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Wind Energy
A National Perspective

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Introduction

As a result of volatile energy prices, resource supply uncertainties, and increasing environmental concerns, policymakers, energy suppliers and consumers have begun to reevaluate the nation's energy mix, particularly as it concerns the ratio of traditional to alternative energy sources. Currently, the U.S. energy supply consists of petroleum (37.1%), natural gas (23.8%), coal (22.5%), renewables† (7.3%), and nuclear electric power (8.5%) (U.S. Energy Information Administration). With only 15.8 percent of total energy needs met by renewables the United States is heavily reliant on non-renewable energy sources, which suffer volatile prices, are extracted from among the world's most unstable regions and emit a variety of environmentally damaging compounds. However, with the recent 50 percent surge in the U.S.'s wind generation capacity alternative energy advocates are identifying wind energy as a potential supplier of at least 20 percent of the country's future electricity needs (a goal of the American Wind Energy Association). Several groups and individuals in the private sector have been conducting research to determine the wind industry's potential growth and the U.S.'s access to resources in the coming years. These pooled efforts suggest that the U.S. has become the biggest generator of wind power in the world with wind accounting for 42 percent of new energy generation, a 40 percent increase since 2004 (The Economist, July 2009). The U.S. is also en route to recording its second best year in wind energy generation and to becoming the home to seven of the world's ten largest wind turbine makers. According to a report published by the U.S. Department of Energy (U.S. DOE), the U.S. could plausibly rely on wind energy to supply 20 percent of its electricity needs by 2030.

In order to better understand the current position and future potential of the wind energy industry in the United States, this report offers a brief explanation of the construction and capabilities of wind turbines, an overview of the history of wind technology and wind plant performance, and the current state of the wind energy industry across the U.S.

Wind Turbine Technologies

By definition, wind turbines are rotating machines that create mechanical energy from the kinetic energy in wind without the emission of greenhouse gases or the use of traditional fuels. The mechanical energy produced can then be used to power machines or be further converted into electricity. In wind speeds of approximately 11 mph and above, the average turbine can produce over 1.5 MW (megawatts) of electrical power. Generally speaking, wind turbines are made up of three major components: a rotor, generator, and structural support. The rotor consists of a structural support for the blades and the blades themselves, which convert the wind energy into low speed rotational energy.

†As defined by the United States Energy Information Administration, renewables, or the renewable energy sector, includes biomass (wood, wood waste, municipal solid waste, landfill gas, ethanol, biodiesel, and other biomass), geothermal, wind, solar (solar thermal and photovoltaic) and conventional hydropower energy. It does not, however, include hydroelectric pumped storage facilities due to the use of non-renewable energy sources in their operation.

FIG. 1: Wind Energy Generation, 2004-2008
(in billion kilowatthours)

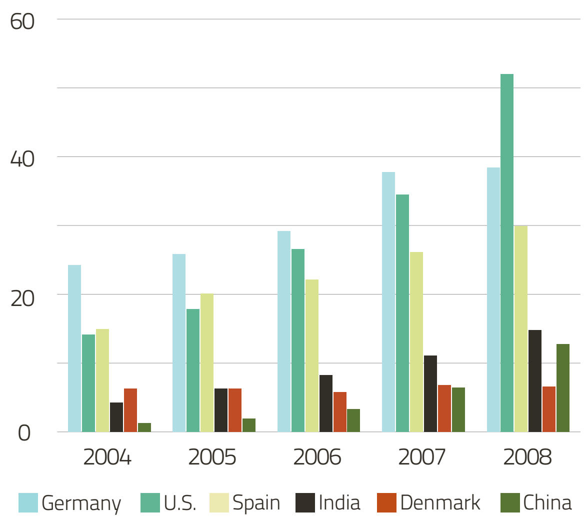
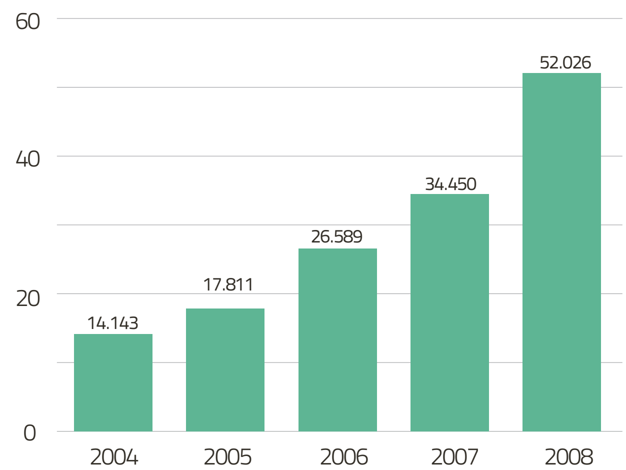


FIG. 2: U.S. Wind Energy Generation, 2004-2008
(in billion kilowatthours)



Source: Fig. 1. and Fig. 2., Energy Information Administration

Modern wind turbines typically have rotors with three blades that can measure a diameter of 230 to 260 feet. The generator includes an electrical generator, the control electronics, and a gearbox component that converts low-speed rotation to high-speed rotation in order to generate electrical energy. The last major component, the structural support, includes the tower and a mechanism that directs the rotor. This mechanism, also known as the nacelle, points the turbine into the wind allowing for the production of the maximum amount of electrical power from the wind speed (U.S. DOE).

Today, two main types of wind turbines are manufactured for commercial and personal use: horizontal-axis (HAWT) and vertical-axis (VAWT). Horizontal-axis turbines are the more common type of turbine, used mainly for the commercial production of electric power on wind farms. This specific type of turbine consists of a main rotor shaft and electrical generator at the top of a support tower (positioned horizontally), and a gearbox that manipulates the speed of the blade rotation in order to power electrical generators. The ability of HAWTs to produce speeds up to six times the current wind speed along with their high efficiency and low torque ripple make this build of wind turbine especially reliable.

A less commonly used turbine, vertical-axis turbines are manufactured primarily for residential use. Their build is similar to that of HAWTs with a few exceptions. Instead of having the rotor shaft positioned horizontally, the shaft is positioned vertically to the tower, hence the name. This enables the turbine to be effective regardless of wind direction, which makes it particularly efficient in providing electric power in residential and urban areas. Additionally, VAWTs' generators and gearboxes are located close to the ground instead of atop the tower near the blades, which allows for easier access in the event of maintenance as well as optimal placement of the turbine in congested urban areas (U.S. DOE).

The History of Wind Technology & Wind Plant Performance

In the pre-industrial United States, wind turbines, also known as windmills, were extensively used to provide for the power needs of rural areas throughout the country. But as the U.S. experienced growth and development moving into the industrial era, reliance on wind energy as a primary power supplier decreased. Now, with the surging interest in alternative energy sources, wind energy is once again being looked to as a potential leader in power supply.

From their inception until the 1970s, wind turbines were primarily utilized on farms and other agricultural locations to supply mechanical power to machines that pumped water and ground grain; occasionally, they were used in rural areas to charge batteries. As their perceived usefulness and popularity grew in the next decade, wind turbines were redesigned using low-cost components manufactured for the agricultural and boating industries in an effort to make them more durable and effective. Although this reengineering resulted in a stronger overall structure, the users of the turbines found them to be too heavy to transport and very maintenance intensive. Mindful of these and other material restrictions, manufacturers and engineers have been working since the 1980s to design more efficient and effective turbines using the most technologically advanced materials. With each new generation of wind turbine (approximately every five years), design improvements are made with the hope of producing more electrical energy per turbine (U.S. DOE).

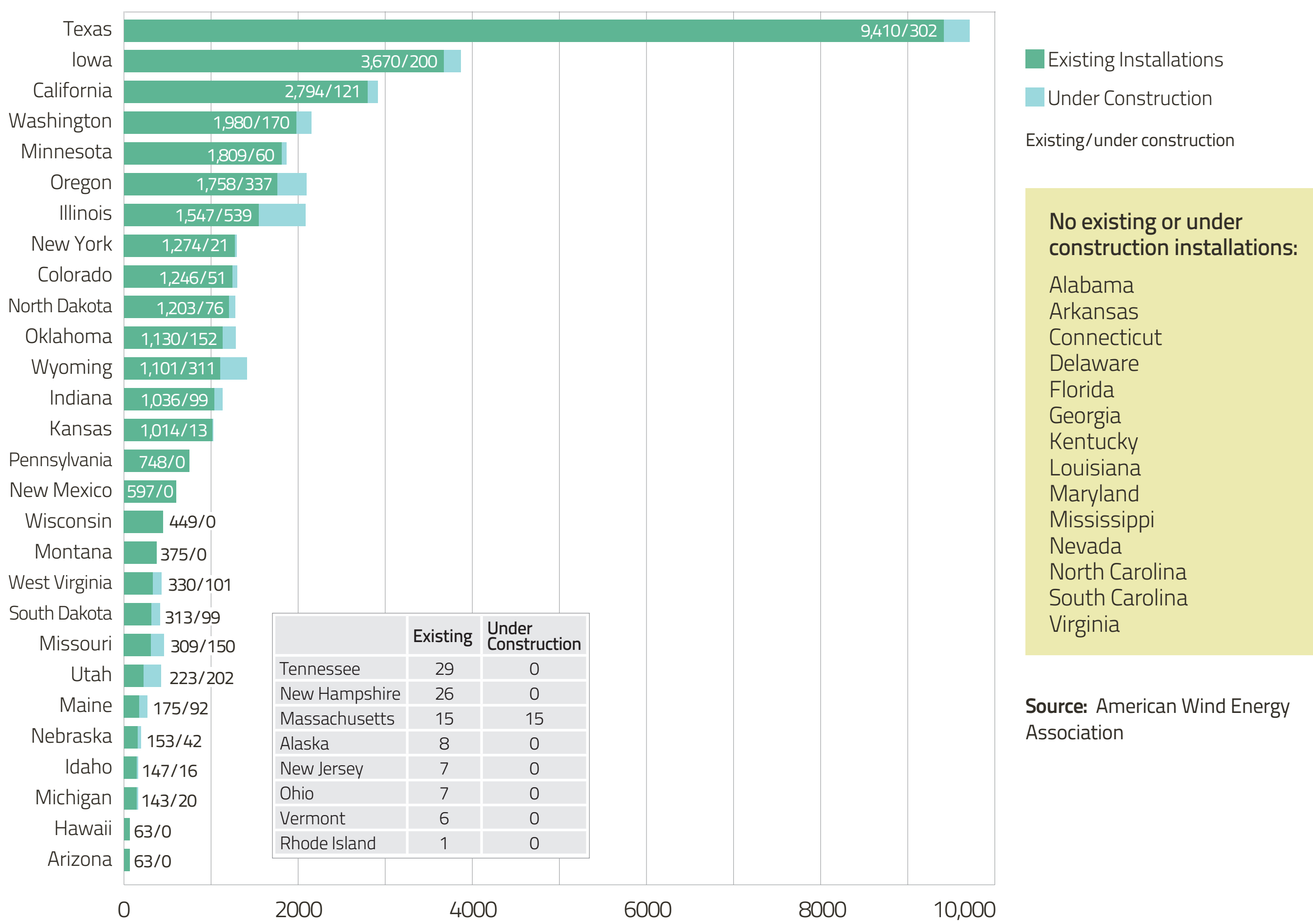
Since the first modern wind turbine was developed in the 1970s, the overall performance and production capabilities of commercial turbines have increased dramatically. Consumer costs of wind-generated electricity have decreased steadily over the past thirty years as well as capital costs for new wind plant investments. However, due to economic and fiscal factors, wind energy prices have been on the rise since 2003 (U.S. DOE). While today's turbines provide only 1 percent of total U.S. electricity generation, it is predicted that the current U.S. land-based and offshore wind resources are capable of supplying electricity to the entire U.S. for all its electrical energy requirements (U.S. DOE).

The Wind Energy Industry in the United States

As mentioned, the United States became the world's biggest generator of wind power in 2008, growing its previous annual capacity by over 50 percent and leading generation for the first time over Germany (EIA). Since 2004, the U.S. has ranked among the top three generators, falling short of Spain in 2004 and 2005 with 14 billion kWh to Spain's 15 billion kWh and 18 billion kWh to Spain's 20 kWh respectively (See Figure 1). Most notably, the U.S. has nearly quadrupled its wind power generation over the past five years, rising from just over 14 billion kWh in 2004 to over 52 billion kWh in 2008 as shown in Figure 2). Data on generation from 2004 to 2008 for the top twenty generators can be found in Appendix, Table 1.

With nearly $17 billion in industry investment last year alone, wind power has become a leading source for new power generation, topping other sources alongside natural gas. Figure 3 shows wind power capacity installations by state as of year-end 2009. As shown, Texas leads the U.S. in capacity installations with over 9,400 megawatts installed,

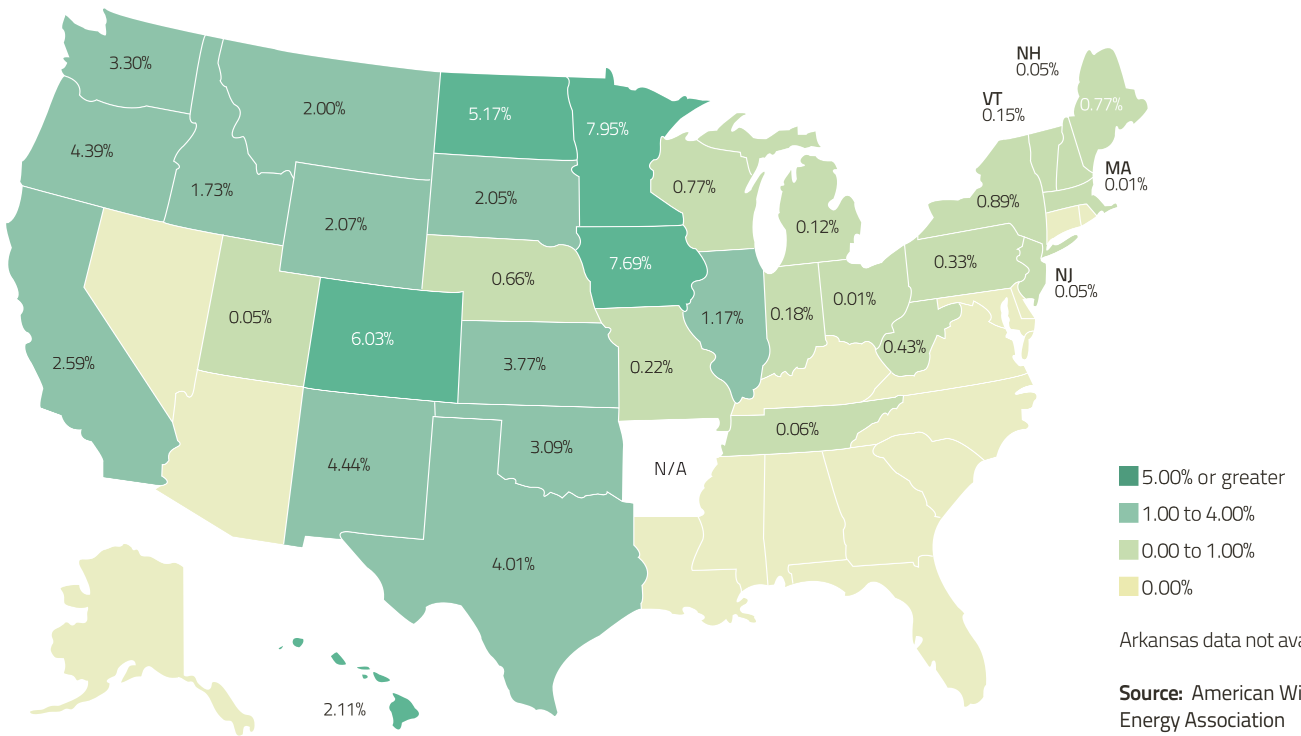
FIG. 3: Wind Power Capacity Installation by State (in megawatts)



	Existing	Under Construction
Tennessee	29	0
New Hampshire	26	0
Massachusetts	15	15
Alaska	8	0
New Jersey	7	0
Ohio	7	0
Vermont	6	0
Rhode Island	1	0

Source: American Wind Energy Association

FIG. 4: Wind Energy Generation by State, 2008 (percent of total energy use)



Arkansas data not available.

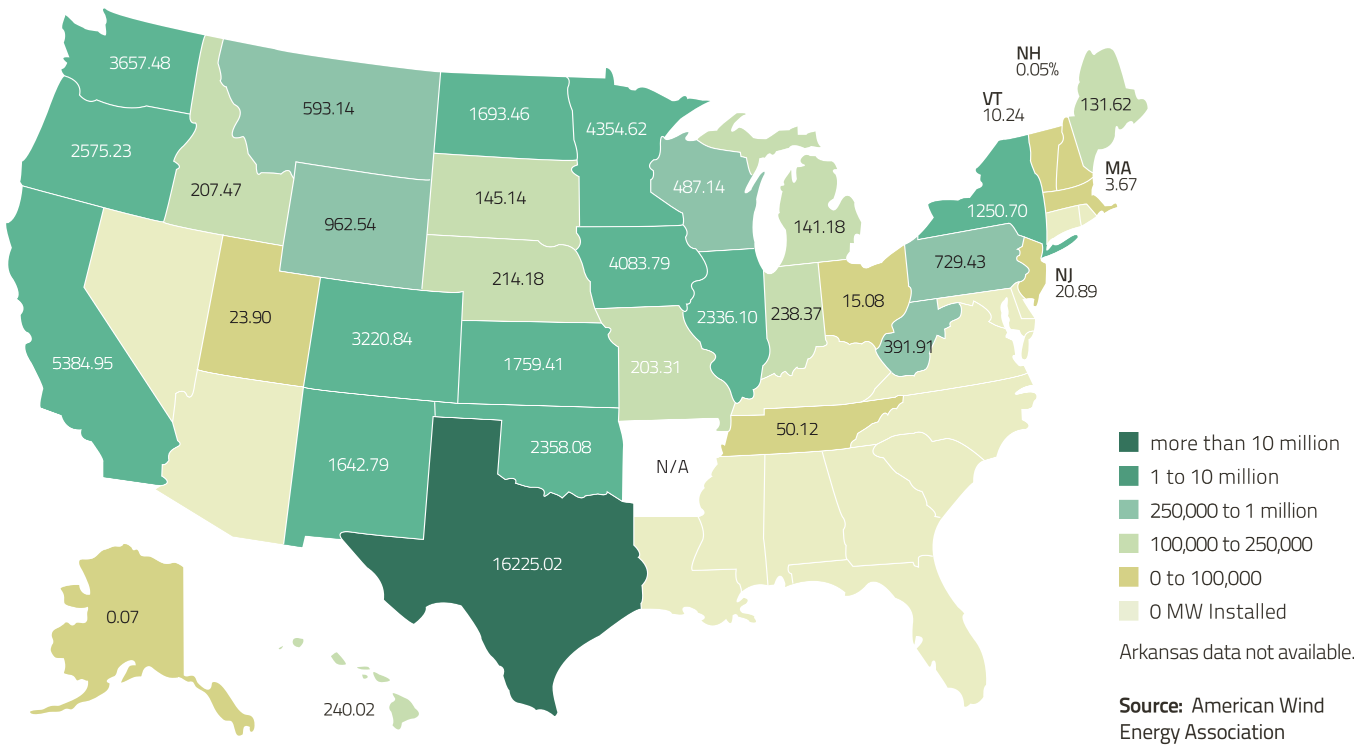
Source: American Wind Energy Association

more than doubling the installations in Iowa, the nation's second leading wind power capacity state. More interestingly, Texas has a larger amount of capacity installation than any country in the world, with the exception of China and the U.S. And while Indiana, Michigan and Utah pale in comparison concerning total capacity installed, the three states top the chart for fastest growing capacity installations.

It is also important to consider wind power generation by state. The percentages reported in Figure 4, indicate that wind provides for over 7 percent of Minnesota's and Iowa's power needs, making those two states the national leaders in wind production. Additionally, thirteen states utilize wind power generation to supply between 1 and 5 percent of their power needs. Keeping these figures in mind, one should consider megawatts installed by state in Figure 5. Topping the list are Texas, Iowa, California, and Minnesota with 7118 MW, 2791 MW, 2571 MW, and 1754 MW respectively. Clearly, two of the four states with the largest amounts of megawatts installed are not leading the country in generation. While alternate explanations should be considered, the primary interpretation is that the larger states (in regard to population) have higher in-state generation demand (AWEA).

Critical to a discussion on the wind energy industry across the U.S. is the role that the wind energy industry plays in creating new employment, particularly in the manufacturing sector. While job creation as a result of wind energy industry growth will be a focus in a forthcoming section, it is pertinent to mention a few key facts here. First, the share of wind turbine components that are manufactured domestically rose from 30 percent in 2005 to approximately 50 percent in 2008. This increase would imply a complimentary increase in manufacturing jobs. Furthermore, multiple manufacturers of wind turbines and their components announced, added or expanded more than seventy facilities in 2007 and 2008, fifty-five of which were in 2008 alone (AWEA). When totaled, all proposed facilities reflect an addition of roughly 13,000 new direct manufacturing jobs and over $2 billion in industry investment (AWEA). Clearly, the wind energy industry is creating and will continue to create a significant number of jobs in the U.S., spurring economic growth and offering potential future job security for thousands of Americans.

FIG. 5: Megawatts Installed by State, 2008 (in thousands)



Source: American Wind Energy Association

Also relevant to this discussion are the costs associated with installation, operations and maintenance of wind turbine projects. According to the U.S. DOE's 2008 Annual Wind Market Report, wind turbine prices have increased over the last several years through 2008 to roughly $1,360/kW. These price increases can be attributed to the recent decline in the value of the U.S. dollar, an increase in materials cost and energy input prices, a shortage of components necessary in the manufacture of turbines, and the rapid increase of size and complexity in turbine design among other things. Subsequently, increasing turbine prices have led to higher project installation costs, which totaled approximately $2,000/kW in 2009, up roughly 50 percent from the average installation cost from 2001 to 2004. But perhaps most important of these costs are the costs associated with the operations and maintenance (O&M) of installed projects. O&M costs contribute significantly to the total cost of a wind installation project and are affected by several factors, including age and size of the project installation. Both larger and newer projects tend to have the lowest O&M costs, with costs increasing as installations age. Currently, the estimated average O&M cost for a project installation (including wages and materials associated with operating and maintaining the facility and the facility rent) is approximately $8/MWh or $8,000/kWh. However, it is important to note that this cost does not include taxes, insurance, or workers' compensation insurance; additionally, this cost estimate may be skewed due to the limited data available at the project level and the lack of accounting for drastic changes in turbine technology.

20% Wind Energy Scenario

In 2008, the U.S. Department of Energy released a report based on the 20% Wind Energy Scenario, which suggested that wind energy will provide 20 percent of electricity within the U.S. by 2030. With a projected 39 percent growth in U.S. demand for electricity from 2005-2030, the 20% Scenario requires that national wind power capacity increase from its current 11.6 GW to over 300 GW in the next twenty years. This equates to a 16 GW yearly installation rate after 2018 (all other things held constant, including the current wind turbine capacity).

If the 20% Wind Energy Scenario is realized, wind energy would sufficiently cover enough electricity demand to displace approximately 50 percent of natural gas consumption and 18 percent of coal consumption associated with electricity utility by 2030. Additionally, the U.S. would see nearly an 11 percent reduction in natural gas consumption across all industries as wind energy replaces traditional energy sources. Other potential impacts include a significant reduction in greenhouses gases, particularly CO2; an 8 percent reduction in cumulative water consumption within the electricity sector, with a realized 17 percent reduction in annual consumption by 2030; and greater U.S. energy security and stability, resulting from a more diversified national energy portfolio, which would reduce price risks associated with the energy sector, reduce U.S. reliance on foreign energy supply, and reduce supply uncertainties.

Another major impact that the 20% Wind Energy Scenario would have on the U.S. is a dramatic increase in jobs, specifically in three sectors: manufacturing, construction, and operations. The manufacturing sector would see an increase of more than 32,000 new full-time positions by 2026 to sustain the wind energy development specified in the scenario. Spread across the U.S., these manufacturing jobs would be used for the production of components and sub-components for turbines installed in the U.S. only.

Furthermore, the construction sector would see a hike in employment from its current level of 9,000 full-time employees to 65,000 employees by 2021. These new employees would be needed to keep up with the demand for new wind plant installations throughout the U.S. Lastly, over 215,000 new full-time workers would be required to maintain all land and off-shore wind plant operations in the U.S. by 2030.

Although the 20% Wind Energy Scenario presents many potential benefits to the U.S. economy, it is not without its challenges. For one thing, the availability of raw materials used in the construction of wind turbines and their components has the potential to be a major constraint on the 20% Scenario. There may not be sufficient materials for the infrastructure required to meet energy production needs. Additionally, the high demand for manufacturing inherent in the wind energy industry poses several issues. First, manufacturing companies who enter the wind industry must determine where new manufacturing capacity can be established. Also, manufacturers will be forced to secure global supply lines due to the current lack of sufficient component suppliers within the U.S. This in turn will inevitably put strain on international supplier operations, and may therefore leave U.S. manufacturers without the necessary components. Furthermore, the 20% Wind Energy Scenario dramatically increases demand within the U.S. labor force. And the availability of a workforce that is qualified for the specific positions within the wind energy industry may not be readily available. Perhaps the biggest challenge to U.S. reliance on wind energy is the expensive and complex grid infrastructure required to transfer generated electricity to power companies and/or end users. Currently, the U.S. possesses only three grids: the eastern, the western, and ERCOT (located in Texas). These grids, along with the extending transmission lines, are insufficient to transport the electricity that would be generated by the proposed wind projects. For the 20% Scenario to be realized, more grids and transmission lines to those grids would have to be constructed, tasks that would prove both time and capital intensive. However, it is neither capital nor technical expertise that is the barrier to expansion. Instead, outdated government policies are proving themselves to be the roadblocks. While the aforementioned challenges may make wind energy growth seem improbable, their strain can be eased by consistent (updated) government policies that support new investment in the renewable energy sector.

Finally, it is pertinent to mention the American Recovery and Reinvestment Act (ARRA) of 2009, legislation developed to stimulate economic development that contains numerous provisions specific to the wind energy industry. One such provision is a three-year extension of the production tax credit (PTC), allowing investors to take advantage of the credit until year-end 2012. The ARRA also encompasses a Treasury Grant program that authorizes developers in the renewable energy sector to obtain funding from the Treasury Department equal to a 30 percent investment tax credit (ITC), assuming that they opt out of a PTC. Other provisions include but are not limited to manufacturing tax credits, extensions of bonus depreciation, workforce training, and research and development funding. (For more detailed information on these and other provisions within the ARRA, the full legislative document is available at www.recovery.gov). While most of the legislation tends to provide incentives for developers and investors in larger development projects, they are not the only ones benefiting from the ARRA. The bill also includes the removal of the previous cap on small wind ITC. What this means for investors in smaller wind energy property is that they now can claim the full 30 percent ITC for qualifying property.

Considering the legislation discussed above and the $14 million that the federal government allocated for wind energy research in 2009, the growth trend of the wind industry in the United States is likely to continue. Using past data on wind energy capacity and generation, the Energy Information Administration has forecasted growth in capacity and a growth in generation. For future forecasts from the Energy Information Administration, please see Appendix, Figure 1.

References

American Wind Energy Association (AWEA). 2009. *Publications: American Wind Energy Association*. http://www.awea.org/pubs/ (accessed August 2009).

Energy Information Administration (EIA). 2009. *Annual Energy Review*. http://www.eia.doe.gov/aer/pecss_diagram.html (accessed September 2009).

The Economist. 2009. "Wind Power in America, Becalmed." *Economist.com*. July 30. http://www.economist.com/businessfinance/displaystory.cfm?story_id=14140349 (accessed August 2009).

U.S. Department of Energy (U.S. DOE). 2008. *20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply*. http://www1.eere.energy.gov/windandhydro/pdfs/41869.pdf (accessed May 2009)

U.S. Department of Energy (U.S. DOE). 2008. *2008 Wind Technologies Market Report*. http://www.windpoweringamerica.gov/pdfs/2008_annual_wind_market_report.pdf (accessed May 2010)

Wikipedia. 2009. *Darrieus Wind Turbine*. http://en.wikipedia.org/wiki/Darrieus_wind_turbine (accessed August 2009).

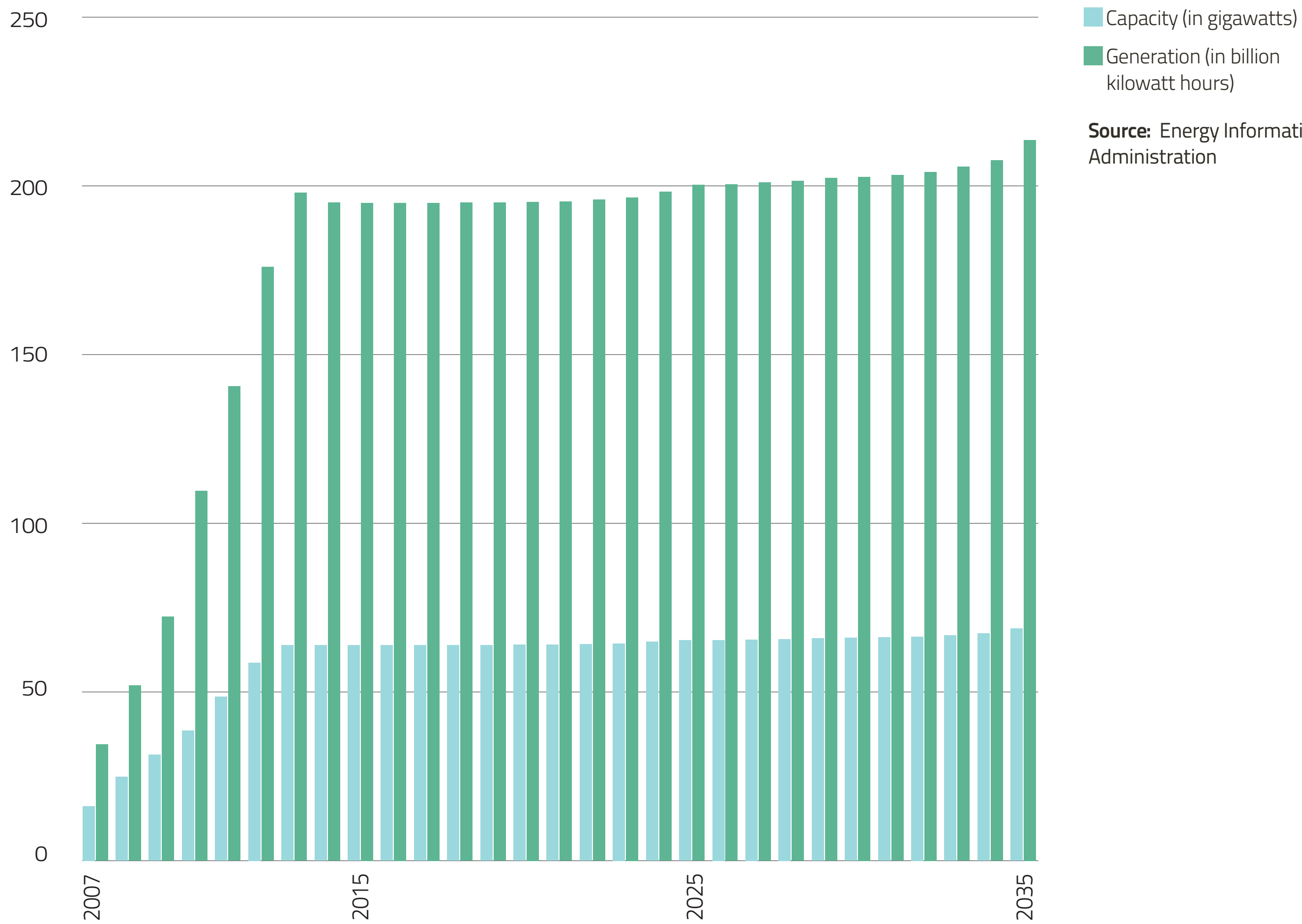
Appendix

TABLE 1: Top 20 Wind Energy Generators, 2004-2008 (in billion kilowatthours)

Country	2004	2005	2006	2007	2008
Germany	24.234	25.868	29.175	37.727	38.380
United States	14.144	17.811	26.589	34.450	52.026
Spain	14.915	20.117	22.132	26.134	29.933
India	4.266	6.273	8.255	11.070	14.800
Denmark	6.254	6.283	5.803	6.814	6.582
China	1.265	1.927	3.304	6.431	12.779
United Kingdom	1.838	2.759	4.014	5.010	6.756
Italy	1.755	2.227	2.822	3.937	6.115
France	0.566	0.914	2.08	3.849	5.425
Portugal	0.775	1.684	2.779	3.835	5.446
Netherlands	1.774	1.964	2.596	3.266	4.046
Canada	0.906	1.398	2.375	2.873	2.871
Japan	1.245	1.666	2.100	2.493	2.773
Australia	0.670	0.841	1.627	2.481	3.121
Austria	0.878	1.262	1.664	1.914	1.889
Ireland	0.622	1.056	1.541	1.860	2.290
Greece	1.065	1.203	1.614	1.727	1.578
Sweden	0.808	0.889	0.938	1.359	1.875
New Zealand	0.340	0.584	0.592	0.890	1.004
Norway	0.239	0.481	0.605	0.855	0.871

Source: Energy Information Administration

FIG. 2: Forecasted U.S. Wind Capacity and Generation



Source: Energy Information Administration