIT News (web.mit.edu/newsoffice/), a popular site that covers news about MIT research, innovation and teaching.

More information: *Tomorrow: Vast amounts of solar energy radiate to* *the Earth constantly, but tapping that energy cost-effectively remains a challenge.*

-- **Read part 1:** "What can make a dent?"

Provided by Massachusetts Institute of Technology