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Overcoming Technical and Market Barriers for Distributed Wind Applications: Reaching the Mainstream

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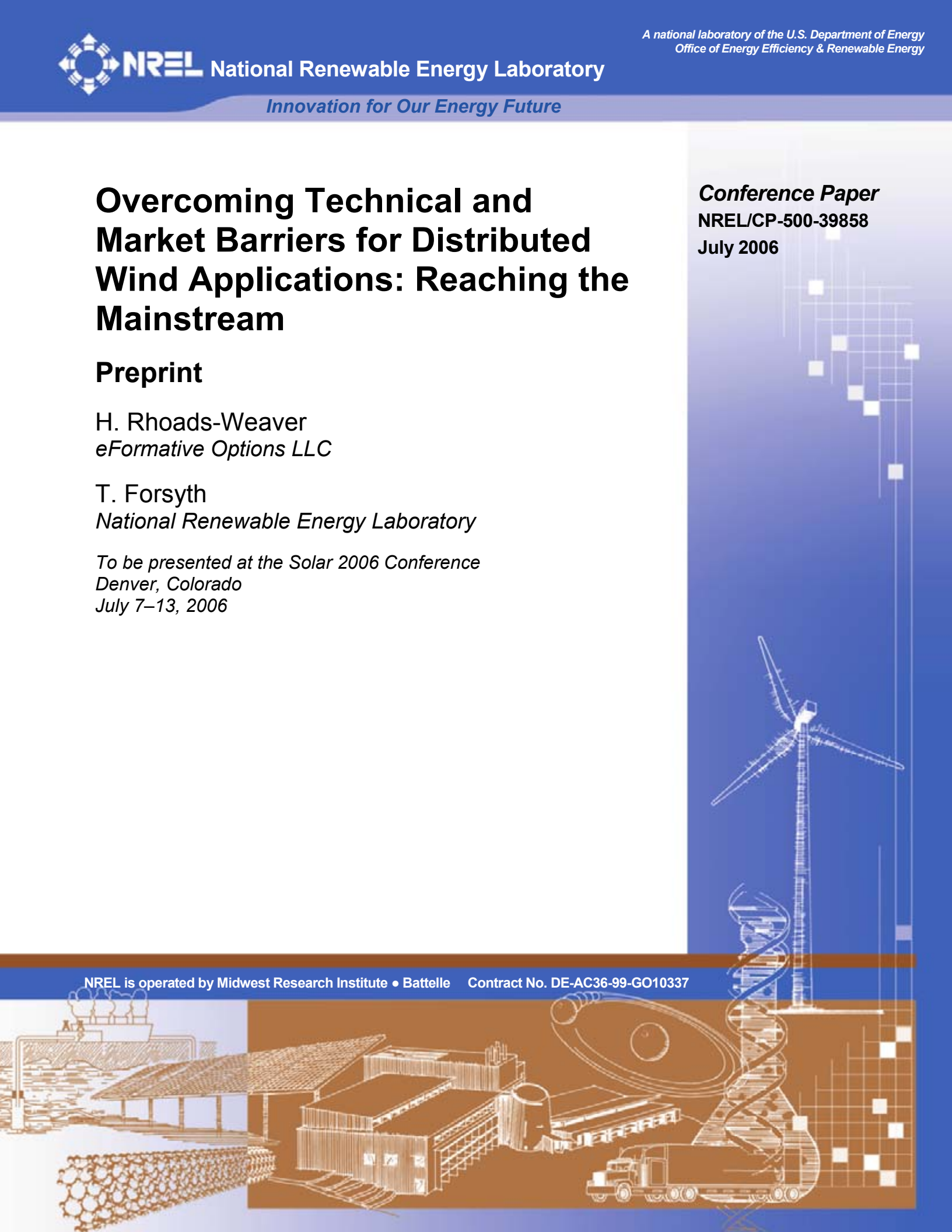

OVERCOMING TECHNICAL AND MARKET BARRIERS FOR DISTRIBUTED WIND APPLICATIONS: REACHING THE MAINSTREAM

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ABSTRACT
The distributed wind industry is poised for rapid market growth in response to continuing energy price hikes and increased demand for on-site power generation. However, for distributed wind to reach its mainstream market potential, the industry must overcome several hurdles, primarily in system costs, interconnection and installation restrictions.

A recent National Renewable Energy Laboratory (NREL) assessment of the five primary distributed wind turbine (DWT) market segments found that the largest expected increases are in the U.S. residential grid-connected wind market and the international "small-scale" community wind market. Together with farm, industry, small business, off-grid, and wind/diesel hybrid applications, the entire DWT wind market is expected to grow from an estimated 410,000 units installed worldwide totaling 8,800 MW in 2005 to about 850,000 units totaling 100,000 MW by 2020.

Technological advances are needed to bring the cost of energy of DWT to a level competitive with conventional generation sources, currently $0.05-0.12/kWh. Small and mid-sized wind turbines offsetting customer loads are typically sited in low wind speed regimes and experience low capacity factors, but increased sales may lead to higher penetration levels on relatively weak rural utility grids. This paper characterizes the principal DWT market segments and constraints related to economics, interconnection and utility acceptance, permitting challenges, and other critical barriers. It recommends research, policy and outreach efforts to address these obstacles for DWT to reach the mainstream.

With large wind turbine and PV manufacturers scrambling to keep up with demand, this paper describes how the distributed wind industry can overcome long-standing stumbling blocks and play an important role both in the U.S. and internationally in supplying power near the point of end use.

1. INTRODUCTION

Distributed wind energy systems provide clean, renewable power for on-site use and help relieve pressure on the power grid, while providing jobs and contributing to energy security for homes, farms, schools, factories, private and public facilities, and remote locations. America pioneered small wind technology in the 1920s, and it is the one renewable energy industry segment that the U.S. still dominates in technology, manufacturing, and world market share.

A 2005 UK Department of Trade and Industry study found that "mini" wind turbines and other "microgeneration" technologies can deliver significant household carbon reductions. Aided by strong government support for product development and market incentives, new turbines from China, India and Europe are providing stiff competition for U.S. products both in overseas markets and domestically.

The high cost of energy generated has historically been the most significant barrier to DWT market growth. DWT economics are highly variable, with reductions in total installed cost from the current range of $4-7/W to $2-3/W after incentives necessary for significant market expansion in the U.S. grid-connected market. This can be achieved through technology improvements as well as policy support. Drivers of market growth include financial incentives, favorable net metering, standardized interconnection policies, and high retail electricity rates. Key technical challenges include the lack of performance standards and ratings, grid integration, product availability and reliability, low wind regime technologies, installation and maintenance, and quiet operation.

2. STUDY BACKGROUND

With the assistance of DWT suppliers, the American Wind Energy Association (AWEA) launched a web-based survey in late 2005 targeting small turbine manufacturers and retailers, distributed wind project developers, service technicians, component vendors, utility and tribal representatives, and state incentive program managers to seek input on key barriers and market drivers. Earlier in the year AWEA obtained 18 responses to a market survey circulated to 80 small wind industry participants, representing a 20% response rate which included all of the principal U.S. small

turbine manufacturers. AWEA broadcast the follow-up questionnaire to more than 600 DWT stakeholders involved, and received more than 200 responses including thorough answers from key industry leaders.

The recent survey examined barriers and drivers for the key DWT market growth areas: grid-connected residential; schools/public facilities; farms and small businesses; remote off-grid/village power; wind/diesel hybrid systems; center pivot irrigation; water desalination; vehicle to grid; and other niche markets including telecom, military, and marine applications. It documented the required cost of energy to compete in these key markets, and the most common alternatives to wind energy. It explored technical challenges such as designing low-cost tower options, new power conversion equipment, complete turbine redesign, and re-engineering specific turbine components. It also collected input on remedies to these barriers and the importance of various policy objectives designed to level the playing field.

AWEA then assisted NREL in compiling more detailed sales data from manufacturers, including geographic breakdowns, estimates of grid-connected and off-grid applications, the number of homes and businesses using wind power on-site, and cost components for two selected market segments, grid-connected residential and "small-scale" community wind, summarized below in Table 1.

For the purpose of this study, *"small-scale" community wind,* a subset of the larger community wind market, is defined as projects utilizing turbines 1 MW in nameplate capacity or less where a local entity has a significant financial stake in the outcome of the project. "Small-scale" community wind projects are typically connected to 13.8 kV or lower distribution lines, either behind the meter offsetting a portion or all of the electricity used on-site by a load in the community, or using a dedicated transformer with all energy sold to the interconnecting utility.

3. CURRENT SITUATION

The federal Production Tax Credit (PTC) has fostered rapid growth in large-scale wind development with periods of stagnation due to the advance planning requirements of large projects and the timing of extensions of the PTC, which has expired three times since Congress first enacted it in 1992. This boom and bust cycle has caused apprehension among turbine suppliers interested in opening facilities in the U.S. as well as shortages of equipment, personnel, and business and legal expertise for community-scale projects. Large wind turbines are essentially unavailable for small projects until 2008, after the current PTC expires. Most of the large turbine manufacturers have minimum order requirements, restricting access to community developers. This situation is leading some community wind project proponents to consider mid-sized 50-900 kW turbines as a viable alternative to the currently more cost-effective multi-MW wind turbines. High thresholds on net metering rules and feed-in tariffs assist in serving medium-sized loads such as schools, many businesses and small manufacturing facilities. Only a few U.S. and foreign suppliers currently have products available to fill this growing market niche.

Moreover, elected officials across the U.S. and internationally are showing increased support for small-scale and community wind. The 2005 Federal Energy Policy Act established Clean Renewable Energy Bonds allowing co-ops, government agencies, tribes, non-profit organizations and other entities not eligible for the PTC to apply for low-interest bonds to finance wind and other renewable resources for local economic development. Minnesota, Iowa, Washington state and Ontario have also recently passed incentives for small and community-scale wind projects.

To date about 270 MW of community wind projects are installed in the U.S., representing $250 million in investment in rural communities. Of these, about 110 MW meet the definition of "small-scale" community wind utilizing wind turbines 1 MW or less. At least 440 MW of new community-owned wind projects are in the advanced planning states in the U.S., however project developers are expecting to utilize turbines larger than 1 MW for nearly all of this future capacity due to their better economics.

John Deere has recently provided equity investments in several wind energy projects in rural areas both in the U.S. and abroad, creating a business unit to provide project development, debt financing and other services to farmers wanting to harvest their wind resources. Supporting the company's goal of helping customers "improve their profitability and productivity," Deere's new initiative signifies major growth potential in the community wind market in attracting a leading financial service provider.

The EU has been the historic leader in community wind, with about 80% of all installed wind turbines considered community applications. Since Europe is by far the largest market for community wind, assuming 25% of these turbines are 1 MW or less with an average turbine size of 750 kW, 11,000 turbines totaling 8.1 GW is a fair estimate of the current international market for this sector.

Grid-connected residential wind installed capacity has historically been less than 5% of the total sales of small turbines (up to 100 kW). However, DWT manufacturers expect that portion to grow to more than 20% by 2020. The U.S. Department of Energy Renewable Electric Plant Information System (REPiS) database has documented nearly 1,200 small wind turbines totaling 16 MW as of 2005 in 45 states. We estimate that about 70% of these documented systems and 40% of the capacity are grid-connected residen-

TABLE 1: SELECTED DWT MARKET SUMMARY INFORMATION

1. "SMALL-SCALE" COMMUNITY WIND*			2. GRID-CONNECTED RESIDENTIAL WIND**		
1.1 Domestic Market Potential (cumulative installations)			**1.2 Domestic Market Potential (cumulative installations)**		
2005	150 Units	110 MW	2005	1,800 Units	9 MW
2010	220-500 Units	160-380 MW	2010	5,100-7,400 Units	29-44 MW
2015	320-1,700 Units	240-1,300 MW	2015	10,000-26,000 Units	72-211 MW
2020	470-6,000 Units	350-4,500 MW	2020	18,000-92,000 Units	170-1,000 MW
2.1 Regions of Specific Interest			**2.2 Regions of Specific Interest**		
1. Midwest (MN, IA, NE, TX, ND, SD, IL)			1. West Coast (CA, WA)		
2. Northeast & Mid-Atlantic (incl. MA, NY, VT)			2. Northeast & Mid-Atlantic (NY, MA, PA, VT)		
3. West (CO, MT, CA, OR, WA, AK)			3. Midwest/Central (TX, OH, MN, IA, WI, CO)		
3.1 International Market Potential (cumulative installations)			**3.2 International Market Potential (cumulative installations)**		
2005	11,000 Units	8.1 GW	2005	1,100 Units	5.5 MW
2010	17,000-29,000 Units	13-22 GW	2010	2,500-3,300 Units	14-19 MW
2015	28,000-79,000 Units	21-59 GW	2015	4,800-11,000 Units	34-86 MW
2020	45,000-210,000 Units	34-160 GW	2020	8,700-37,000 Units	82-410 MW
4.1 Regions of Specific Interest			**4.2 Regions of Specific Interest**		
1. Europe (Germany, Spain, Denmark, Norway, Netherlands)			1. Asia (Japan, China, India)		
2. Asia (China, India, Russia)			2. Europe (UK, Spain, Italy, Germany, Netherlands, Greece)		
3. South America/Central America, Africa, Canada			3. Central & South America		
5.1 Key Market Barriers			**5.2 Key Market Barriers**		
1. Turbine availability			1. Economics (installed cost, COE, payback period)		
2. Economics			2. Lack of incentives (financial and policy, state and federal)		
3. Interconnection			3. Zoning, permitting, neighbor perception, public awareness		
4. Permitting/Siting			4. Connecting to the grid (interconnection stds, REC issues)		
6.1 Key Technical Barriers			**6.2 Key Technical Barriers**		
1. Grid interconnection and integration			1. Lack of performance standards, testing and ratings		
2. Turbine and tower options			2. Product reliability		
3. Installation and maintenance			3. Technologies for low wind regimes		
4. Performance projections			4. Sound levels / quiet operation		
7.1 Expected Turbine Size Range & Coupling			**7.2 Expected Turbine Size Range & Coupling**		
1 MW or less			1 kW to 25 kW, Market void for 5 kW and 15 kW turbines		
540 V to 660 V AC, typically connecting to distribution lines of 13.8 kV or less			120V to 240V, 60 Hz AC, the standard electrical service of most residences		

** "Small-scale" community wind sector (≤ 1 MW) is estimated to be about 20% of 2005 EU wind market.*

*** Grid-connected residential sector is expected to grow from <5% of total small DWT market (≤ 100 kW) to >20% by 2020.*

tial applications. Based on available data, we estimate that the cumulative grid-connected residential wind installed capacity as of 2005 is about 2,900 units totaling 14.5 MW worldwide, with 1,800 units totaling 9 MW in the U.S.

3.1 Market Challenges

Key factors contributing to turbine system costs, the most significant barrier to market adoption and growth of DWT, include turbine size (rotor diameter, rated capacity), average wind speed at hub height, power output control/limitation technology, and applied grid control technology. External factors include infrastructure and transport logistics costs, inadequate net metering, permitting costs and time, and other location-specific conditions. From the perspectives of power generation potential (kWh/kW), return on investment, and cost of energy (cents/kWh), current designs of small and mid-sized turbines are at a disadvantage compared with larger utility-scale wind turbines as they are relatively more expensive to manufacture (both materials and labor) and their limited hub heights (due to cost, setback

requirements, aesthetics, etc.) result in comparatively less energy production. In addition, their low manufacturing volume impede cost reductions with series-scale production.

The lack of effective performance standards, testing and consumer ratings for DWT contribute to product reliability concerns in the market. Inconsistent interconnection standards and the reluctance of utilities to adopt DWT distributed generation programs further constrain the market and hinder market efficiencies. Dealers and installers increasingly report that the insurance industry is requiring additional insurance coverage for DWT owners. Finally, small wind turbines are not consistently addressed in state renewable portfolio standards (RPS), incentive programs and consumer education campaigns.

3.2 Utility Acceptance of DWT

The DWT market is primarily rural homeowners, farms, small businesses and schools. Many DWT sites appropriate for wind power are served by rural electric co-ops (RECs), which typically view net metering and distributed generation as cross-subsidies and inconsistent with co-op principles that members should share equally in the investment, risk and benefits of the co-op. Many RECs believe that net metering results in reduced co-op revenue while the fixed costs remain, and that the co-op's other consumers ultimately subsidize the self-generating consumer. While RECs do hold a large territory, many other utilities in more populated areas do not oppose net metering. However, most utilities still require significant education, softening of interconnection requirements, and generally an improved understanding of the benefits of capturing consumer investments in DWT.

4. MARKET ASSESSMENT

4.1 Mid-Sized Community Wind Market Potential

The U.S. Energy Information Administration forecasts that total domestic wind capacity will grow at an average annual rate of 11% from 2005 to 2010, and then 3% from 2010 to 2020. However, from 1998 to 2003 installed wind capacity grew an average of 28% per year, and growth from 2004 to 2005 was a record 35%. In consideration of recent trends in the community wind market, we estimate a conservative annual U.S. lower bound growth rate for "small-scale" community wind through 2020 to be 8%, although with favorable policies, economic conditions and sufficient availability of competitively priced mid-sized turbines, its average annual growth could be as high as 28%.

From 1995 to 2005, Europe realized average annual growth of 32% in wind capacity and 22% in the number of installations. Using this historical information and recent trends, we estimate the future international market for "small-scale" community wind to have a lower bound annual growth rate of 10% and an upper bound of 22%. The slightly higher lower bound international estimate compared to the U.S. rate reflects the fact that the EU community wind market is already firmly established. The somewhat smaller upper bound estimate reflects the maturity and overall direction of the EU market toward large off-shore wind development.

Germany and Spain are of particular interest for community wind, currently leading the EU in both growth and installed capacity. Together these two countries accounted for 58% of the EU's total wind capacity growth in 2005 and 70% of the EU's total installed capacity. Canada is also showing signs of following the lead of nearly a dozen European nations in enacting feed-in tariff laws to support wind generation.

4.2 Grid-Connected Residential Wind Market Potential

The small DWT industry is increasingly focused on the rural residential market, with new attention on the large-lot suburban residential market. A 2004 survey of readers of *Home Power Magazine* (3,573 respondents) indicated that 38% intended to utilize renewable energy in a rural home, 27% in a suburban home, and 16% in an urban home, with more than 40% of respondents planning to install wind turbines.

The growth potential of the DWT market presents a unique, timely opportunity. Moreover, trends show that growth may occur at significantly increased rates if critical market barriers are overcome. The 2006 AWEA-NREL market survey found that the leading U.S. DWT manufacturers are projecting an average annual growth rate of 32% for the U.S. grid-connected market through 2020, with their potential domestic market share as high as 41,000 units totaling 130 MW in 2020. These aggressive projections signify confidence that the DWT market is poised for strong growth.

AWEA's 2005 study found that in ideal market conditions (with sufficient policy support), annual U.S. sales of DWT could reach $55M by 2010. The same study forecast a slow growth scenario based on scaled-back projections from only the established industry players, estimating annual U.S. sales at $27M in 2010 if the key barriers are not addressed; however, some industry members believe that these projections are too conservative. With increased monitoring of these market trends, it is becoming increasingly evident that the DWT industry has the potential to become one of the leading renewable energy distributed generation industries.

Based on these studies and current industry trends, we conservatively estimate cumulative U.S. on-grid residential wind turbine installations to have a lower bound growth rate of 9% and an upper bound growth rate of 28% through 2020, with the average turbine size increasing. The criteria for states with strong DWT markets listed in section 2.2 of Table 1 include high residential electricity rates and/or loads, adequate wind resources, financial incentives, streamlined permitting requirements, positive public perception of

small turbines, state or utility public education and awareness campaigns, and simplified interconnection processes.

U.S. manufacturers of DWT are in an excellent position to take advantage of the international DWT market. AWEA estimates that more than 40% of U.S.-manufactured DWT are exported. Currently, two U.S. manufacturers are the world's recognized market leaders in sales volume. A recent study conducted by Marbek Resource Consultants Ltd. indicated that 96% of reported sales in Canada are attributed to three U.S. manufacturers. The international export market, therefore, presents a considerable economic opportunity for U.S. manufacturers, both for on-grid and off-grid DWT.

The 2006 DWT market survey conducted for this study confirms a robust international export growth outlook. The leading U.S. DWT manufacturers are projecting an average annual growth rate of 34% for the non-U.S. grid-connected market through 2020, with a potential U.S. export market as high as 22,000 units totaling 66 MW in 2020.

Other estimates of the international DWT market come from AWEA's 2005 DWT market study and a 2002 study by Garrad Hassan Consulting. The AWEA study estimates that the international small wind market is roughly the size of the total domestic DWT market. UK-based Garrad Hassan projects a five-fold increase from 2002 global small wind sales, equating to 150 MW/year and 150,000 turbines/year.

A number of countries have shown considerable interest in DWT technologies. The 2005 UK "microgeneration" study anticipates up to 5 GWh of energy from 1.5 kW residential wind by 2030, with a doubling by 2050 and with small wind supplying 4% of UK's electricity requirement. The study, commissioned by the UK Department of Trade and Industry, estimates an upper bound of nearly 120 MW and a lower bound of 20 MW of installed DWT capacity by 2020, depending on the amount of government support.

The Marbek study concludes that the Canadian DWT market requires incentives in four areas: market development (federal rebate, provincial incentives), policy development (net metering, streamlined environmental processes), technology development (standardized testing, demonstration program), and education and awareness-raising (model interconnection agreements, installation guidelines for siting, zoning, permitting, interconnection).

The Lawrence Berkeley National Lab reports that China manufactured 12,000 small wind turbines in 2000, and that the Chinese market has been strongly supported by government policies and incentives. In February 2005, China passed a groundbreaking law to promote renewable energy. While China has a great potential for wind, as in much of the world, its primary market is off-grid rural electrification.

In consideration of these studies, the large DWT market share held by U.S. manufacturers and our familiarity with current industry trends, we conservatively estimate lower and upper bound international annual growth in grid-connected residential wind installations at 11% and 28% respectively. The lower rate is slightly higher than our U.S. estimate for this sector due to the likelihood that new international markets will continue to emerge and expand. We expect the average turbine size for the grid-connected residential wind sector to increase globally due to the availability of new products.

4.3 Correlations to PV

Considerable market information is available for the PV industry that could be useful to the DWT industry. Examples include trends in grid-connected PV installations and forecasts, cost-of-energy, consumer demographics, purchase criteria, effectiveness of incentives and market drivers, and potential applications and market size for hybrid wind/PV systems. This insight can help inform marketing and technology decisions for the potentially large suburban residential market targeted by some DWT vendors.

The PV industry also has significant public support and resources to advance policy incentives, obtain research funding, and conduct public awareness campaigns. Coordination between the DWT and PV industries due to similar interconnection technologies and overlapping target markets could prove effective for developing recommendations beneficial to both industries. In addition, market growth can be anticipated in hybrid wind/PV systems.

5. CONCLUSIONS

The market for residential, farm and community wind projects is substantial and growing, attracting increasing attention from policy makers, community groups and economic development professionals. However, the U.S. DWT market, and U.S. participation in the international small and community wind markets, are facing major market and technical constraints that need focused attention.

Actively engaging federal, state and local governments in addressing key economic, policy, permitting and public education barriers can ensure the realization of the energy security, self-sufficiency and reliability that DWT promises. The DWT market will be vitally enhanced by cost-competitive and easily obtainable equipment, with production rates keeping up with growing market demand. Technology advances with rotors, towers, and controllers can substantially improve DWT performance as well as ease of installation and maintenance. Industry standards, consistent policy and financial incentives, and public education campaigns will all help enable DWT to compete vigorously in the distributed generation market.

Based on our analysis of critical path technologies, we recommend research and outreach activities in the following high priority areas to enhance market growth and aid U.S. manufacturers in competing in the DWT market space:

- Advancing innovative designs for small and mid-sized turbines, rotors and towers optimized for low winds addressing grid interconnection, productivity, installation and maintenance issues;
- Supporting performance and rating standards development and reliability testing;
- Designing, testing and certifying advanced remote-monitored controllers to simplify grid interconnection processes and support weak rural distribution systems;
- Developing technical "windsmith" training programs to help reduce installation delays and turbine downtime;
- Developing easy-to-use computer tools for analyzing project economics and modeling wind resources to assist with micro-siting, seeking low-cost financing, and taking advantage of incentives;
- Documenting benefits for utilities of in promoting local investment in DWT; and
- Promoting model zoning ordinances and educating local planning officials to aid in adoption of responsible siting requirements while streamlining the approval of small and mid-sized wind turbines.

Distributed wind generation would benefit from technology enhancements and public awareness programs to shift the business paradigm of RECs to include support services for members generating wind power as a "cash crop." Co-ops could aggregate wind power from members for sale to outside parties, upgrading their extensive distribution and transmission infrastructure for bi-directional power. Both private utilities and co-ops could offer small wind turbine sales, leasing, installation, and maintenance for customers.

The DWT industry would also benefit from more detailed market analysis examining customer motivations. With the emergence of more accurate wind resource maps, new low wind turbine technologies, updated census data, and analysis of economic and social market drivers, an in-depth market study focused on end-user purchase decisions would provide valuable data to inform research, product development, marketing and policy decisions.

Oversight of performance certification and compliance testing is urgently needed to address critical reliability and credibility issues in order to support major expected growth in the grid-connected residential wind market. Third party researchers familiar with the issues of both inverter and turbine manufacturers are in the best position to bridge the gap and provide innovative system solutions. On the other hand, without credible, widely used DWT performance and reporting standards, unsafe or poorly performing systems could damage the reputation of the entire wind industry.

Widespread deployment of small wind turbines can increase the public's familiarity with wind energy generation, attract mainstream media coverage, and pave the way for local community support for larger wind developments. Small turbines, in particular installations at schools and other high-visibility locations, can become an important asset in reducing fears about unfamiliar technology, which in turn can reduce the unpredictable nature of siting and permitting large wind projects. Small turbines can be installed in selected neighborhoods to increase public awareness of residential wind options, which can also help utilities increase customer participation in voluntary green power programs and provide local "advertisements" of utilities' green power.

The international market, and more importantly the international impact on the growth of the DWT market, is much larger than the capacity estimates indicate. The added MWs of distributed electricity can make a huge difference to people around the world. Energy security and grid stability can be greatly improved by spreading distributed generation over a broad area. Efforts to enhance the viability of the DWT industry will have major global benefits in securing future energy supplies and meeting increased demand for decentralized, affordable clean power. Mainstream adoption of DWT can enhance awareness and support for the entire wind energy industry.

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