Wind Power Engineering Challenges 2007-2015

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ABSTRACT

Wind power in the United States presents an unprecedented opportunity to simultaneously address key issues surrounding energy security and climate change. A recently released study has determined what it would take to have the U.S. obtain 20% of its electricity from wind power by the year 2030*. This study outlines a number of public policy and strategic implications of achieving this target. The engineering challenges associated with expanding the contribution of wind energy to our nation's power supply provides a number of daunting and aggressive targets that will need to be met.

INTRODUCTION

The generation of electricity from wind power is the only readily-available electric generation technology today to curb emissions that contribute to global warming. Along with energy efficiency, wind power represents the best first step our country can take to address global warming until other technologies such as clean coal/carbon sequestration or advanced nuclear power plants are ready and able to be implemented in this country. Wind power is also a clean and inexhaustible source of electricity. What's more, an aggressive expansion of wind power in this country will actually save U.S. consumers money by reducing our dependence on natural gas to generate electricity—saving this fuel for industry and home heating and making our electricity prices less dependent on natural gas price volatility as well.

Further increasing the percentage of electricity that wind power

*See http://www.20percentwind.org/for a copy of the report.

produces in America will help stabilize electricity costs, generate revenues for farmers and rural communities, and create tens of thousands of jobs, while powering our economy with a domestic, emissions-free source of electricity. The U.S. wind industry installed over 3,000 megawatts (MW) of wind turbines in 2006, and the industry is expected to exceed this level of installation in 2007 and 2008. About 31 billion kilowatt-hours (kWh) of electricity will be generated by wind power during 2007, enough to supply the equivalent of nearly 3 million average homes.

Yet wind power, having become a mature and cost-competitive means of generating electricity in the past few years, has a lot of catching up to do with other forms of electric generation that have been around for many, many decades. Today, wind power accounts for only about one percent of the electricity generated and consumed in the U.S. annually. In his State of the Union address in 2006, President Bush challenged the wind industry by remarking that areas of the country could produce enough electricity from wind power to generate 20% of the nation's electricity.

This statement led to a collaborative effort between the U.S. Department of Energy, the National Renewable Energy Lab (NREL), the American Wind Energy Association, and Black & Veatch to assess what it would take to achieve the target of 20% of the nation's electricity to be generated by wind power. The report used a series of studies and input assumptions to force a production level of 20% wind power using the Wind Deployment System (WinDS) model to determine the necessary generation and transmission expansion. It also determined the effect on natural gas prices and carbon emission reductions resulting from such an expansion of wind generation with commensurate additions of other generation to meet the country's load growth demands. Assumptions were drawn from existing data from the Energy Information Administration (EIA) and other sources.

The results indicate that U.S. wind power growth will need to accelerate rapidly above the 3,000 MW per year incremental rate that the industry currently is producing. Figure 1, shown below, indicates that annual growth in wind power additions will need to accelerate rapidly to initial levels over 10,000 MW of wind turbine additions per year and eventually to close to 20,000 MW per year—far more than the total installed capacity in existence today in the U.S. But these levels of wind power growth are not unprecedented in the world or in other forms of electricity generation in the U.S. historically. But these additions present enormous and significant engineering challenges in several respects.

Figure 2 shows the current levels of wind power installed in the world through the end of 2006. As can be seen in this figure, global wind power installations exceeded 70,000 MW in 2006 and will soon reach 80,000 MW.

Another critical fact shown in Figure 2 is how the dominant markets for wind power shifted to Europe in the 1990s and early part of this century, after the technology was developed and pioneered in this country. The U.S. currently imports a large portion of wind turbine technology and components from Europe as a result of the lack of consistent federal support by the U.S. government combined with stable and long-term policy support by a number of countries in Europe, such as Denmark, Germany, and Spain.

In the report documenting the results of the 20% Wind Vision study, NREL, DOE, AWEA and Black & Veatch indicate that achieving the 20% goal by 2030 is indeed achievable. But this does not represent a forecast or prediction, but rather is intended to represent what is possible to achieve this level of wind power penetration—but not under a "business as usual" approach. The number, scope, and breadth of changes that are needed are significant, but the results and benefits to customers and the nation as a whole are significant as well. Figure 3 shows what such a "power supply curve" would look like for wind power supply, not

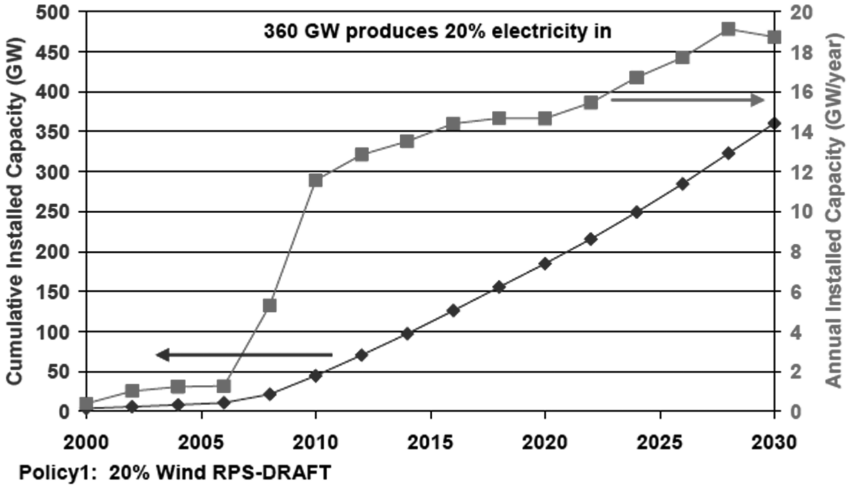

Figure 1. 20% Wind Vision Additions

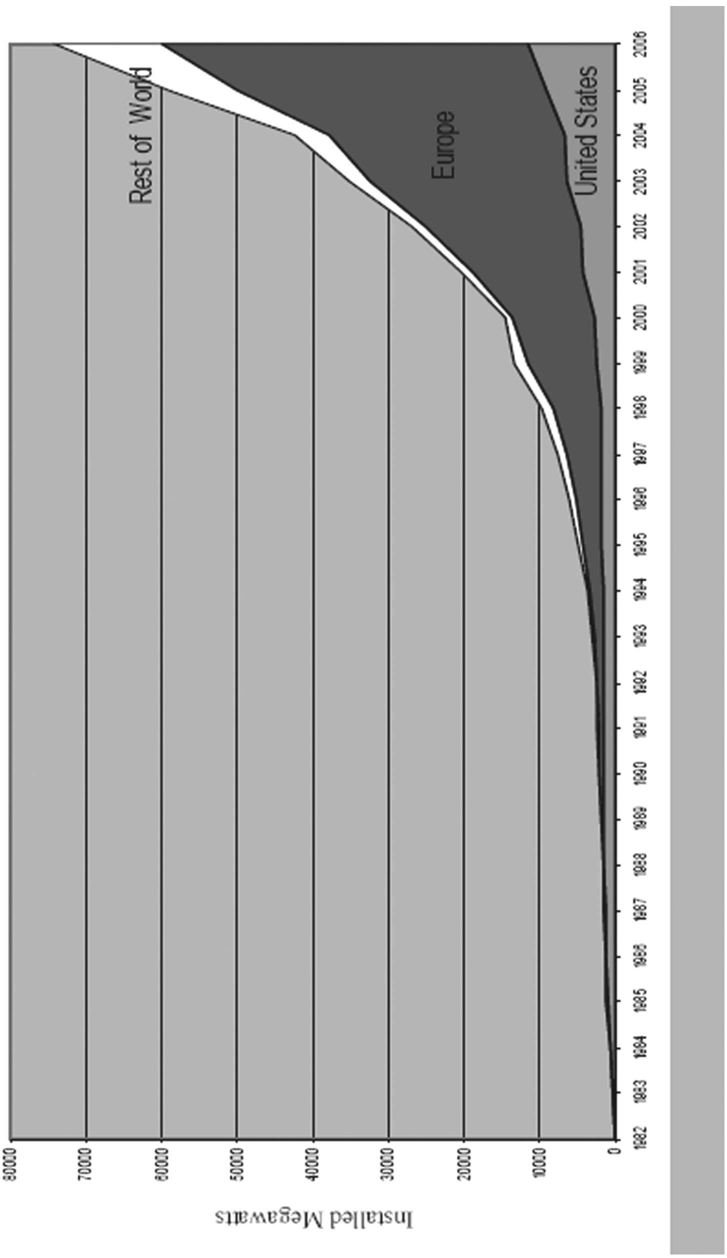

Figure 2. Historical, Cumulative Wind Power Installation. (Source: AWEA 2007)

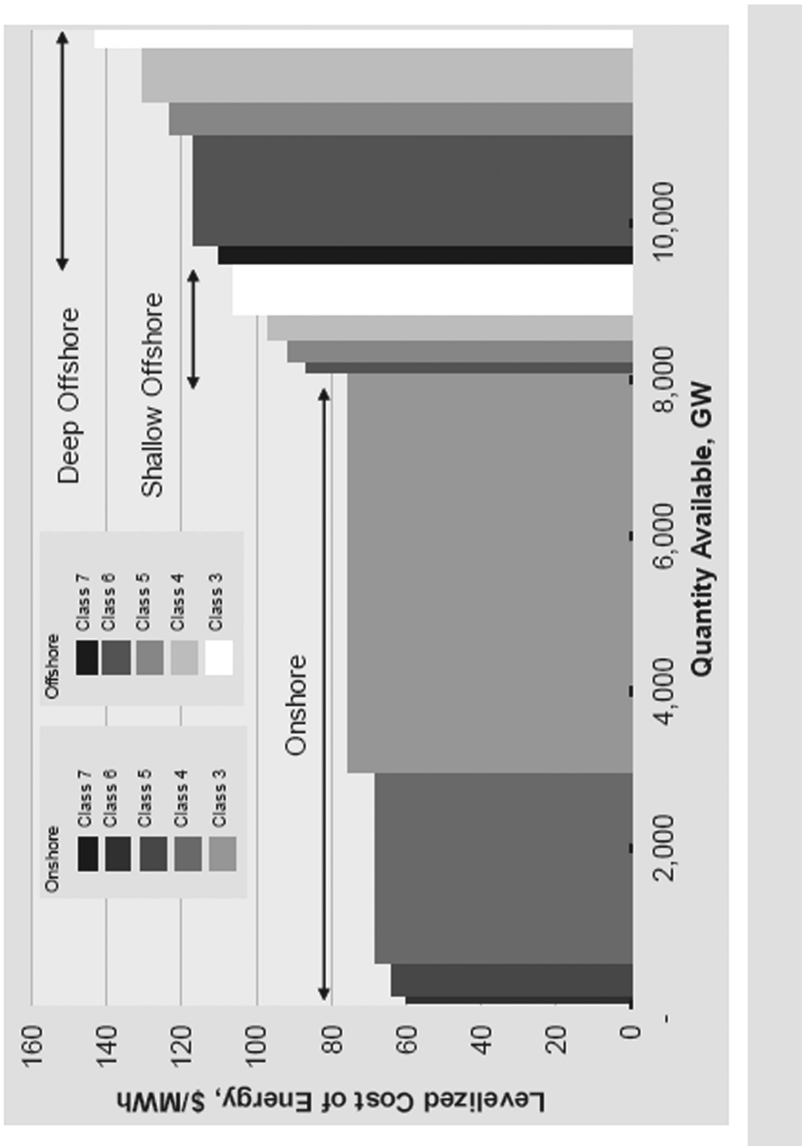

Figure 3. Wind Supply Curve under a 20% Scenario

including transmission or integration costs. The graph shown here is a DRAFT from the report, but shows the results of the work to determine where and how this amount of wind power will be located, sited and connected to the nation's electricity grid. This figure shows both on-shore (land-based) and off-shore wind power, segmented by the "class" of wind power—with class 7 being the best wind resource (and thus the lowest cost for electricity generation, all other factors being equal).

Figure 4 then provides a visual approximation where this wind power would be located by state in the U.S. The darkest shades indicate where higher levels of wind power would be sited by state, in the states with the best combinations of wind resources, available land, and access to existing or new transmission that would be built to transfer the wind power from where it is generated to load centers around the U.S.—typically not located in wind-rich regions. The need to build additional transmission infrastructure is a significant engineering challenge to achieve the vision presented by a 20% level of wind power in the U.S.

ENGINEERING CHALLENGES

The Wind Vision report provides detailed assessments on what it will take to achieve the 20% wind vision, including necessary changes in policy and government support, wind siting and wildlife issues, and collaborative efforts, as well as technology and engineering challenges that will need to be addressed.

The engineering challenges that are needed to grow the wind industry as described above in the 2008-2030 timeframe are numerous, but the wind vision effort provides a common goal for achieving the necessary improvements and changes needed. Some of the engineering challenges will deal with wind turbine manufacturing and component performance, some will deal with wind turbine integration and interconnection to the nation's electricity grid, and other challenges will deal with the huge increases in infrastructure and manufacturing capacity needed in this country to develop and produce the large number of components and turbines envisioned to be installed in increasing numbers in the years leading up to 2030.

The size of wind turbines will continue to increase, although the point of diminishing returns for ever-larger wind turbines will be

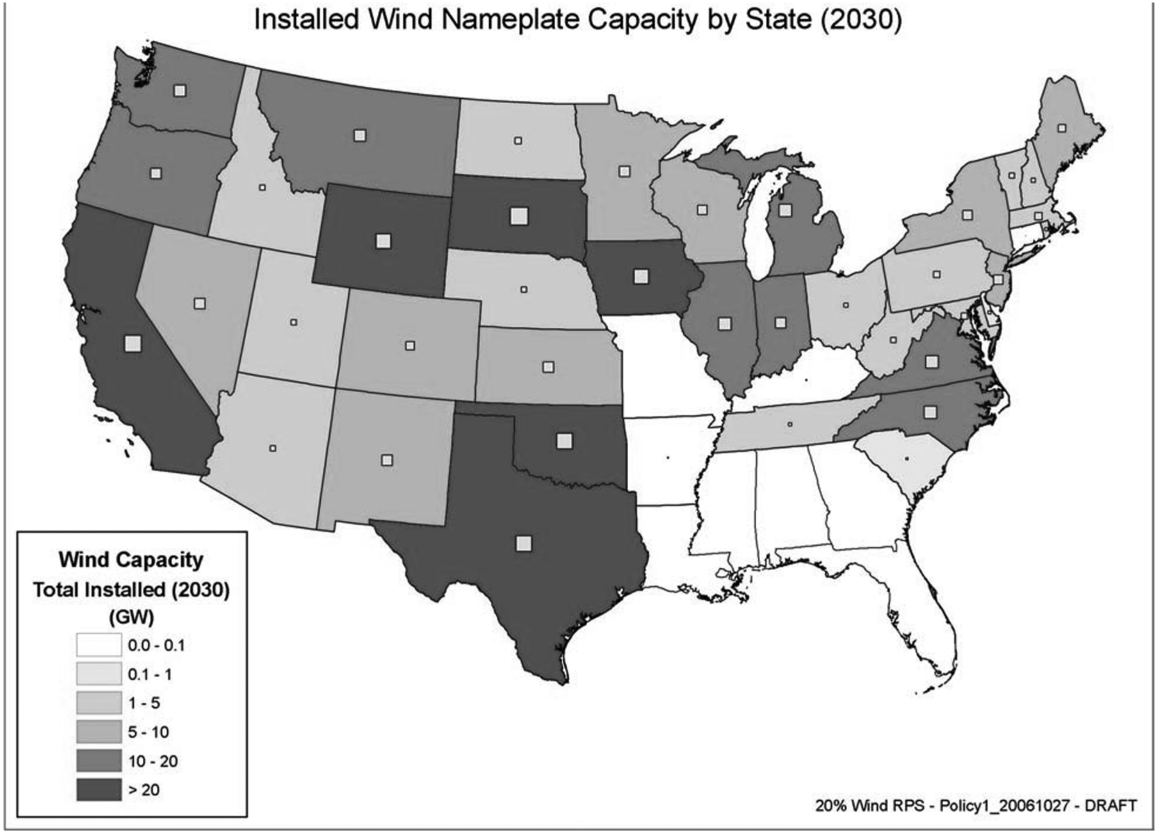

Figure 4. Projects Wind Resources by State, 2030 (DRAFT)

reached at some point in the near future—the ability to transport and erect wind turbines will likely be the limiting condition for turbine size, as larger and larger wind turbines can be designed and constructed, but the transportation and installation of these very, very large structures in often rugged or undeveloped terrains will become cost prohibitive at some point. Nonetheless, development of larger and larger turbines will continue, as shown below in Figure 5 from the DOE "Wind Powering America" program:

The wind vision will outline the following engineering challenges in wind turbine and component manufacturing:

1) Turbine components
   a) Rotor—design, control, operating loads
   b) Blades—overall size/length, materials, manufacturing processes, aerodynamic performance
   c) Controls—sensor integration, new grid interconnection requirements
   d) Drive train: gearbox, generator, power converter—efficiency improvement, life extension and reliability, new and innovative designs, operations and maintenance (O&M) issues, reduced weights, cost reductions
   e) Towers—advanced configuration, tower erection techniques
   f) Balance of station
   g) Overall O&M trends

The items above represent the primary engineering challenges from the "hardware" perspective of wind turbines and their major components. But other categories of engineering challenges exist for the wind industry to achieve the 20% vision, including these four major categories in addition to the wind turbine design and component aspects described above:

2) Wind Integration and Interconnection—additional and aggressive work will be needed to build on the strong effort done to date on integrated and interconnecting wind turbines to the nation's power grid—especially in light of the fact that the grid today was designed and built to specification to accommodate dispatchable, thermal resources—whereas wind power presents new but very manageable changes to accommodate non-dispatchable resources.

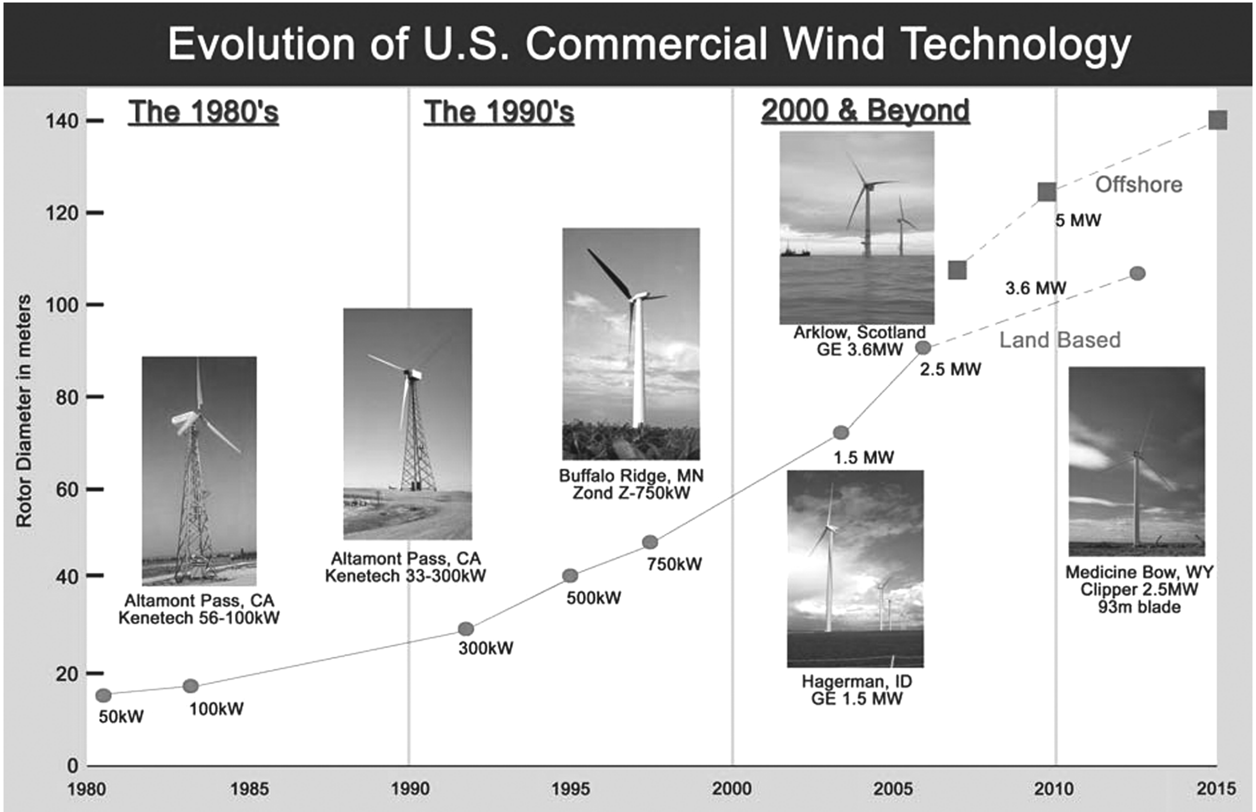

Figure 5. Evolution of Wind Turbine Technology. (Courtesy of Wind Powering American Wind Energy Association)

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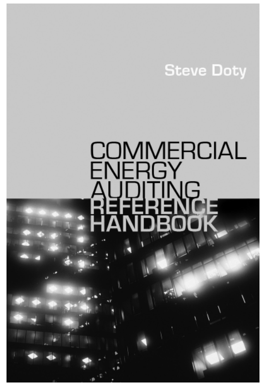

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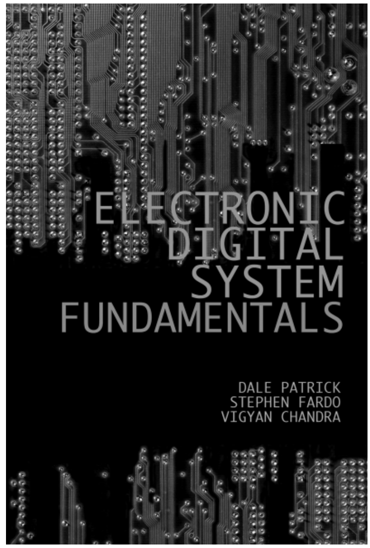

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3) Supply Chain—the engineering challenges to expand and grow the nation's ability to manufacture and supply wind turbines and major components in this country is very significant. The 20% wind vision will not be achievable by relying on wind turbine components manufactured in Europe—supply chain capability must be expanded in this country to achieve that vision.

4) Human Resources—the need for wind industry engineers and technicians in operations, maintenance and manufacturing will be a huge requirement on a workforce that will need rapid expansion and growth along with the manufacturing and supply chain aspects as well.

5) Transmission Infrastructure—one of the most critical barriers to seeing the 20% goal being realized is the need to get better use of our existing electricity transmission system in this country, but also to grow the transmission system sufficiently to expand the ability to move wind power from the areas of the country where it is available the most and at the lowest cost, to the parts of the country where people and industry are located—and these location rarely correlate. Thus, part of the wind vision study looked at the necessary efforts to aggressively grow the transmission infrastructure in the U.S.

The map shown in Figure 6 is one possible solution, a 765 kilo-volt interstate transmission system overlay to provide a more rigorous and expanded "transmission backbone" to the country's overtaxed and aging transmission grid. This is a conceptual description and has not been formally introduced or proposed, but will be discussed as a possible solution to building more transmission to achieve the 20% wind vision in the forthcoming report. American Electric Power (AEP), a large U.S. utility, produced this section of the report (and the map in Figure 6) at the request of AWEA to supplement the wind vision analysis effort.

CONCLUSION

Over a year has been spent on the 20% wind vision analysis since President Bush set the mark for such an achievement in his 2006 State of the Union address. Considerable work has been expended in preparing the technical report released by DOE. To achieve the goal of 20% of

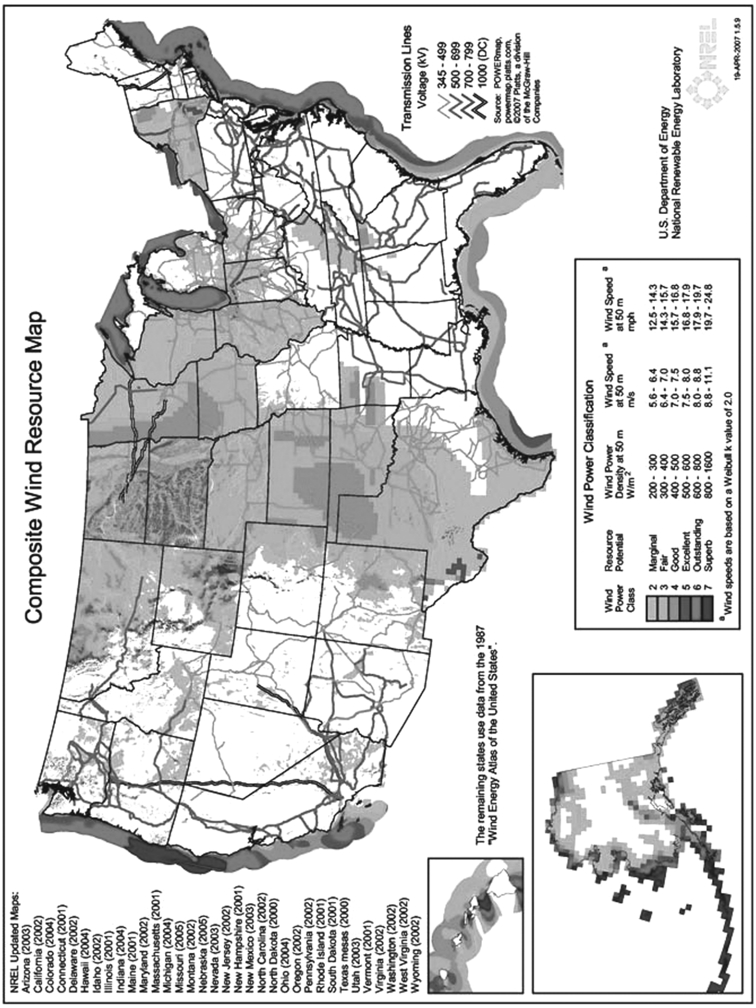

Figure 6. 765-kV Transmission Map. (Source: American Electric Power)

the nation's electricity coming from wind power, a "business as usual" approach will not work. To aggressively grow the wind industry in this country will take significant changes and commitment in federal and state policies and strategies related to the electric industry, massive expansion and growth in the supply chain and manufacturing capabilities in this country to produce wind turbines and turbine components, and a very significant and wide-ranging expansion of the nation's transmission infrastructure. All of these aspects are discussed in greater detail in the report and outline numerous engineering challenges that are involved in each. But the benefits to the U.S. in addressing climate change and securing a greater degree of our energy resources from clean, inexhaustible, and home-grown, domestic resources—combined with the potential to save U.S. consumers billions of dollars in reduced energy costs will make these challenges not only cost-effective, but absolutely necessary to our nation's energy future.

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ABOUT THE AUTHOR

Jeff Anthony joined the American Wind Energy Association (AWEA) in March 2007. As AWEA's manager of utility programs and policy, he is responsible for supporting utilities in their efforts to integrate and adopt wind power as a mainstream generation technology. He works with individual utilities across the U.S. as they expand their use of wind power, to aid them in their understanding of wind's benefits, and to help them address integration and other implementation issues. Jeff also provides support to other policy development areas in AWEA. Prior to joining AWEA, Jeff worked at We Energies (Wisconsin Electric) for 19 years, most recently as the manager of renewable energy strategy. Mr. Anthony graduated from Purdue University with a B.S. in nuclear engineering and received an Executive MBA from Northwestern University. He may be contacted at janthony@awea.org.