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National Renewable Energy Laboratory

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Toward a 20% Wind Electricity Supply in the United States

Preprint

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To be presented at the 2007 European Wind Energy Conference and Exhibition
Milan, Italy
May 7–10, 2007

Conference Paper
NREL/CP-500-41579
May 2007

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Printed on paper containing at least 50% wastepaper, including 20% postconsumer waste

Toward a 20% Wind Electricity Supply in the United States

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Summary: Since the U.S. Department of Energy (DOE) initiated the Wind Powering America (WPA) program in 1999, installed wind power capacity in the United States has increased from 2,500 MW to more than 11,000 MW. In 1999, only four states had more than 100 MW of installed wind capacity; now 16 states have more than 100 MW installed. In addition to WPA's efforts to increase deployment, the American Wind Energy Association (AWEA) is building a network of support across the country. In July 2005, AWEA launched the Wind Energy Works! Coalition, which is comprised of more than 70 organizations. In February 2006, the wind deployment vision was enhanced by President George W. Bush's Advanced Energy Initiative, which refers to a wind energy contribution of up to 20% of the electricity consumption of the United States. A 20% electricity contribution over the next 20 to 25 years represents 300 to 350 gigawatts (GW) of electricity. This paper provides a background of wind energy deployment in the United States and a history of the U.S. DOE's WPA program, as well as the program's approach to increasing deployment through removal of institutional and informational barriers to a 20% wind electricity future.

Background

The U.S. Department of Energy initiated the WPA program in 1999 to enhance wind implementation across the United States. Since WPA's inception, wind energy has grown from 2,500 megawatts (MW) (Fig. 1) to more than 11,000 MW at the end of 2006 (Fig. 2), with an additional 3,000 MW projected in both 2007 and 2008.

In 1999, only four states had more than 100 MW of installed wind capacity. Sixteen states now have more than 100 MW installed. WPA anticipates that five to six additional states will join the 100-MW club in 2007, and by the end of the decade, more than 30 states will have passed the 100-MW milestone. (WPA celebrates the 100-MW milestones because installing the first 100 megawatts is always difficult and leads to significant experience, recognition of the wind energy's benefits, and expansion of the vision of a more economically and environmentally secure and sustainable future.)

The federal production tax credit (PTC) and state policy have been important drivers for wind expansion in the United States. State policies, especially renewable portfolio standards (RPSs), have been instrumental in wind development. Twenty-two states and the District of Columbia have RPSs (Fig. 3), with varying percentages, implementation timetables, rules, qualifying technologies, and technology set-asides. (When the WPA program was initiated in 1999, only 10 states had an RPS [1].) An interesting new federal incentive is Clean and Renewable Energy Bonds (CREBs) for non-profit divisions of state government, such as municipalities and rural electric cooperatives. The USDA Farm Bill 9006 provision offers grants and guaranteed loans for RETs (renewable energy technologies), and wind has fared well in the first 3 years of the program. Section 9006 is intended to encourage the smaller end of the utility-scale projects, as well as distributed small-scale RET applications owned by rural businesses and agricultural producers.

WPA works with national, regional, and state partners to communicate the opportunities and benefits of wind energy to a diverse set of stakeholders. WPA's emphasis remains on the rural agricultural sector, which stands to reap the significant economic development benefits of wind energy development. Additionally, WPA continues its program of outreach, education, and technical assistance to Native American communities, public power entities, and regulatory and legislative bodies. Figure 4 depicts a WPA activities matrix.

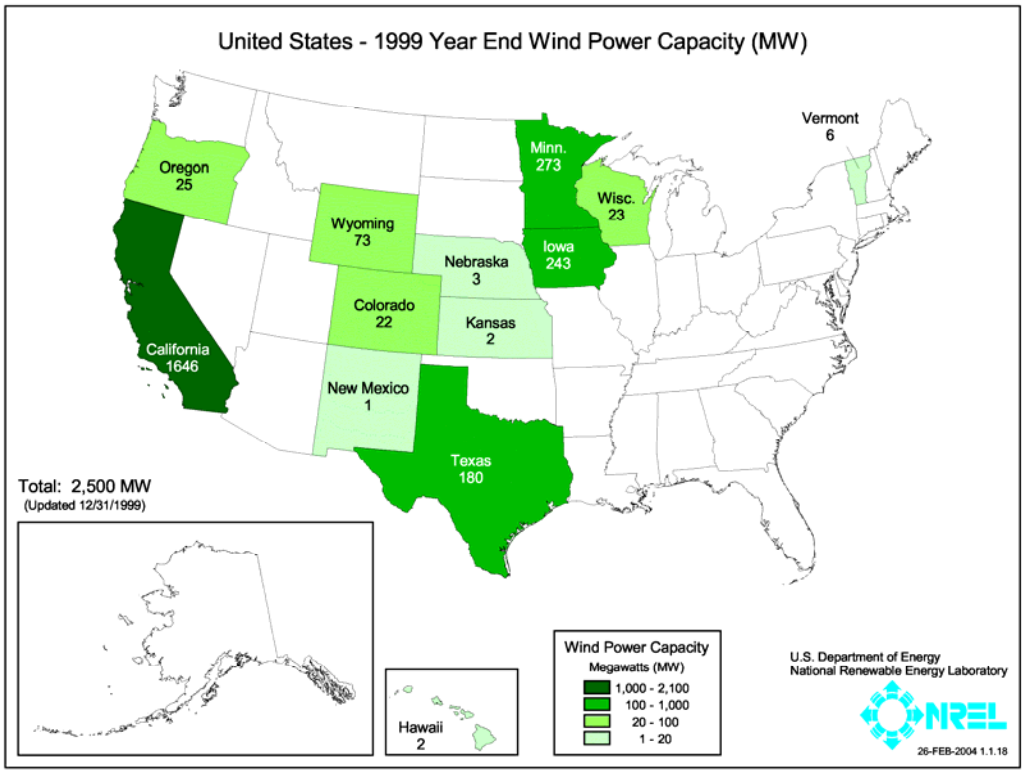

Figure 1. Installed U.S. wind power capacity (MW) in 1999

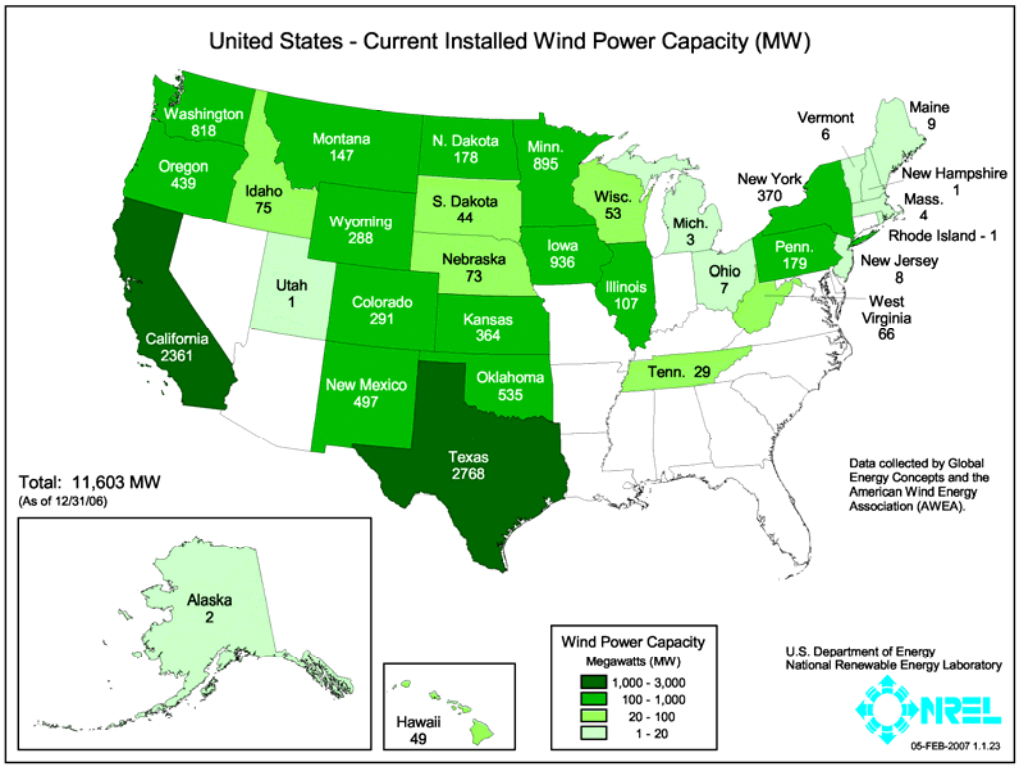

Figure 2. Current installed U.S. wind power capacity (MW)

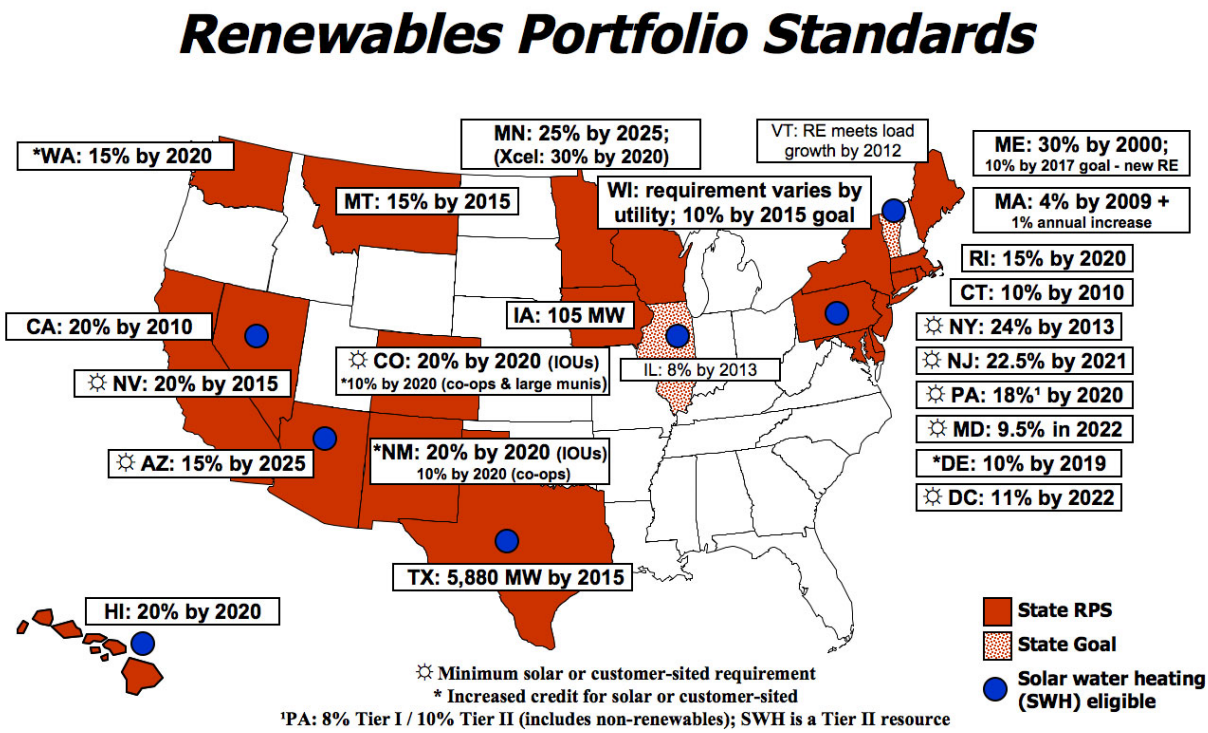

Figure 3. Twenty-two states and the District of Columbia have renewables portfolio standards, with varying percentages, implementation timetables, rules, qualifying technologies, and technology set-asides. Source: Database of State Incentives for Renewables and Efficiency [2]

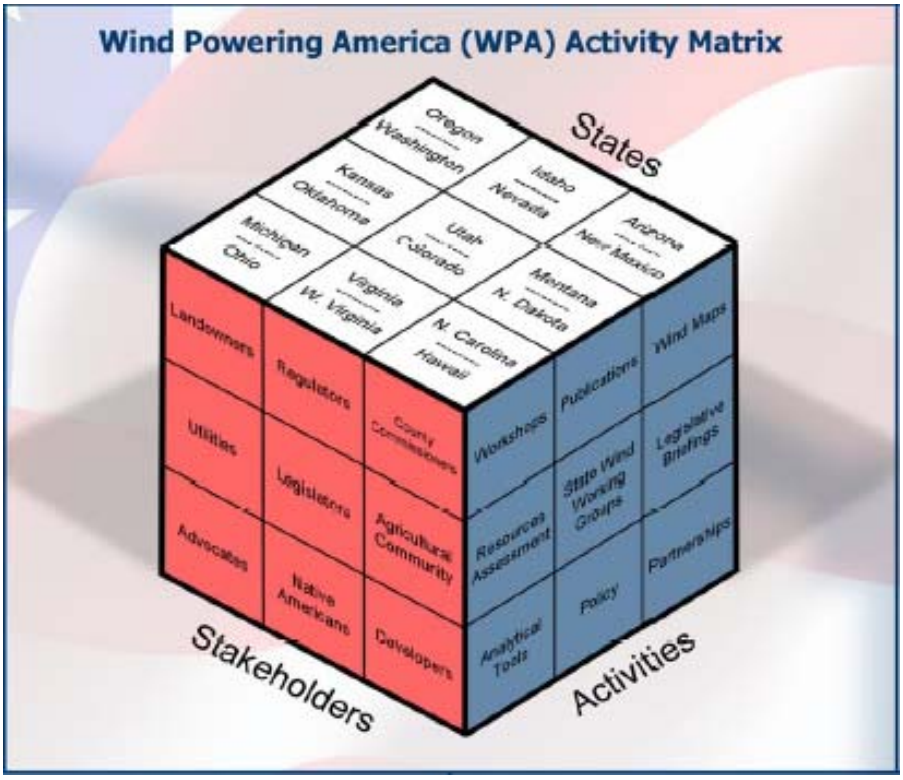

Figure 4. WPA activity matrix, featuring key states, stakeholders, and activities

WPA has focused on forming state wind working groups to evaluate and promote wind energy on a state level. Twenty-nine state wind working groups form strategic alliances to communicate wind's benefits to the state stakeholders and educate the key stakeholder groups. Figure 5 outlines WPA state-level activities, including wind working groups, workshops and Webcasts, exhibits, anemometer loan programs, state-specific small wind consumer's guides, and validated state wind resource maps.

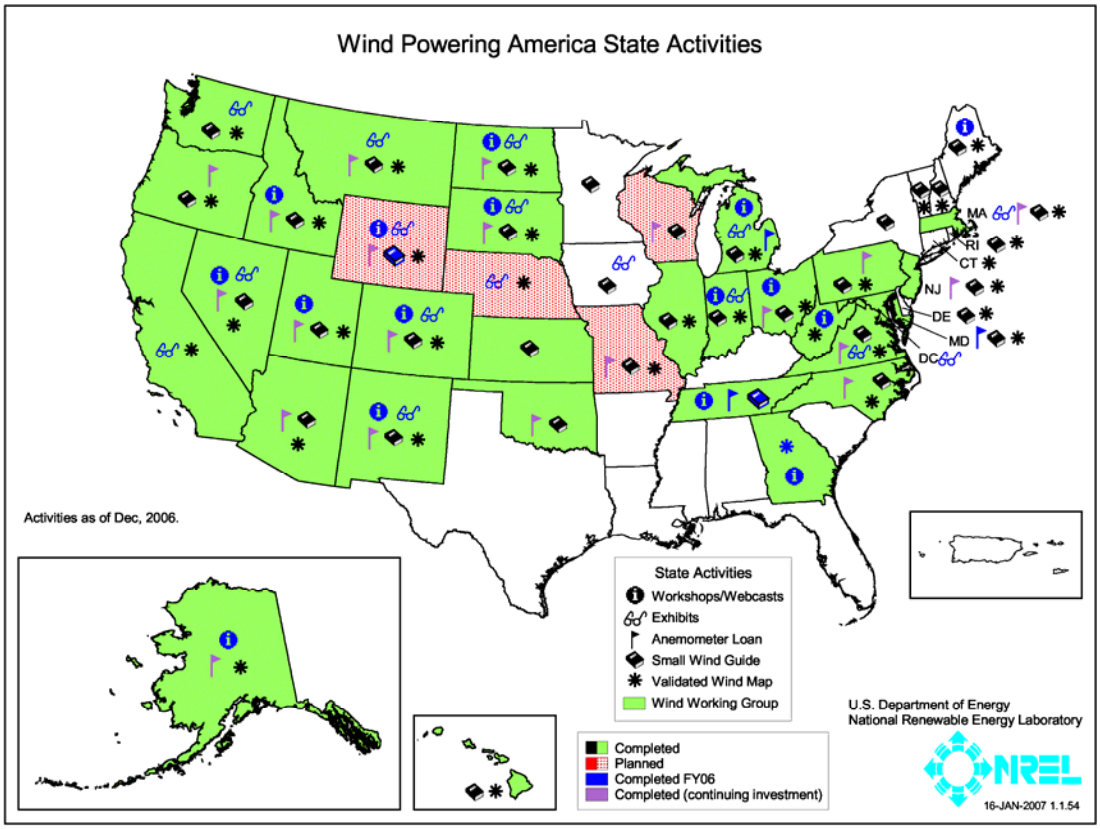

Figure 5. WPA state activities as of December 2006, including state wind working groups

WPA takes a leadership role in understanding and addressing emerging barriers to wind, including wind-radar interactions, and recently helped secure approval of $1.5 billion of new wind projects throughout the Midwest. WPA continues to work on wind-siting issues with other agencies responsible for development on public lands and protection of wildlife. In addition, WPA initiated a Wind for Schools pilot effort in Colorado and will expand it to five additional states in 2007. Through these efforts and many others, WPA continues to expand wind energy as a viable option for power generation.

WPA is not the only organization working to increase the deployment of wind energy in the United States. To build a network of wind energy support across the country, the American Wind Energy Association (AWEA) launched the Wind Energy Works! coalition in July 2005. By August 2006, the coalition comprised more than 70 organizations, including energy-based, agricultural, environmental, economic development, businesses, academic, and others that believe wind power is a part of our national energy solution. The coalition is engaging the public debate with facts about the benefits of using wind energy.

President George W. Bush outlined these wind energy benefits during his State of the Union address in February 2006 when he unveiled his Advanced Energy Initiative [3]. Wind advocates were encouraged to hear the President promise increased investment in "revolutionary" technologies, including wind. The President stated, "Areas with good wind resources have the potential to supply up to 20% of the electricity consumption of the United States." A 20% electricity contribution over the next 20 to 25 years represents 300 to 350 gigawatts (GW) of electricity.

AWEA, DOE, the National Renewable Energy Laboratory, and other stakeholders are currently developing a 20% wind electricity scenario. Achieving this vision requires significantly enhanced outreach efforts to communicate the benefits, the required infrastructure upgrades, and the regulatory actions needed to accomplish this promising future for many stakeholder groups in all regions of the country. WPA's state-based network will need to ramp up its outreach effort to key sectors, as well as

develop regional networks in collaboration with AWEA and other clean energy groups (e.g., 25 x '25 and regional Harvesting Clean Energy initiatives) that can address regional planning and implementation challenges. The following section outlines the effort to remove the institutional and informational barriers to a 20% wind electricity future.

Removing Barriers to a 20% Wind Electricity Supply

General Barriers

General barriers to a 20% electricity supply in the United States include the following:

- The availability of the federal PTC remains uncertain.
- Federal energy and tax policies favor conventional resources over renewables.
- Stakeholder perspectives and interests are mixed (including regional and environmental differences).
- Electricity supply is planned around capacity, not energy, resulting in a competitive disadvantage for wind in all-source solicitations.
- Variable-output wind power is (often incorrectly) viewed as unreliable.
- Energy, economic, and environmental security benefits are often unaccounted for in evaluating wind against conventional generation.
- Because of its relatively low capacity factor, wind power pays higher transmission costs for each megawatt-hour (MWh) of generation than conventional dispatchable generation.
- Wind generation can be built more quickly than new transmission facilities; thus wind development is often constrained by transmission development. Furthermore, FERC rules do not foster dialogue between generation and transmission planners.
- Federal financing sources requirements discourage distribution cooperatives from investing in local wind facilities; often, generation and transmission cooperatives have resisted investing in wind through their member distribution co-ops.
- There is a lack of mechanisms to facilitate interstate cooperation and approval of wind/transmission projects.
- There is a lack of utility financial incentives to invest directly in wind facilities.

Project-Specific Barriers

In addition to the general barriers listed above, specific challenges exist according to market segments: mega-projects, conventional projects, offshore projects, community wind, distributed projects (behind the meter), federal sector projects, power marketing administrations, and Native American projects.

Mega-Projects

Mega-projects are 2,000 MW or larger in size. These projects bring wind from unpopulated land-based or offshore high-wind regions to load centers. They require (and are large enough to justify) dedicated, large-scale transmission to carry the power long distances on land or shorter distances offshore via submarine cables. Realizing the 20% scenario will almost certainly require development of a number of very large projects.

- **Challenge:** multi-state and institutional cooperation for large distribution upgrades and marketing large amounts of power (requiring massive investments and long lead times)
- **Actions:** utility/power buyer incentives are needed to invest/lead projects; state leadership needed to address interstate issues

Conventional Projects

Most wind projects currently being built across the United States by independent power producers and some utility companies are typically sized in the 100-MW to 500-MW range. They are often designed to serve a single service territory and to use existing transmission or new connections to the regional grid. Because they are located in regions with good to excellent wind regimes, they are also frequently far from load centers, and transmission availability is a key consideration. Aggregating turbines into 100- or 200-machine projects produces significant economies of scale. Wind farm projects can be structured to provide long-term stable prices to buyers (in most cases, an electric utility that acts as a local delivery company). Project output is usually sold under long-term Power Purchase Agreements (PPAs). Some recent PPAs transfer ownership of the wind project to the utility power buyer after some interval, and an increasing number of utility companies are considering building their own wind projects in competition with independent wind generating companies.

- **Challenges:** wind is considered a technology risk; capacity is unreliable and often viewed as not cost competitive; integration costs and capacity value calculation methodologies are not standardized; Federal Energy Regulatory Commission (FERC) rules discriminate against wind
- **Actions:** need policies that remove financial risk, FERC rule changes, and standardized methods for capacity valuation and integration costs

Offshore Projects
Offshore wind projects have the advantage of being in excellent wind regimes that are already close to high-density load centers without the need for long-distance transmission. These projects will generally account for their transmission costs up to the point of on-shore grid connection.

- **Challenges:** economics, permitting, view shed
- **Actions:** lower cost, install pilot projects

Community Wind
Community stakeholders have seized wind development as a way to diversify and revitalize rural economies and increase energy independence, advancing "community wind" as a growing portion of the overall U.S. wind industry. Numerous schools, universities, farmers, Native American Tribes, small businesses, rural electric cooperatives, municipal utilities, and even abbeys have installed their own mid-sized and large wind turbines to promote environmental responsibility and keep energy dollars local.

The concept of community wind is simple and flexible. Projects can be any size – one turbine or 100, usually commercial scale and greater than 50 kW, but connected on either side of the meter. Projects can be either land-based or offshore. Community wind includes both onsite wind turbines used to offset the customer's load and wholesale wind generation sold to an unrelated third party. The key is local ownership and local benefits. Community wind projects are in the planning stages in nearly every state with wind development.

- **Challenges:** economics, turbine availability, off-takers
- **Actions:** policies to enable community ownership; wind industry collaboration; valuing diversity and economic development benefits

Distributed Projects (Behind the Meter)
Distributed wind energy (behind the meter wind, or BTMW) is a special subset of community wind that is located on-site to offset the local electricity load, with excess electricity often sold back to the grid on distribution lines. The leading BTMW market is the on-grid sector, where turbines are connected to distribution lines and provide electricity to partially meet local loads at homes or commercial sites such as farms, industrial businesses, schools, business parks, and federal facilities. On-grid installations are currently motivated by state and utility incentives that reduce turbine costs.

BTMW has lower wind speed requirements, so more locations can accommodate and harvest the wind. It expands the suite of distributed generation alternatives, allowing for increased energy independence and security. The U.S. small wind industry holds world preeminence, and as the market continues to expand and manufacturers increase their volume, lower-cost turbines will result.

- **Challenges:** economics and lack of financial incentives across all market segments, turbine reliability (there is a need for testing against common standards), limited turbine size range, interconnection with utilities (especially with rural electric cooperatives), and zoning/permitting (zoning permits are required for towers taller than 35' in suburban markets)
- **Actions:** cost reduction, enabling policies, broader product offerings

Federal Sector
Federal agencies vary widely in size, resources, mission, and operation. In aggregate, the U.S. federal government is the largest single consumer of electricity in the world. Federal electricity consumption was 55,035 GWh (~21 GW wind equivalent at 30% CP).

Federal agencies were encouraged to meet the EO#13123 renewable energy goal of the equivalent of 2.5% of site electricity coming from new renewable energy sources (installed after 1990) by the end of 2005. The target was set at 1,376 GWh of renewable energy based on a 2005 federal electric load estimate of 55,035 GWh. Agencies exceeded the goal considerably with a final tally of 3,811 GWh of electricity from renewable energy representing 6.9% of federal electricity use. There was a dramatic increase in 2004-2005 due to large renewable energy credit (REC) purchases by the Air Force, General Services Administration (GSA), and Environmental Protection Agency (EPA) and the inclusion of previously omitted Department of Defense (DOD) large-scale geothermal projects and waste-to-energy systems. Overall, 96% of the non-DOD renewable energy came in the form of REC purchases.

EPAct 2005 requires federal agencies to incorporate renewable energy into their electricity supply mix at an escalating rate beginning at 3% in 2007 and ratcheting up to 7.5% by 2013. Wind power must compete against low utility rates that large agencies (e.g., DOD) or bulk purchase aggregators (e.g., GSA, Defense Energy Support Center) have negotiated. In times of shrinking budgets and escalating energy prices, federal agencies and aggregators seek to stabilize energy expenses with long-term contracts that can align well with wind farm developers seeking PPAs.

- **Challenge:** energy is not "mission critical" (but shouldn't energy security be?)
- **Actions:** increase federal RET goal to 20%+; encourage uniform development policies for federal land development

Power Marketing Administrations (PMAs)
The Western Area Power Administration (WAPA) and Bonneville Power Administration (BPA) have extensive transmission grids that span enormous wind resources. These grids were built with public monies to support federal hydropower and the development of large areas of the western United States. Today, these publicly created networks are well positioned to help meet national needs for energy security and price stability, low carbon generation, and rural economic development. Demand for wind in areas served by WAPA and BPA exists both among their "preference-right" customers and in adjacent metropolitan areas typically served by investor-owned utilities. Moving wind energy from areas served by WAPA and BPA into load centers is a major opportunity for these federal agencies. Public power customers increasingly demand wind development in their territories.

- **Challenges:** motivation to integrate wind; procedures to bring public power/co-op wind generation to investor-owned utility loads; access to PMA transmission and customers
- **Actions:** 20 % wind integration through analysis and wind-friendly actions and policies

Native Americans
American Indian reservations in the lower 48 states share a wind-generating potential conservatively estimated at more than 150,000 MW, a key component to reaching the industry goal of using wind energy to provide 20% of U.S. electricity consumption. At least 39 Indian reservations with significant wind power potential (Class 4 and above) are located in nine of the 13 high-priority states, with 15 such reservations in six of the eight median priority states. Indian tribes, as governments, have a unique legal relationship with the U.S. federal government and increased opportunities under the EPAct 2005. Within the reservations, tribes can exercise greater permitting authority and promulgate tribal renewable portfolio standards, net-metering, and other renewable energy policies to support the use of wind power to meet their goals of sustainability and energy self-sufficiency within their jurisdictions. Extensive, contiguous communal land holdings on large reservations allow for greater flexibility and minimized transaction costs in siting, placement, and permitting of turbine arrays for economically optimal power production. Reservations are arrayed along the federal transmission grids, and tribal wind can be integrated with federal hydropower, supplementing power marketing agency (BPA and WAPA) allocations. Tribes can use green tags to overcome transmission constraints on remotely generated power. With ownership interests in wind generation and the sale of green tags, Tribes can participate in both wholesale and retail green power markets.

- **Challenge:** current federal and wind policies are ill suited to tribes
- **Action:** sharable PTC; EPAct tribal RET appropriations; PMA priority to tribal wind power

Key Messages
Wind energy stakeholders have differing perspectives (Table 1 provides an overview of stakeholder groups and concerns). Achieving the 20% wind deployment scenario will require communicating the following key messages to a variety of stakeholder groups in all regions of the United States:

- Wind energy provides national economic, energy, and environmental security.
- A convergence of energy security, carbon liability, and fuel uncertainty concerns is likely to transform the U.S. electricity supply market.
- Federal and state policies are needed for a diversified and robust wind energy portfolio (including bulk and distributed wind applications); these policies and incentives should change over time and as markets develop for each segment.
- Offshore wind will most likely be needed in some high-population-density, energy-constrained coastal regions.
- Community and distributed wind are important building blocks for public acceptance of a 20% wind future.
- Targeted messages and education are needed for the diverse set of stakeholder interests and perspectives, including regional variations in same as well as in barriers and incentives.
- Resource planning and procurement should maximize the use of low-marginal-cost, zero-emissions energy resources, which displace more expensive fossil fuel. This saves consumers money and reduces emissions liability.
- All environmental (including water savings) and economic impacts (including natural gas savings and risks, as well as coal risks, costs, and liabilities and benefits) should be included in comparative resource analyses.
- Wind deployment can ramp up rapidly and incrementally to meet local and regional load growth.
- Wind is the crop of the 21st century for rural America, and the resulting economic benefits need to be included in comparative assessments of generation options.
- The federal sector (both facilities and transmission) represents significant opportunities for leadership in use and transmission of wind.
- Non-discriminatory transmission policies and construction are needed to ensure a robust wind energy future.
- Meeting most load growth with wind energy buys time for the development and commercialization of advanced coal technologies able to capture and durably sequester carbon.

Table 1. Stakeholder Groups in the U.S. 20% Wind Energy Scenario

	Planner and Operator G&T	BOD/Executive Management/ Finance/Stockholders	RTOs/ISOs	Regulators - PUC	Regulators - ENV	Manufacturers	Legislators	Developers	Permitting Authorities	Large Customers: Industrial-Commercial	Ag Sector	Advocates	Consumer
Risk		C		C				C					
Profits	C	C				C		C					
Rate Stability	s			C			C			C	s	s	C
Energy Security			C	s			C				s	s	s
System Reliability	C		C			s				C			s
Land Use					s			C	C				s
Environment				s	C		s	s	s			C	s
Health					C		s						C
Water Resource					C		s				C		
Natural Gas Offset				s						s	s		
Economic Development						C	C		C		C		s

***C=critical, s=secondary**

Conclusions

A 20% wind energy penetration scenario is possible in the United States, but it will not happen under business-as-usual scenarios. Policy choices will have a large impact on assessing the timing and rate of achieving a 20% goal. Key issues include market transformation, transmission, project diversity, technology development, policy, and public acceptance. A 20% scenario will be presented at WINDPOWER 2007 in Los Angeles.

References

1. Energy Information Administration. *State Renewable Energy Requirements and Goals: Status Through 2003.* Accessed May 7, 2007, at http://www.eia.doe.gov/oiaf/analysispaper/rps/rps_tables.html

2. Database of State Incentives for Renewables & Efficiency. *Renewables Portfolio Standards.* Accessed May 7, 2007, at http://www.dsireusa.org/documents/SummaryMaps/RPS_Map.ppt

3. The White House National Economic Council. *Advanced Energy Initiative.* February 2006. Accessed April 30, 2007, at http://www.whitehouse.gov/stateoftheunion/2006/energy/energy_booklet.pdf

Acknowledgments

The authors would like to acknowledge the following contributors to the Markets and Acceptance chapter of the 20% wind energy scenario project: Lisa Daniels, Trudy Forsyth, Robert Gough, Ron Lehr, Steve Lindenberg, Dave Olsen, and Robi Robichaud. Highlights of their chapter submissions were reported in this document.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
May 2007

2. REPORT TYPE
Conference Paper

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
Toward a 20% Wind Electricity Supply in the United States: Preprint

5a. CONTRACT NUMBER
DE-AC36-99-GO10337

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
L. Flowers and P. Dougherty

5d. PROJECT NUMBER
NREL/CP-500-41579

5e. TASK NUMBER
WER7.8506

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

8. PERFORMING ORGANIZATION REPORT NUMBER
NREL/CP-500-41579

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)
NREL

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

13. SUPPLEMENTARY NOTES

14. ABSTRACT *(Maximum 200 Words)*

Since the U.S. Department of Energy (DOE) initiated the Wind Powering America (WPA) program in 1999, installed wind power capacity in the United States has increased from 2,500 MW to more than 11,000 MW. In 1999, only four states had more than 100 MW of installed wind capacity; now 16 states have more than 100 MW installed. In addition to WPA's efforts to increase deployment, the American Wind Energy Association (AWEA) is building a network of support across the country. In July 2005, AWEA launched the Wind Energy Works! Coalition, which is comprised of more than 70 organizations. In February 2006, the wind deployment vision was enhanced by President George W. Bush's Advanced Energy Initiative, which refers to a wind energy contribution of up to 20% of the electricity consumption of the United States. A 20% electricity contribution over the next 20 to 25 years represents 300 to 350 gigawatts (GW) of electricity. This paper provides a background of wind energy deployment in the United States and a history of the U.S. DOE's WPA program, as well as the program's approach to increasing deployment through removal of institutional and informational barriers to a 20% wind electricity future.

15. SUBJECT TERMS
wind energy; Wind Powering America; 20% wind energy scenario; 20 percent wind energy scenario; deployment

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (*Include area code*)
Unclassified	Unclassified	Unclassified	UL		

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

F1147-E(12/2004)