



The Future of Composite Manufacturing in the Wind Industry

Optional subtitle

Matteo Bellucci

GE Renewable Energy

Outline

- GE RENEWABLE Energy - Mission
- Market Dynamic
- New Manufacturing Paradigm: 3D Printing
- Digitization of the Factory floor
- Innovation Ecosystem
- Conclusion

Outline

- GE RENEWABLE Energy - Mission



UNLEASHING LIMITLESS ENERGY



ONSHORE WIND



OFFSHORE WIND



LM WIND POWER



DIGITAL SERVICES



GRID SOLUTIONS



HYDRO



HYBRIDS

\$15B

REVENUE

80+

COUNTRIES

40,000+

GLOBAL EMPLOYEES

40,000+

WIND TURBINES
INSTALLED GLOBALLY

25%+

OF WORLD'S HYDRO
INSTALLED BASE

90%

OF UTILITIES
WORLD-WIDE USE
GRID SOLUTIONS
TECHNOLOGY

400+GW

INSTALLED BASE
THE WORLD'S LARGEST
CLEAN ENERGY
FOOTPRINT

>10%

OF GLOBAL
RENEWABLE ENERGY
CAPACITY IS PROVIDED
BY GE TURBINES



Our Priority: Providing Affordable Green Energy

UNLEASHING LIMITLESS ENERGY

Together with our **customers**,
powering the world with **green
electrons**

We're proving that no one ever has to choose between energy that is ...

RELIABLE

- Dispatchable
- Grid Integration
- Quality
- Secure
- Great Customer Experience

AFFORDABLE

- LCOE
(absolute & vs thermal)
- Economic Value
(for customers, partners, and GE)

ACCESSIBLE

- Transmission
- Local Expertise & Capability

SUSTAINABLE

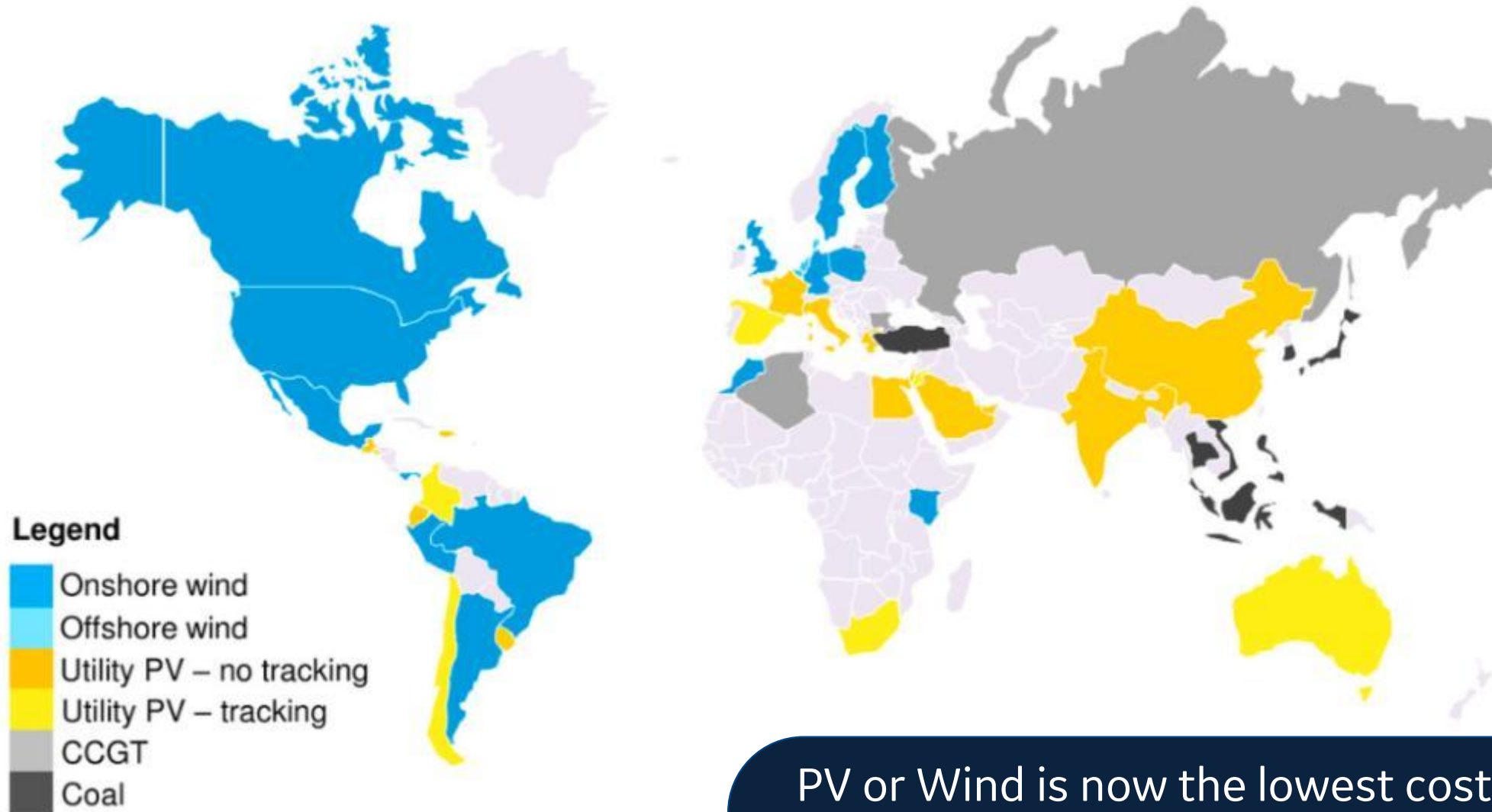
- Wind
- Hydro
- Solar
- Storage
- Hybrids
- Carbon Neutral



Outline

- Market Dynamic

Lowest cost source of new generation



PV or Wind is now the lowest cost option for new generation for 2/3 of global population



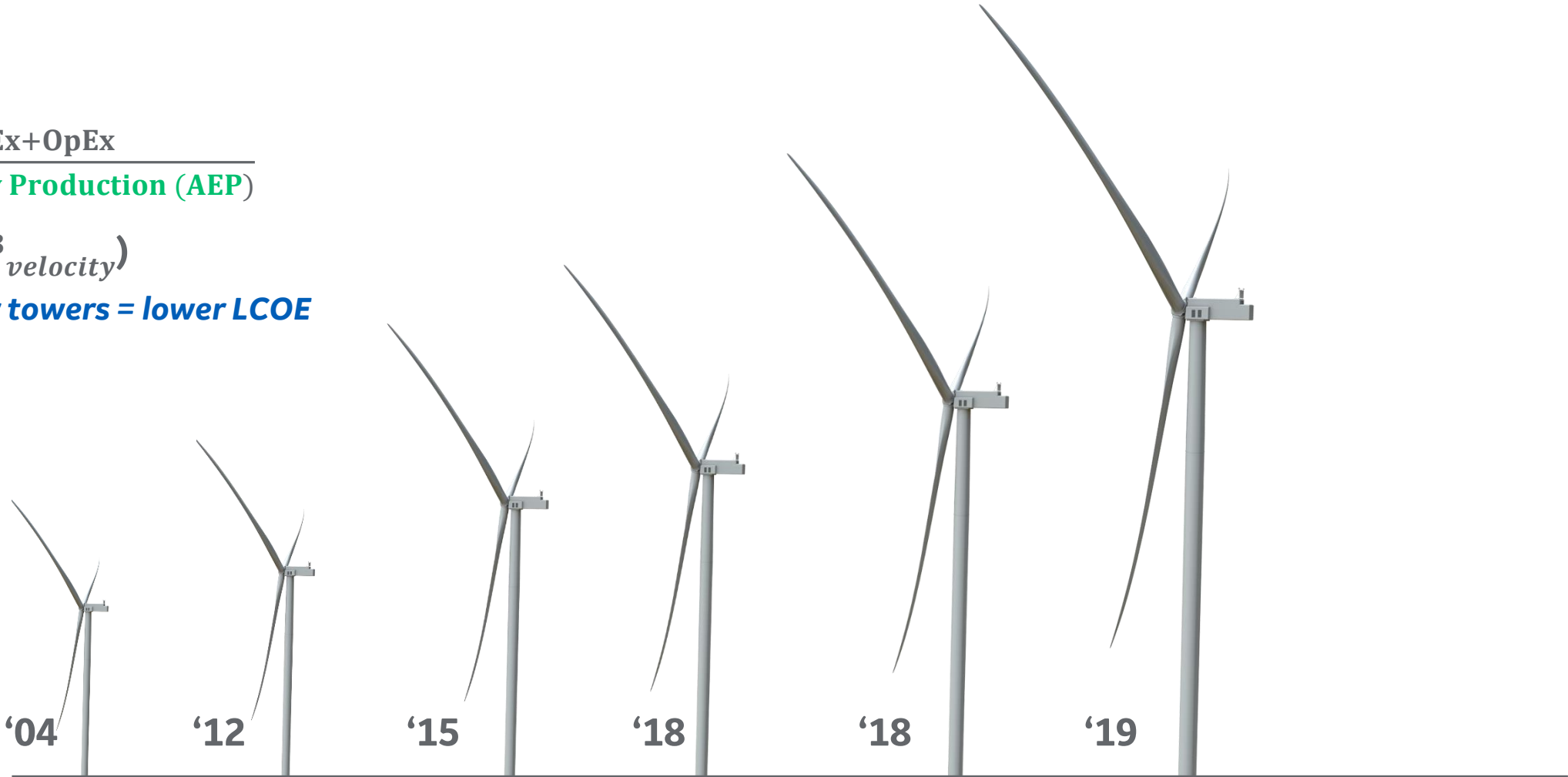
Source: BloombergNEF

LCOE & wind physics ... *technology offsetting cost growth*

$$\text{LCOE} = \frac{\text{CapEx} + \text{OpEx}}{\text{Annual Energy Production (AEP)}}$$

$$\text{AEP} = f(R^2_{\text{rotor}}, V^3_{\text{velocity}})$$

... larger rotors & taller towers = lower LCOE



MW-Rotor-HH	1.5-77-65	1.6-100-80	2.3-116-90	2.5-127-90	3.6-137-131	4.8-158-164
Energy Production	100%	150%	200%	220%	300%	400%
CapEx	100%	95%	85%	85%	70%	75%
LCOE Reduction	0%	20%	50%	60%	55%	70%



Sustainability in GE Renewable Energy

We believe **DECARBONIZATION IS IMPERATIVE AND POSSIBLE** to fight back climate change. Our sustainability approach is pragmatic and humble.

Walking the Talk

We are certified Carbon Neutral for our operations as of 2020, and constantly develop our Product and Sustainability Culture



Blade Recycling Partnership with Veolia



ZEBRA Project - Designing Recyclable Blades for the future



Our Carbon Neutral Operations Pledge



Employee Engagement: Our Green Team Network



Outline

- New Manufacturing Paradigm: 3D Printing



Additive Target Opportunity



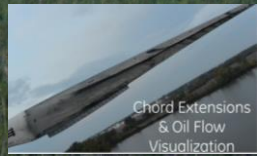
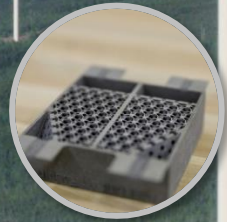
Rapid Prototyping

Service: spare parts on demand, on site

Tower: Concrete printing

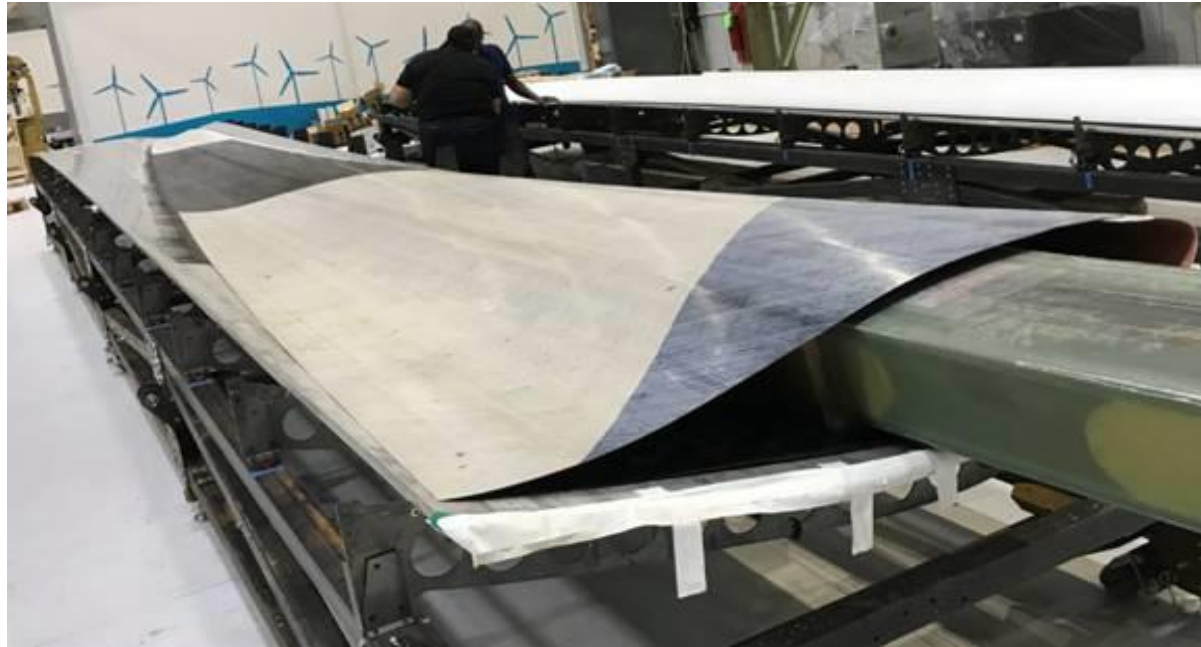
Rotor: Add on, Tooling, Molds

Machine Heads: Thermal Management, Prototyping, Tooling, Large Metal Structures



Short Term Benefit on Tooling, Prototyping... Long Term Potential is Disruptive

Technology | Printing Polymers



Experimenting 3D Printing for Production Parts

- Collaborations Across industries and Research Centers
- Hybrids manufacturing Processes – Additive/thermoforming/Automation
- New Thermoplastic materials

Using 3D Printing for Rapid Prototyping at Scale

- Reducing the time from conception to completion
- Largest ever 3D printed prototype GE has produced to date, mockup of the 2.5 MW rear entry hub.
- Verify design features to validate EHS & Production Tooling 6 months sooner VS conventional methods

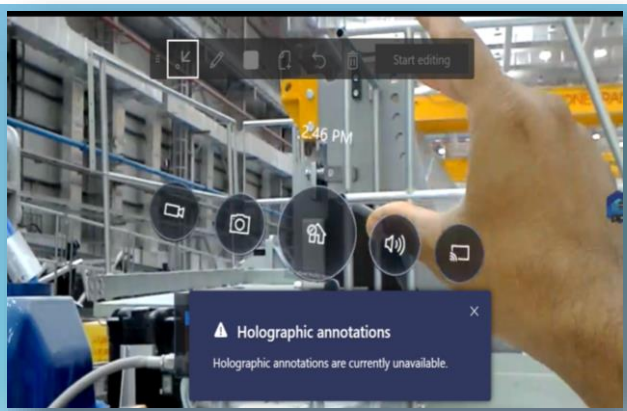


Outline

- Digitization of the Factory floor

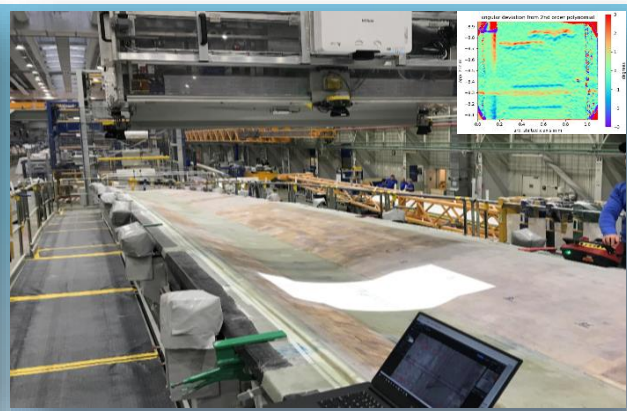


Industry 4.0 | Use Cases in Composite Blade Manufacturing



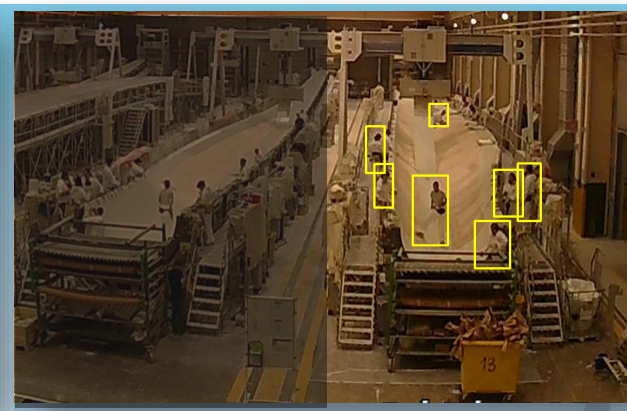
HoloLens 2

Provide remote support during New Product & Technology Introduction, Trainings, and Supplier Support during installation



3D Surface Scanner

Non contact 3D Metrology for Wrinkle recognition



AI Inspection

Use ordinary cameras to identify production phases, EHS Hazards & Ergonomic risks. Understand Best Practices for shared utilization



AI Inspection

Transform Shell manual inspection into an automated process that creates a digital inspection record for higher productivity, reduced defect escapements and over processing

Transforming Supply Chain Through... Digital Technology

Outline

- Innovation Ecosystem

Contemporary research ... GE's innovation legacy & scale

Discovery ... world's firsts

FOREGROUND IP



1879

Electric Lamp



1896

X-ray machine



1941

US jet engine



1998

Multi-slice CT



2006

Most eff. Wind turbine



2014

62%+ eff. Gas turbine



2017

Largest Additive Machine



2018

Patient guided mammo

Portfolio ... differentiated tech

BUILDING BACKGROUND IP

Top 10 global patents ...

63,000+

Broad applicability ...

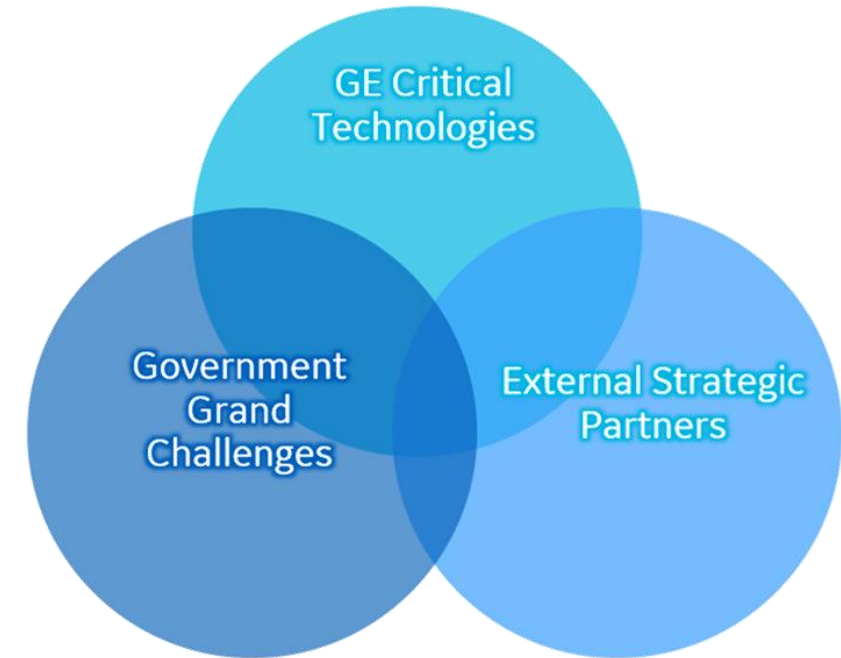
cross business, cross disciplinary

Market tested ...

product deployed

Prosperity ... ecosystem impact

GE BUSINESSES "+"



At the Center Of Moving the World's Technology Forward through Broad Innovation Network,

Knowledge sharing and Technical Depth & Breadth

Outline

- Conclusion

Conclusion

- Acceleration of renewable energy transition through turbine sizes and Sustainable Technology
- Rapid advancements in Additive & Digital manufacturing open up a whole new era for wind turbine design and construction
- GE Renewable Energy partnering across industry, governments and academia to accelerate a sustainable energy transition across design and supply chain

Thank You