Business & Technology Surveillance

Advanced and Emerging Technologies for Wind Generation

By Laura Moorefield

MARCH 2019

NRECA
America's Electric Cooperatives

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This article is a product of the **Generation, Environment, and Carbon Work Group**

This is the forth in a series of NRECA *TechSurveillance* articles about the status of the wind generation market and its impact on cooperatives. The first article provided an overview of how much wind generation capacity electric cooperatives currently own and purchase, and how they do it. The second article focused on current and advanced wind technologies, and the third examined failure and maintenance issues. This fourth article reviews some recent developments with advanced and emerging wind generation technology. Visit **cooperative.com** for the entire series, as well as other helpful resources from NRECA.

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ARTICLE SNAPSHOT

WHAT HAS CHANGED IN THE INDUSTRY?

The U.S. Department of Energy (DOE) projects U.S. wind energy to reach 224 GW by 2030 assuming that transmission line constraints can be removed, and more than 400 GW by 2050. As the production tax credit phase-out approaches, wind farm developers will look to new wind turbine technologies including higher towers and new construction methods to further reduce costs, increase capacity factors, and increase energy production per wind turbine. Engineering improvements, such as longer blades and different form factors, will increase annual energy production (AEP) and capacity factors.

WHAT IS THE IMPACT ON COOPERATIVES?

Wind technologies continue to improve and many new wind energy technologies are getting press. By raising tower hub heights, the wind industry is realizing higher AEP and capacity factors. In addition, many new areas in the U.S. will be able to develop wind projects with the higher heights, such as in the southeastern states. This report is a resource to help co-ops stay informed on the various stages of development. Some of these new and emerging technologies are expected to decrease costs for wind turbines while increasing capacity factors, resulting in continued rapid decrease in levelized cost of electricity and, in turn, in calls for wind Purchase Power Agreements (PPAs). There are much broader implications of higher renewable penetrations to wholesale energy markets and power supply costs, but those are beyond the scope of this paper.

WHAT DO COOPERATIVES NEED TO KNOW OR DO ABOUT IT?

Up-to-date information on new and developing wind energy technologies will help co-ops be better consumers and project developers, evaluate wind PPAs effectively, and stay on top of new opportunities in the industry. This *Surveillance* report will provide electric co-ops a summary of several advanced and emerging wind generation technologies to help them assess new opportunities that may become available from developers.

Introduction

Cutting-edge technologies in wind energy generation have the potential to significantly impact the industry by increasing power output per wind turbine and overall capacity factor of wind turbines, thus reducing capital costs and levelized cost of electricity.

This *Surveillance* report provides electric co-ops a summary of several advanced and emerging wind generation technologies to help them assess new opportunities that may become available from developers. It will also help co-op staff stay informed on industry trends that members may read about in Scientific American, Popular Science, Utility Dive, GTM, and similar journals, and stay abreast of technology that is cutting edge in the wind space. This report is a follow-on from the three previous NRECA ***Surveillance* reports on wind generation**, which have been primarily focused on existing technologies and maintenance issues. Costs are included if available, but because many of these technologies are still in pilot or research phase, firm numbers are not available in most cases.

Harvesting Wind Energy at Higher Elevations

TALLER TOWERS

Advancements in blade and tower construction technologies are enabling taller towers. This has led to major recent developments in the wind industry. Estimates on how much more energy could be generated with increased turbine heights suggest that taller towers could create wind development opportunities in new areas.

Current onshore tower heights (or hub heights) are typically between 80 meters (262 feet) to 100 meters (328 feet) tall. In this range, successful wind farms in the "wind belt" (the U.S. Midwest and Texas) often achieve capacity factors of 40 percent and higher. But, if hub heights were closer to 140 meters (460 feet), wind farms in many areas of the U.S. could achieve similar results, even in the Southeast where lower wind speeds have not provided favorable conditions for onshore wind farms with standard tower heights. In rough terms, each meter of increase in the height of towers can add 0.5 to 1 percent to a turbine's AEP, so that being able to access higher wind speeds with taller towers may make some previously poor wind sites economically viable.[1]

Being able to access higher wind speeds with taller towers may make some previously poor wind sites economically viable.

Using wind speed data, National Renewable Energy Laboratory (NREL) mapped the potential wind resource across the U.S. at 140 meters. See Figure 1. The blue shading indicates which areas could support 35 percent or greater capacity factors. The darker the area, the denser the concentration potential wind sites at 140-meter hub heights.

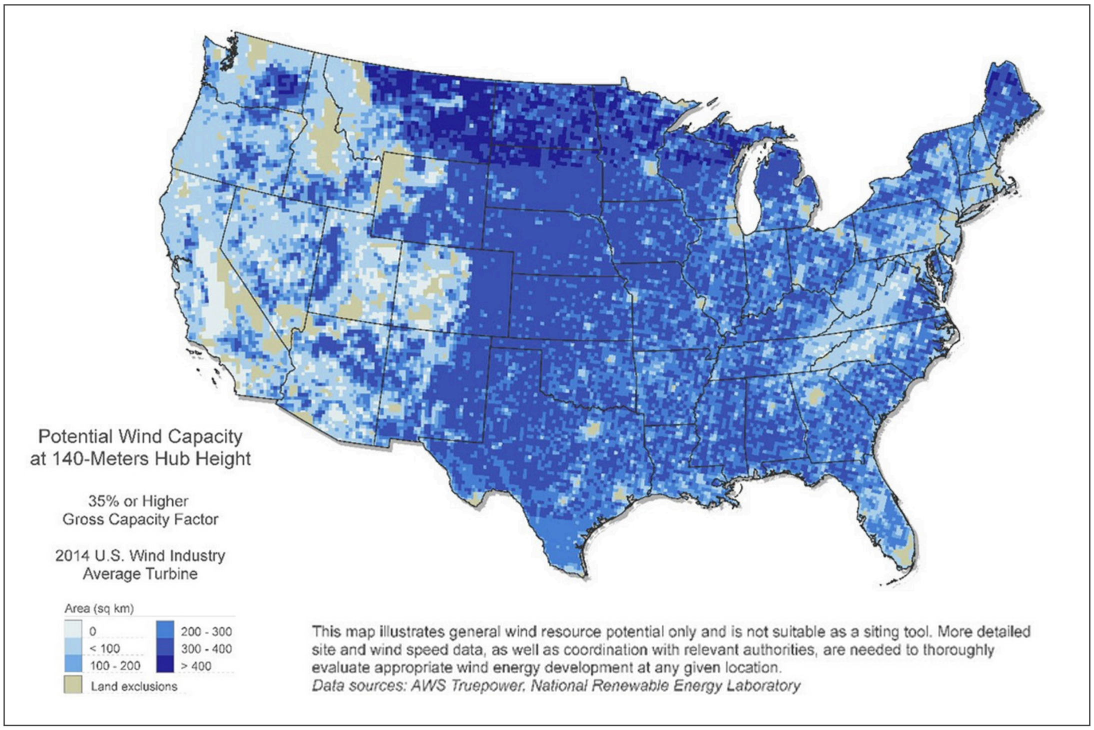

FIGURE 1: Potential Wind Capacity at 140-Meters Hub Height. Source: NREL

[1] Colthorpe 2017

Making turbine towers taller introduces some design, cost, and permitting challenges.

Take Alabama for example. With 2008 typical hub heights of 80 meters, represented by the black line in Figure 2, no area had wind speeds that could support a 30 percent capacity factor. With a 2014 typical hub height of 110 meters (red line), approximately 30,000 square kilometers (km^2) had potential for that same capacity factor or greater. But, when "near future" 140-meter hub heights are evaluated (blue line), Alabama has more than 100,000 km^2 with potential for a 30 percent or greater capacity factor, and about 60,000 km^2 have the potential for a 40 percent capacity factor. Today, a 40 percent capacity factor would be an excellent result for a farm in the wind belt.

For information on all states, see NREL's Wind Exchange website at: **https://windexchange.energy.gov/maps-data/326**

However, making turbine towers taller introduces some design, cost, and permitting challenges, and just because a site may show new generation potential at a high elevation does not automatically mean it is a suitable wind farm site. Sites must also undergo air space evaluations, state and local permitting, and wildlife impact assessments. For example, the Federal Aviation Administration (FAA) requires advance notice for any proposed structure 200 feet or more above ground, so that they can evaluate its impact to aircraft safety and navigation. All proposed structures above 499 feet are automatically subject to an Obstruction Evaluation.[2]

The FAA review process also includes review from Department of Defense (DOD), base commanders, Department of Homeland Security (DHS),

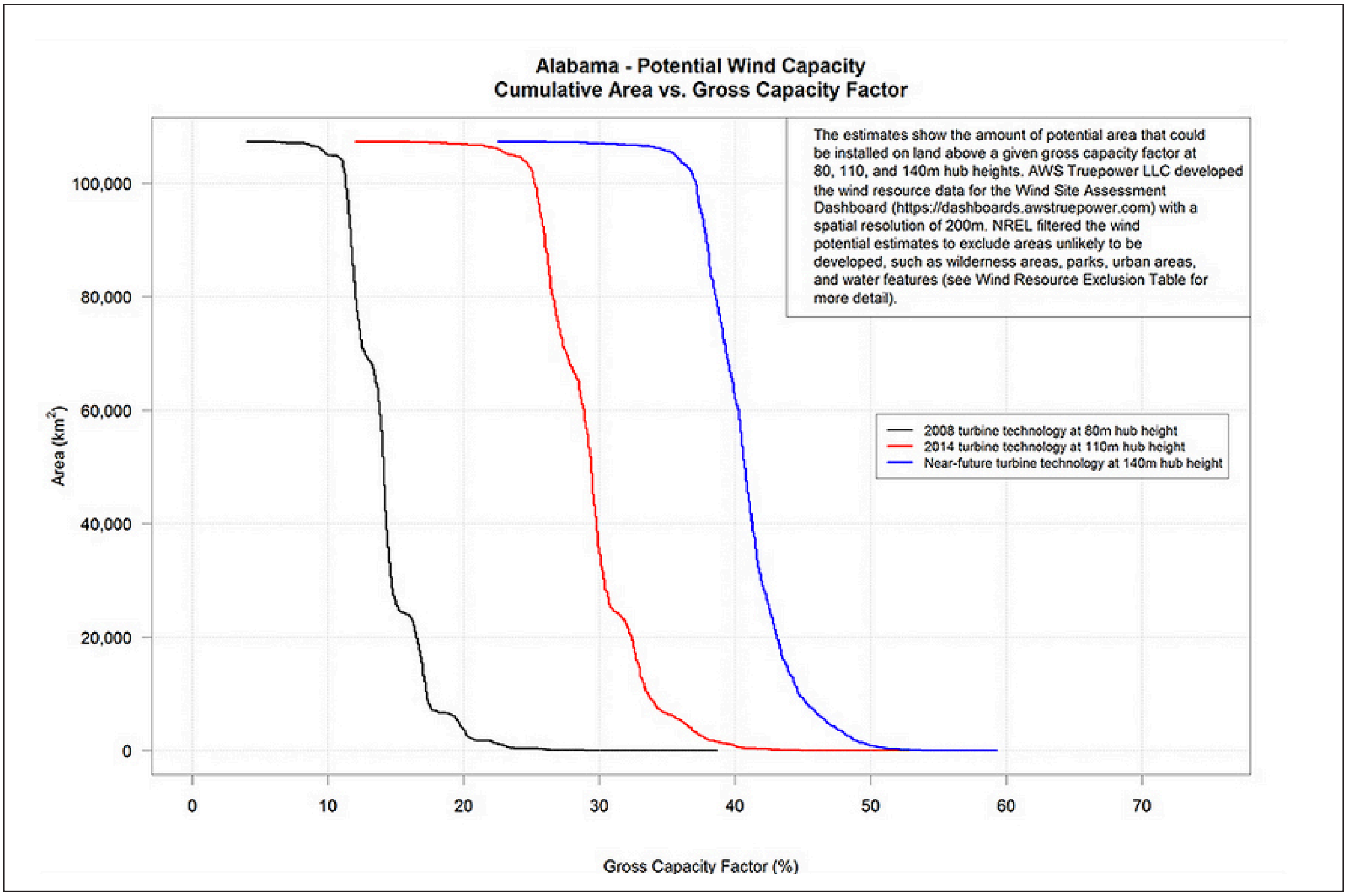

FIGURE 2: Alabama's Potential Wind Capacity at Different Hub Heights. Source: NREL

2 **https://www.faa.gov/air_traffic/obstruction_evaluation**

and other federal agencies to ensure proposed wind farms will not impact military operations, national security, or radar communications. Unlike FAA height rules, DOD review is not tied to a specific height or distance, since operations can vary widely from base to base.[3]

Area infrastructure such as roads, bridges, and overpasses can limit the size of tower segments that can be transported to a site. To address this, some OEMs have built slipform cast prestressed concrete towers on site. But, this can be a slow process and is highly weather-dependent. Manufacturers, developers, and researchers are looking for other solutions.

FIGURE 3: Image showing how Hexcrete cells can be assembled on-site and stacked to 140 meters high by a crane. Image courtesy of Sri Sritharan/Iowa State University

One such project is taking place at Iowa State University, where researchers recently completed an 18-month study to design a better 140-meter tower using a technology they call Hexcrete (see Figure 3). According to Iowa State University (2017),[4,5] "The basic idea of Hexcrete is that it's assembled from precast panels and columns made with high-strength or ultra-high-performance concrete. Those panels and columns can be cast in sizes that are easy to load on trucks. They are tied together on-site by cables to form hexagon-shaped cells. A crane can stack the cells to form towers as high as 140 meters."

The prototype Hexcrete tower segment has passed multiple tests that simulate fatigue and operational loads from a Siemens 2.3 MW turbine operation. Anticipated costs, derived from calculations using NREL models, show a 10 to 18 percent levelized cost reduction for a 120- to 140-meter Hexcrete tower over today's conventional 80-meter tower. Cost calculations were reviewed by multiple wind energy companies. The project's next step is to secure funding to build a complete tower for further testing.

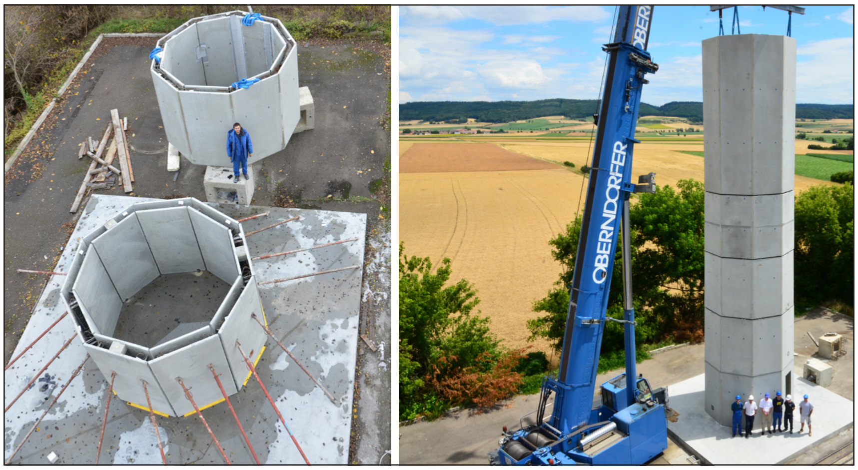

FIGURE 4: Double-wall concrete tower construction. Image courtesy of TU Wien (copyright)

In another project, conducted in 2016 at the Technische Universität Wien (TU Wien) in Vienna, Austria, researchers designed and tested an innovative double-wall concrete tower construction method. Rectangular, double-wall components are transported to the site, and attached together there to form octagonal tower segments. The segments are stacked on top of each other, then the gap in the hollow wall is filled with concrete and reinforcing steel (see Figure 4). This method results in a stable, solid concrete tower while avoiding much of the transportation costs associated with delivering solid tower segments to a site.[6]

3 https://www.awea.org/policy-and-issues/project-development/radar-and-airspace

4 Iowa State University 2017

5 The study was funded by the U.S. DOE, the Iowa Energy Center, and through contributions from and partnerships with Lafarge North America, Inc., Siemens Corporate Technology, Coreslab Structures, and BergerABAM.

6 Technische Universität Wien 2016

More than 50 companies and research institutions have been working on a viable wind kite or energy kite.

FLYING HIGHER WITH KITES AND DRONES

Wind kites and drones may sound futuristic, but a formative research paper on airborne wind energy (AWE) was written in 1980 by Miles Loyd, an engineer at Lawrence Livermore National Laboratory, although this paper was not related to his work there.

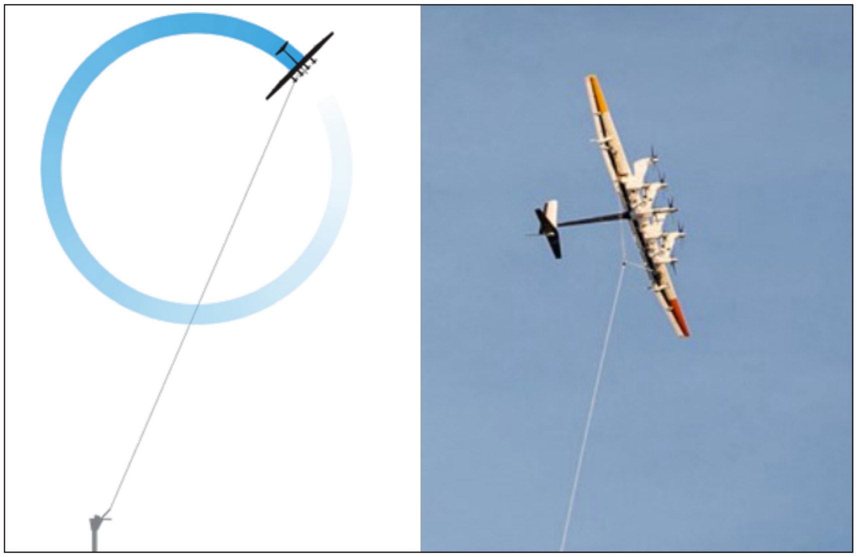

FIGURE 5: Makani M600 Prototype. Image courtesy of Makani (Source: https://www.nbcnews.com/mach/science/enormous-energy-kite-promises-new-way-harness-wind-power-ncna943451)

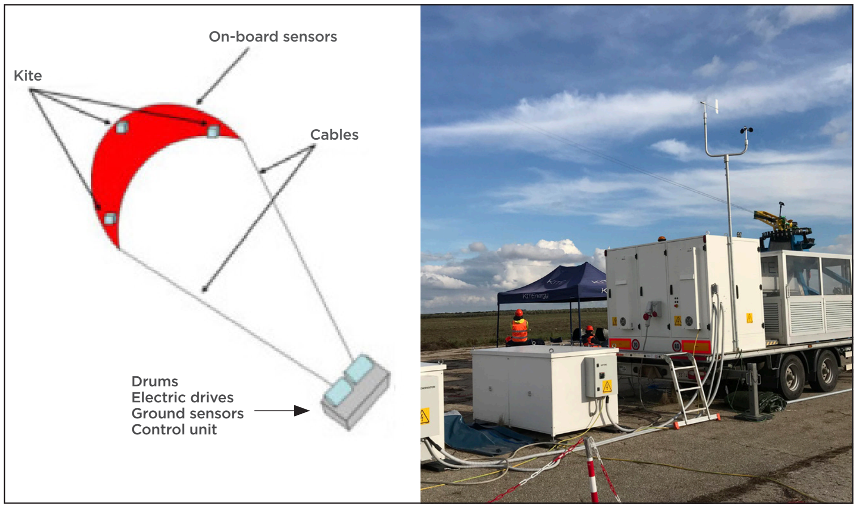

FIGURE 6: KITEnergy Schematic and HAWE Prototype. Image courtesy of KITEnergy

In his analysis, he modeled three different kite sizes (576, 1,000, and 2,000 m^2), different tether lengths (400 and 1,200 m), and lift-to-drag ratios (based on strength and size of the C-5A aircraft) at a wind speed of 10 meters/second. He calculated an average power output potential per kite turbine from 6.7 up to 45 MW. He concluded that while there are many unanswered questions, including ones about manufacturing, land-use, launching and landing, and power transmission, "the large single-unit output of kites and the relatively well-understood technology make kites appear attractive." (Loyd 1980, p. 111).

Since that time, more than 50 companies and research institutions have been working to design a viable wind kite or energy kite, but to date, no models are broadly commercial.[7] Industry watchers do not expect many commercial AWE products to be available before 2025.[8]

Makani,[9] based in Alameda, CA, began working on energy kites more than ten years ago. Their first project was a 2 kW fabric kite. Today, the company is part of X,[10] a research and development company owned by Alphabet, Google's parent company.

Makani's current prototype in development is a 2016 model rated at 600 kW. Units have eight rotors, each connected to a permanent magnet generator. All are affixed to an 85-foot-long carbon fiber wing, making the M600 look like a small airplane. A tether approximately a third of a mile long connects the unit to the ground. See Figure 5. Wind propels the unit in continuous loops and spins the rotors to generate electricity. Makani has not announced when this technology will be commercialized.

KITEnergy, an Italian start-up founded in 2010, is in the research and design phase of a small-scale prototype. Their technology uses kites flown at altitudes of 800 to 1,000 meters to generate electricity "by converting the traction forces acting on the wing ropes into electrical power, using suitable rotating mechanisms and electric generators placed on the ground."[11] See Figure 6.

7 https://www.skypower100.de/english/the-project
8 Deign 2017 Sep 18
9 https://x.company/makani/technology
10 https://x.company
11 http://www.kitenergy.net/technology-2/key-points

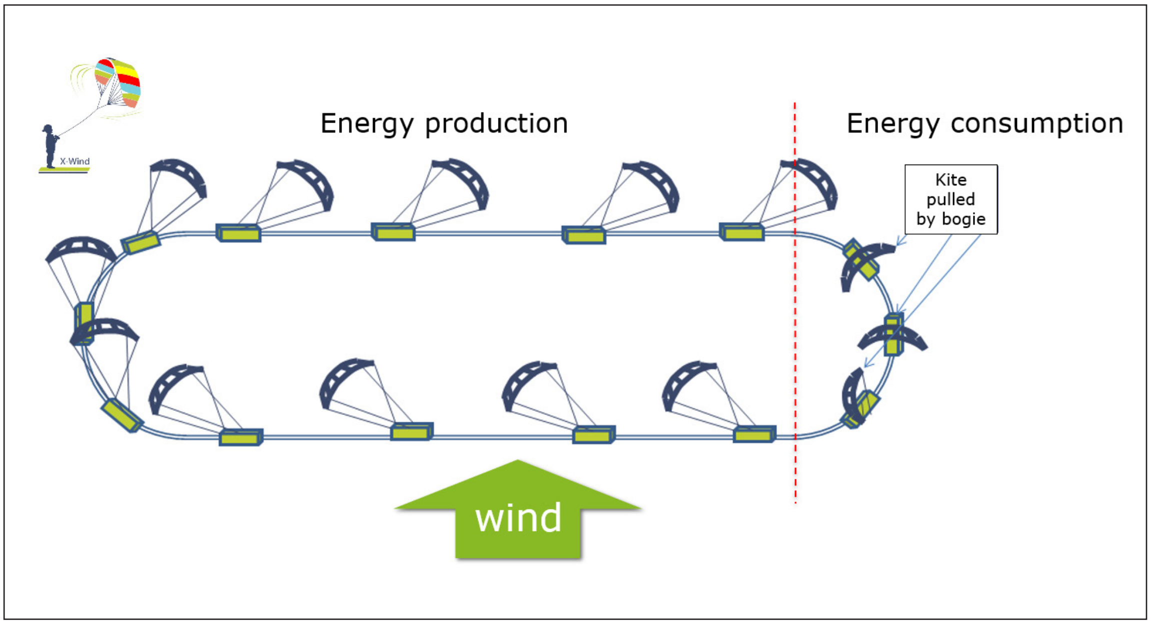

FIGURE 7: X-Wind Energy Kite and Track System. Image courtesy of X-Wind

AWE technology is likely to be suitable for places that do not support conventional onshore and offshore development.

X-Wind (pronounced: cross wind), a German company, is piloting a system of wind energy kites connected to train bogies, also known as railroad trucks. See Figure 7. As the trucks are pulled around a fixed track by fabric kites, electricity is generated through regenerative braking. The kites fly at an elevation of up to 500 meters, enabling them to access wind speeds that are 40 percent higher than 100-meter towers. X-Wind currently has a 2 MW pilot under construction.[12]

A joint pilot research project of four organizations in Germany, SkyPower100 is pursuing a 100 kW AWE system that they hope will be the first to realize "autonomous long-term operation day and night, as well as automatic launching, landing, and stowing of the kite." The project aims to eventually develop an industrial-scale system that lowers traditional wind energy development obstacles, such as noise, wildlife impacts, and permitting.[13]

With prices falling for both conventional onshore and offshore wind farms, AWE manufacturers are eager to get their products into the market soon, while they can still be competitive. Lighter weight materials and reduced materials use should help lower levelized cost of energy (LCOE). For example, the overall weight of Makani 600 is around 2 tons—about 98 percent less than a typical land-based wind turbine with similar capacity (Vestas V44/600 kW). Fabric kites in development by X-Wind and others are significantly lighter. This also reduces visual impacts and noise. Furthermore, AWE technology is likely to be suitable for places that do not support conventional onshore and offshore development, like islands, areas without crane access, land near deep water ports, and areas with transportation limitations.[14] X-Wind points out that their kites can achieve a 60 percent capacity factor by accessing wind at 500 meters (far higher than the 140-meter towers in development).[15]

For technical details on several AWE technologies, see: Cherubini, Papini, Vertechy, & Fontana, 2015.

12 https://www.x-wind.de/en
13 Baristow 2018
14 Deign 2017 Sep 18
15 https://www.x-wind.de/en

Water Batteries for Wind Energy

The tallest overall onshore wind turbine towers in operation today can be found in Germany, but these towers are also garnering attention because they are part of pilot project on wind and hydro pumped storage. Max Bögl Wind, subsidiary of Max Bögl, a global construction firm headquartered in Sengenthal, Germany, is piloting a new wind and hydro energy system, that, if successful, could help Germany reach its goal of 65 percent renewable energy by 2030.[16]

The pilot combines Bögl's concrete and steel *Hybrid Tower* with pumped-storage generation, called the *water battery*, to take advantage of rapidly changing energy needs. When demand on the grid is low, excess wind energy will pump water uphill to be stored inside turbine towers. Up to 10,567 gallons (40,000 liters) of water can be stored in each tower's lower 131 feet (40 meters), and a nearby reservoir has a 42,268-gallon (160,000 liter) capacity.[17] When demand increases or wind generation decreases, water can flow downhill to generate electricity through reversible hydroelectric turbines. See Figure 8. According to the developer, "The [water battery] acts as a short-term storage facility and helps maintain the grid stability."[18]

Towers used in this pilot have hub heights up to 178 meters (584 feet), 30 feet taller than the Washington Monument, or more than one and a half football field lengths high. Using tower foundations for water storage enables an additional 40 meters of height above what would otherwise be possible. According to Bögl, each additional meter of hub height increases the annual energy yield of a wind turbine up to 1 percent, which can significantly improve project payback.[19] Rotor diameters are 137 meters (450 feet), meaning that when one of the blades is pointed straight up, the overall height is 246 meters (809 feet)[20]—about 180 feet taller than St. Louis's Gateway Arch.

Annual wind generation capacity for this four 3.4 MW turbine pilot project is 42 GWh, and the electrical storage capacity of the water battery is 70 MWh.[21] The plant can switch from water storage mode to hydroelectric generation in 30 seconds to enable nearly continuous generation.[22] The capital expenditure (CapEx) costs for the water battery part of the system are $350–$470 USD/kWh (capital cost and $ per kilowatt per hour of storage), and the project is expected to be fully operational by the summer of 2019.[23] Estimated system lifetime is 60 years.[24]

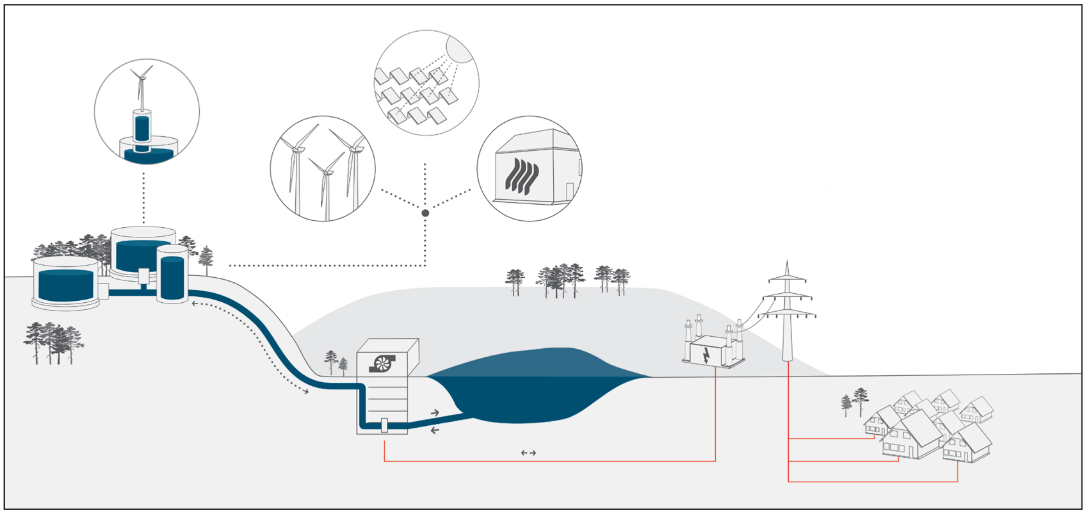

FIGURE 8. Water Battery System. Image courtesy of Max Bögl Wind AG

16 Morris 2018

17 Personal communication, Nancy Fürst, Max Bögl, October 26, 2018

18 https://www.mbrenewables.com/en/water-battery-concept

19 https://www.mbrenewables.com/en/hybrid-tower-concept

20 https://www.solar-consulting.de/en/world-record-energy-transition

21 https://www.mbrenewables.com/en/pilot-project

22 Colthorpe 2017

23 Personal communication, Nancy Fürst, Max Bögl, October 26, 2018

24 Grumet 2016

Recent market and technical research shows promise for bladeless technology.

Blades

Manufacturers are perfecting how to capture more wind energy with longer blades in both onshore and offshore applications. But, one start-up is researching the potential of a different approach—no blades at all.

BLADELESS TURBINES

In 2015 and 2016, bladeless wind turbines were in the news as a recent Spanish start-up, Vortex Bladeless, ramped up research and development.[25] See Figure 9. Instead of using large rotating blades, the company had the idea to harvest energy from vibrations that result from wind passing over a cylindrical structure. These vibrations are called vortex-induced vibrations (VIV) and the phenomena itself is known as vortex shedding. It is the same principle that makes flags move and swirl when it is windy. The resulting Vortex Bladeless technology consists of vertical masts, or straw-like structures, that generate energy using an alternator to convert vibrations created by masts into electricity.[26]

The technology generated both excitement and doubt. Some believed it was not feasible and others were encouraged by its potential advantages over traditional wind turbines—lighter weight, no large rotating parts, reduced noise, lower manufacturing and maintenance costs, and reduced interference with birds. Vortex Bladeless prototyped small models and produced promotional videos, but the technology was not commercialized.

However, there has been renewed interest in the technology. While investors and crowd-funding helped Vortex Bladeless with its initial research, today the company mainly leverages public funding, including the European Union's Horizon 2020 program, a competitive program to support science and innovation.[27]

Recent market and technical research shows promise for the technology, if it can be commercialized.[28] Vortex Bladeless is now testing a 2.75-meter-tall prototype, the Vortex Tacoma, which they hope will be their first commercial product. The company emphasizes its technology's potential role in small-scale, distributed generation.[29] A utility-scale product in not on the near-term horizon.

FIGURE 9. Vortex Bladeless Turbines. Images courtesy of Vortex

[25] Vortex Bladeless was founded in 2013, but did not have significant research and development underway until 2015.

[26] Personal communication, Jorge Piñero, Vortex Bladeless, November 15, 2108.

[27] https://ec.europa.eu/programmes/horizon2020/what-horizon-2020

[28] Transparency Market Research n.d.

[29] https://vortexbladeless.com/technology-design

Longer blades for offshore wind farms are key for enabling turbines to have large capacities.

GIANTS ON THE OCEAN

In September 2017, pricing for electricity from two new offshore wind farms in the U.K. came in at $76.34 (USD)/MWh—less than gas and new nuclear in the U.K.[30] One year later, in August 2018, the 800 MW Vineyard Wind project off of Massachusetts published pricing for Phase 1 (400 MW) starting at $74/MWh (with a 2.5 percent increase each year thereafter for 20 years). Phase 2 (400 MW) will start at $65/MWh. Part of the reason for these very low prices is the extremely long blades planned for these sites—rotor diameters are 164 to 180 meters (538 to 590 feet).[31,32] Each blade is nearly the length of a football field. These longer blades are key for enabling turbines to have large capacities—8 to 10 MW each.

The longer blades and higher towers mean more energy produced per turbine. Fewer turbines are required to produce the same amount of energy, which lowers overall project costs through reduced capital, installation, and maintenance expenses.[33] Also, capacity factors for offshore wind projects are 60 percent or greater—a half to a third better than onshore wind, and equivalent to some fossil fuel plants; and much of the wind blows during the periods of peak loads.[34]

Even larger offshore turbines are on the horizon. GE's 12 MW Haliade-X is the largest turbine planned to date, with a 220-meter rotor diameter and an overall height of 260 meters (Figure 10). With an estimated 63 percent capacity factor, its output will be 67 GWh annually. This means that a single turbine will generate enough electricity to power more than 6,200 average U.S. homes every year. The swept area of the blades is 38,000 square meters (410,000 square feet)—equivalent to seven U.S. football fields.[35]

GE has not made the cost public, but industry analysts suggest the Haliade-X could cost $14 M USD per unit. While the gargantuan size enables increased energy production over existing models, the very long blades present design challenges, such as increased torque on turbine components. First shipment is expected in 2021.[36]

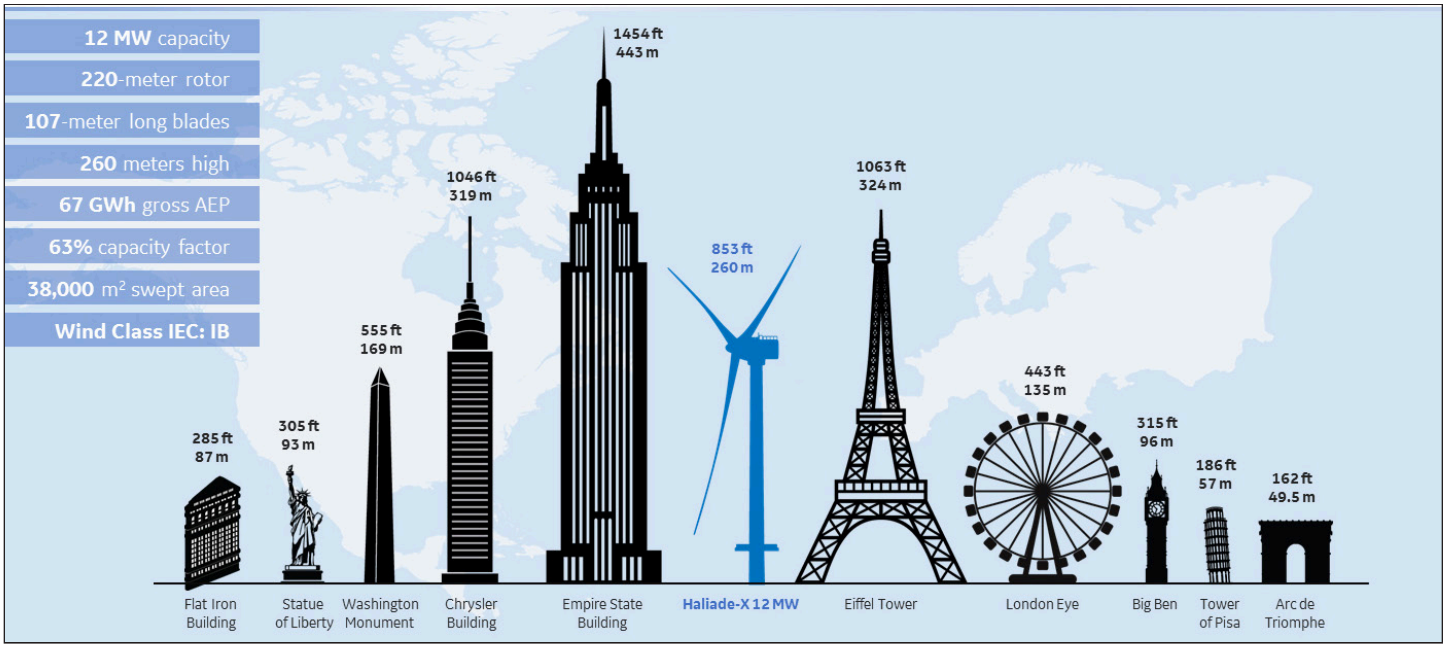

FIGURE 10. Haliade-X 12 MW Size Comparisons. Source: GE

30 Deign 2017
31 Vineyard Wind 2018
32 Renewables Now 2018
33 Williams 2018
34 Chatsko 2018
35 https://www.ge.com/renewableenergy/wind-energy/turbines/haliade-x-offshore-turbine
36 Reed 2018

Two-piece blade design allows for installation at some sites that were previously not feasible.

Wind turbines' risks to birds and bats remains a heavily researched topic.

Despite this impressive development by GE, Siemens still dominates with 70 percent of the global offshore market.[37] Also MHIVestas Offshore Wind, a joint venture between Vestas and Mitsubishi Heavy Industries, currently offers the largest offshore turbines.[38] A 164-meter rotor diameter, 9.5 MW model is available today, and a 10 MW version is available to order now for 2021 installation.[39]

LONGER BLADES ON LAND

New, longer blades are enabling much larger onshore turbines as well. GE is coming out with a 5.3 MW turbine with a 153-meter rotor diameter, meaning that each blade is about 80 meters long, or more than 260 feet. The manufacturer attributes the increased blade length to a new carbon fiber technology that enables a two-piece blade which can be assembled on-site. The two-piece design will allow for installation at some sites that were previously not feasible due to transportation constraints. GE claims their new 5.3-153 model yields a 50 percent increase in annual energy production over their 3 MW turbines.[40]

Not to be left behind, Siemens Gamesa plans to release a 4.5 MW onshore turbine that can support a 155-meter rotor diameter, meaning that each blade is about 76 meters or 250 feet long;[41] and Vestas has a 4.2 MW onshore model with a 150-meter rotor diameter, making each blade 74 meters, or approximately 242 feet long.

To see how fast onshore blade length is growing, compare these 150+ meter rotor diameters to turbines from just a few years ago. In 2016, average rotor diameter of wind turbines installed in the U.S. was 108 meters. That same year, the average installed nameplate capacity was 2.15 MW (Bolinger & Wiser, 2016). These new models' rotor diameters are about 40 percent larger, and a single turbine has at least twice the capacity of an average 2016 installed model.

Birds and Bats

Manufacturers, developers, and researchers are working to reduce wind turbines' risk to birds and bats. Some early wind farms in the U.S., most notably California's Altamont Pass Wind Resource Area, used steel lattice towers that attracted raptors, thereby leading to an unacceptable mortality rate. While these towers are no longer used, impacts to birds and bats remain heavily researched topics. Numerous governmental, scientific, and non-profit agencies, as well as the wind industry, are conducting research and designing new technologies to help.

Strategies to reduce bird and bat fatalities include siting wind farms with consideration for migratory patterns (using, for example, the U.S. Fish and Wildlife Service's Land-based Wind Energy Guidelines), and locating turbines away from landscape features known to attract raptors and bats. Curtailing turbine operation at low wind speeds significantly reduces bat fatalities, and shutting down specific turbines where raptor collision risk is high may also be effective. Other strategies under development include the use of technologies that detect the presence of certain species and curtail operations when they are present, or use different methods to discourage birds from flying near the turbines.

Vestas now offers a bat mitigation system, which they claim can reduce mortalities by up to 60 percent.[42] The system uses known information about bat behavior to control turbine cut-in speeds during times when bats are likely to be present. Because bats prefer to fly in lower wind speeds, blades rotating in low winds can be more problematic than high speed operation.

NRG Systems worked with Bat Conservation International (BCI), a leading conservation group, to develop and promote the Bat Deterrent System. This system uses speakers

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37 Chatsko 2018

38 Reed 2018

39 http://www.mhivestasoffshore.com/innovations

40 https://www.ge.com/renewableenergy/wind-energy/turbines/cypress-platform

41 https://www.siemensgamesa.com/en-int/products-and-services/onshore/wind-turbine-sg-4-5-145

42 https://www.vestas.com/en/campaignsites/batmitigation/home#

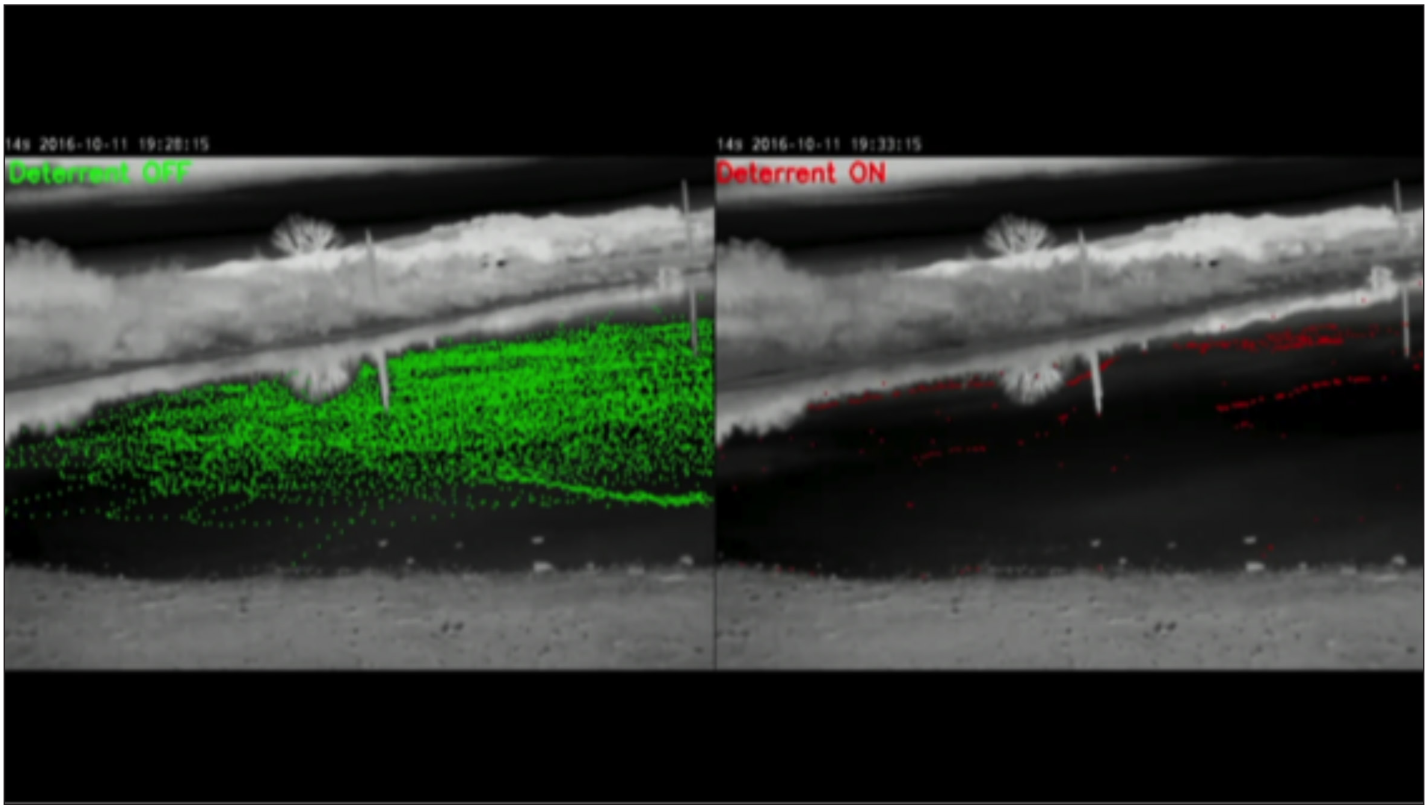

FIGURE 11: Bat Deterrent System testing at a pond. Image courtesy of NRG Systems

to broadcast ultrasonic acoustic deterrents (UAD) to discourage bats from flying around operating wind turbines.[43] According to Weaver (2018), a doctoral student at Texas A&M who evaluated this technology, "The idea behind the UADs is to "jam" the bat's echolocation by creating a disorienting air-space surrounding the wind turbines. Each UAD broadcasts a continuous high frequency sound between 20-50 kHz, which is inaudible to humans, but within the range of all bat species occurring in the region." Figure 11 shows bats' flight paths (green and red dots) over a pond when the Bat Deterrent System is off (left) and on (right).

Weaver's study found that using UAD resulted in a nearly 50 percent reduction in bat fatalities at a Starr County, Texas, windfarm in 2017. NRG Systems plans to make this technology commercially available in 2019.[44]

Cameras connected to computers may be another useful tool. IdentiFlight[45] is one of these new technologies being piloted at wind farms. A series of cameras uses artificial intelligence to detect eagles, and then can identify the specific species and flight path. It then sends signals to wind farm operators, so that they can adjust or temporarily shut down turbine operation in the flight path of the protected species.

Oregon State University researchers are also designing and testing systems that use computer-connected cameras to identify an approaching bird's species, and based on that, create moving images and flashing colors known to deter birds. In the event of an avian impact, sensors in turbine blades can gather data to identify the species.[46]

43 Dvorak 2017 July 14

44 https://www.nrgsystems.com/news-media/pioneering-bat-deterrent-system-from-nrg-systems-reduces-bat-fatalities-by-54-percent-at-texas-wind-energy-facility

45 https://www.identiflight.com

46 Oregon State University 2018

FIGURE 12: Bat being tracked as part of TCU research. Image courtesy of Texas Christian University. *Photo credit: Amy Peterson*

Finally, researchers at Texas Christian University (TCU) are experimenting with a lower tech approach to protect bats—textured paint. Their hypothesis is that bats may mistake the smooth surfaces of turbine towers for water. This behavior has been documented with other smooth solid surfaces, likely because bats use echolocation—bouncing sound waves off surfaces—to locate water. Scientists want to find out if adding texture to turbine towers could scramble the bats' sound signals enough to avoid any confusion. Figure 12 shows the tagging of a bat as part of TCU's research.

With help from DOE funding and a partnership with NextEra, researchers have observed bats' responses to smooth and textured surfaces at an indoor flight center. The next phase will take place at Texas's Wolf Ridge wind farm, a 75-turbine site near the Oklahoma border, where some towers will have the textured paint and others will not. By counting bat carcasses found around turbine bases, the research team can determine if a low-cost coating could be a meaningful part of a bat protection strategy.[47]

Electric cooperatives interested in reducing wildlife impacts of wind energy are encouraged to visit the American Wind Wildlife Institute (AWWI) website (**awwi.org**) or contact AWWI (**info@awwi.org**). AWWI is an independent nonprofit that works with the wind industry and conservation and science organizations to understand the risk of wind energy development to wildlife and develop solutions. They compile and annually update a very useful summary of recent, peer-reviewed research on the impacts of land-based wind power on wildlife in North America (AWWI, 2017).

Conclusion

The wind industry is pushing forward on new technologies on all fronts to increase generation and capacity factor, lower costs, expand storage options, find new locations for economically viable wind farms, and reduce environment impacts. Onshore, longer blades and new access to steady higher-speed winds from taller towers and possibly kites will open up many areas to development. Offshore, increasing the already massive rotor diameters will mean fewer machines to meet the growing demand for renewable energy, increasing AEP and reducing levelized cost of electricity. Furthermore, advances underway in energy storage at wind farms will enable wind to provide electricity when it is needed most, during the hours in the day of maximum system loads usually found in the morning and late afternoon hours. ■

[47] Collier 2017

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- To find more resources on business and technology issues for cooperatives, visit our **website**.

GENERATION, ENVIRONMENT, AND CARBON WORK GROUP

The Business and Technologies Strategies — Generation, Environment, and Carbon Work Group is focused on identifying the opportunities and challenges associated with electricity generation. *Surveillance* research relevant to this work group looks at the various aspects of electricity generation technology, including market status, related policies and regulations, and business models to assist cooperatives in making operational and investment decisions. For more information about technology and business resources available to members through the Generation, Environment, and Carbon Work Group, please visit **www.cooperative.com**, and for the current work by the Business and Technology Strategies department of NRECA, please see our **Portfolio.**