Union of Concerned Scientists

Citizens and Scientists for Environmental Solutions

RENEWABLES:

ENERGY YOU CAN COUNT ON

TAPPING INTO WIND POWER

April 2011

All across the United States, abundant wind resources can be harnessed to produce reliable and clean electricity. When well-sited and well-managed, wind power is one of the most cost-effective sources of electricity available, capable of generating power at prices competitive with new natural gas plants and cheaper than new coal and nuclear plants.

And compared with fossil fuels, wind power offers substantial public health, economic, and environmental benefits. It produces no air or water pollution, global warming emissions, or waste products, and saves water. It can also create jobs and other local economic benefits, stabilize and even reduce energy prices, cut dependence on imported fossil fuels, and conserve natural resources for future generations. For these reasons, wind is a viable energy solution that can play a major role in our transition to a sustainable energy future.

ECONOMIC BENEFITS

More Stable Power Costs

Wind power is steadily becoming one of the more cost-effective choices for electricity in the United States. The up-front costs are typically higher than those of conventional electricity sources because of the expense of manufacturing and installing the turbines. Once the turbines are in place, however, the "fuel" is free, and the price of the power remains stable because operation and maintenance costs are low compared with most other power sources that have to pay for fuel.

© iStockphoto.com/Steve Baxter

Technological advances and growing economies of scale have driven down wind costs by about 80 percent over the last three decades, though U.S. wind turbine prices began to increase in 2005 due to rising global demand, higher materials costs, and a weak dollar. Still, the Department of Energy has found that wind power was roughly competitive with wholesale power from 2003 to 2009 (Wiser and Bolinger 2010).

Over the last several years, wind and natural gas have been the most cost-competitive sources of new power generation, and when natural gas prices spiked to near-record levels in 2008, wind power was often the cheapest available option (when sited in optimal locations). By 2010, increased supplies and low energy demand caused by the recession shifted the economic advantage back toward natural gas, but as the nation's economy recovers, the cost of wind turbines is once again declining. Experts project that well-situated wind will continue to compete with natural gas as the lowest-cost power option (Wiser and Bolinger 2010). The

> Wind is a viable energy solution that can play a major role in our transition to a sustainable energy future.

price stability benefits offered by wind power provide a clear long-term advantage for utilities and their customers over the price volatility associated with natural gas and other fossil fuels.

Job Creation

The wind industry is a proven job creator, even during the recent recession: according to the American Wind Energy Association, the industry employed roughly 85,000 full-time workers at the end of 2009—up from 35,000 in 2007—including more than 18,000 in manufacturing and many others in project development, construction, operations, maintenance, and financial, legal, and consulting services (AWEA 2010). The average 100-megawatt (MW) utility-scale wind project creates 40 to 160 construction jobs, or about one to two jobs for each typical-size turbine. Once such a project has been constructed, approximately 10 to 25 permanent employees are required to operate and maintain it (NREL 2005).

The opportunity for continued job growth in manufacturing is substantial. A single large-scale wind turbine contains more than 8,000 parts (ranging from the many small mechanical, structural, and electrical pieces to the much larger components such as blades, towers, and gearboxes), and a growing percentage of this equipment is being built domestically: about 60 percent in 2009, up from less than 20 percent in 2006 (Wiser and Bolinger 2010). Smart policies and a stable, long-term market for wind power can continue this trend and help revitalize communities across the United States.

© Nick Benson, ottergoose.net

The wind industry is a proven job creator, spurring "direct" employment opportunities in project development, construction, operations, and maintenance, as well as "indirect" employment opportunities (such as transportation, lodging, and other services) that support wind development. Above: Interstate rail brings turbine towers to a project site. Below: Workers assemble turbines at Clipper Turbine Works in Cedar Rapids, IA.

© Clipper Wind Inc.

Stronger Local Economies

Local governments collect property and income taxes and other payments from wind project owners. Owners of the land on which wind projects are built often receive lease payments ranging from $3,000 to $6,000 per megawatt of installed capacity, as well as payments for power line easements and road rights-of-way. Or, they may earn royalties based on the project's annual revenues.

Wind projects therefore keep money circulating within the local economy, and in most states wind production will reduce the need to spend money on coal and natural gas imports. Thirty-eight states were net importers of coal in 2008—from other states and, increasingly, other countries: 16 states spent a total of more than $1.8 billion on coal from as far away as Colombia, Venezuela, and Indonesia, and 11 states spent more than $1 billion each on net coal imports (Deyette and Freese 2010). In 2009, the United States spent $15.7 billion on natural gas imported from other countries (EIA 2010).

Greater Economic Security

Oil and natural gas prices are vulnerable to global market forces and events. Increasing our use of wind power would reduce our dependence on natural gas for electric power generation and, to a lesser extent, on oil for vehicle fuel (as wind would provide a clean power source for the emerging electric vehicle market). Less dependence on fossil fuel imports would help insulate consumers against the risk of fuel supply cutoffs or shortages, reduce payments made to unstable nations, and make our energy supply more secure.

Because wind turbines require no fuel and produce no waste, wind power is also far less risky than conventional energy sources, which carry the risk of fires, fuel spills, and toxic waste leakage. Wind power also avoids the safety, security, and radioactive waste

Innovative financing helps Iowa build its first community-owned wind project

Bill Sutton first thought about using wind energy on his farm in Jefferson, IA, in 2002. Five years later, he and his business partner David Ausberger, along with five other local landowners, fired up the turbines of the Hardin Hilltop Wind Farm—Iowa's first "community-owned" wind project. These projects are owned by local individuals and institutions like farmers, small-business owners, schools, churches, and small rural electric cooperatives, who are seeking a much larger financial return on a project than just lease payments or tax revenues.

By working together, Sutton and his partners were able to share start-up costs, apply for funding sources, find equity partners, increase their total generating capacity, and negotiate better power purchasing agreements with utility companies (Fletcher 2007). Each of the seven local investors own a single 2.1 MW turbine, for a total project size of 14.7 MW—enough to provide power to all 4,500 people living in Jefferson (Suzlon 2011; Wind 2006).

Collaborating with Edison Mission Group (EMG) as an equity partner, the local investors were able to secure project funds by taking advantage of several state and federal incentive programs and by using a unique finance structure known as an LLC flip model. Under this model, EMG provides critical start-up capital and becomes a temporary project owner, receiving in return the tax incentives associated with the project and a guaranteed rate of return on its investment. Once those tax incentives expire, ownership of the project "flips" over to Sutton and his partners (Wind 2006).

David Ausberger

Iowa construction workers install blades at the seven-turbine, 14 MW Hardin Hilltop Wind Farm.

costs associated with nuclear power. And because wind and other renewable energy facilities tend to be geographically dispersed, they require less of the complex, centralized infrastructure that makes our current electricity system vulnerable to accidents, attacks, and other disruptions.

Finally, the damage to public health and the environment caused by our dependence on fossil fuels exacts a major toll on the U.S. economy. The Harvard School of Public Health found that the total cost of damage caused by coal alone—from mining to burning to waste disposal—approaches $523 billion per year, which would add as much as 27 cents per kilowatt-hour to coal's cost if plant owners had to pay for the damage, making it far more expensive than wind (Epstein et al. 2011).

ENVIRONMENTAL BENEFITS

Cleaner Air

Wind turbines produce no air pollution during operation, while fossil-fuel-powered electricity generation releases large amounts of sulfur dioxide (SO_2), nitrogen oxides (NO_X), fine soot particles, and other toxic substances. These pollutants create acid rain and smog, and cause or aggravate a wide range of respiratory and cardiovascular diseases. For example, fine particulate emissions from U.S. power plants contribute to 13,200 premature deaths each year, according to the Clean Air Task Force (CATF) (Schneider and Banks 2010). The CATF also estimated that total health-related damages associated with air pollution from coal-fired power plants amount to more than $102 billion per year.

Less Global Warming Emissions

Per capita, the United States emits far more of the heat-trapping gases that drive global warming (primarily carbon dioxide, or CO_2) than any other nation. Electricity generation, which currently relies heavily on the burning of coal and other fossil fuels that emit CO_2, accounts for roughly one-third of U.S. global warming emissions (EPA 2010).

If left unchecked, these emissions are expected to cause irreversible damage to communities and habitats in the United States and around the world. This damage will likely include more extreme droughts and heat waves, more intense tropical storms, poorer air quality, flooding and erosion in coastal communities due to rising sea levels, reduced agricultural productivity in some regions, and widespread habitat loss and extinctions (Karl, Melillo, and Peterson 2009). One study warns that if heat-trapping emissions continue to rise at the current rate, approximately 1 million species—15 to 37 percent of all non-marine species—could be on an irreversible path to extinction by 2050 (Thomas et al. 2004).

Wind power offers a scalable and affordable way to reduce the electricity sector's global warming emissions. Aside from the relatively minor amount of emissions associated with turbine manufacturing and construction, wind power is carbon-free;

© PhotoDisc

The United States currently generates nearly half of its electricity from coal, the most carbon-intensive energy source. Accelerating the use of carbon-free wind power, along with energy efficiency and other renewable energy technologies, will cut emissions from the electricity sector and save consumers and businesses money.

> The DOE projects that generating 20 percent of the country's electricity from wind power by 2030 would reduce annual CO_2 emissions from power plants by 25 percent.

every megawatt-hour generated with wind turbines instead of coal avoids about one ton of CO_2 emissions (Jaramillo, Griffin, and Matthews 2007). A major deployment of wind power could therefore deliver significant emissions reductions: the U.S. Department of Energy (DOE) projects that generating 20 percent of the country's electricity from wind power by 2030 would reduce annual CO_2 emissions from power plants by 25 percent, or a cumulative total of 7.6 billion metric tons (DOE 2008).

Reduced Water Use

Given power plants' use of water for cooling, the electricity sector accounts for almost half of all U.S. water withdrawals—more than agricultural irrigation, municipal water supplies, and household use combined (Kenny et al. 2009). In 2005, U.S. coal, nuclear, and natural gas plants used more than 100 billion gallons of freshwater per day. In addition, as much as 1.7 trillion gallons are lost to evaporation each year (DOE 2008). Power plant cooling systems also draw in and kill billions of fish per year, and harm other marine life when cooling water is returned to waterways at dangerously high temperatures (EPA 2011).

Wind power uses virtually no water. The DOE calculates that generating 20 percent of the country's electricity from wind energy by 2030 would reduce the electricity sector's cumulative water consumption by 8 percent, saving 4 trillion gallons over 20 years. About 30 percent of these savings would occur in western states, where water scarcity is an ongoing concern and projected to worsen (Karl, Melillo, and Peterson 2009; DOE 2008).

No Water Pollution or Waste

Coal burned in power plants is the leading source of human-caused emissions of mercury, which eventually becomes concentrated in fish such as tuna and swordfish, and can cause brain damage when ingested by young children and birth defects when ingested by women of child-bearing age.

Coal plants also produce solid waste containing heavy metals and other toxic substances that can contaminate drinking water supplies and harm local ecosystems if not disposed of safely. In December 2008, a dike burst at a Tennessee power plant's impoundment pond, sending an estimated 1.1 billion gallons of coal ash slurry into the Emory River, damaging homes and fouling the water with arsenic, selenium, and mercury (Barton 2010; EPA 2009).

Similarly, spent nuclear fuel contains highly radioactive waste that requires hundreds of thousands of years to decay to the point where it becomes harmless. It also contains large quantities of less radioactive, yet still dangerous, waste (NRC 2010).

IMPACTS ON THE NATURAL ENVIRONMENT

Wildlife

Though wind power offers significant benefits to the natural world compared with fossil fuel and nuclear power generation, it can (like all energy sources) harm birds, bats, and other wildlife. A recent National Wind Coordinating Committee (NWCC) review of peer-reviewed research found evidence of bird and bat deaths from collisions, as well as habitat loss or disruption (NWCC 2010). Bats can also be killed by barotrauma, a phenomenon caused by rapid pressure changes as they fly through the area where the blades turn. However, the NWCC concluded that the impact on birds and bats is relatively low at the vast majority of locations and does not pose a threat to species populations.

Over the last several decades, the wind industry has made great strides in reducing and mitigating its impact on wildlife thanks to better research, technological advances, and lessons learned in siting. For example, biologists investigating bat behavior have

Balancing economic development and environmental protection in Wyoming

Teresa Hooper

Part of the 111 MW Dunlap I wind project near Medicine Bow, WY.

With the 2010 opening of its Dunlap I wind project near Medicine Bow, WY, Rocky Mountain Power demonstrated that a utility can create jobs and economic development while minimizing its impact on wildlife. The project consists of 74 General Electric wind turbines supplying 111 MW of cost-effective, carbon-free electricity—enough to power about 32,000 typical homes. The project will not only meet burgeoning local demand but also help satisfy surrounding states' renewable electricity standards (PacifiCorp 2010).

The installation of Dunlap I represents a total investment of $261 million, including the turbines, a new substation, and 11 miles of transmission lines. About 300 people were employed during construction, and as many as 10 full-time employees will remain on-site (LeClair 2009). Rocky Mountain Power projects an annual operating budget for Dunlap I of approximately $2.4 million, including maintenance, salaries, permitting, local taxes, and land-use payments (Bird 2010).

Because 97 percent of the 16,500-acre project footprint (including the space between turbines) is undeveloped scrub or grassland, the project developers investigated concerns about wildlife habitat during the planning process (Bird 2010; Johnson, Bay, and Eddy 2009). This research led to the development of a siting plan for the turbines and the transmission line corridor that minimizes disturbance of the greater sage grouse and its habitat (Johnson, Bay, and Eddy 2009; Rocky Mountain Power 2009).

noted that bats are most active when wind speeds are low and insects are most abundant. The Bats and Wind Energy Cooperative found that keeping wind turbines motionless during times of low wind speeds may reduce bat deaths by more than half without significantly affecting power production, but additional monitoring and research is needed (Arnett et al. 2010).

> The wind industry has made great strides in reducing and mitigating its impact on wildlife thanks to better research, technological advances, and lessons learned in siting.

To help wind developers site and maintain wind farms that will have minimal impacts on wildlife, the American Wind Wildlife Institute funds research on, and communicates significant advances in, risk assessment and mitigation. In addition, an advisory committee created by the U.S. Fish and Wildlife Service and comprised of representatives from industry, state and tribal governments, and nonprofit organizations has published recommendations for land-based wind projects, including a multi-stage decision-making framework for developers (FWS 2010).

Land Use

The direct footprint of a wind turbine is relatively small: a typical 1.5 MW turbine measures about 15 feet across its base, and its concrete foundation (set underground) measures about 30 feet on a side. In the area immediately surrounding the turbine, trees and other ground cover must be cleared to allow for maintenance and overhead transmission lines (if needed in remote locations). Developers also use some land to build access roads.

Wind turbines are usually spaced 5 to 10 rotor diameters apart, depending on the terrain, to maximize performance (Denholm et al. 2009). This can mean as little as 32 acres per megawatt in rolling terrain or up to 50 acres per megawatt in flat areas, but the turbines and related infrastructure occupy just 2 to 5 percent of that area, leaving at least 95 percent of the land free for other uses (AWEA 2009). Wind turbines around the world co-exist safely with schools, highways, hiking trails, and farms.

IMPACTS ON THE HUMAN ENVIRONMENT

Visual Concerns

The impact of wind power that most people will experience is visual, whether in the form of shadow flicker, lighting, or aesthetics. Shadow flicker caused by turning blades can be annoying for some people who live in their vicinity, but it is possible to calculate precisely where shadows will fall over the course of a year. Developers can therefore avoid or minimize these concerns by siting turbines appropriately or mitigating the problem by planting evergreens or installing window awnings that will block the shadows.

Federal Aviation Administration (FAA) rules generally require objects more than 200 feet high such as commercial-scale wind turbines to have flashing red or white lights for aviation safety. However, the FAA recently determined that as long as there are no gaps in lighting greater than a half-mile, it is not necessary to light each tower in a multi-turbine wind project. Daytime lighting is unnecessary as long as the turbines are painted white.

When it comes to aesthetics, wind turbines can elicit strong reactions. To some people, they are graceful sculptures; to others, they are eyesores that compromise the natural landscape. Whether a community is willing to accept an altered skyline in return for cleaner power should be decided in an open public dialogue.

Sound

Modern wind turbines are relatively quiet. From several hundred feet away, they are designed to be no noisier than a refrigerator, though turbines at some sites have reportedly produced higher noise levels under certain conditions. Some people living in close proximity have complained about the sound and vibration, and raised concerns about their potential health impact.

An industry-funded analysis by doctors and audiologists of the peer-reviewed literature found that

© PPM Energy

the sounds from wind turbines have no direct adverse effect on human health (AWEA and CanWEA 2009). Government-sponsored studies in Canada and Australia have reached similar conclusions (Chief Medical Officer of Health of Ontario 2010; NHMRC 2010).

Nevertheless, because the current scientific literature in this area is somewhat limited, public concerns should be taken seriously while additional research is undertaken. Developers should be "good neighbors" and follow best-practice guidelines for the careful siting of turbines. Accurate sound and vibration impact assessments and tours of existing wind farms can also help establish realistic expectations.

Property Values

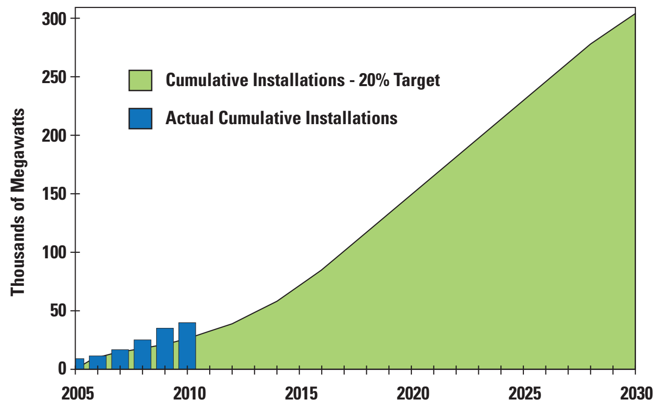
Another concern raised about wind energy projects is their potential effect on local property values. DOE researchers who examined the sales of 7,500 single-family homes located within 10 miles of a wind facility found no conclusive evidence of widespread declines in value; while not ruling out the possibility that individual homes could decrease in value, the study indicates that such declines are likely to be small and infrequent. Further research on home values in close proximity (less than one mile) to wind projects will be critical in establishing guidelines for developers (Hoen et al. 2009).

RELYING ON THE WIND

The fact that the wind does not blow all the time poses some challenges to the electricity sector, but these challenges are neither unique nor insurmountable. Wind power is capable of providing reliable electric service to consumers.

> Many utilities are already demonstrating that wind power can make a significant contribution to their electric supply without reliability problems.

Figure 1. Cumulative Wind Power Installations: 20 Percent Target versus Actual



Sources: AWEA 2010; DOE 2008.

At the end of 2010, more than 40,000 megawatts of wind capacity was in operation in the United States, putting the wind industry well ahead of the trajectory suggested by the Department of Energy for generating 20 percent of U.S. electricity from wind power by 2030.

Today, operators of our nation's electric grid must constantly vary power plants' output as demand rises and falls. Some power plants must therefore be kept in reserve to meet unexpected surges or drops in demand, as well as to respond to power plant outages or downed power lines. Wind energy does make power supplies even more variable, but it can be integrated into the grid through careful and effective management of reserves. New tools such as improved short-term forecasting allow grid operators to plan more accurately for wind power availability, and sophisticated electronic controls allow operators to make continual adjustments to a wind power facility's output.

The costs of integrating wind energy into the grid are manageable. Extensive engineering studies by U.S. utilities, and actual operating experience in Europe, show that the costs increase along with wind's share of the system mix, but even at 20 percent penetration, integration costs add 10 percent or less to wind's wholesale generation cost (DOE 2008). And because wind has low operating costs (since there is no fuel to purchase), it can reduce overall system costs by displacing the output of more expensive units, such as gas turbines.

Many utilities are already demonstrating that wind power can make a significant contribution to their electric supply without reliability problems. According to the DOE, nine U.S. utilities generated between 10 and 38 percent of their power from wind in 2009 (Wiser and Bolinger 2010). The largest user of wind power, Xcel Energy (which serves nearly 3.5 million customers across eight Western and Midwestern states), obtains 11 percent of its electricity from wind and plans to approach 20 percent by 2020 (Xcel Energy 2010; Wiser and Bolinger 2010). Wind power already supplies 20 percent of the electricity or more for several areas in Europe: Denmark currently leads all nations with 20 percent wind penetration, and two states in Germany with a combined population of 4 million get 40 percent of their electricity from wind (Earth Policy Institute 2010).

Promising developments in storage technology have the potential to enhance reliability even more, though there are plenty of opportunities for wind power to expand without storage during the next 20 years at least.

THE FUTURE OF WIND POWER IN AMERICA

Increasingly competitive prices, the ability to create jobs and boost local economies, and the promise of a new energy resource that poses little threat to public health or the environment suggest a bright future for wind power in the United States. The DOE found that expanding wind power from about 2 percent of U.S. electricity in 2009 to 20 percent by 2030 is both feasible and affordable, and would not affect the reliability of the nation's power supply (DOE 2008).

The wind industry is pushing to meet that target. Developers added wind capacity at an average growth rate of 35 percent per year from 2005 to 2010, installing five times as many megawatts during this period as in the previous 25 years (AWEA 2011; AWEA 2010). As a result, U.S. deployment was well ahead of the DOE's suggested trajectory at the end of 2010, with more than 40,000 MW of capacity in operation (Figure 1).

The DOE found that expanding wind power from about 2 percent of U.S. electricity in 2009 to 20 percent by 2030 is both feasible and affordable, and would not affect the reliability of the nation's power supply.

As with any industry that experiences rapid growth, wind power will have its challenges. The recent financial crisis took a heavy toll on the industry, slowing project financing and reducing consumer demand, and the industry is having difficulty gaining access to existing

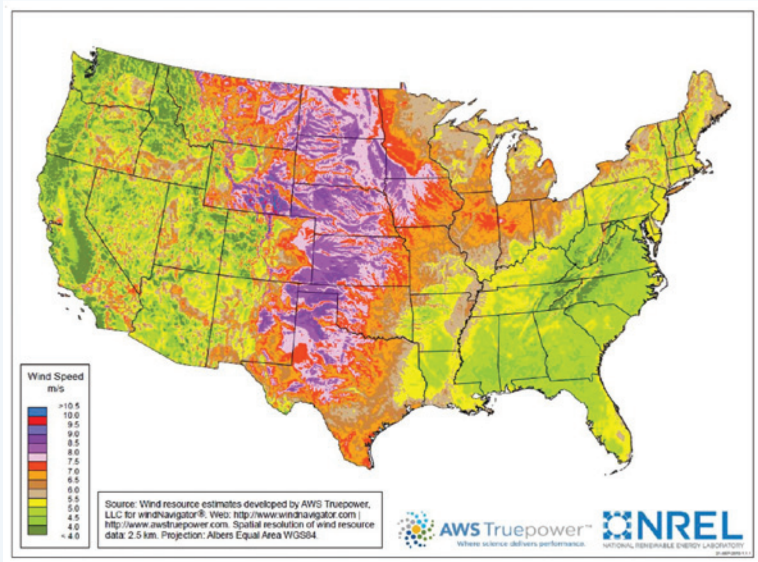
© Peter Beck/Corbis

What Makes a Wind Site Economical?

The United States has excellent wind resources, but not every windy location makes an ideal site for a wind turbine. The quality of a site depends on multiple factors including:

Wind speed. High average wind speeds are the most important factor in choosing a turbine site. Commercial sites are typically located in areas with average wind speeds above 13 miles per hour (mph) or 5.8 meters per second. Because the energy in the wind depends on the cube of the wind speed, even small increases in speed make a significant difference in power output. For example, a turbine at a 16 mph site can produce 50 to 60 percent more electricity than the same turbine at a 13 mph site, which makes the cost

Figure 2. U.S. Annual Average Wind Speeds



Map reflects annual average wind speeds measured at 80 meters (262 feet) above ground. Wind speeds for Alaska, Hawaii, Puerto Rico, and the U.S. Virgin Islands (not pictured) were measured at 50 meters (164 feet) above ground. Source: NREL and AWS Truepower 2010.

transmission lines and building new lines that will be needed to bring its power to market. These obstacles, combined with increased competition due to lower natural gas prices, resulted in the United States installing half as many megawatts of wind power in 2010 as in 2009, and losing the world's top ranking in total capacity to China.

To overcome these challenges, maintain its global leadership, and continue the march toward a clean and sustainable energy future, the United States must adopt stable, long-term policies that encourage wind energy investment and deployment. One of the most effective during the past decade has been state-level renewable electricity standards (RES), which require utilities to supply consumers with a growing percentage of renewable energy over time, developing the best sites and the most cost-effective resources first. As of 2010, 29 states and Washington, DC, had adopted this market-based approach.

State standards are a great start, but a national RES of 25 percent by 2025 would substantially increase the market for wind and other renewable energy resources, create hundreds of thousands of jobs, and save consumers money on their energy bills (UCS 2009). Additional state and federal policies such as tax credits and other financial incentives, increased funding for research and development, and improved processes for transmission planning, siting, and approval are also needed to ensure a successful future for wind power.

Wind power stands out as a smart choice for an economy based on clean, sustainable energy. A determined national effort would allow us to harness our abundant wind resources and produce affordable and reliable electricity, while protecting our health and environment for generations to come.

of the power more affordable and can lead to greater reductions in fossil fuel pollution.

All regions of the country have some suitable wind resources (Figure 2), though the best land-based sites are typically found in the central plains, from the Dakotas south through Texas. Offshore wind resources also hold great potential, though no projects have yet been installed in the United States. Winds tend to be more consistent and blow at higher speeds further offshore, but the expense of constructing and maintaining turbines and connecting them to the electric grid increases rapidly in deep water.

Topography and accessibility. The local landscape can greatly affect wind power potential; good sites are open and generally higher than the surrounding area. Steep hills or cliffs can create turbulence that reduces energy output and can increase maintenance costs, but gradually sloping hills can increase wind speeds. Good sites can also accommodate access roads for construction and maintenance equipment.

Obstacles. Trees and buildings can reduce wind speeds and create turbulence at low altitudes. Siting turbines in open fields or offshore reduces the effect of such turbulence, as does installing turbines on taller towers.

Distance to transmission lines. Electricity generated by a commercial wind turbine must be fed into the electrical grid (the network of power lines connecting generating stations with electricity users). Building new transmission lines can be costly, so wind sites near existing lines reduce this expense. However, in areas with the most abundant wind resources, the addition of new transmission lines would be justified, because the cost of the new lines would be more than offset by the value of the energy available in those areas. Transmission generally accounts for just 5 to 10 percent of a typical electricity bill.

References

American Wind Energy Association (AWEA). 2011. *U.S. wind industry year-end 2010 market report*. Washington, DC. Online at *http://www.awea.org/learnabout/publications/upload/4Q10_market_outlook_public.pdf*.

American Wind Energy Association (AWEA). 2010. *U.S. wind industry annual market report: Year ending 2009*. Washington, DC: American Wind Energy Association.

American Wind Energy Association (AWEA). 2009. *Wind energy and wildlife*. Washington, DC. Online at *http://www.awea.org/learnabout/publications/upload/Wind_Energy_and_Wildlife_Mar09.pdf*.

American Wind Energy Association (AWEA) and the Canadian Wind Energy Association (CanWEA). 2009. Wind turbine sound and health effects: An expert panel review.

Arnett, E.B., M.M.P. Huso, J.P. Hayes, and M. Schirmacher. 2010. *Effectiveness of changing wind turbine cut-in speed to reduce bat fatalities at wind facilities*. A final report submitted to the Bats and Wind Energy Cooperative. Austin, TX: Bat Conservation International.

Barton, B. 2010. *Murky water? Corporate reporting on water risk: A benchmarking study of 100 companies*. Boston, MA: CERES.

Bird, S.A. 2010. Direct testimony before the public utility commission of the state of Oregon. Online at *http://www.pacificpower.net/content/dam/pacific_power/doc/About_Us/Rates_Regulation/Oregon/Regulatory_Filings/Advice_10_003_Docket_UE_217/03-01-10_Application_Direct_Testimony_and_Exhibits/Stefan_A_Bird/Stefan_A_Bird.pdf*.

Chief Medical Officer of Health of Ontario. 2010. *The potential health impact of wind turbines*. Toronto, Ontario: Ontario Ministry of Health and Long Term Care. Online at *http://www.health.gov.on.ca/en/public/publications/ministry_reports/wind_turbine/wind_turbine.pdf*.

Denholm, P., M. Hand, M. Jackson, and S. Ong. 2009. *Land-use requirements of modern wind power plants in the United States*. Golden, CO: National Renewable Energy Laboratory.

Department of Energy (DOE). 2008. *20% wind by 2030: Increasing wind energy's contribution to the U.S. electricity supply*. Washington, DC.

Deyette, J., and B. Freese. 2010. *Burning coal, burning cash: Ranking the states that import the most coal*. Cambridge, MA: Union of Concerned Scientists.

Earth Policy Institute. 2010. Wind power soared past 150,000 megawatts in 2009. Press release, March 31. Online at *http://www.enn.com/press_releases/3297*.

Energy Information Administration (EIA). 2010. U.S. natural gas imports by country. Online at *http://www.eia.doe.gov/dnav/ng/ng_move_impc_s1_a.htm*.

Environmental Protection Agency (EPA). 2011. *National pollutant discharge elimination system: Proposed regulations to establish requirements for* *cooling water intake structures at existing facilities and amend requirements at Phase I facilities*. U.S. EPA #RIN 2040–AE95. Online at *http://water.epa.gov/lawsregs/lawsguidance/cwa/316b/upload/prepub_proposed.pdf*.

Environmental Protection Agency (EPA). 2010. *Inventory of U.S. greenhouse gas emissions and sinks: 1990-2008*. U.S. EPA # 430-R-10-006. Online at *http://www.epa.gov/climatechange/emissions/downloads10/508_Complete_GHG_1990_2008.pdf*.

Environmental Protection Agency (EPA). 2009. Summary of past and current EPA response activities regarding the TVA Kingston coal ash spill. Online at *http://www.epa.gov/region4/kingston/summary.html*, accessed February 15, 2011.

Epstein, P.R., J.J. Buonocore, K. Eckerle, M. Hendryx, B.M. Stout III, R. Heinberg, R.W. Clapp, B. May, N.L. Reinhart, M.M. Ahern, S.K. Doshi, and L. Glustrom. 2011. Full cost accounting for the life cycle of coal. Annals of the New York Academy of Sciences 1219:73–98.

Fish and Wildlife Service (FWS). 2010. Recommendations of the wind turbine guidelines advisory committee. Online at *http://www.fws.gov/habitatconservation/windpower/Wind_Turbine_Guidelines_Advisory_Committee_Recommendations_Secretary.pdf*.

Fletcher, H. 2007. Community wind projects catch on. *Iowa Farmer Today*, March 28. Online at *http://www.iowafarmertoday.com/articles/2007/04/03/top_stories/01wind1.txt*.

Hoen, B., R. Wiser, P. Cappers, M. Thayer, and G. Sethiet. 2009. The impact of wind power on residential property values in the United States: A multi-site hedonic analysis. Berkeley, CA: Lawrence Berkeley National Laboratory.

Jaramillo, P., W.M. Griffin, and H.S. Matthews. 2007. Comparative life cycle air emissions of coal, domestic natural gas, LNG, and SNG for electricity generation. *Environmental Science & Technology* 41(17):6290–6296.

Johnson, G., K. Bay, and J. Eddy. 2009. Wildlife baseline studies for the Dunlap ranch wind resource area, Carbon County, Wyoming. Cheyenne, WY: Western Ecosystems Technology, Inc. Online at *http://deq.state.wy.us/out/downloads/Dunlap%20Addendum4.pdf*, accessed March 2, 2011.

Karl, T.R., J.M. Melillo, and T.C. Peterson. 2009. *Global climate change impacts in the United States*. U.S. Global Change Research Program.

Kenny, J.F., N.L. Barber, S.S. Hutson, K.S. Linsey, J.K. Lovelace, and M.A. Maupin. 2009. Estimated use of water in the United States in 2005. *U.S. Geological Survey Circular* 1344:52.

LeClair, A. 2009. Dunlap ranch wind project gets conditional approval. *Wyoming Energy News*, August 27. Online at *http://wyomingenergynews.com/2009/08/dunlap-ranch-wind-project-gets-conditional-approval*, accessed March 2, 2011.

National Health and Medical Research Council (NHMRC). 2010. *Wind turbines and health: A rapid review of the evidence*. Canberra, Australia: National Health and Medical Research Council. Online at *http://www.nhmrc.gov.au/_files_nhmrc/file/publications/synopses/evidence_review__wind_turbines_and_health.pdf*.

National Renewable Energy Laboratory (NREL). 2005. Wind energy benefits. Wind Powering America fact sheet series. Washington, DC: U.S. Department of Energy. Online at *http://www.nrel.gov/docs/fy05osti/37602.pdf*.

National Renewable Energy Laboratory (NREL) and AWS Truepower. 2010. 80-meter wind maps and wind resource potential. Online at *http://www.windpoweringamerica.gov/wind_maps.asp*.

National Wind Coordinating Committee (NWCC). 2010. Wind turbine interactions with birds, bats, and their habitats: A summary of research results and priority questions. Online at *https://www.nationalwind.org/assets/publications/Birds_and_Bats_Fact_Sheet_.pdf*.

Nuclear Regulatory Commission (NRC). 2010. Radioactive waste. Online at *http://www.nrc.gov/waste.html*, accessed April 4, 2011.

PacifiCorp. 2010. Dunlap 1 wind project generating renewable energy for customers. Press release, October 12. Online at *http://www.pacificorp.com/about/newsroom/2010nrl/dwpgrec.html*, accessed March 2, 2011.

Rocky Mountain Power. 2009. Exhibit 9 greater sage grouse wind project interconnection facilities. Online at *http://www.rockymountainpower.net/content/dam/rocky_mountain_power/doc/About_Us/Rates_and_Regulation/Wyoming/Regulatory_Filings/Docket_20000_348_EA_09/072409_Application_for_CPCN_to_Construct_the_New_111_MW_Dunlap_I_Wind_Project/Cover_Letter_and_Application/exhibits/Exhibit_9.pdf*, accessed March 2, 2011.

Schneider, C., and J. Banks. 2010. *The toll from coal*. Boston, MA: Clean Air Task Force. Online at *http://www.catf.us/resources/publications/files/The_Toll_from_Coal.pdf*.

Suzlon. 2011. Hardin hilltop wind farm: Project profile. Online at *http://www.suzlon.com/pdf/ProjectprofileHardinHilltopUSLow.pdf*, accessed March 2, 2011.

Thomas, C.D., A. Cameron, R.E. Green, M. Bakkenes, L.J. Beaumont, Y.C. Collingham, B.F.N. Erasmus, M. Ferreira de Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A.S. van Jaarsveld, G.F. Midgley, L. Miles, M.A. Ortega-Huerta, A.T. Peterson, O.L. Phillips, and S.E. Williams. 2004. Extinction risk from climate change. *Nature* 427(6970):145.

Union of Concerned Scientists (UCS). 2009. *Clean power, green jobs*.

Wind, T.A. 2006. Hardin hilltop wind farm: An example of community wind in Iowa. Presented at Kansas Community Wind Workshop. Jefferson, IA: Wind Utility Consulting. Online at *http://www.kcc.state.ks.us/energy/comm_wind/cw_thomas_wind_103106.ppt*, accessed March 2, 2011.

Wiser, R., and M. Bolinger. 2010. *2009 wind technologies market report*. Berkeley, CA: Lawrence Berkeley National Laboratory.

Xcel Energy. 2010. *Wind power*. Minneapolis, MN: Xcel Energy. Online at *http://www.xcelenergy.com/Minnesota/Company/Environment/Renewable%20Energy/Pages/Wind_Power.aspx*, accessed March 2, 2011.

The full text of this report is available on the UCS website at *www.ucsusa.org/tappingintowind*.

The Union of Concerned Scientists is the leading science-based nonprofit working for a healthy environment and a safer world.

Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

National Headquarters
Two Brattle Square
Cambridge, MA 02138-3780
Phone: (617) 547-5552
Fax: (617) 864-9405

Washington, DC, Office
1825 K St. NW, Ste. 800
Washington, DC 20006-1232
Phone: (202) 223-6133
Fax: (202) 223-6162

West Coast Office
2397 Shattuck Ave., Ste. 203
Berkeley, CA 94704-1567
Phone: (510) 843-1872
Fax: (510) 843-3785

Midwest Office
One N. LaSalle St., Ste. 1904
Chicago, IL 60602-4064
Phone: (312) 578-1750
Fax: (312) 578-1751

Printed on recycled paper using vegetable-based inks