

A photograph of several offshore wind turbines in the ocean at sunset. The sun is low on the horizon, creating a bright, shimmering reflection on the water's surface. The sky is a clear, pale blue. The turbines are silhouetted against the bright light of the sun.

Wind Power to Spare

**The Enormous Energy Potential
of Atlantic Offshore Wind**



FRONTIER GROUP

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Written by:

Gideon Weissman and Rachel J. Cross

Frontier Group

Rob Sargent

Environment America Research & Policy Center

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Cover photo of Block Island Wind Farm: Courtesy of Deepwater Wind

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Executive Summary

The Atlantic coast states are dependent on fossil fuels, which pollute our air, put our health at risk, and contribute to global warming. In response, states in the region are moving toward an energy system powered by clean, renewable sources: Atlantic states now generate enough wind and solar energy to power nearly 2 million homes, 19 times more than just a decade ago.¹

Yet to achieve a truly clean energy system, Atlantic states – which account for more than a quarter of the nation’s energy use – will need to tap into a massive clean energy resource that is right in our back yard: offshore wind energy.

With enough wind energy resources to generate four times the amount of electricity the region currently consumes, offshore wind can help power the Atlantic coast with clean energy.² In order to capture this tremendous pollution-free resource, state leaders must put in place strong policies to foster development of offshore wind, while ensuring the protection of our oceans and wildlife.

Offshore wind is an abundant resource located close to where we need it most, and it can play a core role alongside other renewable energy sources in providing clean energy for the future.

- Offshore wind off the Atlantic states could produce enough electricity each year to meet four times those states’ electricity consumption (4,574 terawatt hours), even after excluding areas not suitable for current technology and off-limits areas like shipping lanes.³ Almost every Atlantic state (12 out of 14) has wind potential off its shores that exceeds current state electricity consumption.

- Tapping into offshore wind can help meet future electricity demand created by electrifying activities currently powered by gasoline, natural gas and other fossil fuels, like transportation and heating homes and businesses. If developed to its full potential, Atlantic offshore wind could supply double the estimated electricity it would take to power all current electricity needs plus estimated electricity for electrified heating and electric vehicles.⁴

Figure ES-1. Offshore Wind Energy Potential on the Atlantic Coast⁵

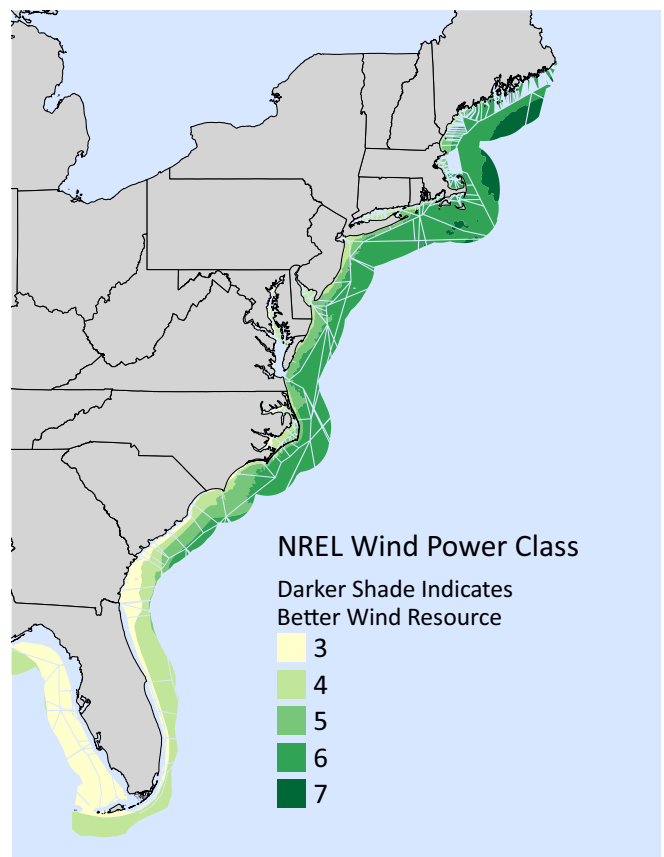
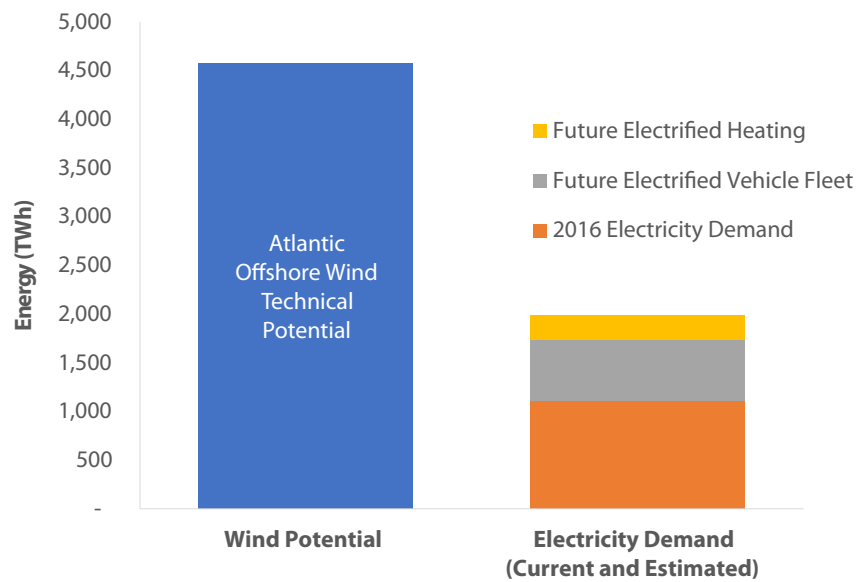


Figure ES-2. Offshore Wind Has the Technical Potential to Supply Double the Energy Demand for Current Electricity Needs Plus Estimated Demand for Electrified Vehicles and Heating⁶



Offshore wind technology is advanced, affordable and proven.

- Offshore wind is proven. Europe is home to 4,100 offshore wind turbines that supply enough electricity to power more than 20 million homes each day.⁷ In Denmark, offshore wind supplied 15 percent of electricity use over the first half of 2017.⁸
- Offshore wind turbine is advanced, and can generate more power, more efficiently than ever before. For example, the turbines at the nation’s first offshore wind project in Rhode Island produce 30 times more electricity each year than the first offshore wind turbines installed in Europe in the early 1990s.
- Offshore wind has become affordable. According to Lazard, the average global levelized cost of energy for new offshore wind fell by 27 percent from 2012 to 2017, to a cost that is comparable to a new coal-fired power plant

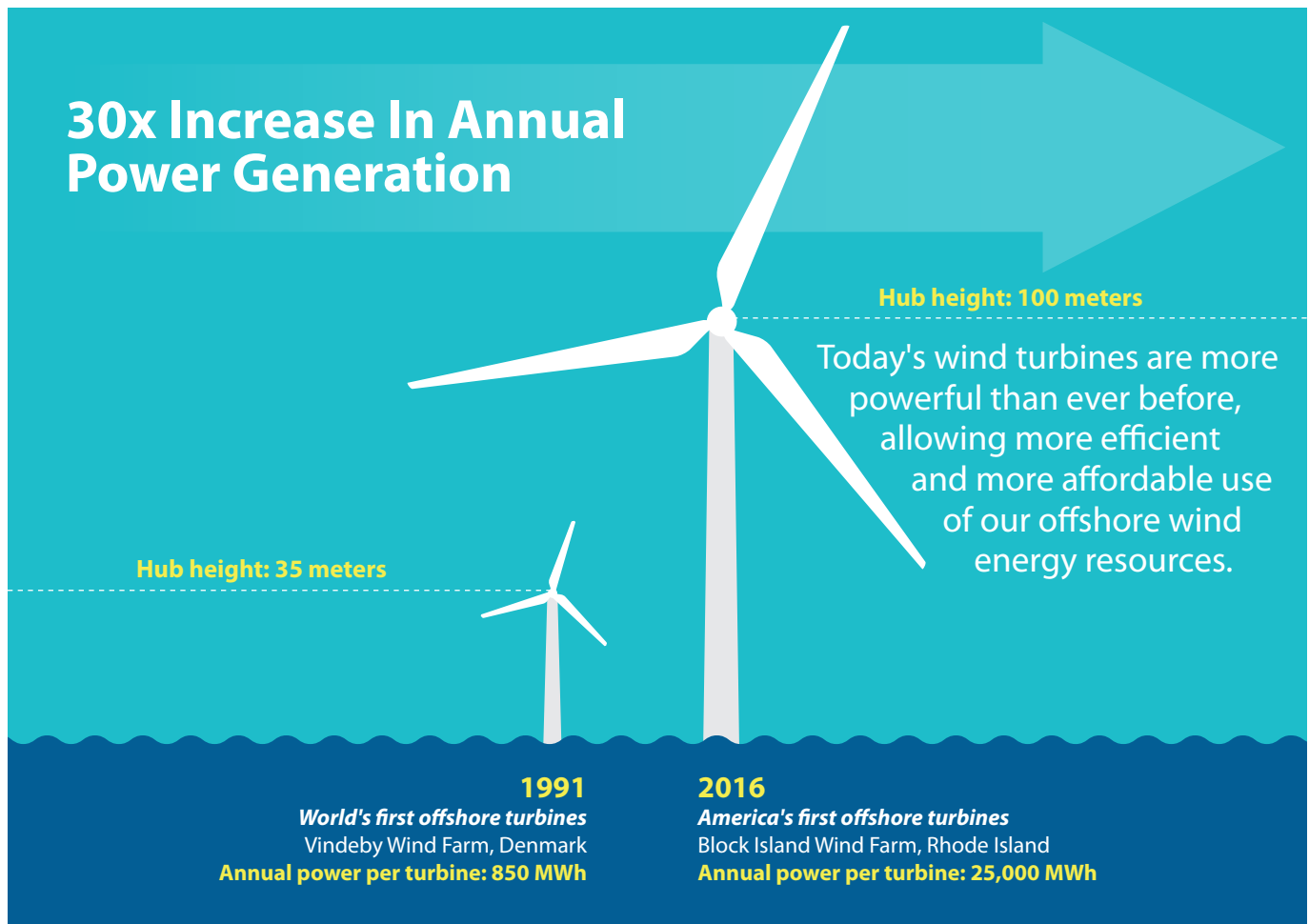
and cheaper than a new nuclear plant over the plants’ entire life cycles.

- Experts predict that offshore wind will continue to fall in price. Bloomberg New Energy Finance projects that the levelized cost of energy for offshore wind will fall by 71 percent by 2040 relative to today’s prices.⁹
- Experience at home and abroad has shown that responsible development of offshore wind can avoid harm to the environment and wildlife, including the North Atlantic right whale.

Offshore wind projects are already planned all along the Atlantic coast.

- More than 8 gigawatts (GW) of offshore wind development are supported by state policy in five Atlantic states. If state offshore wind targets and commitments are met, offshore wind in those states would be able to generate electricity equivalent to the power used by 3 million homes.¹⁰

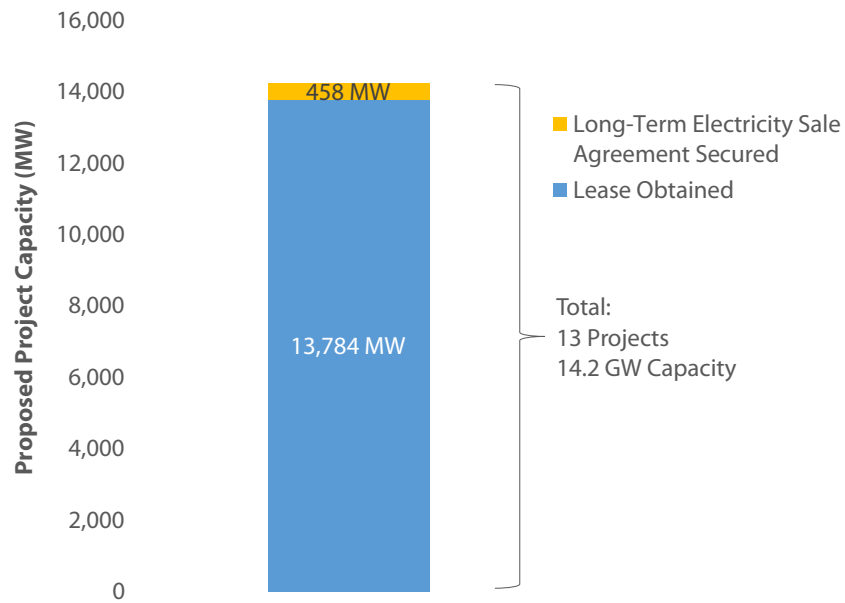
Figure ES-3. Turbines at Block Island Wind Farm Produce 30 Times More Electricity Each Year Than the First Offshore Turbines from 1991



- As of February 2018, 13 Atlantic offshore wind projects had leases and were moving forward.¹¹ With a total estimated capacity of 14.2 GW, these proposed projects could power approximately 5.2 million homes.¹²
- These in-development offshore wind projects could produce a fifth as much energy as we could get annually from Atlantic offshore oil and gas, based on optimistic production estimates from the American Petroleum Institute, an industry trade group.¹³ Capacity of the proposed projects represents just 1 percent of Atlantic offshore wind technical potential.¹⁴

Offshore wind has the potential to help repower the Atlantic coast with clean energy – but taking advantage of the opportunity will require support from policymakers and regulatory bodies. Supportive policies include strong and enforceable state offshore wind targets, policies to ensure a strong market for offshore wind, investments in research, and efforts to work with the federal Bureau of Ocean Energy Management to ensure environmentally responsible and efficient development of offshore wind resources. Policymakers must also create minimum standards for the protection of ocean habitats and wildlife (particularly the North Atlantic right whale).

Figure ES-4. Capacity of Proposed Atlantic Offshore Wind Projects by State and Project Status



Securing a long-term agreement for the sale of electricity (an “offtake” agreement) is an important step in the development of offshore wind projects. These can take forms including power purchase agreements and renewable energy credit agreements.

Introduction

For those of us that live along the Atlantic coast, the ocean is central to our identity. Many of our most special places, and much of our history and our character, are a result of proximity to the ocean.

In the colonial fishing towns of New England, lobster fishermen still set out traps, and hundred-year-old piers jut out into the cold waters. In the Mid-Atlantic, we spend summers along the boardwalks of the Jersey Shore, and host the world's greatest concentration of military sea power at Norfolk. In the Southeast, the sea frames historic port cities, and nourishes lush coastal landscapes of cypress trees, swamps and marshes. And in Florida, the neon, art deco beach communities of Miami, and the 1.5 million acres of coastal mangroves, sawgrass marshes and pine flatwoods that make up the Everglades, draw visitors from around the world.

In communities along 2,000 miles of coastline, we cherish the ocean. Yet today, global warming has added a sense of menace to living in the places where many of us have spent our entire lives. Sea level rise has created the specter of dislocation for millions, including families that have called the Atlantic shore home for generations. Already, coastal flooding throughout the region has increased, in some cases dramatically.¹⁵ Warming oceans are also creating powerful and destructive storms – storms like Hurricane Sandy of 2012, which wreaked havoc and caused nearly \$70 billion worth of damage in

communities from Florida to Maine. Many of the potential impacts of global warming, including changes to agriculture, the environment and the economy, cast a layer of uncertainty over the region's future.

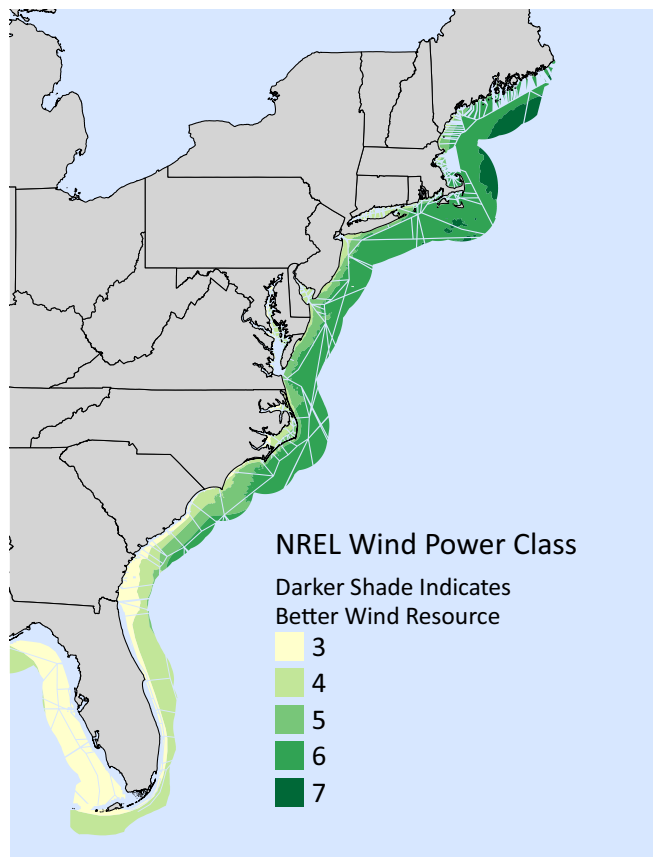
Yet, the Atlantic also holds new promise for our future – and new hope in the effort to curb the future impacts of global warming – thanks to the powerful winds that blow over its waters. For generations, coastal residents have looked at the ocean as a source of wealth and commerce, food to eat, and vibrant coastal habitats. Now, new technology – advanced offshore wind turbines – may enable the ocean to hold a new role in our lives: a source of clean, renewable energy that can power our region.

As this report describes, the winds of the Atlantic Ocean contain immense, abundant energy, and the time is right to begin harnessing that energy to power the region. Offshore wind turbines have been installed by the thousands around the world – including the first American offshore wind farm, now operating off the coast of Rhode Island – have been shown to be safe for ocean habitats when developed responsibly, and have been proven as reliable and cost-effective components of a 21st century clean electric grid.

Atlantic states have already begun to plan the offshore wind farms of the future, and these plans are making the vision of a clean energy future clearer than ever. By tapping into our ocean winds, that vision can become a reality.

Atlantic Offshore Wind Is an Abundant Clean Energy Resource

Figure 1. Offshore Wind on the Atlantic Coast¹⁶



States on the Atlantic coast of the United States account for more than a quarter of the nation's energy consumption and use more energy than all but four countries in the world.¹⁷ As of 2008, more than 48 million people lived in counties immediately adjacent to the Atlantic coast, an increase of 56 percent from 1960.¹⁸

In recent years, many states along the coast have worked to reduce fossil fuel use and adopt renewable energy. Most of the Atlantic Coast states have minimum clean energy requirements – so-called renewable energy standards. And 10 states, from Maryland to Maine, have joined the Regional Greenhouse Gas Initiative, a program that caps carbon emissions from electric power plants and invests revenues from the auction of pollution permits into improved energy efficiency and expanded use of clean energy. The vast majority of energy used by Atlantic states, however, still comes from fossil fuels.

While recent years have seen dramatic increases in the use of renewable energy sources like wind and solar power, truly repowering the Atlantic coast states with clean energy will require tapping into plentiful, nearby clean energy resources. The wind blowing off the Atlantic coast is one of America's biggest and most accessible clean energy resources and can play a core role alongside other clean energy sources in providing clean energy of the future.

Offshore Wind Can Meet Much of the Region’s Electricity Needs

The Department of Energy’s National Renewable Energy Laboratory (NREL) has performed detailed assessments of Atlantic offshore wind potential. In 2016, NREL estimated the United States’ offshore technical potential, in an assessment that excluded those ocean areas too far from shore, too deep to access with current technology, and with insufficient wind speeds.¹⁹

NREL’s analysis found that areas suitable for offshore wind in the Atlantic could supply 4,574 terawatt hours (TWh) of energy per year. That is enough energy to power all Atlantic state electricity needs four times over.²⁰

While offshore wind energy can provide enough energy to meet all of the region’s energy needs, it need not bear the entire load of powering the Atlantic coast with clean energy. In fact, offshore wind is very well suited to complement solar energy, because offshore turbines produce electricity at night and do not have reduced production during the winter.²¹ Because off-

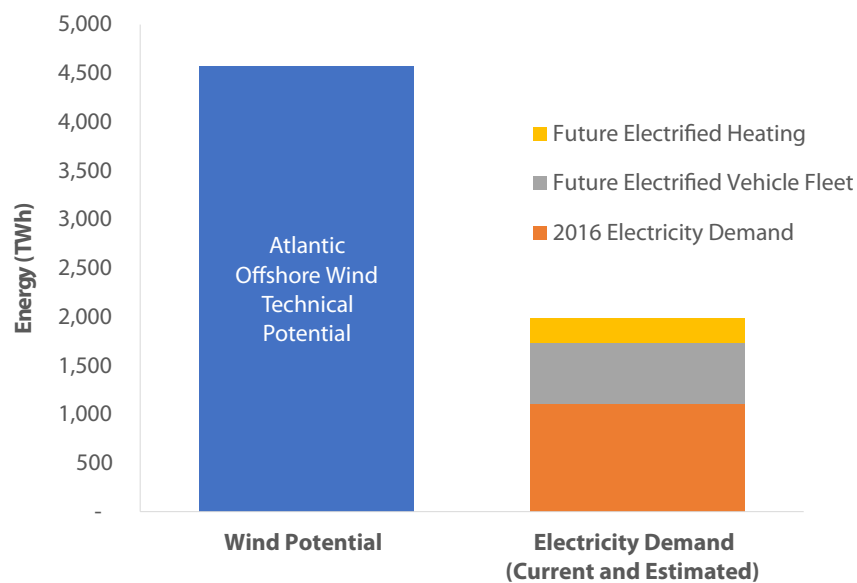
shore wind turbines produce power when solar panels do not, they can help lower the cost of a renewable grid, potentially reducing the need for costly grid additions and reducing demand for costly peak power.²²

Offshore Wind Can Power Electrified Heating and Transportation

Atlantic offshore wind could supply four times the electricity used by states on the Atlantic coast. But achieving a deep reduction in carbon emissions also means reducing emissions from activities not currently powered by electricity. These include transportation and heating, which together account for approximately one third of the nation’s global warming emissions.²³

Renewable energy can also be used to power our transportation and heating. This is possible by upgrading equipment that uses fossil fuels directly – like natural gas heating, and vehicles that use gasoline or diesel fuel – to

Figure 2. Offshore Wind Has the Technical Potential to Supply Double the Energy Demand for Current Electricity Needs Plus Estimated Demand for Electrified Vehicles and Heating



technologies that use electricity, like electric vehicles and electric heating systems (in particular, efficient electric heating systems called air source heat pumps).

Moving these activities to the grid, however, will likely result in an increase in total electricity consumption (although improving economy-wide energy efficiency and reducing energy waste can limit this increase). If the Atlantic states were to replace all current vehicles and fossil fuel heating systems with electric vehicles and efficient air source heat pumps, the result would be an increase in electricity consumption of approximately 80 percent. (See Methodology.)

Atlantic offshore wind can play a key role in meeting this additional electricity demand, producing electricity equivalent to:

- 18 times the estimated electricity it would take to power electrified heating for Atlantic states.
- 7 times the estimated electricity it would take to power an electrified vehicle fleet in the Atlantic states.
- Double the estimated electricity it would take to power all current electricity needs plus estimated electricity for electrified heating and transportation.

Table 1. For 12 of 14 Atlantic States, Offshore Wind Technical Potential Is Greater Than Electricity Use

State	Ratio of Offshore Wind Potential to:	
	Current Electricity Consumption	Current Electricity Consumption + Estimated Electrified Heat and Transportation
Connecticut	0.2	0.1
Delaware	1.8	1.1
Florida	3.3	2.2
Georgia	1.1	0.7
Maine	35.9	13.7
Maryland	1.6	0.8
Massachusetts	19.7	8.3
New Hampshire	0.5	0.2
New Jersey	3.7	1.6
New York	2.0	0.9
North Carolina	4.7	3.0
Rhode Island	8.0	3.3
South Carolina	7.7	4.9
Virginia	1.4	0.9
<i>Total</i>	4.1	2.3

Most Atlantic States Have Abundant Access to Offshore Wind in the Waters off Their Shores

Most states on the Atlantic coast do not have to look far to find all the offshore wind energy they need.

Almost every state on the Atlantic coast has offshore wind potential in the waters off its shores greater than its electricity needs. And most states have enough technical potential to also supply additional estimated demand from electrified heating and transportation sectors. (In reality, states are not constrained to the waters adjacent to their coastlines for offshore wind; for example, New York is currently moving forward with an offshore wind project located off the coast of Long Island in Rhode Island's offshore planning area.)

Based on offshore wind technical potential estimates produced by the National Renewable Energy Laboratory, the offshore wind resource off of 12 of the 14 states with Atlantic coastline could produce electricity equivalent to or greater than the amount that is currently used in those states.²⁴ Even when accounting for estimated future demand for electrified vehicles and heating, eight Atlantic states could meet all electricity demand with offshore wind, often with enough to spare to help neighboring states meet their clean energy needs.

Offshore Wind Technology Is Advanced, Affordable and Proven

The United States is no stranger to wind power – on land. Across a broad swath of America, from the northern Plains to Texas and from Maine to California, wind turbines have become a core piece of energy infrastructure. American wind turbines now generate enough electricity to power 21 million homes, and in 2016 were responsible for 37 percent of electricity generation in Iowa, 32 percent in South Dakota, and 30 percent in Kansas.²⁵

A quarter of America's energy is consumed along the Atlantic coast, hundreds or thousands of miles from the windy plains that are home to the nation's best onshore wind resources.²⁶ While the Atlantic states also have ample potential for onshore wind energy, the most powerful and accessible winds in the region are often those blowing off our shores.

With modern, technologically advanced and proven offshore wind turbines, tapping into these powerful winds is more possible than ever before.

Offshore Wind Is Proven

Thousands of offshore wind turbines are already spinning in waters around the world, providing reliable energy to millions of homes. Offshore wind has been providing reliable power for Europe and Asia for years, with significant offshore wind farm development in Europe beginning in the early 2000s and increasing steadily ever since.²⁷

In Europe, approximately 4,100 offshore wind turbines with a total capacity of nearly 16 gigawatts now pro-

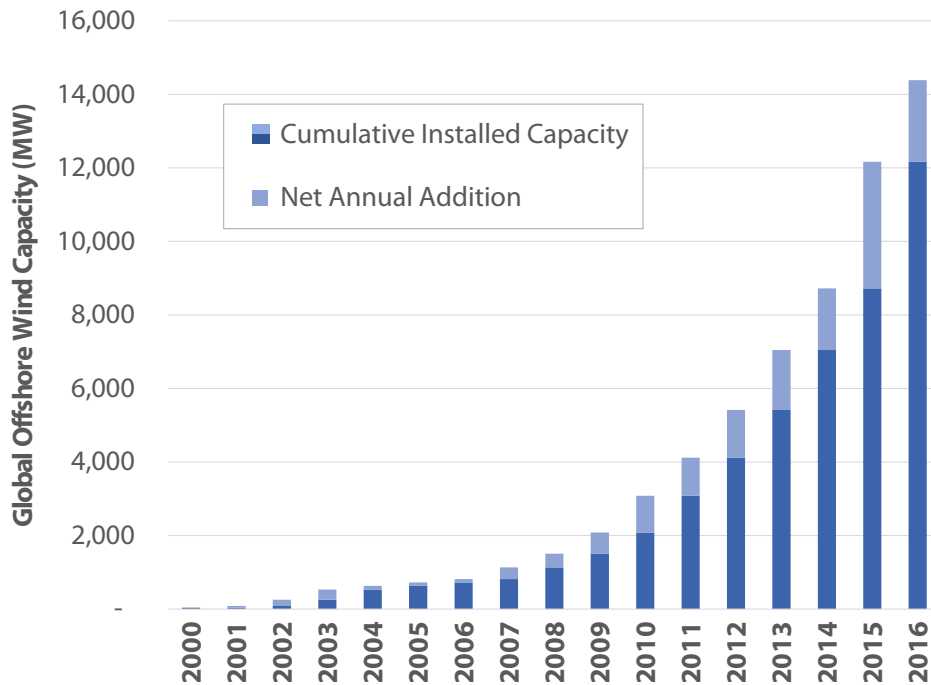
vide electricity to 11 European countries, enough to power more than 20 million EU households each day.²⁸ In Denmark, offshore wind supplied more than 15 percent of electricity use over the first half of 2017.²⁹

Decades of offshore wind development have provided important lessons about developing wind energy responsibly and safely for ocean wildlife and other ocean activities. Since its first offshore wind farm began operating in 1991, Denmark has run an environmental monitoring program to understand impacts on natural ecosystems.³⁰ Denmark has also performed detailed studies on offshore turbine siting and its impacts on safety, navigation, offshore resource extraction, ocean aesthetics, and electric grid connections.³¹

European experiences are already helping guide U.S. offshore wind development. In 2017, Denmark entered into a formal agreement with the U.S. federal government to share offshore wind expertise and provide consultation.³² Such consultation may be particularly helpful in the North Atlantic, where seafloor conditions are similar to many offshore wind sites in the North Sea.³³

While U.S. offshore wind development has been far more limited, the Block Island Wind Farm off the coast of Rhode Island has provided important experience in protecting the North Atlantic right whale. Before project construction, environmental groups helped develop a protection plan that included the restriction of certain construction activities at times when right whales were likely to be nearby.³⁴

Figure 3. Global Offshore Wind Development Since 2000³⁵



Today's Offshore Wind Turbines Are Powerful and Technologically Advanced

There are key differences between onshore and offshore wind technology. Offshore wind support structures are far more complex, and must be built up from the seafloor, or on floating hulls. Offshore turbines must be resilient to saltwater and waves. And because wind speeds are often higher offshore, turbines must be able to withstand and capture energy from high wind speeds. Today's offshore wind turbines, thanks to decades of technological advances, are capable of meeting these challenges.

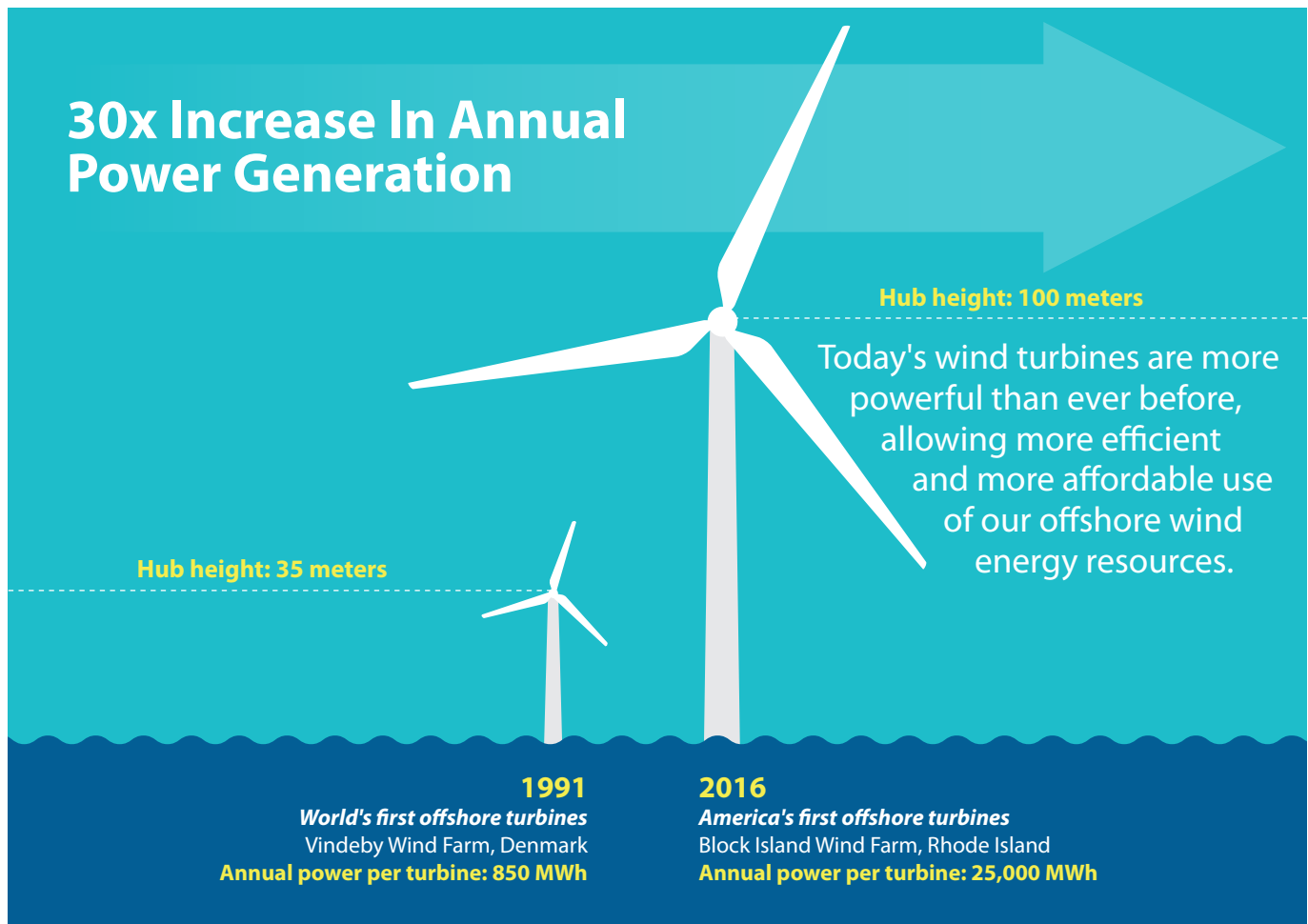
Since the first offshore wind turbines were installed nearly three decades ago, offshore technology has advanced in every way. The world's first offshore wind turbines began spinning in 1991 off the coast of Denmark. Each turbine had a capacity of 0.45 MW and a capacity factor – the average generation as a percentage of peak capacity over the course of a year

– of 22 percent.³⁶ By contrast, the turbines installed in 2016 for the first U.S. offshore wind project in Rhode Island each have a capacity of 6 MW and a capacity factor of 47 percent, meaning they are able to produce approximately 30 times as much electricity each year as the original Danish turbines.³⁷

This dramatic increase in energy production is a product of rapid improvements in technology, leading to turbines that are more powerful, more resilient, and able to be sited in better wind resources than ever before.

For example, in recent years turbines have gotten far larger, enabling greater power production per turbine. A larger rotor diameter (the diameter of the circular area swept by the turbine blades) generally means increased peak capacity, while a taller tower increases capacity factor as the result of access to the consistently higher wind speeds available high above the ocean surface. From 2010 to 2016, the average rotor diameter in offshore projects increased from

Figure 4. Turbines at Block Island Wind Farm Produce 30 Times More Electricity Each Year Than the First Offshore Turbines from 1991



94 to 127 meters – the length of 1.4 football fields – while average hub heights increased to almost 100 meters.³⁸ One of the current largest prototype wind turbines has a swept rotor area larger than the giant London Eye Ferris wheel, a hub height of 140 meters, and capacity of 9 MW – 50 percent bigger than the Rhode Island wind turbines.³⁹ And experts expect turbines to continue getting bigger, with the average new turbine reaching 11 MW by 2030.⁴⁰

The increased size of today's offshore wind turbines has been a key factor in driving reductions in cost. Bigger turbines require less infrastructure to produce a similar amount of power and allow for the generation of more power in a smaller area

of ocean – reducing the cost and increasing the amount of energy that can be produced with offshore wind turbines.⁴¹

Other technology advances are also making offshore wind turbines cheaper and easier to install and expanding the range of viable locations for wind turbines. For example, the easiest and cheapest way to install offshore wind is on a monopile – a relatively simple cylindrical structure supporting the wind turbine. Previously, monopiles were thought to only be usable for wind turbines in up to 30-meter waters; modern monopile designs, however, can be constructed in waters up to 40 meters deep, and for larger capacity wind turbines.⁴²

Advances in turbine structure technology have also given offshore wind far more location flexibility. New offshore projects are being built farther from shore and in deeper waters, allowing access to higher wind speeds, and access to areas free from shipping lanes or obstructions.⁴³ In 2017, the first floating offshore wind farm began operation off the coast

of Scotland.⁴⁴ Floating turbines dramatically expand the ocean areas feasible for offshore wind. While fixed-base offshore turbines are currently only possible in waters up to approximately 50 meters deep, Scotland's offshore wind farm is located in water 78 meters deep, and floating turbines will likely offer access to far deeper waters in the future.⁴⁵

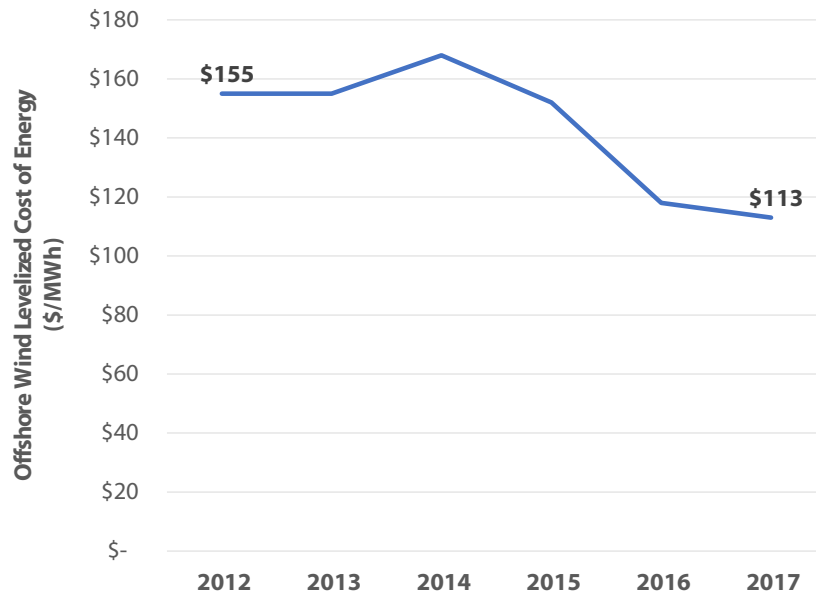


The wind turbines at Rhode Island's Block Island Wind Farm generate 30 times more electricity each year than the original offshore turbines built in the early 1990s. Image: NREL



This National Renewable Energy Laboratory diagram displays various designs for offshore wind turbines, including commonly-used monopiles on the far left, and floating designs on the right. Modern monopile technology allows for affordable installations in waters up to 40 meters deep, while floating turbines dramatically expand the ocean areas feasible for offshore wind. Image: NREL.

Figure 5. The Price of Offshore Wind Fell By 27 Percent From 2012 to 2017 (Lazard Data)⁴⁶



Offshore Wind Prices Are Falling Rapidly

As offshore wind technology has advanced, prices have fallen.

According to Lazard's Levelized Cost of Energy Analysis report series, the estimated cost of energy from new offshore wind fell from \$155 per MWh in 2012 to \$113 per MWh in 2017, a 27 percent price decline.⁴⁷ That price is in line with the price of new coal power plants and cheaper than new nuclear plants.⁴⁸ For projects in the United Kingdom, the country with the largest offshore wind market, the price of offshore wind power fell by approximately 32 percent from 2010 to 2016.⁴⁹ The U.S. Department of Energy (DOE) found that auctions held in Germany, the Netherlands and Denmark during 2016 and 2017 showed "a clear reduction trend in procurement prices over this time frame."⁵⁰ And, here in the U.S., energy prices set for a yet-to-be-built offshore wind farm in Maryland were 45 percent lower than they were for offshore wind at Rhode Island's Block Island Wind Farm, which began operation in 2016 (although some of the energy price difference was likely due to the Maryland project's larger size).⁵¹

Price reductions have been driven by a number of factors. According to the UK managing director for Ørsted (then called DONG Energy), as quoted by the *Financial Times*, increased turbine size is "undoubtedly the biggest cost driver of the projects."⁵² According to the DOE, European offshore wind prices have fallen for a number of reasons, including "increased project size; continued optimization of technology and installation processes; [and] improved market, regulatory, and auction design structures."⁵³

Experts predict that offshore wind will continue to fall in price, much like other renewable technologies, including solar panels and energy storage. A survey of 163 wind energy experts published in *Nature Energy* found that experts expect the levelized cost of energy of fixed-bottom offshore wind to fall by 30 percent by 2030 relative to 2014 prices, and the price of floating offshore wind to fall by 25 percent.⁵⁴ Bloomberg New Energy Finance projects an even more rapid price decline of 71 percent by 2040 relative to today's prices.⁵⁵ Recent research suggests that certain changes in assembly and deployment processes – like moving more of the construction process onshore – may enable even more dramatic price declines.⁵⁶

Tapping Atlantic Offshore Wind Reserves Is a Better Option Than More Offshore Oil Drilling

In January 2018, the Trump administration released a draft program to open nearly all U.S. offshore waters to oil and gas drilling, including nearly 270 million acres of the Atlantic outer continental shelf, where drilling has been blocked for decades.⁵⁷

Offshore drilling would present a variety of grave threats to the future health and well-being of the Atlantic coast's population and environment. The Bureau of Offshore Energy Management's list of potential "stressors" from offshore drilling includes accidental spills, air emissions, habitat disturbance, and drilling debris and discharge.⁵⁸ The history of offshore drilling includes devastating spills, like the 2010 Deepwater Horizon spill that released more than 3 million barrels of oil into the Gulf of Mexico, devastating wildlife and harming nearby communities, and resulting in the deaths of hundreds of dolphins and potentially hundreds of thousands of seabirds.⁵⁹ Increasing offshore drilling would also promote new reliance on fossil fuels, at a time when the world must do all it can to reduce fossil fuel consumption in order to limit the worst impacts of global warming.

Offshore drilling also holds no advantage over offshore wind from the perspective of energy production. According to a 2013 analysis prepared for the American Petroleum Institute (API), an oil trade group, development of Atlantic drilling could result in 1.34 million barrels of oil equivalent per day 2035, if 30 wells were to be drilled each year.⁶⁰ API's study has received criticism for exaggerating potential offshore production, and for being based on extremely speculative Atlantic offshore oil reserve estimates.⁶¹ Yet even API's likely overstated estimate could be matched by developing a modest amount of Atlantic offshore wind.

In fact, the 13 offshore wind projects already moving forward would, by themselves, produce a fifth as much energy as API estimates we could get annually from offshore oil.⁶² In terms of capacity, those proposed projects represent just 1 percent of Atlantic offshore wind technical potential.⁶³ Offshore wind is far safer and cleaner than offshore oil, and just as abundant – and is the far better option for the future of Atlantic energy production.

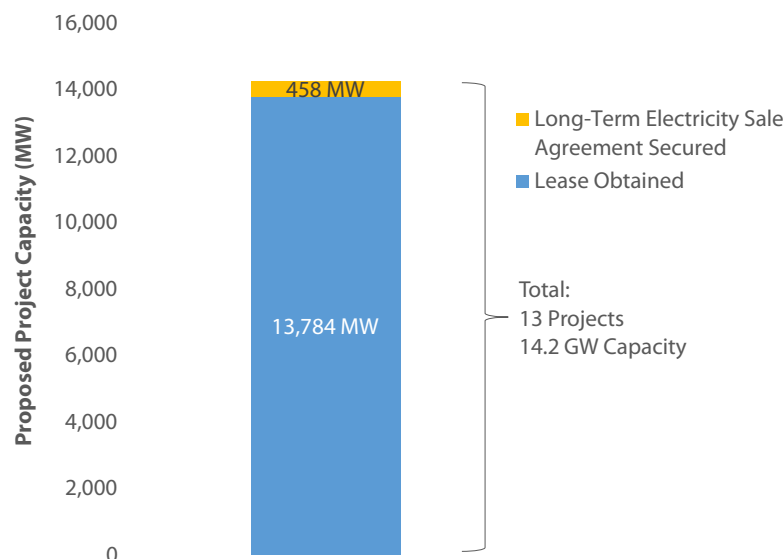
Offshore Wind Projects Are Proceeding All Along the Atlantic Coast

In 2016, the five offshore turbines making up the Block Island Wind Farm began spinning their blades and generating electricity, becoming the United States' first offshore wind farm. Current plans for offshore wind – many in advanced stages of development – will soon dramatically increase Atlantic offshore wind.

As of February 2018, 13 offshore wind projects along the Atlantic seaboard have obtained ocean area leases

and are moving forward.⁶⁴ With a total estimated capacity of 14.2 gigawatts (GW), these proposed projects could power approximately 5.2 million homes.⁶⁵ Nearly 500 MW of proposed projects have both obtained a lease and secured a long-term agreement to sell power from the project (an offtake agreement).⁶⁶ The securing of an offtake agreement is an important step for an offshore wind project, because it ensures a long-term revenue stream to finance the project's development, installation and operation.⁶⁷

Figure 6. Capacity of Proposed Offshore Wind by Project Status



Securing a long-term agreement for the sale of electricity (an “offtake” agreement) is an important step in the development of offshore wind projects. These can take forms including power purchase agreements and renewable energy credit agreements.

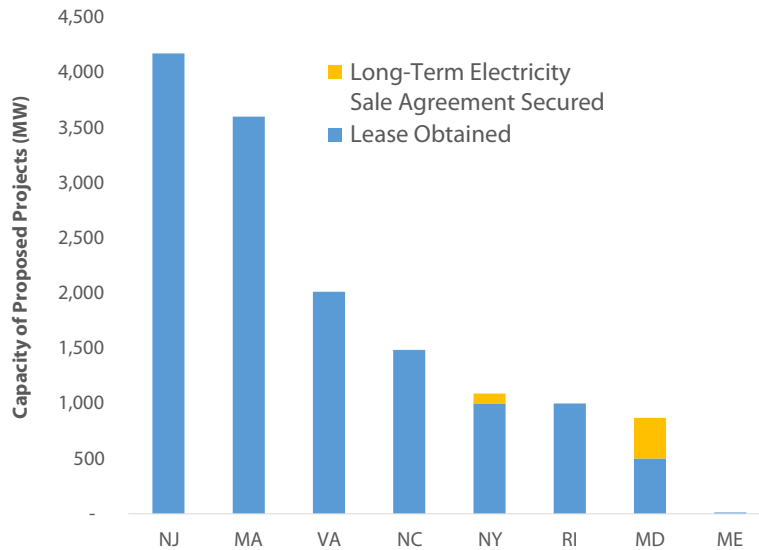
States moving forward with offshore wind projects include:

- **Maine**, where an offshore wind project will demonstrate advanced technology. A Department of Energy Offshore Wind Advanced Technology Demonstration Project will consist of two 6 MW turbines on floating platforms developed by University of Maine researchers.⁶⁸ Floating turbines make offshore wind possible in deep-water areas where the construction of fixed-base offshore foundations is not possible.⁶⁹
- **Maryland**, which is home to the biggest projects that are closest to construction: two proposed wind farms with a combined 870 MW capacity, which have obtained their leases, passed important state review milestones, and set energy prices for 368 MW of turbine capacity with state regulators.⁷⁰ If built, these wind farms would generate electricity equivalent to 43 percent of the annual electricity use of the city of Baltimore.⁷¹
- **Massachusetts**, which has more offshore wind technical potential than any other state in the country, including Pacific states. Massachusetts has two planned offshore wind projects with an estimated total capacity of 3.6 GW. If built, these projects would supply electricity equivalent to more than three times the annual electricity use of the city of Boston.⁷²
- **New Jersey**, which has more offshore wind planned in terms of total capacity than any other state. If built, these projects would supply electricity equivalent to seven times the annual electricity use of Newark.⁷³
- **New York**, which has offshore wind technical potential equivalent to two times its current electricity consumption. Two offshore projects are moving forward in New York, including the South Fork Wind Farm off the eastern tip of Long Island, which secured a power purchase agreement with the Long Island Power Authority in 2017.⁷⁴
- **North Carolina**, which has offshore wind technical potential equivalent to nearly five times its current electricity consumption. One proposed offshore wind project is moving forward in the waters off of North Carolina – if built, it would supply electricity equivalent to 52 percent of the annual electricity use of Charlotte.⁷⁵
- **Rhode Island**, which is already home to the nation's first offshore wind farm, and which has offshore wind potential equivalent to eight times the state's current electricity consumption. If completed, the proposed 1,000 MW Deepwater One offshore wind project could supply electricity equivalent to three times the annual electricity use of Providence.
- **Virginia**, which has offshore wind technical potential equivalent to 1.4 times its current electricity consumption. A pilot project 27 miles off the coast of Virginia Beach is expected to be operational by the end of 2020, paving the way toward a far larger wind farm in Virginia's waters.⁷⁶

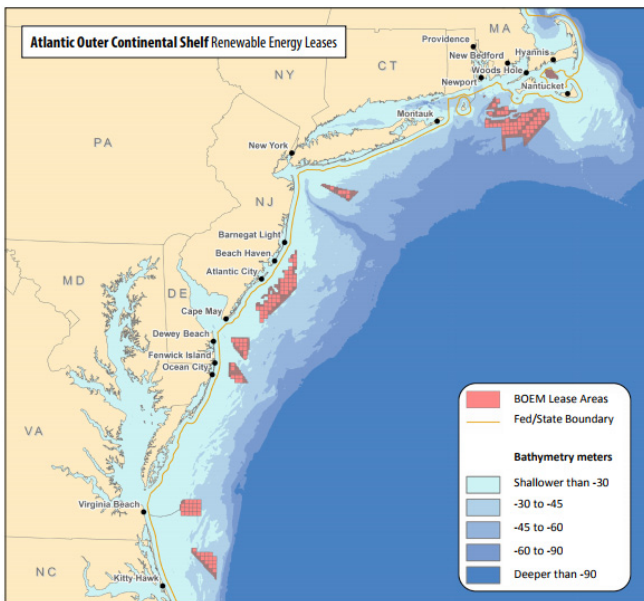
More offshore wind could also be on the way to meet more than 8 GW of state offshore wind commitments and targets in five states. If they are met, offshore wind in those states would be able to generate electricity equivalent to the power used by 3 million homes.⁷⁷

- In January 2018, New Jersey Governor Phil Murphy signed an executive order for the state to build 3.5 GW of offshore wind by 2030.⁷⁸ The order also requires New Jersey to issue a solicitation for 1,100 MW of offshore wind under New Jersey's Offshore Wind Economic Development Act, which was passed in 2010 but never implemented.
- In January 2017, New York Governor Andrew Cuomo released a plan to guide the development of 2.4 GW of offshore wind by 2030.⁷⁹
- In August 2016, Massachusetts Governor Charlie Baker signed a law requiring state utilities to procure 1.6 GW of offshore wind capacity by July 2027.⁸⁰

Figure 7. Capacity of Proposed Atlantic Offshore Wind Projects by State and Project Status



- Maryland has committed to support the development of 368 MW of offshore wind through its long-term Offshore Renewable Energy Credit agreements with the US Wind and Skipjack offshore wind projects.⁸¹
- Connecticut has issued a Request for Proposals (RFP) for an offshore wind project to supply up to 825,000 MWh annually (which would likely mean a project size of approximately 260 MW).⁸² The RFP may also be met by a narrow set of other eligible technologies.



Offshore wind projects are moving forward along much of the Atlantic coast. Pink shading represents currently leased areas for planned offshore wind development. Image: Bureau of Ocean Energy Management



University of Maine researchers are developing new floating wind turbine technology. This turbine above is a 1:8 scale prototype used for testing off the coast of Castine, Maine. The project is planning to eventually deploy two full-size 6 MW turbines. Image: Courtesy of University of Maine

Table 2. Proposed Atlantic Offshore Wind Farm Projects

Project Name	State	Status	Estimated Capacity (MW)	Estimated Number of Homes Powered (Thousands)
Vineyard Wind	MA	Lease Obtained - BOEM lease	1,600	653
Bay State Wind	MA	Lease Obtained - BOEM lease	2,000	816
US Wind	MD	Offtake Secured - Renewable Energy Credit agreement with Maryland Public Service Commission (for 248 MW)	750	253
Skipjack	MD	Offtake Secured - Renewable Energy Credit agreement with Maryland Public Service Commission	120	40
Aqua Ventus I	ME	Lease Obtained - Maine state lease	12	5
Avangrid Renewables	NC	Lease Obtained - BOEM lease	1,485	504
US Wind	NJ	Lease Obtained - BOEM lease	2,226	814
Ørsted	NJ	Lease Obtained - BOEM lease	1,947	712
Statoil Wind	NY	Lease Obtained - BOEM lease	1,000	373
South Fork (Long Island Power Authority)	NY	Offtake Secured - Power purchase agreement with Long Island Power Authority	90	34
Deepwater One	RI	Lease Obtained - BOEM lease	1,000	385
Dominion and Ørsted	VA	Lease Obtained - BOEM lease	12	4
Dominion	VA	Lease Obtained - BOEM lease	2,000	666

Conclusion and Recommendations

The Atlantic region can take on its biggest environmental challenges and meet a large share of its energy needs by turning to one of the nation's best renewable energy sources: Atlantic offshore wind.

The Atlantic coastline has high wind speeds, a relatively shallow seafloor, and provides perfect locations for offshore turbines. Its winds are close to our biggest population centers and some of the nation's biggest energy consumers. Yet today, offshore wind in the Atlantic is all but untapped, with just one offshore wind farm in operation.

There are, however, clear signs that a major expansion of offshore wind energy is on the horizon. Offshore wind has seen dramatic improvements in technology and reductions in price in recent years. And 13 Atlantic offshore wind proposals are currently moving forward, with the potential to power approximately 8 million homes.

Policymakers in state and federal government must do much more to ensure that current projects move forward, and that future development occurs rapidly and responsibly. They should work to create supportive policies including:

- Strong, enforceable targets for the development of offshore wind. Massachusetts, New York, and New Jersey have all set targets for offshore wind development. States that have set targets should devote the necessary resources to meet them quickly, including by soliciting and responding to proposals for new projects.
- Policies to provide market certainty for offshore wind developers. For example, states can include so-called "carve-outs" (or minimum requirements for specific technologies) in renewable energy standards to guarantee demand for offshore wind or require utilities to enter into power purchase agreements with offshore wind projects that meet certain standards.
- Support for the development of the offshore wind supply chain, and coordination between states on development of supply chain infrastructure. Some states are already supporting supply chain infrastructure and research. Massachusetts developed the New Bedford Marine Commerce Terminal in order to "support the construction, assembly, and deployment of offshore wind projects."⁸³ Maine's Deepwater Offshore Test Site conducts research on floating offshore wind turbines.
- Minimum standards to ensure the environmental integrity of offshore wind projects and minimize impact on marine ecosystems and wildlife. Special attention should be paid to protection of the endangered North Atlantic right whale. Policy-makers should look to the right whale protection measures followed by Deepwater Wind in its development of the Block Island Wind Farm.⁸⁴
- Efforts to work with the federal Bureau of Ocean Energy Management to ensure an environmentally responsible, transparent and efficient offshore wind development process.

Methodology

Estimating electricity use for electrified heating and electric vehicles

Estimates for electricity use for electric heating and electric vehicles are based on current energy consumption by those activities, and assume improved efficiency for new equipment.

For transportation, energy consumption is taken from two sources: 1) 2015 motor gasoline consumption for transportation, from the State Energy Data System (SEDS) of the U.S. Energy Information Administration (EIA), and 2) 2016 on-highway diesel fuel consumption from the EIA's *Sales of Distillate Fuel Oil by End Use*, after converting gallons to Btu.⁸⁵

Energy consumption for vehicles in the form of gasoline or diesel use was converted to electricity demand by assuming that electric vehicles were three times more efficient than gasoline-powered internal combustion engines.⁸⁶

For heating, energy consumption is based on residential and commercial energy consumption of natural gas, fuel oil, and propane, also from SEDS. Estimates of the percentage of each fuel used for space heating (as opposed to other uses like water heating) was based on end-use consumption data reported by the EIA's Residential Energy Consumption Survey (RECS) and Commercial Buildings Energy Consumption Survey (CBECS).⁸⁷ For each state, total use of each fuel for the residential and commercial sectors was multiplied by the percentage of that fuel used for heating in that state's region, as reported in RECS and CBECS.⁸⁸

The estimate for electrified heating energy consumption assumes the replacement of natural gas, fuel oil, and propane heating systems with air source heat pumps. Air source heat pumps are modern electric heating systems that transfer heat from outdoor to indoor spaces, even in cold weather, and are able to achieve greater efficiency than typical electric heaters. This estimate does not assume any upgrades to current electric heating systems.

Estimates of reductions in energy use resulting from the use of air source heat pumps were calculated using data from the American Council for an Energy-Efficient Economy's report *Comparative Energy Use of Residential Gas Furnaces and Electric Heat Pumps*, Appendix A.⁸⁹ Estimated energy consumption was based on the lowest-efficiency heat pumps in the study (those with a Heating Seasonal Performance Factor of 8.2). To compare annual energy consumption for each type of equipment, the KWh per year for heat pumps (before electric system losses) was converted to Btu for comparison with natural gas furnace energy use (before gas system distribution losses).

Efficiency factors were applied on a state-by-state basis, to account for the somewhat lower efficiency of air source heat pumps in cold weather. For states not included in ACEEE's analysis, efficiency factors were used for the closest state available.⁹⁰

Although ACEEE's report compares efficiency of natural gas heating systems and air source heat pumps, efficiency improvements were assumed to be the same for heating fuel and propane heating systems, which have similar efficiency as natural gas systems.

Appendix

Table A-1: Estimated Electricity Demand of Electrified Heating and Vehicle Fleets for Atlantic States, as well as Offshore Wind Technical Potential (GWh)

State	2016 Electricity Consumption	Estimated Electrified Heating Electricity Consumption	Estimated Electrified Vehicle Fleet Electricity Consumption	Offshore Wind Technical Potential
Connecticut	28,931	18,619	20,383	6,729
Delaware	11,258	2,141	6,199	20,604
Florida	235,722	3,814	120,032	780,260
Georgia	138,112	10,480	74,048	156,456
Maine	11,449	7,004	11,526	411,184
Maryland	61,354	13,338	39,356	96,289
Massachusetts	53,476	34,993	37,679	1,053,166
New Hampshire	10,905	6,099	9,436	4,991
New Jersey	75,359	36,958	58,330	280,193
New York	147,803	86,273	78,192	295,226
North Carolina	134,404	9,169	64,819	634,153
Rhode Island	7,524	5,644	4,971	60,363
South Carolina	79,578	3,323	43,341	612,639
Virginia	112,281	12,290	59,304	161,812
<i>Total</i>	<i>1,108,156</i>	<i>250,145</i>	<i>627,618</i>	<i>7,202,878</i>

Notes

1 Based on wind and solar generation data from: Gideon Weissman, Frontier Group, Rob Sargent and Bret Fanshaw, Environment America Research & Policy Center, *Renewables on the Rise*, July 2017. States with Atlantic coastline are Connecticut, Delaware, Florida, Georgia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Rhode Island, South Carolina and Virginia.

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3 Based on addition of all offshore wind potential from states with Atlantic coastline, and thus includes a small amount of wind potential from the Gulf of Mexico for Florida. Source: Walter Musial et al., National Renewable Energy Laboratory, *2016 Offshore Wind Energy Resource Assessment for the United States*, September 2016.

4 See Methodology.

5 Wind map data: National Renewable Energy Laboratory, *United States Wind Power Class - With Exclusions*, downloaded from <https://www.nrel.gov/gis/data-wind.html> on 30 January 2018.

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7 Turbines: Wind Europe, *Offshore Wind in Europe Key Trends and Statistics 2017*, February 2018, archived at <http://web.archive.org/web/20180206223928/https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Offshore-Statistics-2017.pdf>; homes based on percentage of offshore generation, from: Wind Europe, *Daily Wind*, accessed at <https://windeurope.org/about-wind/daily-wind/> on 2 February 2018, available at https://frontiergroup.org/sites/default/files/EuropeWind_20180202.pdf.

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10 Annual generation based on capacity factor derived from GWh per MW from Appendices I and H in Walter Musial et al., National Renewable Energy Laboratory, *2016 Offshore Wind Energy Resource Assessment for the United States*, September 2016. Estimated number of homes based on 10,766 kWh per year, from: U.S. Energy Information Administration, *How Much Electricity Does an American Home Use?*, accessed at <https://www.eia.gov/tools/faqs/faq.php?id=97&t=3> on 30 January 2018.

11 Based on Table 3 from Walter Musial et al., U.S. Department of Energy, *2016 Offshore Wind Technologies Market Report*, August 2017. Projects were only included if a developer is attached to the project.

12 See note 10 for details on calculation of annual generation.

13 Currently proposed and leased offshore wind projects could generate 56.6 TWh/year, or 522 trillion bbtu (assuming 9,232 Btu per KWh heat rate for wind, per EIA's *Approximate Heat Rates for Electricity, and Heat Content of Electricity* available at https://www.eia.gov/totalenergy/data/monthly/pdf/sec13_6.pdf). See 12 for details on calculation of proposed project generation based on project capacity. 1.34 million BOE/d is equivalent to 2,796 trillion Btu/year, assuming 5.7 million Btu per barrel.

14 In terms of capacity. There are 14.2 GW of proposed offshore projects, compared to 1.25 TW of Atlantic technical potential. Proposed projects: Walter Musial et al., U.S. Department of Energy, *2016 Offshore Wind Technologies Market Report*, August 2017; potential: Walter Musial et al., National Renewable Energy Laboratory, *2016 Offshore Wind Energy Resource Assessment for the United States*, September 2016.

15 Erika Spanger-Siegfried et al., Union of Concerned Scientists, *Encroaching Tides: How Sea Level Rise and Tidal Flooding Threaten U.S. East and Gulf Coast Communities over the Next 30 Years*, October 2014.

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25 Number of homes: See note 1; generation percentage based on generation data available from U.S. Energy Information Administration, *Electricity Data Browser*, available at <https://www.eia.gov/electricity/data/browser/>.

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32 “The US Signs an Agreement with Denmark to Boost Cooperation on Offshore Wind,” *Climate Action*, 1 November 2017.

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86 According to www.fueleconomy.gov, "EVs convert about 59%–62% of the electrical energy from the grid to power at the wheels. Conventional gasoline vehicles only convert about 17%–21% of the energy stored in gasoline to power at the wheels." See: U.S. Department of Energy, *All-Electric Vehicles*, archived at <http://web.archive.org/web/20180204211743/https://www.fueleconomy.gov/feg/evtech.shtml>.

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