CANADA

Wind Powering Canada to a Low-Carbon Future

Within the past 11 years, Canada has built more wind-energy capacity than any other form of energy generation.

By Robert Hornung

Globally, wind energy is one of the fastest growing major sources of new electricity around the world, with installations of more than 55,000 MW of clean, reliable wind power in 2016 alone. More than 80 countries have now installed wind-energy facilities. The U.S. is the second largest market with more than 82,000 MW, capable of supplying up to 25 million homes. Canada is in eighth place with just more than 12,000 MW, meeting about 6 percent of Canada's electricity needs.

Wind energy has made tremendous progress in Canada, and the future promises continued strong growth. In the past decade, wind has become not just *a* mainstream energy choice; it is now *the* mainstream energy choice. Canadians have built more wind-energy capacity over the past 11 years in the country than any other form of electricity generation.

COSTS HAVE FALLEN

There are good reasons for this. Costs for wind energy in Canada have fallen dramatically over the past decade, making it one of the country's two most cost-competitive sources of new electricity supply. It is clearly the least costly form of emissions-free electricity generation available today.

Unlike its main competition, natural gas, wind energy is not affected by the carbon pricing that is being put in place across Canada. Nor is it subject to potential future commodity price fluctuations. It is also widely recognized that the ongoing evolution of technology will lead to further declines in the cost of wind energy. Taken together, this means wind should only become more affordable over time. Plus, system planners know it can be deployed quickly at whatever scale is required to match customer demand growth.

Canadian politicians, electricity sector leaders, and knowledgeable consumers are increasingly aware that no other electricity technology can offer the same combination of affordability, reliability, scalability, and sustainability that wind energy can.

Wind energy's rapid expansion is driven by wind's two most important attributes: It is low-cost and emissions-free.

GLOBAL COMPETITION

As the Global Wind Energy Council's 2016 Outlook states, wind power is the most competitive option for new power supply in a growing number of global markets with rapidly dropping prices. Some projects are delivering electricity for as low as 4 cents (U.S.)/kWh. The U.S. financial advisory firm, Lazard, has found the levelized cost of wind energy has fallen 66 percent since 2009. Costs are expected to decrease further by up to 26 percent by 2025, according to the International Renewable Energy Agency.

Wind power is also one of Canada's best hopes for addressing climate change. Study after study has shown the only way Canada will be able to reduce greenhouse gas emissions in a significant way (80 percent or more by 2050) is by moving away from the use of carbon fuels in transportation, heating and cooling buildings, and in industrial processes, and replacing them with clean

Wind energy has made tremendous progress in Canada, and the future promises continued strong growth. (Courtesy: Siemens)

electricity. Wind energy's low costs and lack of emissions have become its competitive advantage.

This means wind energy will play a critical role in helping Canada meet its commitments on climate change. The initial goal is to reduce greenhouse gas emissions by 30 percent as of 2030 compared to 2005 levels.

IN THE U.S.

While the U.S. has announced its plans to withdraw from the Paris Climate Agreement, many states and cities have made strong commitments to green energy and to reducing greenhouse gas emissions. Some states such as Iowa and South Dakota already get more than 30 percent of their electricity from wind.

ALSO IN THIS SECTION

Other states are turning to green-energy sources, including renewable energy from Canada. For example, the state of New York plans to get 50 percent of its power from renewable energy sources by 2030, and Massachusetts plans to acquire almost 10 TW/h of additional renewable energy. A recent request for proposals in Massachusetts saw both Quebec and Atlantic Canada submit bids for consideration that included significant quantities of new Canadian wind energy.

Canada now generates 83 percent of its power using non-emitting sources, and the federal government has set a target to up that contribution to 90 percent by 2030. As part of Canada's emission-reduction commitments, it has targeted the complete phase out of coal-fired generation by 2030. Canada's largest province, Ontario, already has closed several stations and is now coal-free. Other provinces will follow suit and replace much of their coal generation with wind. Two western provinces, Alberta and Saskatchewan — both now reliant on coal — are planning to install close to 7,000 MW of renewable energy capacity, most of it wind energy, as part of its plans to green the grid.

Despite wind energy's rapid growth, Canada has still only scratched the surface of wind energy's potential contribution to electricity production. In July 2016, the Canadian Wind Energy Association released the results of a ground-breaking study that found Canada can reliably and cost-effectively get more than a third of its electricity from wind energy. The Pan-Canadian Wind Integration Study found there are no operational barriers to reaching a 35-percent wind contribution to Canada's electricity supply. New transmission interconnections to facilitate the integration of wind energy and its movement to various markets would essentially be paid for within four years through fuel savings as more expensive coal and gas-fired generation

Canada now generates 83 percent of its power using non-emitting sources, and the federal government has set a target to up that contribution to 90 percent by 2030. (Courtesy: Enbridge)

is displaced in both the U.S. and Canada. Air pollution and climate change emissions would decline by millions of tons, while Canada could increase its clean-energy exports by billions of dollars.

OPTIMISTIC FUTURE

Achieving such penetration levels requires a smart approach to limiting emissions from natural gas-fired generation, recognizing that natural gas provides a helpful bridge to a greener economy, but it should not act as a barrier to renewable-energy development. Strategic transmission investments need to be made to ensure Canada can move wind energy from wind-rich areas to those in need of clean power. The evolution of electricity market design and the rules that recognize and reward the value wind energy brings to the power grids also needs to continue.

The wind-energy industry faces the future with optimism. It is becoming clearer by the day that the world's energy supply and its economies are evolving, moving toward a greener future. Britain and France recently announced they will ban the sale of new gasoline and diesel cars by 2040. Volvo is moving toward an all-electric or hybrid fleet by 2019. Tesla has received deposits from 500,000 customers for its new electric car, the Model 3. New supplies of emission-free electricity will be needed to power this clean transportation of the future.

Commercial and industrial companies such as Google are contracting for wind energy to power their operations. In the U.S., one third of all new wind-power purchase contracts are being signed by these customers. In Alberta, IKEA owns two wind farms, part of its commitment to produce more renewable energy than it uses by 2020.

It's not always apparent that the nations of the world share similar objectives. With the healthy expansion of wind energy around the globe, it's clear Canada, the U.S., and a growing number of countries are moving together in one way, toward a cleaner future.

Wind power is also one of Canada's best hopes for addressing climate change. (Courtesy: Siemens)

Despite wind energy's rapid growth, Canada has still only scratched the surface of wind energy's potential contribution to electricity production. (Courtesy: Glen Dhu facility, Nova Scotia)

Robert Hornung has been president of the Canadian Wind Energy Association (CanWEA) since August 2003. He represents the interests of CanWEA members who are Canada's wind-energy leaders — wind-farm owners, operators, project developers, consultants, manufacturers and service providers, and organizations and individuals interested in supporting Canada's wind-energy industry. Hornung is also a board member of the Global Wind Energy Council and was named a fellow of the Royal Canadian Geographical Society in 2009.

OFFSHORE

From Megawatts to Gigawatts

Offshore wind market to make prominent ground in the global energy mix; Europe to continue its dominance in the regional landscape.

By Shikha Sinha

Corresponding to the demands for decarbonization and diversification of energy portfolios, the offshore wind market has witnessed a commendable proliferation on a global scale. Offshore wind has traversed indeed a remarkable jaunt pertaining to its deployment, from a few megawatts of installed capacity since the first commercial scale wind farm commissioned in 2002 to a projected market volume of 60 GW by 2024. Estimates claim the global offshore wind industry size to have been recorded at more than 12 GW at the end of 2015, out of which Europe procured a major chunk of the market share.

2016 also marked another promising year for the global offshore wind market, though the total installations were approximately 31 percent down from the previous year. In 2016, a total of 2,219 MW of new offshore wind power was installed across the seven markets globally. The overall offshore wind market size in 2016 in terms of installation capacity was recorded at 14,384 MW, with an expanse of 14 markets on a global scale.

As of 2016, nearly 88 percent of the global offshore wind-power installations were in 10 European countries, and the remaining 12 percent was shared by China, Japan, South Korea, and the U.S. respectively.

Ireland, Spain, Finland, Japan, South Korea, Norway, and the U.S. are some of the other markets sharing the regional landscape of the offshore wind industry, though the current adoption trends in these economies are quite nascent.

Contemplating the trends of offshore wind market, it is undeniable that Europe will continue its dominance over the foreseeable future as well. However, with the developments in the other corners of the world, it is perceptible that the global growth of the offshore wind market has begun to take off at an appreciable pace.

EUROPE: THE PIONEER OF OFFSHORE WIND

Europe holds the majority of offshore wind capacity and is poised to lead the regional landscape of this industry over the coming years. A plethora of factors have supported the growth trajectory of this continent. The financial backing by both the government and the private entities is one of the major factors providing a push to Europe offshore wind market. As per the statistics, over the period of 2001 to 2015, the overall RD&D expenditure in offshore wind from the public sector was approximately $1 billion to $2 billion. During the same tenure, the financial backing from the private sector was almost two to three times this valuation.

The large-scale publicly funded initiatives include the European Wind Initiative, the European Commission's Framework Programmes, Horizon 2020, and NER300. Other bodies supporting Europe offshore wind market growth include Spain's National Renewable Energy, Offshore Renewable Energy (ORE) Catapult, and Lindoe Offshore Renewables Center (LORC).

The cost declines commenced in 2015 with a recorded low cost of 103 euros/MWh at Danish wind farm Horns Rev 3. (Courtesy: Dong Energy)

The cost declines commenced in 2015 with a recorded low cost of 103 euros/MWh at Danish wind farm Horns Rev 3. The trend was taken forward by the following year, 2016, when Dong Energy won a Dutch tender in June for the 760 MW Borssele 1 and 2 at 72 euros/MWh. In the same year, during September, a Danish nearshore tender was recorded at a still lower value of 64 euros/MWh. Again, the end of 2016 marked the revolutionary era for offshore wind market when Danish Kreiger's Flak project and Borssele 3 and 4 in the Netherlands were valued at 49.90 euros/MWh and 54.50 euros/MWh during November and December.

For Europe, 2016 represented an era where offshore wind power at some instances gave a cut-throat competition to onshore, in terms of cost parameters.

THE COMPETITIVE HIERARCHY

In 2016, Siemens Wind Power was the chief offshore wind-turbine supplier in Europe accounting for 67.8 percent of the overall installed capacity. The second position was grabbed by MHI Vestas Offshore wind with a share of 16.4 percent. Senvion, Adwen, and BARD mark the balance of the regional landscape with a share of 6.2 percent, 5.2 percent, and 3.2 percent respectively.

In terms of new additional capacity, the top five participants securing the ownership include Northland

Power — 23 percent, Dong Energy — 20.4 percent, Global Infrastructure Partners — 10.5 percent, Siemens — 7.7 percent, and Vattenfall — 7.6 percent.

With a capacity so far of more than 5 GW and 27 wind-farm installations, the U.K. is estimated to be the global leader in the offshore wind market, adding a renowned value to the overall European renewable energy landscape. A strong commitment toward decarbonization and a favorable regulatory landscape will further push the U.K. offshore wind market to evolve with the trends of clean and green energy.

With Europe deriving a major quotient of its power needs from wind energy and the continent treading with a slogan of "go-green," it is rather undeniable that Europe will continue to maintain its dominance in the global landscape over the years ahead.

In 2016, Senvion supplied 6.2 percent of Europe's wind turbines. (Courtesy: Senvion)

Global offshore wind market statistics — 2015

Europe:
11.2-GW capacity accounting for 1.6 percent of power generation.
Total number of offshore wind farms: 54, 25 in the U.K., followed by Germany, Denmark, Belgium, Netherlands, and Sweden respectively.

Asia:
1.2-GW capacity, accounting for 0.1 percent of power generation.
Total number of offshore wind farms: 5, all in China.

North America:
2015 marked the first offshore wind project construction on the continent.

ASIA AND U.S.: THE EMERGING CONTENDERS

Over the period of 2001 to 2015, the Asia public sector made an investment of close to $1 billion in offshore wind RD&D. The private sector in the same tenure made investments of approximately $1.5 billion.

China is expected to lead Asia offshore wind market over the coming years.

Despite having a recorded installation capacity of less than 2 GW at the end of 2015, the growth prospects for China look promising over the coming years. With a new target under the 13th Five-Year Plan to achieve an installation capacity of 10 GW by 2020, the country is poised to attain remarkable growth pertaining to offshore wind installations in the years ahead. With ongoing developments toward increasing the reliability of the offshore wind turbines, reduction in energy cost, collaboration between government entities, and favorable norms pertaining to wind-power policy systems, the China offshore wind market is expected to reach 12 GW by 2024.

Companies such as China Renewable Energy Engineering Institute, China Longyuan, and Goldwind are actively partaking in the regional offshore wind-industry growth.

Taiwan forayed into the offshore wind market with its recent announcement of installing 3 GW of offshore wind power by 2025. At present, the country has only two offshore turbines. However, the growth prospects in Taiwan are strongly driven by the fact that the region is an open market with lesser competition.

Speaking of Japan and South Korea, the regions have not shown much development with regards to offshore wind power over the past years. In the case of Japan, however, the country targets to build 1.3 GW capacity in the next 10 years with 2.5 GW under the planning category.

South Korea, addressing the country's focus toward renewables, is estimated to build 1 GW of offshore wind capacity from 2017 to 2026.

U.S. DEVELOPMENTS, TRENDS, AND PROSPECTS

2016 witnessed much awaited development in the U.S. renewables sector with the launch of the first U.S. offshore wind farm with a capacity of 30 MW. The five-turbine Block

Island project was launched in December 2016 off the coast of Rhode Island. Following this launch, several other projects are in the pipeline in both state and federal waters off the Atlantic and Pacific coasts and Great Lakes. A total of 13 offshore wind projects are under multiple stages of development, as per reliable sources. The U.S. Department of Energy anticipates offshore wind to address 2 percent of the U.S. electricity demand in 2030 and 7 percent in 2050.

In March 2017, the U.S. Bureau of Ocean Energy Management and Statoil executed the lease of 321 square kilometers offshore New York. This opened up lucrative opportunities for the Norwegian giant to explore and exploit the potential of offshore wind market. Again, in May 2017, the Commonwealth's Department of Energy Resources issued an appeal for proposals to develop 800 MW of offshore wind.

With this active participation of both the federal and state governments and the growing interests of the investors in this region, the U.S. offshore wind market is slated to witness a lucrative roadmap ahead. According to Global Market Insights, Inc., U.S. offshore wind industry held a valuation of $100 million in 2016.

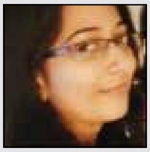
To completely exploit the enormous range of opportunities ahead, the offshore wind industry must meet the growth parameters encompassing its evolution terrain. For instance, energy costs or LCOE for offshore wind should be regularly cut down to compete against the other forms of energy. Also, unlike every other industry, offshore wind market development is proportional to its expansion, penetration, and integration with other markets. For instance, the industry was earlier focused only on shallow waters, close to the shore. However, if the present scenario is considered, new innovations and technologies for different water levels and varied wind regimes are becoming an investment destination at an appreciable pace.

However, the current trends and insights of the offshore wind market assure a long-term growth horizon for its development. What remains to be seen is the turmoil the burgeoning offshore wind industry brings in the regional and competitive landscape over the years ahead.

The five-turbine Block Island project was launched in December 2016 off the coast of Rhode Island. (Courtesy: Deepwater Wind)

Countries	Installed Capacity (%)
U.K.	36
Germany	29
China	11
Denmark	8.8
Netherlands	7.8
Belgium	5
Sweden	1.4

A synopsis of the regional landscape of the offshore wind market in terms of installed capacity (2016).



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Critical Components Essential as Wind Power Scales Up

Offshore wind has unique considerations that require technological expertise and a close, collaborative partnership.

Testing capabilities within Timken's Wind Energy Research and Development Center have the flexibility to focus on wind-turbine applications. (Courtesy: The Timken Company)

By Doug Lucas

The wind industry continues to post impressive numbers. The American Wind Energy Association recently reported a strong outlook for 2017, with second quarter figures indicating a 40 percent uptick in wind development activity over the same time last year.

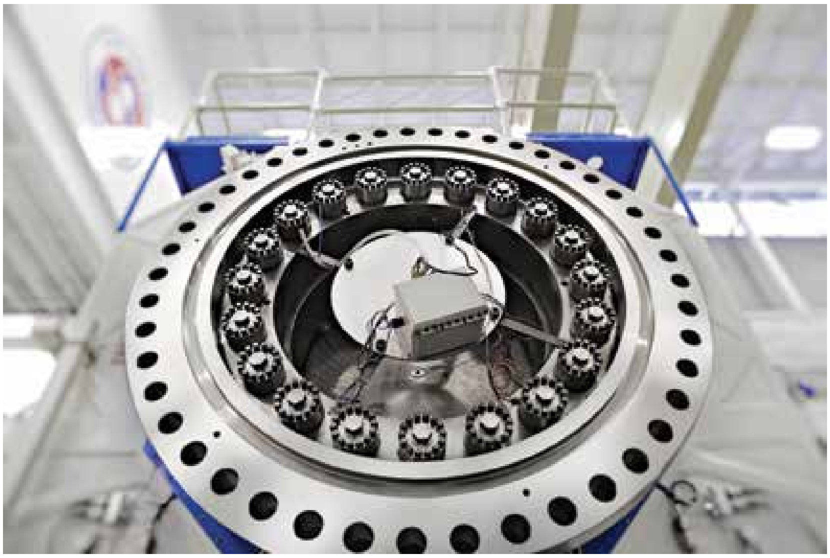
Part of that boost in activity includes momentum in U.S. offshore wind-power development, something that may have seemed unlikely just a few years ago. After the successful completion of America's first offshore wind farm — Rhode Island's Block Island project — the opportunity for more U.S. offshore projects is at hand. The Maryland Public Service Commission recently approved two major offshore projects that will generate 368 MW cumulatively, and other major projects could soon be on the horizon.

Why offshore, and why now? Europe has more than 12,000-MW capacity in offshore wind infrastructure, but that has largely been driven by necessity, with far less available land for turbines to scale up the continent's wind-power capacity. In the United States, where land is plentiful for the proliferation of wind farms, a similar case for offshore wind didn't exist.

But that may be changing. Offshore projects bring with them more powerful and consistent wind loads, with far fewer turbine size restrictions, and that means far greater generative capacity. Consider that roughly 50 percent of the U.S. population lives in coastal areas, including both counties directly on the coast and those that drain into coastal watersheds. According to the Bureau of Ocean Energy Management, energy costs are higher in these areas, and land-based renewable resources can be limited. But offshore wind resources have the potential to deliver enormous quantities of renewable energy to the country's largest and most populous major metropolitan areas.

Consider also that while the typical onshore wind turbine ranges from 2-3 MW, offshore turbines typically generate more than 3 MW. Work is currently being done on large-scale turbines with capacity for 7 MW and up to 10 MW and even larger, driving the potential for offshore power generation even higher.

Those on the frontier of offshore wind development are entering uncharted territory. And with that comes the need for highly engineered, highly reliable component parts for power transmission to seize the potential. The choice of a bearing supplier is critical to this process for today's wind-turbine designers and operators to achieve the most effective wind power generation.



Other testing capabilities within the 18,000-square-foot facility include industries such as off-shore oil rigs, mine trucks, electric shovels (in mining), steel rolling mills, cement vertical mills, and hydraulic roll presses. (Courtesy: The Timken Company)

Timken and Stark State College's Wind Energy Research and Development Center tests ultra-large bearing systems up to 13 feet in outside diameter on sophisticated equipment capable of simulating wind-turbine conditions. The new test facility is expected to shorten development cycles and improve reliability and cost-effectiveness. (Courtesy: The Timken Company)

ONSHORE VS. OFFSHORE: A COMPARISON

The essential functionality of a wind turbine stays the same no matter if that turbine is operating onshore or off. All turbines have towers, nacelles, three-blade design, and other common essential components.

There are a few critical differences that must be considered, however. The first primarily comes down to the size — that of the completed turbine and the component parts that go into it.

Onshore turbines hit some significant limitations revolving around their physical construction. Road conditions, bridge sizes, and weight capacities must all be considered when transporting oversized turbine components to a build site. Many of these sites are in remote regions where access may not be easy. Offshore wind, by contrast, is not limited by those same restrictions. Parts can be shipped to ports built to handle extreme sizes, though the investment in such larger turbines grows when accounting for ship-based transport. With the ability to construct larger turbines, the potential for greater generative capacity is increased.

Another important distinction is wind speeds and loads that occur in onshore versus offshore applications. In Europe, land limitations led to the early adoption of offshore farms, but there was another benefit: higher velocity and more consistent wind speeds at sea. Those conditions allow continuous and consistent operation, efficiently generating the greatest amount of power possible.

By contrast, onshore wind speeds

The $14 million Wind Energy Research and Development Center houses a large test rig that can handle 13-foot OD bearings. It's capable of producing load combinations experienced by utility-scale wind turbines, up to 5 MW. (Courtesy: The Timken Company)

and loads are far less consistent. And though the availability of land will likely lead to the continued adoption of onshore wind power in the United States, these installations will be less efficient than an offshore counterpart. Another factor to consider is inconsistent wind loads, causing the turbine to stop and start up again. This may, in fact, cause more stress on gearbox bearings and other components.

No matter the differences, it is clear that bearing design in all wind turbines must be rigorous and suited to the given application.

HIGHER RISK, HIGHER REWARD IN OFFSHORE

As offshore turbines continue to grow and increase their energy-output potential, components and systems that make it possible are subject to greater loads and expectations. So, as opportunity grows, so does the potential for costly failure if all systems aren't operating reliably and according to plan.

What are some of the biggest challenges? Like any industry, high-performing components are essential for efficient operation, making overall reliability and reduced maintenance a priority. Geographical location comes into play once again — where an onshore major drivetrain component replacement due to failure may cost several hundred thousand dollars, that same failure in an offshore turbine may easily stretch into the millions when the complexities of sea travel and sea-based cranes are factored into the equation.

The need for thorough engineering expertise is clear. Superior performance from gearbox bearings depends on exacting and typically customized clearances for that specific turbine's design and power output. These bearings aren't sold off the shelf — each is unique. In increasingly powerful applications, the right geometry, clearances, and load capacity must be custom engineered by expert partners to meet the needs and requirements of the specific project. Slight over- or under-sizing can cause serious performance issues.

Technical expertise to meet the needs of specific applications is highly valued among turbine OEMs when it comes to bearing suppliers. Likewise, product quality and integrity is paramount, because reliable performance depends on it.

QUALITY AND TRACEABILITY

Given the high cost of bearing failure in any wind application, the integrity of materials selection is something any turbine OEM will be paying close attention to.

For example, material traceability in wind energy is a critical consideration for turbine OEMs. One faulty component can indicate a problem that reaches beyond one individual turbine. The ability to trace one damaged part to its source, and to then determine if like parts are also in use, can help operators identify problems before they happen. With the high cost of failure, complete product traceability in wind energy is not unlike that in the aerospace industry.

This kind of ability to trace products back to their exact source — including the steel heat used in manufacture — in each wind-turbine bearing is essential in wind-energy applications. Likewise, documentation is important to ensure all customer requirements are accounted for when the bearing is manufactured.

BEARING AND SUPPLIER SELECTION

Bearings providing the highest possible performance potential in the most compact designs help reduce overall system size, weight, and manufacturing costs. In larger and more powerful applications, reducing weight and size where possible is a significant goal. Maintaining reduced head mass size as turbines grow more powerful is important to lower the cost of energy (COE), which is a focal point for many turbine OEMs today.

For these reasons, tapered roller bearings have demonstrated unique suitability for wind turbine main bearing applications when compared to the traditional choice of spherical roller bearings. Tapered bearings are power dense, satisfying sizing demands in offshore wind applications. Designed to bear both thrust and radial loads, tapered roller bearings are also well suited for the common stresses in wind applications, including sudden changes in both wind speed and direction.

But in the end, bearing choice for any wind application, be it on or offshore, depends on finding the right design for the right application. And as wind turbines on offshore applications continue to grow larger, new design considerations will be discovered. For example, blades on a wind turbine will grow more flexible at larger sizes. This kind of material behavior can cause different forms of stress on the entirety of the turbine, requiring extensive expertise to determine accurate loads and system compliances.

Offshore wind energy is entering uncharted territory. And for wind-turbine designers and operators, close collaboration with a trusted bearing supplier will better enable problem solving, correct system design, and long-lasting reliability and performance. Seizing on the growing potential of wind energy depends on it.

The Wind Energy Research and Development center in North Canton, Ohio. (Courtesy: The Timken Company)

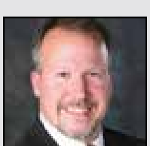
An Investment in Wind Research

With the potential in wind energy growing each year, Timken has committed itself to help push this growing market forward.

In 2013, Timken opened its Wind Energy Research and Development Center, the first of its kind in the United States. Focused on advancing the development of bearing systems in wind applications, the $14-million investment on the campus of Stark State College in North Canton, Ohio, furthers the development of power transmission systems for multi-megawatt turbines. Massive, precision-engineered bearing and sealing systems like those made by Timken are central to that production of power inside these turbines.

As the wind main shaft market trends toward larger applications, Timken identified the need for physical testing capabilities to validate ultra large bearing design practices, component reliability, and additional performance necessities. At the facility, a test cycle equivalent to 20 years can be completed in as little as 4 to 5 months.

Timken collaborates with wind-turbine and gear-drive designers from material selection through engineering and product selection. The company also offers Timken clean steel, antifriction bearings, and a range of power-transmission components for the most demanding megawatt-class turbines. Its services include application development, service engineering, and aftermarket services to help keep equipment running smoothly through its service life.



Doug Lucas is a wind-energy engineer with The Timken Company. Over the last 17 years with Timken, Lucas has worked in application engineering and management functions serving the wind-energy industry. He is responsible for application and new product development that leads to delivering innovative, high-value technology solutions to Timken customers in the global wind-energy markets. He has been involved with many development projects and products for the wind market to drive increased reliability and lower cost of energy. Lucas holds bachelor's and master's degrees in mechanical engineering from The University of Akron as well as a professional engineering license in the state of Ohio.