Wind Energy For A Cleaner America II

Wind Energy's Growing Benefits for Our Environment and Our Health

ENVIRONMENT NEW YORK
RESEARCH & POLICY CENTER

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Executive Summary

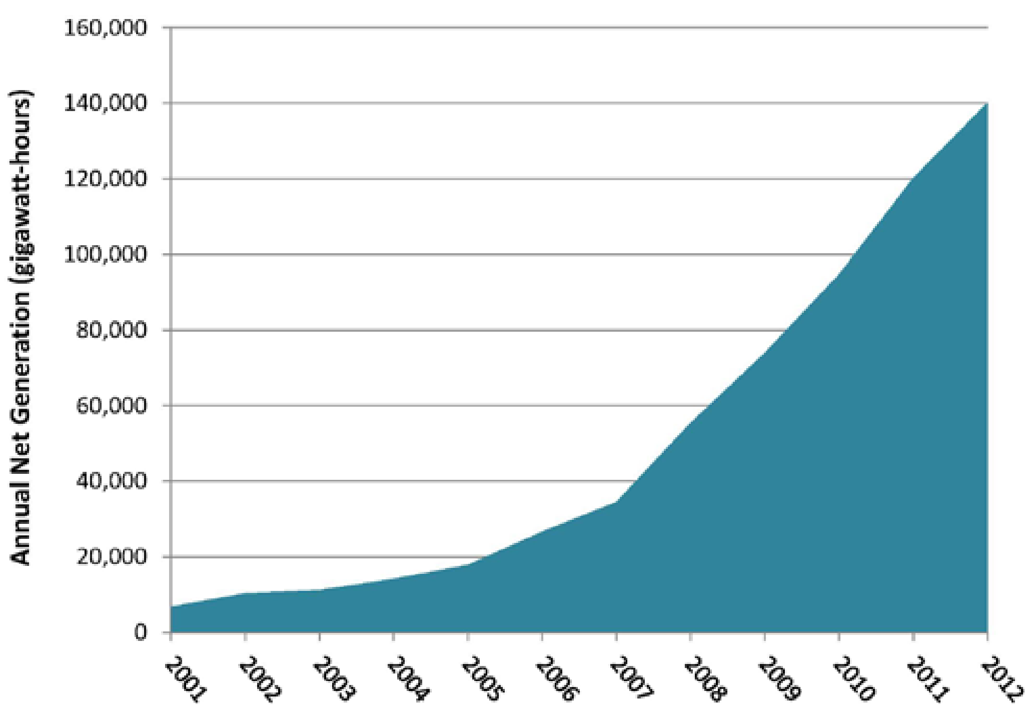
Burning fossil fuels to generate electricity pollutes our air, contributes to global warming, and consumes vast amounts of water—harming our rivers and lakes and leaving less water for other uses. In contrast, wind energy produces no air pollution, makes no contribution to global warming, and uses no water.

America's wind power capacity has quadrupled in the last five years and wind energy now generates as much electricity as is used every year in Georgia. Thanks to wind energy, America uses less water for power plants and produces less climate-altering carbon pollution.

Wind energy displaced about 84.7 million metric tons of carbon dioxide emissions in 2012—more global warming-inducing carbon dioxide pollution than is produced annually in Massachusetts, Maryland, South Carolina or Washington state. Wind energy also saves enough water nationwide to meet the domestic water needs of more than a million people.

America has vast wind energy resources, and there is still plenty of room for growth. But the pending expiration of the federal renewable energy production tax credit and investment tax credit threatens the future expansion of wind power. To protect the

Figure ES-1. Growth in Electricity Generated by Wind Power[1]



environment, federal and state governments should continue and expand policies that support wind energy.

Wind energy is on the rise in the United States.

- Electricity generated with wind power quadrupled in the last five years, from about 34,500 gigawatt-hours (GWh) in 2007 to more than 140,000 GWh at the end of 2012—or as much electricity as is used each year in Georgia. (See Figure ES-1.)
- Wind energy was the largest source of new electricity capacity added to the grid in 2012.
- Nine states now have enough wind turbines to supply 12 percent or more of their annual electricity needs in an average year, with Iowa, South Dakota and Kansas now possessing enough wind turbines to supply more than 20 percent of their annual electricity needs.

By displacing dirty electricity from fossil fuel-fired power plants, wind energy saves water and reduces pollution. In 2012, wind energy helped the United States:

- **Avoid 84.7 million metric tons of carbon dioxide pollution—or as much pollution as is produced by more than 17 million of today's passenger vehicles in a year.** Fossil fuel-fired power plants are the nation's largest source of carbon dioxide, the leading global warming pollutant. In the United States, warmer temperatures caused by global warming have already increased the frequency and severity of heat waves and heavy downpours, resulting in more intense wildfires, floods, droughts, and tropical storms and hurricanes.
- **Save enough water to supply the annual domestic water needs of more than a million people.** Power plants use water for cooling, reducing the amount of water available for irrigation, wildlife, recreation or domestic use. More water is withdrawn from U.S. lakes, rivers, streams and aquifers for the purpose of cooling power plants than for any other purpose.
- **Avoid 79,600 tons of nitrogen oxide (NO_X) and 98,400 tons of sulfur dioxide emissions.** Nitrogen oxides are a key ingredient of smog, which contributes to asthma and other respiratory problems; power plants are responsible for about 15 percent of the nation's total nitrogen oxide (NO_X) pollution each year. Power plants also produce about 60 percent of all sulfur dioxide pollution, which contributes to acid rain. Finally, coal-fired power plants emit heavy metals such as mercury, a potent neurotoxicant that can cause developmental and neurological disorders in babies and children. Nearly two-thirds of all airborne mercury pollution in the United States in 2010 came from the smokestacks of coal-fired power plants.

If America were to continue to add onshore wind capacity at the rate it did from 2007 to 2012, and take the first steps toward development of its massive potential for offshore wind, by 2018 wind energy will be delivering the following benefits:

- Averting a total of 157 million metric tons of carbon dioxide pollution annually—or more carbon dioxide pollution than was produced by Georgia, Michigan or New York in 2011.
- Saving enough water to supply the annual domestic water needs of 2.1 million people—roughly as many people as live in the city of Houston and more than live in Philadelphia, Phoenix or San Diego.
- Averting more than 121,000 tons of smog-forming nitrogen oxide pollution and 194,000 tons of sulfur dioxide pollution each year.

Wind energy's success in reducing air pollution and saving water will continue to grow if America makes a stable, long-term commitment to clean energy at the local, state and national levels. Specific policies that are essential to the development of wind energy include:

- The federal renewable energy **production tax credit** (PTC) and **investment tax credit** (ITC). The PTC provides an income tax credit of 2.3 cents per kilowatt-hour (kWh) for utility-scale wind energy producers for 10 years, while the ITC covers up to 30 percent of the capital cost of new renewable energy investments. Wind energy developers can take one of the two credits, which help reduce the financial risk of renewable energy investments and create new financing opportunities for wind energy. Both the ITC and the PTC, however, are scheduled to expire at the end of 2013.
- Strong **renewable electricity standards**. A strong renewable electricity standard (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 and protect consumers from the sharp swings in energy prices that accompany over-reliance on fossil fuels. Today, 29 states have renewable electricity standards—other states and the federal government should follow their lead.
- Continued coordination and collaboration between state and federal agencies to expedite **siting of offshore wind facilities** in areas that avoid environmental harm.

Introduction

From the Pacific Coast to the Great Plains to the Atlantic Ocean, wind power is on the rise in the United States, producing an increasing share of our electricity with minimal impact on the environment.

Just a decade ago, wind energy was a trivial part of the nation's electricity picture. Today, wind energy is one of the fastest growing forms of electricity generation and an increasingly important part of the nation's energy mix.

The remarkable progress of wind energy is generating real environmental results. Wind energy is reducing demand for electricity from fossil fuels such as coal and natural gas—curbing emissions that cause global warming while minimizing the use of water for cooling.

The boom in wind power is no accident, however. State and federal policy-makers have implemented far-sighted public policies that have created the conditions under which wind energy can thrive. By unleashing the energies of innovative companies and American workers, and tapping the natural power of the wind, these public policies are moving the nation toward a clean energy future and delivering growing benefits for our environment and our health.

With the environmental and economic advantages of wind energy becoming ever more apparent, now is the time for our leaders to renew their commitment to the key public policies that will enable the nation to achieve even greater benefits in the years to come.

Wind Energy Is Growing Rapidly in The U.S.

Wind energy is quickly becoming an important part of the energy mix in the United States. Nationwide, electricity generation from wind power has quadrupled in the last five years, from 34,500 GWh in 2007 to more than 140,000 GWh in 2012—or as much electricity as is used each year in the state of Georgia.[2] (See Figure 1.) Nine states now have enough wind turbines to produce 12 percent or more of their annual electricity needs in an average year—with Iowa, South Dakota and Kansas now having enough wind energy capacity to produce 20 percent or more of their annual electricity needs in a typical year.[3]

With more than 10,000 MW of new wind capacity installed in 2012, wind energy became the largest source of new electricity generating capacity in the United States last year—ahead of even natural gas, which added about 8,746 MW of new capacity.[5] In 2012, wind energy accounted for more than 40 percent of the new electric generating capacity added to the grid in the United States, making it the nation's largest source of new generating capacity.[6] (See Figure 2.)

Figure 1. Growth in Electricity Generated by Wind Power[4]

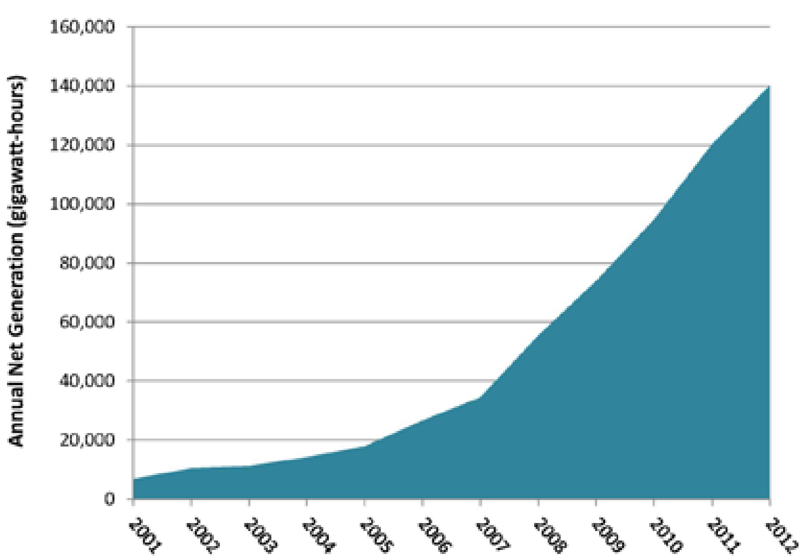
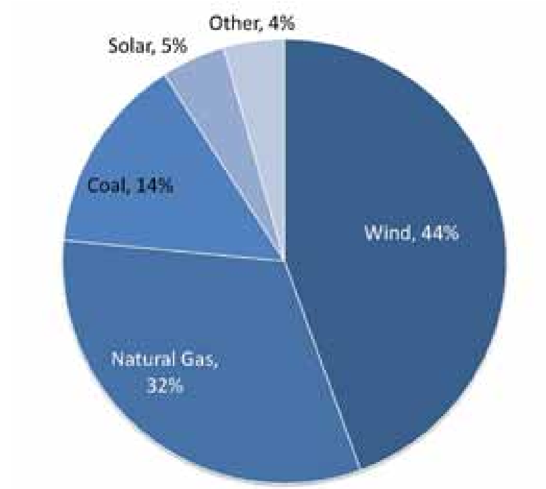


Figure 2. New Electricity Capacity Additions by Technology, 2012[7]



Employment in the wind industry has also grown significantly. In 2003, the wind industry directly employed 24,300 people.[8] By 2012, that number had more than tripled to more than 80,000 people.[9]

As the wind industry has grown and technology has advanced, the cost of wind energy has declined. By 2013, these cost declines had led wind energy to be competitive with other forms of power generation. When the costs imposed by emissions of global warming pollution are factored in, wind power is less expensive than new coal-fired power plants and is competitive with new natural gas power plants and even existing coal-fired plants.[10]

Power Plants Damage the Environment

Burning coal and natural gas to generate electricity damages the environment by contributing to global warming, consuming vast quantities of water, and creating health-threatening air pollution. Wind energy has none of these problems—it emits no air pollution and consumes little or no water. Generating clean electricity using wind power reduces the need for dirty electricity from fossil fuel-fired power plants, avoiding millions of tons of harmful air pollution and saving millions of gallons of water.

Power Plants Are America's Leading Source of Global Warming Pollution

Fossil fuel-fired power plants are the nation's largest source of carbon dioxide pollution, the leading global warming pollutant.[11] In 2011, power plants were responsible for 42 percent of all U.S. global warming pollution.[12] (See Figure 3.)

Figure 3. Energy-Related Carbon Dioxide Emissions by Sector in the U.S., 2011, with Electricity Generation Broken Down by Fuel[13]

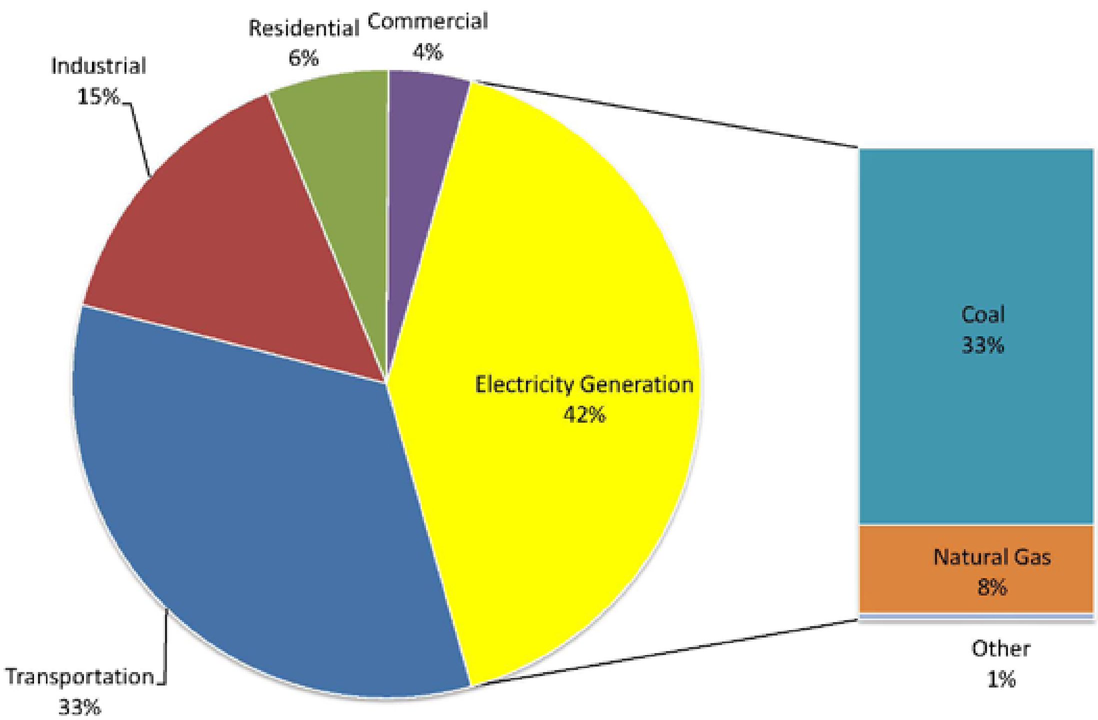
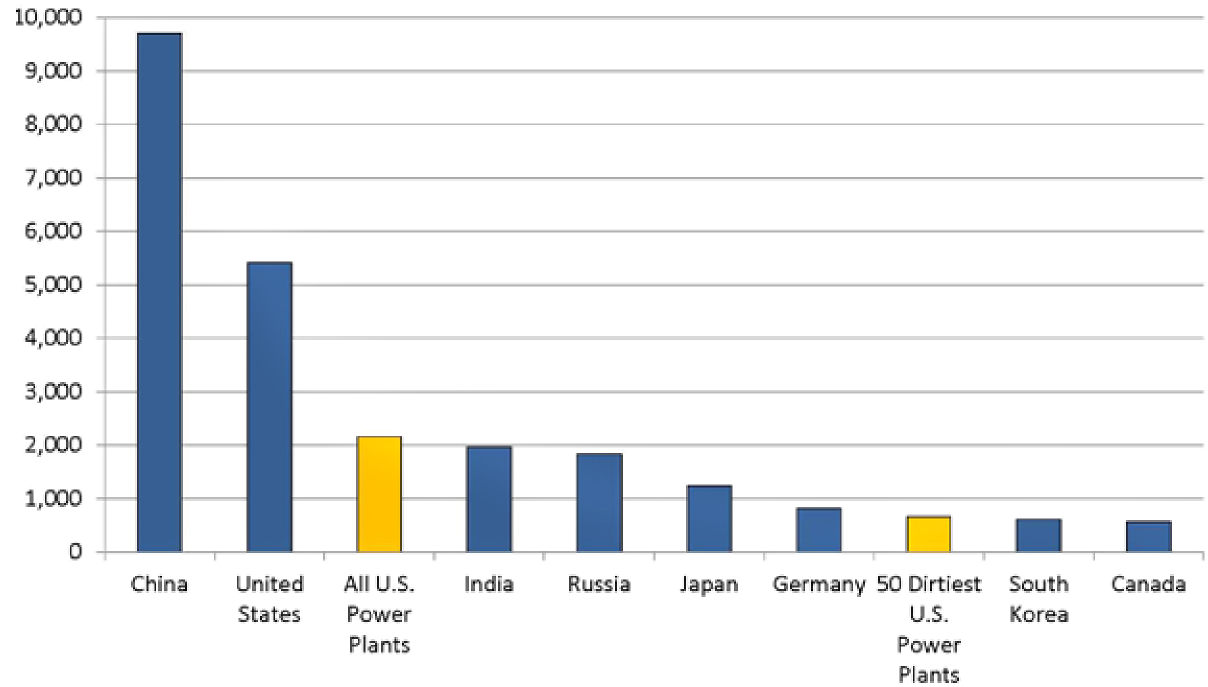


Figure 4. 50 Dirtiest U.S. Power Plants Compared to Total Emissions from Other Countries (MMT CO_2)[15]



America's power plants are also among the most significant sources of carbon dioxide pollution in the world. For example, if the U.S. power sector were an independent nation, it would be the third-largest emitter of carbon dioxide pollution in the world, behind China and the United States as a whole.[14] A large share of those emissions come from just a small number of old, dirty coal-fired power plants. The carbon dioxide pollution coming from America's 50 dirtiest power plants, for example, is greater than the amount of pollution produced annually by the entire economies of South Korea or Canada. (See Figure 4.)

The United States is already feeling the impacts of global warming. In the last 50 years the U.S. average annual temperature has risen 2° F, and experts project that it will continue rising.[16] Depending on the scale of continued greenhouse gas emissions, global average annual surface temperatures are likely to increase by 0.5°F to 8.6 °F by 2100, according to the most recent assessment by the Intergovernmental Panel on Climate Change (IPCC).[17]

Warmer average annual temperatures are connected to increases in extreme precipitation and more intense heat waves.[18] In the United States, extreme downpours now happen 30 percent more often nationwide than in 1948, and the largest annual storms now produce 10 percent more precipitation on average.[19] Meanwhile, the number of heat waves in the United States has increased since 1960 while the projected time between prolonged dry spells has become shorter.[20] The U.S. has also experienced an increase in the frequency and severity of other extreme weather events, including floods, more intense wildfires, and stronger tropical storms and hurricanes.[21]

Sea levels have risen eight inches along some parts of the U.S. coastline in the past 50 years. Rising seas erode shorelines—putting homes, businesses and infrastructure at risk—and can cause saltwater intrusion into coastal fresh water aquifers, leaving some unusable without desalination.[22] According to the IPCC, sea levels are likely to rise 10 to 32 inches by the late 21st century; in the worst case, sea levels could rise by as much as 38 inches.[23]

Science tells us that these and other impacts are expected to become more pronounced in the decades to come, unless we cut the dangerous carbon pollution that is fueling the problem. Increasing our production of wind power will help the United States make the emissions reductions necessary to forestall the worst impacts of global warming.

Power Plants Use Lots of Water

Fossil fuel power plants use vast amounts of water for cooling.

There are two ways to measure the use of water in power plants. *Withdrawals* represent the amount of water taken from waterways or groundwater for use in a power plant, regardless of whether that water is eventually returned to the river, lake or aquifer from which it came. More water is withdrawn from U.S. lakes, rivers, streams and aquifers to cool power plants than for any other purpose.[24] Water *consumption* reflects the amount of water that is lost to a given watershed as a result of its use in power plants, with losses primarily taking place through evaporation.

Almost all fossil fuel-fired power plants use water for cooling, but different power plant technologies have differing impacts on water supplies. Once-through cooling systems withdraw vast amounts of water for cooling and return it—usually at a higher temperature—to the waterways from which it came. Recirculating systems use the same water for cooling multiple times, reducing withdrawals, but plants with recirculating systems typically *consume* more water than once-through systems due to higher losses from evaporation.[25]

Regardless of the type of cooling system used, water use in power plants can create big problems for the environment. Large-scale water withdrawals for power plants can deplete groundwater supplies and affect the ecosystems of the waterways on which they depend. Fish and other aquatic life can be sucked into power plant intakes, while the discharge of heated water can also harm wildlife. Water discharged from a power plant can be 17 degrees hotter than it was when it was withdrawn for cooling.[26] This hotter water can affect the health and viability of the plants and animals living in the receiving waterway by subjecting organisms to water temperatures higher than they are able to tolerate and by depriving the waterway of dissolved oxygen. A 2013 study estimated that half of all power plant cooling systems discharge water at temperatures that can harm aquatic life.[27]

Recirculating cooling systems withdraw less water from waterways and aquifers, but lose more of that water to evaporation, potentially exacerbating local water supply problems. Many regions of the United States currently struggle to balance demands for water from industry, agriculture, and residential and commercial users while maintaining sufficient water levels in rivers and streams to preserve healthy ecosystems. Water consumption in power plants adds to those demands. In arid regions, power plants contribute to the long-term drawdown of critical groundwater supplies. In the Southwest and California, approximately one-third to two-thirds of the water consumed by power plants comes from groundwater.[28]

Power Plants Create Harmful Air Pollution

Coal- and natural gas-fired power plants also produce pollution that contributes to ozone smog, particulate matter and acid rain. This pollution hurts public health and ecosystems.

Each year, power plants are responsible for about 15 percent of the nation's emissions of nitrogen oxides (NO_X) – a key ingredient in ozone smog.[29] When inhaled, ozone quickly reacts with airway tissues and produces inflammation similar to sunburn on the inside of the lungs. This inflammation makes lung tissues less elastic, more sensitive to allergens, and less able to ward off infections.[30] Minor exposure to ozone can cause coughing, wheezing and throat irritation. Constant exposure to ozone over time can permanently damage lung tissues, decrease the ability to breathe normally, and exacerbate or potentially even cause chronic diseases like asthma.[31] Children, adults who are active outdoors, and people with existing respiratory system ailments suffer most from ozone's effects.

Particulate matter pollution also contributes to a host of respiratory and cardiovascular ailments. Sulfur dioxide, too, is a respiratory irritant for sensitive populations.[32] It is also a major component of acid rain that has damaged forests across the eastern United States.[33] Power plants are responsible for nearly 60 percent of U.S. sulfur dioxide pollution annually.[34]

Finally, nearly two-thirds of all airborne mercury pollution in the United States in 2010 came from the smokestacks of coal-fired power plants.[35] Mercury is a potent neurotoxicant, and exposure to mercury during critical periods of brain development can contribute to irreversible deficits in verbal skills, damage to attention and motor control and reduced IQ.[36]

Wind Energy Reduces Pollution and Saves Water

In 2012, the United States generated 140,000 gigawatt-hours (GWh) of electricity from wind power—or as much as electricity as was used in the state of Georgia in 2011.[37] (See Appendix A for a breakdown of wind power generation and its benefits by state.)

Assuming that wind energy displaced generation from natural gas and coal-fired power plants, the environmental benefits of wind power in 2012 included:

- Avoided emissions of 84.7 million metric tons of carbon dioxide, the leading global warming pollutant—as much as would have been emitted by 17.6 million passenger vehicles in a year (see Appendix B).[38] That's more than all the energy-related carbon dioxide emissions in Massachusetts, Maryland, South Carolina or Washington state in 2011.[39]
- Water savings of nearly 38 billion gallons, more than enough to meet the annual domestic water needs of more than a million people (see Appendix C).[40]
- Reductions in air pollution, including reductions of 79,600 tons of nitrogen oxide emissions and 98,400 tons of sulfur dioxide emissions (see Appendix D).[41]

Texas reaps greater savings from wind energy than any other state, avoiding 19.3 million metric tons of carbon dioxide emissions annually, or about 8 percent of 2011 emissions from the state's electric sector.[42] (See Figure 5 and Table 1, next page.) In addition, as the state recovers from the extreme drought in 2011 that caused major rivers run dry, wind power is averting the consumption of at least 8.6 billion gallons of water per year, enough to supply the domestic water needs of more than 172,000 people.

Figure 5. Top 10 States for Carbon Dioxide Emission Reductions from Wind Power in 2012

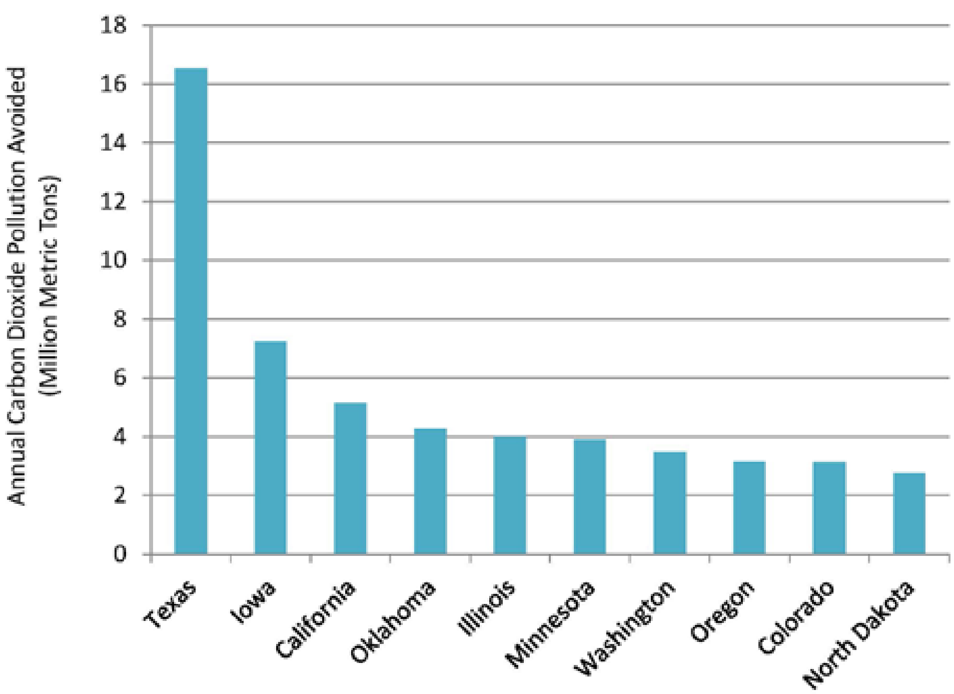


Table 1. Benefits of Wind Energy in Top 10 States, 2012

State	Wind Power Generation (GWh)	Avoided Carbon Dioxide Emissions (million metric tons)	Water Saved (million gallons)
Texas	31,860,000	19.3	8,610
Iowa	13,945,000	8.4	3,769
California	9,937,000	6.0	2,685
Oklahoma	8,234,000	5.0	2,225
Illinois	7,708,000	4.7	2,083
Minnesota	7,529,000	4.6	2,035
Washington	6,688,000	4.0	1,807
Oregon	6,066,000	3.7	1,639
Colorado	6,045,000	3.7	1,634
North Dakota	5,316,000	3.2	1,437

Seven of the top ten wind power-producing states are also on the list of states that suffered from areas of extreme or exceptional drought in 2012.[43] Collectively, wind power helped these seven states avoid consumption of 27.9 billion gallons of water at power plants, enough to serve the annual domestic water needs of 773,000 people—or nearly all the residents of Fort Worth.[44]

America Stands to Benefit Further if We Continue to Expand Wind Power

From the wide plains of the Midwest to the river valleys of the Pacific Northwest to the shores of the Atlantic Ocean, the United States has only scratched the surface of its vast wind energy potential. Tapping just a fraction of this potential by maintaining and expanding America's commitment to wind energy will produce even greater benefits.

Wind turbines can be placed virtually anywhere the wind blows. A 2012 report by the National Renewable Energy Laboratory estimates that as a whole, the United States has the technical potential to install nearly 11,000 GW of onshore wind capacity, and another 4,200 GW of offshore wind capacity.[45] (See Figures 6 and 7.) That amount of wind capacity could produce nearly 49.8 million GWh of electricity annually—12 times the amount of electricity generated in the United States in 2012.[46]

If the United States were to install wind energy between now and 2018 at the same pace that it did from 2007 to 2012, in five years, wind energy would help the United States:

- Avoid 157 million metric tons of carbon dioxide pollution annually—or as much as that emitted by 32 million of today's passenger vehicles in a year.[49] That's also more than all the energy-related emissions of Georgia, Michigan or New York in 2011.[50]
- Save enough water to supply the annual domestic water needs of 2.1 million people—roughly as many people as live in the city of Houston and more than live in Philadelphia, Phoenix or San Diego.
- Averting more than 121,000 tons of smog-forming nitrogen oxide pollution and 194,000 tons of sulfur dioxide pollution each year.

Figure 6: Onshore Wind Energy Technical Potential by State, 2012[47]

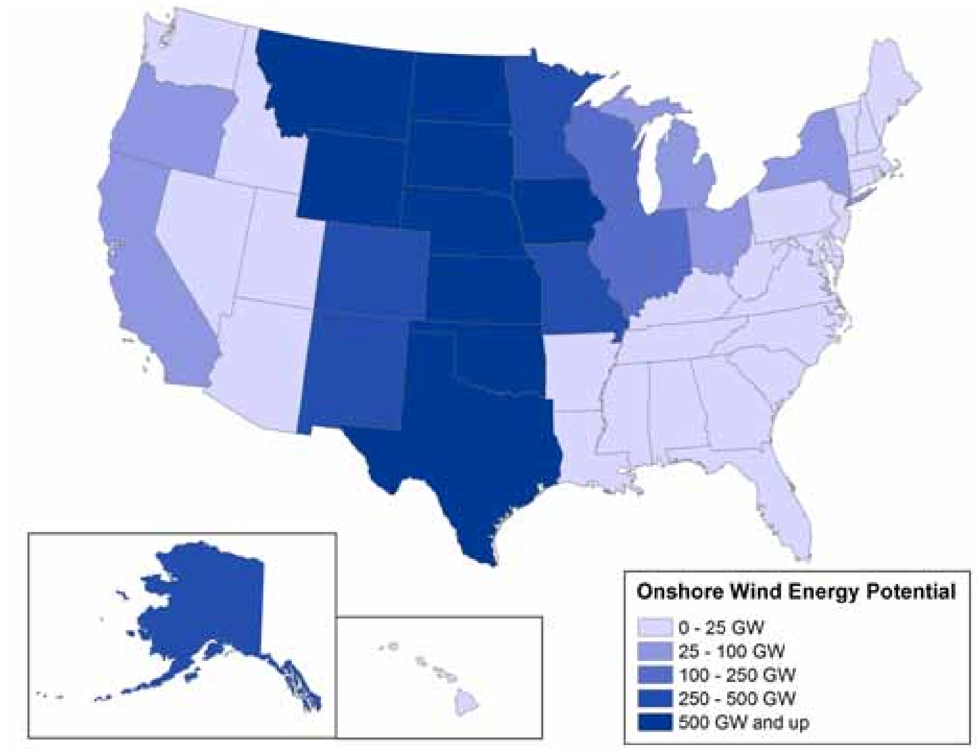
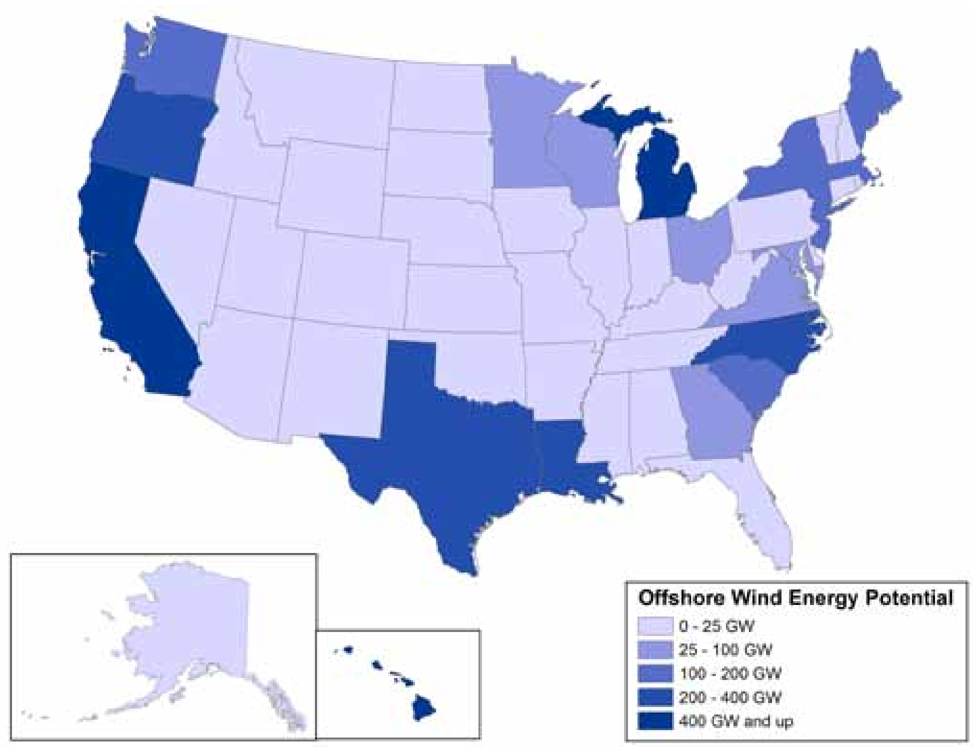


Figure 7: Offshore Wind Energy Technical Potential by State, 2012[48]



America Should Continue to Invest in Wind Energy

America's clean energy boom is no accident. It is the direct result of strong, forward-thinking policies adopted over the last decade at both the state and federal levels, policies that have unleashed the energy of innovative companies and American workers to fuel dramatic growth in renewable energy. As wind energy and other forms of clean, renewable energy take root in the United States—delivering ample benefits for our environment and economy—now is not the time to turn our back on further progress. To further reduce global warming pollution, curb smog and soot, move away from fossil fuels, save water, and grow our economy, the United States should make a long-term commitment to renewable energy with policies to support growth of the wind industry.

Federal Tax Incentives

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 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 that 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.

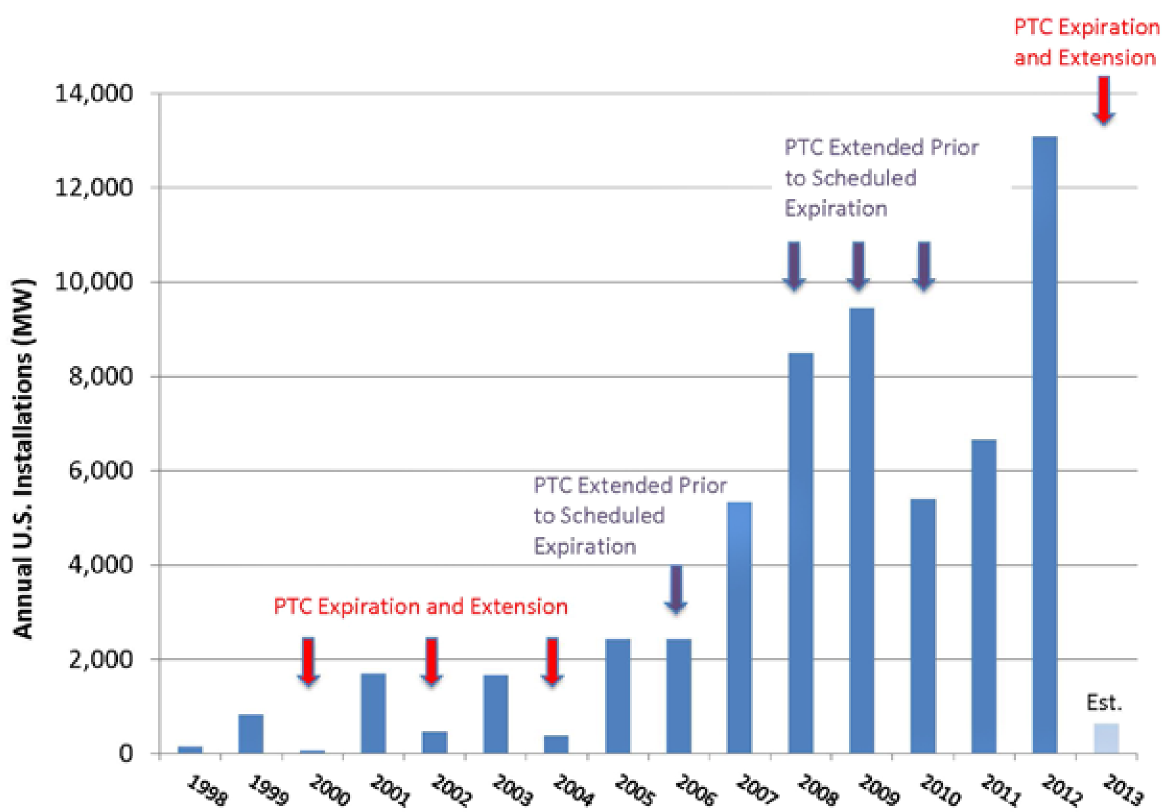
The PTC provides an income tax credit of 2.3 cents per kilowatt-hour (kWh) for utility-scale wind energy producers.[51] It is available for electricity generated during the first 10 years of the wind farm's operation. After expiring at the end of 2012, the PTC was renewed in January 2013 and will be available for all projects that begin construction on or before December 31, 2013.

The investment tax credit (ITC) covers up to 30 percent of the capital cost of new renewable energy investments, with the credit becoming available the moment the wind energy system is placed into service. The ITC also expires on December 31, 2013.[52]

Wind energy developers and other builders of renewable energy systems may choose to take advantage of either the PTC or the ITC, but not both. Different types of renewable energy projects stand to reap greater benefits from one or the other program, depending in part on the capital intensity of the project and the amount of power it produces over time.[53] 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. Over the past 13 years, the renewable energy PTC has been available only sporadically. When the PTC has been renewed by Congress for only for one or two years at a time or even allowed to expire, the ensuing uncertainty has discouraged wind developers from building new capacity, stunting industry growth. For instance, in 2000, 2002 and 2004—years when the PTC was allowed to expire temporarily—new wind installations dropped by 93 percent, 73 percent and 77 percent, respectively, from the previous year when the PTC had been in force.[54] (See Figure 8.)

The economic uncertainty created by the sporadic availability of incentives discourages businesses that manufacture turbines, gear boxes, blades, bearings and towers from entering the market or expanding, restricting the supply chain and increasing costs. On the other hand, long-term consistency in renewable energy policy can encourage new businesses to enter the field and expand operations, bringing new jobs and investment to the United States. For example, between 2005-2006 and 2012—a period of relative stability in clean energy incentives—the amount of domestically produced content in U.S. wind power projects increased from 25 percent to 72 percent, creating new jobs and economic opportunity in the United States.[55]

Figure 8. The Impact of the Sporadic Expiration and Renewal of the PTC on the Wind Industry[56]



Establish Strong Renewable Electricity Standards

A renewable electricity standard (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. This certainty makes it easier for wind developers to finance and build new wind power installations. Today, 29 states have renewable electricity standards.[57] From 1999 through 2012, 69 percent of all new wind capacity was built in states with renewable electricity standards.[58] In 2012, the proportion rose to 83 percent.[59] Some of the states with the strongest standards, such as Colorado, have seen the greatest growth in wind power generation.[60]

Renewable electricity standards have not only proven to be effective at spurring wind energy development, but they have also had little effect on ratepayers, with most policies resulting in either a small net benefit or a small cost to ratepayers on the order of $5 per year.[61] This does not include the economic value of the environmental and public health benefits of renewable energy, nor does it reflect the economic benefits of wind energy-driven job creation, leading to the conclusion that renewable electricity standards are a winner for both the environment and the economy.

In order for RES policies to continue to drive wind energy growth, however, states without RESs will need to adopt them, those with policies will need to strengthen them, and the federal government will need to adopt a national policy of its own. According to the U.S. Department of Energy, existing state RESs will drive the addition of only 3 to 5 GW of renewable energy per year between now and the end of the decade, which is lower than the amount of wind energy added in recent years.[62] Strengthening the nation's renewable energy goals will help keep the United States on pace to tap an increasing share of its wind energy potential.

Facilitate Development of Offshore Wind Resources

Some of the best wind energy resources are offshore. To capture that potential, policymakers need to set a bold goal for offshore wind development in the Atlantic. A goal will help articulate the important role of offshore wind in America's energy future. The Department of the Interior and the Bureau of Ocean Energy Management will need sufficient staff and resources to manage multiple renewable energy leases along the coast and to promote an efficient leasing process. A coordinated effort by federal, state and regional economic development, energy and commerce agencies is needed to develop commitments to purchase offshore wind power. 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.

Methodology

Estimates of the benefits of wind energy were obtained by applying national assumptions regarding the amount of pollution or water consumption avoided per megawatt-hour (MWh) of wind energy to estimated wind energy production in 2012 and the amount of wind energy assumed to be produced in 2018 if the United States continues to add wind energy at a pace consistent with recent experience.

Data on annual wind generation (in MWh) for 2012 were obtained from Energy Information Administration, *Electric Power Monthly*, February 2013.

To estimate output from wind facilities in 2018, we assumed the installation of a modest 640 MW of new wind energy capacity in 2013, based on the assumption that approximately half of the 1,280 MW of new wind capacity under construction as of the end of the second quarter of 2013 would be completed by the end of the year.[63] We then assumed that the United States would add onshore wind capacity at a pace equivalent to the average annual addition of wind power capacity from 2007 to 2012, or 8,620 MW—a level of wind energy development well within the historical experience of the United States.

In addition to onshore wind energy, the United States has ample potential to develop wind energy resources in ocean waters and the Great Lakes. To date, the United States does not have any operational offshore wind energy facilities, but several such facilities are in development. Our analysis assumes that the United States will add 3.4 GW of wind energy capacity between 2013 and 2018, based on data from Navigant Consulting, *Offshore Wind Market and Economic Analysis: Annual Market Assessment*, prepared for the U.S. Department of Energy, 22 February 2013.

Table 2. Actual and Assumed Growth in Cumulative U.S. Wind Installations, 1999-2018[64]

Year	Wind Energy Capacity (MW)
1999	2,472
2000	2,539
2001	4,232
2002	4,687
2003	6,350
2004	6,723
2005	9,147
2006	11,575
2007	16,907
2008	25,410
2009	34,863
2010	40,267
2011	46,916
2012	60,007
Estimated onshore additions in 2013	640
Assumed onshore additions, 2014-18	43,100
Assumed offshore additions, 2013-18	3,380
Installed wind capacity at end of 2018	**107,127**

We apportioned new onshore wind energy capacity among the states according to their share of the nation's existing wind power capacity.[65] New offshore wind capacity was apportioned among the states based on the locations of the projects identified in the Navigant Consulting study.

To estimate electricity generation from these capacity additions in each state, we used regional capacity factors based on historical performance data for existing U.S. wind turbines, per Ryan Wiser and Mark Bolinger, *2011 Wind Technologies Market Report*, U.S. Department of Energy, August 2012. Because the state-level data did not include Alaska or Hawaii, we assumed wind projects in those states achieved the national average capacity factor of 33 percent. We assumed that the southeastern states have the same capacity factor as the East. The capacity factor for offshore wind projects is assumed to be 39 percent, based on U.S. Department of Energy, National Energy Technology Laboratory, *Role of Alternative Energy Sources: Wind Technology Assessment*, 30 August 2012.

Technological improvements could lead to significantly increased capacity factors for onshore and offshore wind installations in the near future. To the extent that those improvements develop and are implemented in U.S. wind energy projects, the environmental benefits presented here can be considered conservative estimates.

Estimating Carbon Dioxide Emission Reductions

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.

In this report, we assume that 75 percent of the generation offset by wind energy is in the form of natural gas generation and 25 percent in the form of coal-fired generation. This simple assumption reflects the frequent status of natural gas as a marginal source of generation in much of the country, as well as the recent dominance of natural gas in proposals for new fossil fuel-fired generation capacity. For wind turbines installed through the end of 2012, we assume that the natural gas generation avoided shares the emission characteristics of existing natural gas power plants; for plants installed in 2013 and later years, we assume that wind offsets new natural gas combined cycle power plants.

The use of simplified national assumptions blurs regional variations in the emission reduction benefits of wind energy generation. In its 2012 market report, the American Wind Energy Association estimated that a megawatt-hour of electricity produced from a newly installed wind turbine will offset 1,300 pounds of carbon dioxide pollution on average nationally, but that the reductions would vary by region from as much as 1,630 pounds/MWh to as little as 970 pounds/MWh.[67] Readers should be aware of these potential regional variations in the emission benefits of wind energy and understand that the emission reductions estimated here may vary by as much as +/- 25 percent.

Table 3. Average Capacity Factor, Based on Projects Built from 2004-2010[66]

Region	Average Capacity Factor
East	25%
New England	28%
California	30%
Great Lakes	31%
Northwest	32%
Texas	34%
Mountain	36%
Heartland	37%
Offshore	39%

We calculated a national average carbon dioxide emissions rate for coal and natural gas plants for 2011 based on emissions figures for the electric power industry from U.S. Department of Energy, Energy Information Administration, *State Historical Tables for 2011*, February 2013, and net generation of electricity from U.S. Department of Energy, Energy Information Administration, *Electricity Data Browser*, accessed at www.eia.gov/electricity/data.cfm, 21 October 2013. For new natural gas-fired power plants, we used the emission rate given for a new natural gas combined cycle power plant without carbon capture and storage in U.S. Department of Energy, National Energy Technology Laboratory, *Life Cycle Analysis: Natural Gas Combined Cycle (NGCC) Power Plant*, 30 September 2010.[68]

To put carbon dioxide emission reductions in perspective, we calculated how many passenger vehicles would have to be removed from the road in order to produce comparable savings. Data on vehicle emissions rates is from Environmental Protection Agency, *Clean Energy: Calculations and References*, updated 19 September 2013 and accessed at www.epa.gov/cleanenergy/energy-resources/refs.html.

It is important to note that U.S. power grids cross state lines, such that electricity generated in one state may be consumed in a neighboring state. The emission reductions attributed to each state in this report reflect the emissions impact of wind power produced within each state.

Estimating Avoided Water Consumption

We estimated water savings using freshwater consumption rates in coal and natural gas combined cycle power plants from U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy, *20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply*, July 2008. We used the same assumption as for carbon dioxide savings that 75 percent of displaced generation is from natural gas power plants and 25 percent is from coal plants, with water consumption for combined cycle plants used to calculate savings for both existing and future wind power capacity. The U.S. DOE study used national estimates of water consumption due to the lack of regional variation in water consumption patterns among specific technologies, and used the same figures for current and future generation technologies.

In this report, we present data on water *consumption* by power plants, which is the amount of water lost to a watershed (usually through evaporation) as a result of power plant operation. We do not present data on water *withdrawals* for power plant operations. Withdrawals are also a critical measure of power plants' environmental impact as high levels of water withdrawals can have significant impacts on the environment and wildlife. By reducing the need for fossil fuel-fired power plants, wind energy can also reduce the amount of water withdrawn for power plant cooling.

We calculated the number of individuals whose domestic water needs could be met with this amount of saved water. We obtained state-level per capita domestic water use from Joan Kenny et al., *Estimated Use of Water in the United States in 2005*, U.S. Geological Survey, 2009.

As with estimates of the carbon dioxide emission benefits of wind power, estimates of water savings based on national averages may overstate or understate water savings experienced in a particular state, depending on the specific mix of electricity generation that is avoided through the use of wind energy.

Estimating Avoided Emissions of Nitrogen Oxides and Sulfur Dioxide

We also estimated avoided emissions of nitrogen oxides (NO_X) and sulfur dioxide (SO_2) by multiplying electricity generation from wind power by an annual emissions rate for each pollutant. We created an average annual emission rate for each pollutant assuming that 25 percent of the electricity displaced by existing wind generation would be from existing coal plants, and 75 percent from natural gas power plants. As with our estimates of carbon dioxide emission reductions, we assumed that wind turbines built through the end of 2012 offset emissions from natural gas-fired power plants at a rate characteristic of the existing generation fleet, while new wind turbines offset emissions at a rate characteristic of new natural gas combined cycle power plants.

We calculated a national average emissions rate for coal and natural gas plants for 2011 based on emissions figures for the electric power industry from U.S. Department of Energy, Energy Information Administration, *State Historical Tables for 2011*, February 2013, and net generation of electricity from U.S. Department of Energy, Energy Information Administration, *Electricity Data Browser*, accessed at www.eia.gov/electricity/data.cfm, 21 October 2013. For new natural gas-fired power plants, we used the emission rate given for a new natural gas combined cycle power plant without carbon capture and storage in U.S. Department of Energy, National Energy Technology Laboratory, *Life Cycle Analysis: Natural Gas Combined Cycle (NGCC) Power Plant*, 30 September 2010.[69]

As with the other estimates of environmental impacts in this report, reductions in nitrogen oxide and sulfur dioxide may vary by region depending on the specific characteristics of the electric grid in those areas, as well as regulatory limits on pollution from power plant smokestacks.

Appendix A: Current and Possible Future Wind Generation by State

State	Wind Energy Production, 2012 (MWh)	Rank, Wind Energy Production in 2012	Possible Production from Wind Energy Added 2013-18 (MWh in 2018)
Texas	31,860,000	1	32,970,227
Iowa	13,945,000	2	12,161,374
California	9,937,000	3	10,651,416
Oklahoma	8,234,000	4	7,419,456
Illinois	7,708,000	5	7,077,142
Minnesota	7,529,000	6	7,069,080
Washington	6,688,000	7	5,749,346
Oregon	6,066,000	8	6,455,729
Colorado	6,045,000	9	5,300,178
North Dakota	5,316,000	10	3,974,878
Kansas	5,119,000	11	6,420,410
Wyoming	4,394,000	12	3,247,828
Indiana	3,163,000	13	3,060,546
New York	3,033,000	14	2,620,145
South Dakota	2,914,000	15	1,856,048
New Mexico	2,226,000	16	1,792,064
Pennsylvania	2,208,000	17	2,143,464
Idaho	1,821,000	18	1,992,206
Wisconsin	1,546,000	19	1,287,294
West Virginia	1,286,000	20	932,567
Nebraska	1,275,000	21	1,086,640
Missouri	1,245,000	22	1,086,640
Montana	1,238,000	23	1,320,630
Michigan	1,108,000	24	1,959,702
Ohio	988,000	25	918,294
Maine	884,000	26	689,428
Utah	712,000	27	748,613
Hawaii	367,000	28	434,963
Maryland	314,000	29	191,952
New Hampshire	260,000	30	273,532
Arizona	255,000	31	548,215
Nevada	129,000	32	350,120
Vermont	109,000	33	190,352
Massachusetts	85,000	34	1,184,880
Tennessee	47,000	35	46,388
Alaska	14,000	36	124,577
New Jersey	13,000	37	1,558,346
Delaware	5,000	38	3,199
Rhode Island	3,000	39	80,096
Alabama	0	40 (tie)	0
Arkansas	0	40 (tie)	237
Connecticut	0	40 (tie)	0
Florida	0	40 (tie)	0
Georgia	0	40 (tie)	0
Kentucky	0	40 (tie)	0
Louisiana	0	40 (tie)	0
Mississippi	0	40 (tie)	0
North Carolina	0	40 (tie)	0
South Carolina	0	40 (tie)	0
Virginia	0	40 (tie)	0

Note: Assumptions about future onshore wind capacity are based on a national growth rate, apportioned to states based on historical wind energy development patterns. Technological, economic or policy changes could result in a different distribution of wind power capacity between now and 2018 than is assumed here.

Appendix B: Carbon Dioxide Emissions Avoided by Wind Energy

	Avoided Carbon Dioxide Emissions, 2012 (metric tons)		Equivalent in Cars Off the Road	
State	**Reductions from Wind Energy in 2012**	**Reductions from Possible Additional Wind Energy, 2013-18**	**Reductions from Wind Energy in 2012**	**Reductions from Possible Additional Wind Energy, 2013-18**
Alabama	–	–	–	–
Alaska	8,468	65,940	1,764	13,737
Arizona	154,242	290,176	32,134	60,453
Arkansas	–	125	–	26
California	6,010,609	5,637,907	1,252,210	1,174,564
Colorado	3,656,449	2,805,441	761,760	584,467
Connecticut	–	–	–	–
Delaware	3,024	1,693	630	353
Florida	–	–	–	–
Georgia	–	–	–	–
Hawaii	221,988	230,231	46,247	47,965
Idaho	1,101,471	1,054,496	229,473	219,687
Illinois	4,662,351	3,746,006	971,323	780,418
Indiana	1,913,209	1,619,980	398,585	337,496
Iowa	8,434,935	6,437,144	1,757,278	1,341,072
Kansas	3,096,338	3,398,391	645,070	707,998
Kentucky	–	–	–	–
Louisiana	–	–	–	–
Maine	534,707	364,921	111,397	76,025
Maryland	189,930	101,602	39,569	21,167
Massachusetts	51,414	627,170	10,711	130,660
Michigan	670,198	1,037,291	139,625	216,102
Minnesota	4,554,079	3,741,739	948,766	779,529

	Avoided Carbon Dioxide Emissions, 2012 (metric tons)		*Equivalent in Cars Off the Road*	
State	**Reductions from Wind Energy in 2012**	**Reductions from Possible Additional Wind Energy, 2013-18**	**Reductions from Wind Energy in 2012**	**Reductions from Possible Additional Wind Energy, 2013-18**
Mississippi	–	–	–	–
Missouri	753,065	575,170	156,889	119,827
Montana	748,831	699,023	156,006	145,630
Nebraska	771,211	575,170	160,669	119,827
Nevada	78,028	185,322	16,256	38,609
New Hampshire	157,267	144,783	32,764	30,163
New Jersey	7,863	824,849	1,638	171,844
New Mexico	1,346,444	948,558	280,509	197,616
New York	1,834,576	1,386,870	382,203	288,931
North Carolina	–	–	–	–
North Dakota	3,215,498	2,103,945	669,895	438,322
Ohio	597,613	486,063	124,503	101,263
Oklahoma	4,980,513	3,927,197	1,037,607	818,166
Oregon	3,669,151	3,417,086	764,407	711,893
Pennsylvania	1,335,557	1,134,558	278,241	236,366
Rhode Island	1,815	42,396	378	8,832
South Carolina	–	–	–	–
South Dakota	1,762,596	982,426	367,207	204,672
Tennessee	28,429	24,554	5,923	5,115
Texas	19,271,210	17,451,491	4,014,835	3,635,727
Utah	430,669	396,249	89,723	82,552
Vermont	65,931	100,756	13,736	20,991
Virginia	–	–	–	–
Washington	4,045,381	3,043,190	842,788	633,998
West Virginia	777,865	493,617	162,055	102,837
Wisconsin	935,132	681,378	194,819	141,954
Wyoming	2,657,806	1,719,110	553,710	358,148
U.S. Total	**84,735,862**	**72,504,016**	**17,653,305**	**15,105,003**

Appendix C: Water Consumption Avoided with Wind Energy

	Avoided Water Consumption (gallons)		*Equivalent in Number of People Whose Daily Water Use Could Be Met*	
State	**Reductions from Wind Energy in 2012**	**Reductions from Possible Additional Wind Energy, 2013-18**	**Reductions from Wind Energy in 2012**	**Reductions from Possible Additional Wind Energy, 2013-18**
Alabama	–	–	-	-
Alaska	3,783,500	33,666,891	113	1,003
Arizona	68,913,750	148,155,070	1,349	2,899
Arkansas	0	63,979	0	2
California	2,685,474,250	2,878,545,113	59,334	63,600
Colorado	1,633,661,250	1,432,373,178	36,990	32,432
Connecticut	–	–	-	-
Delaware	1,351,250	864,584	61	39
Florida	–	–	-	-
Georgia	–	–	-	-
Hawaii	99,181,750	117,548,806	1,647	1,952
Idaho	492,125,250	538,393,588	7,210	7,888
Illinois	2,083,087,000	1,912,597,572	63,412	58,222
Indiana	854,800,750	827,112,683	30,815	29,817
Iowa	3,768,636,250	3,286,611,347	158,847	138,529
Kansas	1,383,409,750	1,735,115,821	46,792	58,688
Kentucky	–	–	-	-
Louisiana	–	–	-	-
Maine	238,901,000	186,317,797	12,121	9,453
Maryland	84,858,500	51,875,025	2,133	1,304
Massachusetts	22,971,250	320,213,817	767	10,699
Michigan	299,437,000	529,609,417	10,255	18,137
Minnesota	2,034,712,250	1,910,418,821	81,979	76,971

	Avoided Water Consumption (gallons)		*Equivalent in Number of People Whose Daily Water Use Could Be Met*	
State	**Reductions from Wind Energy in 2012**	**Reductions from Possible Additional Wind Energy, 2013-18**	**Reductions from Wind Energy in 2012**	**Reductions from Possible Additional Wind Energy, 2013-18**
Mississippi	–	–	-	-
Missouri	336,461,250	293,664,514	10,475	9,143
Montana	334,569,500	356,900,169	8,184	8,730
Nebraska	344,568,750	293,664,514	6,993	5,960
Nevada	34,862,250	94,620,045	503	1,364
New Hampshire	70,265,000	73,921,910	2,567	2,700
New Jersey	3,513,250	421,143,114	139	16,722
New Mexico	601,576,500	484,305,229	15,403	12,401
New York	819,668,250	708,094,085	23,151	20,000
North Carolina	–	–	-	-
North Dakota	1,436,649,000	1,074,210,717	43,253	32,341
Ohio	267,007,000	248,168,912	10,602	9,854
Oklahoma	2,225,238,500	2,005,108,032	71,724	64,629
Oregon	1,639,336,500	1,744,660,826	37,118	39,503
Pennsylvania	596,712,000	579,271,108	28,681	27,843
Rhode Island	810,750	21,646,052	28	751
South Carolina	–	–	-	-
South Dakota	787,508,500	501,596,904	22,953	14,620
Tennessee	12,701,750	12,536,464	435	429
Texas	8,610,165,000	8,910,203,822	172,186	178,186
Utah	192,418,000	202,312,596	2,834	2,980
Vermont	29,457,250	51,442,733	1,261	2,202
Virginia	–	–	-	-
Washington	1,807,432,000	1,553,760,735	48,076	41,329
West Virginia	347,541,500	252,026,161	9,427	6,836
Wisconsin	417,806,500	347,891,206	20,082	16,722
Wyoming	1,187,478,500	877,725,415	21,404	15,821
United States	**37,859,052,250**	**37,018,358,774**	**1,071,304**	**1,042,700**

Appendix D: Nitrogen Oxide and Sulfur Dioxide Emissions Avoided with Wind Energy

	Avoided Nitrogen Oxide Emissions (tons)		*Avoided Sulfur Dioxide Emissions (tons)*	
State	**Reductions from Wind Energy in 2012**	**Reductions from Possible Additional Wind Energy, 2013-18**	**Reductions from Wind Energy in 2012**	**Reductions from Possible Additional Wind Energy, 2013-18**
Alabama	-	-	-	-
Alaska	8	37	10	87
Arizona	145	165	179	384
Arkansas	-	0	-	0
California	5,649	3,206	6,978	7,468
Colorado	3,437	1,595	4,245	3,716
Connecticut	-	-	-	-
Delaware	3	1	4	2
Florida	-	-	-	-
Georgia	-	-	-	-
Hawaii	209	131	258	305
Idaho	1,035	600	1,279	1,397
Illinois	4,382	2,130	5,413	4,962
Indiana	1,798	921	2,221	2,146
Iowa	7,928	3,660	9,793	8,526
Kansas	2,910	1,932	3,595	4,501
Kentucky	-	-	-	-
Louisiana	-	-	-	-
Maine	503	208	621	483
Maryland	179	58	221	135
Massachusetts	48	357	60	831

	Avoided Nitrogen Oxide Emissions (tons)		*Avoided Sulfur Dioxide Emissions (tons)*	
State	**Reductions from Wind Energy in 2012**	**Reductions from Possible Additional Wind Energy, 2013-18**	**Reductions from Wind Energy in 2012**	**Reductions from Possible Additional Wind Energy, 2013-18**
Michigan	630	590	778	1,374
Minnesota	4,280	2,128	5,287	4,956
Mississippi	-	-	-	-
Missouri	708	327	874	762
Montana	704	397	869	926
Nebraska	725	327	895	762
Nevada	73	105	91	245
New Hampshire	148	82	183	192
New Jersey	7	469	9	1,093
New Mexico	1,265	539	1,563	1,256
New York	1,724	789	2,130	1,837
North Carolina	-	-	-	-
North Dakota	3,022	1,196	3,733	2,787
Ohio	562	276	694	644
Oklahoma	4,681	2,233	5,782	5,202
Oregon	3,449	1,943	4,260	4,526
Pennsylvania	1,255	645	1,551	1,503
Rhode Island	2	24	2	56
South Carolina	-	-	-	-
South Dakota	1,657	559	2,046	1,301
Tennessee	27	14	33	33
Texas	18,112	9,923	22,374	23,115
Utah	405	225	500	525
Vermont	62	57	77	133
Virginia	-	-	-	-
Washington	3,802	1,730	4,697	4,031
West Virginia	731	281	903	654
Wisconsin	879	387	1,086	902
Wyoming	2,498	978	3,086	2,277
United States	**79,641**	**41,228**	**98,378**	**96,033**

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44. For calculations of water savings, see methodology. The population of Fort Worth was about 782,000 in 2012, per U.S. Census Bureau, *2012 American Community Survey 1-Year Estimates,* downloaded from factfinder2.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t , on 16 October 2013.

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