GE Perspective on Wind Systems Engineering

2nd NREL Wind Energy Systems Engineering Workshop

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GE Global Research

Renewable Energy Systems Lab

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GE Global Research

Market-focused R&D

Global Research Center
Niskayuna, NY

India Technology Center
Bangalore, India

China Technology Center
Shanghai, China

Global Research Europe
Munich, Germany

Advanced Manufacturing & Software Technology Center
Ann Arbor, MI

Global Software Center
Silicon Valley, CA

Brazil Technology Center
Rio de Janeiro, Brazil

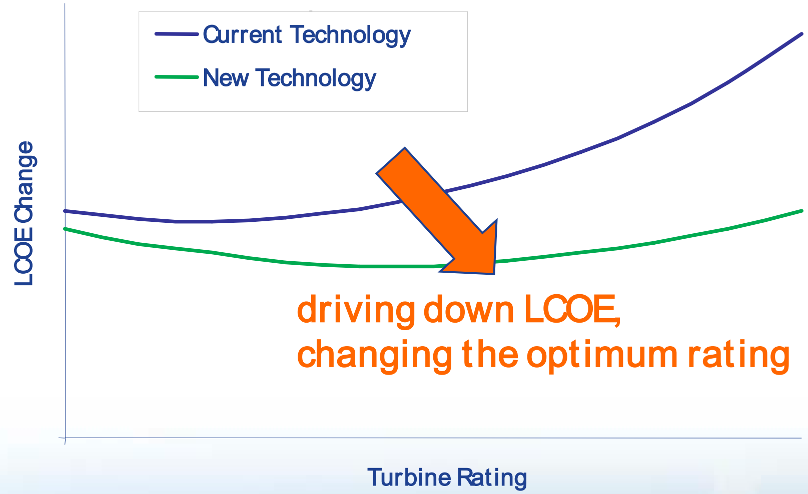
- ~2000 scientists/engineers, nearly two-thirds PhDs.
- 3,615 US patents filed by GE in 2011
- One of the world's most diversified industrial research organizations, providing innovative technology for all of GE's businesses

Cornerstone of innovation for GE

Wind System Engineering Objectives

Goal: Assess the system-level value of new technologies & next-generation product designs

- Many system-level trades
  - rating & rotor diameter
  - hub height
  - control strategies (loads vs. AEP)
  - component technologies (cost vs. perf)
  - rotational speed (noise, DT size, loads)
- Need system-level approach to optimize
  - performance
  - capital cost
  - operation & maintenance
- Non-obvious interactions abound



Optimizing technology development & product moves around lifetime value to wind farm

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System Value Optimization

Customers focus areas

	Component Level	Turbine Level	Farm Level	Fleet Level
Key Metrics	Lifecycle Costs	Lifecycle Costs Rotor Diameter & Rating	LCOE, NPV, IRR	Fleet Operations Balancing Costs
Operation & Maintenance	Planned maintenance Failure rates	Overall turbine O&M cost	Servicing strategy Grid Integration	
Annual Energy Production	Component efficiency	Turbine power curve	Wind Resource Wake & cable losses (siting)	Forecasting
Capital Cost	Localized loads Materials	Full loads Operational limits	BOP Costs Logistics	

Technologists typical focus areas

Complex multi-physics, multi-dimensional optimization at farm and fleet levels.

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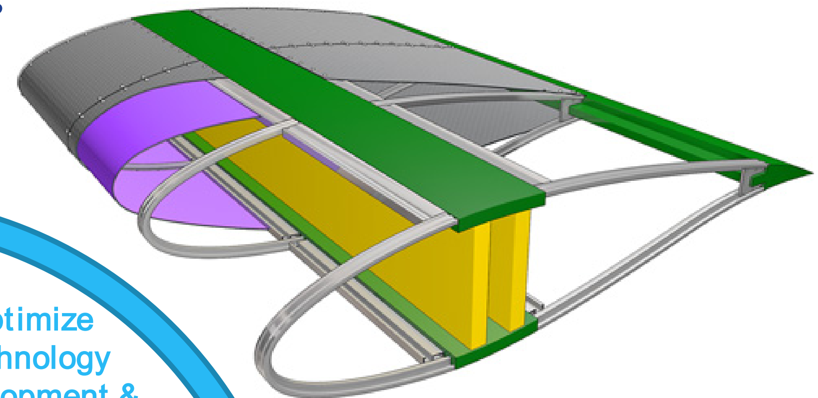
Technology Development Example

<u>Fabric Covered Blades</u>

GE (lead), NREL, & Virginia Polytechnic Institute
Wrapping architectural fabric around metal wind turbine blades



Component Level
- Reduce mass and cost of blade
- Aero performance
- Required maintenance

Specify turbine parameters

Turbine Level
- Turbine loads
- Operational limits such as noise
- Turbine power curve
- Overall turbine O&M

Specify market & environment parameters

Farm Level
- Logistic costs
- Foundation Size
- Installation costs
- Wake losses

Technology Value to Customer

Optimize Technology Development & Turbine Architecture

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Evaluate Technology Options Example

DFIG Drivetrain

GE moving multi-MW turbines to DFIG

Component Level
- Gearbox & generator cost (material costs)
- Gearbox & generator efficiency
- Required maintenance

Specify turbine parameters

Turbine Level
- Structural costs (bedplate, tower, etc.)
- Converter cost & efficiency
- Grid requirements
- Turbine power curve

Specify market & environment parameters

Farm Level
- Logistic costs
- Foundation size
- Installation costs

Technology Value to Customer

Evaluate Technology Options via Lifecycle Value to Customer

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Next Generation Product Designs

Inputs to Next-Generation Product Design

- **Environmental Conditions**
  - Wind speed distribution …most popular
  - Wind shear
  - Air density
  - Farm size

- **Market Conditions**
  - location …logistic costs
  - Incentives …reduces impact of capital or increases impact of generation
  - Financing & target rate of return …influences customer value

- **Technology Options**

Inherent Variability

Inherently Dynamic w/ Time

Requires system engineering to optimize new products decisions

Next Generation Product Example

	2003	2006	2009	2012
1.X Products				
IEC Class II	1.5-70 → 1.5-77 →		→ 1.6-82.5 →	→
IEC Class III		1.5-82.5 →		→ 1.6-100 →

Conditions leading to 1.6-100

<u>Wind Resource</u>:

- Increased market in IEC Class III …lower wind speeds

<u>Technology</u>:

- Better blade design …lower mass & cost
- Better control technologies …reduced loads
- Noise reduction technologies …allows rotor scaling

→ New Optimal for this Combination

Constraints leading to 1.6-100

Minimize component modifications:

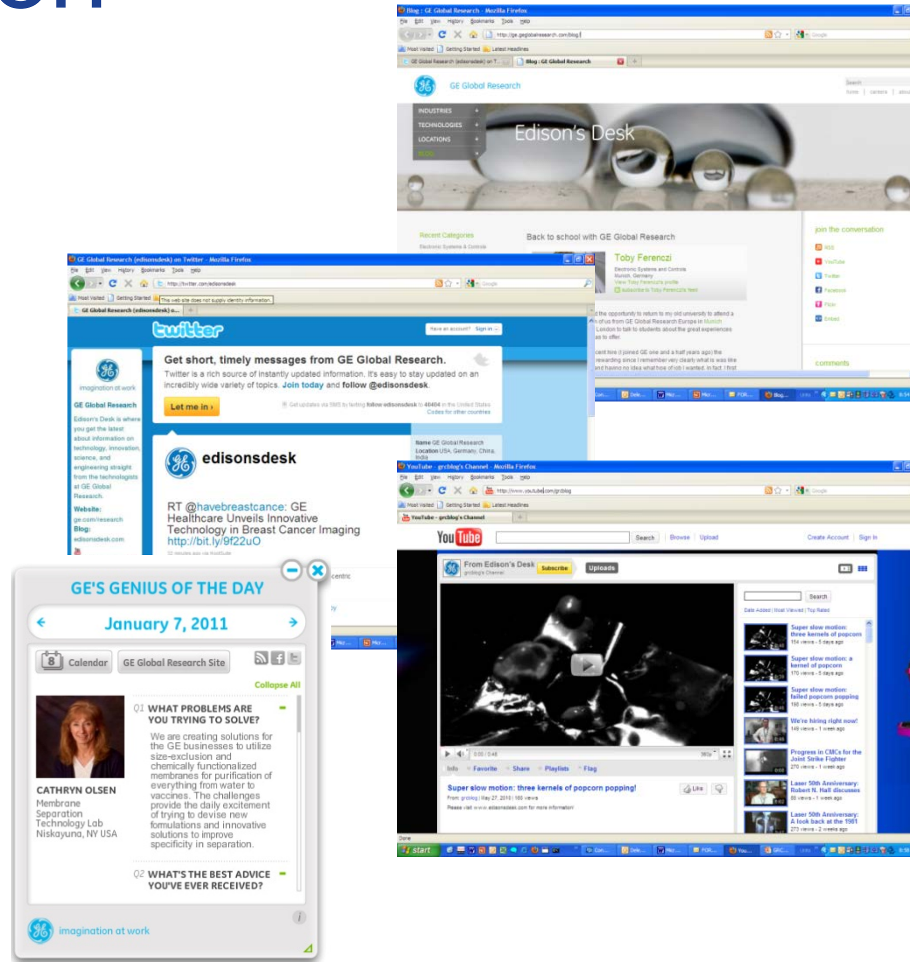
- Proven aerodynamics from 2.5MW rotor
- Proven high performance, reliability, & availability from existing turbines
- Fast product development …market & technology changing at a faster speed
- Minimize impact on supply chain
- Optimize current equipment

→ Many New Products are Evolutionary

Typical system-engineering

Industry specific design objectives

Join the conversation



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