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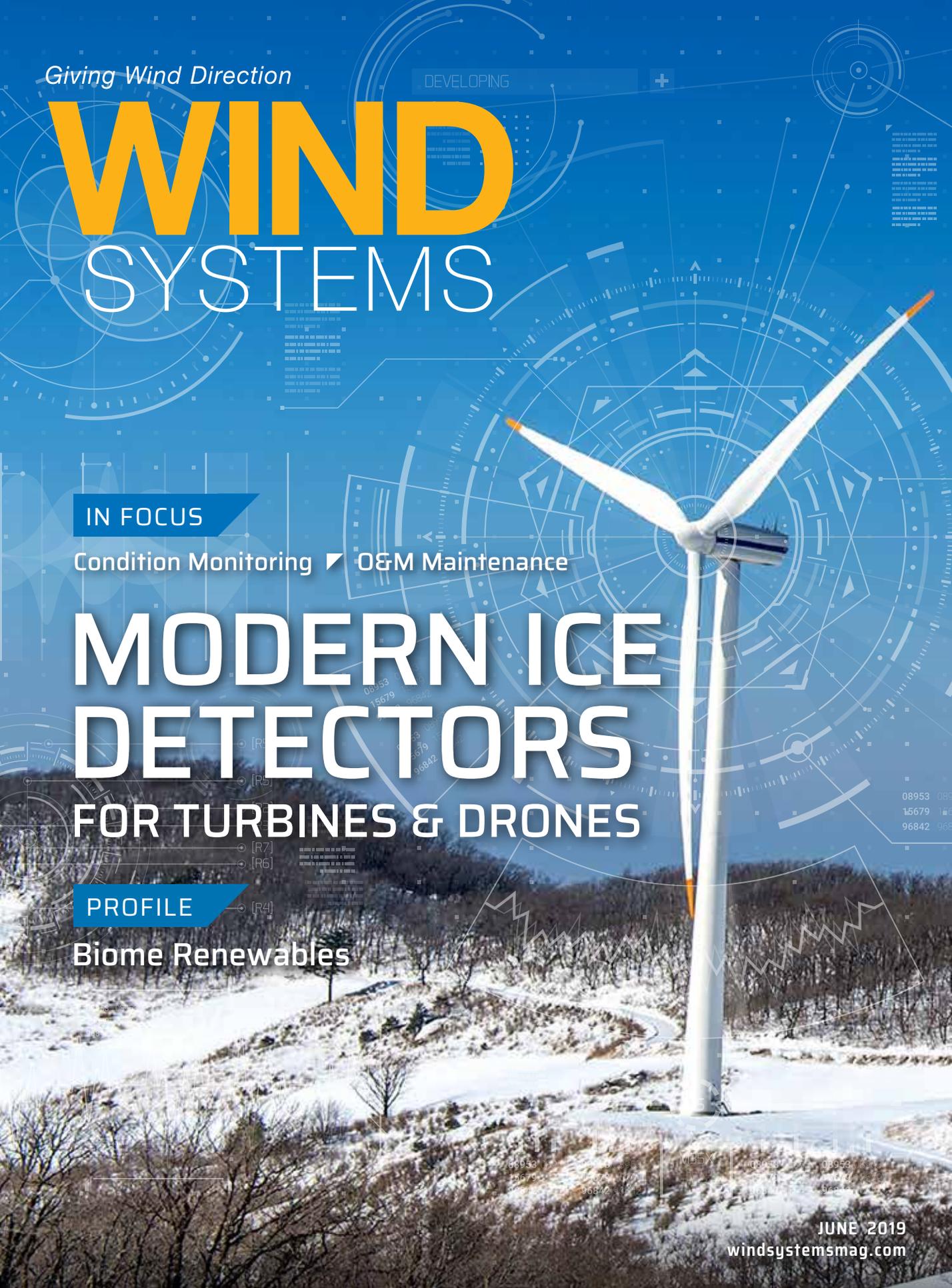
IN FOCUS

Condition Monitoring ▶ O&M Maintenance

# MODERN ICE DETECTORS FOR TURBINES & DRONES

PROFILE

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## IN FOCUS

# MODERN ICE DETECTORS

*Solutions for detecting ice on turbines have been complex and expensive — until now.*

## THE SCIENCE BEHIND A SUPERIOR WEAR-RESISTANT COATING

*How Timken engineered ES302, a better way to avoid costly mainshaft and gearbox repairs in wind turbines.* **16**

## MONITORING WIND-TURBINE OILS

*Oil analysis and condition monitoring for wind turbines is being done using online sensors.* **20**

## PROFILE

Biome Renewables is developing innovative technology to increase the efficiency of wind turbines by harnessing millions of years of R&D conducted by nature. **24**



## CONVERSATION

Brian Hill, general manager for North America with Bachmann electronic, says as technology has advanced, Bachmann has advanced with it. **28**



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## ▸ THE FUTURE OF WIND



**DIRECTION**

**8**

*Allete Clean Energy to sell wind power to Fortune 500 companies  
 ▸ Connecticut governor announces offshore wind plan ▸ Turbine engineering and services firm moves to Portland*



**CROSSWINDS**

**36**

## TECHNOLOGIES TRANSFORMING WIND

*There are five emerging innovations, many of which are already being deployed successfully, that have the potential to solve some of the complex problems facing the wind-energy sector.*

## TAILWINDS

### THE BUSINESS OF WIND

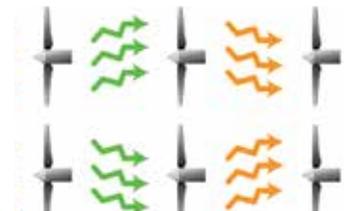


#### ▸ CONSTRUCTION

New turbine foundation wins construction industry award **30**

#### ▸ MANUFACTURING

Siemens Gamesa secures two orders in the U.S. **31**



#### ▸ INNOVATION

Emerson, Vayu to optimize wind farms with machine learning **33**

#### ▸ MAINTENANCE

CTV operators driving transparent approach to offshore wind operations **34**





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## Tackling an aging power grid

Thousands of wind turbines creating electricity without the proper power grid to distribute it is a little like a chocolate factory whose only way to get goodies to the sugar-addled masses is by horse and buggy.

A recent report from AWEA makes it clear that an interconnected, modern transmission grid is more important than ever as distributed solar, energy storage, and electric vehicles begin to scale up.

AWEA's report charts dozens of independent studies from across the country that quantify how transmission investments support consumer savings, improved grid reliability and resilience, a cleaner environment, and a more competitive economy. Grid-operator analysis consistently finds that well-designed transmission projects provide consumer benefits two- to four-times greater than their costs by unlocking low-cost energy sources, such as wind and solar, and reducing electricity market congestion.

*Wind Systems* supports the necessity of an updated power grid, and it's going to take bipartisan support as well as private investors to make it a reality. According

to the report, that support is ready and waiting.

The country may be divided, but the need for power — as well as the need to get that power to the public quickly and efficiently — is one thing we can all agree on.

In the meantime, the technology to make turbines more efficient keeps advancing.

In this month's issue, we focus on turbine maintenance and condition monitoring.

An article from *New Avionics* takes a look at how modern ice sensors can be a simple solution to challenges that have been historically complex and expensive.

Our friends at The Timken Company share the history of its groundbreaking wear-resistant coating for roller bearings and its role in helping owner-operators avoid costly mainshaft and gearbox repairs.

The road that keeps a turbine spinning to delivering that power to the public is often a complex one, but human ingenuity always finds a way to tackle any challenge it may face.

And *Wind Systems* will always endeavor to share those insights.

Enjoy your summer, and as always, thanks for reading!



**Kenneth Carter, editor**

Wind Systems magazine  
editor@windssystemsmag.com  
(800) 366-2185, ext. 204

**David C. Cooper**  
Publisher

### EDITORIAL

**Kenneth Carter**  
Editor

**Jennifer Jacobson**  
Associate Editor

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P.O. Box 1987 • Pelham, AL 35124  
(800) 366-2185 • (205) 380-1580 fax  
info@msimktg.com

**David C. Cooper**  
President

**Chad Morrison**  
Vice President

**Teresa Cooper**  
Operations Director

## U.S. wind grew by 6.2 GW in first quarter

From AWEA

- A burst of new wind-farm announcements in the first quarter of 2019 propelled the total volume of U.S. wind power construction and development activity to a record level according to the newly released U.S. Wind Industry First Quarter 2019 Market Report.
- The American Wind Energy Association's (AWEA) report reveals that U.S. project developers announced new wind farms with a total capacity of 6,146 MW in the first quarter of 2019.
- The additional capacity brings the U.S. construction and advanced development pipeline to a record-breaking 39,161 MW, an 11 percent increase over the previous quarter. Eight states are now on track to double their installed wind capacity.
- Of the total wind pipeline, 17,213 MW were under construction across 21 states at the end of first quarter.
- Texas boasted the most wind under construction with 6,528 MW — 1,255 MW of which is new this year.
- A total of 841 MW of wind projects came online during the first quarter, elevating the country's total installed capacity to 97,223 MW.
- Nearly 30 percent of projects that have already selected a turbine model are deploying turbines with nameplate capacities of 3 MW or higher — with 3.5 MW and larger models being used in 18 different projects.
- New York is increasing the state's offshore wind goal to 9,000 MW by 2035, up from the previous target of 2,400 MW.



The American Wind Energy Association (AWEA) is the premier national trade association that represents the interests of America's wind energy industry. For more information, go to [www.awea.org](http://www.awea.org)

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# DIRECTION

THE FUTURE OF WIND



European wind power electrolysis proposals could accelerate the decarbonization of industry and boost wind operator revenues. (Courtesy: New Energy Update/Michael Utech)

# Offshore wind hydrogen production could be subsidy-free within 10 years

New offshore wind hydrogen proposals in Germany and Netherlands expand the revenue potential for offshore wind and deployment learnings will lower hydrogen production costs toward natural gas reforming levels, project participants told New Energy Update.

Europe's leading offshore wind developers are looking to hydrogen production through electrolysis as a way to expand wind power potential and accelerate the decarbonization of energy supply.

In March, Denmark's Ørsted announced it is developing green hydrogen projects as part of its bid for the Holland Coast South 3&4 projects in the Netherlands. Ørsted is the world's largest offshore wind developer by capacity and plans to increase its installed capacity from 5.6 GW to 15 GW by 2025.

Recent offshore wind tenders have produced zero-subsidy bids, exposing winning developers to wholesale market risks. Ørsted wants to use power from the Holland Coast South 3&4 wind farms to produce hydrogen, which would be sold to industrial customers to provide additional revenue to the operator.

Hydrogen production can help mitigate grid capacity limitations restricting offshore wind-power expansion in many parts of Europe.

Shell, Siemens, and grid operator TenneT recently joined forces to propose new joint offshore wind power and hydrogen tenders in Germany.

The tenders, drawn up by E-Bridge Consulting, could support the installation of 900 MW of wind capacity and 800 MW of hydrogen capacity per tender, in offshore sites not used for regular wind projects, the partners said. Tenders could be held every two years from 2021-2022 and project construction could start in 2026-2030.

Investors in the projects would receive a tariff premium for hydrogen production while electricity revenues

would be market-based, Vigen Nikogosian, principal consultant at E-Bridge Consulting told New Energy Update.

As more hydrogen production capacity is deployed, this tariff price would fall, Nikogosian said.

**MORE INFO** [newenergyupdate.com](http://newenergyupdate.com)

## Connecticut governor announces offshore wind plan

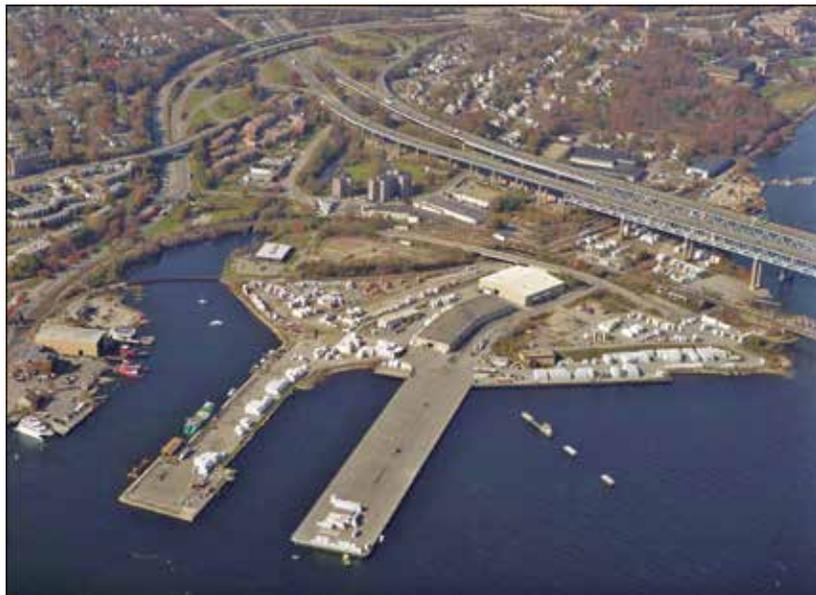
Connecticut Gov. Ned Lamont recently announced that the state and its partners have reached an agreement on a harbor development plan for State Pier in New London that will enable its revitalization and put in place the needed components to establish the region as a central hub in New England for the developing offshore wind industry.

The Connecticut Port Authority, the state's quasi-public agency responsible for marketing and coordinating the development of the state's ports and maritime industry, and terminal operator Gateway, are partnering with Bay State Wind, a joint venture

between Ørsted and Eversource, on a new deal that will redevelop State Pier into a world-class, state-of-the-art port facility through combined public-private investment of \$93 million to upgrade its infrastructure and heavy-lift capability. These upgrades will allow State Pier to meet the facility requirements of the offshore wind industry and will benefit the port's long-term growth by increasing its capability to accommodate heavy-lift cargo for years to come.

"Connecticut's maritime economy has significant potential to drive economic growth and create jobs across the state, and redeveloping State Pier is a central component to that growth," Lamont said. "This new public-private partnership reaffirms the unwavering commitment of the state to increase procurement of offshore wind and make the economic expansion of our maritime economy a reality. We look forward to working with our new partners to position Connecticut as a leader in the offshore wind industry and expand economic opportunity throughout the region."

The State Pier harbor development



State Pier in New London Connecticut. (Courtesy: State of Connecticut)

plan calls for a two-phased effort at State Pier. First, a three-year development project will upgrade the facility infrastructure to meet the heavy-lift requirements of Ørsted and Eversource's offshore wind components.

Second, following the successful completion of the project, Ørsted and Eversource will enter into a 10-year lease agreement granting their joint venture the use of State Pier for wind-turbine generator assembly and staging.

"The Connecticut Port Authority was established to grow the state's economy and create jobs by investing in the maritime industry," said Scott Bates, chairman of the Connecticut Port Authority. "For over a year, we have been working toward a vision where increased port activity drives economic growth and creates jobs throughout the state. This Harbor Development Plan brings that vision to life. In the short-term, our local workforce will upgrade State Pier into a world-class port facility, and our regional manufacturing workforce will build components for our new partners in the offshore wind industry. Longer-term, the increased capacity of State Pier will continue to expand the flow of cargo into New London, which will extend our state's economic reach even farther, benefiting workers throughout Connecticut."

This deal aligns with the Lamont administration's plans to expand the use of carbon-free energy sources.

"We've worked closely with the Connecticut Port Authority, Ørsted, and Eversource to help realize the collective vision of bringing the offshore wind industry to New London," Philippe De Montigny and Matthew Satnick, co-CEOs of Enstructure, Gateway's financial partner, said in a joint statement. "We believe our partnership will yield strong long-term growth for the City of New London and the State of Connecticut. As the port operator for both New Haven and New London, we will also ensure that our maritime terminal operations continue to deliver best-in-class service for our conventional cargo customers."

"(The) announcement lays the foundation for Connecticut to play a leading role in the United States' fast-growing offshore wind industry and supports our transition from older, dirtier fuel sources to clean, affordable, carbon-free energy," said Lee Olivier, Eversource executive vice president for Enterprise Energy Strategy and Business Development. "Our collaboration with the State of Connecticut, the Connecticut Port Authority, the City of New London, and Gateway Terminal brings together the resources and expertise needed to redevelop the New London State Pier into a state-of-the-art offshore wind facility to help Connecticut reach its critical greenhouse gas reduction goals."

**MORE INFO** [orsted.com](http://orsted.com)

## Turbine engineering and services firm moves to Portland

Greater Portland Inc. recently announced Diamond WTG Engineering & Services Inc., a division of Mitsubishi Heavy Industries, Ltd. has relocated its headquarters to Portland, Oregon, from California.

The company provides products, services, and engineering expertise for onshore renewable assets — namely wind turbines. Diamond has sold 3,615 onshore wind turbines across the U.S. and remains committed to the owners of those wind turbines, who are among the largest owners of renewable assets in the country.

The relocation process began in 2017 and was completed in early 2019. Diamond will occupy more than 10,000 square feet of office space in downtown Portland, where staff will support its engineering, accounting, supply-chain, and commercial functions, as well as Diamond's operational and inventory facilities in Texas and New Mexico. The Portland office is at 1618 SW First Ave.

Diamond chose to relocate to Portland due to its proximity to MHI cus-



Diamond WTG Engineering & Services Inc. has sold 3,615 onshore wind turbines across the U.S. (Courtesy: Diamond WTG Engineering & Services Inc.)

tomers, access to local engineering and other professional talent, lower real estate costs, excellent mass transit system, long-standing civic and cultural relationship between Portland and Japan, and availability of nonstop flights between PDX and Tokyo.

The firm's investment in the Greater Portland region represents yet another foreign direct investment in the region from a firm with roots in Japan. More than 140 Japanese companies are located in Greater Portland.

The company's recruitment was also supported by GPI partners Business Oregon, Portland General Electric and Prosper Portland.

**MORE INFO** [DiamondWTG.com](http://DiamondWTG.com)

## Allete to sell wind power to Fortune 500 companies

Allete Clean Energy recently announced it has acquired the Diamond Spring wind project in Oklaho-

ma from Apex Clean Energy and will build, own, operate, and sell wind power from the site to two large Fortune 500 companies under 15-year power sales agreements.

Diamond Spring will be the first Allete Clean Energy wind site to have contracts with corporate customers. Corporate and industrial customers represent a growing market as companies embrace sustainability goals and demonstrate to customers they are powered by clean energy.

“Allete Clean Energy is honored to work with well-known and highly respected companies to advance their sustainability goals and add renewable energy to reduce their carbon footprints,” said Allete Clean Energy President Allan S. Rudeck Jr. “In addition to renewable energy, these customers are seeking competitive energy costs, and the Allete Clean Energy team is pleased to deliver clean energy supplies with a track record of timely, responsible, and cost-effective project execution. Serving the corporate and industrial market opens new opportunities for Allete Clean Energy, and the southern Oklahoma location is strategic in that it provides a new beach-head in the highly attractive Southwest Power Pool where significant potential exists for serving new customers in the utility and corporate and industrial segments. We are pleased to be working with Apex Clean Energy to bring Diamond Spring to market.”

Allete Clean Energy purchased a 100-percent interest in the up to 303-MW Diamond Spring wind farm from the project’s developer, Apex Clean Energy. The purchase includes two power sales agreements negotiated by Apex totaling up to 228 MW and additional capacity to serve the growing corporate and industrial market.

“Corporations are taking a clear leadership position in curbing carbon emissions, and we applaud them for aggressively working to achieve their sustainability goals,” said Mark Goodwin, president and CEO of Apex Clean Energy. “Apex is proud to part-

ner with Allete at Diamond Spring Wind, one of several Apex projects this year that is expected to help leaders in the corporate, commercial, and industrial sectors meet their clean energy commitments.”

Allete Clean Energy will begin construction this year with the wind project coming online in 2020. It will be the largest wind facility owned by Allete Clean Energy, pro-

ducing enough power for 114,000 homes, and increase the company’s total wind capacity to approximately 1,000 MW at nine sites.

The project has the support of the local communities, where benefits include \$48 million in tax revenue and \$54 million in payments to landowners. ✂

**MORE INFO** [www.allete.com](http://www.allete.com).

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# MODERN ICE DETECTORS FOR TURBINES AND DRONES

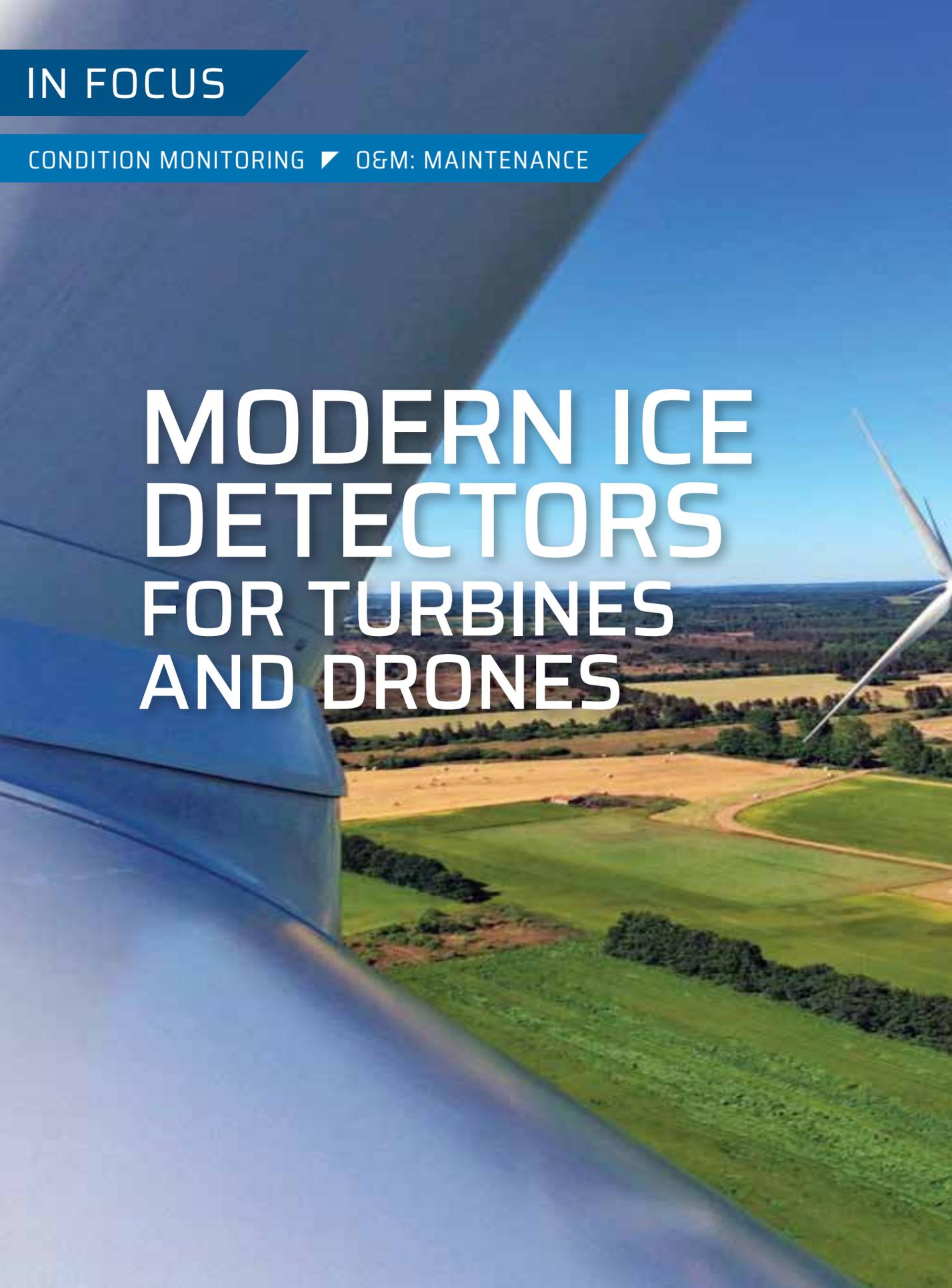
An aerial photograph of a wind turbine in a rural landscape. The turbine's nacelle and part of a blade are visible in the foreground on the left, partially obscuring the view. The background shows a mix of green and yellow fields, with a clear blue sky above. The overall scene is bright and clear, suggesting a sunny day.



Figure 1: Weather conditions for wind farms are not always benign. Ice sensors are crucial for operating efficiency and safety. (Courtesy: Wind Cluster)

*Turbine ice can be hazardous to people and things, limit energy production, and add stress to blades and towers. Solutions have been complex and expensive – until now.*

By RICHARD HACKMEISTER and PETER JENSEN

**O**ne ice detector solution for OEMs and operators is to borrow off-the-shelf technology from the global telecommunications industry.

Smart phones are manufactured in extremely high volumes around the world. This has forced the price of optical lasers and LEDs down to just pennies apiece. Plastic optical fibers are likewise made in vast quantities, with prices just pennies a foot.

With today's tele-components being reliable, common, and cheap, they should make excellent building blocks for wind-turbine ice sensors – and they do. (Figure 1)

Modern ice detectors are entirely optical. In the modern ice sensor, a tele-component light source and receiver monitor the opacity and refractive index of whatever substance is in contact with the probe. Other than ice itself, little else would have intimate contact with an ice sensor high atop a wind-turbine nacelle. Liquid water simply runs off by gravity, but ice sticks to the optical surfaces for sensing.

Since they have no moving parts, modern ice sensors and housings can be scaled very small – about the size of a thumb – and potted solid against the elements. This is an improvement over hermetic sensor housings, because solid sensors are robust against moisture and vibration as well.

Modern ice detectors work as a combined optical spectrometer and optical switch. A change in opacity registers as rime ice; a change in refractive index registers as clear ice.



Figure 2: Modern ice sensors provide a local “ice alert” indicator for the convenience of technicians working aloft. (Courtesy: NAS)

The wavelength of the sensor's excitation signal is invisible to the human eye, so as not to cause a distraction. At the same time, its clear sensor probe is useful to display a blue ice-indicating LED, helpful to turbine technicians working aloft (Figure 2).

Modern ice sensors eliminate many of the problems



Figure 3: A shatterproof polycarbonate cage allows unimpeded airflow around a sensor body, protecting against falling chunks of ice and debris. (Courtesy: Vestas)



Figure 4: The 3/8-inch plastic dot in a musical greeting card contains more electronic functionality than a modern ice sensor. Custom chips like this are low cost and high quantity. This manufacturing technique promises deeply eroding sensor prices with increasing quantity. (Courtesy: NAS)

with legacy ice sensors, being generally lower in cost, lighter in weight, and smaller in size. Simple relay contacts eliminate the need for interpretation and send a “go/no-go” “ice/no-ice” indicating status to the host control system. This simplifies the interface while reducing software complexity and cost.

Optical ice sensors (Figure 3) are lightweight and easy to carry aloft and install. They run on any convenient DC power source 8-30 volts and need only 2 watts to look for ice. Unlike legacy sensors, modern ice sensors detect and report the absolute presence of ice on a wind turbine, do not artificially melt the sensed ice away, and do not require additional power supplies and power budgets.

## BEARING HEAT SIGNATURES

Following the path of legacy ice sensors, modern ice sensors were also recently developed for aircraft. Smaller, lighter, more sensitive, and cost effective, they are easily adapted to wind turbines and autonomous drones for wind farms.

Other, wider applications for modern ice sensors include virtually any place with a need to sense the formation of hazardous ice and take corrective action in a timely manner, such as heat pumps, radio and TV broadcast towers, HVAC cooling towers, hydrogen car engines, traffic signals, vehicular bridges and overpasses, remote power lines, water-level



Figure 5: NASA's Glenn Icing Research Tunnel in Cleveland, Ohio. Modern ice sensors were originally developed for aircraft; tested here for compliance with SAE Aerospace Standard 5498 ¶5.2.1.1.1. (Courtesy: NAS)



Figure 6: A fifth-generation ice detector protects wind-farm drones from hazardous ice during daytime and nighttime operations, helping to comply with FAA regulations. (Courtesy: NAS)

sensors in oil and gas installations, and more.

Ice sensor prices are eroding because overall demand and production volumes are increasing.

They are increasing because modern ice sensors enjoy wider applications in high-volume drones and refrigerator defrost controls. The ultimate manufacturing volume for optical ice sensors is projected to approach that of musical greeting cards (Figure 4) in multi-million-unit volumes, with prices expected in the sub-\$10 range.

Tested in the the world's largest icing wind tunnel at NASA Glenn (Figure 5), modern optical ice sensors comply with SAE Aerospace Standard AS 5498 ¶ 5.2.1.1.1 for FAA-mandated ice protection of autonomous BVLOS (beyond visual line of sight) drones.

FAA compliance is a major breakthrough for wind-farm drones. Modern ice sensors invite drones to use the darkness of night to autonomously monitor the IR heat signatures of turbine bearings and other equipment for signs of impending failure.

If the sensors flag anomalous high temperatures, observe nighttime intruders, the movement of wildlife, flocks of birds, or colonies of bats, the sound of an ultrasonic horn will safely shoo them away, autonomously, without damage to the blades or requiring the services of an FAA-licensed drone pilot. The pilot is built right into the operating sys-

## A dozen other ways to detect ice

**Daytime visual:** Visual observation of ice on turbine members during daytime hours, with field glasses or naked eye.

**Nighttime visual:** Strategic illumination of turbine members with either white or red light. A red light shining upward through an acrylic panel is inconspicuous at night, but when ice forms on it, the red light diffuses and provides a visual form of ice alert.

**Mechanical obstruction:** A scraper rotating on an exposed surface. As ice accretes on the surface, the torque required to rotate the scraper increases. At some preset torque, a signal is generated, setting off an ice alert.

**Differential pressure:** A hollow probe senses air pressure through small orifices on its upwind face. As ice blocks the orifices, a pressure differential signal is created setting off an ice alert.

**Latent heat:** A periodic current pulse is sent through a resistance element to heat an exposed probe. If ice has accreted on the probe, the temperature increase will temporarily dwell at 0°C and set off an ice alert.

**Vibration:** Ice on a vibrating reed slows its resonant frequency, which is detected and used to energize a heater, which melts the ice and pulses pneumatic boots on an aircraft wing. The frequency of pulses sets off an ice alert.

**Microwave:** A microwave transducer consisting of a resonant surface waveguide is embedded into an exposed surface on which ice accretes. The ice acts as part of the waveguide; changes its phase, and sets off an ice alert.

**Electromagnetic beam interruption:** An EM source is placed on one side of a flattened tube and directed at a sensor on the other side of the tube. As ice accretes on the tube, the signal is blocked and sets off an ice alert.

**Ultrasonic:** Sound waves are reflected off an ice/air interface and sensed by a transducer. When ice is present, the reflected waves are perturbed, sensed, and used to set off an ice alert.

**Capacitance:** A total impedance ice detector uses the capacitance of a surface-mounted electrical circuit to determine the presence and thickness of ice and sets off an ice alert.

**Optically occluding:** An optical source directs light at an optical receiver. An accreting surface close to the beam accretes the ice, senses ice blocking the path of the beam, and sets off an ice alert.

**Optically refractive:** An optical source sets off an ice alert by using un-collimated light to monitor the opacity and optical index-of-refraction of whatever substance is on the probe, either air or ice.

tem, along with a virtual GPS-defined “fence,” delineating airspace beyond which the drone is disabled, and cannot fly.

### DYNAMIC BLADE INSPECTION

Modern fifth generation ice sensors are capable of detecting the formation of ice films only molecules thick.

Upon sensing an initial film of ice molecules, the modern ice sensor of a BVLOS wind-farm drone (Figure 6) would help protect the drone against ice by sending an interrupt to the host operating system and prompt it to briefly reverse the fan blades. The top surfaces of a drone’s fan blades are more susceptible to ice molecules than the bottom surfaces because air above the blades is colder due to lower pressure (lift), while the air below the blades is warmer due to higher pressure.

Warmer air briefly swept over the top of the fan blades overcomes newly-formed ice molecules’ latent heat of fusion, changes their state back into liquid water, and retards formation of ice on the drone. (The latent heat of fusion of water is 80 calories/gram.)

This proven fan-reversing ice removal technique is common on HVAC cooling towers for large data centers, apartment buildings, campus buildings, hospitals, etc., which also use modern optical ice sensors for ice protection.

### DAYTIME AND NIGHTTIME DETECTION

Protected against ice during daylight hours on a fixed schedule under SCADA control, autonomous wind-farm drones would take off and inspect a specific circuit of turbines.

Rather than stop the turbines and lose valuable production time, each dedicated wind-farm drone would take advantage of its inherent agility and inspect turbine blades in

a spiral on the fly, without stopping the turbine. Record high resolution blade images and other key features, fly autonomously to the next turbine like a honey bee collecting nectar in a field of flowers. It then would return to its garage for a robotic battery swap-out or charge.

Protected against ice during nighttime hours, autonomous wind-farm drones would also serve as night watchmen, using the cover of darkness to monitor the heat signature of turbine bearings and other equipment for signs of impending failure.

In the unlikely event of fire or other anomaly, SCADA would immediately dispatch its BVLOS drone for video monitoring and situational awareness before technicians and fire apparatus could arrive.

In addition to end-of-warranty inspections and preventive maintenance, inherent advantages of ice-protected autonomous drones include safety, objectivity, uniformity, accuracy, low cost, and real time dissemination of critical data.

Ice on wind turbines may be hazardous to people and things, but the use of abundant, low-cost optical components to make ice sensors provides simple, inexpensive solutions for turbines and dedicated on-site drones. ✎

### ABOUT THE AUTHORS

Richard L. Hackmeister is vice president of New Avionics Corp.; 2501 East Commercial Blvd. #209; Fort Lauderdale, Florida. He can be reached at RLH@newavionics.com. For more information, go to [www.newavionics.com](http://www.newavionics.com). Peter Nyegaard Jensen is managing director of Wind Cluster ApS; Aahavevej 69, DK-8600; Silkeborg, Denmark. He can be reached at [pnj@windcluster.com](mailto:pnj@windcluster.com). For more information, go to [www.windcluster.com](http://www.windcluster.com)

# THE SCIENCE BEHIND A SUPERIOR WEAR-RESISTANT COATING FOR ROLLER BEARINGS

Today's multi-megawatt wind turbines require stronger bearing solutions, particularly those operating in hard-to-access locations. (Courtesy: The Timken Company)

# How Timken engineered ES302, a better way to avoid costly mainshaft and gearbox repairs in wind turbines.

By VIKRAM BEDEKAR and DOUG LUCAS

Steel-to-steel contact is why many bearings fail, why proper lubrication is critical, and why The Timken Company, manufacturer of engineered bearings and power transmission components, works hard to develop advanced surface coatings that combat the problem in the toughest conditions.

To extend the life of roller bearings operating in wind turbines, Timken developed ES302, a special coating that adds durability where adhesive wear (the rubbing together of two metal surfaces) is a significant problem. Follow along as Timken bearing experts Vikram Bedekar and Doug Lucas explore the science behind this proprietary surface treatment that has been proven to prevent common damage modes in wind bearings.

## STRONGER BEARINGS WANTED

Wind turbines place huge demands on mainshaft and gearbox bearings as many wind-farm operators already know, having experienced the disruption of a major mechanical overhaul that can cost \$100,000 or more anytime a bearing is unexpectedly taken out of service.

By the late 2000s, with bearing failures mounting, the U.S. wind-energy industry began to widely recognize that turbines designed to produce electricity for 20 years were requiring large corrective work within five to 10 years. Early wind-turbine designs, for instance, tended to use two-row mainshaft spherical roller bearings that, due to the dynamic loading forces commonly experienced in turbines, were required to support a radial reaction as well as wind-thrust loading on only the downwind row of rollers.

This uneven pressure led to premature mainshaft bearing wear while also transferring damaging axial deflection loads to gearbox bearings. Furthermore, wind-energy producers found it challenging to keep bearings well-lubricated under these complex loading conditions. In wind turbines, lubricant films are particularly difficult to maintain, and bearing damage can occur quickly. As years passed, the urgency for wear-resistant bearing solutions grew stronger as turbine operators looked for answers.

## ADVANCING WIND ENERGY

Timken has been committed to the wind industry for nearly 20 years with dedicated research and development, engineering, and field service teams actively engaged in solving the industry's biggest challenges. By 2009, the Timken R&D team was nearing the production stage on a special plasma coating process for roller bearings that it had been pioneering since the late 1990s.

At that time, physical vapor deposition — or PVD — was a technology unfamiliar to most. PVD is a vacuum deposition method used to produce thin films on objects such as bearing rollers, gears, and engine components. Previously,

Timken had demonstrated promising results for PVD-coated bearings in various oil and gas, mining, military and pump drive applications and saw an opportunity to help wind producers increase their productivity by bringing the same surface engineering technology to turbine mainshaft and gearbox bearings.

## ABOUT PVD

PVD uses physical processes such as heating, sputtering, or transfer by laser or electron beams to produce a vapor of material, which is then deposited on the object that requires coating. This highly complex process is a rigorous one that must be controlled within world-class production facilities and with stringent design and quality specifications. For wind bearings, Timken chose a plasma-based PVD sputtering method whereby atoms are ejected from a source material (the target) by high-energy particles and transferred to a substrate.

First, bearing rollers are placed in a chamber in a vacuum environment and introduced to very low quantities of a special mixture of reactive gases (Ar/C<sub>2</sub>H<sub>2</sub>). These gases react with the metallic targets (such as WC) in the presence of strong electric and magnetic fields. The atoms from the target are then dislodged by high-energy collisions (that is, plasma ions bombard the source material, causing some of it to ionize). These ionized atoms then condense on the surface of the object in microthin layers.

PVD coatings are more uniform, more durable (up to six times) than conventional electroplated or spray coatings. PVD is also considered to be a more environmentally friendly process as it does not produce any hazardous waste materials to dispose of.

Once confined to special laboratories, PVD methods have been scaled up in recent years to meet the needs of heavy industry, with ongoing development allowing the production of new coatings with properties that were previously unachievable.

Essentially, PVD methods allow coatings to be deposited on surfaces atom by atom. This precise, nanometer control of the coating structure allows Timken to create coatings that possess the exact performance characteristics an application requires. This level of accuracy and consistency is simply not achievable using a traditional bath dip or spray-paint process. The result is a fabrication of atomic layers having the exact microstructure and properties desired.

## SOLVING FOR STEEL-ON-STEEL

By employing PVD coating technology to make roller surface less “steel-like” than the bearing rings, Timken theorized it could effectively combat the steel-on-steel adhesive wear issues plaguing turbine mainshaft and gearbox bearings.

The coating Timken developed — dubbed ES302 — is a super-thin engineered combination of nanometer-sized ceramic particles embedded in an amorphous hydrocarbon matrix measured in fractions of a human hair. The coating's nanocomposite, metal-carbide matrix design provides extremely hard and low-friction, near-surface properties that inhibit microwelding and adhesive wear at the roller and race interfaces.

Essentially, ES302 is both hard and wear-resistant like a drill bit, yet slippery and nonstick like a frying pan. When applied to bearing rollers, the coated surface acts as dissimilar material to the steel rings to reduce adhesive wear. Such coatings have proven effective in low-lubrication conditions or where debris is present, offering a wide range of advantages in heavy-duty bearing applications. Benefits can include reduced friction and torque, reduced component scuffing and smearing damage, decreased false-brinelling wear, and greater oil-out protection.

## EXCITEMENT FOR ES302

During ES302 development, Timken experts traveled the world to talk to wind-farm operators, OEMs, and others about the problems they were experiencing. This direct customer contact was key to uncovering real-world challenges, building collaborative relationships, and gathering extensive feedback on wear-resistant bearings. In 2011, Timken began sending prototype parts out for evaluation and received promising reports in return. In one instance, a bearing that had previously lasted just 200 hours was documented to have crossed the 2,000-hour threshold with no disruptions, prompting an enthusiastic email from the customer.

At the same time, Timken conducted laboratory testing that indicated an ES302-coated bearing could experience up to six times greater life when operated in standard conditions, and up to three times greater life under debris-contaminated conditions compared to an uncoated bearing.

The company soon established a healthy aftermarket strategy of replacing standard mainshaft and gearbox bearings with wear-resistant bearings featuring ES302 coating on the rollers. Furthermore, the new coating was showing promise in agricultural applications such as large farming implements, tractors and combines. Timken aerospace customers also found uses

for ES302, along with paper mills and cement plants where high temperatures, water ingress, and abrasive particles pose a constant threat to bearings.

Ultimately, the investment by Timken to identify fundamental problems in customers' applications and to work on the cutting edge of engineering and scientific knowledge to solve them is what spurred the success of the ES302 project. As materials and processes shift over time, it is a collaborative mindset that keeps Timken focused on the problems customers care most about.

## AWARD-WINNING INNOVATION

Since commercializing its proprietary coating, Timken has garnered widespread industry acclaim including the prestigious Engineering Materials Achievement Award from ASM International in 2017. The pre-eminent materials information society recognized Timken for ES302's "significant contributions to the field of materials science and evidence of industrial impact." Previous winners of the annual award, established in 1969, include General Electric Co., Northrop

## TIMKEN COATING PORTFOLIO

Coating	PRODUCT INFORMATION				PROCESS INFORMATION			
	Product	Surface	Key Features	Application	Technique	Coating Thickness (nominal value)	Chemistry	Nano-hardness (GPa)
ES200	Tapered roller bearings, cross (X) roller bearings	Roller ends	Oil out, adhesive wear mitigation	Aerospace, off-highway, wind	Reactive Physical Vapor Deposition	1-2 µm	TiC <sub>x</sub> Cr <sub>1-x</sub>	12 ± 1
ES300	Tapered roller bearings, pump shaft	Roller ends, sliding surfaces	Wear resistance, oil out, adhesive wear mitigation	Aerospace, fuel injector pins, automatic transmission pumps	Reactive Physical Vapor Deposition	2-3 µm	WC <sub>x</sub> Cr <sub>1-x</sub>	12.5 ± 0.8
ES302	Cylindrical roller bearings, spherical roller bearings, tapered roller bearings, thrust bearings	Roller body and ends	Wear resistance, debris resistance, oil out	Wind, oil and gas, mining trucks, gulleys, axle pinions, slurm drives	Reactive Physical Vapor Deposition	1-2 µm	WC <sub>x</sub> Cr <sub>1-x</sub>	13 ± 1.5
AquaSpox®	Tapered roller bearings	Inner and outer rings (all surfaces)	Corrosion, fretting and galling resistance	Boat trailer bearings, rolling mills, crank breakers	Electrodeposition	8-10 µm	Zn-Ni	4.4 ± 0.3
Thin Dense Chrome (TDC)	Tapered roller bearings, spherical roller bearings, Surhor™ series ball bearing housed sets and axle roller ring ball bearing, inner ring bore, housed balls	Inner and outer rings (all surfaces)	Corrosion and wear resistance	Conveyors, ovens, fans, blowers, aerospace	Electrodeposition	1-1.5 µm	Cr	9.5 ± 2
Black Oxide	Cylindrical roller bearings, spherical roller bearings, tapered roller bearings	Inner and outer rings and rollers (all surfaces)	Retains lubricant and increases shock resistance especially during run-in periods	Wind, industrial, aerospace	Alkaline bath	1-2 µm	Fe <sub>3</sub> O <sub>4</sub>	2.6 ± 0.1
Zinc Phosphate	Tapered roller bearings, backing rings, and caps, seal cases	Inner and outer rings, auxiliary components (all surfaces)	Lubrication during fitting, corrosion, galling and wear resistance	Rail	Phosphate bath	1-2 µm	Zn-Phosphate	2.6 ± 1.1
E-Coat	Timken® Type E tapered roller bearing housed unit, rail auxiliary components, backing rings	Auxiliary components (all surfaces)	Corrosion resistance	Used on all Type E housings	Cathodic epoxy	15-20 µm	Epoxy	N/A
Powder Coat	Housings for ball housed units (Timken® Fatzer® and IJ series), Timken® spherical roller bearing solid block housed units, sealcases bearing surface	Coat non-housing surface, seal locking collars	Corrosion resistance	Conveyors, ovens, fans, blowers	Electrostatic powder coating	90-100 µm	Epoxy mixed with ceramic	N/A
Dielectric Coat	TWTF outer ring O.D. ball bearings, cylindrical roller bearings	O.D. surfaces in contact with housings and shafts	Electric insulation	Rail traction motors, electric motor and generator bearings	Plasma spray	220-280 µm	Alumina based dielectric coat	N/A

Timken has developed a robust coatings portfolio for meeting different application needs from wind energy to all sectors of heavy industry. (Courtesy: The Timken Company)



Mainshaft spherical roller bearings with engineered coatings can offer up to six times longer life compared to standard uncoated bearings. (Courtesy: The Timken Company)

## HOW BEARING DAMAGE OCCURS

In a standard mainshaft spherical roller bearing, radial and thrust forces result in higher loads on the downwind row of the bearing, as well as a full 360-degree loaded arc of rollers.

For every shaft revolution, the full-loaded arc of rollers increases the number of stress cycles occurring on a point on the inner raceway of the bearing.

Given that a mainshaft typically rotates at slow speeds in the 25 to 35 rpm range, this may not generate a significant lubricant film, even with higher-viscosity lubricants.

Taken together, the result is greater loading, more stress cycles, and thinner lubricant film thickness on the downwind row of the bearing, which increases the risk of micropitting and other damage modes.

Grumman, IBM, Boeing and General Motors Corp., to name a few.

For Timken development team members, the honor brought home a broader sense of how much their customers and technical peers appreciated the work that went into developing ES302. Many Timken engineers and analysts made

valuable contributions to the project, including Gary Doll, Timken professor of surface engineering and director of the Timken Engineered Surfaces Laboratory at the University of Akron; Ryan Evans, director of R&D for bearings; Jim Gnagy, product development specialist; and Tim Springer, program manager.

## FIELD-PROVEN PERFORMANCE

Recently Timken was presented an opportunity to reinforce its initial lab results when one 230/600-series ES302-coated mainshaft bearing was removed from a 1.5-MW turbine in New Mexico (due to nonbearing-related issues) and returned for analysis following seven years of reliable service. Because the turbine was planned to be repowered, the operator didn't relubricate the bearings for the last two years of operation.

A close examination showed that the bearing exhibited little to no adhesive wear, and it demonstrated the expected surface finish and remained consistent with the original design profile, leading Timken to conclude the bearing was in "very good" condition for this stage of operation and the lack of relubrication for two years. Furthermore, there was no evidence of the bearing entering the next stages of damage. Based on its own application engineering practices, Timken can confidently estimate the bearing would have continued to provide reliable, trouble-free operation into the 15- to 20-year time frame.

## THE POWER BEHIND THE POWER

Currently there are more than 1,000 ES302-coated bearings installed in wind turbines around the world. According to the American Wind Energy Association (AWEA), U.S. wind power alone now supports a record 114,000 jobs, more than 500 domestic factories and more than \$1 billion a year in revenue for states and communities hosting wind farms. With the ability to power more than 30 million homes, the industry is bringing economic opportunities to towns and cities across America.

Timken is proud to play its part in helping to grow renewable energy technologies by producing wear-resistant bearings that customers do not have to think about again. ES302 and other surface engineering developments from Timken help bearings do their jobs dependably wherever rotating parts require them.

Today, Timken researchers continue to look for ways to reduce costs and make coatings more accessible to a wider variety of customer applications. By partnering with energy producers, OEMs, and centers of excellence worldwide, the company is delivering on its mission to engineer the next generation of coating technologies that improve bearing life and eliminate downtime. ✎

## ABOUT THE AUTHORS

Vikram Bedekar is a materials specialist and Doug Lucas is an advanced engineering technologist with The Timken Company. For more information, go to [www.timken.com/wind-energy](http://www.timken.com/wind-energy).

# MONITORING WIND TURBINE OILS

Oil analysis and condition monitoring for both onshore and offshore wind turbines are being done increasingly using online oil and machine monitoring sensors. (Courtesy: Canstock)

# *Oil analysis and condition monitoring for wind turbines is being done using online sensors.*

By R. DAVID WHITBY

**M**ost wind turbines tend to be in remote locations, making physical access to the gears, bearings, and control systems difficult and not always practical. Condition monitoring programs for wind turbines generally include time-scheduled oil analysis. Unfortunately, servicing of wind turbines is often limited to specific times each year. When the first large wind turbines were installed more than 20 years ago, oil samples were only taken every six months or so. Trend analysis for important oil quality parameters was difficult and erratic.

Consequently, oil analysis and condition monitoring for both onshore and offshore wind turbines are being done increasingly using online oil and machine monitoring sensors, similar to those being used in automotive engines and marine systems. The oil sampling intervals are thereby reduced from every six months or so to either daily or continuously. This allows a more precise trending of important oil and machine parameters.

## **OIL PROPERTIES**

The most important oil properties that need to be monitored for wind turbines are:

- ▣ Viscosity.
- ▣ Acid number.
- ▣ Oxidation.
- ▣ Water content.
- ▣ Additive contents, particularly phosphorous.
- ▣ Elemental contents, particularly wear metals.

All these can now be done using electronic sensors from a number of suppliers. Bosch has developed a multifunction oil-condition sensor, which determines oil level and oil condition. The oil level information enables the system to be monitored for leaks. The oil-condition sensor constantly measures the oil's viscosity, permittivity, conductivity, and temperature. The measured viscosity and permittivity (or dielectric constant) are the primary values supporting the oil-condition evaluation. A novel microacoustic device determines the viscosity. This device uses the piezoelectric effect to electrically excite high-frequency mechanic (or acoustic) vibrations at a sensitive surface.

When this sensitive surface comes into contact with the oil, the electrical device parameters, such as oscillation frequency and damping, are changed according to the oil's mechanical properties, especially viscosity. In contrast to conventional viscometers, the microacoustic sensor does not contain any moving parts.

Oil degradation and wear metals can be detected using a dielectric sensor, and several companies, including Mercedes-Benz and Delphi Corp., now use these devices for online oil monitoring. Wear metals and particulate contaminants also can be detected using online optical particle counters. When particulate contents start to trend upward,



Oil degradation and wear metals can be detected using a dielectric sensor. (Courtesy: Canstock)



An online sensor developed by the Technical University of Munich has been found to be able to provide test results for acid number, oxidation, water content, phosphorous, silicon, zinc, and copper that agree closely with those obtained by conventional FTIR. (Courtesy: Canstock)

more detailed oil sampling and analysis are required.

### SPECTROSCOPY VS. SENSORS

In a conventional oil analysis laboratory, Fourier Transform Infrared (FTIR) spectroscopy can be used to monitor oxidation, water content, and additive elements. An online sensor developed by the Technical University of Munich has been found to be able to provide test results for acid number, oxidation, water content, phosphorous, silicon, zinc, and copper that agree closely with those obtained by conventional FTIR.

The sensor consists of a collimated infrared light source, a cuvette, a Linear Variable Filter (LVF) and a linear pyroelectric detector array with application-specific integrated circuit (ASIC). The LVF is a spectral device that uses a Fabry-Pérot structure to provide virtually constant resolution over the required wavelength region.

Compared to conventional FTIR spectrometers, the LVF spectrometer has a reduced resolution and a limited spectral range. It operates in a range of about  $1,800\text{ cm}^{-1}$  to  $900\text{ cm}^{-1}$  at a wavelength dependent resolution of about  $36\text{ cm}^{-1}$  at  $1,800\text{ cm}^{-1}$ . (Standard FTIR spectrometers normally operate in a wavelength range of  $4,000\text{ cm}^{-1}$  to  $500\text{ cm}^{-1}$  at

a spectral resolution of  $4\text{ cm}^{-1}$  or better.) Even so, the new sensor has been shown to provide acceptable correlation with laboratory test results, using data from several hundred oil samples. Extracting the oil quality parameters from the measured infrared spectra requires sophisticated data processing, using a multivariate regression model.

### INTERNET ACCESSIBLE

Data from all these sensors, all of which can be fitted to the bypass filtration line of a wind-turbine gearbox, can be fed into Internet-based data analysis systems, allowing electrical system maintenance management to track the condition of an entire array of wind turbines in real time and receive email alerts when emerging problems are identified. ✎

### ABOUT THE AUTHOR

R. David Whitby is chief executive of Pathmaster Marketing Ltd. in Surrey, England. You can reach him at pathmaster.marketing@yahoo.co.uk. This article reprinted with permission from the September 2017 issue of TLT, the monthly magazine of the Society of Tribologists and Lubrication Engineers, an international not-for-profit professional society headquartered in Park Ridge, Illinois, www.stle.org.

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PROFILE

BIOME RENEWABLES

# TAKING A CUE FROM NATURE

A large white wind turbine stands prominently in a lush green field under a clear blue sky. The turbine's three blades are spread out, and its tall tower reaches towards the top of the frame. The background shows rolling green hills, suggesting a rural or agricultural setting.

## **BIOME RENEWABLES**

**FOUNDED**  
2015

**HEADQUARTERS**  
Toronto, Ontario

**WEBSITE**  
[www.biome-renewables.com](http://www.biome-renewables.com)

Representation of the PowerCone.  
(Courtesy: Biome Renewables)

# *Biome Renewables is developing innovative technology to increase the efficiency of wind turbines by harnessing millions of years of R&D conducted by nature.*

By **KENNETH CARTER** ▶ Wind Systems editor

**W**hen it comes to the annual energy production (AEP) for a wind turbine, the industry says that gains of more than 1 to 2 percent aren't possible. And that's been the assumption for many years.

But the minds behind Biome Renewables say they have the means to increase that AEP by 10 to 13 percent with the company's innovative PowerCone technology.

"We're redefining the expectation for wind because that expectation, for a very, very long time, has been getting 1 to 2 percent more AEP; it's been that way for decades now," said Ryan Church, founder, CEO, and CTO of Biome Renewables. "So, for someone to come along and say, 'I can do 10,' that's such a meaningful shift, and a lot of people are skeptical and rightly so. Because, every expectation is that 1 to 2 percent is the only thing that's possible. And it's really because no one is seeing and effectively tackling the biggest problem in wind."

That problem, according to Church, is at the center the turbine.

"It's really at the center where you can make the biggest impact," he said. "It's non-intuitive, but on a physics basis, it actually makes sense. I decided that's where the innovations would start."

## **LOOKING TO NATURE**

Biome's central tenant is to look to nature for solutions to industrial challenges, and a serendipitous moment while watching a falling maple seed ended up being the virtual seed behind Church's invention: the PowerCone.

"We have a family cabin up in BC, and there's a maple tree next to the deck, and I saw a maple seed fall onto the deck," Church said. "I'd seen maple seeds fall many times before that, of course, but for whatever reason, this time around it just seemed to be falling slower than I thought it should be."

The aerodynamics of the maple seed caught Church's attention.

"I ran a quick thought experiment in my mind, trying to ascertain what might be happening there aerodynamically," he said. "I looked into it a bit and realized that's a very efficient structure, and I actually went back to the problem of root leakage, which is an area of low pressure around the hub, and thought for a second: well, hang on, we can sort of use the principles of what the maple seed is doing and apply that to a PowerCone-like structure for the turbine."

With that inspiration, Church built a crude wind tunnel in his living room to test various turbine configurations with structures made from plasticine and modeling clay and soon enough, sculpted a design that made meaningful gains.

"That was the first time that I realized that, hey, I might actually have something here, even at that crude level," he

said. "More research followed in the same kind of vein, and I filed a provisional patent."

Knowing that he always wanted to start his own venture, Church understood that this was his opportunity, and seized the moment with this new biomimetic design.

Once the patent was filed, came investments, incorporation and a first wind-tunnel test at TU Delft, according to Church.

## **POSITIVE FEEDBACK**

The initial response to the PowerCone technology has been positive and encouraging, Church said, and that's due to the statistical gains in performance that show up with the PowerCone.

"We want to see PowerCones on as many turbines globally as possible," he said. "We want to help customers achieve the lowest cost of energy that they can, which may not be happening today, just due to maintenance issues and the fact that turbines are not operating as they should. That goes to the fact that, it's not just power production, but it's lifetime asset management. We're giving the customer more power, but we're also helping them on the loads front."

"When you improve the aerodynamics, you also improve the loads," he said. "They go a little bit hand-in-hand. Understanding the design-driving loads behind turbine design is very important to us, so we've learned a lot about that, leveraging partners like DNV."

When the aerodynamics of a structure are improved, that means less drag, less flow separation, and less turbulence, according to Church.

Even though Biome launched in 2015, the technology that helped birth the company is definitely on the fast track, Church said.

"We have been getting multiple validation points of the technology working in different environments and at different scales," he said. "Engineering a product of this scale is no simple feat. I mean, it has to be one of the largest R&D projects happening in wind in the last five or 10 years. It's a huge undertaking that normally no private company outside of an OEM attempts. At least, I haven't seen one. So, it's an exciting thing to do to be blazing a trail of innovation and to be doing things that no one else has done before."

Biome has received a number of awards, most recently named as one of the world's top 100 clean-tech innovators from the World Energy Council.

## **IT'S ALL ABOUT PHYSICS**

To put it matter-of-factly, the industry would love to see a boost in AEP and wants it to happen, according to Church.

"We are excited about the customer reaction and industry reaction, and it makes us keep going and keep pushing."



Manufacturing the PowerCone at CCI, showing structural layering of the fiber sheets. (Courtesy: Biome Renewables)

he said. “The PowerCone does that on its own. It’s making a claim that has not been made before. It’s solving a problem that has not been solved before. From early research we really found that the wind industry was playing at the edges. Whereas, we’re coming in and seeing the problem and solving it.”

That speaks volumes as to how Biome approached this challenge, according to Church.

“At Biome, at least on the R&D and engineering side, we actually strip it back to the math and physics first,” he said. “You use the physics-first principle of looking at this problem. And it started with Betz’s law — that’s a hundred-year-old theory, which started with a number of assumptions,

some of which are no longer true. We peeled that back, and we looked at the physics that are actually happening, and we looked at how turbines have been designed today, and there’s a gap. And that gap is filled through innovation.”

That’s the thrust of what Biome does; the company relies heavily on design, engineering, and innovation.

### BIOMIMICRY: THE CORE OF DESIGN

“Biomimicry helps us innovate in ways that other companies just can’t or don’t,” he said. “It’s the multiple iteration loops that we go through — from talking to customers on the one hand and co-creating something with them, asking them what their problems are, and then on the other hand, we are looking at the math and the physics of it. And we’re pulling at it from multiple angles. And then nature comes in with the biomimicry piece, because nature is very good at solving problems.”

To that end, that’s what makes the wind industry and Biome such a good fit, according to Church.

“This is what the wind industry is; it’s fluid dynamics at the end of the day,” he said. “So, when you look at nature and fluids to get a sense of how nature would solve that problem, you start off with what is a near maximally efficient solution. That has to be changed and adapted, of course, to fit engineering requirements and different situations, but you’re starting off so much farther ahead than any company in the innovation chain, because you’re looking to nature pretty early on for clues of how to solve this huge problem. That is no easy feat, so the complexity keeps most other companies away. I think we’re unique globally, in that everything we design is biomimetic — even our corporate structure and business model is influenced by natural processes.”

### GROWING WITH THE INDUSTRY

With the wind industry growing by leaps and bounds, Church expects the PowerCone to help the industry grow even more than expectations.

“OEMs are making engineering leaps to make larger and larger blades and larger and larger towers for generators, but they’re not taking enough time and turbines are growing too quickly,” he said. “When that happens, down the line you end up with O&M issues.”

The PowerCone can help the industry grow in a more sustainable fashion, according to Church.

“You’ll be able to get the sort of normalized cost in energy drops that the industry is looking for without having to make a longer and longer blade,” he said. “Blade length determines just about everything. It kind of ripples through the whole engineering process of how you’d think about designing and building a turbine. All the different loads and all the characteristics of all the components, it all has a cascading effect. So, I think we can help the wind industry. We can help it grow obviously, but we can help it grow in a more sustainable way, and in a way that drops the levelized cost of energy both onshore and offshore. Both markets benefit from that.”

**PowerCone™**

**More Power**  
10-13% increased AEP

**Less Noise**  
Helps your turbine reach rated power sooner, reducing both blade pitch angle and sound output.

**Reduced Loads**  
Smooths incoming gusts and aligns the airflow with the turbine blades. Reduces turbulence, vibration, and the associated loads.

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Primary benefits and massive gains of the PowerCone. (Courtesy: Biome Renewables)

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## Brian Hill

General manager for North America ▸ Bachmann electronic

*“As technology has advanced, we’ve advanced with it, and our customers are the ones that benefit from that.”*

### ▸ What’s a typical day like for you at Bachmann?

We’ve got a lot of projects going, so our technical folks are working on those busily, and I’m also managing our sales and other efforts. I try to keep tabs on all the activities that they do and the progress on the projects while keeping tabs on our salesmen and on their pipeline of projects that are coming.

### ▸ How does Bachmann modernize and extend a wind turbine’s life?

We have a long history in the wind space and a lot of experience working with different OEMs. With that experience, we’ve put together a template on how to operate a wind turbine based on IEC standards. We can completely retrofit the entire controls of a wind turbine and replace the hardware and software that runs it, or we can do a subset of that, which could be just the data system – condition monitoring equipment that either is stand alone or integrated with our controls. Then we can help owner-operators with special projects on data that they’re required to get by the grid operators or their management – having the keys to the data stream, which is basically what the control system is. We can help customize what the customer sees and the information they get. We can help them gain access for that data. That’s probably one of our biggest attributes or maybe even advantages over the others out there is being able to provide access to more data.

### ▸ How do solutions offered by Bachmann create those economic opportunities for your customers?

Each piece has different functions, and the condition monitoring system can help a customer get away from time-based maintenance to knowing exactly what’s going on with their equipment – when things need to be fixed and replaced. It allows them to plan ahead for crane call outs and even avoid crane call outs when it’s possible. That’s one aspect.

The other is with our control software and SCADA. Again, we can help provide more information than they’re likely

getting now or possibly will be in the future with some OEMs. There’s sometimes a conflict of interest between the OEMs and the owner-operators where the owner-operator wants more information and the OEM wants to provide less. With the access we can provide, it allows the owner-operator to be able to even microsite turbine by turbine. It can allow them to make adjustments that they wouldn’t normally be able to do with the OEM solutions.

### ▸ How has the changing face of technology helped Bachmann within the wind industry?

It is a rapidly changing business, and there’s downward pressure to pricing. We’ve been able to utilize the highest tech solutions and technology and still keep our pricing and our piece of the overall turbine fairly constant. An example of that is where we recently were talking to a customer that was looking to extend the life of their older turbines. The turbines weren’t worth a huge amount of money just because of their age, but it had a high PPA, and that PPA required that they couldn’t make significant changes in the turbine. They couldn’t repower by changing out the whole nacelle, extending the blade length, and some other things that you hear about with customers utilizing the PTC, due to constraints written into the PPA. They basically had to kind of stay within certain constraints and not do a whole lot with major components of the turbines in order to maintain that PPA.

This turbine is no longer being manufactured, but the folks are still around that made it, and their solution is 1980s technology with open circuit boards. We were able to do that with a very sophisticated control system for virtually the same price.

On top of that, there are just the years of development and experience that we’ve gained after working with all these different manufacturers, providing solutions on the OEM side. When there’s an improvement for one, the other manufacturers gain from that improvement when we perfect something and help find a solution. We’re going to offer



Bachmann has a long history in the wind space and a lot of experience working with different OEMs. (Courtesy: Bachmann electronic)

that and likely make it a standard offering going forward. Our hardware and software have developed and improved over the years. As technology has advanced, we've advanced with it, and our customers are the ones that benefit from that.

► **Your customer base ranges from the big companies to the smaller operator. Are there similarities as to how you approach that range of clientele?**

The smaller operators are the ones without as much resources as some big operators that can do their own programming and have teams of engineers to be able to take our open solutions and customize it to their needs. We often deal with customers that have only a few turbines, and they certainly don't have an engineering team. For instance, we have a customer that has 14 turbines, and they need a lot of support. What we try to do with our standard offering is have it be user friendly, and if they have the capability of customizing it if they need to, they can go ahead and do that with their engineering teams. But if they don't and they require something, we can customize it for them.

► **What are some of the ways Bachmann approaches wind-energy challenges now that were not possible 10 years ago?**

Well, 10 years ago, there were a lot of turbines coming into the market, and some of those OEMs have disappeared. There has been a lot of requirements put on by the grid operators that weren't there 10 years ago, and so there's been a need for things to improve. When these turbines were sold about 10 years ago, I was a developer and buying wind turbines. When we were having those conversations, we were talking about these turbines lasting 25-30 years and didn't assume that there would be a need for control changes. We knew there were certain maintenance things that would be done, but those people didn't foresee some of

the things that have come to pass in the industry.

With the PTC that is soon expiring, that gave a number of the owner-operators an opportunity to reinvest in those older assets and either spend big dollars on repowering, if that was a possibility, or they got a smaller upgrade, but they got that government money. I don't think you can count on that in the future. There's talk about extending the PTC, but there's certainly no guarantees, and those needs are still out there for a whole lot of turbines. So, we're trying to position ourselves to be a resource for those that weren't part of those repowerings and other major things. There was only so much bandwidth that even the big repowering OEMs had. There are only so many turbines that they could do, and that leaves a whole lot left after the PTC goes away. We're positioning ourselves to be a resource across the automation spectrum of the wind industry.

► **Where do you see wind in the next 10-20 years and Bachmann's place in that future?**

I fully believe that we'll have an active place in it with multiple OEMs as we do now and as we continue to add on. It may look different; there's been consolidation and that could likely continue. There are a couple of turbine manufacturers that are struggling, and we actually happen to be a provider to some of those companies now, and we're hoping that if they get consolidated or bought by someone else, that company will see the advantages of us continuing to be a provider.

But we're continuing to grow, and a huge amount of our overall turnover goes to R&D – a lot bigger than most companies. With that being the case, we're planning to grow and fill the needs for new turbines being built as well as the older fleets are out there that want to keep running for 30 years. ↵

**MORE INFO** ► [www.bachmann.info](http://www.bachmann.info)



The RUTE system is stronger than standard concrete, so wind farms can upgrade to larger towers without additional costs. (Courtesy: RUTE Foundations)

## CONSTRUCTION

### New foundation wins construction industry award

An Oregon cleantech company that developed a new concrete-saving, CO<sub>2</sub>-reducing foundation system for wind-turbine towers has been awarded the 2019 Merit Award from the Post-Tensioning Institute (PTI), based on the first installation of the foundation technology.

The industry-first modular wind-turbine tower base, developed by RUTE Foundation Systems with early support from climate impact accelerator VertueLab, cuts the amount of concrete needed by 75 percent over the life cycle of a wind farm. Because concrete contains cement, a material that generates large amounts of CO<sub>2</sub> during production, the RUTE system

also reduces CO<sub>2</sub> emissions.

“Using our precast, segmental foundation at a single 60-tower wind farm would keep about 65 million pounds of CO<sub>2</sub> out of the atmosphere,” said Doug Krause, CEO of RUTE Foundations. “This CO<sub>2</sub> reduction is realized through lower concrete usage, a much longer lifecycle of our precast components and the fact new wind farms can come on line a month earlier because our foundations don’t have to cure.”

Traditional poured-in-place foundations require concrete footings that are 60 feet in diameter, weigh almost 2 million pounds and use 40 truckloads of concrete, or approximately 400 cubic yards. Curing that amount of concrete takes weeks before towers can be installed, and the life of the structure is less than half that of the RUTE foundation, which can last 60 years.

The precast, modular components in the RUTE system are made in beam manufacturing plants and use post-tensioning technology (a method

of strengthening concrete with high-strength steel strands common in bridge construction).

The RUTE technology is entering the marketplace just as the wind farm industry is upgrading from 1.5-MW turbines to 3.5-plus-MW turbines, which require taller towers. The RUTE system is stronger than standard concrete, so wind farms can upgrade to larger towers without additional costs.

“The PTI recognition is huge for us,” said Jeff Colwill, RUTE’s vice president of Operations, who accepted the award at the annual Post-Tensioning Institute convention in Seattle. “Because RUTE can also manufacture the foundations locally, near the wind farms, our technology will also help create local jobs.”

The first RUTE 30BX Foundation was installed at Palmers Creek Wind Farm in Granite Falls, Minnesota, last November and supports a GE 2.5 MW turbine on a 295-foot (90 meter) tower hub height. RUTE partnered on the project with a team of engineering

and construction firms, including Structural Technologies/VSL, RUTE's post-tensioning partner based in Maryland.

**MORE INFO** [rutefoundations.com](http://rutefoundations.com)

## CONSTRUCTION

### RES starts construction on Kansas project

RES (Renewable Energy Systems), the world's largest independent renewable energy company, recently announced construction on Southern Power's 200 MW Reading Wind Facility in Osage and Lyon counties, Kansas. Once complete in 2020, the 200 MW project will generate roughly 760,000 megawatt hours of clean energy per year.

Southern Power, which announced it acquired the project from RES in October 2018, will operate and maintain the facility upon completion in the second quarter of 2020. The project consists of 62 Siemens Gamesa wind turbines, and the energy output will be sold to Royal Caribbean Cruises Ltd. under a 12-year PPA.

The Reading Wind project will generate significant benefits to the community, including creating about 125 full-time jobs during peak construction and up to eight permanent jobs once operational. During construction and operation, both Osage and Lyons counties will benefit from increased local spending on goods and services.

"This project will mark RES' first project in our joint development agreement with Southern Power, which has been a tremendous partner in bringing renewable energy to communities across the country," says Rick Ortiz, VP of Wind Construction. "We are excited to bring significant benefits to the local communities of Osage and Lyon counties."

**MORE INFO** [www.res-group.com](http://www.res-group.com)

## MANUFACTURING

### Siemens Gamesa secures two orders in the U.S.

Siemens Gamesa Renewable Energy was selected by EDF Renewables North America to supply turbines for the Coyote and Oso Grande projects in the United States. The deals further confirm the commercial success of the SG 4.5-145 and feature a service and maintenance agreement for Siemens Gamesa's premium maintenance program, offering the best in scale and flexibility to maximize energy asset returns.

Coyote, located in Scurry County, Texas, will feature 48 SG 4.5-145 and 11 SWT-2.3-108 wind turbines. Project completion is expected for the summer of 2020.

The Oso Grande wind project will also use 48 SG 4.5-145 and 13 SWT-2.3-108 wind turbines, and is in New Mexico, about 43 miles southeast of Roswell. The commissioning of the wind farm is scheduled for the last quarter of 2020.

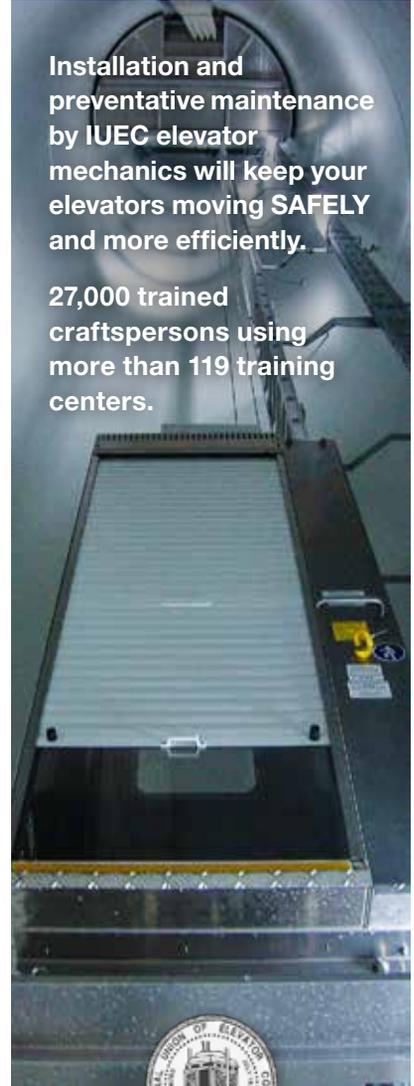
The SG 4.5-145 offers a flexible power rating from 4.2 MW to 4.8 MW depending on site conditions and has a rotor diameter of 145 meters. The 71-meter blade integrates aerodynamics and noise reduction features — including Siemens Gamesa DinoTails® Next Generation technology — to guarantee a high production of energy and reduced noise emission levels. This turbine model is optimized for medium wind onshore locations to maximize energy production.

"We are extremely proud to partner with EDF Renewables North America on these important orders for the SG 4.5-145 wind turbines in the U.S.," said José Antonio Miranda, CEO of Onshore Americas at Siemens Gamesa Renewable Energy. "This new generation turbine offers best-in-class LCOE based on proven technology and evidences our commitment to continued innovation."

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Siemens Gamesa has provided turbines with an output capacity of more than 19 GW in the U.S. and has a strong U.S. footprint consisting of manufacturing, service, and offices. (Courtesy: Siemens Gamesa)

“The evolution of our partnership with Siemens Gamesa to include this new technology is a significant milestone for both companies as it contributes to our long-standing efforts to reduce LCOE,” said Art Del Rio, vice president, Wind Technology Strategy at EDF Renewables. “This new SG 4.5-145 turbine is the ideal fit for the Coyote and Oso Grande projects, helping EDF Renewables achieve the value necessary to build a competitive project.”

**MORE INFO** [www.siemensgamesa.com](http://www.siemensgamesa.com)

## MANUFACTURING

### Vestas secures order for 420 MW in the U.S.

Vestas has received an order for 420 MW of V120-2.2 MW turbines for a project in the U.S.

The order includes supply and commissioning of the turbines.

Deliveries are expected in the second quarter of 2020, with commissioning expected in the fourth quarter of 2020.

The project and customer are undisclosed at the customer’s request.

**MORE INFO** [www.vestas.com](http://www.vestas.com)

## MANUFACTURING

### Siemens Gamesa gets order for 43 turbines in Canada

Siemens Gamesa Renewable Energy recently announced it has signed a contract to supply and commission 43 SG 4.5-145 wind turbines, with flexible rating up to 4.8 MW, for a wind project in Canada with an undisclosed customer. The order is for a nominal

capacity of 194 MW.

The SG 4.5-145 will be the most powerful turbine with the largest rotor size to date in Canada. The 71-meter blade integrates aerodynamics and noise reduction features — including Siemens Gamesa DinoTails® Next Generation technology — to guarantee a high production of energy and reduced noise emission levels.

“We’re proud that our partners chose Siemens Gamesa and our SG 4.5-145 turbine for this project,” said David Hickey, head of the Siemens Gamesa business in Canada. “The new SG 4.5-145 turbine will provide extremely cost competitive and clean energy to the consumers and communities of Canada.”

With more than 3,000 MW installed in Canada, Siemens Gamesa Renewable Energy is the market leader by cumulative installed capacity. The team of employees provides technical expertise, service, products, and ongoing support to all of its customers. Canada is eighth in the world for total onshore installed wind capacity with 12.8 GW as of December 2018, with a 20 percent annual growth rate for the last 10 years.

**MORE INFO** [www.siemensgamesa.com](http://www.siemensgamesa.com)



With more than 3,000 MW installed in Canada, Siemens Gamesa Renewable Energy is the market leader by cumulative installed capacity. (Courtesy: Siemens Gamesa)

## MANUFACTURING

# Siemens Gamesa gets investment grade rating

Siemens Gamesa Renewable Energy (SGRE) has become the first wind turbine manufacturer to attain an investment grade rating. The company obtained a BBB-long-term credit rating, with positive outlook, from Standard & Poor's (S&P), and a Baa3 outlook stable rating from Moody's. Siemens Gamesa has debuted in the public rating arena within investment grade.

S&P highlighted Siemens Gamesa's leading position in the competitive and consolidating onshore and offshore wind markets with an improved scale, installed base and technology, which should help the group to increase market share and lead market consolidation. The rating agency also underlined the company's conservative financial management and transparent financial policy, with a strong balance sheet, which enable it to preserve strong credit metrics and liquidity.

Moody's also said the rating is primarily supported by Siemens Gamesa's leading market position, its high revenue visibility, as evidenced in the order book, its technological edge over its competitors, as well as the related and growing service activities, good regional diversification and moderate financial leverage.

**MORE INFO:** [www.siemensgamesa.com](http://www.siemensgamesa.com)

## INNOVATION

# Emerson, Vayu to optimize wind farms with machine learning

Emerson has formed an alliance with Vayu, a Ystrategies Corp. company, to provide automation technology solutions for wind-farm energy optimization in the Americas, Caribbean, and

Europe. The three-year collaboration combines the advanced power applications and networking capabilities of Emerson's Ovation™ automation platform with Vayu's cloud-computing wind-energy optimization technology. Using this approach, Vayu has identified more than \$500 million in revenue opportunities from just a fraction of the approximately 450 wind farms in the United States.

"Combining the respective strengths of Emerson and Vayu creates a first-of-its-kind, intelligent solution for wind-farm optimization," said Bob Yeager, president of Emerson's power and water business. "This initiative will help wind-energy producers maximize their aggregate power output, achieve their financial objectives, and deliver more clean power to their communities."

The wind-power market continues to grow: 53.9 GW were added in 2018, bringing the overall capacity of all wind turbines installed worldwide

to 600 GW, according to the World Wind Energy Association. The United States — the second-largest wind power market — added 7.6 GW of capacity last year.

**MORE INFO** [emerson.com](http://emerson.com)

## INNOVATION

# Vaisala fortifies comprehensive wind-industry product range

Vaisala, a global leader in weather, environmental, and industrial measurements, recently introduced Leosphere's industry-leading Lidar (Light Detection and Ranging) technology into its portfolio of offerings in North American markets, broadening Vaisala's extensive range of weather and environmental measurement solutions. With the Leosphere acquisition,



## Wind Turbine Services Company

Airway Services is an international full-service provider of on-demand technical staffing, project management and operations, and maintenance for utility-scale wind energy projects. Our team of knowledgeable and experienced technicians are committed to providing the highest standard of service to the growing wind industry. Airway Services is proficient in delivering complete service and expert solutions to a wide array of issues unique to wind energy projects.

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- Troubleshooting
- Operational technician support
- Blade repairs
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Airway Services is now an ISO 9001:2015 registered company through QAS International.

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[www.airwayservicesinc.com](http://www.airwayservicesinc.com)

Vaisala now provides end-to-end sales and support services for the Windcube portfolio of Lidar systems to customers in the U.S. and the rest of the world.

“According to the American Wind Energy Association, a record number of wind farms were under construction in the U.S. in 2018. Vaisala can now provide this burgeoning industry with the most complete suite of environmental sensing devices available,” said Matt Jones, vice president, Weather and Environment Americas, Vaisala.

Lidar is a remote sensing method that leverages pulsed laser to measure wind to the height required by modern wind turbines — a key capability of the Windcube Lidars now available through Vaisala. Leosphere Lidars offer a wide range of solutions to track wind speed and direction required for new wind farm planning and construction. To date, there are more than 1,400 Leosphere Lidars installed worldwide.

By redefining the use of Lidar within the renewable energy space, the Leosphere Windcube suite of systems is discreet, mobile, and capable of remotely reaching greater heights to aggregate superior data for wind prospecting. The Windcube systems empower owners to increase efficiency in long-term wind-energy production by enabling the potential for full rotor sweep measurement.

Vaisala offers four distinct Leosphere Windcube Lidar systems:

► **Windcube Vertical Profiler:** An ultra-portable Lidar providing accurate wind measurements up to 200 meters, validated onshore and offshore by international standards and guidelines.

► **Windcube Scanning Wind Doppler Lidar:** Offers wind measurement up to 10 kilometers as well as multiple scanning patterns. Used for leading edge applications in wind energy, meteorology, severe weather research, vortex measurements, and real-time wind shear detection at airports.

► **Wind Iris:** Mounted on wind turbine nacelles for power performance data to measure and optimize wind turbine performance.

► **Wind Iris TC (Turbine Control):**



The drive for vessel-performance transparency comes in response to rising demand from offshore wind project owners for CTV operational and performance data. (Courtesy: Reygar)

Integrated in wind turbines on and offshore. Provides real-time characterization of wind, enabling turbine manufacturers to improve wind turbine design and efficiency.

**MORE INFO** [www.vaisala.com](http://www.vaisala.com)

## ► MAINTENANCE

### CTV operators driving transparent approach to offshore operations

Leading CTV operators are driving for more transparency around vessel performance as the market seeks to “level the playing field” in offshore wind support. While historically project owners have led demands for greater transparency around operational and performance data, a number of CTV vessel operators have identified a clear market opportunity in being ahead of the curve.

That is, at least, according to Reygar, a leading provider of innovative remote monitoring and reporting platforms to the marine industry, whose BareFLEET system continues to be rolled out by many offshore wind CTV operators.

The drive for transparency has been a long time in the making, coming in response to rising demand from

offshore wind project owners for CTV operational and performance data. This data, which includes motion, engine performance, weather conditions, and fuel consumption, has a strong influence on procurement decisions as owners look to increase “time on turbine” for their technicians, as well as the overall safety and cost-efficiency of their projects.

To date however, supplying this data has been seen as a “check-box” requirement. Initiatives such as “p-plot,” supported by wind-farm owners, have provided a strong model for increasing clarity by looking to formulate a standard to measure the relative operational performance of CTVs in different sea states.

However, this top-down approach to shared data has received a mixed reception from vessel operators, given the perceived commercial risk of opening their data to the market and the cost of gathering and processing the necessary operational data.

In contrast, leading operators including Seacat Services, CWind, Tidal Transit, High Speed Transfers, and Maritime Craft Services have found that taking data monitoring into their own hands through the installation of the BareFLEET system is an opportunity for commercial development, rather than a hurdle.

**MORE INFO** [www.reygar.co.uk](http://www.reygar.co.uk)

## MAINTENANCE

### PSI surpasses 40,000 repaired parts milestone

PSI Repair Services, Inc., a subsidiary of Phillips Service Industries and leading independent service provider (ISP) to the wind-energy industry, recently announced it surpassed 40,000 repaired wind turbine parts for the wind-energy market, following a busy 2018.

PSI offers component repair and engineering services for GE, Vestas, Gamesa, Siemens, RePower, Acciona, Suzlon, Nordex, Mitsubishi, and Clipper wind turbines. PSI covers the critical electronic, hydraulic, and precision mechanical components that drive the turbines' pitch and yaw systems and down-tower electronics. Commonly repaired components include printed circuit boards, pitch drive systems, inverters, IGBTs, PLCs, VRCC units, AEBIs, proportional valves, hydraulic pumps, pitch and yaw motors, encoders, slip rings, transducers, yaw modules, 3-phase bridge rectifiers, blade bearing automatic grease dispensers, active crowbars, line reactors, oil level sensors, battery chargers, cold climate converters, anemometers, and more.

PSI's engineering services include custom tests, root cause analysis, product upgrades, remanufacturing, and new product manufacturing services. The custom test program uses advanced diagnostic equipment, allowing PSI to detect hard part failures, as well as parts degraded due to stress, down to the microchip level.

The root-cause analysis service allows PSI to get a comprehensive view into a customer's production environment to identify all the elements connected to recurring problems so the appropriate corrective actions eliminate the problem. The product upgrade service allows PSI to improve upon legacy design with newer, more reliable technology.

**MORE INFO** [www.psi-repair.com](http://www.psi-repair.com)

## MAINTENANCE

### EdgeData welcomes new director of operations

EdgeData, LLC recently added Lorie Hines as director of operations. In this role, Hines will manage operations of BladeEdge, EdgeData's artificial intelligence (AI)-driven image analysis engine for the wind industry.

"Lorie brings valuable insight and experience to the BladeEdge team during a time of rapid growth," said Chris Shroyer, president and co-founder of EdgeData. "She possesses a combination of technical knowledge and project management expertise that will enable BladeEdge's capacity for growth. We're delighted to add her capabilities to our leadership team."



Lorie Hines  
(Courtesy: BladeEdge)

As director of operations, Hines will draw on her experience in technology, risk management, and problem solving to oversee the technical architecture that supports all BladeEdge applications. BladeEdge is powered by EDDIE, the company's AI analytics engine designed specifically for the wind industry. EDDIE enables automated condition assessment of blade inspection images, data analytic processing, and report generation.

The BladeEdge application suite includes the BladeEdge Controller Application (BE-APPSM), the BladeEdge Capture Assurance Tool (BE-CATSM), BladeEdge Analytics, and the BladeEdge User Dashboard. Together, these applications streamline wind-farm management, from data capture to data management, and ultimately artificial intelligence and analytics.

Hines also will manage the BladeEdge application development team to ensure the regular and timely

release and integration of innovative operations solutions.

**MORE INFO** [bladeedge.net](http://bladeedge.net)

## MAINTENANCE

### Pure Safety Group introduces Checkmate Tr3 Tripod

Pure Safety Group (PSG), the largest company dedicated solely to fall protection, has introduced the Checkmate TR3 Tripod, used as Personal Protective Equipment to access workers and provide fall protection in confined space environments.

The tripod features an innovative new crown and foot design that makes it stronger yet more lightweight than other tripods. The design is representative of the new advancements in height safety that are being created by the innovation team at Checkmate.

The TR3 is one of 20 new fall protection products PSG is launching in 2019 into the construction, oil and gas, energy, utilities, telecom, mining, and transportation industries. It is the first Checkmate product to be launched in North America. Checkmate is a U.K.-based company that was acquired by PSG in 2018. Checkmate products are made of superior materials and designed for companies who want the latest high-performance products for their workers at height.

The TR3 tripod legs lock in the open position automatically during use, easily disengage for folding, and are adjusted for proper height with captive pins. Detent pins secure them to the tripod using PVC-coated keeper wires.

The tripod's pivoting spiked feet and rubber soles allow for its use on soft or hard surfaces. Its anti-splay webbing, which prevents the tripod legs from splaying under a load, can be neatly tucked into its own housing slot for storage. ↵

**MORE INFO** [www.checkmateuk.com](http://www.checkmateuk.com)



CROSSWINDS

THE FUTURE OF WIND

# TECHNOLOGIES TRANSFORMING WIND

By using autonomous drones for visual inspections, wind-farm operators are able to complete turbine inspections in as little as 15 minutes. (Courtesy: Clobotics)

*There are five emerging innovations, many of which are already being deployed successfully, that have the potential to solve some of the complex problems facing the wind-energy sector.*

By **GEORGE CHRISTOPHER YAN**

**W**ind power is on the rise. In the U.S. alone, the wind industry invested more than \$11 billion in new power plants in 2017 and added more than 7,000 MW of new capacity, representing a full 25 percent of all electric capacity additions across the broader energy industry. In April, the U.S. Department of Energy announced \$28.1 million in funding aimed at advancing wind energy nationwide across the land-based, offshore, and distributed wind sectors. However, as with other renewable energies, the wind-power industry faces many obstacles. One of the biggest challenges to growth remains the high costs of constructing wind farms, as well as the ongoing operations and maintenance costs. The industry also still relies heavily on government subsidies and federal tax incentives, which can be unreliable and phased out, depending on whichever way the ‘winds’ of the current political climate are blowing.

While utility-scale wind energy in the United States has grown to 90 GW, significant opportunities for cost reductions remain, especially in the areas of offshore wind, distributed wind, and tall wind. To further its growth, reduce costs and increase profitability, the wind-power industry needs to turn to emerging technologies, including the Internet of Things (IoT), autonomous drones, earth-modeling technologies, and 3D printing. Research, development, and demonstration of innovative wind technologies have the potential to drive down costs and expand the success seen in the land-based, utility-scale wind sector to the emerging distributed wind and offshore wind sectors.

Here’s a look at five key emerging wind-power technologies, the complex problems they solve, and the impact they will have in the coming years.

## **EARTH MODELING TECHNOLOGIES FOR SITE IDENTIFICATION**

The process of identifying the optimum location to build a wind farm is known as siting. Increasingly, energy companies are turning to technology to improve siting decision making.

The most common approach uses artificial intelligence together with satellite remote sensing, global positioning systems, and open source geographic information systems to analyze a wide variety of data to determine the best locations to not only build farms, but also where, precisely, they

should place each turbine. Another approach involves using Big Data simulations to model the Earth to allow wind-power companies to divide the surface down to 30-by-30-kilometer high-resolution grids and estimate the amount of wind power generated in each individual square.

Through sophisticated computer modeling techniques, wind farms can estimate the return on investment (ROI) for each location or turbine, helping them determine potential profitability and make smarter investments.

## **IoT IN THE MANUFACTURING PROCESS**

Even before wind farms are built or turbines are installed, IoT technologies, advanced data analysis, and AI are being applied throughout every step of the supply chain in the tur-



Some wind farms are using the data collected from their systems to predict when faults will occur and schedule maintenance before it’s needed. (Courtesy: Clobotics)

bine manufacturing process. Today, more than 80 percent of nacelle assembly and tower manufacturing for turbines installed in the U.S. occurs domestically.

Using RFID tags and IoT sensors affixed to components, turbine manufacturers track and trace each part as it works its way through the supply chain, assuring provenance of components, identifying delays or bottlenecks in manufacturing, even monitoring the condition of components at each point in the chain of custody. Data from IoT sensors on the manufacturing machines themselves enable predictive maintenance so manufacturers can repair machines before they develop problems that could shut down the production line and cause costly delays.

With these types of IoT technologies and data analysis enabling greater automation and increased efficiency in the manufacturing processes, domestic wind-turbine manufac-

▼ By using autonomous drones for visual inspections, wind-farm operators are able to complete turbine inspections in as little as 15 minutes. ▼



Large-scale 3D printing technology is being used by companies to develop complex projects for the energy industry, including wind turbines. (Courtesy: Clobotics)

turers have been able to dramatically increase productivity in recent years.

### 3D PRINTING

Innovation in the design and manufacturing of wind-power generation components continues to be critical to achieving our national renewable energy goals. Large-scale 3D printing technology is being used more and more by companies to develop complex projects for the energy industry, including big structures such as solar panels or vertical wind turbines.

The U.S. Department of Energy (DOE), for example, has started exploring 3D printing for blade molds, partnering with public and private organizations to apply additive manufacturing to the production of wind-turbine blade molds, which could help save significant time and money during the blade molding and manufacturing process.

The traditional method of blade design requires the cre-

ation of a plug, or a full-size representation of the final blade, which is then used to make the mold. Creating the plug is one of the most time-intensive and labor-intensive processes in wind-blade construction, so 3D printing can save these critical resources.

### AUTONOMOUS DRONES FOR TURBINE INSPECTION

Though many turbines today are equipped with a variety of IoT sensors measuring vibrations, sounds, and more, wind-farm operators still need greater – and earlier – visibility into the condition of blades. Emerging technologies such as autonomous drones equipped with artificial intelligence (AI), machine learning (ML), and advanced computer vision are making a dramatic impact.

Traditionally, visual inspections required shutting down a turbine and sending one or more highly trained technicians up the tower, on ropes, to inspect the blades. A typical

# AD INDEX

Abaris Training Resources .....	7
Airway Services .....	33
American Chemical Technologies .....	3
American Gear Manufacturers Assn (AGMA) .....	5
AWEA (American Wind Energy Assn) .....	IBC
Bachmann Electronic Corporation .....	1
Elevator Industry Work Preservation Fund .....	31
NTC Wind Energy .....	7
Stahlwille Tools LLC .....	39
Thermal Cam USA .....	39
The Timken Company .....	BC
TORKWORX LP .....	IFC
Wanzek Construction .....	11
<i>Wind Systems</i> .....	23,27,40

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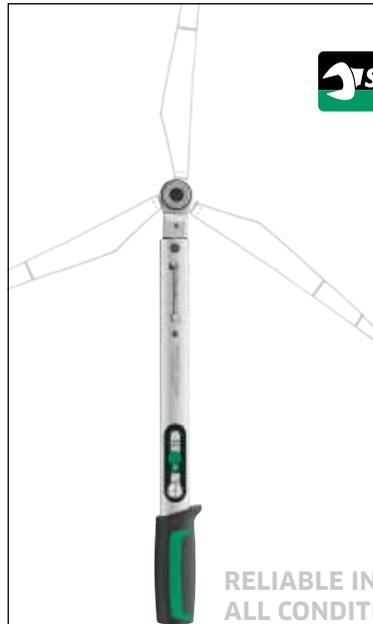
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inspection could take six to eight hours per turbine. By using autonomous drones for visual inspections, wind-farm operators are able to complete turbine inspections in as little as 15 minutes. Furthermore, by leveraging AI and ML, these autonomous drone solutions are able to analyze huge volumes of data in the cloud, almost instantaneously, and deliver real-time insights to help wind farms identify trends and make decisions to improve operational performance.

Using autonomous drones for visual inspections has demonstrated promise such that analysts estimate the market to grow at a compound annual growth rate (CAGR) of 12.93 percent during the period of 2017 to 2021 as more and more farms adopt this technology.

### DATA ANALYTICS FOR PREDICTIVE MAINTENANCE

In addition to using data analytics to identify necessary repairs and existing blade damage on turbines, some wind farms are using the data collected from their systems to predict when faults will occur and schedule maintenance before it's needed. The longer a wind farm waits to fix a problem, the costlier it becomes as turbines need to be powered-down and are not producing electricity.

An article in *Composites World* reported that an out-of-service turbine can cost \$800 to \$1,600 per day, with most repairs taking one to three days. If a crane is required to

repair or replace a blade, the cost can run up to \$350,000 per week. An average blade repair can cost up to \$30,000. A new blade costs, on average, about \$200,000.

With the real-time data from visual inspections and turbine sensors, wind-farm operators are able to understand the growth rate of defects and determine if component failure is imminent. Predictive and preventative maintenance allows operators to save time and money by scheduling maintenance in advance, with the ability to schedule repairs for times of year when the weather conditions are best.

As new digital technologies continue to proliferate, we are beginning to see the many ways they can be used to transform the global wind-power industry and drive further growth. From reducing downtime and extending the life of turbines, to improving energy production and increasing productivity, these emerging technologies are helping create a smarter and more sustainable energy sector. ✈

### ABOUT THE AUTHOR

George Yan is the founder and CEO of Clobotics, a computer vision technology-based company focusing on providing an end-to-end solution for enterprise customers, the coverage including but not limited to wind energy, telco, and retail. Clobotics is headquartered in Shanghai, has a branch office in Beijing, and an R&D center in Seattle. Yan holds a master's degree in financial engineering from Columbia.

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