Offshore Wind for America

The promise and potential of clean energy off our coasts

Environment Rhode Island Research & Policy Center

Frontier Group

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Cover photo: A turbine in the Block Island wind farm, Rhode Island. Photo credit: Gary Norton/NREL

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Executive summary

The United States currently relies heavily on fossil fuels to heat our homes, fuel our cars, power our machines and produce electricity, harming our health and our climate.[1]

Across the country, however, America is beginning to embrace the promise of clean, renewable energy. Today, the U.S. gets about 11.5% of our electricity from wind, solar and geothermal sources, up from about 0.6% two decades ago.[2] America's abundant renewable energy resources, coupled with energy efficiency measures and technological advances that make renewable energy cheaper and better than ever, open the possibility of transitioning our entire economy to run on 100% renewable energy.

To get there, we must take advantage of a massive and underutilized energy resource just off our coasts: offshore wind. That will require policymakers to remove the barriers slowing down the growth of the offshore wind industry, and instead support and hasten that growth to provide clean energy where it's needed most.

Offshore wind has the technical capacity to power the country with clean energy. The United States has the technical potential to produce more than 7,200 terawatt-hours (TWh) of electricity from offshore wind, which is almost two times the amount of electricity the U.S. consumed in 2019 and about 90% of the amount of electricity the nation would consume in 2050 if we electrified our buildings, transportation system and industry and transitioned them to run on electricity instead of fossil fuels.[3]

Nineteen of the 29 states with offshore wind potential have the technical capacity to produce more electricity from offshore wind than they used in 2019. And 11 of them have the technical capacity to produce more electricity than they would use in 2050 if the country electrified homes and commercial buildings, transportation and industry. While the U.S. neither will, nor should, develop all of its technical potential for offshore wind energy, the sheer size of the resource illustrates the critical contribution that offshore wind can make toward an energy system powered by 100% renewable energy.

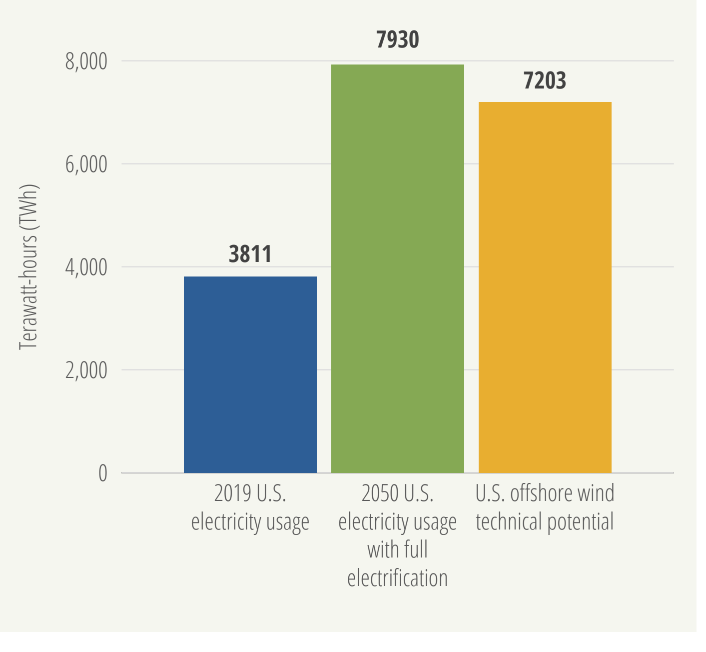

Figure ES-1: U.S. offshore wind technical potential and electricity usage (electrification scenario based on research by National Renewable Energy Laboratory)

Every coastal region of the United States has offshore wind potential, though opportunities and obstacles to offshore wind development vary by region.

- The **Atlantic region** – from Maine to Florida – has the technical potential to produce almost 4,600 TWh of electricity each year, more than four times as much power as those states used in 2019, and almost twice as much as they would use in 2050 if the country underwent maximal electrification, based on estimates from the National Renewable Energy Laboratory. The Atlantic region, especially the Northeast, has strong, consistent wind and a wide, shallow continental shelf, making deployment of offshore wind relatively straightforward using existing technology.
- The **Pacific region** – including Hawaii but excluding Alaska – has the technical potential to produce almost 869 TWh of electricity each year from offshore wind, more than twice as much as it used in 2019, and almost 90% of what it is projected to use in 2050, assuming maximum electrification. The Pacific region has a very narrow continental shelf, resulting in much of the wind resource being in deep water and necessitating the use of floating turbines.
- The **Gulf region** – Texas, Louisiana, Mississippi and Alabama – has the technical potential to produce more than 1,400 TWh of electricity each year from offshore wind generation, more than twice the amount of electricity the region used in 2019 and over 20% more electricity than the region would use in 2050 assuming the country undergoes maximum possible electrification. The Gulf region's low wind speeds and many conflicting uses reduce the area available for offshore wind development.
- The **Great Lakes region** – Illinois, Indiana, Michigan, Minnesota, Pennsylvania, Ohio and Wisconsin – has the technical potential to produce 344 TWh of electricity each year from offshore wind generation, almost half as much as it used in 2019 and about one fifth as much as it is projected to use in 2050 after maximal electrification. The Great Lakes region is limited in usable area and hampered by winter ice floes that could damage floating turbines.[5]

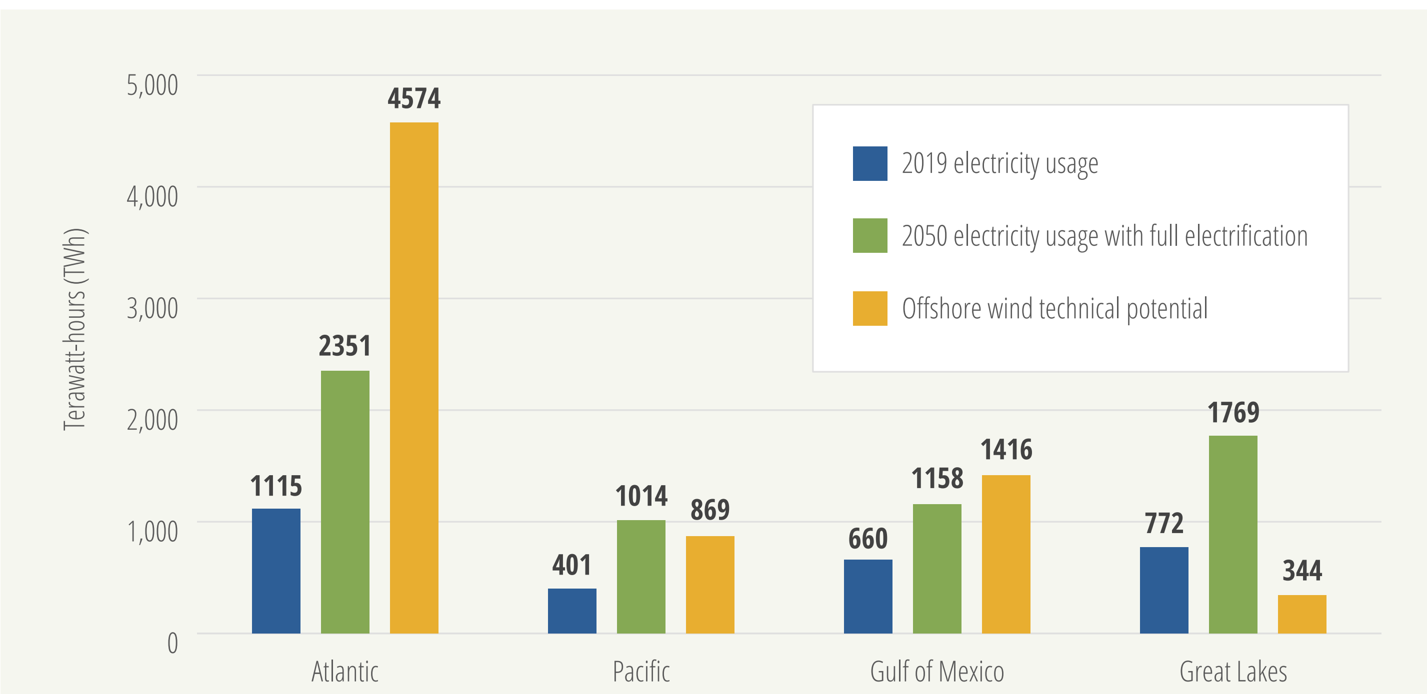

Figure ES-2: Regional offshore wind technical potential and electricity usage

Out of every state in the U.S., Massachusetts has the largest potential offshore wind generation capacity, while Maine has the highest ratio of potential generation capacity to electricity usage.

Offshore wind technology is advanced and proven, widely deployed in Europe and Asia, and continues to improve.

- There are more than 5,500 offshore turbines currently deployed around the world, and more than 27 gigawatts (GW) of installed generating capacity – enough to power 7.3 million U.S. homes.[6]
- The average capacity of the turbines currently installed is more than 12 times larger than that of the turbines in the first offshore wind farm built in 1991, and today's turbines are hundreds of feet taller and more efficient even than turbines installed in 2010.[7] They are being installed in much deeper water, and tens of miles farther from shore.[8]
- Turbines that will be available in the next few years promise a new level of efficiency and generation capacity and could help reduce the costs of offshore wind while helping it power more of our energy needs.[9]

The United States already has many projects in the development pipeline. In addition to the two operational pilot projects, there are 34 proposals for offshore wind development, which includes 27 projects in various stages of planning and development.[10] Together, they total more than 26 GW of site capacity.[11] The U.S. is set to see huge growth in offshore wind, which will help mature the industry and continue to drive down costs.

Offshore wind can help repower the U.S. with clean energy – but taking advantage of the opportunity will require support from policymakers and regulatory bodies. To help the industry grow, and to hasten the transition to renewable energy, governments and regulatory agencies at all levels should:

- Provide market certainty for offshore wind, as Connecticut, Maryland, Massachusetts, New Jersey, New York and Virginia have done by setting enforceable targets for offshore wind deployment.
- Support domestic supply chain development.
- Set national standards to ensure the environmental integrity of offshore wind projects and to avoid, minimize and mitigate impacts to marine ecosystems and wildlife.
- Direct the Bureau of Ocean Energy Management and relevant state agencies to accelerate the offshore wind leasing and permitting process while ensuring transparency and environmental responsibility.
- Increase and extend tax credits for offshore wind power.
- Plan for regional offshore wind development, including transmission infrastructure.
- Support research and development of new offshore wind technologies.

Introduction

Building a world powered by 100% renewable energy will make us both healthier and safer. To get there, we need to make simultaneous use of every source of renewable energy because each has its unique advantages and complements the others.

For the United States, offshore wind energy is a largely untapped resource with many benefits – a key element of a future energy system powered by renewable energy.

Offshore wind energy is abundant. As is discussed in this report, the U.S. has the technical capacity to meet its 2019 electricity demand almost twice over with power from offshore wind. Even if we electrified homes and businesses, transportation and industry – replacing fossil fuel-powered appliances, vehicles and machinery with electricity-powered alternatives – by 2050, offshore wind could theoretically meet nearly all of that electricity demand. While using the entirety of the U.S. offshore wind resource is unlikely, impractical and would have far too high an environmental impact, we will need to take advantage of the enormous benefits of offshore wind to transition to a 100% renewable energy system.

Offshore wind is also conveniently located near major sources of electricity demand. About 40% of the American population lives in counties on the coast of an ocean or Great Lake.[12] That means power generated by offshore wind does not have to travel far to get where it is needed, reducing the difficulty of transitioning to 100% renewable power.

And finally, offshore wind is reliable. Because wind on the water tends to be strong and consistent, offshore wind turbines can have very high capacity factors, meaning they turn wind into electricity consistently.[13] Offshore wind is also strongest – and therefore generates the most power – when we will need it after transitioning our buildings, vehicles and industry to run on electricity: during the winter months, when the East Coast will be heating buildings; and during the afternoon and evening, when electricity demand is at its peak.[14]

These characteristics – abundance, convenience and reliability – make offshore wind an integral piece of a 100% renewable energy system, complementing other sources of energy like solar and geothermal. It fits our needs and can help make us, and the climate, healthier. To take advantage of offshore wind's immense potential, however, policymakers need to act quickly to remove barriers to offshore wind development while ensuring and accelerating its growth.

Offshore wind is ready to grow

Offshore wind is a large and growing source of energy around the world, and is poised for rapid growth in the U.S. The technology has improved dramatically, with larger turbines generating much more power and turbines successfully being put much farther from shore and in much deeper water. New announcements promise still better designs, opening up even more area for possible deployment of offshore wind turbines. This section explores the current state of offshore wind technology and its presence around the world.

Offshore wind is a global energy source

Offshore wind is widely used in Europe and China and is being adopted elsewhere in the world. Global offshore wind capacity topped 27 GW by early 2020, though the U.S. represents less than two-tenths of 1% of that.[15]

Globally, 6.1 GW of installed capacity was added in 2019, almost 40% of it by China and almost all of the rest by Germany, Denmark, the United Kingdom and Belgium.[16] Those five countries are also those with the largest total installed offshore wind capacity, accounting for the vast majority of the world's offshore wind production.[17]

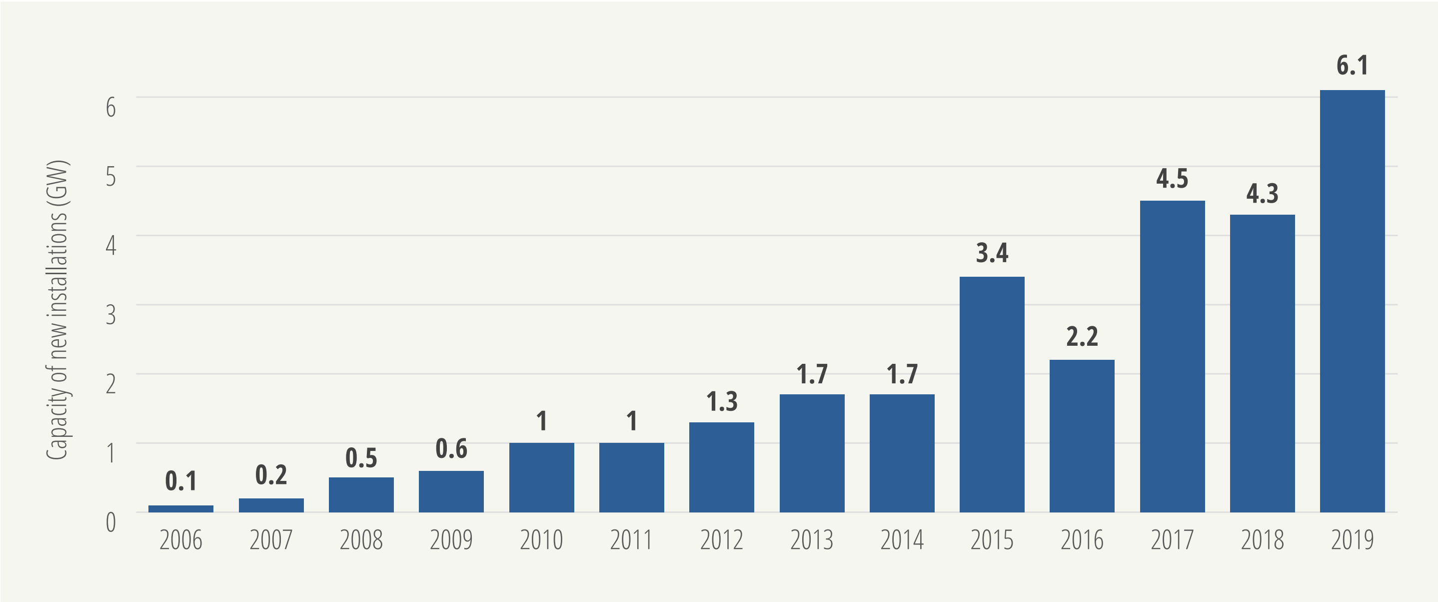

Figure 1: Global offshore wind installations by year[18]

As of 2019, there were more than 5,500 offshore wind turbines powering the grid in 17 countries around the world.[19] That capacity is set to expand rapidly, with about 150 projects in 19 countries – including all over Asia, Oceania, Europe and the U.S. – in the pipeline.[20] According to NREL's *2019 Offshore Wind Technology Data Update*, that global pipeline represents more than 200 GW of capacity coming online in the near future.[21]

The rest of the world is setting big goals, too. The European Union, for instance, recently set a goal to expand its offshore wind capacity from 12 GW to 60 GW by 2030, and 300 GW by 2050.[22]

The U.S. is currently far behind the leaders in offshore wind. But, with the projects in the pipeline and the upcoming growth in the domestic supply chain, the U.S. could soon become a major producer of offshore wind turbines and of power from offshore wind.

Offshore wind technology is good, and getting better

Offshore wind technology has advanced dramatically in recent decades, enabling offshore wind farms to produce more energy more efficiently than ever before.

Denmark's Vindeby, the first offshore wind farm in the world, installed in 1991, had 11 turbines, each with a capacity under half a megawatt (MW), and used onshore turbines placed on concrete foundations in shallow water.[23] In 2019, by contrast, the average capacity of installed offshore wind turbines around the world was over 6 MW, with the average capacity per turbine for projects coming online in 2025 anticipated to reach 11 MW worldwide – a roughly 20-fold improvement over the first generation of turbines.[24]

A big piece of the growth in capacity of offshore wind turbines has been the increase in height and rotor diameter. In 2010, the tip of a 3 MW turbine – the largest turbine commercially available that year – reached about 330 feet high, just a bit taller than the Statue of Liberty.[25] Just six years later, an 8 MW turbine had a tip height of almost 660 feet.[26] As the turbines increase in size, they are also able to capture more energy from the wind, and the average capacity factor of installed turbines – the percentage of their technical capacity for generating power that is actually realized – increased from 38% in 2010 to 43% in 2018.[27]

Wind turbines at the Vindeby wind farm. Photo credit: Siemens AG/NREL

Two recently announced turbines – which are taller and have bigger rotors, have higher efficiency, and can generate more power – are promising to push the industry even further. Siemens Gamesa, the largest turbine supplier in the world, has announced a 15 MW turbine with a 730-foot diameter rotor, which will be available in 2024.[28] General Electric's Haliade-X turbine, the first prototype of which was installed in the Netherlands, promises capacity of between 12 MW and 14 MW capacity, an 850-foot height and 720-foot rotor diameter, and a 60%-64% capacity factor.[29]

This new generation of turbines could be deployed in the U.S. to enormous effect: At full power, the Haliade-X turbine can generate enough power in under seven seconds to serve an average American home for a day.[30] And developers of U.S. projects are taking notice: Vineyard Wind recently announced that it will use Haliade-X turbines in the 800 MW wind farm planned off the coast of Martha's Vineyard in Massachusetts.[31]

Offshore wind projects are also moving farther from shore. While older projects were mostly within 31 miles of land, new projects being commissioned are more than

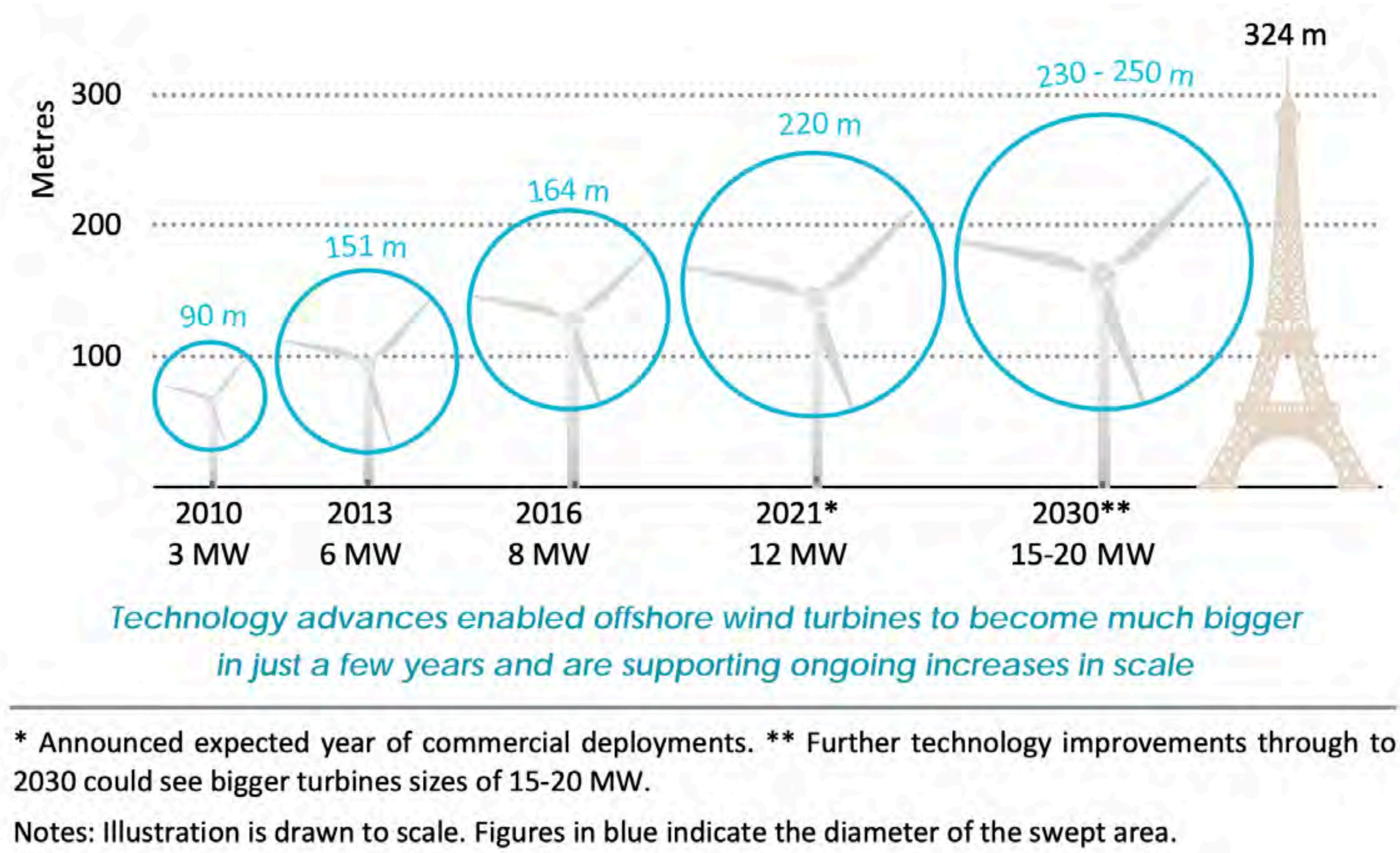

Figure 2: Growth of offshore wind turbines, in meters[32] *(Image: International Energy Agency, all rights reserved.)*

62 miles out, making use of better foundation technology and adapting lessons from the oil and gas industry.[33] Floating turbines are allowing projects even farther out and in deeper water. Some announced projects are as far as 93 miles from shore, and some installed floating turbines are in water almost 1,000 feet deep.[34] Developing floating technology is going to be crucial for offshore wind industry growth because most of the world's offshore wind resources are in deep water.[35]

There are already multiple international demonstration and commercial floating turbine projects deployed or in development in countries such as Scotland, Japan and Spain. Domestically, the University of Maine is developing a new, lower-cost floating hull for offshore wind turbines, and the state of Maine is looking to develop a floating turbine research array.[40]

Fixed-bottom vs. floating turbines: what's the difference?

Fixed-bottom turbines use piles driven or drilled into the sea floor; large-diameter shallow cylinders slightly embedded in the sea floor; or wide, heavy bases that rest on the sea floor to stabilize rigid towers and support the turbine.[36] Types of foundations include monopiles, jacket foundations, tripods, jack-up foundations, suction buckets and gravity foundations, which work best in different depths and with different sea floor conditions.[37]

Floating turbines use buoyant hulls and steel structures that float or ride under the surface of the water to support and provide stability to the turbine, and are anchored to the sea floor with cables.[38] Types of floating turbines include spars, semi-submersible hulls and tension leg platforms, as well as some second-generation hybrid designs, which all work in much deeper water than fixed-bottom foundations, possibly at depths greater than 3,000 feet.[39]

Both fixed-bottom and floating platforms are being improved as companies look to lower costs, reduce impacts, support larger turbines and access new areas for offshore wind development.

From left to right: a monopile, jacket, twisted tripod, floating semi-submersible, floating tension leg platform and floating spar. Image: Josh Bauer/NREL-Department of Energy[41]

U.S. offshore wind resources could power the country

As the U.S. looks to transition away from fossil fuels and towards renewable energy, offshore wind stands out as an abundant energy source and a powerful solution for delivering clean electricity to major population centers.[42] While Europe and Asia have large and fast-growing offshore wind industries, the U.S. has very little installed capacity, and no domestic supply chain. What the country does have, however, is enormous potential for offshore wind generation, and the beginnings of a large, reliable offshore generation sector in the Atlantic, Pacific, Gulf of Mexico and Great Lakes.

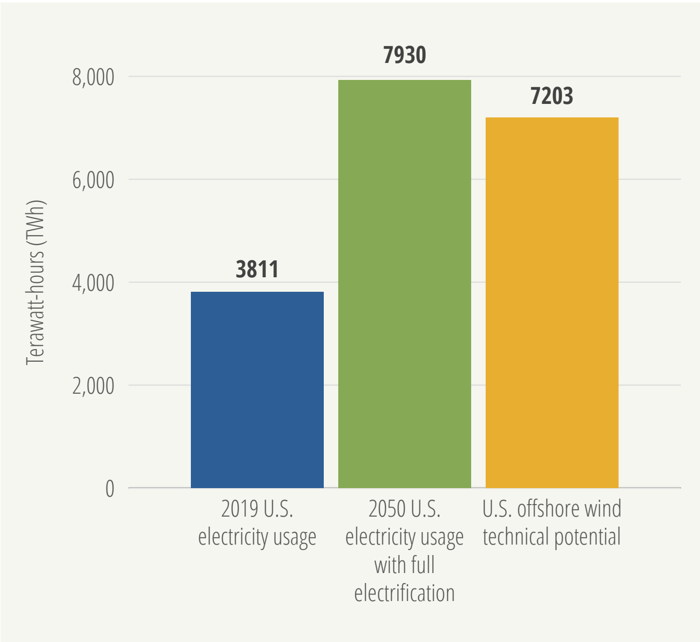

Figure 3: U.S. offshore wind technical potential and electricity use

There are 29 coastal and Great Lakes states with the potential for offshore wind generation, not counting Alaska.[43] According to the National Renewable Energy Laboratory (NREL), those states have the technical potential to produce 7,200 terawatt-hours (TWh) of electricity annually. This is almost twice as much as the 3,800 TWh of electricity the entire nation used in 2019, and about 90% of the approximately 7,900 TWh the country might use in 2050 if we electrified as much of our energy use in buildings, transportation and industry as possible.

The trend of increasing capacity factors in current and future turbines means that technical potential for offshore wind could be even higher than the figures used in this report.

More specifically, 19 of the 29 states with offshore wind potential have the technical potential to produce more power in a year from offshore wind than they used in their entire economies in 2019. And 11 of them have the technical potential to produce more power than they would use in 2050, even if our country electrified buildings, transportation and industry as much as possible. But there are significant variations among regions and individual states in offshore wind potential, and in the opportunities and hurdles facing offshore wind development. The following sections explore the offshore wind resources and requirements in the four regions of the country that have such resources: the Atlantic states, the Pacific states, the Gulf states and the Great Lakes states.

What is technical potential?

"Technical potential" as used in this report represents the potential generating capacity after geographic, conflicting use and technological limitations have been taken into consideration. NREL defines such potential as the "subset of [total] resource potential that can be considered recoverable using available technology within reasonable limits," and considers "nominal land-use and environmental siting constraints… system performance and loss criteria, conflicting use and environmental constraints, and technology limits" in calculating state-by-state technical potential.[44]

New turbines are larger and have higher capacity factors than those used in NREL's modeling of technical potential, and the turbines that will become available in the next few years continue those trends. Actual technical potential using currently available technology or technology available in the near future, therefore, could be even higher than the figures used in this report.

The technical potential of offshore wind is the theoretical maximum for a technology that can play an important role in building a 100% renewable energy system for the U.S. Offshore wind's impact on that transition to renewable energy can be large even if only a fraction of its technical potential is deployed. That fact is crucial, because developing offshore wind to its technical potential is unnecessary and could have damaging environmental impacts.

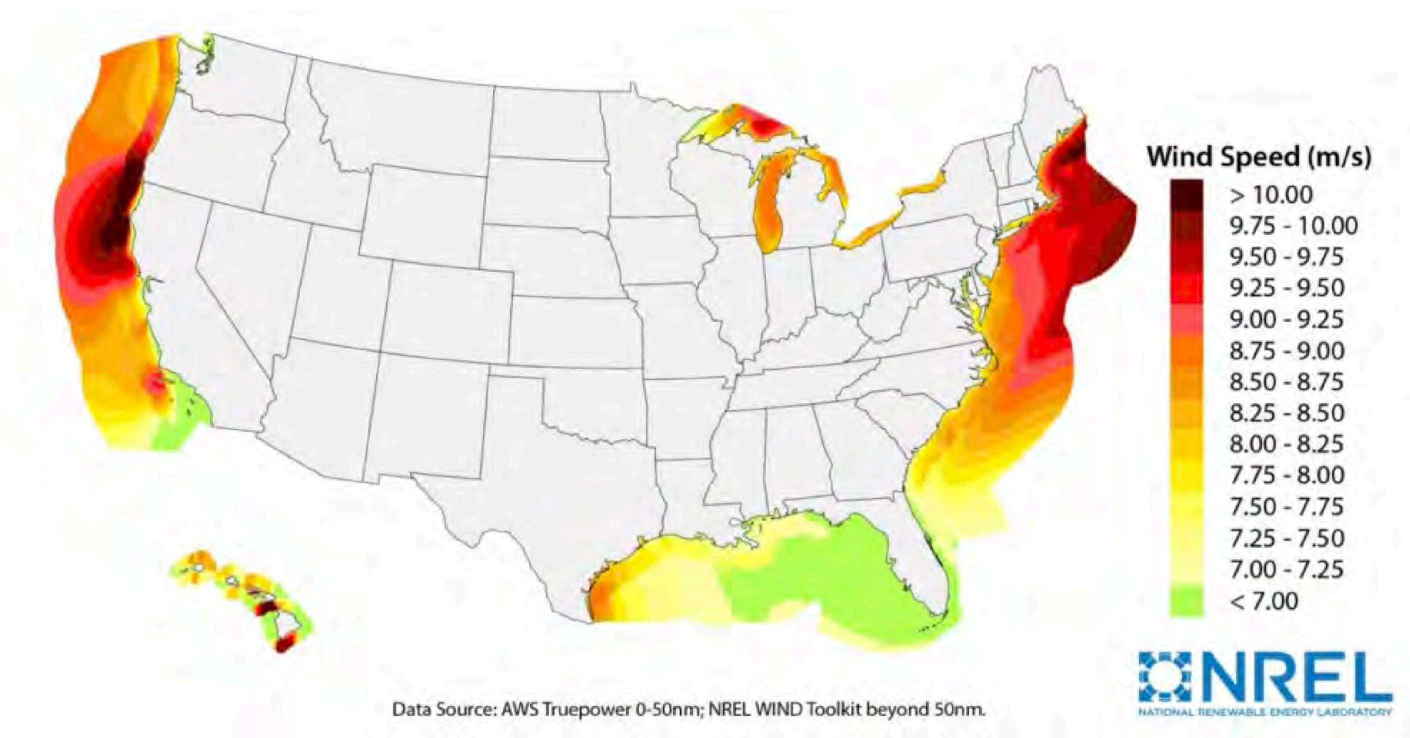

Figure 4: Offshore wind speed at 100m height[45]

Offshore wind in the Atlantic

States: Connecticut, Delaware, Florida, Georgia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Rhode Island, South Carolina and Virginia[46]

States on the Atlantic coast of the United States accounted for almost 30% of the nation's 2019 electricity consumption and used more electricity in 2019 than any nation in the world besides China, India and the United States did in 2018.[47] The population of Atlantic states in 2019 was almost 106 million, representing nearly a third of the total U.S. population.[48]

The Atlantic coast has the largest offshore wind potential of any region of the country. With 29,369 miles of coastline and a shallow continental shelf that allows for fixed turbines far from shore, there is a tremendous amount of area along the eastern U.S. that could produce energy.[49]

In fact, as a region, the Atlantic states have the technical potential to produce almost 4,600 TWh of electricity, more than four times as much electricity as those states consumed in 2019, and almost twice as much as they would use in 2050 if the country underwent maximal electrification of transportation, buildings and industry.

Of the 14 states along the Atlantic seaboard, 12 have the technical potential to produce more electricity from offshore wind than they used in 2019, and seven have the potential to produce more than they would use in 2050 if the country electrified as much as possible.

Massachusetts has far and away the highest technical potential for offshore generation at more than 1,000 TWh, followed by Florida, the Carolinas and Maine. But, because of how little electricity it uses, Maine has by far the highest ratio of technical potential for offshore generation to electricity use in 2019 or projected electricity use in 2050, as shown in Table 1.

TABLE 1: OFFSHORE WIND RESOURCES IN THE ATLANTIC[50]

State	Total 2019 retail electricity sales (TWh)	2050 electricity usage with full electrification (TWh)	Annual offshore wind generation technical potential (TWh)	Offshore potential as percentage of 2019 electricity use	Offshore potential as percentage of 2050 electricity use with full electrification
Connecticut	27.9	70.3	6.7	24%	10%
Delaware	11.5	22.4	20.6	180%	92%
Florida	240.3	470.7	780.3	325%	166%
Georgia	139.3	269.7	156.5	112%	58%
Maine	11.7	30.7	411.2	3,505%	1,338%
Maryland	60.7	155.2	96.3	159%	62%
Massachusetts	51.3	129.4	1,053.2	2,052%	814%
New Hampshire	10.7	28.4	5.0	47%	18%
New Jersey	73.9	167.4	280.2	379%	167%
New York	145.6	361.4	295.2	203%	82%
North Carolina	136.4	274.7	634.2	465%	231%
Rhode Island	7.3	18.6	60.4	821%	325%
South Carolina	80.2	129.9	612.6	764%	472%
Virginia	118.4	222.2	161.8	137%	73%

Because of its huge offshore potential and shallow waters, the Atlantic region also has the most and the largest offshore wind projects in the planning stage. According to NREL, as of October 2020 the Atlantic region had two operational projects and 28 proposals for offshore wind development – including 26 projects in various stages of planning and development – with a combined total of more than 26 GW of site capacity.[51]

TABLE 2: ATLANTIC REGION OFFSHORE WIND PIPELINE[52]

Project name	Status	Location	Announced project capacity (MW)	Total site capacity (MW)
Block Island Wind Farm	Operating	RI	30	30
Coastal Virginia Offshore Wind	Operating	VA	12	12
Skipjack	Permitting	DE	120	120
Park City Wind	Permitting	MA	804	804
Vineyard Wind	Permitting	MA	800	1,221
Mayflower Wind	Permitting	MA	804	1,551
Sunrise Wind	Permitting	MA	880	880
MarWin	Permitting	MD	248	966
New England Aqua Ventus I	Permitting	ME	12	12
Ocean Wind	Permitting	NJ	1,100	1,947
Empire Wind	Permitting	NY	816	2,400
Revolution Wind	Permitting	RI	704	704
South Fork	Permitting	RI	130	130
Garden State Offshore Energy	Site control	DE		1,050
Bay State Wind	Site control	MA		2,277
Beacon Wind	Site control	MA		1,564
Liberty Wind	Site control	MA		1,607
Kitty Hawk	Site control	NC		1,485
Atlantic Shores Offshore Wind	Site control	NJ		2,500
Dominion	Site control	VA		2,640
Fairways North Call Area	Planning	NY		
Fairways South Call Area	Planning	NY		
Hudson North Call Area	Planning	NY		
Hudson South Call Area	Planning	NY		
Grand Strand Call Area	Planning	SC		
Winyah Call Area	Planning	SC		
Cape Romain Call Area	Planning	SC		
Charleston Call Area	Planning	SC		
Wilmington West Call Area	Unleased	NC		627
Wilmington East Call Area	Unleased	NC		1,623

Understanding the steps in the offshore wind pipeline

The National Renewable Energy Laboratory includes in *2019 Offshore Wind Technology Data Update* the status of U.S. offshore wind area leases and proposed offshore wind power projects. NREL defines the stages of the process – included in the tables of regional offshore wind pipelines in this section of the report – as follows:

- Planning: begins with the initiation of the formal site control process and ends when a developer receives control of the site.
- Site control: begins when the developer obtains site control and ends when they file major permit applications.
- Permitting: begins when the developer files permit applications and ends when the relevant regulatory entities authorize the project for construction and certify its offtake agreement.
- Operating: begins when all turbines are installed and feeding power to the grid.[53]

The Wilmington call areas listed as "unleased" have been identified by BOEM as sites for offshore wind development but have not been opened to applications from developers.[54] The call areas listed in the Pacific offshore wind pipeline table are described as "open to project proposals" because BOEM requested project nominations for those areas.[55]

Offshore wind in the Pacific

States: California, Hawaii, Oregon and Washington

Deploying offshore wind off the western continental United States and around Hawaii is more challenging than it is off the East Coast. In the Pacific region, the water deepens rapidly with distance from shore.[56] This makes using traditional fixed-bottom turbines, which generally require depths less than 200 feet, impossible in the areas where much of the resource lies.[57] Luckily, floating systems have been designed that can support and stabilize turbines, and have been proposed for use at depths up to almost 3,300 feet.[58] If successful, these designs would greatly expand the area usable for offshore wind, including in the United States' Pacific region.

The floating turbine projects already installed around the world are helping to prove the technology and provide baseline costs for future deployment.[59]

All four states in the Pacific region have the technical potential to produce more power from offshore wind than they used in 2019, and all but California have the technical potential to produce more power than they would use in 2050 after maximum electrification of the country.

As a region, the Pacific states have the technical potential to produce almost 869 TWh of electricity, more than twice as much as the 401 TWh of electricity they used in 2019, and almost 90% of the 1,014 TWh they would use in 2050 with full electrification of buildings, transportation and industry.

California, with its huge coastline, has the highest absolute technical potential for offshore wind generation, followed by Oregon, Washington and then Hawaii. However, because of its low electricity usage, Hawaii has the highest ratio of technical offshore wind generation potential to electricity usage – it has the technical potential to produce more than 10.5 times its 2019 electricity use and almost 4.5 times its 2050 electricity use with full electrification.

The Pacific region has five proposals for offshore wind development, three in California and two in Hawaii, all of which are call areas open to applications from developers.[60]

TABLE 3: OFFSHORE WIND RESOURCES IN THE PACIFIC

State	Total 2019 retail electricity sales (TWh)	2050 electricity usage with full electrification (TWh)	Annual offshore wind generation technical potential (TWh)	Offshore potential as percentage of 2019 electricity use	Offshore potential as percentage of 2050 electricity use with full electrification
California	250.4	761.1	391.9	157%	52%
Hawaii	9.5	22.7	99.9	1,057%	441%
Oregon	50.4	89.9	230.2	457%	256%
Washington	91.1	139.9	146.6	161%	105%

TABLE 4: PACIFIC REGION OFFSHORE WIND PIPELINE[61]

Project name	Status	Location	Announced project capacity (MW)	Total site capacity (MW)
Diablo Canyon Call Area	Open to project proposals	CA		
Morro Bay Call Area	Open to project proposals	CA		
Humboldt Call Area	Open to project proposals	CA		
Oahu South Call Area	Open to project proposals	HI		
Oahu North Call Area	Open to project proposals	HI		

Offshore wind in the Gulf

States: Alabama, Louisiana, Mississippi and Texas[62]

Offshore wind in the Gulf of Mexico faces two main challenges: wind speed and conflicting uses. Water in the Gulf is shallow enough to allow fixed-bottom turbines far from shore, and in particular Texas and Louisiana have a large area of the Gulf suitable for offshore wind development.[63] However, low average windspeed means lower capacity factors and less power that can be produced than in other regions.[64]

In addition to low wind speed, the Gulf of Mexico also has extensive conflicting uses, including shipping and oil and gas operations, which reduce the area usable for offshore wind generation.[65] While not all of these conflicting uses exclude deployment of offshore wind generation, they do present a logistical challenge and will prevent development in certain areas of the Gulf.[66]

Still, offshore wind can make an important contribution of renewable energy to the Gulf states. Both Louisiana and Texas have the technical potential to produce more electricity from offshore wind generation than they used in 2019, and Louisiana has the technical potential to produce more electricity than it is projected to use in 2050 after nationwide maximal electrification. Texas has the largest potential generation capacity, closely followed by Louisiana, but Louisiana has by far the highest ratio of potential generation capacity to electricity use in the Gulf.

As a region, the Gulf states have the technical potential to produce more than 1,400 TWh of electricity from offshore wind generation, more than twice the 660 TWh of electricity the region used in 2019 and over 20% more electricity than the region is projected to use in 2050 assuming the country undergoes maximum possible electrification.

TABLE 5: OFFSHORE WIND RESOURCES IN THE GULF OF MEXICO

State	Total 2019 retail electricity sales (TWh)	2050 electricity usage with full electrification (TWh)	Annual offshore wind generation technical potential (TWh)	Offshore potential as percentage of 2019 electricity use	Offshore potential as percentage of 2050 electricity use with full electrification
Alabama	88.1	150.6	52.8	60%	35%
Louisiana	93.1	134.3	641.6	689%	478%
Mississippi	49.0	86.3	9.7	20%	11%
Texas	429.3	786.5	712.0	166%	91%

Offshore wind in the Great Lakes

States: Illinois, Indiana, Michigan, Minnesota, Ohio, Pennsylvania and Wisconsin[67]

Offshore wind resources are more limited in the Great Lakes region than in the other regions. Because of the smaller total area and the fact that current floating turbine technology cannot withstand freshwater ice floes, both the area that could be developed for offshore wind generation and the technical potential for generation are much smaller in the Great Lakes than on the coasts of the U.S.[68]

Despite these limitations, Michigan has the technical potential to produce more power from offshore wind generation than the state consumed in 2019. No Great Lakes states have the technical potential to produce as much electricity as they are projected to use in 2050 after nationwide electrification, but Michigan could produce 72% of that amount. Michigan has the highest generation potential and the highest ratio of potential to electricity use, followed by Ohio and Wisconsin.

As a region, the Great Lakes states have the technical potential to produce 344 TWh of electricity from offshore wind generation; almost half as much as the 772 TWh of electricity they used in 2019 and about one fifth as much as the 1,769 TWh they are projected to use in 2050 assuming complete electrification of the nation.

The Great Lakes region has one project in the pipeline: Ohio's Icebreaker, which is a 21 MW project in the permitting phase scheduled to be completed in 2023.[69]

TABLE 6: OFFSHORE WIND RESOURCES IN THE GREAT LAKES

State	Total 2019 retail electricity sales (TWh)	2050 electricity usage with full electrification (TWh)	Annual offshore wind generation technical potential (TWh)	Offshore potential as percentage of 2019 electricity use	Offshore potential as percentage of 2050 electricity use with full electrification
Illinois	138.3	359.4	16.8	12%	5%
Indiana	102.1	204.3	3.4	3%	2%
Michigan	101.2	276.1	199.4	197%	72%
Minnesota	67.0	158.1	0.4	1%	0%
Ohio	148.5	331.5	62.7	42%	19%
Pennsylvania	145.6	257.8	12.8	9%	5%
Wisconsin	69.2	181.9	48.6	70%	27%

The future of U.S. offshore wind

Although the U.S. currently has only seven active offshore wind turbines in two locations – five at the first offshore wind farm in the U.S., the Block Island Wind Farm in Rhode Island, and two at the first wind farm in federal waters, the Coastal Virginia Offshore Wind pilot – there are many projects in development that could come online throughout the next decade.[70]

Today, in addition to the two operational offshore wind farms, the U.S. has 34 proposals for offshore wind development – including 27 projects in various stages of planning and development – with a combined total of about 26.1 GW of site capacity.[71] Most of the projects are along the East Coast, and the remainder are off of California and Hawaii.[72] Most of the projects are in the site control and permitting phases, which means the developer has signed a lease or in some way been given control of the site, and the planning for the project has begun but has not yet been fully approved.[73]

Even with the chaos of the COVID-19 pandemic, 2020 was a surprisingly good year for offshore wind. According to NREL, the amount of offshore wind capacity with a signed offtake agreement – meaning some entity had signed an agreement to purchase the power – had more than tripled from March 2019 to March 2020, to a total of almost 6.5 GW.[74] Other developments also pointed to future success of the industry. Vineyard Wind, which has been delayed repeatedly but is still scheduled to be one of the first U.S. projects to come online, recently restarted its permitting process. A Bureau of Ocean Energy Management (BOEM) report about Vineyard Wind – one of the many delays in the project's development – detailed manageable environmental impacts and many benefits from developing offshore wind.[75] The year also saw lower-than-expected prices for new offshore wind, signaling strong economics for new projects.[76] Additionally, Maryland, Virginia and North Carolina entered into an agreement to work together on offshore wind development, a formal recognition of the importance of regional cooperation.[77]

New projects are in the development process along the East Coast, from Maine to North Carolina.[78] On the West Coast, California is starting to plan for offshore wind to help the state reach 100% renewable energy.[79] Investment is beginning to flow as well: Siemens Gamesa – one of the largest turbine suppliers in the world – is considering a U.S. manufacturing facility and states and companies are putting money into offshore wind infrastructure and equipment.[80] New Jersey has announced that it will develop the New Jersey Wind Port for staging, assembly and manufacturing, and that two offshore wind companies have invested $250 million in a monopile manufacturing facility in the state.[81]

With planned projects set to go online in the next few years, prices continuing to drop, and a domestic supply chain emerging, the offshore wind industry has lots of potential, but federal policies and practices have slowed its growth.

Impediments to offshore wind slow its growth

There are two major impediments to the growth of offshore wind in the U.S. Both are federal practices that slow development and make the transition to 100% renewable energy harder.

Short-term and unpredictable tax credits: The U.S. currently has both a production tax credit (PTC) and an investment tax credit (ITC) for offshore wind.[82] In December 2020, congressional action extended the PTC at 60% of its per-kilowatt value for one year (until 2022), and created the ITC set at 30% of the cost of projects that begin construction before 2026.[83] These tax credits reduce the cost of offshore wind development and the power wind turbines produce, helping to jump-start deployment and grow the industry to the point where it is competitive without the credit.

However, Congress' pattern of extending tax credits for short periods of time, as opposed to making a consistent commitment to supporting offshore wind, makes it hard for developers to plan and commit to projects. As the Union of Concerned Scientists showed, this short-term cycle of tax credit extension and expiration, which has happened many times since the implementation of the renewable energy PTC in 1992, has led to a "boom-bust cycle" in which development slows significantly when the credits expire and then pick up when the credit is renewed.[84] Short-term extensions like those enacted in December 2020 – while necessary to prevent a drop-off of financial support for renewables – serve to introduce uncertain incentives for offshore wind, rather than allowing long-term and consistent growth.

Lack of action and delays by the Bureau of Ocean Energy Management (BOEM): BOEM has not leased a new area for offshore wind development since February 2019.[85] This means two years without new projects getting to start planning and design, despite plenty of interest.[86]

Additionally, the BOEM process for permitting and approval is very slow and is currently delaying U.S. offshore wind development. This is abundantly clear in the case of Vineyard Wind; the Massachusetts wind farm off of Martha's Vineyard that is set to be America's first major utility-scale operation.[87] Vineyard Wind has faced multiple delays in the federal permitting process – separate from the state and local processes that themselves are not smooth – which threatened to scuttle the entire project.[88] These repeated delays have forced the project's operational timeline back at least one year, and involved reviews of multiple proposed projects along the Atlantic coast all at once.[89]

President Joe Biden has signaled an interest in boosting U.S. offshore wind development, which could cause BOEM to speed up the processes for leasing, environmental impact studies and permitting.[90]

Conclusions and recommendations

The United States can take on some of its biggest environmental challenges by taking advantage of one the most underutilized energy resources in the country: offshore wind.

America has sufficient offshore wind potential to power nearly the entire country even after a nationwide transition away from fossil fuels to electricity. Moreover, much of that potential is close to the biggest population centers and largest sources of electricity demand in the U.S.

While deploying offshore wind in the U.S. to its full technical potential would both be impractical and have negative environmental impacts, even using a fraction of the abundant energy off our shores would add another source of clean and reliable energy to rapidly growing onshore wind and solar energy. Deploying offshore wind strategically also allows mitigation of environmental impacts and is a crucial step in the path to 100% renewable energy for the United States.

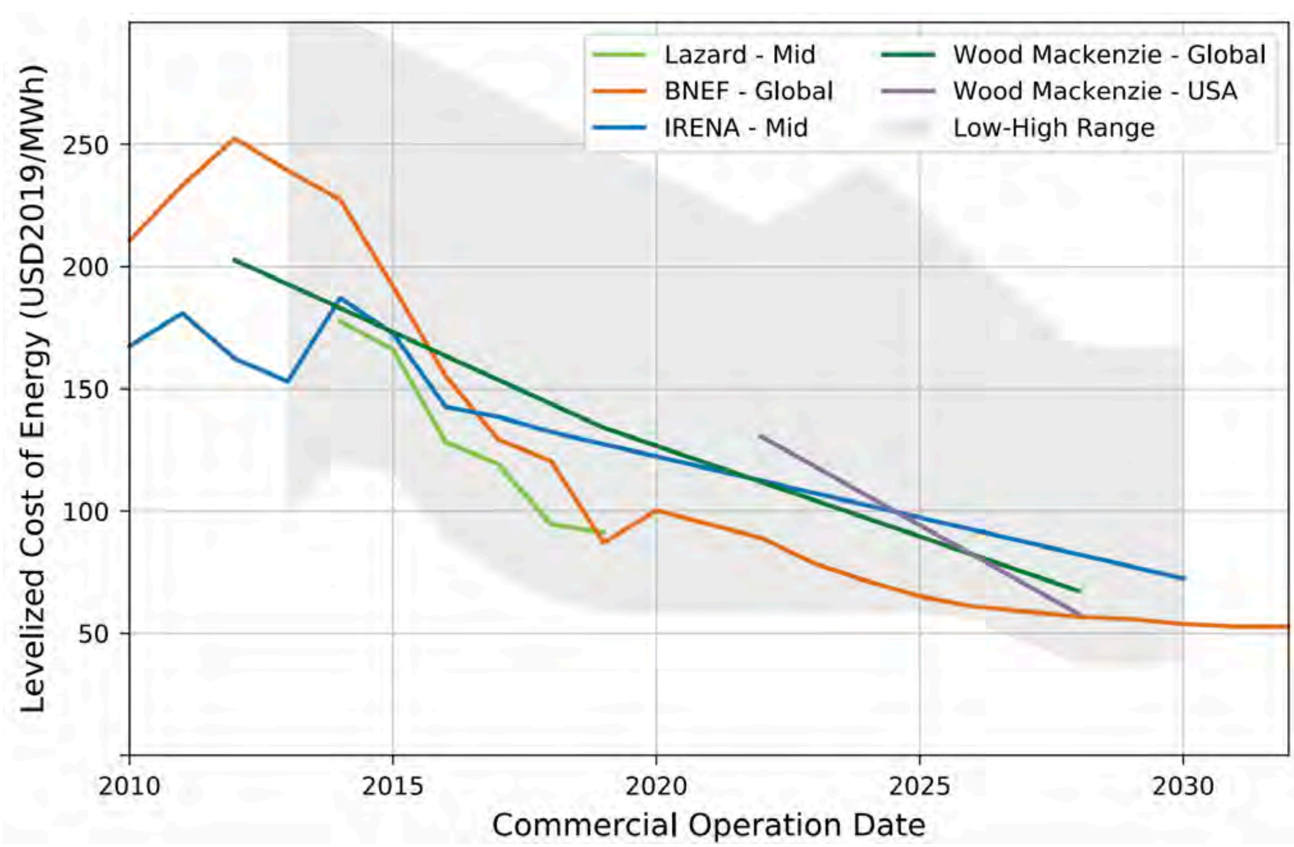

Figure 5: Levelized cost of energy estimates for fixed-bottom offshore wind development[92] *(Image: National Renewable Energy Laboratory)*

In recent years, offshore wind technology has improved dramatically, and prices have fallen far enough that new offshore wind developments are cost competitive with new fossil fuel power plants. (See Figures 5 and 6.) Lazard, an asset management firm that forecasts energy prices, puts the unsubsidized levelized cost of energy for offshore wind lower than that of nuclear, coal and gas peaking power plants, and nearing competitiveness with gas combined cycle plants.[91] The rate of deployment of offshore wind is growing rapidly across the globe, and the U.S. pipeline for projects shows states' ambition to make offshore wind a major piece of the energy economy.

But the development of offshore wind requires policies to ensure that deployment happens quickly, effectively and responsibly. To that end, policymakers in local, state and federal government should:

- **Provide market certainty for offshore wind**. Policymakers can enact "carve-outs," or minimum requirements for specific technologies in state renewable electricity standards, or they can require utilities to enter into power purchase agreements with offshore wind projects that meet certain standards. States can also set and increase their targets for offshore wind deployment, which should be strong and enforceable. Targets and renewable electricity standard minimums help to drive growth in the industry. To date, Connecticut, Maryland, Massachusetts, New Jersey, New York and Virginia have set targets for offshore wind development, totaling over 28 GW of capacity.[94] States that set targets or enact minimum requirements should devote the resources necessary to deploy capacity quickly, including by soliciting and responding to proposals for new projects.
- **Support domestic supply chain development.** States have begun to put infrastructure in place to create a domestic supply chain for offshore wind and to help the offshore wind industry grow and deploy. For instance, New York and New Jersey have both announced projects to build or upgrade ports to facilitate use by the offshore wind industry.[95]

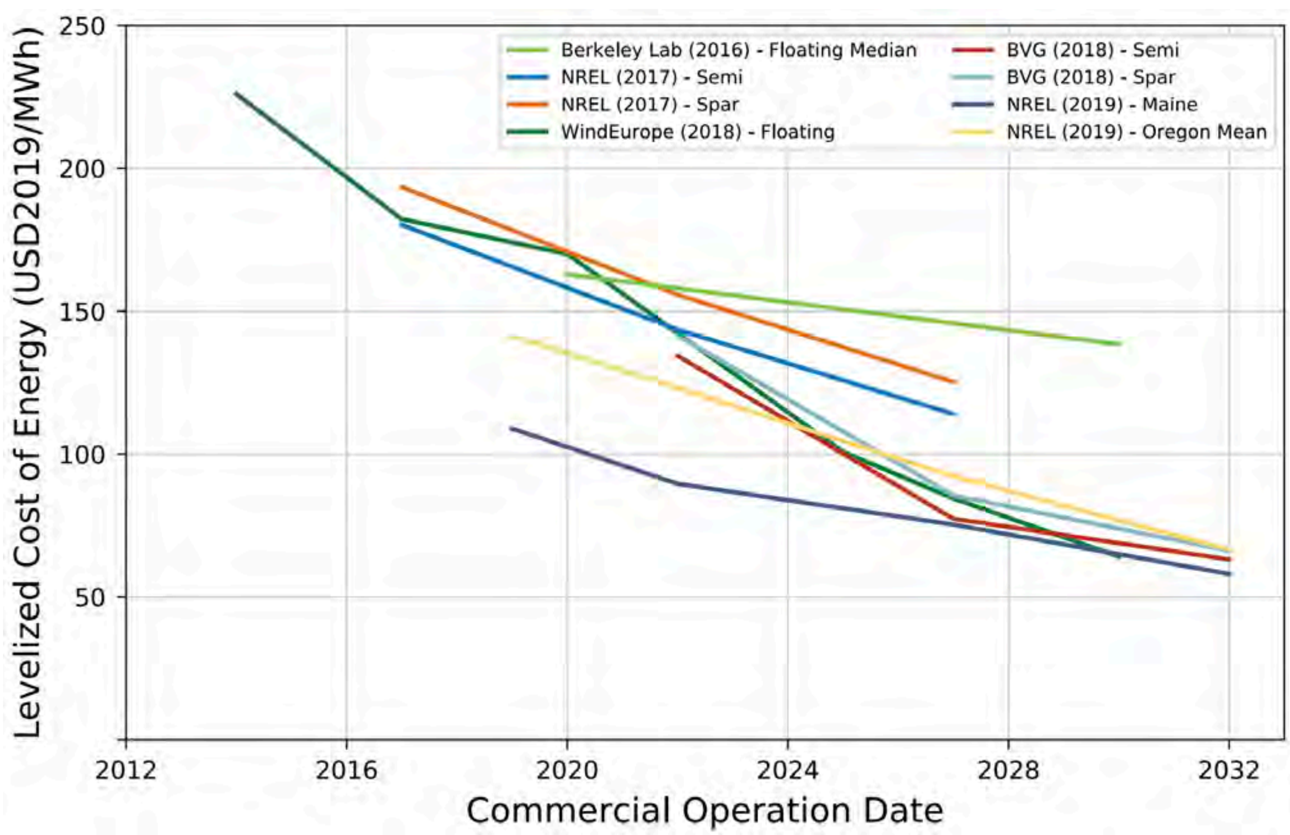

Figure 6: Levelized cost of energy estimates for floating offshore wind development[93] (Image: National Renewable Energy Laboratory)

Encouraging companies to build factories in the U.S., as states are encouraging Siemens Gamesa to do, could also help grow the industry in the U.S.[96] Domestic construction of the vessels needed to build and repair turbines will be required under the Jones Act, and having a U.S. based fleet would speed up construction of new offshore wind farms.[97]

- **Set national standards to ensure the environmental integrity of offshore wind projects and to avoid, minimize and mitigate impacts to marine ecosystems and wildlife**. Although they can become new habitat for marine life, offshore wind turbines can also negatively impact birds and marine life both during construction and during operation.[98] Noise and habitat destruction from pile driving during construction, disruption to habitats or migration routes, and even direct collisions with turbines can all be harmful.[99] These impacts can threaten important struggling and endangered species, including the critically endangered North Atlantic Right Whale.[100] There are, however, best management practices that can reduce the impact of deployment, and can make sure offshore wind farms don't harm wildlife. State and federal agencies must work together to make sure offshore wind development happens in an environmentally responsible way, and proven methods and best practices should be mandated for all projects.[101] All projects should be required to incorporate a research and monitoring plan for mitigating environmental impacts and relevant agencies should develop an industry-wide impact assessment for the North Atlantic Right Whale, including required coordination and best practices to mitigate harm to the species.

- **Direct the Bureau of Ocean Energy Management and relevant state agencies to accelerate the offshore wind leasing and permitting process while ensuring transparency and environmental responsibility.** BOEM and state permitting authorities need to streamline and accelerate the permitting and review processes to allow new projects into the pipeline and to help deployment happen quickly and responsibly, while protecting local communities and ecosystems. BOEM also needs to coordinate with state and local permitting authorities where appropriate to further the same goals. In particular, BOEM should prioritize issuance of final Records of Decision for projects in the review process and Notices of Intent to Prepare an Environmental Impact Statement for those projects that already have contracts for their power. It should also begin auctioning new Wind Energy Areas as soon as possible. Finally, the transparency of the development process should include community engagement with relevant stakeholders, including the fishing industry, local communities and environmental advocates and experts.

- **Extend offshore wind tax credits.** Both the production tax credit and the investment tax credit for offshore wind should be extended for a long enough time period to encourage new projects to enter the pipeline and to allow the industry to grow and mature.

- **Plan for regional offshore wind development, including transmission infrastructure.** While states should set their own goals and requirements for offshore wind development, projects should be developed with a long-term plan for integration across state boundaries. The Federal Energy Regulatory Commission should require planning around these efforts. Regional partnerships, like that of Maryland, Virginia and North Carolina, can encourage this method of planning. Regional integration will help maximize economic potential and lower overall costs for offshore wind projects. Regional cooperation and planning are particularly important for the transmission infrastructure needed to integrate power from offshore wind farms into the wider power system.[102] A coordinated, planned approach can reduce transmission needs, costs, risks and environmental impacts while encouraging increased participation of offshore wind and transmission developers in the process.[103]

- **Support research and development of new offshore wind technologies**, including floating platforms, deeper water non-floating structures, taller turbines, larger rotors, more efficient designs, better transmission technology, better materials, turbine designs that can better withstand hurricanes and ice floes, and recycling procedures to reduce waste from end-of-life decommissioning of turbines.

Methodology

Nationwide and state 2019 electricity usage data was obtained from the U.S. Energy Information Administration's *State Electricity Profiles*, archived at https://web.archive.org/web/20210109111454/https://www.eia.gov/electricity/state/#nav-learn.

Estimates of state and national electricity use in 2050 after electrification are derived from data produced for the National Renewable Energy Laboratory's (NREL) *Electrification Futures Study*. This NREL report examines estimates of energy use in 2050 in several scenarios, including an electrification technical potential scenario in which all possible electrification of transportation, buildings and industry occurs as fast as possible, which formed the basis of this analysis. The *Electrification Futures Study* does not assume improvements in energy efficiency beyond those projected under business as usual conditions by the Department of Energy and may therefore overestimate the electricity demand after electrification.[104] Detailed state-by-state data were obtained from the NREL, *Electrification Futures Study Technology Data*, accessed 2 October 2019 and available at https://data.nrel.gov/submissions/92. Data were filtered by year, scenario, and energy type to arrive at the estimates presented here.

Offshore wind generation potential data was obtained from NREL's *2016 Offshore Wind Energy Resource Assessment for the United States* report in Appendix I, archived at https://web.archive.org/web/20201206044939/https://www.nrel.gov/docs/fy16osti/66599.pdf.

Electricity usage and offshore wind generation potential were converted to TWh for comparison, and ratios calculated for each state and region and the nation as a whole.

Appendix

TABLE A1: OFFSHORE WIND RESOURCES IN THE UNITED STATES[105]

State	Total 2019 retail electricity sales (TWh)	2050 electricity usage with full electrification (TWh)	Annual offshore wind generation technical potential (TWh)	Offshore potential as percentage of 2019 electricity use	Offshore potential as percentage of 2050 electricity use
Alabama	88.1	150.6	52.8	60%	35%
California	250.4	761.1	391.9	157%	52%
Connecticut	27.9	70.3	6.7	24%	10%
Delaware	11.5	22.4	20.6	180%	92%
Florida	240.3	470.7	780.3	325%	166%
Georgia	139.3	269.7	156.5	112%	58%
Hawaii	9.5	22.7	99.9	1,057%	441%
Illinois	138.3	359.4	16.8	12%	5%
Indiana	102.1	204.3	3.4	3%	2%
Louisiana	93.1	134.3	641.6	689%	478%
Maine	11.7	30.7	411.2	3,505%	1,338%
Maryland	60.7	155.2	96.3	159%	62%
Massachusetts	51.3	129.4	1,053.2	2,052%	814%
Michigan	101.2	276.1	199.4	197%	72%
Minnesota	67.0	158.1	0.4	1%	0%
Mississippi	49.0	86.3	9.7	20%	11%
New Hampshire	10.7	28.4	5.0	47%	18%
New Jersey	73.9	167.4	280.2	379%	167%
New York	145.6	361.4	295.2	203%	82%
North Carolina	136.4	274.7	634.2	465%	231%
Ohio	148.5	331.5	62.7	42%	19%
Oregon	50.4	89.9	230.2	457%	256%
Pennsylvania	145.6	257.8	12.8	9%	5%
Rhode Island	7.3	18.6	60.4	821%	325%
South Carolina	80.2	129.9	612.6	764%	472%
Texas	429.3	786.5	712.0	166%	91%
Virginia	118.4	222.2	161.8	137%	73%
Washington	91.1	139.9	146.6	161%	105%
Wisconsin	69.2	181.9	48.6	70%	27%

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42 See Methodology for details of the data sources and calculations presented in this report.

43 Alaska is excluded because NREL does not include Alaska in its model of offshore wind resources in the U.S. See: Walter Musial, et al., *2016 Offshore Wind Energy Resource Assessment for the United States*, National Renewable Energy Laboratory, September 2016, archived at https://web.archive.org/web/20201206044939/https://www.nrel.gov/docs/fy16osti/66599.pdf.

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46 Offshore wind potential from New York's Great Lakes waters and Florida's Gulf of Mexico waters are included in the Atlantic region due to limitations of the NREL data and the difference in resources on its two coasts. See Walter Musial, et al., *2016 Offshore Wind Energy Resource Assessment for the United States*, National Renewable Energy Laboratory, September 2016, p. 25, p. 28 and p. 33, archived at https://web.archive.org/web/20201206044939/https://www.nrel.gov/docs/fy16osti/66599.pdf.

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61 This includes unleased call areas: places that BOEM has made available to site offshore wind projects but for which it has not yet finalized any leases; total pipeline capacity includes the potential capacity of the leased area as well as announced capacity of planned projects; location is the state closest to the site of the project. See note 59.

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