The Clean Air Benefits of Wind Energy

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Executive Summary

Wind energy is a widely available, affordable, reliable, non-emitting, readily quantifiable and verifiable, and rapidly deployable electric generation method for significantly reducing air pollution, including emissions of carbon dioxide (CO_2), nitrogen oxides (NOx) and sulfur dioxide (SO_2). Indeed, the current fleet of wind turbines in the U.S. is already reducing carbon emissions by nearly 127 million tons per year.

In May 2014, the U.S. Global Change Research Program (USGCRP)[1] issued its National Climate Assessment.[2] The report documents the existing evidence and impacts of climate change here at home, including on a regional basis as well as on specific sectors like energy and human health. Wind energy is specifically identified as one of the available mitigation options.

Similarly, the U.N. Intergovernmental Panel on Climate Change[3] issued several volumes that make up its Fifth Assessment Report[4] earlier this year, which found a need to triple or nearly quadruple electric generation from zero- and low-carbon energy resources by 2050 in order to avert the worst consequences of climate change.

The U.S. Environmental Protection Agency (EPA) also notes the following about the benefits from reducing SO_2 and NOx: "By reducing SO_2 and NO_x, many acidified lakes and streams will significantly improve so that they can once again support fish life. Visibility will improve, allowing for increased enjoyment of scenic vistas across our country, particularly in National Parks. Stress to our forests that populate the ridges of mountains from Maine to Georgia will be reduced. Deterioration of our historic buildings and monuments will be slowed. Most importantly, reductions in SO_2 and NO_x will reduce fine particulate matter (sulfates, nitrates) and ground level ozone (smog), leading to improvements in public health."[5]

In order to address the aforementioned challenges and pursuant to decisions by the U.S. Supreme Court, the EPA in June 2014 will propose a rulemaking to, for the first time ever, provide for federal limits on carbon pollution from existing power plants under section 111(d) of the Clean Air Act.[6] States will play a key role in the compliance process with the final rule, in part through the submission of state plans that will detail how generators in their states will meet the carbon pollution standards set forth by the EPA.

As detailed in this white paper, wind energy is widely available across the country as a compliance option under 111(d) and is already playing a significant role in reducing carbon emissions in nearly every state, as well as emissions of other air pollutants. Further, as also described in the following pages, wind energy is doing so affordably and reliably for consumers.

Of particular note, this paper provides state-by-state numbers, calculated using the EPA's own Avoided Emissions and generation Tool (AVERT), for the emissions reductions

[1] The USGCRP is made up of 13 federal agencies and departments.
[2] A team of more than 300 experts guided by a 60-member Federal Advisory Committee produced the report, which was extensively reviewed by the public and experts, including federal agencies and a panel of the National Academy of Sciences. The report is available online at: http://nca2014.globalchange.gov/
[3] http://www.ipcc.ch/
[4] http://www.ipcc.ch/report/ar5/index.shtml
[5] Available at: http://www.epa.gov/airmarkets/progsregs/arp/basic.html#bens
[6] For more information, see: http://www2.epa.gov/carbon-pollution-standards

attributable to the currently installed wind turbine fleet in the U.S.

Among the key findings in this paper:

- The 167.7 million megawatt-hours (MWh) of wind energy produced in the U.S. in 2013 reduced CO_2 emissions by 126.8 million tons, the equivalent of reducing power sector emissions by more than 5 percent, or taking 20 million cars off the road.

- The top 10 states by volume of carbon reductions from wind energy are: Texas, Illinois, California, Colorado, Iowa, Missouri, Oklahoma, Wisconsin, Minnesota and Wyoming.

- States achieving a reduction in carbon emissions of 10 percent or more from wind energy alone include California, Colorado, Idaho, Iowa, Kansas, Minnesota, Nebraska, Oregon, South Dakota, Vermont, and Washington State, with Oklahoma, Wisconsin and Wyoming coming in just under 10%.

- One MWh of wind energy avoids .75 tons, or 1,500 pounds, of carbon dioxide emissions on average. A typical 2 MW wind turbine avoids around 4,000-4,500 tons of carbon emissions annually, equivalent to the annual carbon emissions of more than 700 cars.

- Wind energy currently reduces SO_2 emissions by nearly 347 million pounds per year and NO_x by 214 million pounds per year.

- Wind energy saved 36.5 billion gallons of water in 2013 that would have been consumed at conventional power plants, the equivalent of roughly 116 gallons per person in the U.S., or 276 billion bottles of water, providing critical relief in drought-stricken areas.

- There are 61,110 megawatts (MW) of wind energy capacity installed in 39 states and Puerto Rico, representing more than 46,000 operational utility-scale wind turbines. There are now 16 states with 1,000 MW or more of installed wind energy capacity.

- Over the last five years, wind energy has accounted for 31 percent of all newly installed electric generating capacity, second only to natural gas. In 2012, wind energy was the largest source of all new generating capacity at 42 percent.

- In some regions, such as the Pacific Northwest, Plains states and the Midwest, wind energy has been the primary source of new capacity over the last three years, providing 60 percent or more of all new electric generating capacity. In the Upper Midwest, wind energy provided more than 80 percent of all new generating capacity from 2011-2013.

- The existing wind turbine fleet provides the electrical output equivalent to 53 average coal plants or 14 average nuclear plants.

- On an average annual basis, wind energy produces more than 25 percent of the electricity in two states, 12 percent or more in nine states, and five percent or more in 17 states.

- The average power purchase price of wind energy has fallen 43 percent over the last 5 years, with both the Energy

Information Administration and Lazard finding that wind energy is second only to a combined cycle natural gas plant in terms of lowest cost source of new electric generation.

- While other generation may need to ramp up or down to accommodate the variability of wind energy (and other far larger sources of variability on the power system like electricity demand and the sudden failure of large conventional generators), two recent studies from different regions in the U.S. document that such cycling has virtually no net effect on the emissions reductions from wind energy, with wind producing 99.8 percent of the carbon emissions savings expected of a zero emissions resource.

- Wind energy can play an even greater role in reducing emissions reductions going forward. More than a dozen utility and independent grid operator studies have found wind can reliably provide an even larger share of our electricity needs, which will, in turn, produce even larger emissions reductions. For example, an NREL study for the Eastern U.S. found that obtaining 20 percent of electricity from wind energy cut power sector carbon emissions by 25 percent, and 30 percent wind cut carbon emissions by 37 percent, relative to the baseline generation mix.

- Wind energy can continue to rapidly scale up. Since the end of 2005, the U.S. wind energy industry has doubled its installed capacity, on average, every 36 months. The U.S. industry installed a high of more than 13,000 MW in 2012, and there are currently more wind projects under construction in the U.S. than at any point in history. U.S. wind energy's five year average annual growth rate is 19.5 percent from 2009-2013.

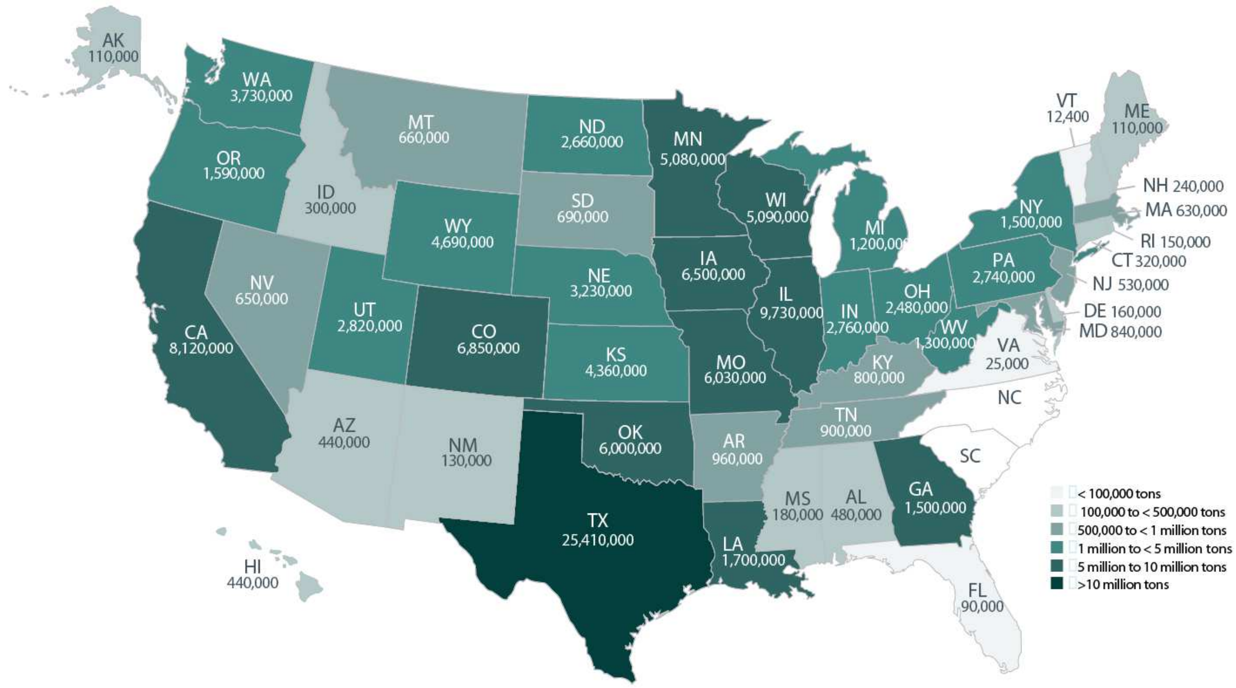

Figure 1: Wind energy's 2013 emissions reductions by state, using EPA's AVERT tool[7]

Wind energy is greatly reducing emissions of carbon dioxide and other pollutants in nearly every state.

AWEA used a new EPA modeling tool to quantify the state-by-state pollution reductions wind energy is currently providing, and the results are shown in the map and tables below. The 167.7 million megawatt-hours (MWh) of wind energy produced in the U.S. in 2013 reduced CO_2 emissions by 126.8 million short tons, the equivalent of reducing power sector emissions by more than 5 percent or taking 20 million cars off the road. These emissions savings were broadly distributed across nearly every state, accounting for the fact that wind energy is widely deployed and that many utilities in states without wind plants are purchasing wind energy from other states. Emissions savings are reported in the states where the AVERT model indicates fossil-fired power plants

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[7] EPA recently released a new tool, AVERT, that allows for the calculation of emissions reductions associated with wind energy and other non-emitting solutions. EPA's AVERT tool uses empirical power system data to identify the power plants that are most likely to have their fuel use and emissions reduced by the addition of wind energy or another zero-carbon solution, and then reports in highly granular detail the impact of that solution on each power plant's emissions. AVERT is available for download at http://epa.gov/statelocalclimate/resources/avert/index.html. AWEA put DOE EIA 2013 state-by-state wind generation data, available at http://www.eia.gov/electricity/monthly/current_year/february2014.pdf, into the AVERT tool. For this analysis, which was intended to calculate where wind power is reducing emissions in physical reality, emissions reductions were counted in the wind-producing region for power purchase contracts that are not known to call for physical delivery of the wind generation, such as those involving renewable energy credit purchases. However, as a policy matter, AWEA is advocating that EPA allocate credit for emissions reductions to the entity purchasing the wind generation and associated environmental attributes, which would result in a different state-by-state distribution. This analysis modeled emissions savings in the receiving region only for power purchase contracts that are known to call for the physical delivery of wind generation from one AVERT region to another, such as those from wind plants in the Northwest to utilities in California and from Upper and Lower Midwest wind plants to utilities in the Southeast. Because the AVERT tool's regions are not perfectly coterminous with actual grid operating areas, particularly in the Southeast and to a lesser extent the Western U.S., to better reflect reality calculated emissions savings in the Southeast were allocated to states with utilities that have wind development or wind purchases with physical delivery of the generation. AVERT does not model Hawaii and Alaska, so those were calculated separately using EIA fuel mix and emissions data. The share of total electric sector CO_2 emissions is calculated from EIA data for 2011, the most recent year for which data is available.

are reducing their emissions due to wind generation, which in interstate power markets are not always the states in which the wind plants are located. Results are listed alphabetically by state name in the first table, and ranked by amount of carbon emission reductions in the second.

According to the results from the AVERT tool, one MWh of wind energy avoids .75 tons, or 1,500 pounds, of carbon dioxide emissions on average. A typical 2 MW wind turbine avoids around 4,000-4,500 tons of carbon emissions annually, equivalent to the annual carbon emissions of more than 700 cars.

Importantly, the AVERT analysis prepared by AWEA also demonstrates that wind energy plays an important role in reducing emissions of SO_2 and NO_x, facilitating compliance with EPA regulations limiting those pollutants. Wind energy currently reduces SO_2 emissions by nearly 347 million pounds per year and NO_x by 214 million pounds per year.

Wind energy reduces emissions because electricity produced by a wind project results in an equivalent decrease in electricity production at another power plant. Due to its low operating costs (and zero fuel cost), grid operators use wind energy to ramp down the output of the online power plants with the highest operating costs, which are typically the least efficient fossil fuel-fired power plants due to their high fuel costs. Wind energy is also occasionally used to reduce the output of hydroelectric dams, which allows the dam to store water that is used later to displace fossil generation.

As discussed in AWEA's most recent annual market report, independent power system operators have also conducted studies that identify the impact of wind generation on system-wide carbon emissions, and have concluded that wind energy displaces 0.48 to 0.81 short tons of carbon dioxide per MWh of wind generated,[8] which is consistent with the results from the AVERT analysis above. Wind's emissions savings vary somewhat by region due to variations in the fossil-fuel generation mix, primarily driven by variations in the share of time that coal versus gas provide marginal generation.

The AWEA report also calculated that in 2013 wind energy saved 36.5 billion gallons of water that would have been consumed at conventional power plants, the equivalent of roughly 116 gallons per person in the U.S. or 276 billion bottles of water, providing critical relief in drought-stricken areas.[9]

[8] AWEA U.S. Wind Industry Annual Market Report for the Year Ending 2013, available at http://www.awea.org/AMR2013

[9] Ibid.

Table 1: State-by-state analysis of wind energy's 2013 emissions reductions using EPA's AVERT tool, ***listed alphabetically by state name***

	CO2 reductions (tons)	Share of 2011 electric sector CO_2 emissions	SO2 reductions (pounds)	NOX reductions (pounds)
Alabama	479,000	0.59%	3,419,000	776,000
Alaska	115,000	3.19%	202,000	1,079,000
Arizona	437,000	0.75%	217,000	548,000
Arkansas	959,000	2.48%	2,528,000	1,843,000
California	8,117,000	16.83%	66,000	6,502,000
Colorado	6,849,000	13.81%	11,413,000	14,384,000
Connecticut	321,000	4.25%	191,000	358,000
Delaware	162,000	3.71%	216,000	145,000
Florida	88,000	0.07%	259,000	115,000
Georgia	1,497,000	1.97%	7,324,000	2,334,000
Hawaii	437,000	5.07%	2,097,000	2,490,000
Idaho	303,000	38.19%	3,000	78,000
Illinois	9,727,000	8.84%	25,665,000	9,438,000
Indiana	2,760,000	2.26%	18,038,000	5,799,000
Iowa	6,496,000	13.70%	27,682,000	14,737,000
Kansas	4,356,000	10.37%	6,666,000	8,126,000
Kentucky	804,000	0.77%	3,651,000	1,040,000
Louisiana	1,705,000	3.23%	8,003,000	2,434,000
Maine	109,000	4.53%	187,000	60,000
Maryland	841,000	3.35%	3,096,000	1,509,000
Massachusetts	635,000	3.88%	1,664,000	564,000
Michigan	1,197,000	1.65%	5,510,000	2,285,000
Minnesota	5,081,000	13.76%	7,023,000	8,640,000
Mississippi	180,000	0.71%	262,000	203,000
Missouri	6,032,000	6.52%	21,689,000	7,729,000
Montana	662,000	3.50%	2,330,000	1,756,000
Nebraska	3,225,000	10.35%	13,314,000	6,467,000
Nevada	651,000	3.91%	1,049,000	1,340,000
New Hampshire	243,000	4.27%	574,000	375,000
New Jersey	532,000	3.01%	224,000	599,000
New Mexico	130,000	0.38%	82,000	374,000
New York	1,500,000	3.87%	2,504,000	2,415,000
North Dakota	2,662,000	7.85%	6,129,000	7,882,000
Ohio	2,477,000	1.99%	16,410,000	4,037,000

Oklahoma	5,996,000	9.98%	18,215,000	15,845,000
Oregon	1,586,000	18.38%	3,214,000	1,712,000
Pennsylvania	2,736,000	2.13%	14,425,000	6,914,000
Rhode Island	150,000	3.77%	6,000	58,000
South Dakota	685,000	18.04%	5,005,000	4,006,000
Tennessee	900,000	1.98%	4,947,000	819,000
Texas	25,413,000	8.86%	68,602,000	29,397,000
Utah	2,818,000	7.08%	2,785,000	10,676,000
Vermont	12,000	66.11%	171	8,000
Virginia	25,000	0.08%	144,000	77,000
Washington	3,727,000	31.52%	1,855,000	9,989,000
West Virginia	1,220,000	1.52%	2,933,000	1,265,000
Wisconsin	5,087,000	9.96%	18,602,000	6,324,000
Wyoming	4,689,000	9.40%	6,561,000	8,873,000
Total	**126,814,000**	**5.11%**	**346,981,000**	**214,422,000**

Table 2: State-by-state analysis of wind energy's 2013 emissions reductions using EPA's AVERT tool, ***ranked by carbon emissions reductions***

State	CO2 reductions (tons)	Share of 2011 electric sector CO_2 emissions	SO2 reductions (pounds)	NOX reductions (pounds)
Texas	25,413,000	8.86%	68,602,000	29,397,000
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Nebraska	3,225,000	10.35%	13,314,000	6,467,000
Utah	2,818,000	7.08%	2,785,000	10,676,000
Indiana	2,760,000	2.26%	18,038,000	5,799,000
Pennsylvania	2,736,000	2.13%	14,425,000	6,914,000
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Total	**126,814,000**	**5.11%**	**346,981,000**	**214,422,000**

Wind energy is a widely available electric generating resource.

AWEA's *U.S. Wind Industry Annual Market Report for the Year Ending 2013* finds there are 61,110 megawatts (MW) of wind energy capacity installed in 39 states and Puerto Rico (Figure 1), representing more than 46,000 operational utility-scale wind turbines. There are now 16 states with 1,000 MW or more of installed wind energy capacity.

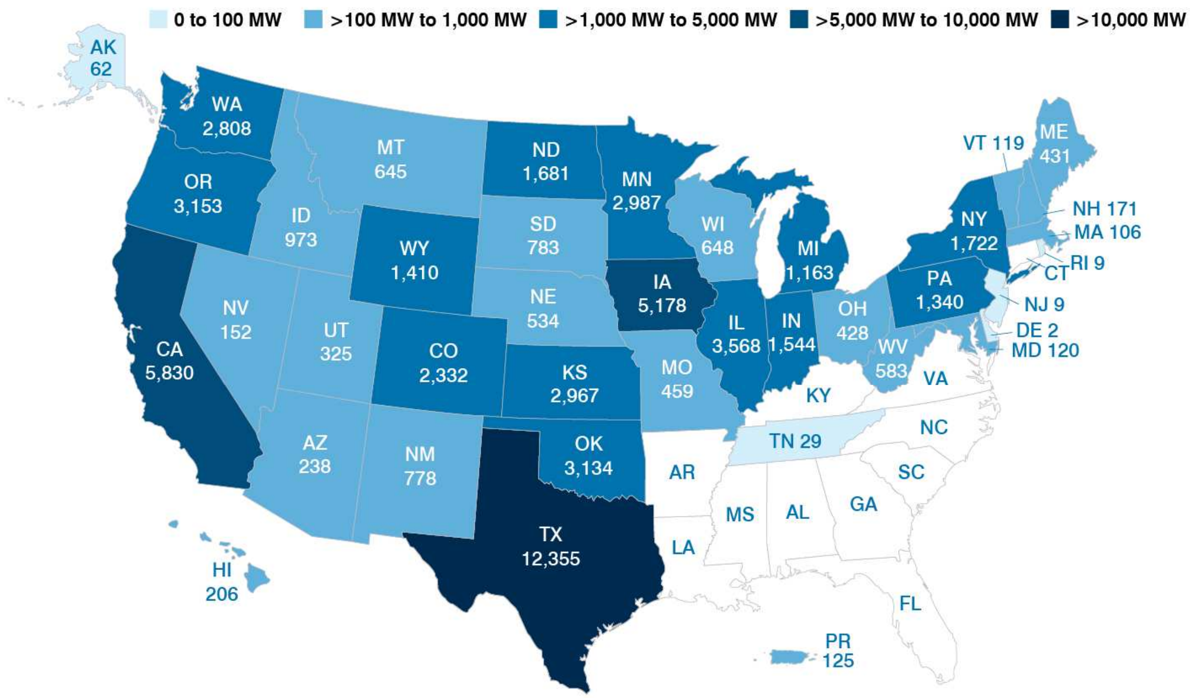

Figure 1: Installed U.S. Wind Energy Capacity in MW, by State through 2013

This represents 5.7 percent of total installed U.S. electric generating capacity. In terms of actual electricity production, wind energy accounted for 4.1 percent of electric generation in 2013 (up from 2.9 percent in 2011 and 3.5 percent in 2012). The existing wind turbine fleet provides the electrical output equivalent to 53 average coal plants, or 14 average nuclear plants.

Over the last five years, wind energy has accounted for 31 percent of all newly installed electric generating capacity, second only to natural gas. In 2012, wind energy was the largest source of all new capacity at 42 percent.

In some regions, such as the Pacific Northwest, Plains states and the Midwest, wind energy has been the primary source of new capacity over the last three years, providing 60 percent or more of all new electric generating capacity. In the Upper Midwest, wind energy provided more than 80 percent of all new generating capacity from 2011-2013.

On an average annual basis, wind energy produces more than 25 percent of the electricity in two states, 12 percent or more in nine states, and five percent or more in 17 (Figure 3).

Even the states not colored in on the two charts above increasingly have opportunities to take advantage of the environmental benefits of wind energy through both projects in-state as well as contracting for wind energy from out-of-state.

Wind energy technology is rapidly improving, mostly through the use of taller towers and longer blades that allow access to higher wind speeds and make lower-wind-speed sites more economic. As a result, wind project developers are now exploring opportunities in states where wind energy was not previously viable, such as much of the Southeast. In addition to the 39 states with existing installed wind energy capacity, wind energy project developers have publicly acknowledged the pursuit of wind projects in Kentucky, Virginia, North Carolina, Florida, and Alabama, with initial prospecting in Georgia and Louisiana, according to press reports. Moreover, utilities in Tennessee, Arkansas, Georgia, Alabama, and Louisiana have already signed power purchase contracts to buy electricity from wind energy facilities in other states, demonstrating that wind energy is a widely available compliance option nationwide.

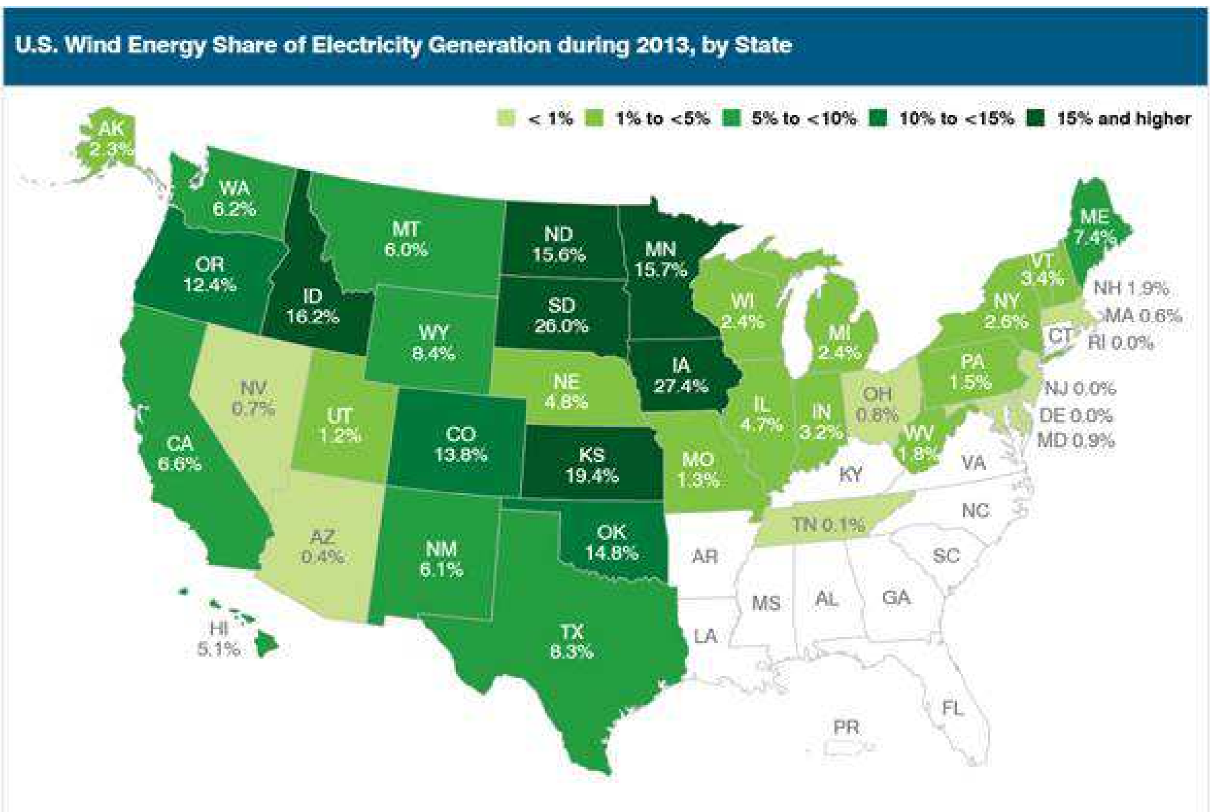

Figure 2: Percentage share of electricity generation by Wind during 2013, by State

Wind energy is affordable.

Wind energy's costs are declining dramatically. Lazard, a widely-respected financial advisory and asset management firm reported[10] (Figure 3) in 2013 that wind energy is second only to natural gas combined cycle power plants for being the most affordable source of new electric generation, even without considering incentives. This analysis included operating, maintenance and transmission costs.

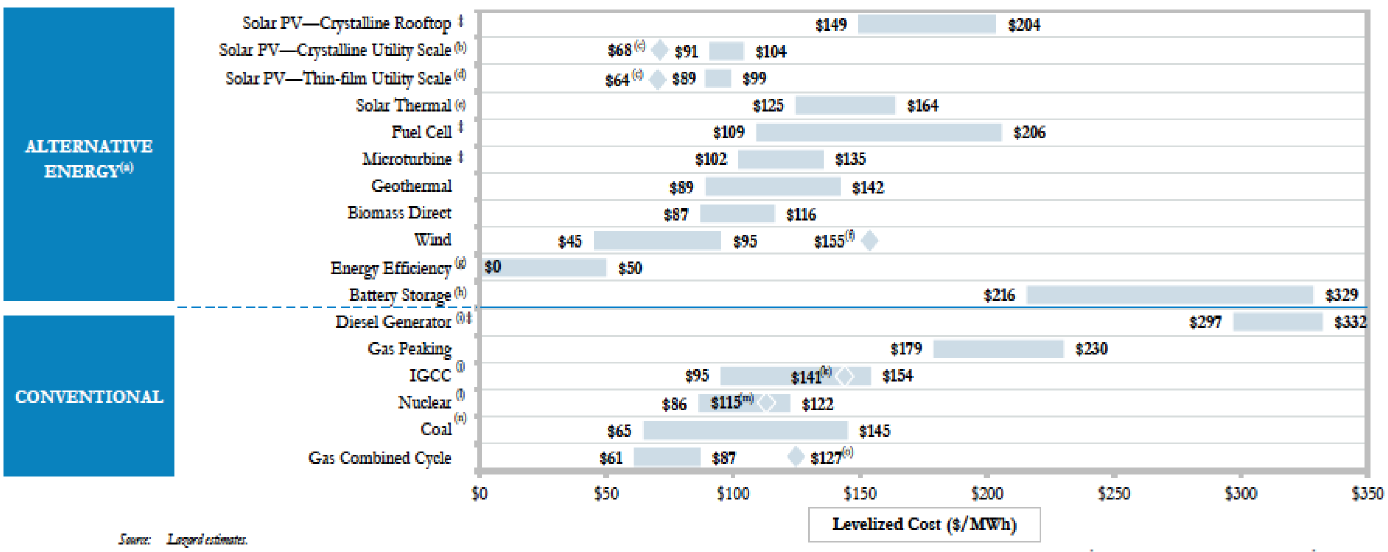

Figure 3: Levelized cost of energy (LCOE) analysis from Lazard

The U.S. Energy Information Administration projects similar results for 2019, with wind energy being one of the most affordable options second only to combined cycle natural gas.[11] Wind energy costs declined dramatically, more than 7 percent, since last year's EIA assessment.

Other DOE data confirm the marked decline in wind energy's costs, with data based on real-world contracts for wind energy showing even lower costs. DOE's annual wind market report[12] indicates the price of wind energy power purchase agreements declined 43 percent from 2009-2012 to a low of $40/MWh in 2012. Those declines appear to have continued over the last year based on recent public announcements of very low-priced wind power purchase agreements. For example, in wind-rich areas, some wind power purchase agreements have been recorded in the $20-30/MWh range.

A May 2013 report[13] by Synapse Energy Economics found that doubling the use of wind energy in the Mid-Atlantic and Great Lakes states would save consumers $6.9 billion per year on net, after accounting for all wind and transmission investment costs.

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[10] Lazard's Levelized Cost of Energy Analysis, image available at http://i0.wp.com/cleantechnica.com/files/2013/09/Screen-shot-2013-09-11-at-1.50.34-PM.png. Wind's range of costs in the image are primarily due to regional variations in wind plant capacity factor and installed costs for wind. The dot at $155/MWh in the image represents offshore wind.

[11] http://www.eia.gov/forecasts/aeo/electricity_generation.cfm , Table 1

[12] DOE 2012 Wind Technologies Market Report, available at: http://emp.lbl.gov/sites/all/files/lbnl-6356e.pdf

[13] Synapse Energy Economics, *The Net Benefit of Increased Wind Power in PJM,* by Bob Fagan, Patrick Luckow, Dr. David White, and Rachel Wilson (Cambridge, MA, 2013), available at: http://www.synapse-energy.com/Downloads/SynapseReport.2013-05.EFC.Increased-Wind-Power-in-PJM.12-062.pdf

More than a dozen other studies confirm the finding that wind energy drives electricity prices down, which is of course good for consumers.[14]

In addition to its current affordability, contracted wind energy is guaranteed to remain affordable tomorrow because it offers the stability of a long-term fixed energy price for 15-25 years. This is in contrast to the volatile prices that can characterize non-renewable fuels.[15] Wind energy keeps energy prices low much like a fixed rate mortgage protects homeowners from interest rate spikes. As the Lawrence Berkeley National Lab reported, wind energy acts as a hedge to protect consumers even in an environment in which gas prices are below historic averages.[16]

Newly released Department of Energy data[17] show that energy prices in states that use the most wind energy have on average trended lower than in states that use less wind energy. The eleven states that produce more than seven percent of their electricity from wind energy have seen their electricity prices fall by a demand-weighted average of 0.37 percent over the last 5 years, while all other states have seen their electricity prices increase by 7.79 percent over the same time period. Between the end of 2008 and the end of 2013, these eleven top wind states more than doubled their operating wind power, increasing their wind capacity by 116 percent.

Wind energy's emissions reductions are easily quantified and verified.

Wind energy's emissions reductions are readily quantifiable and verifiable, making wind energy an attractive solution for states to comply with 111(d). All utility-scale wind projects have revenue-grade metering equipment that measures the amount of wind energy production. Among other reasons, such equipment and verification is necessary to ensure compliance with power purchase contract generation requirements and for

[14] See page 4 at http://awea.files.cms-plus.com/AWEA%20White%20Paper-Consumer%20Benefits%20final.pdf

[15] The following quotes provide examples of utilities acknowledging the affordability of wind energy: "Wind Prices are extremely competitive right now, offering lower costs than other possible resources, like natural gas plants. These projects offer a great hedge against rising and often volatile fuel prices." David Sparby, president & CEO of Xcel Energy's Northern States Power announcing 600 MW of new wind power contracts on July 16, 2013, available http://www.greentechmedia.com/articles/read/wind-power-said-to-beat-natural-gas-in-midwest; an AEP subsidiary in Oklahoma tripled the amount of wind energy it planned to buy last year because "extraordinary pricing opportunities that will lower costs for PSO customers by an estimated $53 million in the first year of the contracts…annual savings are expected to grow each year over the lives of the contracts." available at: http://www.nawindpower.com/e107_plugins/content/content.php?content.12588; John Kelley, Alabama Power's Director of Forecasting and Resource Planning stated: "These agreements [referring to contracts to purchase wind power] are good for our customers for one very basic reason, and that is, they save our customers money." available at: http://www.renewableenergyworld.com/rea/news/article/2012/10/alabama-power-wants-more-affordable-wind-power; MidAmerican Energy's 2013 press release after the Iowa Utilities Board approved the addition of 1,050 MW of wind generation in Iowa "The expansion is planned to be built at no net cost to the company's customers and will help stabilize electric rates over the long term by providing a rate reduction totaling $10 million per year by 2017, commencing with a $3.3 million reduction in 2015." Available at: http://www.midamericanenergy.com/wind_news.aspx

[16] Ernest Orlando Lawrence Berkeley National Laboratory, *Revisiting the Long-Term Hedge Value of Wind Power in an Era of Low Natural Gas Prices* 21 (March 2013), available at http://emp.lbl.gov/sites/all/files/lbnl-6103e.pdf (". . . even in today's low gas price environment, and with the promise of shale gas having driven down future gas price expectations – wind power can still provide protection against many of the higher-priced natural gas scenarios . . .").

[17] U.S. Energy Information Administration, Electric Power Monthly with Data for November 2013 (January 2014), available at: http://www.eia.gov/electricity/monthly/pdf/epm.pdf. Additional analysis available in the AWEA report *Wind Power's Consumer Benefits* available at: http://awea.files.cms-plus.com/AWEA%20White%20Paper-Consumer%20Benefits%20final.pdf

purposes of claiming the federal production tax credit (PTC), which is based on electricity actually generated, on tax returns.

In addition, rigorous accounting mechanisms for renewable energy credits are in wide use in 29 states and the District of Columbia for compliance with state renewable portfolio standard requirements in those states, and accounting mechanisms are in place nationwide for verifying renewable energy production to satisfy voluntary purchases of such credits. These well-established accounting mechanisms could be readily adopted for compliance with section 111(d) to ensure that renewable energy production is not double-counted and can be precisely and rigorously quantified.

Several tools, such as marginal emissions calculations[18] and power system modeling, allow carbon emissions reductions to be calculated based on the measured wind energy production. EPA's AVERT, used for the wind emissions savings analysis above, is a free and easy-to-use option for calculating wind energy's pollution reductions.[19]

The cycling of other generation has a negligible impact on wind's emissions savings.

While other generation may on occasion need to ramp up or down to accommodate the variability of wind energy (plus the variability of other far larger sources of variability on the power system like electricity demand and the sudden failure of large conventional generators), two recent studies from different regions in the U.S. document that such cycling has virtually no negative effect on the emissions reductions from wind energy.

A peer-reviewed analysis by a Department of Energy lab found that wind energy produces 99.8 percent of the carbon emissions savings expected of a zero-emissions resource.[20] The study examined real-world hourly emissions from every power plant in the western U.S. and analyzed the impact wind energy has on the efficiency of other power plants by causing them to change their output more frequently. The study found that for a scenario with wind and solar providing 33 percent of electricity on the Western U.S. power system, one MWh of wind energy saves more than 1,190 pounds of carbon pollution on average, with those savings reduced by only 0.2 percent, or 2.4 pounds, as a result of increased cycling of fossil-fired power plants.

[18] Marginal generation and emissions data track which power plant or power plants are economically "on the margin" in each operating hour, and thus which generating units would have been dispatched down had demand been 1 MW lower or an additional 1 MW of low-cost supply (such as from wind) been available, allowing one to calculate the marginal emissions savings based on the heat or emissions rate for those marginal units. When combined with an hourly wind output profile for the region, that allows one to calculate wind's total emissions savings with a very high degree of accuracy. Some Independent System Operators (ISOs) and utilities already calculate and publicly release data on marginal fuel mixes and emissions, and other utilities should already have the data necessary to conduct such a calculation. For example, see http://www.iso-ne.com/genrtion_resrcs/reports/emission/.

[19] Available at: http://epa.gov/statelocalclimate/resources/avert/index.html

[20] National Renewable Energy Lab Western Wind and Solar Integration Study, Phase 2 Results, available at: http://www.nrel.gov/docs/fy13osti/55588.pdf; all WWSIS documents available at: http://www.nrel.gov/electricity/transmission/western_wind.html

Emission Impacts of Cycling Are Relatively Small Compared to Emission Reductions Due to Renewables

	Emission Reduction Due to Renewables	Cycling Impact
CO_2	260–300 billion lbs 29%–34%	Negligible Impact
NO_x	170–230 million lbs 16%–22%	3–4 million lbs
SO_2	80–140 million lbs 14%–24%	3–4 million lbs

Figure 4: National Renewable Energy Lab, Western Wind and Solar Integration Study Phase II results

This finding was confirmed by PJM's March 2014 renewable integration study, which found scenarios with large amounts of wind energy still yielded the expected emissions reductions after cycling impacts were taken into account.[21]

DOE data also show that states that have ramped up their use of wind energy the most have seen the efficiency of their fossil-fired power plants hold up as well or better than states that use the least wind energy.[22]

As explained in the next section, the impact of cycling is virtually non-existent because wind energy only incrementally adds to existing power system variability and flexible reserve needs..

[21] See http://www.pjm.com/~/media/committees-groups/task-forces/irtf/postings/pjm-pris-task-3a-part-g-plant-cycling-and-emissions.ashx at page 91. The differences in CO_2 emissions savings among the study's scenarios are driven by the fact that, due to their different output profiles, onshore wind tends to offset more carbon-intensive coal generation while other renewable resources, such as offshore wind and solar, tend to offset more gas generation. The high onshore wind cases all produce emissions reductions that are almost directly proportional to the quantity of fossil MWh displaced, indicating the impact of cycling is minimal.

[22] Goggin, M., 2013, "Wind energy's emissions reductions: A statistical analysis," available at http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=6672865&url=http%3A%2F%2Fieeexplore.ieee.org%2Fiel7%2F6657332%2F6672065%2F06672865.pdf%3Farnumber%3D6672865

Large amounts of wind energy can be reliably integrated onto the power system

Grid operators are now reliably accommodating very large quantities of renewable energy in the U.S. and Europe. As explained above, wind energy produces more than 25 percent of the electricity in two states, 12 percent or more in nine states, and five percent or more in 17 states on an annual basis. In certain hours, wind has supplied more than 60 percent of the electricity on the main utility system in Colorado without any reliability problems, and other grid operators have also reliably integrated very large amounts of wind energy, as indicated in Figure 6.

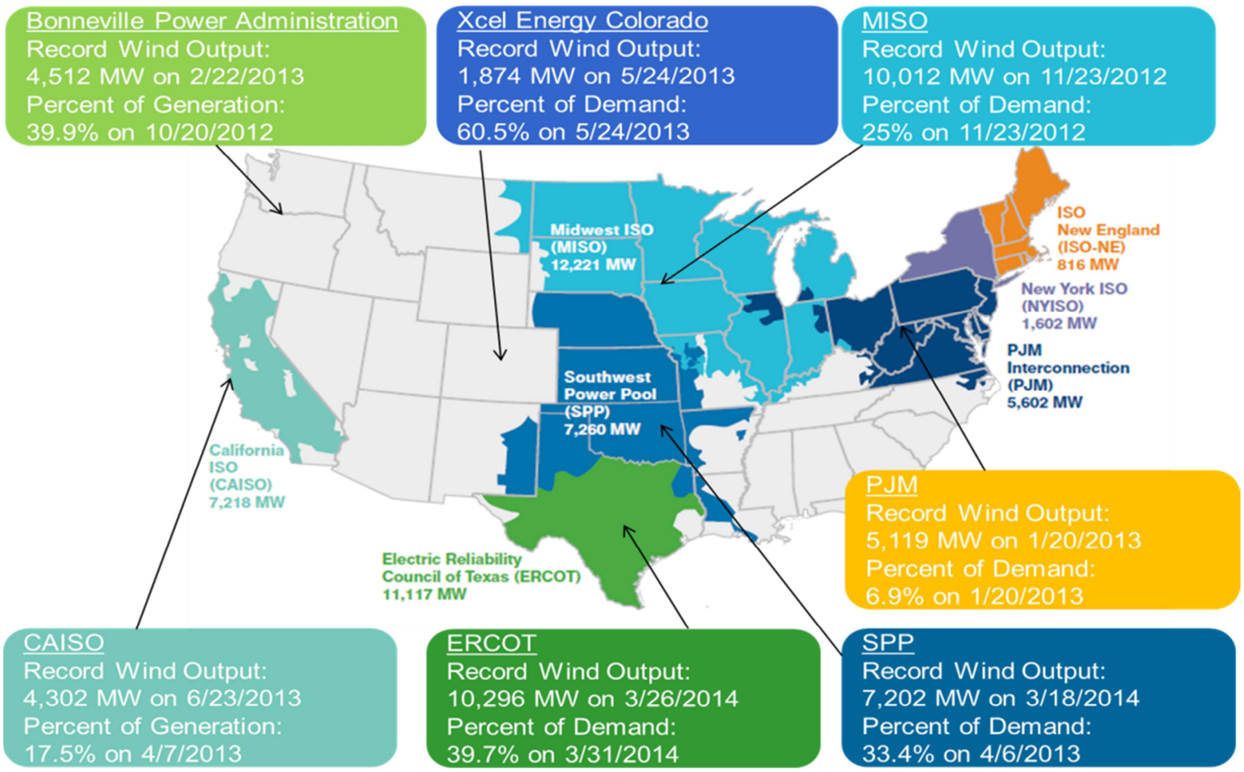

Figure 5: Wind energy integration records set in the U.S. 2012-2014; Source: AWEA Annual Market Report for the Year Ending 2013

Grid operators in Texas have integrated more than 10,000 MW of wind energy with only very small increases in their need for flexible reserves, with the need for fast-acting flexible reserves increasing by less than 100 MW.[23] The Midcontinent Independent System Operator (MISO) has also stated that the impact of wind power has had on its need for flexible reserves, used to accommodate variability in electricity supply and demand, has been “little to none.”[24]

The March 2014 renewable integration study[25] by the PJM grid operator confirms that wind energy only minimally contributes to total power system variability, with the addition of 28,000 MW of wind capacity in the 14 percent renewable energy scenario, causing an increase in operating reserve needs of only 340 MW. This is about 1/10 of the 3,350 MW of the operating reserves PJM needs at all times to maintain

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[23] Available at: http://variablegen.org/wp-content/uploads/2012/12/Maggio-Reserve_Calculation_Methodology_Discussion.pdf
[24] Available at: http://variablegen.org/wp-content/uploads/2012/12/Navid-Reserve_Calculation.pdf
[25] Renewable Integration Study for PJM, available at: http://www.pjm.com/~/media/committees-groups/task-forces/irtf/postings/pjm-pris-final-project-review.ashx, at page 111

reliability in case a large conventional power plant abruptly fails, and less than one-third the amount of reserves necessary to deal with variability in electricity demand. Current data indicate the largest hourly changes in electricity demand are 10 times larger than the largest hourly changes in wind energy output for PJM.[26] PJM's integration study concluded that the "PJM system, with adequate transmission and ancillary services in the form of Regulation, will not have any significant issue absorbing the higher levels of renewable energy penetration considered in the study."[27]

Dozens of in-depth wind integration studies[28] confirm that far larger amounts of wind energy can be added to the power system without harming reliability. How is this possible when the wind doesn't blow all the time?

Every day, grid operators constantly accommodate variability in electricity demand and supply by increasing and decreasing the output of flexible generators – power plants like hydroelectric dams or natural gas plants can rapidly change their level of generation. Thus, the water kept behind a dam or the natural gas held in a pipeline may be thought of as a form of energy storage, with operators using this energy when it is needed and "storing" it when it is not.

Grid operators have always kept large quantities of fast-acting generation in reserve to respond to abrupt failures at large conventional power plants, a challenge and cost that is far greater than accommodating any incremental variability added by the gradual and predictable changes in the aggregate output of a wind fleet. Grid operators use these same flexible resources to accommodate any incremental variability introduced by wind energy that is not canceled out by other changes in electricity supply or demand. Wind energy's impact on total power system variability and uncertainty, and, in turn, its impact on reserve needs, is greatly reduced as most changes in wind output are offset by other changes in supply or demand.

In addition, wind plant technology has matured significantly over the last decade so that modern wind turbines provide equivalent or better capabilities[29] for supporting power system reliability needs as conventional power plants in almost every category. Recent analysis by WECC, the entity responsible for power system reliability in the Western U.S., found that in a scenario with very high renewable penetration across the West, "the system results did not identify any adverse impacts due to the lower system inertia or differently stressed paths due to the higher penetration of variable generation resources."[30] Analysis conducted for the California grid operator identified no major concerns for frequency response in a transition to a high-renewable future, finding that "None of the credible conditions examined, even cases with significantly high levels of wind and solar generation (up to 50% penetration in California), resulted in under-frequency load shedding (ULFS) or other stability problems."[31] This occurs in part because adding wind generation causes conventional power plants to have their output reduced, which provides them with more

[26] http://www.pjm.com/~/media/committees-groups/task-forces/irtf/20130417/20130417-item-05-wind-report.ashx, and http://www.pjm.com/markets-and-operations/energy/real-time/loadhryr.aspx

[27] http://www.pjm.com/~/media/committees-groups/committees/mic/20140303/20140303-pjm-pris-final-project-review.ashx, page 12

[28] For the full list, see: http://variablegen.org/resources/

[29] See this NERC report: http://www.nerc.com/docs/pc/ivgtf/IVGTF_Report_041609.pdf, at page 22

[30] Available at http://www.wecc.biz/committees/StandingCommittees/PCC/RS/RPEWG%20-%20RS%20Meetings8-21-13/Lists/Minutes/1/VGSStudy7-15-13.doc

[31] Available at http://www.caiso.com/Documents/Report-FrequencyResponseStudy.pdf

range to increase their output and provide frequency response.[32]

In addition, new techniques employing wind plants' sophisticated controls and power electronics enable wind plants themselves to provide fast-acting frequency response. The National Renewable Energy Laboratory (NREL) recently released an in-depth analysis that concluded "wind power can act in an equal or superior manner to conventional generation when providing active power control, supporting the system frequency response and improving reliability."[33] The report further documented how major utilities like Xcel Energy are using this capability of wind plants in some hours to provide all of the frequency response and regulation needed to maintain power system reliability, which has enabled Xcel's Colorado power system to at times reliably obtain more than 60 percent of its electricity from wind energy.

Going forward, the emissions reduction potential from wind energy is even greater.

More than a dozen utility and independent grid operator studies have found wind can reliably provide an even larger share of our electricity, producing even larger emissions reductions. An NREL study for the Eastern U.S.[34] found that obtaining 20 percent of electricity from wind energy cut power sector carbon emissions by 25 percent, and 30 percent wind cut carbon emissions by 37 percent, relative to the baseline generation mix.

The Department of Energy found that a scenario of 20 percent wind energy by 2030[35] was technically and economically feasible. The U.S. is currently ahead of schedule in reaching 20 percent wind energy by 2030. This DOE study found that the 20 percent wind scenario would avoid 825 million tons of CO_2 annually by 2030, cutting expected electric sector emissions by 20-25 percent, the equivalent of taking 140 million vehicles off the road. This 2008 DOE study is being updated and is expected to be released later in 2014.

Real-world experience in European countries confirms that wind energy is a reliable and highly effective tool for reducing carbon dioxide emissions. Denmark, Germany, Ireland, Portugal, and Spain lead the world in obtaining the largest share of their electricity from wind energy, and all have seen drastic declines in the carbon intensities of their electric sectors. As indicated in the table below[36], there is a very strong relationship between growth in wind generation and a decline in carbon intensity. Interestingly, Germany would have seen a far larger decline in carbon intensity had it not, for unrelated reasons, reduced the share of electricity it obtains from nuclear energy from 29.6 percent in 2001 to 17.7 percent in 2011.

Country	Wind % '01	Wind % '11	Share growth	CO_2/MWh % change
Denmark	11.9%	29.1%	17.2%	-28.9%
Germany	1.9%	8.5%	6.6%	-12.3%
Ireland	1.4%	16.6%	15.2%	-36.1%
Portugal	0.6%	17.9%	17.4%	-32.4%
Spain	3.0%	15.2%	12.2%	-23.8%
OECD Europe	**0.8%**	**5.3%**	**4.4%**	**-11.0%**

32 http://web.mit.edu/windenergy/windweek/Presentations/GE%20Impact%20of%20Frequency%20Responsive%20Wind%20Plant%20Controls%20Pres%20and%20Paper.pdf
33 Available at http://www.nrel.gov/news/press/2014/7301.html
34 National Renewable Energy Lab Eastern Wind Integration Study, available at: http://www.nrel.gov/electricity/transmission/eastern_renewable.html

35 20% Wind Energy by 2030: Increasing Wind Energy's Contributions to U.S. Electricity Supply, U.S. Department of Energy, available at: http://www.nrel.gov/docs/fy08osti/41869.pdf
36 The data to create this chart came from International Energy Agency statistics through 2011, the most recent year for which data on CO_2 per MWh are available. IEA statistics are available at: http://www.iea.org/statistics/

Wind energy is scalable and rapidly deployable, and thus ideal as an emissions reduction tool.

Wind plants offer a rapidly deployable solution for reducing emissions of carbon dioxide and other pollutants. Wind developers already have a large backlog of wind projects in the development pipeline, and it is typically possible to build a wind project in a little over a year, far faster than many other low- or zero-carbon solutions.

Since the end of 2005, the U.S. wind energy industry has doubled its installed capacity, on average, every 36 months. Over the last decade, the industry has gone from a low mark of installing 396 MW in 2004 to a high of more than 13,000 MW in 2012, and there are currently more wind projects under construction in the U.S. than at any point in history. U.S. wind energy's five year average annual growth rate is 19.5 percent from 2009-2013. The previously mentioned DOE 20 percent wind report found that with existing technology, the industry can ramp up to sustained deployment of around 16,000 MW of newly installed wind capacity per year.

In 2003, wind energy generated only 11 million MWh, or 0.3 percent of the generation mix. By 2008, wind energy generated 55 million MWh, or 1.3 percent of the mix. In 2013, wind energy generated 167 million MWh, or 4.1 percent of total generation.[37]

[37] The statistics in this section come for the AWEA annual market report for the year ending 2013.