Wind Power for a Cleaner America

Reducing Global Warming Pollution, Cutting Air Pollution and Saving Water

ENVIRONMENT OHIO
RESEARCH & POLICY CENTER

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Executive Summary

Coal- and natural gas-fired power plants pollute our air, are major contributors to global warming, and consume vast amounts of water—harming our rivers and lakes and leaving less water for other uses. Wind energy has none of these problems. It produces no air pollution, makes no contribution to global warming, and uses no water.

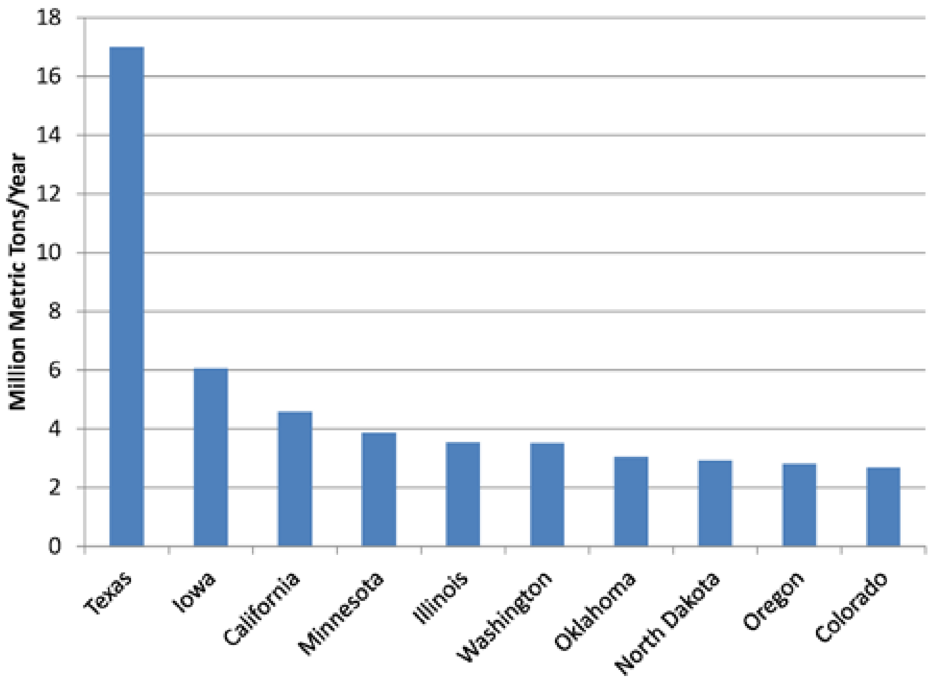
America has more than doubled its use of wind power since the beginning of 2008 and we are starting to reap the environmental rewards. **Wind energy now displaces about 68 million metric tons of global warming pollution each year—as much as is produced by 13 million cars. And wind energy now saves more than enough water nationwide to meet the needs of a city the size of Boston.**

There is still plenty of room for growth in wind energy. But the pending expiration of the production tax credit threatens the future expansion of wind power. To protect the environment, federal and state governments should continue and expand policies that support wind energy.

Burning fossil fuels for electricity generation has widespread environmental and public health consequences.

- Combustion of coal and natural gas exacerbates global warming, the effects of which are already being felt across the nation. The average annual temperature in the U.S. has already risen 2° F in the past 50 years, and the number of heat waves has increased. Extreme rain and snowfall events have become 30 percent more common. Sea

Figure ES-1. Top 10 States for Global Warming Emission Reductions from Wind Energy in 2011



level has risen eight inches or more along parts of our coasts.

- Coal- and natural gas-fired power plants require vast amounts of water for cooling, reducing the amount of water available for irrigation, wildlife, recreation or domestic use, now and in the future. More water is withdrawn from U.S. lakes, rivers, streams and aquifers for the purpose of cooling power plants than for any other purpose.
- Air pollution from power plants threatens the health of millions of Americans.

Wind energy avoids about 68 million metric tons of global warming pollution annually—equivalent to taking 13 million of today's passenger vehicles off the road—and saves more than enough water to supply the annual water needs of a city the size of Boston. Wind energy also avoids 137,000 tons of nitrogen oxide emissions and 91,000 tons of sulfur dioxide emissions, important contributors to ozone smog and soot pollution.

- Texas, Iowa and California lead the nation in wind energy capacity, delivering the greatest reductions in global warming pollution, water consumption, and health-threatening air pollution. (See Figure ES-1 and appendices.)

If construction of new wind energy projects continues from 2013 to 2016 at a pace comparable to that of recent years, the United States could reduce global warming pollution by an additional 56 million metric tons in 2016—equivalent to the amount produced by 11 million passenger vehicles. These projects would also save enough water to meet the annual water needs of 600,000 people, and reduce air pollution by an additional 108,000 tons of nitrogen oxides and 79,000 tons of sulfur dioxide.

America has abundant wind energy potential. The U.S. Department of Energy estimates that 20 percent of the nation's electricity could be supplied by wind power in 2030, up from 3 percent in 2011. To achieve that level of generation, construction of new generating capacity would need continue at levels comparable to that of recent years.

Wind energy's success in reducing air pollution and saving water will continue to grow if policies such as tax incentives and renewable electricity standards are continued and expanded at the state and federal level:

- **The production tax credit.** The federal renewable electricity production tax credit (PTC) has been one of the most important tools to help grow the wind industry in the United States, but it is set to expire at the end of 2012. The loss of the tax credit could cause new construction to drop by 75 percent—and allow global warming pollution and water consumption to continue unabated.
- **The offshore wind investment tax credit.** The offshore wind investment tax credit (ITC) is designed to address the longer timelines for development and construction of offshore wind energy facilities. It covers up to 30 percent of the cost of new wind investments and grants offshore wind developers eligibility for the credit at the point that construction begins. The offshore wind ITC also expires on December 31, 2012.
- **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.
- **Tax policies for renewable energy.** Changes to the federal tax code could make more private investment available to wind energy nationwide by expanding two tax provisions that have benefited investors in non-renewable sources for decades.
- **Transmission policies.** Upgrading and expanding existing electricity transmission infrastructure can connect areas with high electricity demand to areas of high wind energy output. Transmission upgrades should occur only where clearly necessary and where environmental impacts will be minimal.

Introduction

There is a clean energy revolution happening in America.

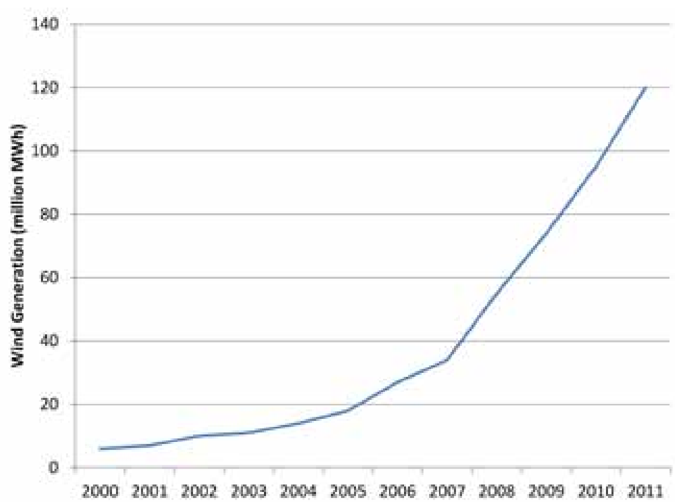
From the Pacific Coast to the Great Plains to the Northeast, renewable energy is on the rise, producing an increasing share of our electricity with minimal impact on the environment.

Consider wind energy. Just a decade ago, wind power was a trivial part of America's energy mix. Today, wind power accounts for 3 percent of our electricity. From 2006 to 2011 the amount of electricity America gets from wind power has quadrupled.

That remarkable progress 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 and harm our health while minimizing the use of water for cooling.

The boom in renewable energy, however, is no accident. It has taken the leadership of far-sighted state and federal policy-makers to create the conditions under which wind energy and other forms of renewable energy can thrive. With the environmental and economic benefits of wind energy becoming ever more apparent, now is the time for our leaders to renew their commitment to key clean energy policies.

Figure 1. Growth in Electricity Generated from Wind Power[1]



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.

Power Plants Help Fuel Global Warming

Power plants produce 40 percent of America's energy-related global warming pollution.[2] (See Figure 2.) While coal-fired power plants emit twice as much carbon dioxide as natural gas plants per unit of electricity, natural gas is far from a clean fuel.[3] Leaks during the extraction, storage and transportation of natural gas can release methane, a particularly potent global warming pollutant.[4] Recent studies suggest that those leaks may make natural gas—especially gas produced through hydraulic fracturing—nearly as damaging to the climate as coal.[5]

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. By 2100, the United States Global Change Research Program (USGCRP) anticipates a temperature increase of 4 to 11° F, depending on the scale of greenhouse gas emissions.[7]

Global warming has been linked to an increase in the frequency of intense rain and snowstorms across 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.[8] 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.[9]

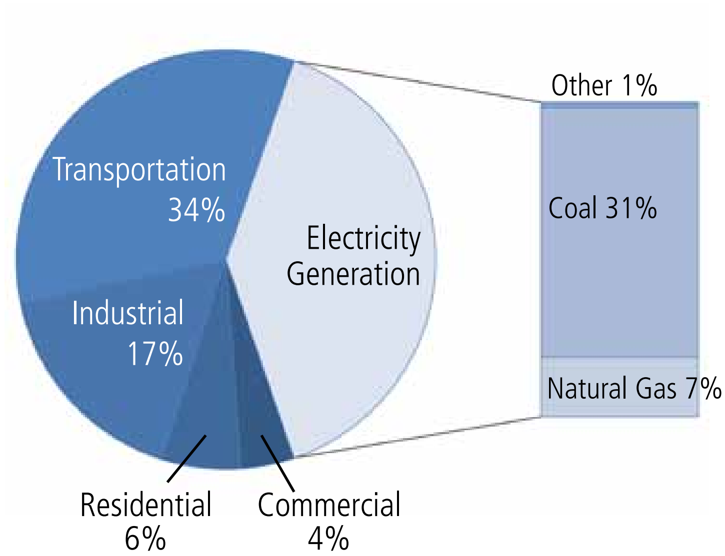
Sea levels have risen eight inches along some parts of the U.S. coastline in the past 50 years. Rising seas erode shorelines—putting homes, businesses and infrastructure at risk—and can cause saltwater intrusion into coastal fresh water aquifers, leaving some unusable without desalination.[10]

These and other impacts are expected to become more pronounced in the decades to come. Public health could suffer as heat waves become more frequent, longer lasting, and more intense, causing more heat-related deaths. Air quality will also be compromised as higher temperatures contribute to ozone "smog" formation, causing more illness, missed days of work and school, and hospitalizations.[11]

Rising temperatures may cause larger and more frequent forest fires, push some tree species northward and to higher altitudes, and eliminate other species altogether. In the oceans, warmer temperatures will cause shifts in marine species. Lobster catches in the southern part of the Northeast have already declined sharply due to the rise of a temperature-sensitive bacterial shell disease.[12]

Science tells us that we need to reduce our emissions of global warming pollution immediately and dramatically if we are to prevent the worst impacts of global warming.[13] Replacing fossil fuel-fired power plants with those using clean renewable energy is an important piece of any strategy to reduce global warming pollution.

Figure 2. Energy-Related Carbon Dioxide Emissions by Sector in the U.S., 2011, with Electricity Generation Broken Down by Fuel[6]



Power Plants Consume Lots of Water

More water is withdrawn from U.S. lakes, rivers, streams and aquifers for the purpose of cooling power plants than for any other purpose.[14] Power plants draw water from local sources for cooling, then either release the heated water back into waterways or evaporate it in a cooling tower. Consumption of water by power plants threatens critical ecosystems and reduces the amount available for human use and the protection of wildlife.

Power plants' thirst for water adds to the strain on local water supplies at times and in places where water is scarce. In Georgia in 2007, for example, a severe drought caused fierce competition for water from Lake Lanier, a major drinking water reservoir for Atlanta.[15] Georgia residents needed the water in the lake for domestic use, while a coal-fired power plant in Florida wanted more water released for cooling. At the same time, two endangered species of mussels downstream also required an adequate water flow.

Power plants in arid regions also 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.[16] For many of these regions, water withdrawn for electricity generation—combined with water pumped for other purposes—has been causing water levels in aquifers to drop, threatening the long-term viability of those aquifers.

By lowering water levels in rivers and streams and raising water temperatures, power plants also threaten aquatic ecosystems. Water discharged from a power plant can be 17 degrees hotter than it was when it was withdrawn for cooling.[17] Discharge temperatures may exceed 90 degrees. This hotter water affects the health and viability of the plants and animals living in the receiving waterway. In addition to the threat posed by heat stress, warmer water holds less dissolved oxygen. For example, fish in Lake Norman, in North Carolina, have been killed by hot water discharged from the cooling systems of two power plants and low dissolved oxygen levels caused in part by the heat.[18] Low water levels due to drought and power plant withdrawals compound the problem, allowing water temperatures to rise faster and higher.

Long before fuel is burned in a power plant, the mining and extraction of coal and natural gas hurts water supplies. Natural gas extraction through hydraulic fracturing involves mixing large volumes of water with chemicals and sand. Most of the water is pumped deep underground and is lost to the water cycle forever. The little that returns to the surface usually is too polluted for any use other than more mining or fracking. Coal production, too, destroys water supplies through pollution and destruction of waterways.

When Water Runs Low, Less Electricity May Be Produced

The dependence of most coal and natural gas-fired power plants on water supplies is not just an environmental problem—it can also threaten the stability of the electric grid. Without sufficient access to cool water, power plants have to reduce their output, often at the times when their electricity is in highest demand.

In 2007, drought and high water temperatures forced Duke Energy to curtail generation at two coal-fired power plants in North Carolina.[19] During the Texas drought in 2011, the cooling water supply serving the Martin Creek Power Plant dropped so much that water had to be piped in from a nearby river to cool the plant.[20] Officials in Texas warned that if the 2011 drought continued unabated into 2012, more power plants would be affected.[21] Thus, during hot summer months—when demand for power to run air conditioners is at its highest—power plants dependent on water for cooling can be forced offline.

Power Plants Create 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.

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.[22] 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.[23] 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.[24] In addition, it is a major component of acid rain that has damaged forests across the eastern U.S.[25]

Wind Energy Reduces Pollution and Saves Water

Wind energy is delivering substantial reductions in global warming pollution and water consumption across the U.S. Maintaining and expanding America's commitment to wind energy will produce even greater benefits.

Benefits from Existing Wind Facilities

Wind power is delivering environmental benefits across the nation by displacing generation from coal and gas plants. In 2011, the United States generated 120 million megawatt-hours (MWh) of electricity from wind power, or nearly 3 percent of electricity generated in the U.S.[26] (See Appendix A for a breakdown of wind power generation by state.)

Assuming that wind energy displaced generation from natural gas and coal-fired power plants, the environmental benefits of wind power in 2011 included:

- Avoided emissions of 68 million metric tons of carbon dioxide—as much as would have been emitted by 13 million passenger vehicles in a year (see Appendix B).
- Water savings of 26 billion gallons, more than enough to meet the annual domestic use needs of a city the size of Boston (see Appendix C).
- Reductions in air pollution, including reductions of 137,000 pounds of nitrogen oxide emissions and 91,000

pounds of sulfur dioxide emissions (see Appendix D).

Texas reaps greater savings from wind than any other state, avoiding 17 million metric tons of carbon dioxide emissions annually, or nearly 8 percent of 2009 emissions from the state's electric sector.[27] (See Figure 3 and Table 1 on p. 15.) In addition, as the state recovers from the extreme drought in 2011 that caused major rivers to run dry, wind power is averting the consumption of 6.5 billion gallons of water per year, enough to supply all the residents of Waco.

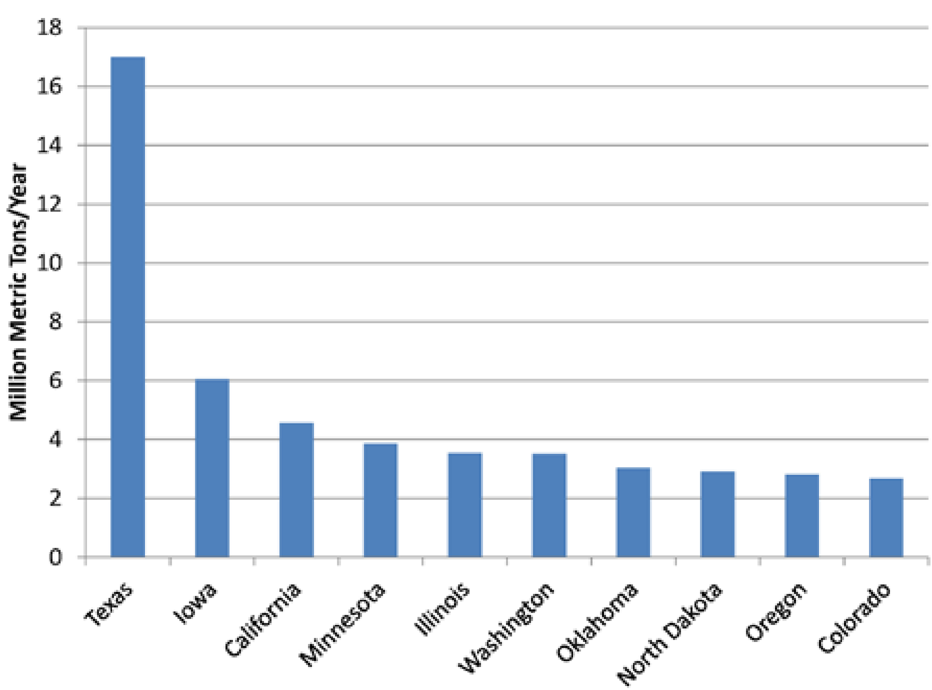
Seven of the top ten wind power-producing states are also on the list of states suffering from areas of extreme or exceptional drought in 2012.[28] Not including any new wind projects that were completed in 2012, wind power will have helped these seven states avoid consumption of 14.7 billion gallons of water at power plants, enough to serve more than 400,000 people.

The total benefits in 2012 will be greater as projects currently under construction are completed. Projects in progress could save an additional 17 million metric tons of carbon dioxide emissions per year, or as much as is emitted by 3.3 million passenger vehicles in a year. The nation can also expect to save an additional 6.5 billion gallons of water, enough for more than 175,000 people. (See appendices for full details.)

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

If construction of new wind capacity continues at a similar pace in coming years, environmental benefits will add up quickly.

Figure 3. Top 10 States for Carbon Dioxide Emission Reductions from Wind-Powered Generation in 2011



Assuming that the construction patterns observed in recent years continue, an additional 99 million MWh of electricity could be produced from wind in 2016. That would bring total generation from wind power to 249 million MWh in 2016, or 6 percent of all electricity generated in the U.S. in 2011.

Under this scenario, global warming pollution would be reduced by an additional 56 million metric tons. That is as much pollution as is released by 11 million passenger vehicles. Water savings would increase, too, with the addition of 21.6 billion gallons of savings, or enough for more than 600,000 people. This additional amount of water saved from wind energy would be almost enough to serve a city the size of Denver. Air pollution would decline by an additional 108,000 tons of nitrogen oxides and 79,000 tons of sulfur dioxide.

The U.S. has vast untapped potential wind energy. The U.S. Department of Energy estimates that 20 percent of the nation's electricity could be supplied by wind power in 2030, up from 3 percent in 2011.[29] That level of wind power could reduce electric sector water consumption by 17 percent in 2030 and cut global warming emissions by 825 million metric tons.

Table 1. Benefits of Wind Energy in Top 10 States, 2011

State	Wind Energy Production (MWh/year)	Avoided Carbon Dioxide Emissions (metric tons/year)	Water Saved (billion gallons/year)
Texas	30,051,000	17,005,000	6.54
Iowa	10,700,000	6,055,000	2.33
California	8,084,000	4,575,000	1.76
Minnesota	6,826,000	3,863,000	1.49
Illinois	6,263,000	3,544,000	1.36
Washington	6,209,000	3,514,000	1.35
Oklahoma	5,369,000	3,038,000	1.17
North Dakota	5,150,000	2,914,000	1.12
Oregon	4,961,000	2,807,000	1.08
Colorado	4,729,000	2,676,000	1.03

Table 2. Benefits in 2016 from Wind Energy Built in Top 10 States, 2013-2016, if Current Trends Continue

State	Possible New Wind Energy (MWh/year)	Avoided Carbon Dioxide Emissions (metric tons/year)	Water Saved (billion gallons/year)
Texas	20,645,000	11,683,000	4.49
Iowa	9,436,000	5,340,000	2.05
California	8,332,000	4,715,000	1.81
Oklahoma	5,761,000	3,260,000	1.25
Minnesota	5,487,000	3,105,000	1.19
Illinois	5,466,000	3,093,000	1.19
Oregon	5,012,000	2,836,000	1.09
Kansas	4,989,000	2,823,000	1.09
Washington	4,623,000	2,616,000	1.01
Colorado	4,116,000	2,329,000	0.90

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.

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 continue and expand its commitment to renewable energy.

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 offshore wind investment tax credit (ITC).

The PTC provides a 2.2 cents per kilowatt-hour (kWh) income tax credit for utility-scale wind energy producers, helping them compete effectively with other sources of electricity by guaranteeing low electricity prices for consumers. It is available for electricity generated during the first 10 years of the wind farm's operation. The PTC is set to expire on December 31, 2012.[30]

The offshore wind investment tax credit (ITC) is designed to address the longer timelines for development and construction of offshore wind energy facilities. It covers up to 30 percent of the cost of new wind investments and grants offshore wind developers eligibility for the credit at the point that construction begins. This is important for offshore wind because of the longer timelines for development. The offshore wind ITC also expires on December 31, 2012.[31]

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 volatility of coal and natural gas prices, and can deliver reliable, affordable electricity for decades, making them a smart long-term investment in the nation's energy future.

Over the past 13 years, the PTC has been only sporadically available. When the PTC has been renewed by Congress for only for one or two years at a time or even allowed to expire, the environment of economic 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.[32]

The loss of the PTC could cause new construction to fall by 75 percent.[33] Failing to extend the PTC beyond 2012 could result in the loss of $10 billion in investment and 37,000 jobs in 2013, according to an analysis by Navigant Consulting for the American Wind Energy Association.[34] Opponents of tax credits like the PTC and ITC argue that they are too expensive, costing taxpayers billions of dollars per year.[35]

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.[36] Some of the states with the strongest standards, such as Colorado, have seen the greatest growth in wind power generation. Raising the goals of existing state-level renewable electricity standards and adopting a national renewable electricity standard would further promote construction of wind capacity.

Transmission Infrastructure

Policymakers should prioritize upgrading and expanding existing electricity transmission infrastructure to connect areas with high electricity demand to areas of high wind energy output. Old and inefficient transmission infrastructure is one of the largest impediments to integrating more wind energy into the grid. Transmission upgrades should occur only where clearly necessary and where environmental impacts will be minimal.

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

We obtained data on annual wind generation (in MWh) in 2011 from Energy Information Administration, *Electric Power Monthly*, February 2012.

To estimate output from wind facilities currently under construction, we obtained data on wind capacity (in MW) under construction from American Wind Energy Association (AWEA), *Wind Energy Facts* (factsheets), August 2012. We assume that the capacity factor of wind farms varies by region, shown in Table A-1, 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, which have wind resources similar to the eastern region, have the same capacity factor as the East.

Our estimate of future wind energy construction is based on a national projection of an additional 34 GW of capacity from 2013 through 2016 in Navigant Consulting, for the American Wind Energy Association, *Impact of the Production Tax Credit on the U.S. Wind Market*, 12 December 2011.

Table A-1. Average Capacity Factor, Based on Projects Built from 2004-2010[37]

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

We apportioned this out to the states according to their share of the nation's existing and under-construction wind power capacity in MW, per AWEA, *Wind Energy Facts* (factsheets), August 2012. (Note that this produces results that appear to be at odds with the sum of output from existing and under-construction facilities. Some states have installed capacity (MW) that produced relatively little output (MWh) in 2011, but which was factored into future capacity and output.) We translated this future wind capacity into megawatt-hours (MWh) of generation following the same method as for facilities currently under construction, described above.

Estimating Carbon Dioxide Emission Reductions

When a wind turbine generates electricity, it displaces some other source of electricity on the grid. In the short run, this means that production at another power plant is reduced; in the longer run, it means that fewer fossil fuel-fired plants are built. In our calculations, we assume that 75 percent of the time, the power generator that is no longer producing electricity is a natural gas-powered plant and 25 percent of the time the facility is coal fired. Typically, in practice, the plant that is turned off is that with the highest marginal cost of production.

The fuel used in the marginal plant varies from region to region and from time to time based on a particular region's generating mix and prices. In the PJM generating region, which stretches from Maryland to New Jersey to Illinois, wind historically has displaced coal 60 percent of the time and natural gas and oil the rest of the time.[38] In contrast, in California and the Pacific Northwest, where a much smaller portion of electricity is generated by coal, natural gas is far more often the marginal fuel.

A ratio of 75 percent natural gas and 25 percent coal displacement is broadly representative of how wind influences the electricity grid. We obtained a national average emissions rate for coal and natural gas plants from Environmental Protection Agency, *eGRID2012 Version 1.0 Year 2009 GHG Annual Output Emission Rates*, 10 May 2012.

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, *Greenhouse Gas Equivalencies Calculator*, May 2011.

Estimating Water Consumption Avoided

We estimated water savings using freshwater and saltwater consumption rates in coal, natural gas combined cycle and natural gas combustion turbine plants from U.S. Department of Energy, 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 and 25 percent is from coal.

We calculated how many individuals' 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.

Estimating Avoided Emissions of Nitrogen Oxides and Sulfur Dioxide

We also estimated avoided emissions of nitrogen oxides and sulfur dioxide for each state. We calculated an average emissions rate for natural gas and coal generation in each state using 2010 nitrogen oxides and sulfur dioxide emission data from Energy Information Administration, *State Historical Tables for 2010* (EIA-767 and EIA-906), December 2011. We divided emissions by generation from natural gas and coal plants in 2010, per Energy Information Administration, *Net Generation by State by Type of Producer by Energy Source, Annual Back to 1990* (EIA-906, EIA-920 and EIA-923). We then created an average emission rate for each state based on a 25 percent coal/75 percent natural gas split.

Appendix A. Current and Future Annual Wind Generation by State

State	Rank: Existing Wind Energy	Existing Wind Energy (MWh/year)	Wind Energy Under Construction (MWh/year)	In 2016, Possible New Wind Energy (MWh/year)
Texas	1	30,051,000	4,685,000	20,645,000
Iowa	2	10,700,000	1,974,000	9,436,000
California	3	8,084,000	3,062,000	8,332,000
Minnesota	4	6,826,000	865,000	5,487,000
Illinois	5	6,263,000	1,342,000	5,466,000
Washington	6	6,209,000	586,000	4,623,000
Oklahoma	7	5,369,000	3,121,000	5,761,000
North Dakota	8	5,150,000	681,000	3,087,000
Oregon	9	4,961,000	932,000	5,012,000
Colorado	10	4,729,000	1,564,000	4,116,000
Wyoming	11	4,709,000	0	2,526,000
Kansas	12	3,759,000	4,243,000	4,989,000
Indiana	13	3,289,000	546,000	2,377,000
New York	14	2,826,000	473,000	2,030,000
South Dakota	15	2,692,000	0	1,441,000
New Mexico	16	2,089,000	85,000	1,390,000
Pennsylvania	17	1,968,000	940,000	1,663,000
Idaho	18	1,308,000	883,000	1,483,000
Montana	19	1,243,000	642,000	992,000
Wisconsin	20	1,196,000	0	972,000
Missouri	21	1,179,000	0	844,000
West Virginia	22	1,099,000	0	724,000
Nebraska	23	1,018,000	389,000	840,000
Maine	24	713,000	75,000	536,000
Utah	25	576,000	0	581,000
Michigan	26	437,000	1,358,000	1,520,000
Hawaii	27	326,000	330,000	339,000
Maryland	28	319,000	0	149,000
Arizona	29	249,000	0	426,000
Ohio	30	175,000	5,000	648,000
New Hampshire	31	78,000	105,000	215,000
Tennessee	32	53,000	0	36,000
Vermont	33	33,000	138,000	135,000
Massachusetts	34	28,000	74,000	122,000
Alaska	35	16,000	121,000	89,000
New Jersey	36	16,000	3,000	13,000
Delaware	37 (tie)	0	0	2,000
Nevada	37 (tie)	0	483,000	274,000
Rhode Island	37 (tie)	0	10,000	9,000
Virginia	37 (tie)	0	83,000	47,000

Appendix B. Annual Carbon Dioxide Emissions Avoided by Wind Energy

	Avoided Carbon Dioxide Emissions (metric tons/year)			Vehicles Equivalent of Avoided Pollution		
State	**Existing Wind Energy**	**Wind Energy Under Construction**	**In 2016, Possible New Wind Energy**	**Existing Wind Energy**	**Wind Energy Under Construction**	**In 2016, Possible New Wind Energy**
Alaska	9,000	69,000	50,000	2,000	13,000	10,000
Arizona	141,000	0	241,000	28,000	0	47,000
California	4,575,000	1,733,000	4,715,000	897,000	340,000	925,000
Colorado	2,676,000	885,000	2,329,000	525,000	174,000	457,000
Delaware	0	0	1,000	0	0	0
Hawaii	184,000	186,000	192,000	36,000	37,000	38,000
Idaho	740,000	500,000	839,000	145,000	98,000	165,000
Illinois	3,544,000	759,000	3,093,000	695,000	149,000	607,000
Indiana	1,861,000	309,000	1,345,000	365,000	61,000	264,000
Iowa	6,055,000	1,117,000	5,340,000	1,187,000	219,000	1,047,000
Kansas	2,127,000	2,401,000	2,823,000	417,000	471,000	554,000
Maine	403,000	42,000	303,000	79,000	8,000	59,000
Maryland	181,000	0	84,000	35,000	0	17,000
Massachusetts	16,000	42,000	69,000	3,000	8,000	14,000
Michigan	247,000	768,000	860,000	48,000	151,000	169,000
Minnesota	3,863,000	490,000	3,105,000	757,000	96,000	609,000
Missouri	667,000	0	477,000	131,000	0	94,000
Montana	703,000	363,000	561,000	138,000	71,000	110,000
Nebraska	576,000	220,000	475,000	113,000	43,000	93,000
Nevada	0	273,000	155,000	0	54,000	30,000
New Hampshire	44,000	59,000	122,000	9,000	12,000	24,000
New Jersey	9,000	2,000	7,000	2,000	0	1,000
New Mexico	1,182,000	48,000	786,000	232,000	9,000	154,000
New York	1,599,000	268,000	1,149,000	314,000	52,000	225,000
North Dakota	2,914,000	385,000	1,747,000	571,000	76,000	342,000
Ohio	99,000	3,000	367,000	19,000	1,000	72,000
Oklahoma	3,038,000	1,766,000	3,260,000	596,000	346,000	639,000
Oregon	2,807,000	527,000	2,836,000	550,000	103,000	556,000
Pennsylvania	1,114,000	532,000	941,000	218,000	104,000	185,000
Rhode Island	0	6,000	5,000	0	1,000	1,000
South Dakota	1,523,000	0	816,000	299,000	0	160,000
Tennessee	30,000	0	20,000	6,000	0	4,000
Texas	17,005,000	2,651,000	11,683,000	3,334,000	520,000	2,291,000
Utah	326,000	0	329,000	64,000	0	65,000
Vermont	19,000	78,000	77,000	4,000	15,000	15,000
Virginia	0	47,000	27,000	0	9,000	5,000
Washington	3,514,000	332,000	2,616,000	689,000	65,000	513,000
West Virginia	622,000	0	410,000	122,000	0	80,000
Wisconsin	677,000	0	550,000	133,000	0	108,000
Wyoming	2,665,000	0	1,429,000	523,000	0	280,000

Appendix C. Annual Water Consumption Avoided with Wind Energy

	Water Saved (million gallons/year)			Water Saved Could Provide Domestic Water for This Many People		
State	Existing Wind Energy	Wind Energy Under Construction	In 2016, Possible New Wind Energy	Existing Wind Energy	Wind Energy Under Construction	In 2016, Possible New Wind Energy
Alaska	3	26	19	100	800	600
Arizona	54	0	93	1,100	0	1,800
California	1,759	666	1,813	38,900	14,700	40,100
Colorado	1,029	340	896	23,300	7,700	20,300
Delaware	0	0	1	0	0	0
Hawaii	71	72	74	1,200	1,200	1,200
Idaho	285	192	323	4,200	2,800	4,700
Illinois	1,363	292	1,189	41,500	8,900	36,200
Indiana	716	119	517	25,800	4,300	18,600
Iowa	2,328	430	2,053	98,100	18,100	86,500
Kansas	818	923	1,086	27,700	31,200	36,700
Maine	155	16	117	7,900	800	5,900
Maryland	69	0	32	1,700	0	800
Massachusetts	6	16	26	200	500	900
Michigan	95	295	331	3,300	10,100	11,300
Minnesota	1,485	188	1,194	59,800	7,600	48,100
Missouri	257	0	184	8,000	0	5,700
Montana	270	140	216	6,600	3,400	5,300
Nebraska	222	85	183	4,500	1,700	3,700
Nevada	0	105	60	0	1,500	900
New Hampshire	17	23	47	600	800	1,700
New Jersey	3	1	3	100	0	100
New Mexico	455	19	302	11,600	500	7,700
New York	615	103	442	17,400	2,900	12,500
North Dakota	1,121	148	672	33,700	4,500	20,200
Ohio	38	1	141	1,500	0	5,600
Oklahoma	1,168	679	1,254	37,700	21,900	40,400
Oregon	1,080	203	1,091	24,400	4,600	24,700
Pennsylvania	428	204	362	20,600	9,800	17,400
Rhode Island	0	2	2	0	100	100
South Dakota	586	0	314	17,100	0	9,100
Tennessee	12	0	8	400	0	300
Texas	6,539	1,019	4,492	130,800	20,400	89,800
Utah	125	0	126	1,800	0	1,900
Vermont	7	30	29	300	1,300	1,300
Virginia	0	18	10	0	700	400
Washington	1,351	127	1,006	35,900	3,400	26,800
West Virginia	239	0	158	6,500	0	4,300
Wisconsin	260	0	211	12,500	0	10,200
Wyoming	1,025	0	550	18,500	0	9,900

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

	Avoided NO_X Emissions (tons/year)			Avoided SO_2 Emissions (tons/year)		
State	**Existing Wind Energy**	**Wind Energy Under Construction**	**In 2016, Possible New Wind Energy**	**Existing Wind Energy**	**Wind Energy Under Construction**	**In 2016, Possible New Wind Energy**
Alaska	40	310	230	20	120	90
Arizona	100	0	180	50	0	90
California	6,110	2,310	6,300	1,730	650	1,780
Colorado	3,680	1,220	3,210	1,700	560	1,480
Delaware	0	0	0	0	0	0
Hawaii	70	70	80	70	70	80
Idaho	9,310	6,280	10,550	14,050	9,490	15,940
Illinois	3,310	710	2,890	4,270	910	3,720
Indiana	1,710	280	1,230	3,100	520	2,240
Iowa	8,480	1,560	7,480	7,420	1,370	6,540
Kansas	5,540	6,250	7,350	1,290	1,460	1,720
Maine	670	70	500	1,110	120	840
Maryland	310	0	140	160	0	70
Massachusetts	10	20	40	30	80	140
Michigan	260	820	920	420	1,310	1,470
Minnesota	5,480	690	4,400	3,480	440	2,800
Missouri	520	0	370	1,000	0	720
Montana	5,450	2,810	4,350	340	180	270
Nebraska	1,290	490	1,060	780	300	640
Nevada	0	270	160	0	140	80
New Hampshire	30	40	80	230	310	630
New Jersey	10	0	10	10	0	10
New Mexico	1,830	70	1,220	340	10	230
New York	1,420	240	1,020	2,940	490	2,110
North Carolina	0	0	0	0	0	0
North Dakota	35,050	4,630	21,010	5,750	760	3,450
Ohio	70	0	250	240	10	880
Oklahoma	4,940	2,870	5,300	3,810	2,220	4,090
Oregon	3,470	650	3,510	4,700	880	4,750
Pennsylvania	780	370	660	1,880	900	1,590
Rhode Island	0	0	0	0	0	0
South Dakota	3,530	0	1,890	2,670	0	1,430
Tennessee	30	0	20	40	0	30
Texas	16,780	2,620	11,530	22,990	3,580	15,800
Utah	390	0	390	120	0	120
Vermont	10	60	60	0	0	0
Virginia	0	50	30	0	100	50
Washington	3,850	360	2,870	600	60	450
West Virginia	640	0	420	410	0	270
Wisconsin	600	0	480	1,030	0	840
Wyoming	10,740	0	5,760	2,040	0	1,090

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