More Wind, Less Warming

How American Wind Energy's Rapid Growth Can Help Solve Global Warming

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Executive Summary

Wind power is on the rise across America. The United States generates 24 times more electricity from wind power than we did in 2001, providing clean, fossil fuel-free energy that helps the nation do its part in the fight against global warming.

American wind power is already significantly reducing global warming pollution. In 2013 alone, wind power averted 132 million metric tons of carbon dioxide emissions – as much as would be produced by 34 typical coal-fired power plants. But with the United States and the world needing to move toward a future of 100 percent clean energy in order to prevent the worst impacts of global warming, America must do much more.

If America were to take advantage of just a fraction of its wind energy potential to get 30 percent of its electricity from the wind by 2030, the nation could cut carbon emissions from power plants to 40 percent below 2005 levels. That much wind power would help states meet and exceed the carbon dioxide emission reductions called for by the Environmental Protection Agency's draft Clean Power Plan, and help the nation meet its commitment to cut U.S. carbon pollution by 26 to 28 percent by 2025.

Power plants are the biggest source of carbon dioxide emissions in the United States. By implementing policies that increase the production of wind energy, both on- and offshore, America can help put the nation – and the world – on a course to prevent the worst impacts of global warming.

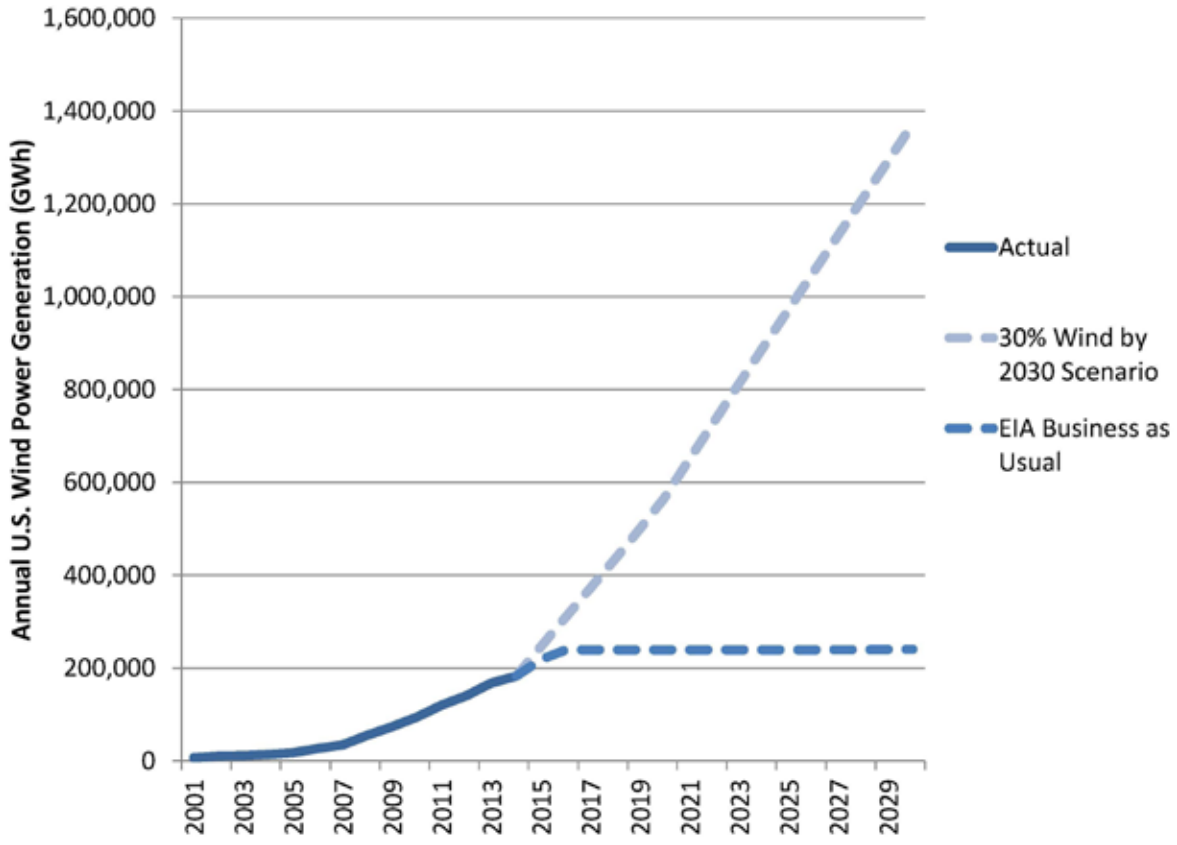
Wind power has already significantly reduced carbon pollution.

- In 2013, wind power displaced more than 132 million metric tons of carbon dioxide.
- Since 2001, wind power has displaced more than 620 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 now accounts for 4 percent of total U.S. electricity generation.
- Nine states – Iowa, South Dakota, Kansas, Idaho, Minnesota, North Dakota, Oklahoma, Colorado, and Oregon – now generate more than 12 percent of their total electricity production with wind power.
- Wind power capacity in Iowa and South Dakota now supplies more than a quarter of all in-state electricity generation.

By aggressively expanding wind energy, America can displace even more carbon pollution – putting the nation and the world on track to addressing global warming.

- America has enough wind energy potential to power the nation more than 10 times over.
- America will need to tap its ample offshore wind energy potential in order to hit a goal of 30 percent wind generation by 2030. Offshore wind energy is a proven technology that has provided Europe with clean energy for a decade, with 69

Figure ES-1. A Path to 30 Percent Wind Electricity



offshore wind farms now operational there. The first two U.S. offshore wind projects are on track for construction in 2015 and areas have been designated for offshore wind development off the U.S. coast capable of producing enough electricity for 6.4 million homes.

- If the nation were to set a course for obtaining 30 percent of its electricity from wind power by 2030, America could avert nearly 705 million metric tons of carbon dioxide per year by 2025 and 968 million metric tons per year by 2030. That's the equivalent of:
  - Eliminating emissions from 185 of today's typical coal-fired power plants in 2025 and from 254 coal plants in 2030.
  - 10 percent of America's 2005 emissions of global warming pollution in 2025 and 13 percent of those emissions in 2030.
  - 2.5 percent of the world's 2005 emissions of carbon dioxide by 2025 and 3.5 percent of those emissions by 2030.
  - Reducing U.S. power plant emissions to 40 percent below 2005 levels. The EPA Clean Power Plan calls for reductions in power plant emissions of 30 percent below 2005 levels by 2030.
- Rapid expansion of wind energy is feasible and affordable. The cost of wind energy is now at or below the cost of new natural gas power plants in regions with the best resources and more than a dozen reports by utilities, independent grid

Figure ES-2. Carbon Dioxide Emissions Reductions in 2030 Under 30 Percent by 2030 Wind Energy Scenario and EPA Clean Power Plan (Compared with EIA Business as Usual Case)

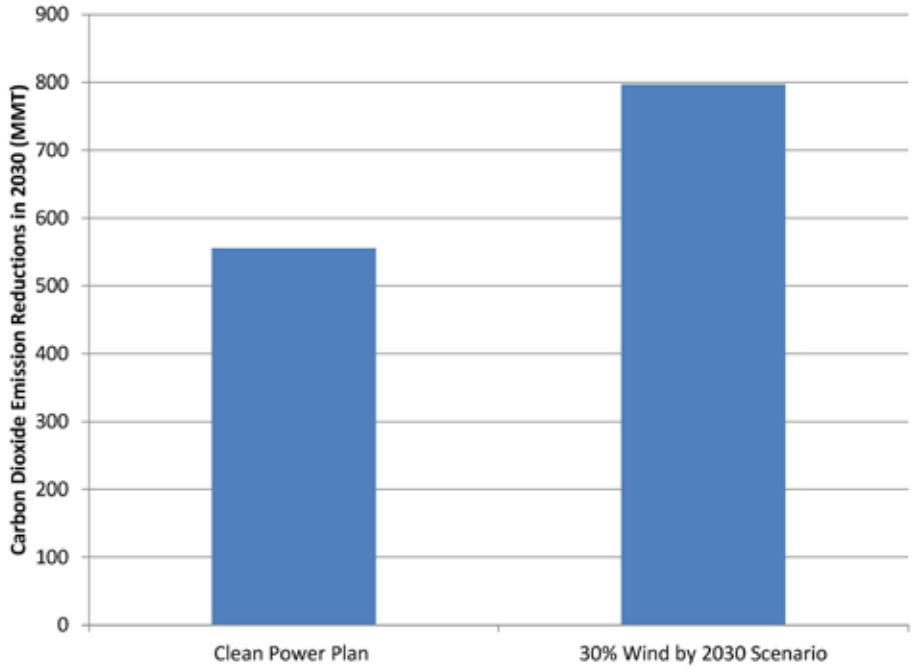
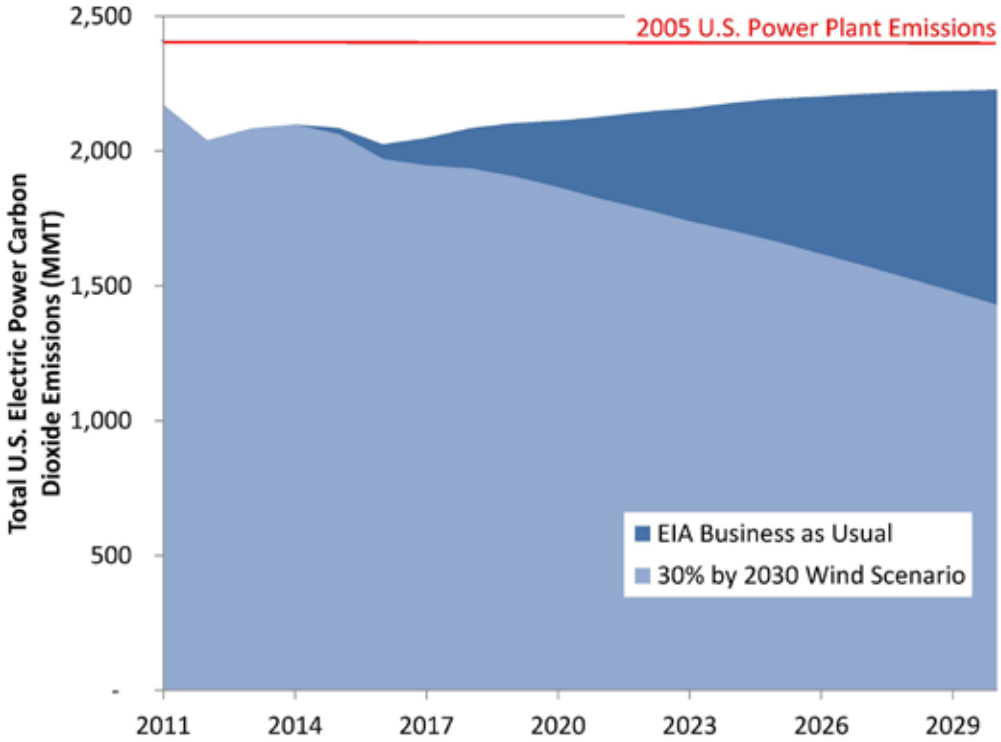


Figure ES-3. A Future of 30 Percent Wind Power Would Dramatically Reduce Power Plant Carbon Dioxide Pollution



operators, the U.S. Department of Energy, and other experts have found that the electric grid can accommodate much more wind energy than we currently generate.

- Offshore wind energy is also poised to make a major contribution to America's energy portfolio. The U.S. Department of Energy found that "under conservative assumptions about transmission, fossil fuel supply, and supply chain availability, the United States could feasibly build 54 GW of offshore wind power by 2030." If reached, this level of offshore wind would avert 125 million tons of carbon dioxide emissions in 2030 and provide 14 percent of the wind energy needed to achieve a 30 percent by 2030 target.

Federal and state governments should use the tools available to them to expand wind energy – both on land and offshore – and ensure that large amounts of wind energy can be integrated into the grid.

- The federal government should strengthen and adopt the Clean Power Plan, the Environmental Protection Agency's proposed plan to reduce U.S. global warming pollution from the power sector to 30 percent below 2005 levels by 2030. Wind energy should play a significant role in states' plans to meet the requirements of the Clean Power Plan.
- State and federal governments should set ambitious goals for expansion of wind energy, along the lines of the 30 percent target evaluated in this report, 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 help states expand wind by renewing and extending the Production Tax Credit (PTC), which helped drive the explosion of wind growth over the last ten years, and the Investment Tax Credit (ITC), which is vital to the successful launch of the offshore wind industry.

Introduction

The United States is already feeling the impacts of global warming. Average temperatures are increasing every decade.[1] With warmer average temperatures have come more extreme weather events, such as heavy rainstorms and more intense heat waves.[2] Sea levels are rising – eight inches along some parts of the U.S. coastline in the past 50 years.[3] Science tells us that these and other impacts will become more pronounced in the decades to come, unless we reduce the carbon pollution that is warming the planet.

America and the world must reduce emissions of climate pollution dramatically in the years to come if the world is to avoid the worst impacts of global warming, with the United States and other developed countries needing to curb emissions by 80 percent or more by 2050.

President Obama's recent commitment – made in agreement with China – to reduce U.S. carbon pollution by 26 to 28 percent by 2025 represents an important and positive step. To get there, however, and to deliver the sustained reductions in carbon pollution that are needed to safeguard the climate, America must replace our current fossil fuel-fired power plants with clean, renewable energy sources such as wind power.

Wind power is emission-free, abundant, proven and increasingly inexpensive. In just the last decade, wind energy has become one of the nation's fastest growing forms of electricity generation, and an increasingly important part of the nation's energy mix.

Wind power's recent dramatic expansion is already averting significant amounts of carbon dioxide pollution, making a significant contribution in the fight against global warming. This report examines the major role that wind energy can play in the nation's efforts to prevent the worst impacts of global warming, especially if the expansion of wind energy continues on a path to provide 30 percent of the nation's electricity by 2030.

As the federal and state governments begin to take more concrete action to prevent the worst effects of global warming, they should set aggressive goals to ensure that wind power is a significant part of our long-term energy future.

Wind Power Is on the Rise Across America

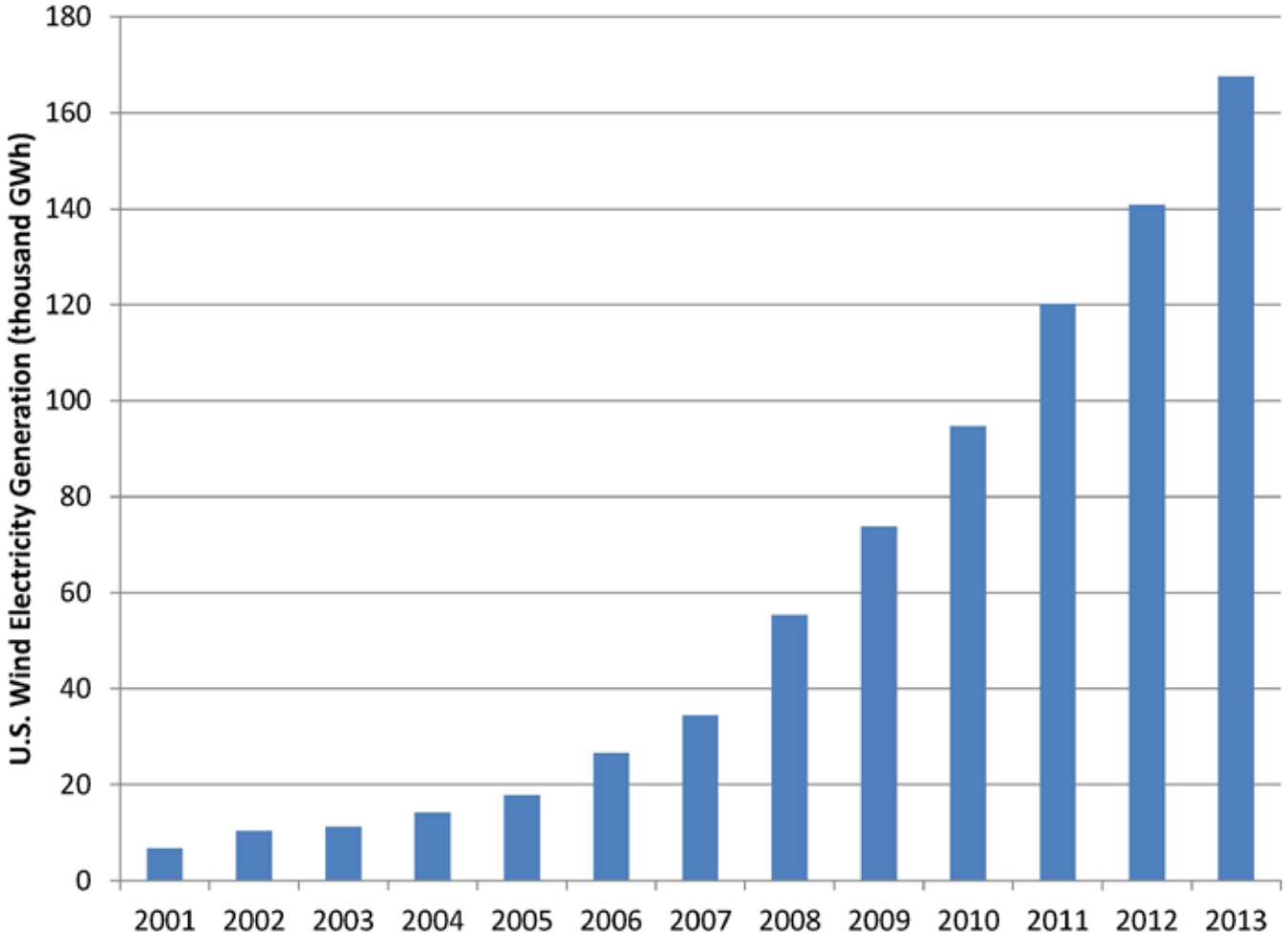
Over the last decade, America saw dramatic growth in wind energy. America generated 24 times as much electricity from wind power in 2013 as it did in 2001, with wind energy generation growing from 7 million megawatt-hours to 168 million megawatt-hours.[4] Today, wind power generates more than 4 percent of all electricity in the United States.[5]

The growth of American wind power was no accident. Improvements in technology, along with government policy, were the primary drivers of wind energy growth. State governments helped lead the way by adopting renewable electricity standards (RES) that required utilities to meet a certain share of electricity demand with renewable energy, including wind energy. At the federal level, tax policies, including the renewable energy production tax credit, reduced the risk of wind energy investments and spurred investments across the country.

The growth in the wind energy industry and the development of economies of scale has helped to drive down wind prices, with the levelized cost of energy from new wind power plants falling by 58 percent since 2009. Today, new wind power plants in areas with good resources produce electricity at or below the cost of new natural gas-fired power plants.[7] When accounting for the costs of climate change, the price of wind is even more competitive.[8]

The growth of American wind power was no accident. Improvements in technology, along with government policy, were the primary drivers of wind energy growth.

Figure 1. Wind Power's Growth in the United States Since 2001[6]



Wind energy growth has been especially pronounced in a handful of states. Texas generates more wind energy than any other state, producing 36 million MWh in 2013. Nine states – Iowa, South Dakota, Kansas, Idaho, Minnesota, North Dakota, Oklahoma, Colorado, and Oregon – now generate more than 12 percent of their total electricity production with wind power, while wind power capacity in Iowa and South Dakota now supplies more than a quarter of all in-state electricity generation.[9]

While untapped today, offshore wind holds enormous potential for powering the United States, especially along the densely populated Atlantic Coast. Areas have been designated for offshore wind development off the U.S. coast capable of producing enough electricity for 6.4 million homes.[56] Offshore farms promising a total of nearly 5 GW of capacity are already in advanced planning stages, with construction imminent in some cases.[10] And the U.S. Department of Energy (DOE) says that "under conservative assumptions about transmission, fossil fuel supply, and supply chain availability, the United States could feasibly build 54 GW of offshore wind power by 2030."[11]

Wind Power Is Reducing Global Warming Pollution Today

Over the last decade, the dramatic growth in American wind energy has displaced hundreds of millions of tons of power plant carbon pollution, making a significant contribution in the fight against global warming.

Fossil Fuel Power Plants Release Massive Amounts of Carbon Pollution

Power plants that burn coal, oil, and natural gas release enormous amounts of global warming pollution in the form of carbon dioxide. Fossil fuel electricity generation is the biggest creator of global warming pollution in the United States, emitting more carbon dioxide than the industrial, commercial, and residential sectors combined. [13]

In 2013 alone, these power plants released more than 2 billion metric tons of carbon dioxide.[14] In fact, if U.S. power plants were an independent nation, they would be the third-largest emitter of carbon dioxide pollution in the world, behind China and the United States as a whole.

Figure 2. U.S. Power Plant CO_2 Emissions Compared To Total Emissions from Other Countries[12]

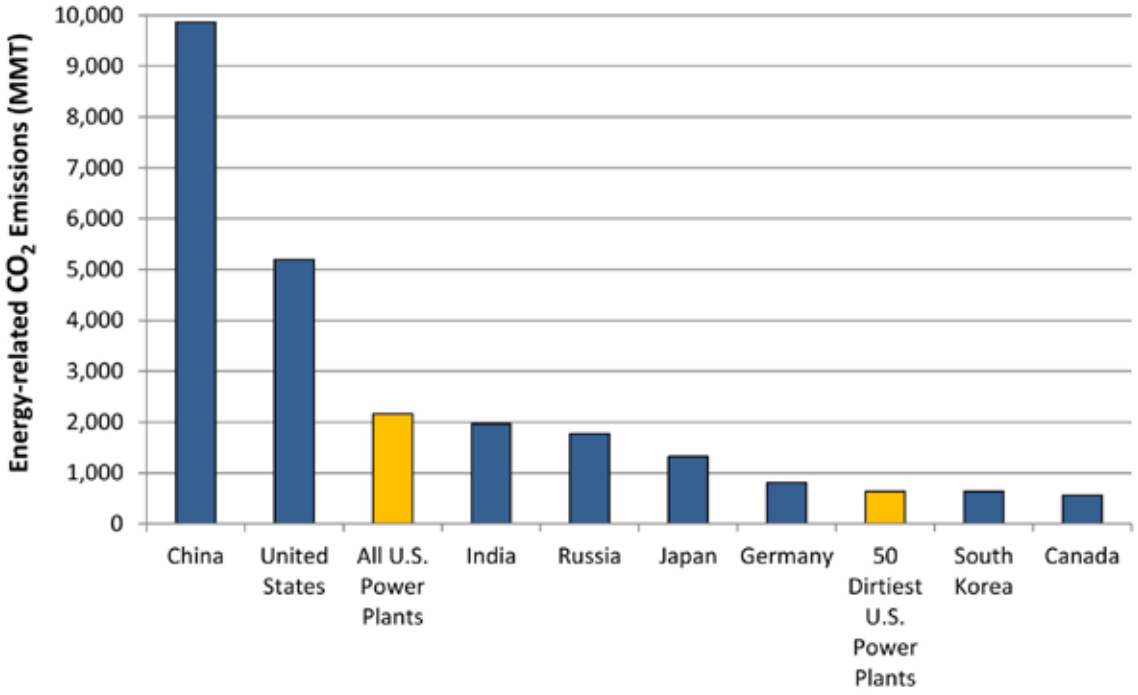
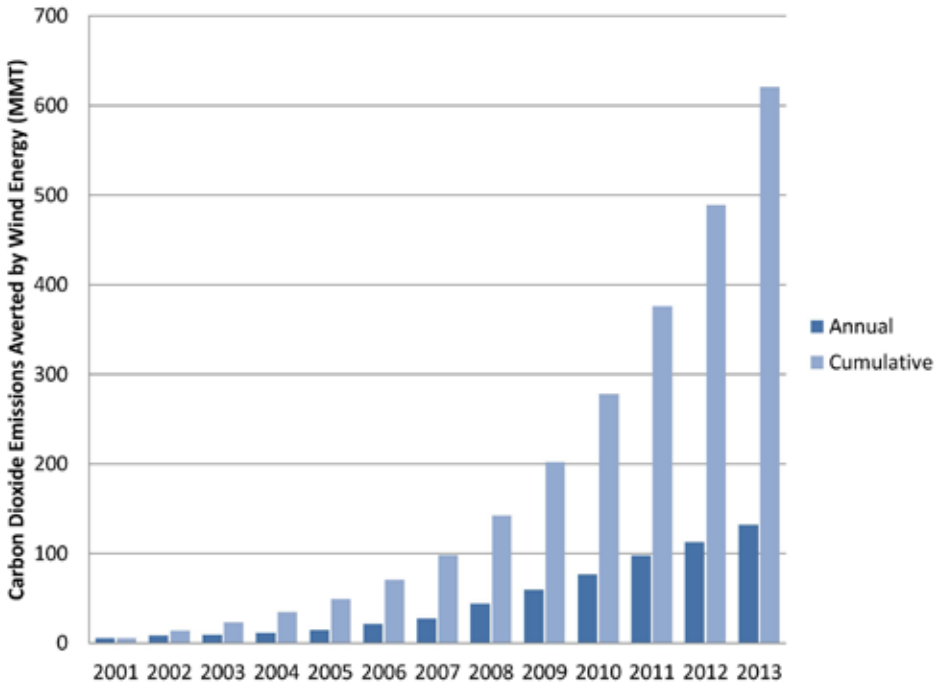


Figure 3. Carbon Dioxide Emission Reductions from Wind Power Since 2001



Rapid Wind Energy Growth Has Led to Big Emission Reductions

In contrast to fossil fuel power plants, wind turbines produce no carbon dioxide. Over their entire life-cycle, including the production of materials for wind turbines and construction of wind farms, wind power's greenhouse gas emissions are tiny, with wind turbines responsible for 98 percent fewer greenhouse gas emissions per unit of electricity than modern natural gas combined-cycle power plants.[15]

The recent rapid growth in wind energy has resulted in growing savings of carbon pollution. In 2013, wind power averted nearly 132 million tons of carbon dioxide emissions from fossil fuel-fired power plants – an increase from just 6 million tons in 2001. Since 2001, wind power has displaced more than 620 million metric tons of carbon pollution – more than the annual carbon dioxide emissions of the entire country of Canada.[16]

Texas, Iowa, and California are leading the way when it comes to wind power's displacement of carbon pollution. In 2013, Texas wind energy displaced 23 million metric tons of carbon dioxide, while in Iowa wind energy displaced nearly 16 million metric tons. In California, wind energy displaced nearly 10 million metric tons. The 48 million metric tons of carbon dioxide averted by these three states is more than the total yearly carbon dioxide emissions of the state of Connecticut.[17]

Table 1. Carbon Dioxide Pollution Displaced by Wind Power in the Top 10 States

State	MMT	Equivalent In Millions of Vehicles	Equivalent In Typical U.S. Coal Plants
Texas	23.0	4.8	6
Iowa	15.9	3.4	4
California	9.4	2.0	2
Oklahoma	9.3	2.0	2
Minnesota	8.3	1.7	2
Kansas	8.0	1.7	2
Illinois	8.0	1.7	2
North Dakota	5.7	1.2	2
Oregon	5.3	1.1	1
Colorado	5.2	1.1	1

Ambitious Growth in Wind Energy Would Dramatically Reduce Carbon Dioxide Pollution

The United States and the world must reduce carbon dioxide emissions dramatically, starting now, if we are to avoid the worst impacts of global warming. Wind energy can play a central role in achieving those emission reductions.

America Can Get 30 Percent of its Electricity from the Wind by 2030

America's potential for wind energy is virtually endless. The National Renewable Energy Laboratory (NREL) found that America has the technical potential to generate 32.7 billion MWh per year of electricity from onshore wind turbines, and 17 billion MWh of electricity from offshore wind.[18] That adds up to 49.7 billion MWh of potential wind energy – enough to power the entire United States more than ten times over.[19]

The nation also has the capability to incorporate much larger amounts of wind energy into the grid without disruption. DOE studies have analyzed the grid integration impact of accommodating high percentage wind scenarios. A study of integrating as much as 30 percent wind power in the eastern United States found that expanding wind to that level is "technically feasible with significant expansion of the transmission infrastructure."[20] A separate study found no technical barriers to integrating 35 percent wind and solar energy in most of the western U.S.[21] More than a dozen studies by government agencies, utilities and grid operators have found that large amounts of wind energy could be integrated into the electric grid while preserving reliability.[22]

A 2014 DOE study investigated the potential of the United States to receive 20 percent of its electricity from wind energy by 2030 and 35 percent by 2050. The analysis concluded that the scenario would reduce electric system spending – even when the benefits of reduced greenhouse gas emissions, emissions of other air pollutants and water savings are not taken into account.[23]

Expanding wind energy production to supply 30 percent of America's electricity by 2030 would be ambitious. Meeting that goal would require significant investment and effort. But America's vast wind energy potential, the electric grid's capacity to incorporate increased amounts of wind energy, the declining cost of wind electricity, and the growing need to take action against global warming all point to the aggressive expansion of wind energy as a necessary and achievable step for the United States.

Figure 4. A Path to 30 Percent Wind Energy

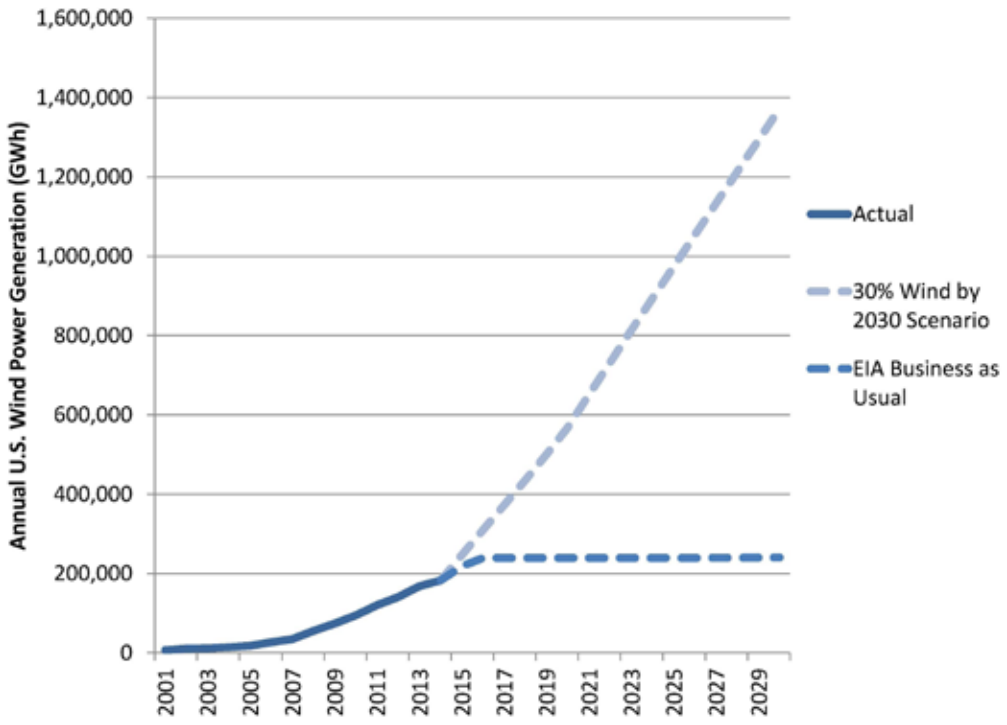
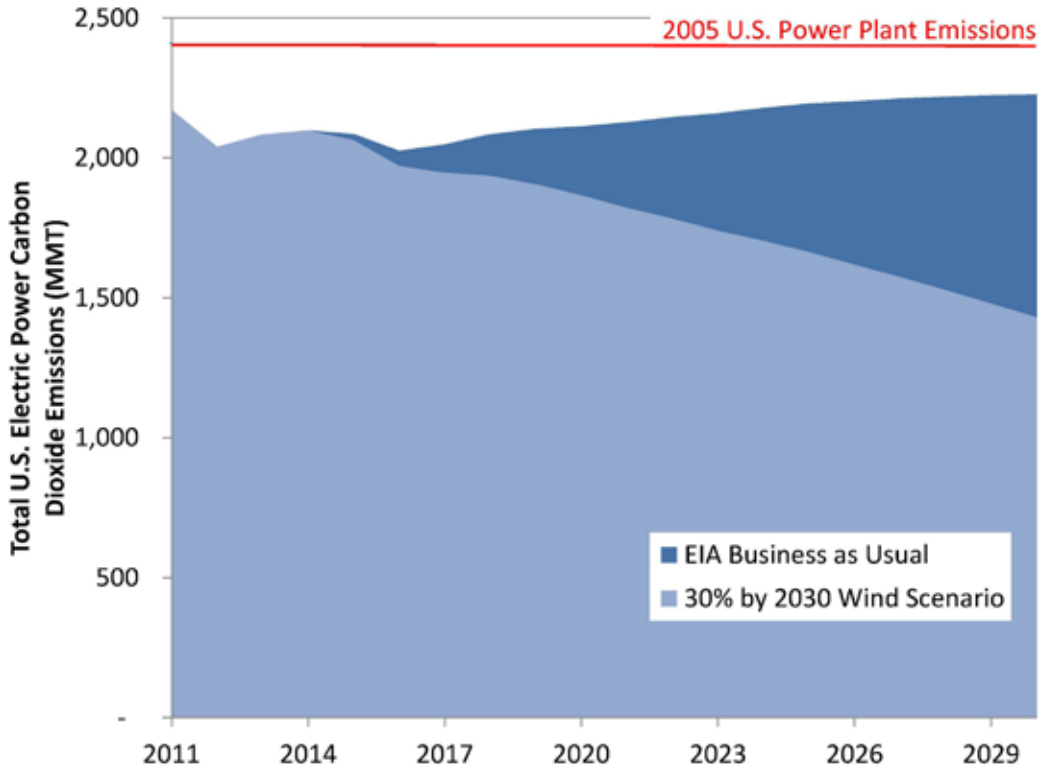


Figure 5. 30 Percent Wind Electricity Would Dramatically Reduce Power Plant CO_2 Pollution



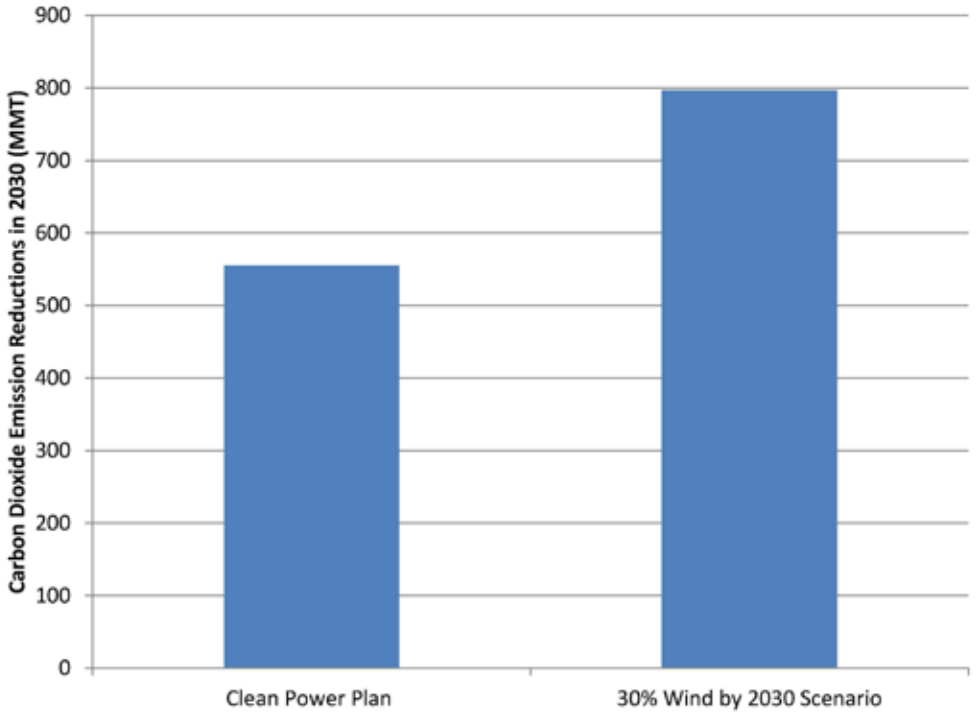
Wind Energy Can Cut Power Plant Pollution to 40 Percent below 2005 Levels by 2030

Assuming that wind energy generation grows over time to meet 30 percent of the nation's electricity needs by 2030, that a significant and rising amount of that energy comes from offshore wind energy, that onshore wind energy is distributed across the United States in a manner similar to wind energy built to date, and that wind energy displaces fossil fuel-generated power (see Methodology), America can achieve significant reductions in global warming pollution.

If America were to set a course for generating 30 percent of its electricity in 2030 using wind power, the nation would avert 705 million metric tons of carbon dioxide in 2025 and 968 million metric tons of carbon dioxide pollution in 2030. That's equivalent to:

- 24 percent of forecast U.S. power plant carbon dioxide emissions in 2025 and 36 percent of forecast power plant emissions in 2030.[24]
- The annual carbon dioxide emissions from 185 typical coal-fired power plants in 2025 and from 254 coal plants in 2030.[25]
- Emissions from nearly 150 million of today's vehicles by 2025 and more than 200 million of today's vehicles by 2030.[26]
- 10 percent of America's 2005 emissions of global warming pollution by 2025 and 13 percent of those emissions by 2030.[27]
- 2.5 percent of 2005 global carbon dioxide emissions in 2025, and 3.5 percent of those emissions in 2030.[28]

Figure 6. Carbon Dioxide Emission Reductions in 2030 Under 30 Percent by 2030 Wind Energy Scenario and EPA Clean Power Plan (Compared with EIA Business as Usual Case)



Achievement of 30 percent wind energy by 2030 would result in carbon dioxide emissions from electricity generation 40 percent lower than in 2005. The EPA's proposed Clean Power Plan calls for reductions in power plant pollution of 30 percent relative to 2005 levels by 2030. Rapid development of wind energy, therefore, can help enable many states to achieve the emission reduction goals of the EPA's Clean Power Plan while taking a strong step to prevent the worst impacts of global warming.[29]

The potential of wind energy to drive significant reductions in emissions has been validated by other studies. Studies of wind integration in the eastern and western U.S. have found that aggressive wind energy scenarios would result in carbon dioxide emission reductions of similar levels. In the West, the National Renewable Energy Laboratory (NREL) found that integration of up to 33 percent wind and solar energy would lead to CO_2 emissions reductions of 29 to 33 percent.[30] In the East, a similar analysis found that integration of 30 percent wind energy would reduce CO_2 emissions by 37 percent.[31]

Assuming wind generation increases at a linear rate between now and 2030, the cumulative amount of carbon dioxide displaced through 2030 would be more than 9 billion metric tons. That's greater than:

- The total amount of energy-related carbon dioxide emitted by China in 2012.[32]
- More than one-quarter of global CO_2 emissions in 2012.[33]

Setting a course for 30 percent wind energy would deliver carbon dioxide emission reductions that are significant on a global scale, enabling the United States to make a significant contribution toward meeting the challenge of global warming.

The Role of Offshore Wind

America's offshore wind technical potential is 17 billion MWh, enough to power the entire country more than four times over.[34] States with offshore wind potential are either coastal – the Atlantic, Pacific and Gulf Coast states, and Hawaii – or on the Great Lakes. Offshore wind energy is particularly appealing because of the close proximity of offshore wind resources to major coastal cities, which are large sources of electricity demand. NREL says that "offshore wind resources have the potential to be a significant domestic renewable energy source for coastal electricity loads."[35]

Offshore wind energy is also a proven technology: Over the last decade, offshore wind power has been booming in Europe, with 69 offshore farms providing more than 6 GW of capacity.[36]

The DOE found that "under conservative assumptions about transmission, fossil fuel supply, and supply chain availability, the United States could feasibly build 54 GW of offshore wind power by 2030."[37]

Although legal delays and other obstacles have held up American offshore wind power, offshore wind is poised to begin supplying electricity within the next several years.[38] A 2014 analysis of offshore wind projects prepared for the DOE found that, in total, 14 offshore projects are in the "advanced" stage of development, "defined as having either been awarded a lease, conducted baseline or geophysical studies, or obtained a power purchase agreement (PPA)."[39] The Cape Wind project, which will consist of 130 wind turbines off the coast of Massachusetts, as well as the 30 MW Block Island Wind Project off the coast of Rhode Island, are both expected to begin construction in 2015 and produce power in 2016.[40] Other planned large-scale offshore wind farms, off the coasts of states including Rhode Island, Maryland, Virginia, Delaware, and New Jersey, are expected to come on line by the end of the decade.[41]

Our 30 percent scenario assumes offshore wind energy growth in line with the assumptions of the DOE's 2014 *National Offshore Wind Energy Grid Interconnection Study*, which assumed the development of 54 GW of offshore wind energy capacity along the coasts of 28 states by 2030.[42]

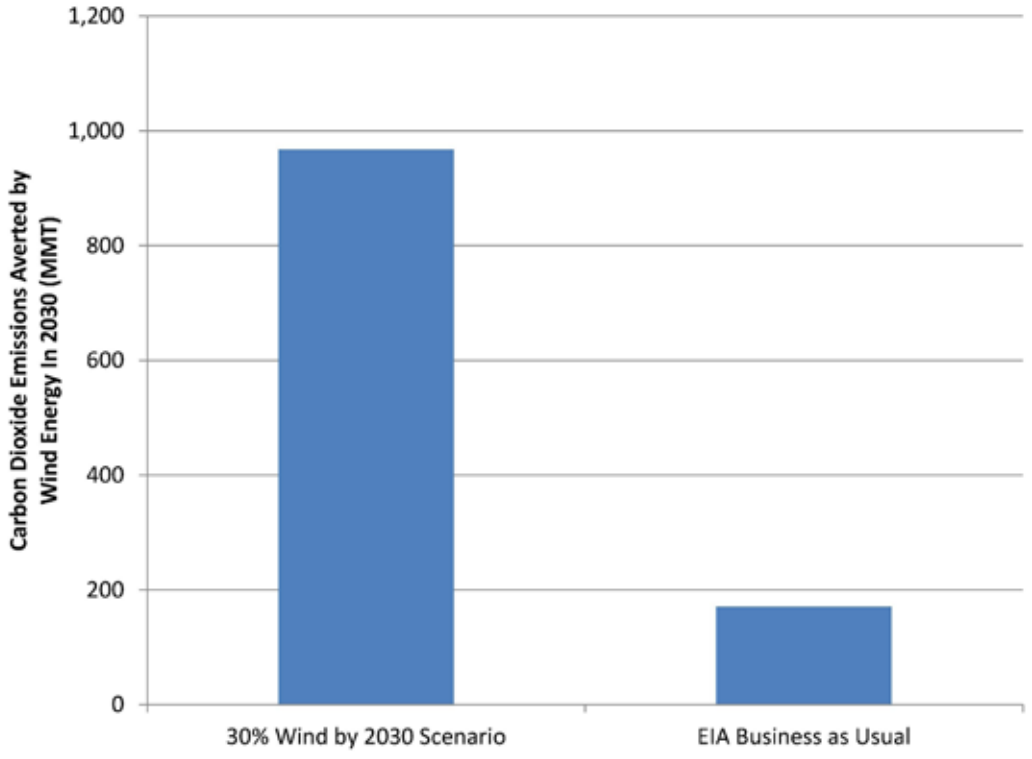
That level of offshore capacity would generate nearly 187 million MWh of electricity – 14 percent of the amount of wind energy generated in 2030 in our 30 percent wind scenario. It would displace approximately 125 million metric tons of carbon dioxide in 2030, equivalent with taking nearly 4 million vehicles off the road for a year.

Getting 30 Percent of America's Electricity from the Wind Will Require Policy Action

America is unlikely to achieve a 30 percent wind energy goal without strong policy action. Much of the nation's recent growth in wind energy has been driven by policies such as state renewable electricity standards. Continuing and expanding those policies will be necessary to keep wind energy growing quickly.

The Energy Information Administration (EIA), for example, forecasts that wind energy will increase through the end of 2016, but experience almost no growth through the end of 2030. Under the EIA scenario, wind energy will generate 224 million MWh of energy by 2030, and displace barely 158 million tons of carbon dioxide (compared with fossil fuel-generated power) annually.[43] Failing to expand wind energy beyond those levels would represent an enormous missed opportunity, with barely a third more carbon displaced in 2030 than today.

Figure 7. Current Policies Represent a Missed Opportunity for Reducing Carbon Dioxide Pollution



Policy Recommendations

State and federal governments should move aggressively to expand America's production of clean, renewable wind energy. Specifically:

The federal government should strengthen and adopt the EPA's Clean Power Plan. States should maximize the role of renewable energy sources such as wind energy in compliance with the Clean Power Plan.

On June 2, the EPA released its proposal for the Clean Power Plan. If adopted, the plan will be the biggest step ever taken by the U.S. to limit global warming pollution.

The plan is designed to "cut carbon emissions from the power sector by 30 percent nationwide below 2005 levels, which is equal to the emissions from powering more than half the homes in the United States for one year."[44] The EPA estimates that the plan should "shrink electricity bills roughly 8 percent by increasing energy efficiency and reducing demand in the electricity system."[45]

The plan sets state-by-state targets for the carbon intensity of electric power plants in each state and empowers the states to choose their compliance path; using tools ranging from increased use of renewable energy, to improved energy efficiency and expanded use of energy-saving tools such as combined heat and power, to expansion of natural gas or nuclear power.

The EPA can strengthen the targets of the Clean Power Plan by recognizing the full potential for renewable energy to avert carbon dioxide emissions from power generation, and by ensuring that the recent rapid growth in renewable energy is reflected in program assumptions.[46] States, meanwhile, should design plans for complying with the Clean Power Plan that maximize the use of clean sources of energy such as wind power, other forms of renewable energy, and energy efficiency.

State and federal governments should set ambitious goals for expansion of wind energy and adopt renewable electricity standards consistent with those goals.

An ambitious goal for wind energy generation can provide a rallying point for states, helping to drive the identification and adoption of key policies that remove roadblocks to wind power. One of the most effective policies for spurring wind energy is the renewable electricity standard (RES).

A RES helps 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, 30 states have renewable electricity standards.[47] From 1999 through 2012, 69 percent of all new wind capacity was built in states with renewable electricity standards.[48] In 2012, the proportion was 83 percent.[49]

State and federal agencies should coordinate to expedite the responsible development of offshore wind facilities, ensuring strong environmental protections throughout the development process.

Some of America's best wind energy resources are offshore. To capture the potential for offshore wind energy, policymakers need to set bold goals for offshore wind development and adopt policies to make those goals a reality. Federal officials should ensure that the Department of the Interior and the Bureau of Ocean Energy Management have sufficient staff and resources to manage multiple renewable energy leases along the coast and to promote an environmentally responsible, efficient leasing process. Federal and state governments should help to create a strong market for offshore wind power by advancing key contracts and power purchase agreements and developing regional approaches to offshore wind economic development. State and federal governments should align transmission and siting policies to expand access and eliminate obstacles to the development of wind power. Strategic investments in research, infrastructure development and planning can also help to unlock the potential of offshore wind energy. Finally, offshore wind projects must be sited, constructed and operated responsibly in order to avoid and mitigate conflict with local marine life and other uses.

The federal government should help states expand wind power by renewing and extending the Production Tax Credit (PTC) and the Investment Tax Credit (ITC), which have helped drive the explosion of wind power over the last ten years.

Two of the most important tools that have helped grow the wind industry in the United States are the federal renewable electricity production tax credit (PTC) and the offshore wind investment tax credit (ITC). Policies such as the PTC and ITC recognize that renewable energy is a key component of an electricity grid that is not only cleaner but also delivers stable, reasonable prices for consumers. Renewable energy sources such as wind are not subject to the fuel price volatility of coal and natural gas, and can deliver reliable, affordable electricity for decades, making them a smart long-term investment in the nation's energy future. However, renewable energy projects are often capital intensive. Unlike fossil fuel power plants, for which fuel costs represent a significant share of the overall cost of producing power, the vast majority of the costs of building a wind turbine or installing a solar panel are incurred before the first kilowatt-hour of electricity is produced. Public policies that defray some of those initial capital costs, or that help assure a reliable rate of return over the long term, can reduce the risk for investors—opening the floodgates for investment and the rapid expansion of renewable energy.

The PTC, which expired at the end of 2013, provided an income tax credit of 2.3 cents per kilowatt-hour (kWh) for utility-scale wind energy producers, and was available for electricity generated during the first 10 years of the wind farm's operation. The ITC, which is critical for launching an American offshore wind industry, also expired at the end of 2013, provided a 30 percent tax credit for offshore wind power.

Federal renewable energy tax credits have been a key contributor to the growth of wind energy over the last decade, but their effectiveness has been hamstrung by their "here today, gone tomorrow" inconsistency. Renewing and expanding these policies with long-term consistency in mind would go a long way toward encouraging future growth in wind energy.

Methodology

This report estimates the carbon dioxide emission reductions that result from wind energy in the United States. It provides estimates of past and present emission reductions, as well as estimates of the emission reductions that would result from integration of large amounts of wind energy into the U.S. electric grid by 2030.

Generation from Wind Power

Data on historical generation of wind energy by state were obtained from the U.S. Energy Information Administration's (EIA's) *Electric Power Monthly July 2014* report.[50] Wind generation for 2014 was projected by comparing wind generation for the first six months of 2014 to generation in the first six months of 2013 and applying the rate of growth to full-year 2013 data.

We evaluated two possible scenarios for future growth in wind energy. The first scenario, which assumes that 30 percent of the nation's electricity comes from wind energy by 2030, was constructed as follows:

1. The total amount of wind generation called for in 2030 was estimated by multiplying the Energy Information Administration's reference case forecast of net electricity generation in 2030 by 30 percent. We assumed that total wind power generation would experience linear growth between 2014 and 2030.

2. The wind power generated under the 30 percent scenario was divided into offshore and onshore components. The offshore component was based on data from two reports: a report from Navigant Consulting on offshore wind projects in the

Table 2. Actual and 30 Percent Scenario Growth in U.S. Wind Generation (GWh)

Year	Actual	
2011	120,177	
2012	140,822	
2013	167,665	
2014	*182,748*	
	EIA Business as Usual	**30% Scenario**
2015	218,489	246,180
2016	239,111	309,825
2017	239,117	372,601
2018	239,095	435,233
2019	239,086	500,834
2020	239,080	568,250
2021	239,061	650,826
2022	239,088	731,864
2023	239,054	812,903
2024	239,046	893,941
2025	239,083	973,613
2026	239,262	1,053,285
2027	239,458	1,132,957
2028	239,754	1,212,629
2029	240,144	1,292,301
2030	240,541	1,371,973

advanced stage of development; and DOE's 2014 *National Offshore Wind Energy Grid Interconnection Study*.[51] Our scenario for offshore wind assumed that all advanced-stage projects in the Navigant report would be built and begin generation on their current timelines. Beyond 2020, our scenario assumes that offshore wind capacity will grow from the projects listed in the Navigant study as being completed by 2020 to the 54 GW by 2030 assumed in the DOE study, with that capacity distributed among the states as described in Appendix A of the study.

3. To estimate annual electricity generation from the offshore wind farm capacities listed in the Navigant and DOE studies, we assumed a capacity factor of 39 percent, based on U.S. Department of Energy, National Energy Technology Laboratory, *Role of Alternative Energy Sources: Wind Technology Assessment,* 30 August 2012.

4. The amount of offshore wind generation was subtracted from the total amount of wind energy generation in the 30 percent scenario to create an estimate of national growth in onshore wind energy. Added onshore wind generation was divided among the states based on their share of national wind energy generation in 2013.

The second scenario was based on rates of growth in wind energy generation by Electricity Market Module (EMM) region in the Reference Case in EIA's *Annual Energy Outlook 2014*. In order to make use of the EMM wind growth forecast, we assigned generation data from EMMs to states, in a method detailed below.[52] Because 1.5 percent of electricity sales are not accounted for in the EMM-to-state conversion, there is a small amount of error: we assumed zero growth in wind for the portions of state electricity not accounted for, resulting in that 1.5 percent of electricity being apportioned among the remaining 98.5 percent.

Carbon Dioxide Emission 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 emission 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.[53]

Emission reduction rates for each state were based on the actual and forecast electricity generation mixes for the EIA 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 EIA 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.[54] 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 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 percent of 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. This led to a more conservative CO_2 displacement estimate, because we assumed wind in those states 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 numbers 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 downward trend of emission factors in recent years. 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.

Appendix

Table A-1. Wind Generation and Wind Energy CO_2 Displacement by State*

	2013 (Actual)		2030 (30% Wind Scenario)	
	Wind generation (GWh)	CO_2 Displaced by Wind (MMT)	Wind generation (GWh)	CO_2 Displaced by Wind (MMT)
National	**167,665**	**132**	**1,371,973**	**968**
Arizona	462	0	3,065	2
California	13,230	9	90,412	59
Colorado	7,382	5	50,076	32
Connecticut	-	-	2,381	1
Delaware	4	0	1,575	1
Florida	-	-	8,613	4
Georgia	-	-	3,290	2
Iowa	15,571	16	107,105	96
Idaho	2,545	2	19,229	12
Illinois	9,607	8	67,390	52
Indiana	3,483	3	24,518	20
Kansas	9,430	8	73,021	54
Massachusetts	187	0	16,200	8
Maryland	318	0	10,133	8
Maine	1,045	1	21,853	11
Michigan	2,524	2	36,082	29
Minnesota	8,065	8	61,539	55
Missouri	1,168	1	7,355	6
Montana	1,661	1	13,182	9
North Carolina	-	-	29,876	23
North Dakota	5,530	6	42,772	39
Nebraska	1,799	2	16,543	15
New Hampshire	383	0	3,918	2
New Jersey	13	0	25,467	20
New Mexico	2,188	2	15,230	10

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Table A-1. Wind Generation and Wind Energy CO_2 Displacement by State*

Continued from previous page

	2013 (Actual)		2030 (30% Wind Scenario)	
	Wind generation (GWh)	CO_2 Displaced by Wind (MMT)	Wind generation (GWh)	CO_2 Displaced by Wind (MMT)
Nevada	251	0	1,880	1
New York	3,548	2	58,155	30
Ohio	1,137	1	7,982	6
Oklahoma	10,881	9	79,984	60
Oregon	7,452	5	52,850	35
Pennsylvania	3,339	3	21,703	18
Rhode Island	2	0	3,245	2
South Carolina	-	-	14,274	11
South Dakota	2,688	3	19,141	17
Tennessee	47	0	338	0
Texas	35,937	23	246,241	139
Utah	535	0	4,940	3
Virginia	-	-	6,874	5
Vermont	238	0	2,078	1
Washington	7,008	5	49,627	32
Wisconsin	1,562	2	10,813	9
West Virginia	1,391	1	8,464	7
Wyoming	4,415	3	30,533	20

*Alaska and Hawaii not included in table, as CO_2 emission conversion factors were not available for these states. See the Methodology for more details.

Table A-2. Offshore Wind Power Annual Generation in 30% by 2030 Scenario (GWh)[55]

	2025	2030
California	705	1,411
Connecticut	1,191	2,381
Delaware	1,543	1,548
Florida	4,306	8,613
Georgia	1,645	3,290
Indiana	1,389	2,778
Massachusetts	9,035	14,762
Maryland	4,197	8,394
Maine	7,284	14,527
Michigan	5,097	10,195
North Carolina	14,938	29,876

	2025	2030
New Hampshire	600	1,199
New Jersey	13,893	25,377
New York	16,195	32,391
Ohio	92	92
Oregon	1,247	2,391
Rhode Island	2,520	3,228
South Carolina	7,137	14,274
Texas	817	1,121
Virginia	6,874	6,874
Washington	1,180	2,361

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