

## Industry Analysis

# Sure as the wind blows: the potential of wind energy in the U.S.

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- Efficiency gains and government support behind the expansion of wind energy
- Positive outlook due to technology and growing incentives to lower CO2 emissions
- Still, uncertainty about Clean Power Plan and storage technologies could hinder the prospects for wind and other renewables

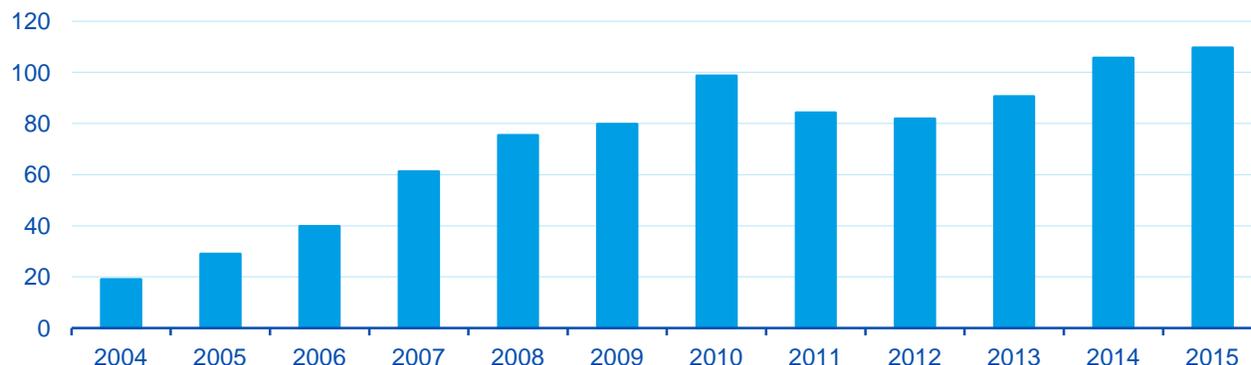
## Introduction

From grinding grain, pumping water or propelling ships, humans have benefited from wind power for centuries. Today, utility-scale wind farms onshore and offshore produce enough electricity to supply the needs of millions of businesses and individuals around the world. The expansion of utility-scale wind-powered electricity has been exponential thanks to government support, technological change and private investments.

Global cumulative wind generated capacity reached 432 GW in 2015, equivalent to 22% of total renewables capacity. Wind energy is the second largest source of renewable generation capacity after hydropower, with 95% of wind capacity located in Asia, Europe and North America. In 2015, wind generation capacity increased by 17% or 63 GW, more than any other renewable source, and faster than the growth of total renewables capacity (8.3%).<sup>1</sup> Global investments in wind energy projects totaled nearly \$875 billion from 2004 to 2015, second only to solar energy (\$1,044 billion). In 2015, global wind investments reached a record \$109.6 billion.

Chart 1

### Global Trend in Wind Energy Investment (\$billion)



Source: IRENA

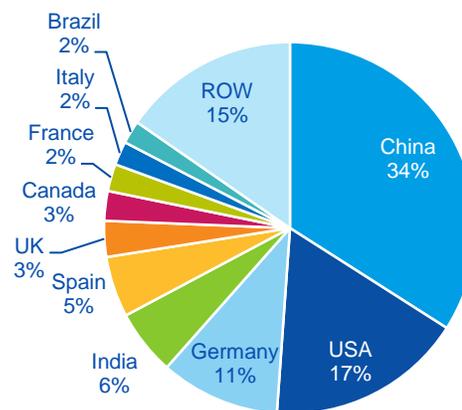
<sup>1</sup> International Renewable Energy Agency (IRENA). 2016. "Renewable Capacity Highlights." <http://goo.gl/v5DnNg>

**Chart 2**  
World Installed Wind Power Capacity (GW)



Source: IRENA

**Chart 3**  
Total Wind Power Capacity Installed by Country, 2015 (share of total)



Source: World Wind Energy Association

## Characteristics of wind energy projects

A wind power plant or farm is comprised of a series of turbines located in places where wind flows are abundant. The wind farm is connected to the grid, which distributes electricity to the final consumers. Typically, wind farms make money by engaging in long-term purchase agreements with utilities. There are three basic elements to consider in a wind energy system: connection to the grid (connected vs. stand-alone), type of installation (offshore/onshore) and type of turbine (horizontal/vertical axis).

Wind turbines are the costliest part of a wind system, representing between 60 and 80% of the total capital cost for onshore projects and 30 to 50% for offshore projects. The productivity of a turbine is proportional to the diameter of its rotor/hub and the cube of the wind speed. Significant progress has been made to expand the size of the rotor, which is projected to increase from 15 meters in 1985 to 250 meters in 2017 while maximum turbine capacity is expected to move from 0.05 MW up to 10 MW in the same period.<sup>2</sup> The International Renewable Energy Agency (IRENA) estimates that turbine prices have gone down 30% since they peaked in 2008-2009, with the sharpest decline occurring in China, where prices fell by 35% from their peak in 2007.<sup>3</sup>

The wind turbine manufacturing industry is dominated by a few international companies. The top manufacturers are for the most part based outside the U.S., with the sole exception of General Electric.<sup>4</sup> In 2015, Goldwind became the first Chinese firm to top Bloomberg's annual ranking of onshore wind turbine manufacturers; in fact, five out of the top 10 firms hailed from China, with companies from Denmark, Germany, U.S. and Spain rounding out the list.<sup>5</sup> China's interest in developing an onshore wind industry is the result of high pollution levels in its major cities, creating the need for government support, such as access to land, feed-in tariffs, subsidies to suppliers, and guaranteed supply contracts.

<sup>2</sup> IRENA. 2016. "Wind Power Technology Brief." <http://goo.gl/Q1Ghur>

<sup>3</sup> *Ibid.*

<sup>4</sup> National Renewable Energy Laboratory. 2015. "2014 Cost of Wind Energy Review." <http://goo.gl/KrXtXK>

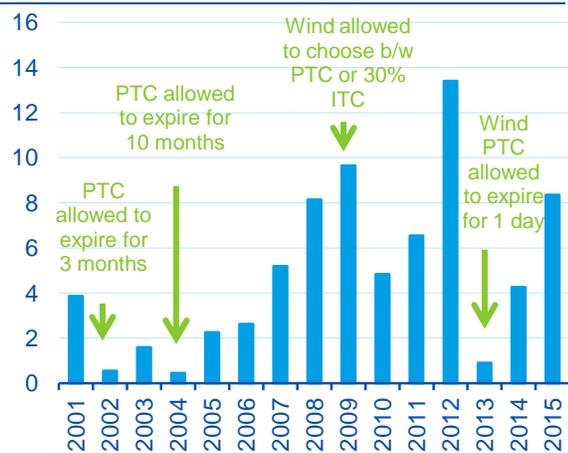
<sup>5</sup> Bloomberg New Energy Finance. 2016. "In a First, Chinese Firm Tops Annual Ranking of Wind Turbine Makers." <http://goo.gl/vcgQvi>

Globally, better technologies have driven down the cost of producing electricity with wind. According to IRENA, the levelized cost of electricity (LCOE) for onshore wind projects gravitates between \$0.040 and \$0.16/kWh, similar to that of fossil fuels (\$0.045 and \$0.14/kWh). Offshore wind's LCOE is higher, between \$0.091 and \$0.25/kWh. The weighted average LCOE for onshore energy declined to \$0.06 from \$0.07/kWh between 2010 and 2015, but slightly increased for offshore wind from \$0.157 to \$0.159.<sup>6</sup>

### The U.S. Wind Energy Industry

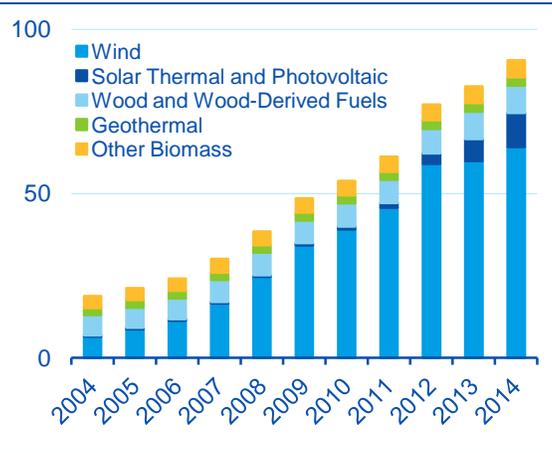
In 2015 alone, the U.S. installed 8.6 GW of wind generation capacity—more than in 2013 and 2014 combined. In the same year, wind energy was responsible for generating 4.7% of total electricity (74.5 GW) in the U.S., up from 0.2% in 2001.<sup>7</sup> From 2014 to 2015, wind energy added more electric generation capacity than any other source followed by natural gas and solar photovoltaics.<sup>8</sup> Together, these three sources were responsible for 96% of total capacity additions, with wind accounting for 41%. Nevertheless, the trend of wind capacity additions has been volatile over time, reflecting the uncertainty of government support. However, although wind is leading generation capacity among renewables, it still lags behind coal or natural gas, which together make up around 60% of total generation. From an energy consumption perspective, wind accounts for only 2% (1.8 quadrillion BTU) of total primary energy consumption in the country.

Chart 4  
**U.S. Annual Wind Capacity Additions (GW)**



Source: Energy Information Administration

Chart 5  
**Existing Net Summer Capacity of Renewable Sources by Producer Type (GW)**



Source: Energy Information Administration

The U.S. is the leader in exports of small wind turbines (less than 100 kW), typically used for stand-alone electricity systems or rural electrification. The nation's largest export markets for these turbines are Canada and Brazil, but local content requirements (LCRs) in those countries may limit the strength of U.S. exports in the future. The use of LCRs in these countries is an effort to foster the manufacturing of high technology components in order to spur their nascent domestic wind industries. The International Trade Administration

<sup>6</sup> In 2015 dollars. Source: IRENA.

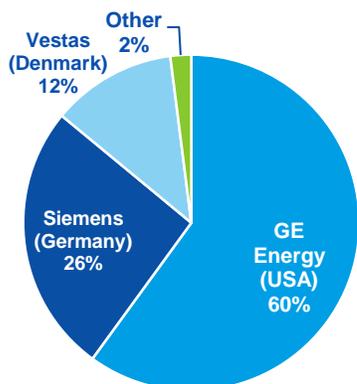
<sup>7</sup> U.S. Department of Energy. 2015. "Wind Vision: A New Era for Wind Power in the United States." <http://goo.gl/IOCwJ8>

<sup>8</sup> Energy Information Administration (EIA). 2016. "Wind adds the most electric generation capacity in 2015, followed by natural gas and solar." <http://goo.gl/86eK06>

projects that Canada, Brazil, Mexico, Uruguay and China will account for the majority of U.S. wind exports through 2020.<sup>9</sup>

In contrast, for turbines larger than 100 kW, the U.S. wind energy industry depends heavily on imports. However, the share of wind power equipment imports (e.g. blades, towers, generators) as a fraction of total turbine cost declined from 75% in 2006-07 to 30% in 2012-13. The customs value of wind-powered electric generating sets imported into the U.S. totaled \$226 million in 2015, down from its 2008 peak of over \$2.6 billion. In 2015, the top countries from which these imports originated were Denmark, Spain, Germany, India and Japan. China does not appear in the top five, although some of the largest wind turbine manufacturers are in the country. This is largely due to a trade dispute in 2012, after which the U.S. imposed substantial tariffs on imported towers from China. Domestic sourcing is more prevalent for large, transportation-intensive components, such as towers, of which 20-30% were imported, versus smaller parts such as generators, of which over 85% were imported.<sup>10</sup>

Chart 6  
U.S. Capacity-Weighted OEM Suppliers (%)



Source: NREL

Chart 7  
U.S. Imports Wind-Powered Electric Generating Sets by Country (\$ billions, customs value)



Source: USITC

**Cost competitiveness:** The LCOE is a useful measure for comparing the competitiveness of utility-scale projects, as it takes into account the costs of capital, fuel, operations, maintenance, and financing. However, comparing LCOE across technologies should be taken with caution since it tends to overlook other aspects such as the value of the energy source displaced by the new technology and the cost of environmental and health externalities, particularly of fossil fuels. In addition, the LCOE can vary significantly depending on the methodology used.

The National Renewable Energy Laboratory estimated that the total LCOE for a land-based wind project using 1.94 MW turbines is \$65/MWh<sup>11</sup>, while a study from Bloomberg New Energy Finance shows that the LCOE for onshore wind was \$83/MWh in 2H15.<sup>12</sup> According to financial firm Lazard, the unsubsidized LCOE for wind is

<sup>9</sup> International Trade Administration. 2016. "2016 Top Markets Report: Renewable Energy." <http://goo.gl/WssPHc>

<sup>10</sup> U.S. Department of Energy. 2015. "2014 Wind Technologies Market Report." <http://goo.gl/dRhJil>

<sup>11</sup> National Renewable Energy Laboratory. 2015. *Op. Cit.*

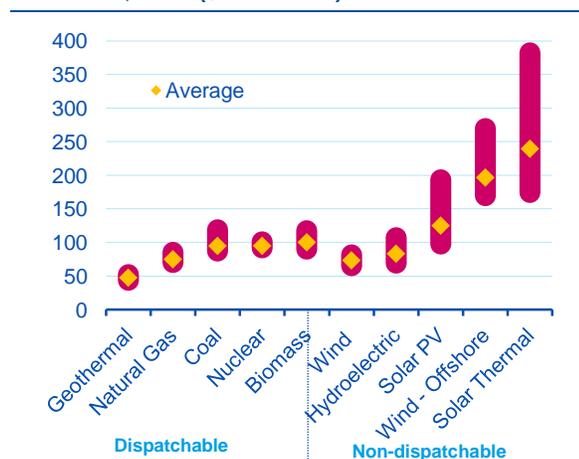
<sup>12</sup> Down from \$85/MWh in 1H15. Bloomberg New Energy Finance. 2015. "Wind and Solar Boost Cost-Competitiveness Versus Fossil Fuels." <http://goo.gl/7owjRO>

between \$32 and \$77/MWh, falling within \$14 and \$63/MWh with subsidies in place; coal and natural gas are less cost competitive—ranging from \$65 to \$150/MWh and \$52 to \$78/MWh, respectively.<sup>13</sup>

In its Annual Energy Outlook 2015, the Energy Information Administration (EIA) estimates the average LCOE for different types of technologies. The analysis includes companies that will become operational in 2020. When accounting for type of technology and subsidies, the LCOE of onshore wind is one of the lowest (73.6 2013\$/MWh) among both dispatchable and non-dispatchable technologies. It is also close to the LCOE of natural gas-fired plants with combined cycle. Among non-dispatchable technologies (offshore wind, solar photovoltaics (PV), solar thermal, and hydroelectric), onshore wind has the lowest LCOE.<sup>14</sup>

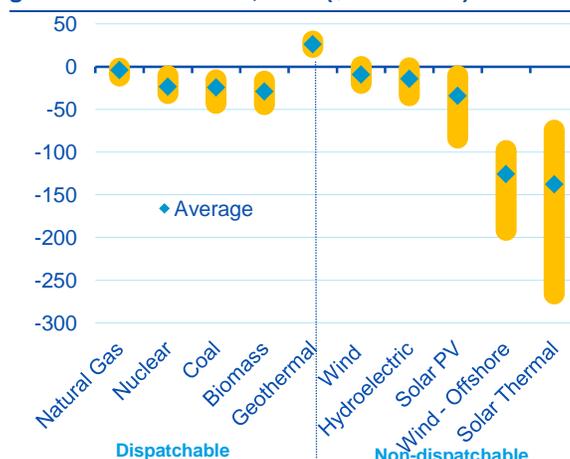
To address the limitations of LCOE, the EIA calculates the difference between the levelized avoided cost of electricity (LACE) and the LCOE for projects coming online in 2020 and those that could become operational in 2040. According to EIA, this difference can be read as an approximation to the net economic value of a project. When adjusted for subsidies, technology, year and region, some wind projects becoming operational in 2020 show positive values, meaning that there are regions for which wind makes economic sense relative to the displaced technologies; however, the same occurs with natural gas, suggesting strong competition within the two sources over time. The same pattern occurs for 2040 projects, although other technologies like solar PV and geothermal also gain in competitiveness.<sup>15</sup>

Chart 8  
Regional variation in LCOE for new generation resources, 2020 (\$2013/MWh)



Source: Energy Information Administration

Chart 9  
Regional variation in LACE-LCOE for new generation resources, 2020 (\$2013/MWh)



Source: Energy Information Administration

**Offshore wind:** At the moment, U.S. wind generation remains entirely land-based, but there are 21 offshore wind projects in the development pipeline, representing 15.7 GW. In July 2015, the U.S. reached a major milestone when one of these projects, the Block Island Wind Farm off the coast of Rhode Island, was the first to reach the construction phase and is expected to come online in the fall of 2016.<sup>16</sup> By 2050, the Department of Energy (DOE) projects that 86 GW of offshore wind energy could be installed in the U.S., with projects deployed

<sup>13</sup> Lazard. 2015. "Lazard's Levelized Cost of Energy Analysis—Version 9.0" <https://goo.gl/rOV4eG>

<sup>14</sup> Energy Information Administration. 2015. "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2015." Annual Energy Outlook 2015. <https://goo.gl/7wJplW>

<sup>15</sup> *Ibid.*

<sup>16</sup> National Renewable Energy Laboratory. 2015. "2014-2015 Offshore Wind Technologies Market Report." <http://goo.gl/mlqHHe>

on the East and West Coasts, the Great Lakes and the Gulf of Mexico.<sup>17</sup> The U.S. offshore industry has had a slow start, but has the advantage of leveraging the expertise of Europe, which is the worldwide leader in this sector with over 84 offshore wind farms and 3,230 turbines that feed 11.03 GW through the grid.<sup>18</sup>

Developing offshore wind energy in the U.S. has the potential to provide abundant renewable energy, particularly to those living in coastal cities with high energy costs and demand, such as Boston and New York City. In addition, compared to onshore wind farms, those located offshore can harness the energy of stronger and more uniform winds.<sup>19</sup> One major barrier is cost; the total system LCOE of offshore wind farms that enter service by 2020 is \$196.9/MWh, higher than that of onshore wind, solar PV and hydroelectric technologies.<sup>20</sup> However, a recent study found that the LCOE could decline 55% by 2030, given anticipated technology improvements and the development of offshore wind at scale.<sup>21</sup> This will ultimately allow developers to offer clean power at competitive market rates.

## The role of government

Government intervention has been critical in the development of the U.S. wind energy industry. Initially, investment tax credits were introduced as part of the Energy Tax Act of 1978.<sup>22</sup> Credits were based on installation levels rather than performance, resulting in low equipment productivity and reliability.<sup>23</sup> To remedy the situation, the production tax credit (PTC) was introduced in the Energy Policy Act of 1992, offering a tax credit of \$0.023/kWh of energy produced. The PTC has undergone a cycle of expiration and renewal since its inception, having been allowed to lapse five times, with its most recent expiration at the end of 2014.<sup>24</sup> PTC cycles are behind the volatility observed in capacity additions (Chart 4).

Government interest in wind and other renewables intensified in 2008, when the DOE published a landmark report establishing a framework for reaching a 20% contribution of wind energy to U.S. electricity supply by 2030 and laid out the technological and regulatory roadmap to get there.<sup>25</sup> Later in 2015, the DOE reaffirmed its commitment to wind power and established additional scenarios of 10% wind by 2020 and 35% by 2050.<sup>26</sup>

In August 2015, the federal government announced the implementation of the [Clean Power Plan](#) (CPP), a vital step to achieving a higher share of renewables in the energy mix, as it sets strong and achievable standards for cutting carbon dioxide emissions from power plants and creates customized goals for states to meet these standards. However, the CPP was almost immediately challenged in court, and in February 2016, the Supreme Court stayed the CPP pending the decision of the D.C. Circuit Court of Appeals which is expected later this year. Nevertheless, the stay has not deterred many states from planning for the implementation of the CPP. In fact, 17 states, such as California and Colorado, are currently continuing planning while nine states, including Arizona, Florida and New Mexico, are assessing the situation.<sup>27</sup> The American Wind Energy Association has found that

<sup>17</sup> U.S. Department of Energy. 2015. "Wind Vision: A New Era for Wind Power in the United States." <http://goo.gl/IOCwJ8>

<sup>18</sup> European Wind Energy Association. 2016. "The European Offshore Wind Industry—Key Trends and Statistics 2015." <http://goo.gl/Fzvrew>

<sup>19</sup> Bureau of Ocean Energy Management. "Offshore Wind Energy." <http://goo.gl/MNqDzQ>

<sup>20</sup> Energy Information Administration. 2015. *Op. Cit.*

<sup>21</sup> University of Delaware. 2016. "Massachusetts Offshore Wind Future Cost Study." <https://goo.gl/cRlVkt>

<sup>22</sup> Congressional Research Service. 2008. "Energy Tax Policy: History and Current Issues." <https://goo.gl/fRq0TI>

<sup>23</sup> RESOLVE, Inc. 2004. "Proceedings of the Wind Energy and Birds/Bats Workshop: Understanding and Resolving Bird and Bat Impacts." <http://goo.gl/Hiw5cR>

<sup>24</sup> Congressional Research Service. 2015. "The Renewable Electricity Production Tax Credit: In Brief." <http://goo.gl/C2w1LG>

<sup>25</sup> U.S. Department of Energy. 2008. "20% Wind Energy by 2030." <http://goo.gl/f57h7L>

<sup>26</sup> U.S. Department of Energy. 2015. "Wind Vision: A New Era for Wind Power in the United States." <http://goo.gl/IOCwJ8>

<sup>27</sup> Sierra Research. 2016. "State Responses to Clean Power Plan." <http://goo.gl/nZ9L14>

states can use low-cost wind energy to provide a majority of the clean power they need to comply with the carbon emission standards under the CPP.<sup>28</sup>

Congress continued to play its part in the development of wind energy by including a five-year phase-out for the PTC in the [omnibus spending](#) bill passed in December 2015, with the credits stepped down to 80% of today's value in 2017, 60% in 2018 and 40% in 2019. The omnibus also included a five-year extension of the Investment Tax Credit (ITC). Wind facilities that commence construction prior to 2020 can elect to claim the ITC in lieu of the PTC. The main difference between the two tax credits is that one pays out the credit based on the amount of energy produced (PTC), while the other requires actual dollars to be spent (ITC) in order to qualify for the credit. The extension of the ITC and PTC could ultimately result in 44 GW of new wind installation versus 25 GW without the most recent extension—a 76% increase—according to Bloomberg New Energy Finance.<sup>29</sup>

## Regional perspective on wind

Government support to the wind industry has also come from states. As of today, 29 states have established Renewable Portfolio Standards (RPS). Texas was one of the first to establish them in 1999 and is now the leader in installed wind capacity. On the other hand, California, Colorado and Hawaii have established the most ambitious standards for renewable energy—50% by 2030, 30% by 2020 and 100% by 2045, respectively.<sup>30</sup> Many states are linked by regional planning bodies; therefore, when one state establishes a RPS, the regional committee must put the infrastructure in place for a higher level of renewables in the region, making it easier for neighboring states to follow suit. States continue to revise their goals as the number of installations rise and the costs of solar and wind energy decline.

As states continue to move towards their long-term targets, more challenges surrounding system integration and flexibility are expected to come to light. For example, Texas and California, which are among the nation's leaders in terms of installed wind capacity (23.8% and 8.2% of total, respectively), have such abundant wind resources that they have faced the challenge of having too much energy supply on their grids when wind farms are generating at their peak. Last year, in Texas, spot prices for electricity at one major hub were negative for 50 hours in November and again in March, and utilities were forced to offload the excess power to grid operators.<sup>31</sup>

Although Texas, Iowa and California lead the nation in terms of capacity, the states which obtain the highest share of their electricity from wind power are Iowa (28.5%), South Dakota (25.3%) and Kansas (21.7%). This reflects differences in state mandates for renewable energy. Recently, an Iowa-based utility owned by Berkshire Hathaway announced a \$3.6 billion plan to build up 2 GW of wind turbines in the state, which has the potential to boost the share of wind in Iowa's energy mix to 40%.<sup>32</sup>

The Southeast lags behind the rest of the nation in the development of wind farms, as turbines were originally designed for high-speed wind areas and thus ill-suited to the Southeast. However, the development of taller turbines with longer blades has improved energy output in low-speed wind areas, and the Southeast could prove viable for wind energy, especially offshore, upon further innovation in turbine technology.<sup>33</sup>

<sup>28</sup> American Wind Energy Association. "Clean Power Plan." <http://goo.gl/39k6JS>

<sup>29</sup> Bloomberg New Energy Finance. 2015. "Impact of Tax Credit Extensions for Wind and Solar." <http://goo.gl/zqLHrd>

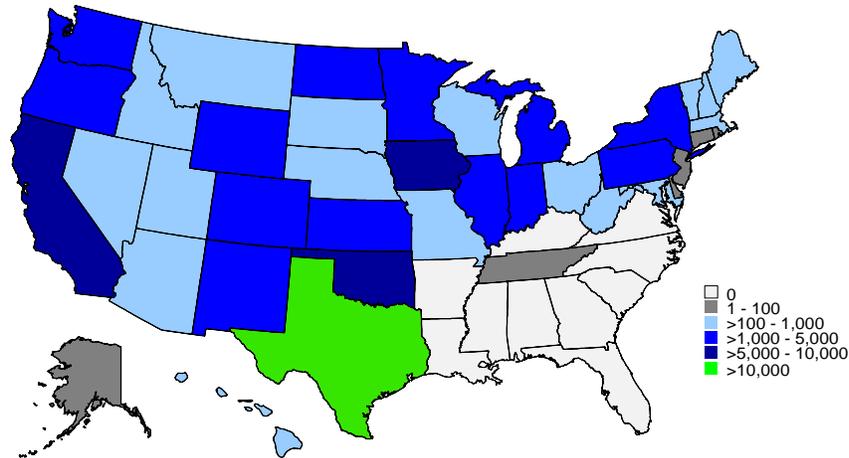
<sup>30</sup> National Conference of State Legislatures. 2016. "State Renewable Portfolio Standards and Goals." <http://goo.gl/JUDFZn>

<sup>31</sup> MIT Technology Review. 2016. "Texas and California Have Too Much Renewable Energy." <https://goo.gl/evfJoN>

<sup>32</sup> Wall Street Journal. 2016. "MidAmerican Energy Makes Big Bet on Iowa Wind." <http://goo.gl/816l0Z>

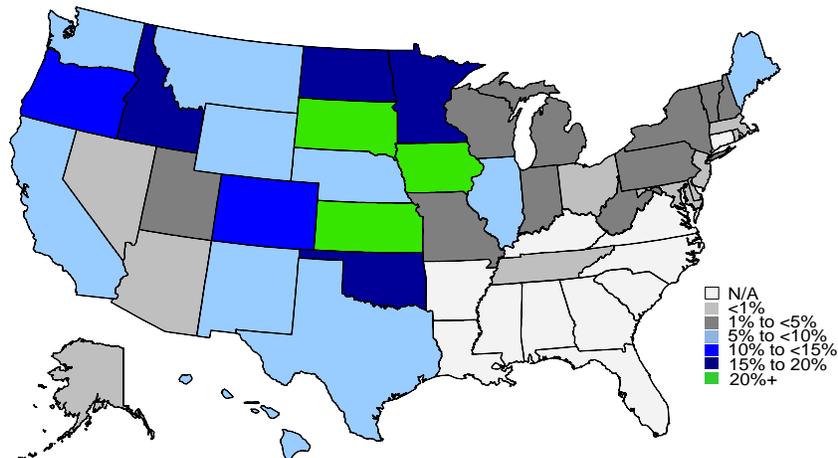
<sup>33</sup> Southeastern Wind Coalition. 2014. "Southeast Wind Energy Fact Sheet." <http://goo.gl/fnMqx3>

Chart 10  
Installed Wind Capacity by State, 2015 (MW)



Source: AWEA

Chart 11  
Wind Share of In-State Energy Production, 2014 (%)



Source: AWEA

## Financing wind energy

According to the American Wind Energy Association, investors have put nearly \$90 billion in wind energy projects in the United States over the last five years. Wind projects are funded mainly through project finance under two modalities: tax equity and debt. The former is more popular since returns are based on cash flows from the project's long-term purchase agreements and from federal and state fiscal credits and deductions. Investors include banks, insurance companies, energy companies, hedge funds, and private equity. Tax equity projects tend to favor projects that opt for PTC. Among the risks that need to be considered are regulation/political, environmental (siting and permitting), technology (commercial vs. emerging), and resource availability (how much wind is available).

## Fair winds ahead

Wind has secured its reputation as a reliable and scalable source of energy. From a macroeconomic perspective, prospects for the U.S. are encouraging in the following years. The economy is expected to grow by an average 2.3% over the next five years, which together with population growth, low interest rates, and government incentives, will support demand for electricity and encourage investments in wind projects.

Wind farms will continue to enjoy the benefits of PTC at least until 2020, when it is set to expire. However, government actions will continue to play a decisive role even when the industry achieves further efficiency gains and subsidies become less needed. One reason is the extremely low cost of natural gas resulting from the American shale boom. Efforts to contain global warming seek to drastically reduce or eliminate fossil fuels from electricity generation, a goal that becomes difficult to achieve when natural gas prices are too low. Natural gas has become the most effective alternative to coal-based electricity plants, but its low cost hinders the transition to zero emission sources. Regulations that impose limits to CO<sub>2</sub> emissions make renewables more competitive against fossil fuels; thus, they are likely to be embraced by future federal and state administrations committed with the climate change cause. Although the PTC and the ITC exist to support the renewable energy industries, regulations like the CPP and state mandates will ultimately drive the transition from fossil fuels.

By establishing limits to CO<sub>2</sub> emissions, the CPP is expected to lower the cost of renewables relative to fossil fuels. However, if the plan is not upheld by the Court, there will be less money flowing to renewables and the industry would have to continue relying on state and local policies. If CPP is upheld, the American wind energy industry could experience a bonanza characterized by the emergence of several offshore projects as well as further investments in onshore and transmission infrastructure.

Another source of uncertainty has to do with the development of complementary technologies. Because of its natural limitations (the wind does not always blow with the same intensity during the day and across geographies), the success of wind as a major source of electricity depends to a certain extent on the development of storage technologies. This will allow buyers to smooth the consumption of electricity and sellers to avoid economic losses from periods of over or under-supply. Storage technologies are for the most part in the early stages of development, and it is unclear when they can become commercially viable.

Last but not least, changes in consumer preferences and behavior could end up being an additional source of support for wind and other renewables. For example, a recent survey showed that 80% of Millennials were in favor of a transition to mostly renewable energy by 2030.<sup>34</sup> At the institutional level, corporations and public entities around the country are expected to increasingly adopt zero emissions policies in order to appeal to a growing number of stakeholders concerned about the environment. In fact, some universities have started to divest their endowment funds away from fossil fuels. In the near future, more and more states will embrace green energy, not only to comply with regulations, but also as way to increase fiscal revenues by attracting non-energy businesses and human capital looking for places with high renewable quotients.

Technological advances, private investments, government support and consumer preferences create a positive outlook for renewable energy sources, including wind energy. Nevertheless, uncertainties will remain significant at least until incentives converge towards a new energy paradigm.

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<sup>34</sup> USA Today. 2016. "USA TODAY/Rock the Vote poll: Millennials' agenda for the next president" <http://goo.gl/x5YIWJ>

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