

GE Power & Water  
Renewable Energy

# 1.5 MW

## Wind Turbine Series



imagination at work

a product of  
**ecomagination**



**1996**

First 1.5 MW installed ... still operating today

**2002**

GE enters wind industry

**2003**

LVRT introduced;  
1,000th unit shipped

**2004**

First 1.5-77 installed; First GE designed 37 meter blade

**2005**

First 1.5-82.5 installed; GE introduces HALT testing

*CONTINUAL 1.5 MW*



# GE's 1.5 MW Wind Turbine Series

Changing and growing energy needs are driving new opportunities for a more reliable, affordable and efficient supply of electric power with zero greenhouse gas emissions. That is why GE continues to drive investments in cutting-edge wind turbine technology. GE's strategy is built around differentiating ourselves with leading technology in production, efficiency and reliability. Trusting in our deep, rich heritage in power generation, GE pulls in expertise from our core business to drive product strategy, product leadership and product value. Every initiative we pursue bears our uncompromising commitment to quality and product innovation.

Building on a strong power generation heritage spanning more than a century, our 1.5 MW wind turbine series—known as the industry workhorse—delivers proven performance and reliability, creating more value for our customers. Our reputation for excellence can be seen in everything we do. GE's commitment to customer value and technology evolution is demonstrated in our ongoing investment in product development. Since entering the wind business in 2002, GE has invested more than \$1 billion in driving reliable and efficient renewable energy technology.

## 2006

GE designed pitch system introduced; 5,000th unit shipped

## 2007

First GE designed 40 meter blade; GE launches Mark\* V1e controller for wind

## 2008

10,000th unit shipped

## 2009

First 1.6-82.5 uprate in TC II

## 2010

1.6-82.5 100 meter tower for TC I; 13,000+ units shipped

## 2011

On schedule for 15,000th unit shipped

## SERIES INVESTMENT



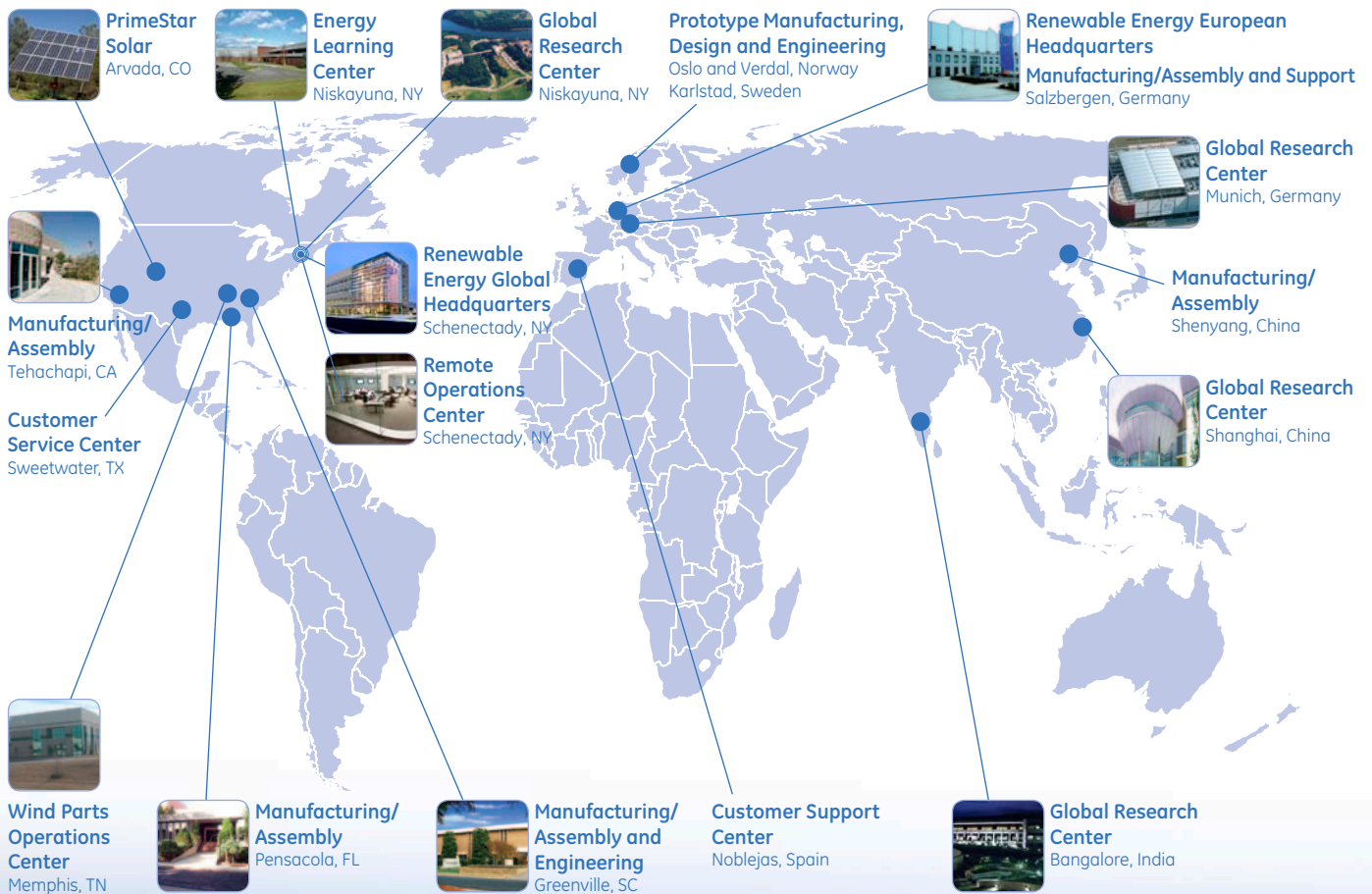
## The Industry Workhorse

- Continual investment ...  
focused on increasing customer value
- Product evolution...  
world's best running fleet
- Provide portfolio flexibility ...  
value where you need it

# 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.



# Advancing Wind Capture Performance

As a leading global provider of energy products and services, GE continues to invest in advancing its 1.5 MW wind turbine series with a core focus on enhancing efficiency, reliability and site flexibility. GE understands what customers value and responds with technology enhancements aimed at capturing maximum wind energy for greater return on investment.

Launched in 2004, the 1.5-77 model has earned the reputation for being the industry workhorse and delivers exceptional turbine performance and reliability. Relying on proven technology and experience, GE continues to differentiate its product leadership with evolutionary advancements in blade, drive train and controls technology.

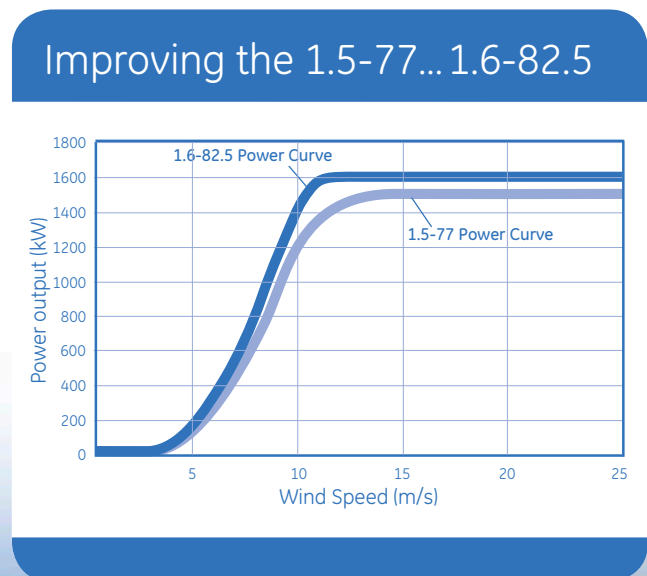
With the use of advanced load controls the 1.5-77 can now be sited in IEC Class I wind regimes. GE advanced its original Class I wind turbine, the 1.5-70.5, with increased rotor length and controls technology resulting in a greater annual energy production. GE's 1.5-77 wind turbine is available in both 50 and 60 Hz for use in IEC Class I environments.

## Advancing the Industry Workhorse

GE's 1.6-82.5 model was designed and built on the success of the 1.5-77, changing only what was required to increase customer value. The 1.6-82.5 model provides a 15% increase in swept area relative to the 1.5-77 and greater energy capture providing a strong return on investment. With the use of advanced load controls, the 1.6-82.5 can be sited in IEC Class II wind regimes.

Enhancements to GE's 1.6-82.5 wind turbine include an improved gearbox design and an upgraded pitch system. GE's 1.6-82.5 wind turbine utilizes GE Energy's proven Mark\* V1e controller and advanced diagnostic capability to increase troubleshooting efficiency.

1.5 MW	2002	2009
Rotor Diameter (m)	70	82.5 → +12.5 m
Capacity Factor (%)	39	52 → +13 pts
Reliability (%)	85	98 → +13 pts





GE's 1.5 MW wind turbine series models are designed to maximize customer value by providing proven performance and reliability. Our commitment to customer satisfaction drives our continuous investment in the evolution of the 1.5 MW wind turbine series. The models described below provide flexibility for customer wind site conditions and optimization of wind turbine placement.

## 1.5 MW Wind Turbine Series Models

	1.6-82.5	1.5-77
Rotor Diameter (m)	82.5	77
Hub Heights (m)	80/100	65/80
Frequency (Hz)	50/60	50/60
Vavg (m/s)	8.5	10.0
Vref (m/s)	40.0	45.0
Ve50 (m/s)	56.0	70.0
Cut-In (m/s)	3.5	3.5
Cut-Out (m/s)	25	25
IEC Wind Class	IEC TC IIB	IEC TC IB



# Improved Flexibility

## Reinforced Tower

GE's investment in a reinforced tower design opens up new potential wind sites for our customers, enabling us to deliver reliable and safe products that meet product and regulatory compliance expectations. GE's reinforced tower sections have the same length and external diameter as the standard GE North American modular system, but are specially built to handle seismic loads.

- Allows wind farms to be located in designated seismic prone areas with good wind resources
- GE provides an evaluation to determine if the site requires reinforced tower due to seismic activity

## Increased Reliability

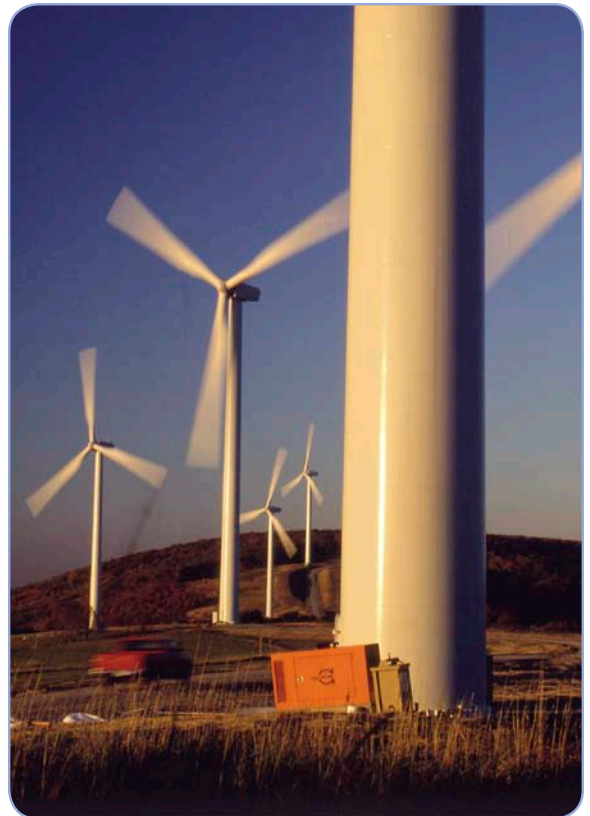
### Condition Based Maintenance (CBM)

GE Energy's integrated Condition Based Maintenance (CBM) offering proactively detects potential drive train issues, enabling increased performance and decreased maintenance expenses. Factory or field installed and tested, the CBM solution can improve reliability on a single wind farm or multiple wind farms. GE's CBM allows operators to understand an issue weeks in advance.

The CBM offering could allow wind farm operators to:

- Continue to produce power while parts, crane, and labor are resourced
- Plan multiple maintenance events with the same resources
- Reduce or limit the extent of damage to the drive train and reduce repair costs

Coupling our design expertise and Mark\* VIe control technology, based on GE Bently world leading vibration monitoring technology, enables all these system offerings.



# Inside the Industry Workhorse

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 more than \$1 billion in driving reliable and efficient renewable energy technology.

**GEARBOX**

- HALT testing on every design
- Cylindrical roller bearings
- Improved oil filtration, heating and cooling

**SOFT BRAKE SYSTEM**

- Hydraulic secondary brake

**CONTROL**

- GE Mark\* V1e controller
- Integrated pitch and converter diagnostics

**COUPLING**

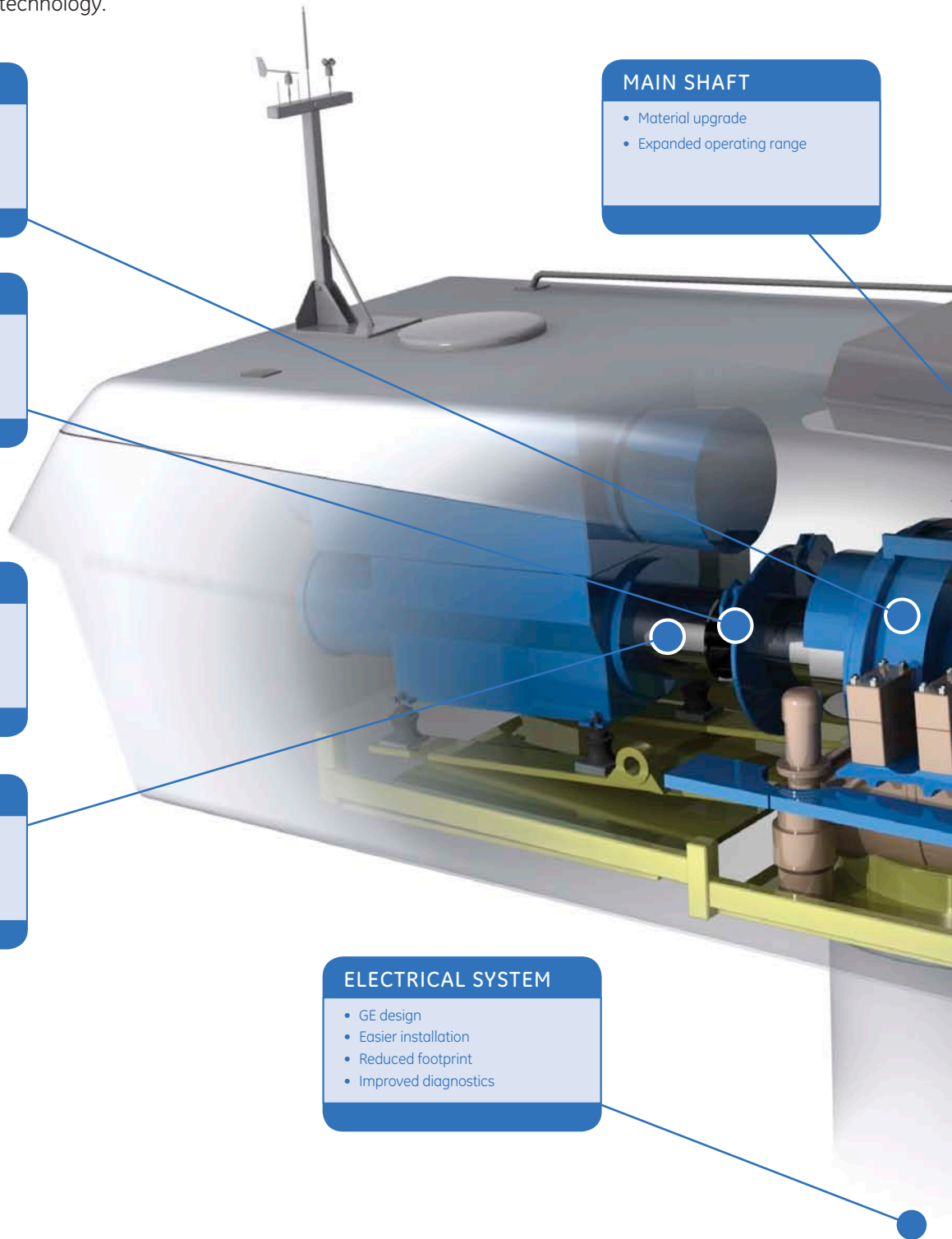
- Slip coupling design to reduce gearbox loads

**MAIN SHAFT**

- Material upgrade
- Expanded operating range

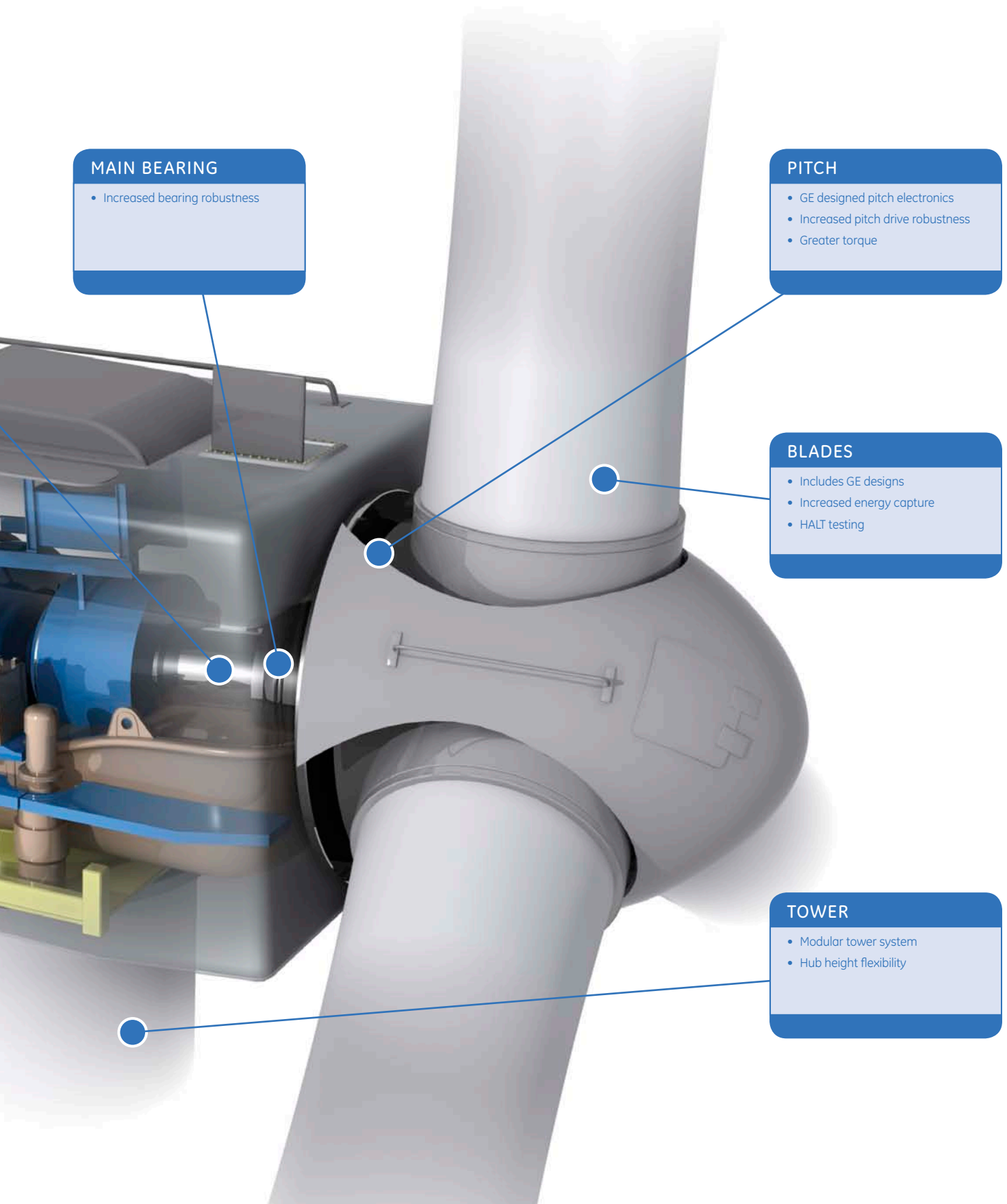
**ELECTRICAL SYSTEM**

- GE design
- Easier installation
- Reduced footprint
- Improved diagnostics





To optimize turbine reliability and availability, GE focuses on reducing the number of downtime faults, and providing faster Return-to-Service (RTS). Our rigorous design and testing process—including specialized 20-year fatigue testing and Highly Accelerated Life Testing (HALT)—reflects our ongoing investment in key turbine components.

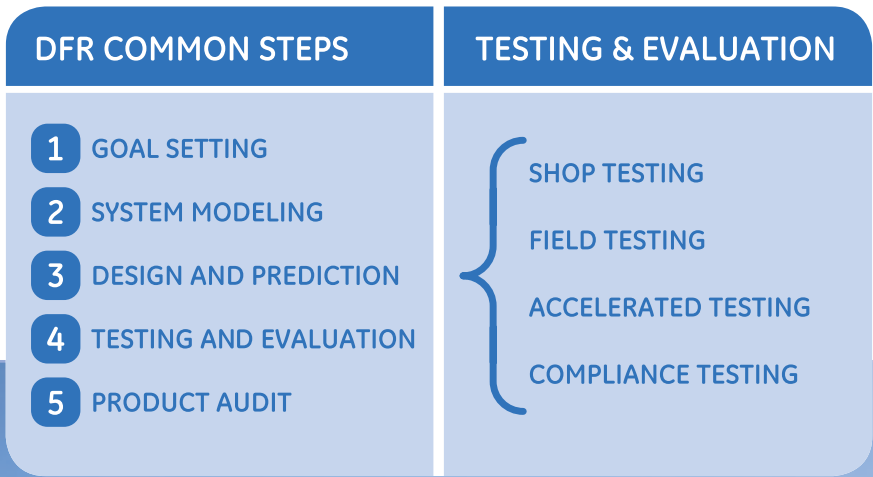


# Reliability by Design

The 1.5 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 applied 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 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 1.5 MW wind turbine series 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

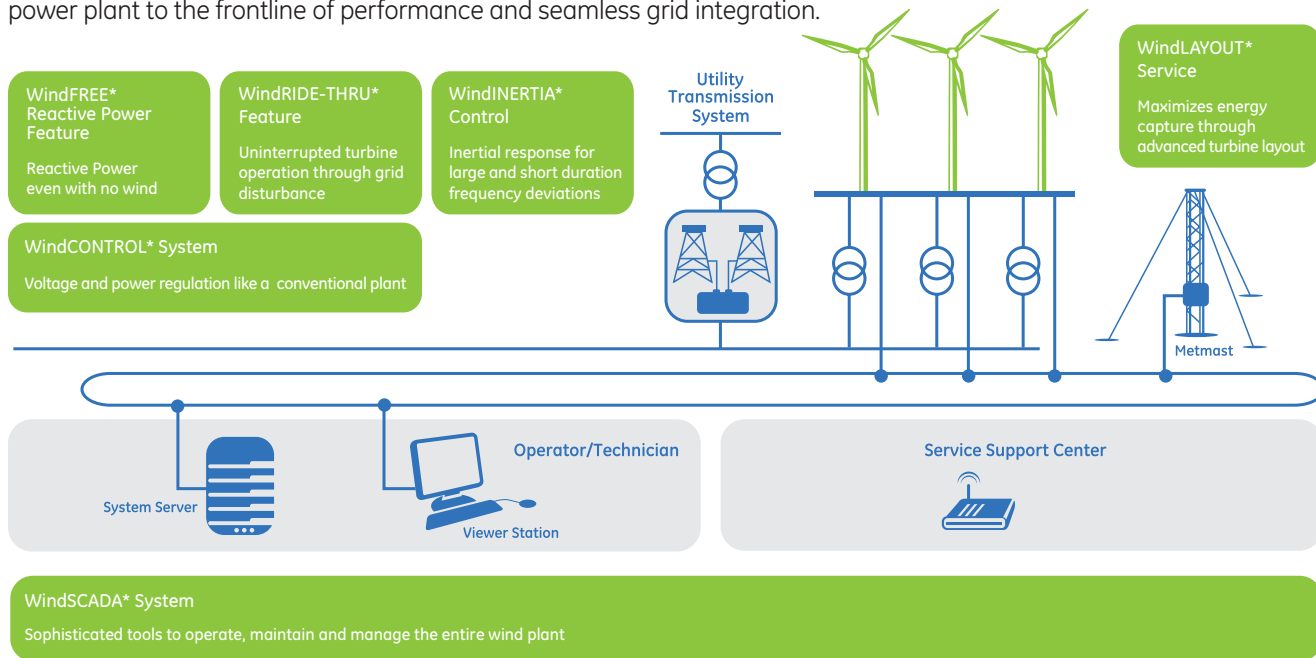
### Solar

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



# Optimized Wind Power Plant Performance

Wind turbine performance is a critical issue in light of increasingly stringent grid requirements. Our unrivaled experience in power generation makes us the industry leader in grid connection. By providing a sophisticated set of grid-friendly offerings similar to conventional power plants, GE's patented integrated suite of controls and electronics take your wind power plant to the frontline of performance and seamless grid integration.



Feature	Description	Benefits
<b>WindCONTROL* System</b>	Voltage and power regulation like a conventional power plant	Ability to supply and regulate reactive and active power to the grid Additional features include power frequency droop, power ramp rate limiters and integrated capacitor/reactor bank control
<b>WindFREE* Reactive Power Feature</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
<b>WindRIDE-THRU* Feature</b>	Low voltage, zero voltage and high voltage ride-through of grid disturbances	Uninterrupted turbine operation through grid disturbances Meets present and emerging transmission reliability standards
<b>WindINERTIA* Control</b>	Provides temporary boost in power for under-frequency grid events	Provides inertial response capability to wind turbines that is similar to conventional synchronous generators without additional hardware
<b>WindLAYOUT* Service</b>	Service to optimize turbine layout for a site	Opportunity to increase annual energy production for a site
<b>WindSCADA System</b>	Tools to operate, maintain and manage wind power plant	Real-time data visualization, reporting on historical data, alarm management and secure user access

# 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 state-of-the-art 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.

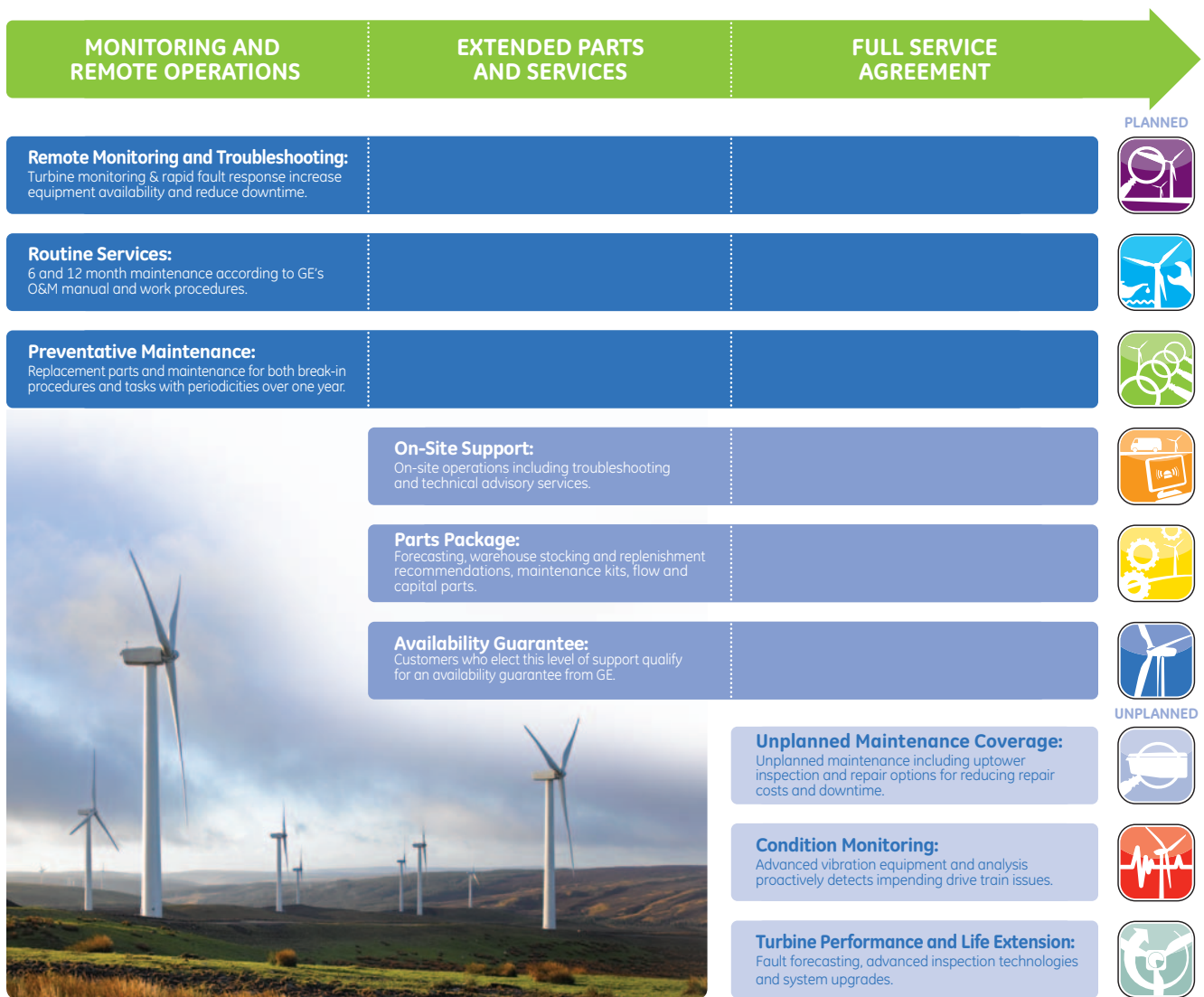
### **Wind Parts Center of Excellence:**

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. That's why the 1.5 MW wind turbine series has been engineered for ease of integration and delivery to a wide range of locations, including those with challenging site conditions.

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 Global Projects Organization utilizes decades of fulfillment expertise in project management, logistics, plant start-up and integration from Gas Turbine, Combined Cycle, Hydro, and Aero plants.

Here are some examples of how GE has worked with customers to solve project challenges and maximize their value through on-time delivery and advanced logistic capabilities:

**Challenge:**

Site with late grid availability due to project location change

**GE's solution:**

Pre-commissioning service: GE can utilize portable generators on site and pre-commission turbines even without back feed power

**Customer benefit:**

Faster commissioning once grid became available



**Challenge:**

Project site with difficult geographic access

**GE's solution:**

Well-choreographed team with challenging terrain transportation expertise

**Customer benefit:**

More site flexibility; schedule target met



## 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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GEA14954D (05/2010)