GE Renewable Energy
Onshore Wind
2019 Business & Product Overview

Imagination at work.

24 Internet-connected GE 2.85-103 wind turbines
Lake Huron, Ontario, Canada

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GE Renewable Energy
US$10B Revenue, 13k Employees, 55 Countries

Onshore Wind
Delivering low cost energy solutions with differentiated products & services
2 & 3MW wind turbine platforms
Optimizing hardware to get the most out of the wind resource

Wind Services
Focus on customer outcomes, realizing 1 AEP & profit over the lifetime of the fleet

Digital Wind Farm
A farm level solution—dynamic, connected & adaptable wind energy ecosystem

Offshore Wind
Setting the benchmark for the marine energies industry
Fixed bottom offshore wind turbines:
Haliade* 150-6MW
Floating offshore wind turbines
Haliade* 150-6MW
Wind services
(preventive and corrective maintenance)

Tidal turbines
Oceade* tidal turbines platform, including Oceade* 18 - 1.4MW, electrical subsea hub

Hydro
Collaborating with customers as the #1 player in the hydropower market
Hydropower solutions, products and services for:
- Low head hydropower plants
- Medium head hydropower plants
- High head hydropower plants
- Pumped storage hydropower plants
- Small hydropower plants
- Concentrated solar power plants
- Geothermal power plants
- Biomass power plants

Powering our customers with the world’s largest clean energy footprint

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GE Onshore Wind

- Advanced Manufacturing and Software Technology Center, Detroit, Michigan, USA
- Global Research Headquarters, Niskayuna, NY, USA
- Software CoE, San Ramon, CA, USA
- Greenville, SC, USA
- Pensacola, FL, USA
- Brazil Technology Center, Customer focused R&D, Rio de Janeiro, Brazil
- Sao Paulo, Brazil
- Camaçari, Brazil
- Onshore Wind Headquarters, Schenectady, NY, USA
- Global Research Europe, Munich, Germany
- Global Research Europe, Salzbergen, Germany
- Global Research Europe, Barcelona, Spain
- Pune, India
- Jack Welch Technology Center, Bangalore, India
- LM Wind Power, Wuxi, China
- LM Wind Power, Qinhuangdao, China
- Shenyang, China
- + 3 Customer Innovation Centers

Areas where Onshore Wind is commercially active
- Onshore Wind Energy Centers
- GE Global Research locations

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Evolution of the GE Portfolio

- 2002: GE enters the wind industry
- 2004: 2.5-88
- 2006: 2.5-100
- 2008: 2.75-100
- 2010: 2.75-103
- 2012: 2.5-120
- 2014: 2.5-120
- 2016: 2.75-120
- 2017: GE acquires Alstom
- 2019: 3.8-130
- 2019: 4.2-117

Nearing 40,000 deployed units and 20 years in wind
GE’s diversified wind product portfolio

Enhancing farm economics for a broad range of site conditions
Industry leading fleet availability

Our Track Record
94% Fleet availability
98%

Fleet availability chart showing year-over-year improvement from 2007 to 2017.

Our Guarantee
- 150+ rules and algorithms
  Early anomaly detection
- 120+ engineers
  Committed to fleet reliability
- 6 minute
  Remote Return to Service rate
- 325+ suppliers
  Right parts right away

Time Based
Timely delivery of maintenance with laser focus on uptime

Production Based
More production with strategic maintenance during low wind periods

2 Remote Operations Centers
11k turbines monitored 24/7/365

2 Repair Development Centers
Reduced downtime

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## 4.2-117

*High power & strength ... for high wind and Typhoons*

### What’s NEW?

<table>
<thead>
<tr>
<th>New Feature</th>
<th>Previous Models</th>
</tr>
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<tbody>
<tr>
<td>Advanced aero blade</td>
<td>3.2-103</td>
</tr>
<tr>
<td>Electrical upgrades</td>
<td>3.8-130</td>
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<tr>
<td>Typhoon strengthening</td>
<td>4.2-117</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC ed3 Wind Class</td>
<td>1S, 10 m/s</td>
</tr>
<tr>
<td>50-yr Vref</td>
<td>45 m/s</td>
</tr>
<tr>
<td>Gross AEP</td>
<td>20.3 GWh</td>
</tr>
<tr>
<td>Gross CF</td>
<td>54%</td>
</tr>
<tr>
<td>Hub Height</td>
<td>76.5, 85 m tube</td>
</tr>
<tr>
<td>Noise</td>
<td>107 dBA</td>
</tr>
</tbody>
</table>

**Technology**

- Model based controls
- Low noise trailing edge
- Typhoon strengthening
- Lightning enhanced blade
- Weak grid support

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## What’s NEW?

**NEW PLATFORM BUILT ON PROVEN ARCHITECTURE**

<table>
<thead>
<tr>
<th></th>
<th>5.3-158</th>
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</thead>
<tbody>
<tr>
<td>Wind Class</td>
<td>IEC Class 3S</td>
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<tr>
<td>Gross AEP</td>
<td>~20 GWh @ 7.5 m/s</td>
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<tr>
<td>Hub Height</td>
<td>101 or 121 m tube, up to 161 m hybrid</td>
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<tr>
<td>Noise</td>
<td>106 dB, NRO modes down to 98dB</td>
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<tr>
<td>Design Life</td>
<td>25 years</td>
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<tr>
<td>Amb Temp</td>
<td>-15 to +40 deg C</td>
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<tr>
<td>DECS</td>
<td>Prov: Available, Full: Aug ‘19</td>
</tr>
<tr>
<td>Type Cert</td>
<td>Prov: Oct ‘19, Full: 2Q’20</td>
</tr>
<tr>
<td>Key Technology Changes</td>
<td>• Carbon blade</td>
</tr>
<tr>
<td></td>
<td>• Up-tower DFIG MV electrical</td>
</tr>
<tr>
<td></td>
<td>• Loads management &amp; control</td>
</tr>
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<td></td>
<td>• AC pitch system</td>
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LM 77.4 P blade overview

Blade architecture & structure – LM design
- Gelcoating
- UW & DW shells
- Carbon main spar
- Two shear webs
- LM root inserts
- Lightning system IEC 61400-24 Level 1

Blade geometry – Onshore Wind (ONW) lead
- Mix of ONW & LM profiles, fully tested in wind tunnels
- Optimized for aero add-ons (e.g., vortex generators, serrations)

Tip joint
- Split line at 65.4m to allow for better site access & reduced transport cost
- Blade tip connection developed by ONW, LM, Blade Dynamics, GE Global Research
- Blade root and tip joint connected at site through simple mechanical assembly
Blade logistics to site

- Example of blade root end transported with Schnabel-Dolly system...depending on country and project, a super wind carrier may be possible
- Total length of blade transport under 80m

Sample road study for a project in Germany
65.4m split blade on 78m transporter can pass – longer transports fails

Flexibility with tip clamp positions at 45m, 50m, 54m, 57m
Cypress Validation Unit

Validation Unit #1 status:

- Site is located in ECN test field, Netherlands
- Validation machine installation completed ✔
- First time online, 1st kWh Feb’19 ✔
- Rated power reached, 5.3MW, March ‘19 ✔
- Commissioning finalized: Early March ’19 ✔
- Operability phase: March/April ’19

Validation campaign:

- Installation of turbine power curve and load measurement systems ✔
- Power curve, noise & loads measurement starting in April’19
- Full blade static and fatigue tests at LM, expected complete 2Q’20
- 100+ tests of component, subsystem, operability, serviceability planned