Design drivers
Siemens Gamesa Renewable Energy

13 September 2017
We are stronger than ever

Order Book €20b
Products and technology in 90+ countries
Close to 27,000 employees
Annual revenue €10b
Installed capacity 75GW
Market capitalization €14b

Figures as of May 2017
A message from Markus Tacke, CEO

“Our company, Siemens Gamesa Renewable Energy, has tremendous capabilities. We have a unique opportunity to establish ourselves as a market leader and a technology leader, while at the same time delivering sustainable value to our many stakeholders. I am proud to lead this effort.”

Markus Tacke, CEO
A broad and versatile **Product Portfolio**

<table>
<thead>
<tr>
<th>Wind Speed</th>
<th>Product</th>
<th>Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Wind</td>
<td>G114-2.1 MW</td>
<td>Siemens</td>
</tr>
<tr>
<td>Medium Wind</td>
<td>SWT-2.3-108</td>
<td>Gamesa</td>
</tr>
<tr>
<td>High Wind</td>
<td>G97-2.0 MW</td>
<td>Siemens</td>
</tr>
</tbody>
</table>

- **Onshore < 3 MW**
  - SWT-2.5-120
  - G126-2.625 MW

- **Onshore > 3 MW**
  - SWT-3.15-142
  - G132-3.465 MW

- **Offshore**
  - 4 – 6 MW
  - 8 – 10 MW

**Platforms**

- Siemens G2 platform: Geared turbine with asynchronous generators and FC
- Siemens D3/D6 platform: Direct Drive turbine with PMG + FC
- Gamesa 2.0 MW platform: Geared turbine with DFIG
- Gamesa 2.5/3.3 MW platforms: Geared turbine with DFIG (PMG + FC optional)
- ADWEN 5.0/8.0 MW platform: Geared turbine with PMG + FC

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May 2017

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Market update

There is a market for renewables

Total energy consumption (Mtoe)

thereof Electricity (TWh)

2014

- Wind: 5.4x TWh forecasted

2040: Forecast

- Wind: 8.6x TWh needed!

2040: Required for 2°C target

- Wind: 450 scenario - Required scenario for 2°C Paris target

Significant growth of renewables beyond all current FC required to reach the ambitious 2°C target

1) IEA WEO 2016 NPS  
2) 450 scenario - Required scenario for 2°C Paris target  
3) Other RE incl. Hydro

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Market update

Wind power needs to be competitive with all energy sources

Levelized Cost of Electricity – Wind

Unsubsidized Levelized Cost of Energy Comparison

Source: Lazard – Levelized Cost of Electricity ver 10.0, December 2016

Continuous focus on cost required to compete with alternative energy sources
Market update

Wind market is characterized by high development cost and complexity

- **Automotive**
  - High R&D cost
  - Short product life cycle
  - High volume
  - Fast development

- **Aircraft**
  - High R&D cost
  - Long product life cycle
  - Low volume
  - Slow development

- **Wind turbine**
  - High R&D cost
  - Short product life cycle
  - Low volume
  - Fast development

Innovation is required to handle the wind market development conditions
How do we deliver best design solutions to customers?

1. Understand and meet CUSTOMER NEEDS
2. Consider the VALUE CHAIN
3. Follow the DESIGN APPROACH
Customer needs

What matters to the customer?

- Levelized cost of electricity
- Capacity factor
- TCO Service Warranty

Customer focus is key – and broader than LCoE
Customer needs

Holistic view on the costs and performance is the key for success

Levelized Cost of Electricity

Investments
- Project cost (CAPEX)
  - WTG++
  - Project Management cost
  - Financing costs

Investments
- Grid access
- Foundation
  - Transition Piece
  - Installation Logistics

Operation & Maintenance Cost
- O&M cost (fixed and variable)

CAPEX

BOP

OPEX

Lifecycle Energy Output

Energy Output
- Annual Energy Production (net)
Innovative thinking is necessary to further increase the capacity factor

**Onshore wind capacity factor**

- Some subsidy schemes (PTC)
- Auction based tender system
- Large scale integration in utility system

Source: Bloomberg New Energy Outlook 2017

Capacity constraints in some onshore and offshore markets drives development towards larger rotor size
Customer Needs

Total Cost Of Ownership (TCO)

De-risk of TCO

- Low CAPEX
- Known O&M cost
- Long Term Program - LTP ®
- Proven technology

Net present value (NPV)

Leading edge protection example

Initial AEP knockdown needs to counterbalance NPV of repair costs and AEP over lifetime

Initial CAPEX is certain, whereas NPV of future energy production (AEP) and O&M is uncertain

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Product development value chain consists of various elements:

1. Manufacturing Concept
2. Factory & Transport Constraints
3. Global Footprint
4. Development Cost
5. Product Platform Strategy
6. Customer & Market

Time-to-market:

- Research & Development
- Design & Engineering
- Prototyping & Industrialization
- Component Production
- System Integration
- Sales & Service
Product development and the global footprint has to be aligned
Blade factory in Aalborg, Denmark
Transporting 6MW nacelle to test site in Høvsøre
Value Chain

Manufacturing concepts for safe and innovative product portfolio

Why Integral Blades?

- One-shot manufacturing technology
- No adhesive joints
- Vacuum-assisted epoxy resin transfer molding (VARMT)
- Unrivaled strength and performance
- Reduced EHS risk
Value Chain

Product platform strategy that increases flexibility and minimizes cost

Different rotors with same nacelle, generator and hub

Onshore Direct Drive
Siemens D3 Platform

Low wind, IEC IIIA
Medium wind, IEC IIA
High wind, IEC IA

Modularization enables shorter time-to-market and lower CAPEX
Value Chain

Product platform strategy that increases flexibility and minimizes cost

Same rotor for further developed machine

Offshore
Direct Drive

Siemens
D8 Platform

Modularization enables higher flexibility and larger volume
Most of the development costs are committed in the early design phases

- The product cost is determined by
  - Development costs
  - Capital costs
  - Manufacturing costs
- The return of investment is governed by capital cost and time-to-market
- All cost factors tie back to the product development early phases
Value Chain

TD planning and integration into the PD ensures short Time-to-Market

What technology choice? When do we start to sell? When do we start to manufacture?

Product Development (PD) Technology Development (TD)

Time-to-Market

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There are various elements to consider regarding the design approach:

- Design for Manufacture
- Design Risk
- Design Tools
- Technology Roadmap
- Design Strategy
- Design Knowledge
- Modularization

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Design Approach

Initial design choices are governed by the design strategy

- Overall vision and marketing sets the direction
- Innovation and R&D profile sets the bar
- History and capability is the foundation
The demand for technology must come from product needs…
…therefore products must drive the technology development
Design Approach

Modularization approach allows to save cost and increase flexibility

Product architecture:

- Allocate product function to physical components
- Specify interfaces between physical components
- Design modules independently

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Design Approach

Technology readiness level (TRL) is the key factor in risk management

<table>
<thead>
<tr>
<th>TRL 1</th>
<th>Basic principles observed and reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRL 2</td>
<td>Technology concept and/or application formulated</td>
</tr>
<tr>
<td>TRL 3</td>
<td>Analytical and experimental critical function and/or characteristic proof-of-concept</td>
</tr>
<tr>
<td>TRL 4</td>
<td>Component and/or breadboard validation in a laboratory environment</td>
</tr>
<tr>
<td>TRL 5</td>
<td>Component and/or breadboard validation in a relevant environment</td>
</tr>
<tr>
<td>TRL 6</td>
<td>System/subsystem model or prototype demonstration in a relevant environment</td>
</tr>
<tr>
<td>TRL 7</td>
<td>System prototype demonstration in a space environment</td>
</tr>
<tr>
<td>TRL 8</td>
<td>Actual system completed and “flight qualified” through test and demonstration</td>
</tr>
<tr>
<td>TRL 9</td>
<td>Actual system “flight proven” through successful mission operations</td>
</tr>
</tbody>
</table>

Simulation & Validation

System demonstration

Field experience

Source: NASA, Technology Readiness Level (TRL), Oct. 28, 2012
Design Approach

Manufacturing has to be integrated into the design

Design to Manufacture (DFM) best practice:

- Focus on manufacturing and product life cycle
- Focus on concept phase
- Use cost modelling to understand direct & indirect cost
- Set common objectives for product & manufacturing
- Use balanced scorecard to drive product design choices

1. Do the right thing  ➔  2. Do things right

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Design Approach

Design knowledge hand over plays a crucial role

**Tacit knowledge**
- In People's heads
- Exchanged person-to-person
- Learned on-the-job

**Codified knowledge**
- Written down in design rules & design manuals
- Documented fleet experience
- Basis for most design tools

Designers make a difference when combining results from tools with their design knowledge

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Summary

- Understand how Market and Customer link to products and technology
- Optimize the value chain – not the turbine
- Design for manufacture – and cost
- Have a clear design approach – from strategy to design tools
- There is not a single grand tool out there – Use your own toolbox!
What are YOUR design drivers?
Thanks