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# Which Way Will the Wind Blow?

## Marine scientists have a key role to play in the debate over wind farms in the coastal ocean

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*A wind came up out of the sea,*
*And said,'O mists, make room for me.'*
*-- Henry Wadsworth Longfellow*

Two centuries ago, citizens of the new American republic relied on the winds along their shores as an economic engine. Salt farms and gristmills dotted the coastline, their windmills tapping the sea breezes for energy.

Two centuries later, Americans are looking to tap coastal winds again to fuel the modern economy, to reduce air pollution, and to mitigate global warming. Wind energy is the fastest-growing sector of the global electric power industry, and several companies have proposed to build large wind turbines and utility-scale electric power-generating facilities in the coastal waters of the United States.

Such facilities could change the way people use the ocean, and the public is divided over the costs and benefits. The environmental and economic benefits of renewable, nonpolluting sources of energy are clear. But there may be side effects from the placement of modern wind farms in the ocean, including the degradation of seascapes, impacts on birds and marine animals, and the disruption of existing patterns of human use of the ocean. The laws and regulations related to the placement of wind turbines in the ocean are at best rudimentary and inchoate; at worst, they are non-existent.

Marine scientists and engineers can

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*Situated 8 to 12 miles (14 to 20 kilometers) off the west coast of Denmark, the Horns Rev wind farm is the world's largest. The 80 turbines are spread across 7.7 square miles (20 square km), with blades stretching 360 feet (110 meters) into the air. Completed in 2003, the project added 160 megawatts (MW) of power-generating capacity to the country's electrical grid, and it is expected to produce nearly 2 percent of the nation's electric power. European nations have plans to add nearly 5,000 MW of wind power production in the coming years, and nearly 50 wind farms have been proposed for U.S. waters.*

make an important contribution to this growing public debate by clarifying our understanding of the nature of these side effects. They might also inform public policies that balance the value of various ocean resources with the rights and interests of all who wish to use them.

### Major Freeman's legacy

Just after the American Revolution, Major Nathaniel Freeman of Harwich, Massachusetts, suggested using wind energy to pump seawater into large vats onshore, where it could evaporate to form salt crystals. As chronicled by historian William Quinn, salt was crucial for preserving fish and furs both for American consumers and European markets. Spurred by government incentives and federal tariffs on imports, 1,260 "salt mills" sprouted along the coast of Cape Cod by the 1830s.

During their heyday, coastal salt works were so lucrative that they were referred to as a "lazy man's gold mine." The bottom fell out of the business in the mid-19th century, when it became cheaper to harvest salt from the more saline springs of Virginia, Kentucky, and upstate New York.

At least 39 wind-powered gristmills were built on Cape Cod in those early years as well. Operated by "dry-land sailors," the gristmills provided energy for industry and incidentally served as important navigational landmarks. The advent of steam power meant the end of the gristmills, though some were relocated to the properties of affluent landowners who admired their beauty and sound construction.

Ironically, many coastal property owners now oppose building modern windmills. This opposition is one measure of how Cape Cod and other coastal areas have shifted their economic bases from farming and natural resource exploitation to tourism and recreation.

### Winds of change

In the past decade, worldwide electricity production from wind has grown by 30 percent. Several factors have rejuvenated interest in wind power. Technological advances in turbine and blade designs over the past 20 years have reduced the cost of producing electricity with wind by as much as 80 percent. At the same time, governments have responded to the growing public interest in technologies that reduce pollution and mitigate the impact of global warming caused by carbon dioxide emissions from the burning of fossil fuels.

Government policies also have encouraged this development. At the U.S. federal level, a tax credit subsidizes the production of electricity from wind power at the rate of 1.6 cents per kilowatt hour (kWh). Generating facilities powered by wind are also eligible for accelerated capital depreciation, making it easier to recoup some of the expenses of building wind farms.

Many states have begun to adopt policies requiring utility companies to supply a proportion of power from renewable sources, including wind, hydropower, and biomass. In addition, many states have adopted tax breaks that parallel the federal subsidies. Some have developed research and development programs for renewable energy, financed by so-called "public benefit charges" on consumer electricity bills.

With subsidies and the economies of scale that can be achieved with large turbines, wind power can now be produced in some areas of the United States for as little as 3 cents per kWh, making it competitive

Courtesy of William Quinn. Engraving by J.W. Barber and S. E. Brown

*An engraving by J.W. Barber from the 1840s shows the coastline of Provincetown, Massachusetts, dotted with wind-powered salt mills. The artist noted: "The numerous wind or salt mills, and the elevations of sand, give the place a novel appearance."*

with other energy sources. Land-based, utility-scale wind turbines now operate in 26 states. The U.S. accounts for roughly 16 percent of the world's wind power generating capacity. Although U.S. capacity is now nearly 6,400 megawatts (MW), wind power supplies less than one percent of current U.S. energy needs.

### New proposals on the horizon

Utilities in Europe have been generating power from ocean wind for more than a decade, ever since the Vindeby facility off Denmark became operational in 1991. Wind farms are being developed off the coasts of Denmark, Great Britain, Sweden, and the Netherlands, creating 246 MW of power generating capacity—including 160 MW at the Horns Rev wind farm that came online in 2003 along Denmark's west coast. An additional 5,000 MW of capacity is planned for northern Europe.

In recent years, proposals have been floated—some serious and some ridiculous—for as many as 50 wind farms in the U.S. coastal ocean and Great Lakes. The ocean attracts wind energy companies because winds tend to be stronger and more consistent over open areas, such as large bodies of water. Also, the "land" for placing turbines is cheap because the ocean is a public resource and not privately owned.

There is little precedence for modern wind farming in the United States, so there are no provisions for renting areas of the ocean to wind farmers, as there are for oil and natural gas producers. The lack of a precedent leads to contradictions. For instance, is it sensible for the government to subsidize wind power on one hand while charging a "land rent" on the other?

There are also serious questions about which agencies, federal and local, have the authority to make decisions about this resource. The existing federal permitting process for regulating offshore wind farms is loosely based on the Rivers and Harbors Act of 1899, which gives jurisdiction to the U.S. Army Corps of Engineers over any "obstructions to navigation." While navigational issues for ships are important, the issues surrounding wind farming go well beyond navigation. Neither the old law nor the more recently developed public review process appears adequate for making decisions about the exclusive use of the ocean for activities such as wind farming.

Courtesy of William Quinn

*The Judah Baker gristmill (center) and a salt mill (left) stood near the coast of South Yarmouth, Massachusetts, in 1866 at the height of a boom in "dry-land sailing." The wind powered nearly 1,300 salt- and gristmills along the shores of Cape Cod in the 19th century. The Baker gristmill has since been moved inland and serves as a tourist attraction.*

### Running aground on the shoals

These vagaries and gaps have spawned an impassioned debate and a public policy quandary. Since 2002, the center of that debate has been Nantucket Shoals, off the southeast coast of Cape Cod.

Successful small-scale wind power projects on Cuttyhunk, Nantucket, and other islands in the 1970s and 1980s inspired interest in placing large wind turbines and a utility-scale power facility in the coastal waters of New England. The current proposal includes 130 wind turbines—each 400 feet tall—to be located 0.3 to 0.5 miles apart within a 25-square mile area of Nantucket Sound.

Public opposition to wind farms in nearshore waters is based mainly on worries that they will spoil seascapes and have detrimental effects on birds, marine animals, and their habitats. Other groups have expressed concerns about the potential impact on sailors and important commercial fisheries.

Cape Cod and the islands of Nantucket and Martha's Vineyard are national tourist havens. Many summer homes have outstanding views of the nearby sounds, where the sailing is superb, the stripers and blues run thick, and fishing for lobster, scallops, and squid has been a popular livelihood for ages. If the wind farm is built on Nantucket Shoals, these views, and quite possibly the established pattern of ocean activities, could be altered permanently. Consequently, many Cape Codders and Islanders who otherwise support the idea of renewable energy—just not on Nantucket Shoals—have become opponents to the wind farmers.

### Need for coastal ocean research

Why not put wind farms far out in the ocean, beyond the sight of land, where

winds are even stronger? After all, if wind farms are developed in more remote sites, the potential for public opposition should dwindle significantly and the wind resource would grow. (In fact, civil engineering professor William Heronemus of the University of Massachusetts suggested in 1972 that it was feasible to construct an array of floating "wind stations" as far offshore as Georges Bank.)

As with most environmental problems, this potential solution entails tradeoffs. Wind energy developers would prefer to place wind turbines in shallow, protected waters that are close to existing electrical transmission lines. These criteria limit the number of good locations for ocean wind farms. Business models suggest that deep-water sites are less profitable, but the true costs and benefits of building wind farms in deep water are not yet understood.

Given the uncertainties surrounding wind energy as a new use of the ocean, a number of research questions have emerged. What are the effects of the ocean environment on wind turbines placed in the ocean? What are the effects of wind turbines on the ecosystem? And what are the features of a public policy that could make the tradeoffs easier to understand, leading to more rational and balanced decisions about human uses?

Marine scientists and policy experts are in a good position to help clarify and resolve these issues, and research is needed in several key areas:

• Ocean physics—What is the nature of wind and wave patterns and current flows (particularly during extreme storm events) around each proposed wind farm site? How does the seafloor change over time, as a consequence of both flowing currents and seismic events? What is the likelihood of ice formation and movement through a wind farm area?

• Environmental impact—How would wind turbines affect songbirds that migrate through these regions or seabirds that frequent them as productive habitat? How do these structures affect marine ecological processes or important commercial fisheries? What is the impact of turbine noise on protected species, including whales, dolphins, and seals?

• Marine policy—How do we design a system of access that balances the needs of ocean wind developers against the legal interests of people and businesses already benefiting from these areas? What can we learn from the existing models of planning for use of the ocean and public lands?

All of these research efforts must be undertaken with an awareness of the economics of ocean wind power because the answers to these questions will affect the engineering design of offshore structures.

**U.S. Electric Energy Generation by Source (2003)**

| Type | Generation (billion kWh/yr) | Generation (% of Total) | Cost (¢/kWh) |
|---|---|---|---|
| Coal | 1,928 | 51 | <1-6 |
| Nuclear | 781 | 21 | <1-15 |
| Natural gas | 648 | 17 | 2-6 |
| Hydropower | 296 | 8 | 1-6 |
| Biomass | 34 | 1 | 7-10 |
| Oil | 31 | 1 | 1-3 |
| Wind | 17 | <1 | 3-6 |
| Geothermal | 14 | <1 | 2-8 |
| Solar | 1 | <1 | 25-30 |
| TOTAL | 3,750 | 100 | |

Sources: U.S. Department of Energy; California Energy Commission

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*Recent advances in the design of wind turbines, as well as government incentives, have made the cost of wind power production comparable to other forms of energy. But calculating their true power-generating impact is tricky. Wind farms often cite total capacity, but average production is typically 70 percent lower because winds do not always blow at optimal strength.*

## Prospects

Some environmentalists believe that the production of energy from both ocean- and land-based wind farms has the potential to satisfy the global demand not only for electricity, but also for all forms of energy. Realizing such a vision would require many thousands of large wind turbines, as well as the development of technologies to store the energy (such as the production of hydrogen as a fuel). It would also require a process for locating wind turbines in the coastal ocean that balances the benefits with the costs.

When faced with a new activity that might change the way we use the ocean environment, the public is often ambivalent. Today we are faced with a split between those who favor renewable energy through offshore wind farms and those who decry the potential degradation of the seascape. As new information is discovered and learning occurs, societal preferences about the mix of appropriate uses of the coastal ocean undoubtedly will shift. At the same time, science may uncover new options and opportunities, perhaps revealing the true potential for wind farms in the coastal ocean.