

GE Power & Water  
Renewable Energy

# 2.5MW

## Wind Turbine Series



imagination at work

a product of  
**ecomagination**



**2002**

GE enters wind industry

**2004**

First 2.5s turbine installed

**2006**

First 2.5xl technology  
demo unit installed

*EVOLUTION OF*



# The Evolution of Power

Minute by minute, the world is growing. Economic development and increased attention to sustainability means the world needs a steady supply of cleaner, reliable power. GE continuously stays a step ahead, driving cutting-edge wind turbine technology.

Building on a strong power generation heritage spanning more than a century, the 2.5 MW wind turbine is evolutionary technology based on a unique design strategy. Higher efficiency, increased reliability, improved maintainability and seamless grid integration make it a powerhouse of precision. In fact, GE's 2.5 MW wind turbine leads the industry by producing the highest annual energy yield in its class, creating more value for our customers.

**2008**

First 2.5xl unit installed

**2009**

Certification for 50 Hz

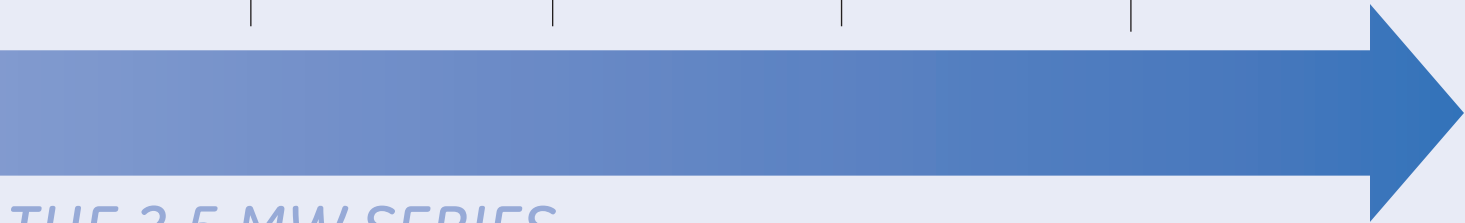
**2010**

Certification for 60 Hz and launched in North America.

2.5 series:  
200<sup>th</sup> unit installed

**2011**

Technology improvements and new variants:  
103 meter rotor for IEC Class III



## THE 2.5 MW SERIES

Drawing on GE's experience of more than 13,500 wind turbines in operation worldwide, the 2.5 MW wind turbine is designed to meet the growing demands of the wind industry. Product evolution is one of the things GE does best and our product strategy is focused on results that contribute to our customers' success. Our reputation for excellence can be seen in everything we do. The 2.5-100 is a product of GE's evolution in the wind industry and is a leader in the multi-megawatt wind sector. The 2.5 MW wind turbine is now available in 50 and 60 Hz, and GE continues to invest in advancing the technology for higher capacity factors and greater annual energy production for our customers.

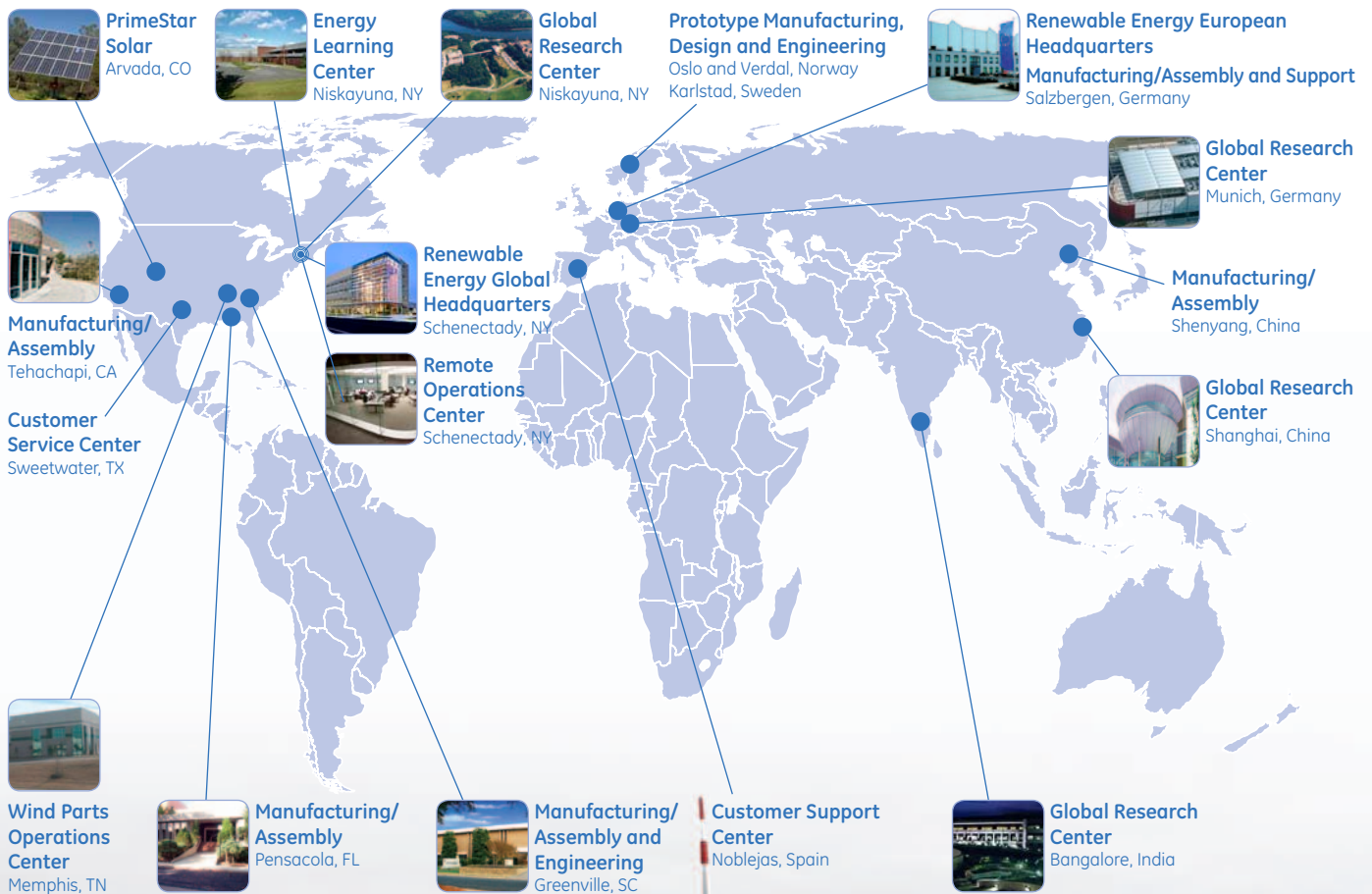
2.5 MW Series	2004	2009
Rotor Diameter (m)	88	100/103 →+15 m
Capacity Factor (%) 7.5 m/s	34.7	41.9 →+7 pts
Capacity Factor (%) 8.5 m/s	39.5	48.7 →+9 pts



# Global Footprint

GE Energy is one of the world's leading suppliers of power generation and energy delivery technologies—providing comprehensive solutions for coal, oil, natural gas and nuclear energy; renewable resources such as wind, solar and biogas, and other alternative fuels. As a part of GE Energy—which includes the Power & Water, Oil & Gas, and Energy Services businesses—we have the worldwide resources and experience to help customers meet their needs for cleaner, more reliable and efficient energy.

GE has 11 global locations specifically devoted to wind technology. Our facilities are registered to ISO 9001:2000 and our Quality Management System, which incorporates our rigorous Six Sigma methodologies, provides our customers with quality assurance backed by the strength of GE. We believe wind power will be an integral part of the world energy mix throughout the 21st century and we are committed to helping our customers design and implement energy solutions for their unique energy needs.



# The New Industry Standard

## Suitable for a Wide Variety of Sites

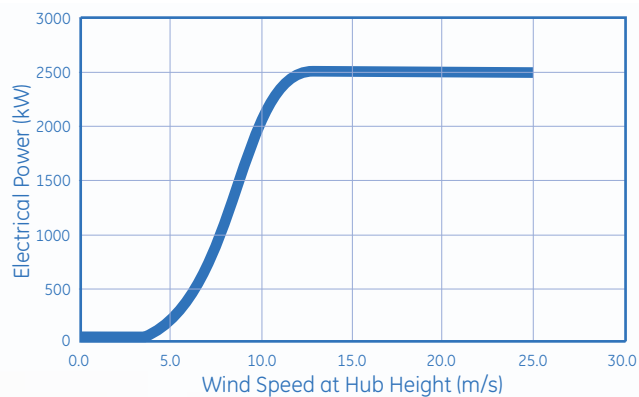
Designed for IEC Class II and Class III, the 2.5 MW wind turbine can be deployed on over 85% of the sites being developed today. The 103 meter rotor diameter optimizes the 2.5 MW turbine for IEC Class III applications and provides an increase in Annual Energy Production for IEC Class III.

The 2.5 MW wind turbine also excels on sites that are constrained by environmental regulations. GE's innovative and patented rotor blade technology provides the 2.5 MW wind turbine with very competitive acoustic performance. In fact, with the optional sound-reduced operation modes, the 2.5 MW wind turbine can be deployed even at sites with the most stringent sound constraints, while simultaneously maintaining a high energy yield.

The 2.5 MW wind turbine can be equipped with various towers resulting in hub heights of 100 meter, 85 meter and 75 meter (50 Hz only), meeting potential tip height constraints and maximizing energy yield.

With more than 210 units installed and over two million operating hours, customers in eight countries around the world are already benefiting from our advanced 2.5 MW technology. Building on GE's industry leadership with over 6,000 MW in cold weather operating conditions, the 2.5 MW wind turbine series can be equipped with a cold weather extreme option.

### 2.5-103 Power Curve



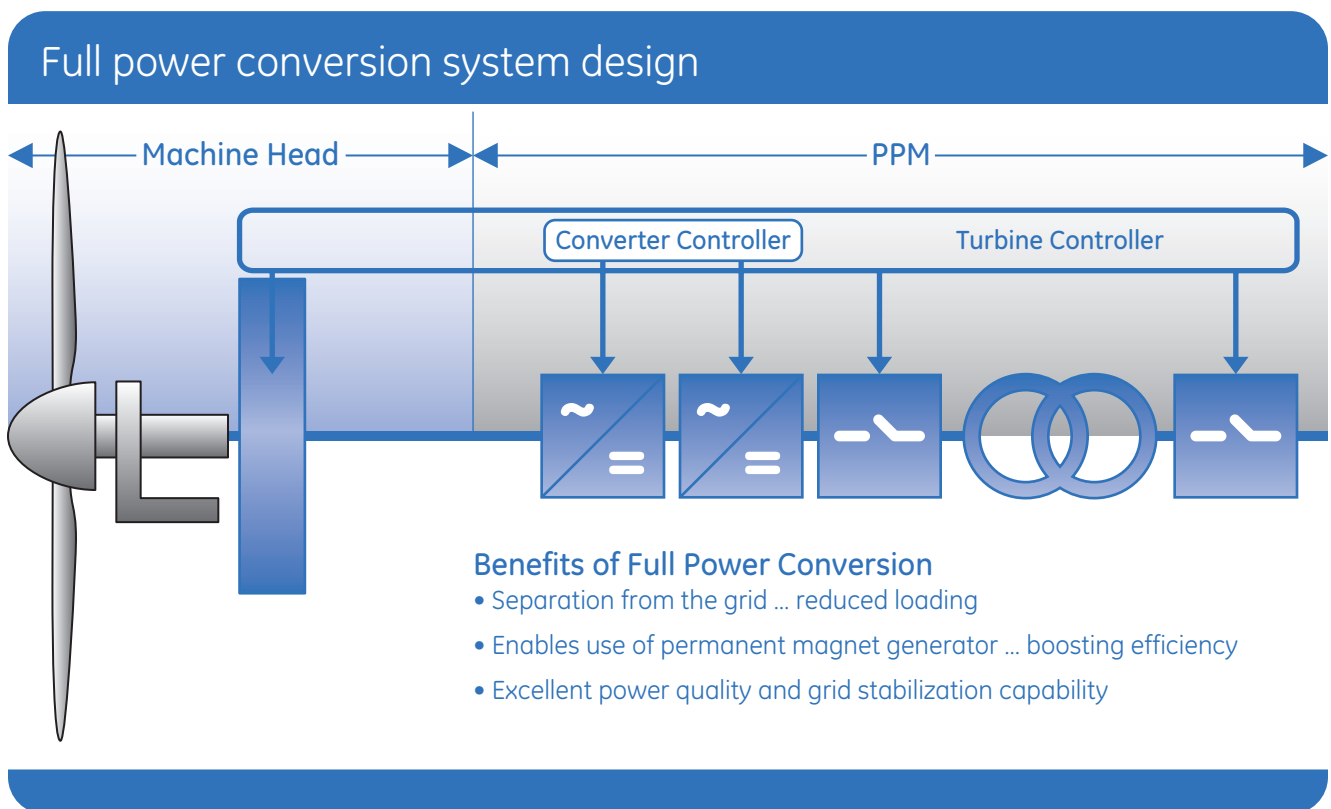
### 2.5 MW Series

	TC3 2.5-103	TC2 2.5-100
Rotor Diameter (m)	103	100
Hub Heights (m)	85/100	75/85
Frequency (Hz)	50/60	50/60
Vavg (m/s)	7.5	8.5
Vref (m/s)	37.5	42.5
Ve50 (m/s)	52.5	59.5
Cut-In (m/s)	3.0	3.0
Cut-Out (m/s)	25	25
IEC Wind Class	IEC TC IIIA	IEC TC IIB



## Higher Efficiency

The 2.5 MW wind turbine is equipped with a permanent magnet generator, ensuring high efficiency even at low wind speeds. Compared to a conventional doubly-fed system, the efficiency in the partial load range is remarkably higher, resulting in increased revenues for wind power producers. Employing magnets instead of copper coils in the generator rotor reduces electrical losses in the generator and current flow through the rotating parts of the generator.



## Optimal Maintainability

The interior of the nacelle is designed to optimize maintainability and ergonomics for the maintenance crew. It provides an environment that facilitates safe and efficient maintenance and inspection work.

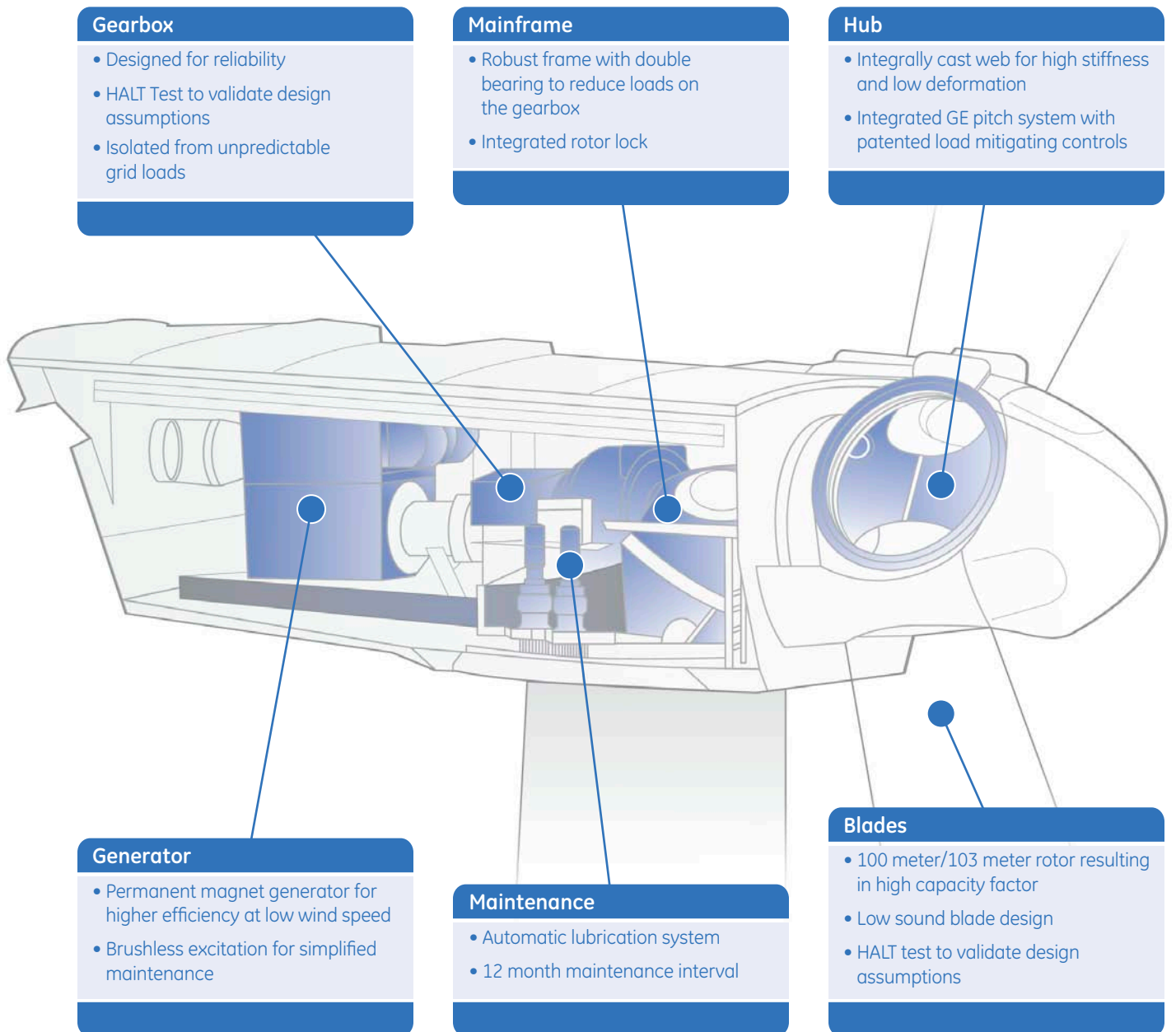
Automatic lubrication systems for the grease-lubricated bearings accommodate a 12-month maintenance interval under normal operating conditions. Not only does this minimize turbine downtime and provide the opportunity to avoid maintenance in the windiest seasons, it also provides the operator of remote sites with the opportunity to plan for maintenance in the season when the turbine is most accessible.

The optional elevator and climb-assist facilitate ergonomically optimal operations and maintenance of the turbine, enabling technicians to visit more wind turbines per day. This improves availability and reduces the size of the labor force required to operate a wind plant.

# Reliability by Design

With technology centers of excellence in the United States, Europe, India and China, our teams of engineers and scientists use Six Sigma methodology, coupled with the latest computational modeling and power electronic analysis tools to manufacture wind turbines with the reliability, efficiency and maintainability necessary to meet the challenges our customers face in today's energy environment.

GE's commitment to customer value and technology evolution is demonstrated by our ongoing investment in product development. Since entering the wind business in 2002, GE has invested over \$750 million in driving reliability and efficient wind technology.



## Advancing Technology

A double-bearing main shaft minimizes gearbox thrust and bending loads by transmitting loads through the bedplate to the tower. The gearbox is only subjected to torque loading—which is controlled by the wind turbine through the converter—resulting in lower and easily predicted loads compared to conventional drive-train designs.

The double-bearing main shaft also improves overall drive-train reliability and improves gearbox life. Additionally, a full power converter separates the generator and gearbox from the grid, allowing them to remain essentially unaffected by transient grid loads. This unique system design results in robust and reliable power conversion.

The main bearings remain well lubricated even under severe conditions due to grease lubrication, which—unlike oil—requires no heating at low ambient temperatures in order to maintain its lubricating properties.

The hub design contains an integrally cast web in the blade root opening, providing high stiffness to the hub assembly. Higher stiffness results in less deflection of the hub, and therefore reduced loads on the components mounted to the hub. Consequently, stresses on the pitch bearing and pitch drive are reduced significantly when compared to conventional designs.

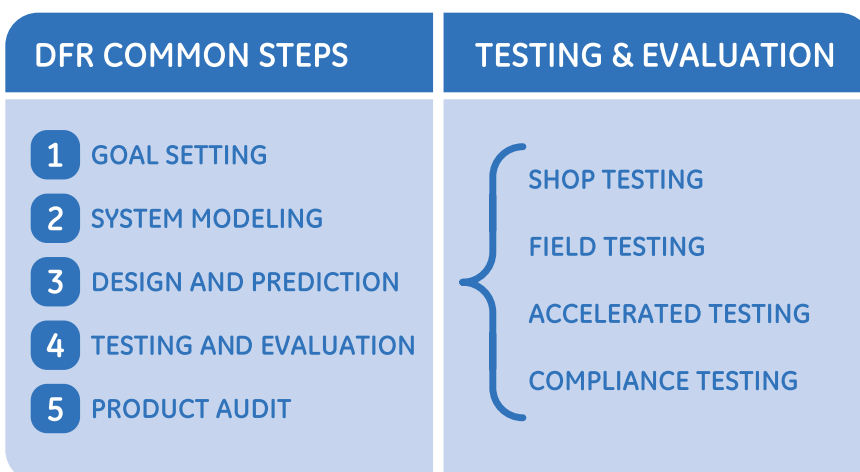
## Designing for Reliability

The 2.5 MW wind turbine is designed according to our Design for Reliability (DFR) methodology. DFR starts with the definition of reliability goals and the environmental conditions in which the wind turbine components must operate. The reliability targets are then broken down to component level models that are developed to predict reliability.

A key step in the DFR process is validating design assumptions on both component levels and system levels. GE conducts extensive product validation, including climate chamber testing, compliance testing and Highly Accelerated Life Testing (HALT). In the test, components are subjected to loads of the entire design life in a very short time frame.

The 2.5 MW design was validated with more than four years and 500,000 hours of operating experience. After extensive field validation, one turbine was decommissioned so that our engineers could teardown and inspect all of the major components and apply findings to technology advancements.

The last step of the DFR methodology is production auditing. While validation is focused on ensuring that the design is free of flaws, the production audit is focused on ensuring that each unit is delivered with consistent quality by understanding the impact of manufacturing variability.





# Combined Strength

GE's 2.5 MW wind turbine utilizes expertise from many areas of GE as well as from our four global research centers. The result of this combined strength is a reliable and efficient product line that is based on proven technology.



GE Energy



GE Energy  
Financial Services



GE Oil & Gas



GE Transportation



GE Aviation



GE Global  
Research Centers

## \$1 Billion and Growing Renewable Energy Technology Investment

### Blade Innovation

- Aero elastic sweep – bend twist
- Advanced materials-carbon

### Power Conversion

- Increased power density and reliability with higher voltage
- Control for integration with weak grids

### Drive Train

- Direct drive ... 50% greater output at the same weight
- Compact drive ... 25% less weight

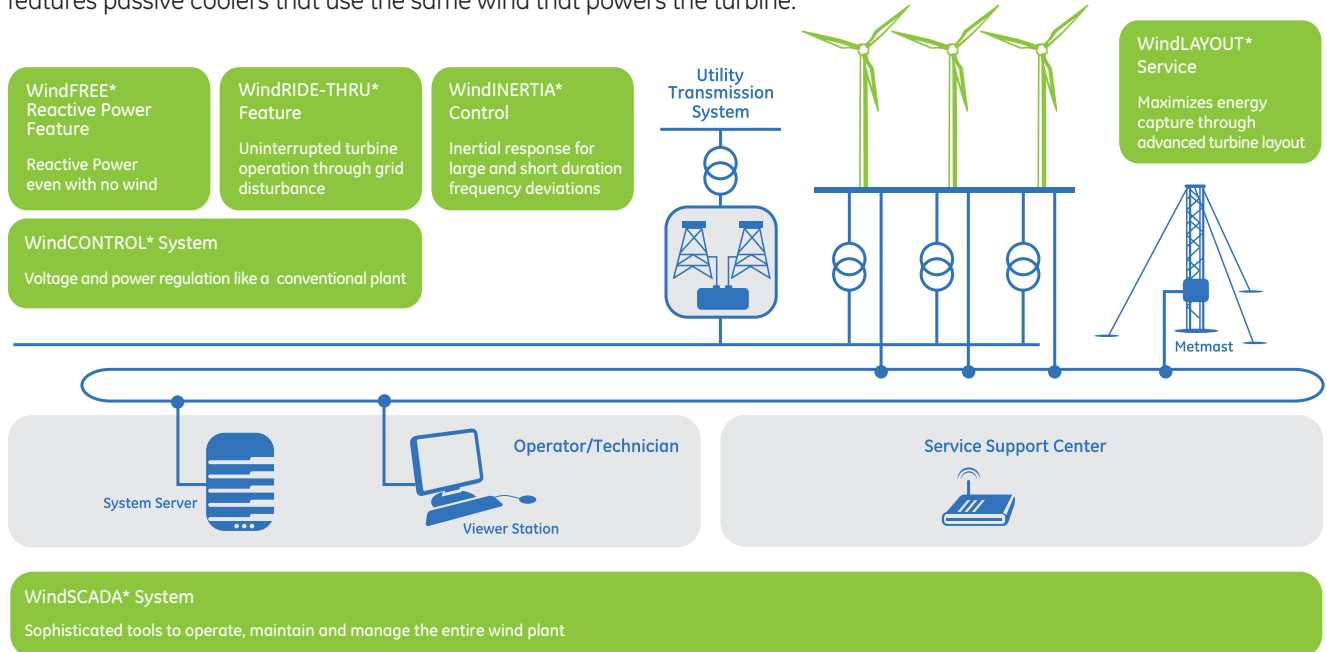
### Solar

- Thin film technology leadership through PrimeStar
- Differentiated utility-scale Brilliance\* inverter



# Optimized Wind Power Plant Performance

The electrical system design of the 2.5 MW wind turbine consists of a permanent magnet generator and full power conversion. In the lower tower section, the power module efficiently converts the energy from the permanent magnet generator into power that provides frequency and voltage control required by transmission system operators. The integration of the converter and transformer down tower, rather than the nacelle, ensures that vibration loads do not affect the reliability of the power electronics. However, to meet the needs of customers in regions throughout the world with varying EHS requirements, GE also now offers a pad mount transformer option. With this flexibility, customers can determine if it makes more sense for them to have the transformer in GE's scope inside the tower, or their own scope outside of the tower. The converter cooling system has been designed to minimize moving parts for reliability and features passive coolers that use the same wind that powers the turbine.



Feature	Description	Benefits
<b>WindRIDE-THRU* Operation System</b>	Uninterrupted turbine operation through grid disturbances Offered in two standard packages: <ul style="list-style-type: none"> <li>• Low Voltage Ride Through</li> <li>• Zero Voltage Ride Through</li> </ul>	Meets present and emerging transmission turbine reliability standards similar to those demanded of thermal generators
<b>WindCONTROL* Power Regulation System</b>	Voltage and power regulation like a conventional power plant	Provides frequency droop and power ramp limiters to help stabilize power system frequency  Reduces Balance of Plant costs
<b>WindFREE* Reactive Power System</b>	Provides reactive power even with no wind	Provides smooth fast voltage regulation by delivering controlled reactive power through all operating conditions  Eliminates the need for grid reinforcements specifically designed for no-wind conditions, and may allow for more economic commitment of other generating resources that will enhance grid security
<b>WindSCADA* System</b>	Tools to operate, maintain and manage the wind power plant	Intuitive operation and maintenance control Secure user-access
<b>WindINERTIA* Control</b>	GE's WindINERTIA control provides an internal response capability for wind turbines that is similar to conventional synchronous generators during under-frequency grid events	By utilizing the mechanical inertia of the rotor, GE's WindINERTIA power pulse characteristics can provide a 5% to 10% increase in turbine power over operational wind speeds
<b>WindLAYOUT* Service</b>	Maximizes energy capture through advanced turbine layout	Utilizes a powerful set of advanced optimization tools that directly integrate turbine performance, mechanical loads, site conditions, and project constraints for maximizing energy production

# Flexible Wind Service Solutions

## Global Resources, Local Support

GE's wind turbine fleet is one of the fastest growing and best-run fleets in the world. GE provides advanced technology solutions built from our extensive global resources, expertise, and regional capability—helping to ensure that your wind turbine assets are operating at peak performance.

### **24/7 Remote Monitoring and Troubleshooting:**

GE's customer support and remote operations centers in Schenectady, New York and Salzbergen, Germany provide continuous monitoring and diagnostics services 24 hours a day, 365 days a year. These centers offer capabilities developed using our in-depth product knowledge, service engineering expertise and years of successful fleet operation, helping us to respond quickly and accurately to your needs.

### **Dedicated Regional Support:**

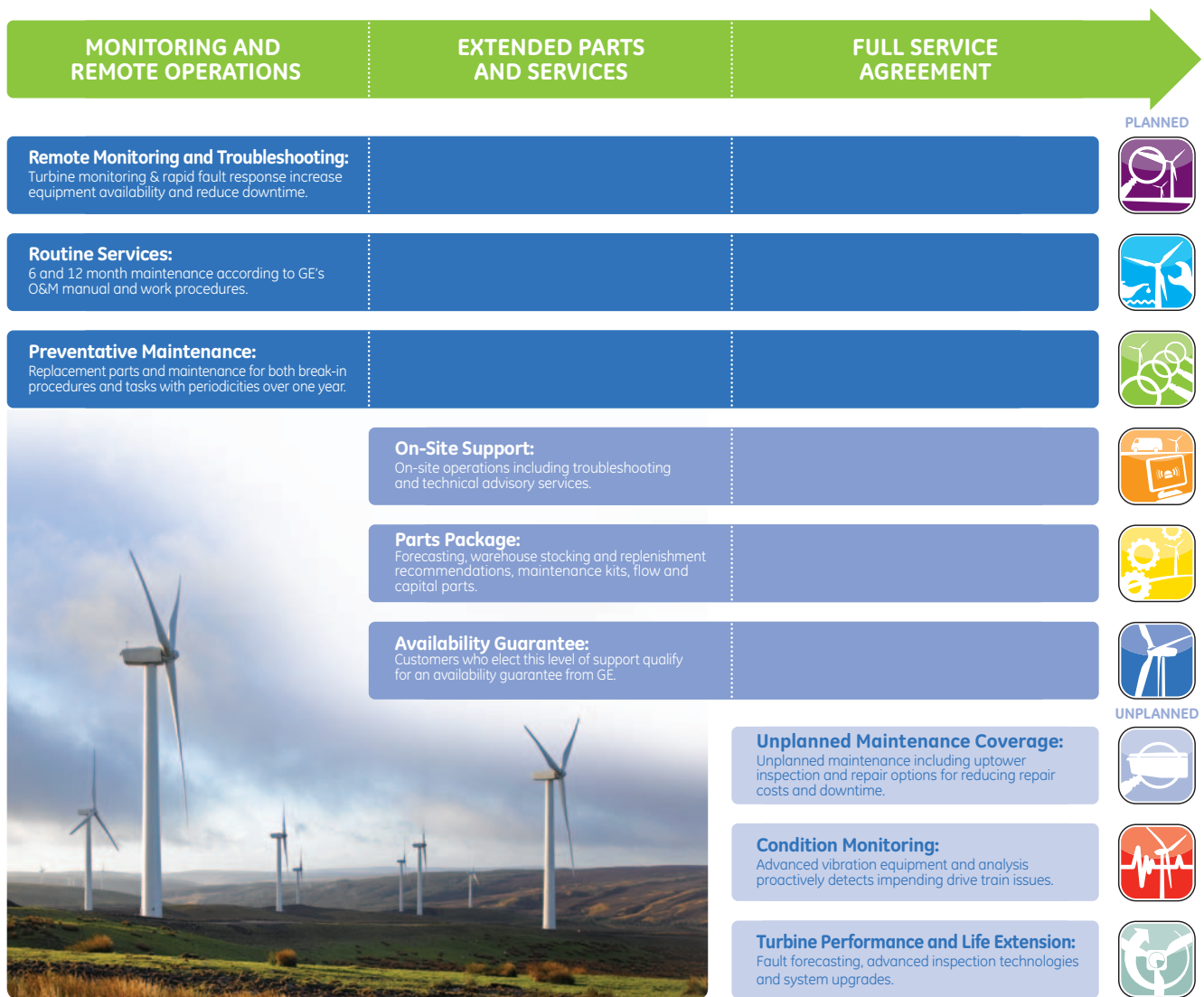
GE-trained regional technicians are available to ensure a timely resolution—whenever and wherever you need us. GE's technicians are equipped to perform procedures such as fault inspections and technical advisory services and manual resets in a timely and efficient manner. If an issue is detected, you can rely on our top-of-the-line repair and replacement capabilities and our highly skilled team to fix the issue immediately.

### **Wind Parts Center of Excellence:**

Availability of parts is critical to wind power plant operations. GE's Wind Parts Center of Excellence provides a full range of offerings for all parts and refurbishment needs from routine maintenance kits, wear and tear, and flow parts, to vital capital parts such as gearboxes and blades. With the launch of our 24/7 parts call center (877-956-3778), and the development of online ordering tools, we are increasing the channels that our wind plant operators can utilize to order required wind turbine parts, including emergency requests for down-turbine needs.



# GE's Wind Service Packages



## Monitoring and Remote Operations (MRO)

This package brings GE's technical expertise to provide a defined scope of planned maintenance, including routine inspections, consumable parts replacement, and labor required in the replacement of wear and tear parts—as well as improved availability and reliability with remote operation services including 24/7 remote monitoring (with remote reset capability).

## Extended Parts and Services Agreement (EPSA)

Adding coverage for manual resets, initial trouble shooting, competitive parts pricing and inventory management, and a limited availability guarantee together with performance analysis reports, the EPSA ensures the highest standards of operation for the project while offering customers competitive solutions to unplanned service events.

## Full Service Agreement (FSA)

Maximize turbine operating performance and life by adding predictive Condition Monitoring services, unplanned maintenance with advanced services and uptower repairs, as well as options for turbine performance and life extension enhancement. Under this comprehensive package GE provides the customer with worry-free operation and maintenance with the highest level of performance.



# Project Execution

GE understands that grid compatibility, site flexibility, and on-time delivery are critical to the economics of a wind project. For that reason, the 2.5 MW wind turbine has been engineered for ease of integration and delivery to a wide range of locations.

Our global project management and fulfillment expertise offer customers on-time delivery and schedule certainty. Regardless of where wind turbine components are delivered, GE's integrated logistics team retains ownership and responsibility for this critical step. Utilizing the GE Energy Power Answer Center, our engineering and supply chain teams are ready to respond to any technical, mechanical or electrical questions that may arise.

As one of the world's largest power plant system providers, GE is uniquely positioned to provide customers with full-service project management solutions.

With offices in North America, Europe, and Asia, our world-class Power Plant Systems division utilizes decades of fulfillment expertise in project management, logistics, plant start-up and integration from gas turbine, combined-cycle, and aero plants.



# Environmental Health and Safety, a GE commitment

Maintaining high Environmental Health and Safety (EHS) standards is more than simply a good business practice; it is a fundamental responsibility to our employees, customers, contractors, and the environment we all share.

GE is committed to maintaining a safe work environment. We incorporate these values into every product, service and process, driving EHS processes to the highest standards.





# Powering the world...responsibly.

For more information please visit [www.ge-energy.com/wind](http://www.ge-energy.com/wind).



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