Turning to the Wind

American Wind Power is Cutting Carbon Pollution Today and Paving the Way for a Clean Energy Future

ENVIRONMENT CALIFORNIA
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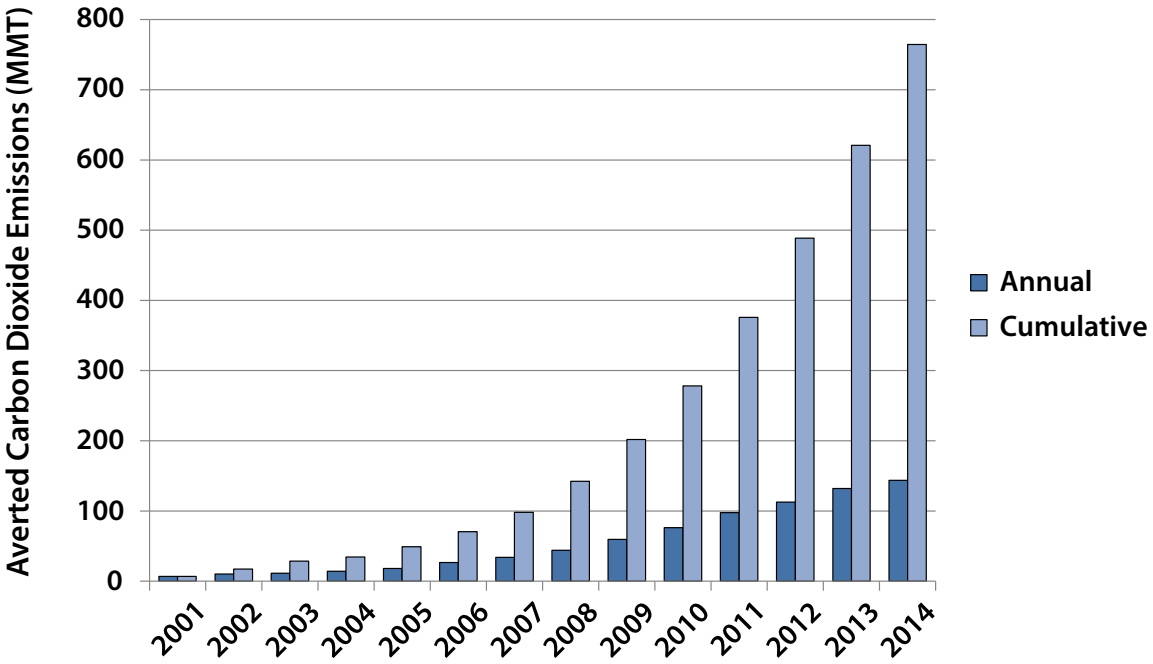
Executive Summary

Wind power continues to grow as a source of clean energy across America. The United States generated 26 times more electricity from wind power in 2014 than it did in 2001. American wind power has already significantly reduced global warming pollution. **In 2014 alone, wind-generated electricity averted an estimated 143 million metric tons of carbon dioxide emissions – as much as would be produced by 37 typical coal-fired power plants.** With America's massive potential for wind energy on land and off our coasts, wind power can play a key role in meeting the emission reduction targets of the recently adopted Clean Power Plan and moving the nation toward a future of 100 percent renewable electricity.

To take advantage of that potential, however, the nation must create a public policy environment that is supportive of continued wind energy growth. Long-term renewal of federal tax incentive programs for renewable energy, including the Production Tax Credit and the Investment Tax Credit for wind energy, both of which expired at the end of 2014, can help the United States maintain momentum in the fight against global warming.

Figure ES-1. Carbon Dioxide Pollution Displaced by Wind-Generated Electricity, 2001-2014



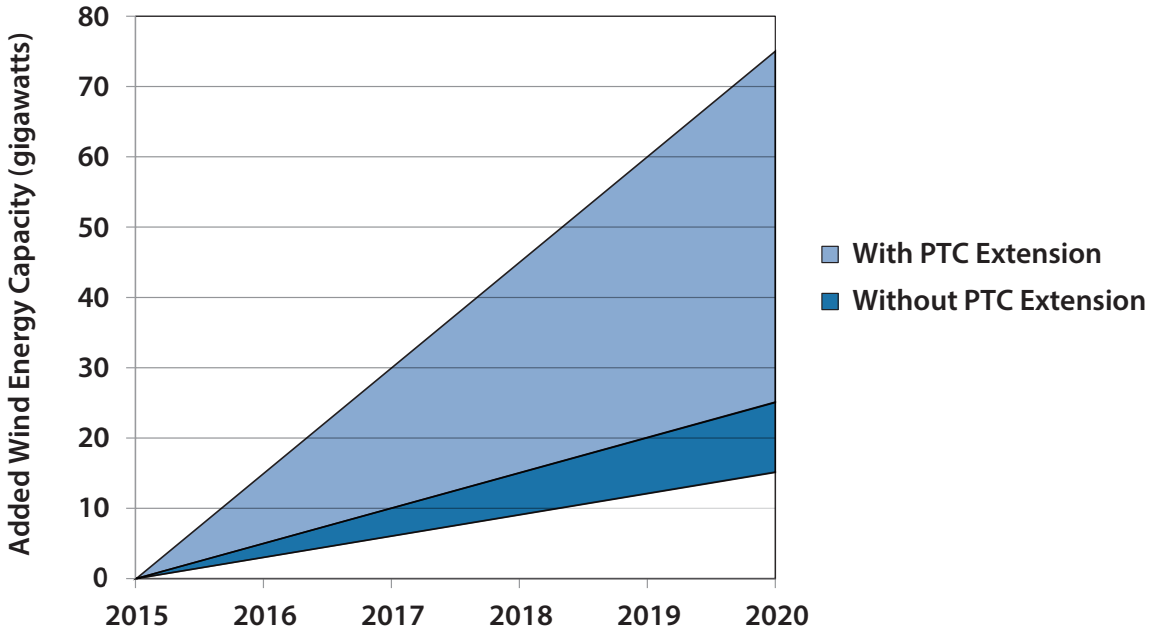
Wind power has already significantly reduced climate-altering carbon pollution.

- Since 2001, wind power in the United States has displaced more than 764 million metric tons of carbon dioxide – more than a year's worth of CO_2 emissions from the entire country of Canada.
- After more than a decade of rapid growth, wind energy accounted for 4.4 percent of total U.S. electricity generation in 2014.
- Nine states – Colorado, Idaho, Iowa, Kansas, Minnesota, North Dakota, Oklahoma, Oregon and South Dakota – generated more than 12 percent of their total electricity production with wind power in 2014.
- In 2014, wind power in Iowa and South Dakota accounted for over a quarter of in-state electricity generation.

By renewing the Production Tax Credit, America can displace even more carbon pollution – a critical step towards protecting future generations from the worst impacts of global warming.

- The uncertainty created by the on-again, off-again Production Tax Credit has undermined steady progress on wind energy. Since its inception in 1992, the credit has expired a number of times, including at the end of 2014.
- A recent analysis by the National Renewable Energy Laboratory found that renewing the Production Tax Credit would add between 10,000 and 50,000 MW of wind capacity to the U.S. energy grid by 2020, compared with projected levels of wind capacity in the absence of the tax credit.
- Depending on overall electricity demand and the prices of competing fossil fuels, the Production Tax Credit would avert between 4.2 and 20.8 million metric tons of additional carbon dioxide per year from 2016 through 2020. That is a total of between 20.8 and 104.2 million tons of avoided carbon dioxide pollution by 2020.

Figure ES-2. Estimated Impact of PTC Renewal on Wind Energy Capacity through 2020



By expanding opportunities for offshore wind energy, America can further reduce carbon pollution.

- Offshore wind energy is a proven technology that currently provides carbon-free electricity for several European and Asian countries.
- The construction of America's first offshore wind facility—the 30 MW Block Island Wind Farm in Rhode Island—began in July 2015. The project is expected to begin operations by the end of 2016.
- Several offshore wind projects in Atlantic states have reached advanced development stages and are scheduled to begin commercial operations by 2020. Energy generated by these projects could offset over 9.3 million metric tons of carbon dioxide in 2020. That's equivalent to the annual emissions of nearly 2 million passenger vehicles.

Wind energy is reducing America's contribution to global warming now, and can do so even more in the future. To take advantage of America's vast wind energy potential:

- The federal government should establish a consistent, predictable and supportive public policy playing field for renewable energy, including the long-term extension of key policies such as the Production Tax Credit and the Investment Tax Credit, which helped drive the explosion of wind growth over the last 10 years.
- State and federal governments should set ambitious goals for the steady expansion of wind energy and adopt renewable electricity standards consistent with those goals.
- State and federal agencies should coordinate to expedite the responsible development of offshore wind facilities, ensuring strong environmental protections throughout the development process.
- The federal government should defend the Clean Power Plan and both the federal government and state governments should ensure that wind power plays a key role in its implementation.

Introduction

Devastating drought and fires on the West Coast and flooding from major storms are just the most recent reminders of the very real damage that extreme weather causes in our communities. Global warming threatens to increase the frequency and severity of extreme weather events, putting our health and welfare at risk.

To protect ourselves and future generations from the worst impacts of global warming, America must move toward repowering our economy with 100 percent clean energy.

Over the past decade, America has made tremendous progress in expanding our use of renewable electricity, including clean wind power. An afterthought just a mere 15 years ago, wind energy has quickly emerged as a large and growing source of clean energy for America's economy.

But the growth of wind energy has only begun to scratch the surface of the nation's wind energy potential. With wind energy continuing to become cheaper, new wind turbine designs enabling wind energy to be produced with greater consistency in more places, and vast, untapped potential for wind energy growth across the country, the United States is well-positioned for a transition to a clean energy future fueled in large part by the wind.

The Clean Power Plan (CPP), released by the EPA in August 2015, will help to encourage the development of wind energy as a means to cut carbon pollution from power plants. The CPP sets national standards to reduce carbon pollution from power plants by 32 percent by 2030, requiring states to demonstrate progress as early as 2022.

But if America is to truly take advantage of our potential for clean wind energy, the CPP must be accompanied by a suite of consistent, predictable and supportive clean energy policies.

Over the last two decades, the lack of consistent policy regarding wind energy development in the United States has created uncertainty that discourages investment in wind energy technology and manufacturing. Instead, programs such as the on-again, off-again federal Production Tax Credit (PTC) have contributed to a series of boom-bust cycles, with wind energy installations growing rapidly, only to fall again.

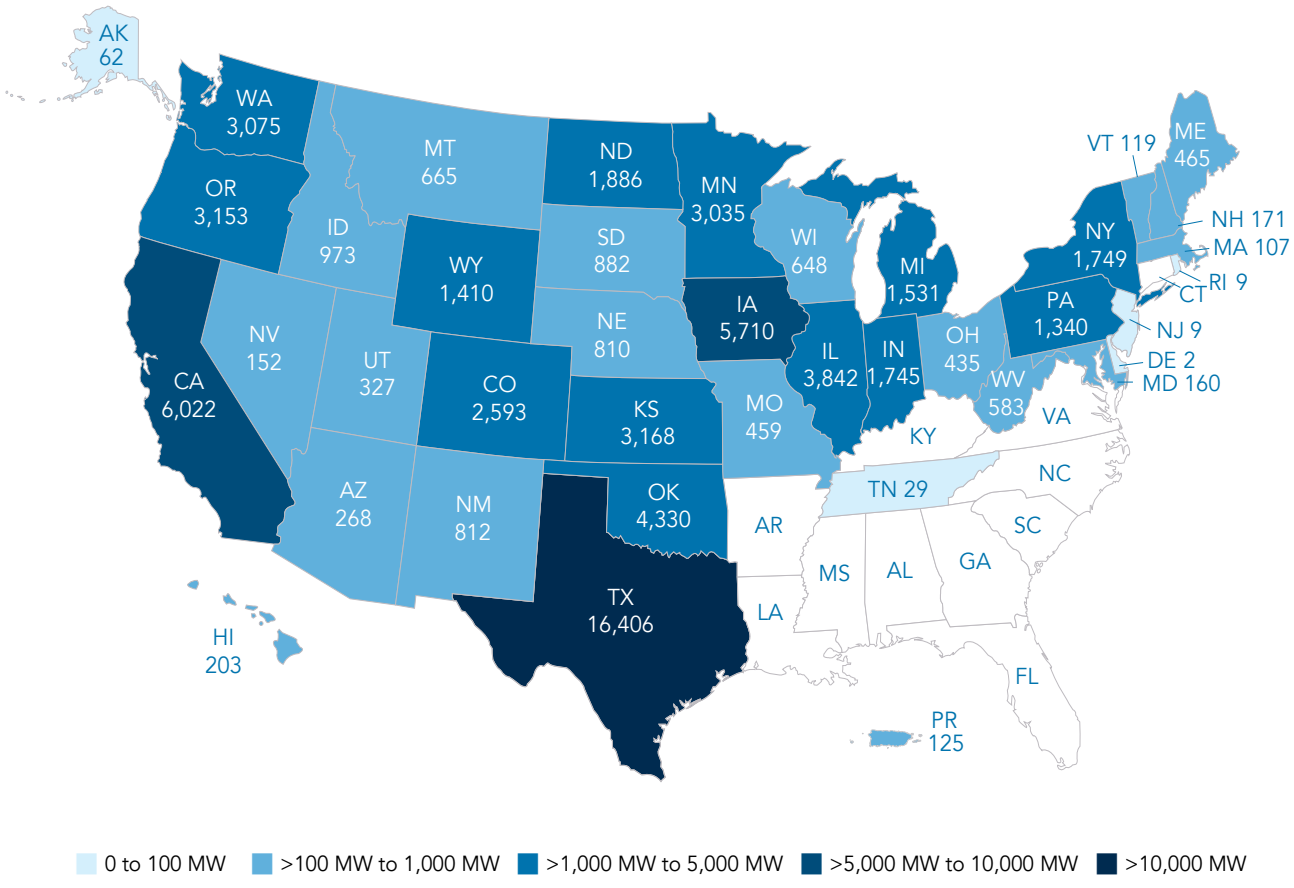
Consistent public support for wind energy through an extended PTC can result in America having significantly more wind energy in 2020 than would otherwise be the case, resulting in lower carbon dioxide emissions and setting up the United States for an eventual transition to a 100 percent renewable electricity system.

In this report, we highlight the value of wind energy in fighting global warming by calculating the total amount of carbon dioxide averted by U.S. wind power plants to date. We then estimate the amount of carbon pollution that could be averted by renewing the PTC and expanding opportunities for offshore wind energy. By building on the progress of wind energy in dozens of states, the United States can meet and exceed the goals of the Clean Power Plan, and ensure a supply of clean, affordable energy for future generations.

Wind Power Continues to Grow

According to the American Wind Energy Association, the total wind power capacity in the United States reached 69,343 megawatts (MW) by the end of September 2015, with 49,800 wind turbines.[1] (See Figure 1.) U.S. wind farms now provide enough power for 18 million American homes and have attracted over $100 billion in private investment to the U.S. economy since 2008.[2] The wind energy industry also employs more than 73,000 people in the U.S., with a manufacturing supply chain of more than 500 factories across 43 states.[3]

Figure 1: Current Installed Wind Power Capacity (Megawatts through 9/30/2015)[4]

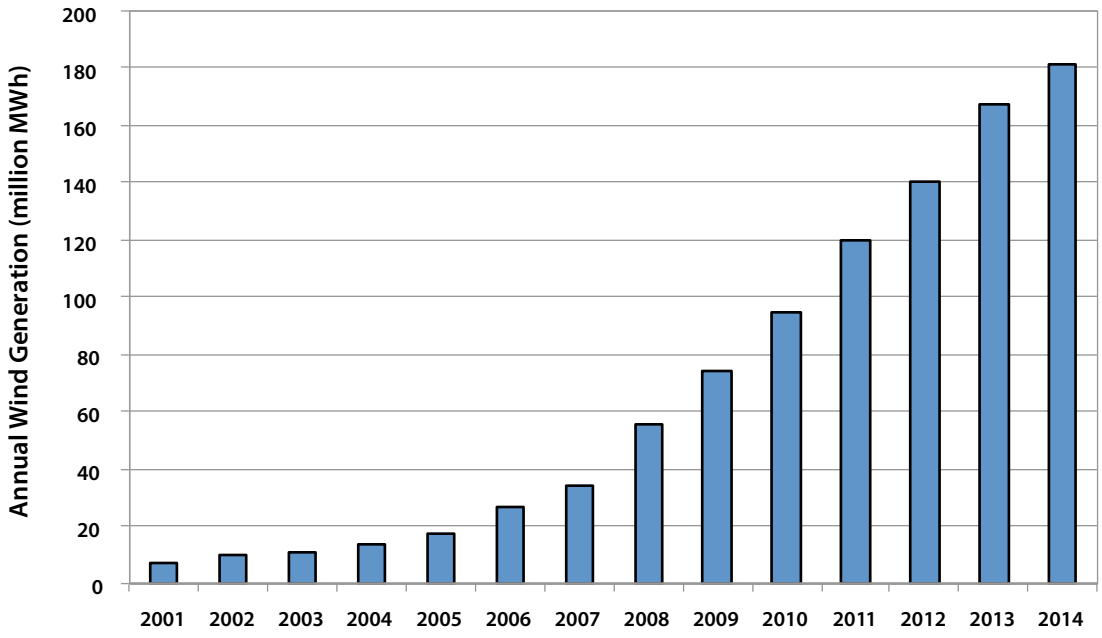


Wind Generation Growth, 2001-2015

The U.S. has made significant progress over the past decade and a half toward building wind power into its total energy mix. The U.S. Energy Information Administration reports that in 2014, wind power accounted for 4.4 percent of national power generation. In some states, this figure was significantly higher. For example, wind energy accounted for about 29 percent of all electricity produced in Iowa and 25 percent in South Dakota.[5] In 2014, wind power accounted for over 12 percent of electricity generation in seven other U.S. states – Colorado, Idaho, Kansas, Minnesota, North Dakota, Oklahoma and Oregon.[6]

Between 2001 and 2014, the U.S. generated over 955 million megawatt-hours (MWh) of electricity from the wind.[7] That includes nearly 182 million MWh in 2014 alone, when America generated 26 times as much electricity from wind power as it did in 2001. (See Figure 2.)

Figure 2: The Growth of U.S. Wind Power since 2001[8]



Wind Power is Reducing Global Warming Pollution Today

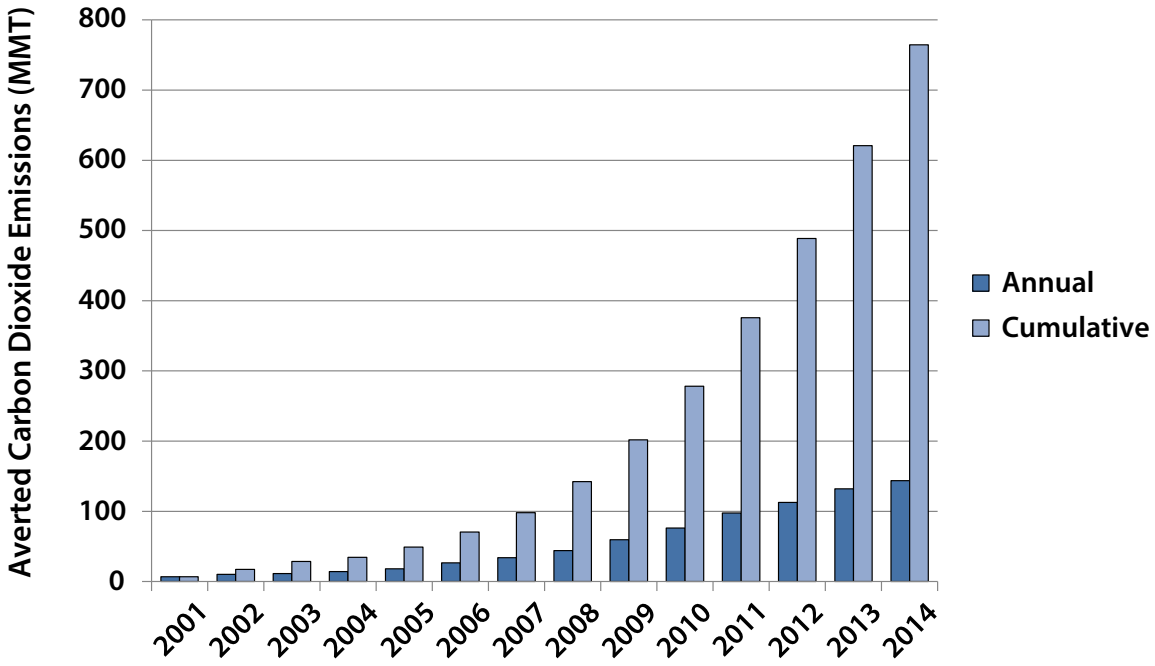
Carbon-intensive fossil fuels such as coal, oil and natural gas were used to produce about 67 percent of America's electricity in 2014.[9] Fossil fuel-fired power plants are by far the largest source of carbon dioxide pollution in the United States, contributing 31 percent of nation-wide greenhouse gas emissions.[10] The good news is that wind energy has come to replace increasing amounts of fossil fuel-fired electricity since the turn of the century, which has led to large reductions in carbon emissions.

Rapid Wind Energy Growth Has Led to Big Emission Reductions

In contrast to fossil fuel power plants, wind turbines do not emit carbon dioxide. Over the entire life-cycle of a wind turbine, 98 percent fewer greenhouse gases are emitted per unit of electricity produced than would be emitted over the life cycle of a modern natural gas power plant.[11]

The rapid growth in wind energy has significantly reduced carbon pollution in the United States. In

Figure 3. Carbon Dioxide Emissions Averted by Wind Energy



2014, wind power averted over 143 million metric tons (MMT) of carbon dioxide emissions from fossil fuel-fired power plants – an increase from about 6 MMT in 2001. (See Figure 3.) Since 2001, wind power has displaced more than 764 MMT of carbon pollution – more than the annual carbon dioxide emissions of the entire country of Canada.[12] (See Appendix A for details.)

Wind power plants in Texas and Iowa lead the nation when it comes to reducing global warming pollution. In 2014, Texas wind energy displaced an estimated 25 MMT of carbon dioxide, while in Iowa, wind energy displaced approximately 16 MMT. The 41 MMT of carbon dioxide averted by wind turbines in these two states is more than the total yearly carbon dioxide emissions of the state of Connecticut.[13] Also making significant progress towards reducing carbon pollution in 2014 were California, Oklahoma, Kansas and Minnesota, where wind turbines averted over 9 MMT of carbon dioxide emissions each. (See Appendix A for state-by-state estimates of carbon dioxide emissions reductions from wind energy.)

Strong, Stable Policies Can Fuel Further Growth in Wind Energy

The recent growth in wind energy has been facilitated by supportive public policies at the state and federal level. Among those policies is the federal Production Tax Credit (PTC) for renewable energy. The PTC has played a critical role in fueling wind energy growth, but it has been applied erratically, reducing its effectiveness. Extending the lifetime of the PTC would result in the addition of more wind energy in the United States over the next several years, accelerating the nation's transition to a low-carbon electricity system.

The Production Tax Credit Is a Key Tool for Supporting Wind Energy

The Production Tax Credit (PTC) was designed to support the long-term production of renewable electricity. The PTC provided utility-scale wind energy producers with a tax credit of $23 per MWh (2.3 cents per kilowatt hour) for electricity generated during the first 10 years of a wind farm's operation.[14] The lower wind energy prices resulting from the PTC have translated into consumer savings, increasing market demand for wind energy among energy suppliers to businesses, governments and households. Recent estimates indicate that the PTC reduced contracted prices for wind power by roughly 25 to 50 percent.[15]

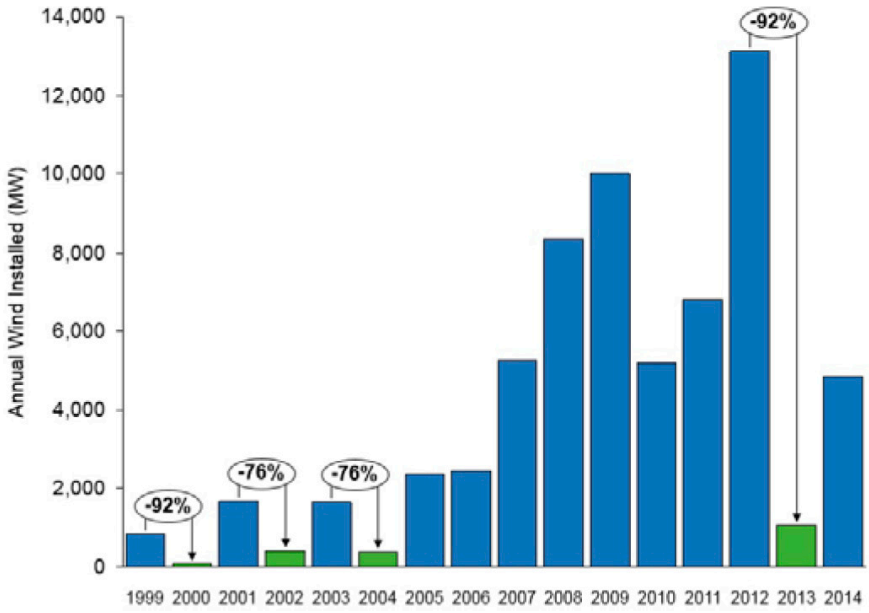
Since the PTC is based on the amount of energy generated rather than installed capacity, it rewards actual facility performance. Some wind energy developers have credited this incentive structure with significant gains in the efficiency of wind power equipment over time, citing the fact that typical wind turbines installed today generate 17 times more electricity than they did in 1990.[16] Such improvements have helped position the U.S. as the largest generator of wind power in the world.[17]

The Unpredictable and Inconsistent Application of the PTC Disrupts Progress Toward Expanding Wind Energy

Since its inception in 1992, the PTC has generally been renewed in one- to two-year intervals and has even been allowed to expire on several occasions.[18] This on-again, off-again approach creates uncertainty in the market that discourages investment in wind energy production and technology as well as private sector research and development. For example, in 2012, it was not known whether the PTC would be extended. Unsure whether financing would continue, companies throughout the wind industry were forced to delay their development plans, which dramatically decreased the number of orders received by manufacturers. As a result, wind installations dropped by 92 percent in 2013. (See Figure 4.)

Once Congress agreed to pass a one-year extension of the PTC for 2013, wind energy development projects started up again. However, Congress failed to reauthorize the PTC for 2014 until the final month of the year. Although the policy was renewed in mid-December and retroactively applied to any new wind plants that started construction during the previous

Figure 4. Historic Impact of the Production Tax Credit (PTC) Expiration[19]



11 months, it expired again two weeks later and has not been renewed since.[20] The unpredictable and inconsistent implementation of the PTC undermines the effectiveness of the policy support.[21]

Renewing and Extending the PTC Would Reduce Carbon Emissions

A recent study by the National Renewable Energy Laboratory (NREL) analyzed the potential impact of extending the PTC on wind energy production in the United States. Authors compared the expected amount of wind capacity that could be produced by 2020 under several scenarios, two of which are described below. Under the first scenario ("PTC Not Renewed"), the PTC remains expired and wind developers no longer receive this financial support for their projects. Under the second scenario ("PTC Renewed"), the PTC is renewed for every year through 2020 at the most recent level of $23 per MWh (2.3 cents per KWh).

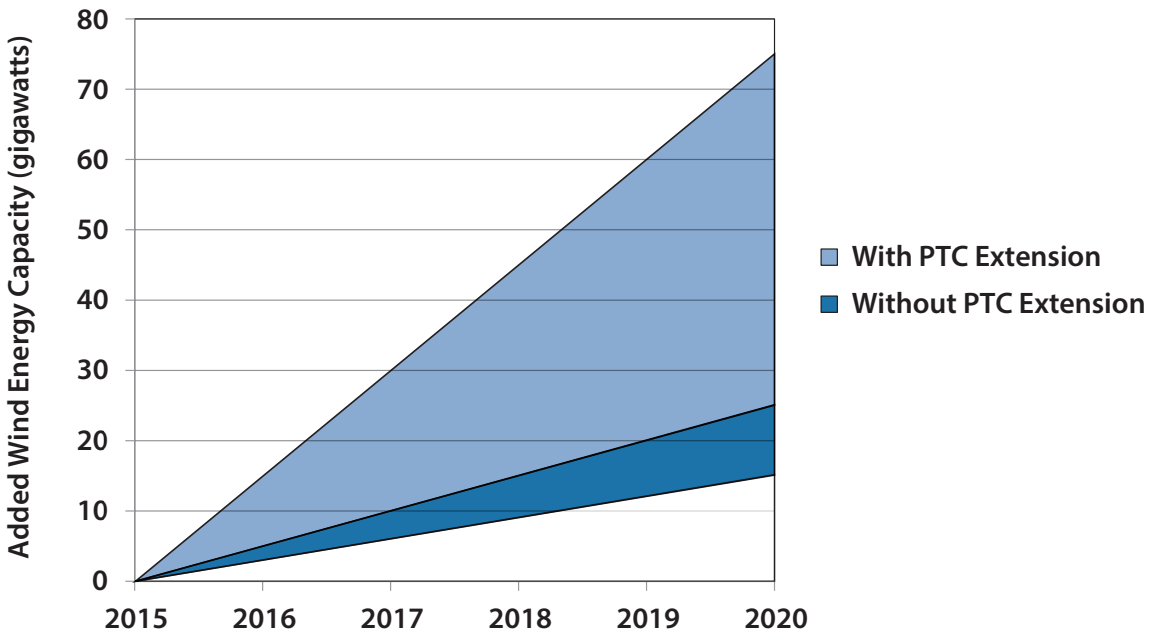
The study found renewing the PTC would result in additional installed wind energy capacity of between 2,000 MW and 10,000 MW per year over and above the amount that would be installed without the PTC.[22] Table 1 compares the study's projected amount of wind capacity added between 2015 and 2020 under the two scenarios. For each scenario, researchers computed a range of expected wind energy growth, with upper and lower bounds corresponding to different assumptions about future natural gas prices and future electricity demand.

Assuming an annual difference between the two scenarios of 2,000 and 10,000 MW of installed wind capacity from 2016-2020, renewing the PTC would create between 10,000 and 50,000 MW of additional wind energy capacity for the U.S. electrical grid by the end of 2020. (See Figure 5.) That is enough to power between 2.8 million and 14.3 million homes for a full year.[23] This amount of wind electricity could avert an average of between 4.2 and 20.8 MMT of additional carbon dioxide pollution per year, a total of between 20.8 and 104.2 MMT by 2020. (See Appendix B for state-by-state estimates of the impact of Production Tax Credit renewal on wind energy in 2020.)

Table 1. Estimated Impact of PTC Expiration on New Wind Energy Capacity, 2016-2020

Scenario Type	PTC Status	Capacity Added, Lower Bound	Capacity Added, Upper Bound
PTC Not Renewed	PTC remains expired through 2020	3,000 MW/year	5,000 MW/year
PTC Renewed	PTC is renewed at a constant level of $23 per MWh of wind energy generated through 2020	5,000 MW/year	15,000 MW/year
Annual Difference		2,000 MW	10,000 MW
Cumulative Difference 2016-2020		10,000 MW	50,000 MW

Figure 5. Estimated Impact of PTC Renewal through 2020[24]

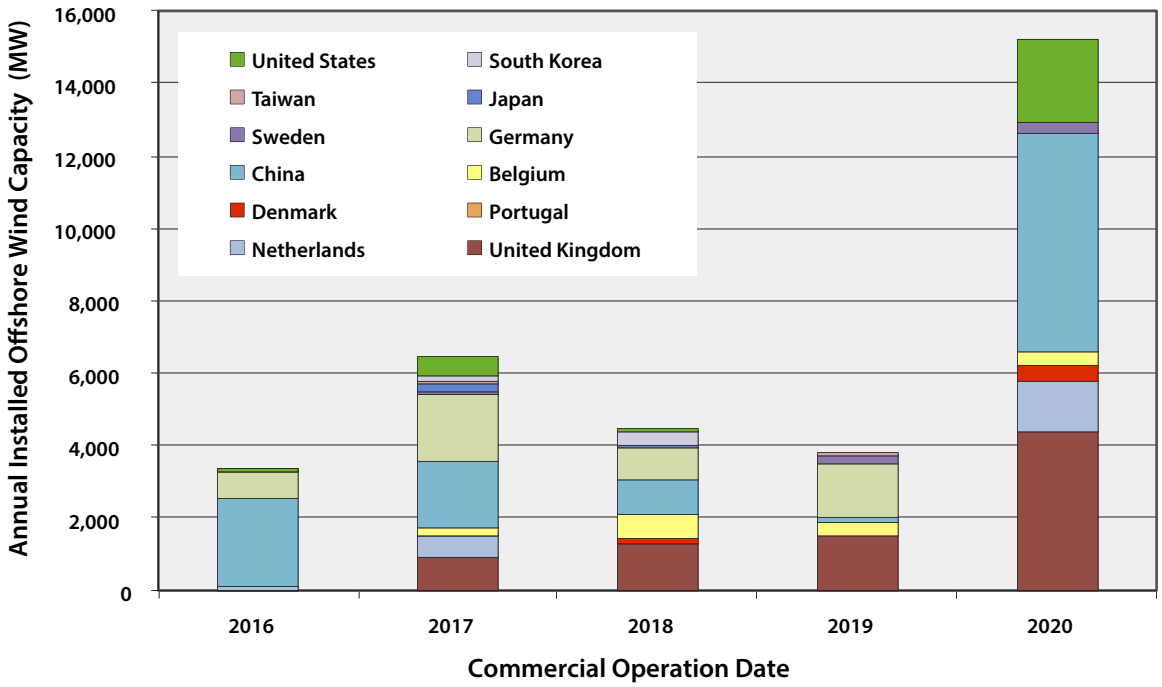


By Expanding Opportunities for Offshore Wind Energy, the U.S. Could Avert Even More Pollution

Offshore wind energy is a proven technology; over the last few decades, it has served as an effective and reliable source of electric power in several European countries as well as China and Japan. The United Kingdom leads the world in offshore wind deployment with over 4,600 MW in operational projects. Across the globe, NREL estimates that the total operating capacity of offshore wind energy facilities reached 8,990 MW by the second half of 2015.[25]

Recent figures released by the European Wind Energy Association suggest offshore wind energy is expanding rapidly. In the first six months of 2015, Europe connected 584 new commercial offshore wind turbines to its power grid with an combined estimated capacity of nearly 2,343 MW.[26] European waters now house at least 82 offshore wind farms with over 3,070 wind turbines across 11 countries, including demonstration sites.[27]

Figure 6: Global Offshore Wind Project Pipeline, 2016-2020[29]



2015: A Record-Breaking Year for Global Offshore Wind Deployment

NREL estimates that by the end of 2015, the global wind industry will have installed more offshore wind capacity than in any other year.[28] Compared with 1,069 MW of new capacity installed in 2014, there are 3,996 MW of wind turbines on track to begin operation in 2015. Analysts now expect cumulative global offshore wind capacity to reach 11,800 MW by the end of the year, and more than 47,000 MW by 2020. Although most of this capacity is being developed in Europe, the industry is becoming more geographically dispersed and beginning to expand to the United States. (See Figure 6.)

In July 2015, wind developer Deepwater Wind began construction of America's first offshore wind project—the 30 MW Block Island Wind Farm in Rhode Island. The project will become the first operating U.S. offshore wind facility by the end of 2016.

The 30-MW Block Island Wind Farm under construction. Photo courtesy of Deepwater Wind.

Developing Offshore Wind Projects in the U.S. Could Add Much More Wind Energy to the Grid

By September 2015, the U.S. Department of the Interior's Bureau of Ocean Energy Management (BOEM) had issued nine commercial offshore wind development leases in Maryland, Massachusetts, Rhode Island, Virginia and Delaware.[30] On November 9, 2015, the Department gave the green light to offshore wind in New Jersey after it successfully completed the first ever auction of wind energy areas off the coast of the state. The two leasing areas totaled close to 344,000 acres with the two lease auction winners, U.S. Wind Incorporated and Res Americas, bidding nearly $2 million. These wind energy areas off the coast of New Jersey could produce more than 3,400 megawatts of pollution-free wind energy.[31]

Other Atlantic states that are actively pursuing leases for offshore wind development include North Carolina and New York.[32] In the Pacific Ocean, Hawaii has requested a lease to build 51 floating turbines with an estimated combined wind energy capacity of 816 MW.[33] In addition, Washington, Oregon and California have agreed to collaborate with BOEM and other federal agencies to evaluate the potential benefits and impacts of renewable ocean energy projects off the West Coast.[34]

Offshore Wind Power Could Reduce Global Warming Pollution in 2020 and Beyond

U.S. offshore wind projects for which the BOEM has issued leases are scheduled to add 3,600 MW of energy capacity to the electric grid by 2020.[35] The energy generated by these projects could avert over 9.3 MMT of carbon dioxide in the year 2020.[36] (See Table 2.) That is equivalent to removing nearly 2 million passenger vehicles from the road for an entire year.[37]

With an established offshore wind market and supply chain by 2020, the United States can integrate much

Table 2. Carbon Dioxide Averted by Selected Offshone Wind Projects in 2020

State	Estimated Total Capacity of Projects Added by 2020 (MW)	Total Averted Carbon Dioxide in 2020 (MT)
Maryland	500	1,552,518
Rhode Island/ Massachusetts	1,000	1,824,460
Massachusetts	400	717,759
New Jersey[38]	1,700	5,217,830
Total	**3,600**	**9,312,568**

more wind energy into its electric grid.[39] For example, a recent Department of Energy study shows the U.S. could install 22,000 MW of offshore wind capacity by 2030.[40] This could avert more than 56 MMT tons of carbon dioxide pollution from the electric sector, the amount produced by 14.8 coal-fired power plants over a full year.[41]

The United States has the technology, the wind resources and the available space to generate an enormous amount of power from offshore wind. NREL estimates that America is technically capable of installing over 4.2 million MW of offshore wind capacity.[42] That is roughly four times the amount of electricity currently used in the country.[43]

Policy Recommendations

Wind power in the United States has expanded significantly since the turn of the century, averting over 764 million metric tons of carbon dioxide pollution from 2001 through 2014. Wind energy is increasingly being integrated into the nation's electricity grids, displacing carbon-intensive fossil fuels and reducing global warming pollution.

The rapid growth of wind energy over the past decade is in part due to the support provided by federal renewable energy tax credits. However, the effectiveness of policies such as the Production Tax Credit has been limited by their inconsistent and unpredictable application. To spur the continued growth of wind energy and move America toward a future of 100 percent clean energy, policymakers should do the following:

Renew the Production Tax Credit at its most recent level for the long term. This would encourage future growth in wind energy, leading to lower energy prices, economic growth and reduced carbon emissions across the country. NREL estimates that renewing the PTC could add between 2,000 and 10,000 MW of wind energy capacity per year from 2016 through 2020. This could avert a total of between 20.8 and 104.2 million metric tons of carbon dioxide, a significant step towards preventing the worst impacts of global warming.

Along with the PTC, policymakers should renew the federal Investment Tax Credit (ITC). The ITC provides owners of new wind energy systems with the option of a tax credit equal to 30% of a facility's value.[44] This is particularly useful for early stage technologies such as offshore wind energy because it can help offset the capital costs of facility construction, when the bulk of project expenses are incurred.[45] Like the PTC, the ITC for offshore wind energy projects expired at the end of 2014.

Both state and federal governments should set ambitious goals for expansion of wind energy and adopt renewable electricity standards consistent with those goals. Renewable Electricity Standards help support wind energy development by requiring utilities to obtain a percentage of the electricity they provide to consumers from renewable sources. These standards help ensure that wind energy producers have a market for the electricity they generate, as electricity suppliers seek to reach their required threshold for renewable electricity. Today, 29 states and Washington, D.C. have some form of renewable electricity standard.[46]

Both federal and state governments should ensure that wind power plays a key role in the implementation of the Clean Power Plan. Expanding the use of renewable energy is one of the most cost-effective ways that states can reduce carbon emissions and comply with Clean Power Plan standards.[47]

America should accelerate development of its vast offshore wind potential by working to overcome obstacles to construction of the nation's first wave of offshore wind facilities in the next several years and setting up offshore wind for long-term success. Specifically, they should:

- Set a bold goal for offshore wind development.
- Increase collaboration with state governments to ensure an efficient offshore wind power leasing process that is coordinated with states' energy planning processes.
- Increase critical investments in offshore wind power, including federal incentives and support for federal research, development and deployment programs at both the Department of the Interior and the Department of Energy.
- Spur markets for offshore wind power through power purchase commitments and collaboration among key agencies, including the federal Departments of Defense, Energy and Commerce and state and regional economic development and energy agencies.
- Ensure that offshore wind projects are sited, built and operated responsibly in order to avoid, minimize and mitigate conflicts with marine life and other ocean uses. Wind energy development should be consistent with the National Ocean Policy and key state and regional planning efforts.

Methodology

Historical and Current Wind Generation and Installed Wind Capacity

Data on historical wind electricity generation was obtained from the U.S. Energy Information Administration (EIA) data available through agency website, accessed 1 October 2015 at www.eia.gov/electricity/data. For historical wind generation data by state from 2001 to 2014, we used the table titled "Net Generation from Electricity Plants for Wind, Annual."

Carbon Dioxide Emissions Reductions Estimates

When a wind turbine generates electricity, it displaces some other source of electricity on the grid. The type of electricity production that is offset by wind depends on several factors: regional variations in the electricity resource mix, the degree to which wind energy offsets new versus existing generation capacity, the relative price of competing forms of electricity generation (including marginal prices), and the way in which wind energy is integrated into the grid, among others.

To estimate carbon dioxide emissions reductions from wind energy, we assumed that wind energy added to the grid would offset fossil fuel generation only, and would offset coal and gas-fired generation in proportion to their contribution to each state's particular electricity mix, as defined by the regional electricity grids that serve that state. The assumption that wind energy overwhelmingly offsets fossil fuel generation, even at high levels of penetration, is supported by recent analyses of high renewable energy penetration scenarios in both the western and eastern U.S.[48]

Emissions reduction rates for each state were based on the actual and forecast electricity generation mixes for the EIA Electricity Market Module (EMM) regions of which they are a part. The EIA's *Annual Energy Outlook 2014*, Tables 73-94, provided data on annual electricity generation and emissions for coal and natural gas power plants in each EMM region. We assigned each EMM region to one of the interconnection regions identified by the North American Electric Reliability Corporation (NERC), using maps of EMM regions and NERC regions.[49] We estimated an emissions factor for fossil fuel-fired generation for each NERC region, using the generation and emissions data for the constituent EMM regions.

To arrive at an avoided emissions factor for each state, we determined the percentage of electricity sales in each state that come from within each NERC region, using data from U.S. Department of Energy, Energy Information Administration, *Electric Power Sales, Revenue, and Energy Efficiency Form EIA-861*, 29 October 2013. State emission factors were created by multiplying each state's percentage of electricity sales per NERC region by each region's emission factor. NERC regions could not be identified for utilities responsible for a total of 1.5 percent of electricity sales nationally, including for the states of Alaska and Hawaii, as well as Washington, D.C. This led to a more conservative CO_2 displacement estimate because we assumed wind energy in those locations displaced no CO_2 pollution.

The use of a constant emission factor for each state masks hourly variations in the carbon intensity of electricity on the grid, meaning that the estimates in this report do not fully reflect the ways in which additional wind energy might affect hourly dispatch of different electricity generators in each region of the country.

To estimate total emissions savings for each state, we multiplied wind generation for that scenario by the emission factor for that state and year. National estimates for each year were based on a sum of all state estimates.

Because of a lack of comparable, updated data prior to 2011, we used 2011 emission factors to estimate wind's cumulative and yearly CO_2 displacement between 2001 and 2011. In one sense, this created a conservative estimate, given the general trend toward cleaner forms of electricity generation during that time. However, by basing our emissions reduction estimates on displacement of all resources from the grid, rather than the marginal source of electricity production or non-baseload sources, this method may lead to larger estimates of emissions reductions than other analyses.

Production Tax Credit Impact Estimates

Data on the impact of PTC renewal were derived from the recent NREL study of the impacts of the PTC.[50] The analysis applies NREL's Regional Energy Deployment System (ReEDS) model to assess the potential impact of several PTC extension scenarios on future deployment of wind generation capacity.[51] Our current analysis focuses on two of these scenarios—one in which the PTC is not renewed and another in which the PTC is renewed at its most recent level of $0.023 per kilowatt hour of generated wind energy through the year 2020.

The study produces an estimated range of wind capacity (MW) that will be installed by 2020 under both scenarios. Under the Current Policy scenario, the U.S. will install between 3,000 and 5,000 MW of wind capacity each year through 2020. Under the Constant 2020 scenario, the U.S. will install between 5,000 and 15,000 MW of wind capacity. The upper and lower bounds of this range reflect a different set of assumptions about future prices of natural gas and the level of demand for electricity. We took the difference between the two scenarios, directly comparing both upper and lower bounds for each of the capacity ranges given by the study. This produced an estimated annual PTC impact of between 2,000 and 10,000 MW. To estimate the cumulative impact of the PTC on wind energy capacity by 2020, we multiplied the annual impact by five to account for each full year between 2015 and 2020.

In order to estimate the impact of the PTC on carbon emissions, we needed to convert figures for wind power capacity (MW) into wind energy generation (MWh). To do this, we applied the 2014 average national capacity factor for wind-generated electricity of 33.9 percent, obtained from the EIA's Electric Power Monthly, *Table 6.7.B. Capacity Factors for Utility Scale Generators Not Primarily Using Fossil Fuels, January 2013-July 2015, available at* www.eia.gov/electricity/monthly.

There are a few reasons why we expect the use of this single capacity factor to result in a lower estimate of averted carbon pollution than the use of several state- and year-specific multipliers. First, because offshore wind is estimated to amount to only 3 percent of total added wind energy capacity, we applied land-based capacity factors to our conversions of PTC impacts. This may reduce estimated carbon emission reductions by a small amount because offshore capacity factors are generally higher than land-based ones. For example, the Block Island Wind Farm expects a net capacity factor of 47.5 percent, comparable to net capacity factors at the best European offshore project locations.[52]

Second, our application of a 2014 capacity factor to wind power additions from 2016-2020 may underestimate the amount of wind energy generated because capacity factors typically rise with time as technology improves. The amount of power generated by a particular wind turbine also depends on its design, its location and the properties of the wind resource. Newly installed wind turbines are taller with larger rotors, which can enable them to take advantage of stronger winds at higher altitudes.[53] Some analysts suggest that capacity factors for new wind turbines could nearly double, reaching 60 percent in strong resource locations in the near future.[54]

Wind power additions under the PTC scenario were allocated to states based on relative wind energy growth rates in the U.S. Department of Energy's March 2015 report, *Wind Vision: A New Era for Wind Power in the United States*, available at en.openei.org/apps/wv_viewer/.[55]

The Wind Vision Study Scenario dataset provided a breakdown of national wind capacity and generation projections by state. For each state, we calculated the number of MWh "added" to the U.S. electric grid between 2016 and 2020 as the difference between the total state wind energy generation (MWh) in years 2015 and 2020. To estimate of each state's proportional contribution to the total U.S. wind generation added from 2015 to 2020, we divided the number of MWh added for each state by the total number of MWh added by all states (See Appendix B). To estimate each state's proportional contribution to added wind power capacity resulting from PTC extension, we multiplied these proportions by the estimated PTC impact (MW), the difference between the two PTC scenarios.

To compute the amount of carbon pollution averted in 2020 as the result of PTC renewal, we applied state-specific emissions factors for the year 2020, derived using the methods described above. We multiplied these emissions factors by the amount of wind energy generated (MWh) by each state in the year 2020.

U.S. Offshore Wind Potential

Data on prospective offshore wind development comes from the National Renewable Energy Laboratory (NREL)'s September 2015 report, *2014–2015 Offshore Wind Technologies Market Report*.[56] Data files from this report are available at www.nrel.gov/docs/fy15osti/64283_data_tables.xlsx. To estimate U.S. offshore wind capacity added by 2020, we added the owner-announced capacity figures listed for projects for which the BOEM has issued leases in "Table 3. Summary of Awarded Commercial Offshore Leases and Wind Energy Areas." We counted only projects with scheduled commercial operations in 2020 or earlier, as indicated in "Appendix C. U.S. Offshore Wind Projects: Planning with Site Control," with the single exception a recently-leased offshore wind area in New Jersey. For the planned New Jersey site, we divided the estimated potential capacity of 3,400 MW given by the BOEM in half based on the experience of similar projects that have reached more advanced planning stages, because actual capacity is often significantly lower than initial estimates given at the time of leasing.

Our intention was to arrive at the most accurate possible projection of U.S. offshore wind capacity developed by 2020. For this reason, we chose to exclude from our calculations any offshore projects that have yet to receive development leases from the BOEM or projects that, for varying reasons, appear uncertain to be completed by the end of the decade. In total, we estimate that 3,600 MW of offshore wind capacity in the U.S. development pipeline will be operational by 2020.

To compute the amount of carbon dioxide that completing these projects could avert in the year 2020, we first converted wind energy capacity figures (MW) into wind energy generation (MWh). For this conversion, we used a capacity factor of 0.43, the average listed for European offshore wind facilities with commercial operation dates between 2011 and 2017, as given in "Figure 22. Net capacity factor for selected European offshore wind projects (by country)" of the same report. We recognize that figure may result in an underestimate of wind energy generation for 2020, should advances in technology and more experience with offshore wind development significantly improve wind energy efficiency over the next five years.

To estimate the amount of carbon dioxide that could be averted by the offshore wind energy projects in 2020, assuming projects have begun commercial operations by then, we applied 2020 regional emissions factors (metric tons per MWh) using the same methodology described in the previous section. While the timeline and successful completion of individual offshore wind energy projects in the development pipeline is not possible to predict with full certainty, we are confident that with continued policy support, the U.S. offshore wind energy can make great strides by the end of the decade.

Appendix A: U.S. Wind Power by State

State	Wind Capacity as of October 2015 (Megawatts)	Wind Generation 2001-2014 (Thousand Megawatt Hours)	Averted Carbon Dioxide Emissions 2001-2014 (Million Metric Tons)
Alaska	62	372	n/a
Alabama	-	-	-
Arkansas	-	-	-
Arizona	268	1,875	1
California	6,022	91,634	72
Colorado	2,593	39,011	30
Connecticut	-	-	-
Delaware	2	3	0.003
Florida		-	-
Georgia	-	-	-
Hawaii	203	2,897	n/a
Iowa	5,710	87,425	88
Idaho	972	9,738	7
Illinois	3,842	44,410	38
Indiana	1,745	18,040	16
Kansas	3,167	41,021	35
Kentucky	-	-	-
Louisiana	-	-	-
Massachusetts	107	544	0.3
Maryland	160	1,240	1
Maine	465	4,766	2
Michigan	1,531	9,076	8
Minnesota	3,035	55,610	56
Missouri	459	6,348	5
Mississippi	-	-	-

State	Wind Capacity as of October 2015 (Megawatts)	Wind Generation 2001-2014 (Thousand Megawatt Hours)	Averted Carbon Dioxide Emissions 2001-2014 (Million Metric Tons)
Montana	665	9,523	8
North Carolina	-	-	-
North Dakota	1,886	32,649	33
Nebraska	810	8,553	9
New Hampshire	171	1,229	1
New Jersey	9	137	0.1
New Mexico	812	17,933	15
Nevada	152	680	0.5
New York	1,749	21,283	11
Ohio	435	3,489	3
Oklahoma	4,330	50,689	43
Oregon	3,153	40,561	32
Pennsylvania	1,340	16,119	14
Rhode Island	9	10	0.01
South Carolina	-	-	-
South Dakota	882	13,792	14
Tennessee	29	460	0.4
Texas	16,406	229,955	146
Utah	327	3,114	2
Virginia	-	-	-
Vermont	119	795	0.4
Washington	3,075	44,836	35
Wisconsin	648	9,162	9
West Virginia	583	8,136	7
Wyoming	1,410	28,297	22
Total	**69,343**	**955,412**	**764**

Appendix B: Projected Impact of Production Tax Credit on Wind Energy in 2020

State	Added Wind Capacity in 2020 (Lower Bound) (Megawatts)	Added Wind Capacity in 2020 (Upper Bound) (Megawatts)	Additional Carbon Dioxide Averted 2016-2020 (Lower Bound) (Metric Tons)	Additional Carbon Dioxide Averted 2016-2020 (Upper Bound) (Metric Tons)
Alaska	-	-	-	-
Alabama	0.01	0.07	31	157
Arkansas	-	-	-	-
Arizona	6	28	11,756	58,779
California	548	2,742	1,140,938	5,704,691
Colorado	38	192	54,699	273,496
Connecticut	71	354	172,049	860,247
Delaware	-	-	-	-
Florida	-	-	-	-
Georgia	-	-	-	-
Hawaii	-	-	-	-
Iowa	133	663	363,058	1,815,288
Idaho	23	114	46,574	232,869
Illinois	110	552	257,017	1,285,086
Indiana	229	1,144	546,566	2,732,829
Kansas	100	501	233,478	1,167,392
Kentucky	-	-	-	-
Louisiana	-	-	-	-
Massachusetts	133	663	185,671	928,357
Maryland	105	525	254,535	1,272,677
Maine	98	491	139,642	698,211

State	Added Wind Capacity in 2020 (Lower Bound) (Megawatts)	Added Wind Capacity in 2020 (Upper Bound) (Megawatts)	Additional Carbon Dioxide Averted 2016-2020 (Lower Bound) (Metric Tons)	Additional Carbon Dioxide Averted 2016-2020 (Upper Bound) (Metric Tons)
Michigan	3	17	8,026	40,131
Minnesota	50	250	136,759	683,794
Missouri	184	921	423,505	2,117,523
Mississippi	-	-	-	-
Montana	745	3,726	1,595,263	7,976,314
North Carolina	91	456	209,714	1,048,571
North Dakota	115	577	318,927	1,594,637
Nebraska	72	360	194,981	974,904
New Hampshire	62	308	86,618	433,092
New Jersey	391	1,953	935,515	4,677,574
New Mexico	327	1,634	709,779	3,548,895
Nevada	13	65	27,312	136,559
New York	-	-	-	-
Ohio	457	2,287	1,099,166	5,495,830
Oklahoma	177	885	413,582	2,067,911
Oregon	144	721	303,599	1,517,997
Pennsylvania	610	3,048	1,469,955	7,349,774
Rhode Island	-	-	-	-
South Carolina	-	-	-	-
South Dakota	146	729	387,354	1,936,768
Tennessee	0.02	0.08	39	194
Texas	3,180	15,900	5,631,703	28,158,517
Utah	20	101	41,850	209,250
Virginia	23	117	54,829	274,146
Vermont	41	205	57,590	287,951
Washington	107	535	224,472	1,122,362
Wisconsin	177	886	461,790	2,308,951
West Virginia	5	26	12,399	61,996
Wyoming	1,265	6,324	2,634,529	13,172,647
Total	**10,000**	**50,000**	**20,845,273**	**104,226,365**

Notes

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