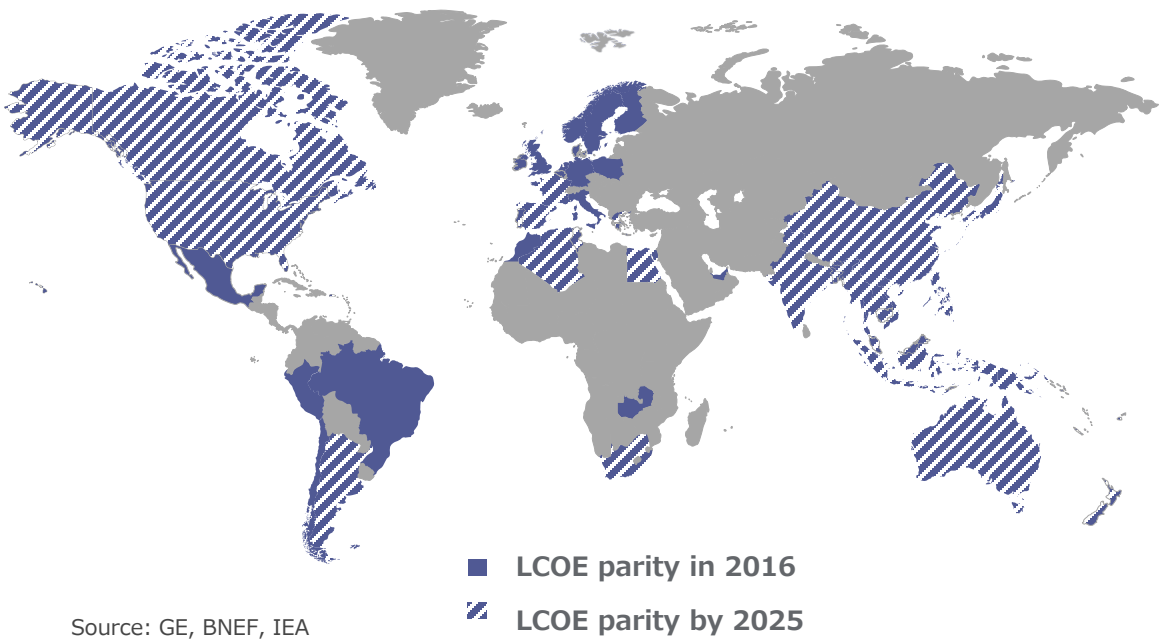
REvision2018:
Towards Massive Deployment of Low Cost, Renewable Electricity

Session 3: Bringing Sun and Wind in Japan

GE Renewable Energy
Hideyuki Ohnishi
March 7, 2018

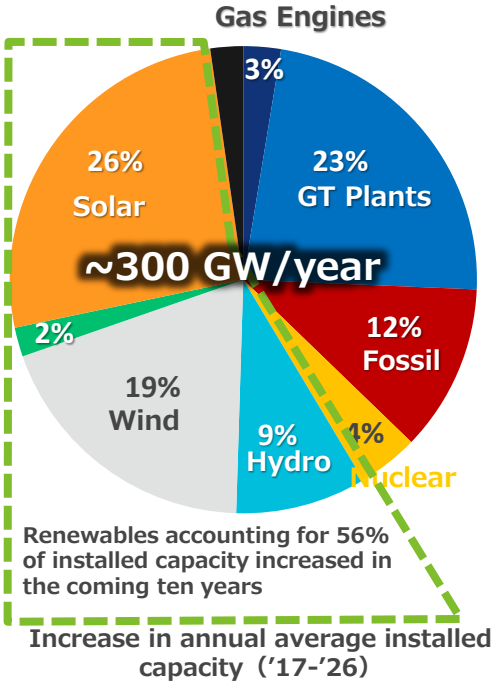
Renewable energy as main energy source

Renewable energy achieving grid parity



Source: GE, BNEF, IEA

Global investment in power plants
Mainly renewables and GT



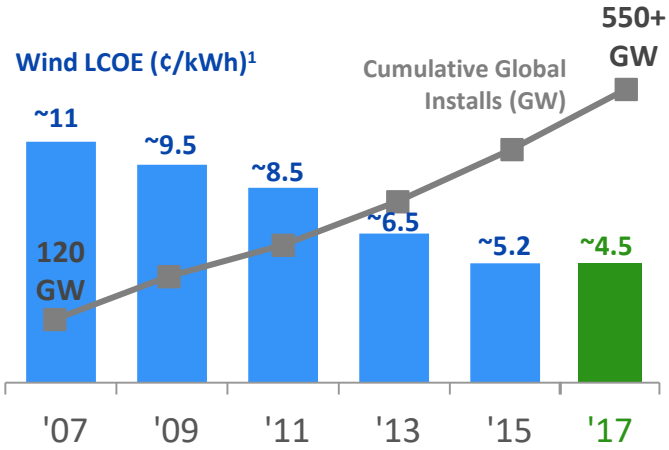
Source: GE, BNEF, IEA

- Renewables are expected to account for more than 50% of annual average installed capacity increased in the coming ten years.
- Some countries have already achieved grid parity of renewable energy and many countries are expected to achieve it by 2025.
- For the integration of renewable energy, countries have been increasingly reducing and abolishing subsidies and adopting an auction and bidding system.
- With the advance in renewable energy integration, renewables are required to achieve grid stabilization and flexible power instead of conventional generators. They have also raised new issues such as the reduced operation rate of fossil fuel power plants.

- Renewable energy has already become a part of the mainstream energy and "GRID FRIENDLINESS" is a further growth condition.
- The critical question is how to introduce competitive power sources and to sustainably reduce energy costs from the viewpoint of society as a whole.

Wind power generation in the world – Technological innovation and cost competitiveness

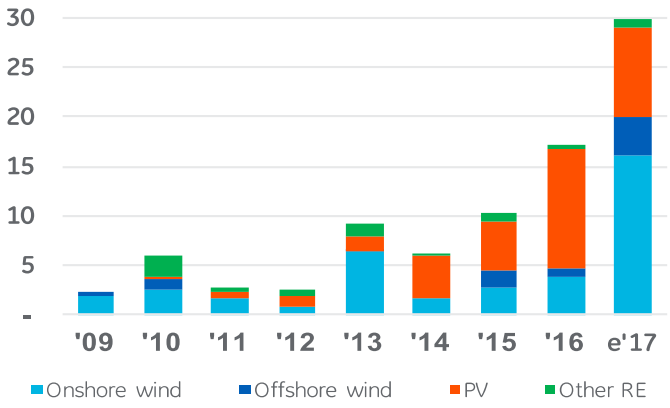
Quadruple the growth in ten years, 60% cost reduction



1- Germany, 7.5 m/s @164m hh, k=2, AD=1.21, σ=0.2, 5% WACC

Increasing auctions across the world

GW allocated through auction, by year, by technology

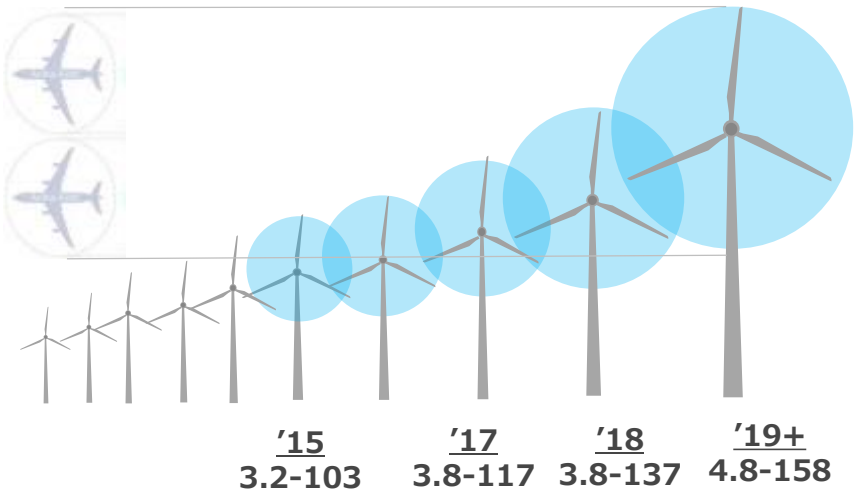


Sources: Bloomberg data 12/6/2016; GE Onshore Wind

Impact from the latest technology

- Installed capacity of wind power has been quadrupled and the power costs have been reduced by 60% in the last 10 years. Wind power as well as fossil fuels has become one of least expensive energy sources.
- Reduction of power costs has been further accelerated with market expansion and auction deployment in recent years.
- The history of wind turbines has been one of how to balance enlarged size, durability, reliability and cost reductions.
- GE has launched the latest wind turbine with a rotor diameter of more than 150 m, approximately 50 m bigger than the 2015 model.

The time to market of GE's latest wind turbine



Enlarged wind turbine – Project example

Project for large-sized wind turbine in Thailand

Project at the site of 5.4 m/s average wind speed

- 24 x 2.5-120, 60 MW, 110-m tower
- Started operation in July 2016

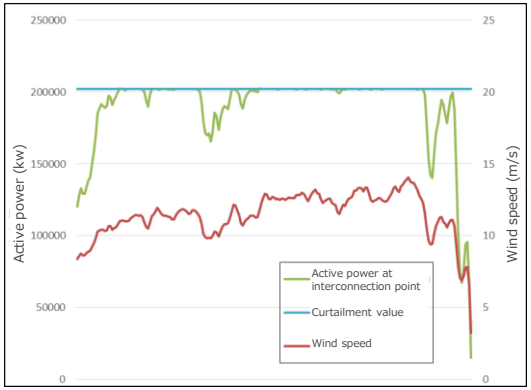
Project at the site of 6.0 m/s average wind speed

- 30 x 2.5-120, 75 MW, 120-m tower
- Started operation in Feb. 2017

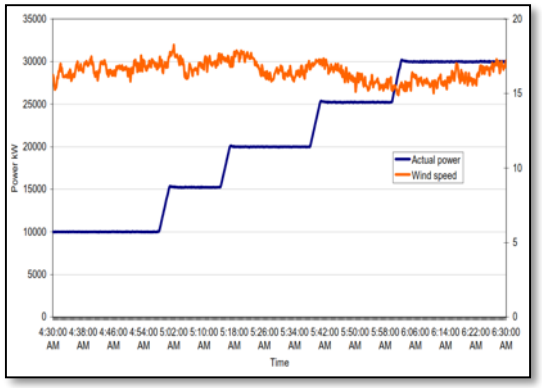
Other project at 5.0 m/s site

The world's largest onshore wind turbine blade shipped from LM Wind plant

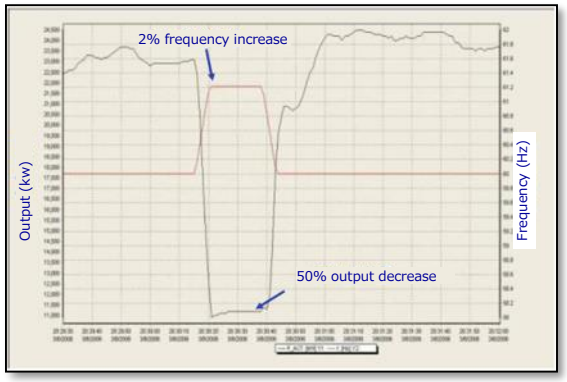
Wind power is an energy source capable of grid stabilization (ancillary service)



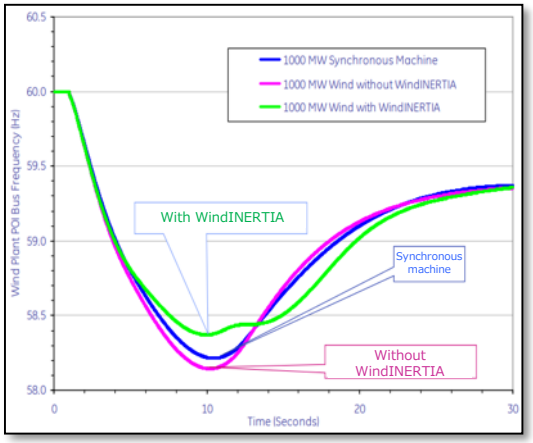
Curtailment
Operation to curtail power plant's output so as not to exceed predetermined output at interconnection point



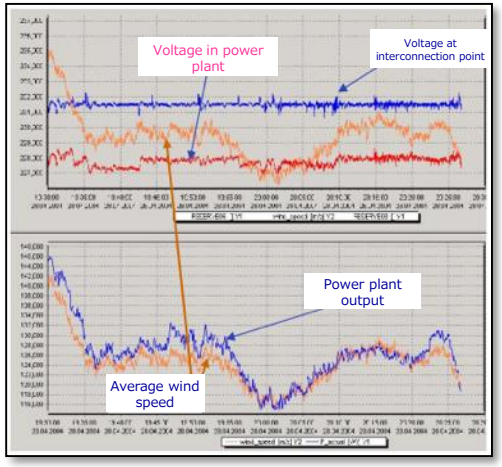
Output rate-of-change limiting
Control to change each wind turbine according to required control for output rate-of-change limiting due to system operation



Frequency droop
Automatically-controlled function to raise output with a decrease of frequency and reduce output with an increase of frequency



Inertial response (INERTIA)
Though frequency is lowered because of a shortage of supply power in the power system in case of accidents of a large-scale power source, etc., rotational energy of synchronous machines makes it possible to supply energy (inertia) and plays a role in preventing system breakdown beforehand



Voltage control
Function to apply constant voltage at interconnection point by continuously controlling reactive power of wind turbines

Source : GE

Wind power has already evolved to conduct output curtailment, upward and downward reserve capacity and reactive power supply, and can perform functions of system stabilization and flexible power similar to those performed by conventional thermal power plants.

Wind power generation does not depend on a wind.

Examples of renewable energy integration in Texas and Ireland

Texas

- Maximum power demand: 70 GW peak (82 GW ERCOT)
- Installed wind turbine (2017): 21 GW
- Generation by wind turbines: 12.6% in 2016
- Maximum wind power rate: 50% (23/03/2017)
- Storage of electricity: 52 MW cells

  (317 MW/96hr CAES compressed air verification test)
- Regional interconnection: 1,106 MW to East & Mexico

Success in Texas

- Creation of new market rule

  - From 15 minutes to 5 minutes, shift to nodal pricing

  - Request for role allotment for strict grid stabilization with wind turbines

  (Voltage ride-through, Primary Frequency response)

  - Estimation of power generation amount
- Arrangement of transmission lines in designated Competitive Renewable Energy Zone (CREZ)
- Dynamic pricing
- New ancillary service under current consideration (Ultra-short-term frequency stabilization and INERTIA)

Ireland

- Maximum power demand: 6,800 MW peak
- Installed wind turbine (2017): 3,800 MW
- Generation by wind turbines: 25% in 2016
- Maximum wind power rate: 68% (24/12/2016)
- Storage of electricity: 292 MW pumped-storage hydropower

  (300 MW/6hr CAES compressed air verification test)
- Regional interconnection: 500 MW to Great Britain

Success in Ireland

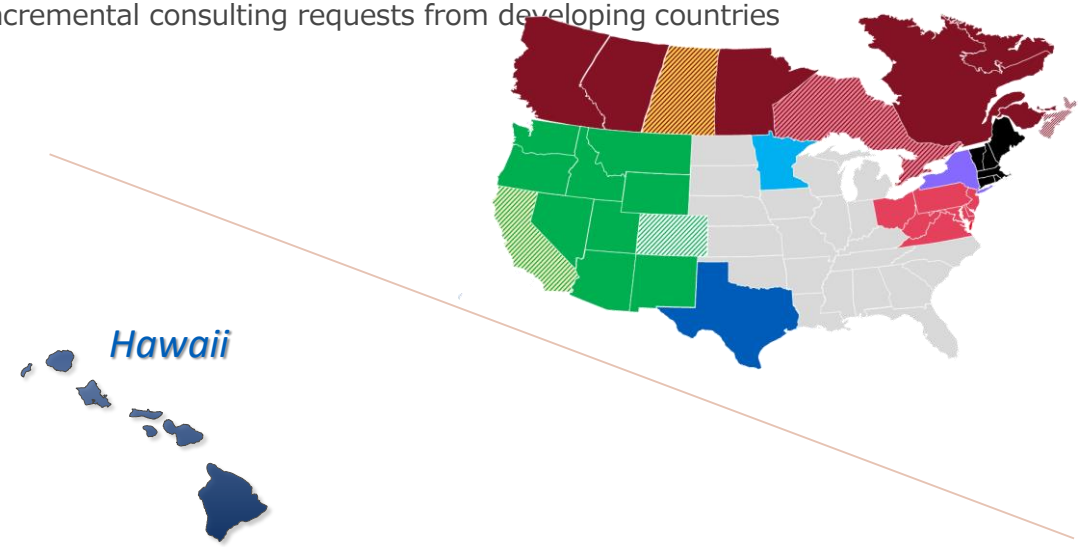
- Making use of favorable wind conditions and setting clear target of renewable energy integration as a nation (40% by 2020)
- Introducing the SNSP (System Non-Synchronous Penetration) index with a view to stabilizing the system frequency and increasing the rate from the current 60% to 100% in the future

  (An increase in SNSP from the current 60% to 75% as a part of the achievement of 40% renewables by 2020 is expected to cause a reduction in curtailment of wind power from 14% to 7%.)
- Trying to establish new ancillary service focusing on FFR (Fast Frequency Response) and stabilize frequency using wind turbine functions

Visualization of problems – system analysis/consulting service

GE Energy Consulting Service

- Projects requested from power companies, ISO, administrative agencies, etc.
- Integration analysis of renewables of more than 100 GW in total throughout the world
- Comprehensive analysis of cost efficiency, technical issues, environmental impacts, etc. and recommendation related to massive integration of renewable energy sources
- Incremental consulting requests from developing countries



Source: GE Energy Consulting

Project examples in North America

2004 New York
3 GW Wind
10% Peak Load
4% Energy

2005 Ontario
15 GW Wind
50% Peak Load
30% Energy

2006 California
13 GW Wind
3 GW Solar
26% Peak Load
15% Energy

2007 Texas
15 GW Wind
25% Peak Load
17% Energy

2009 Western U.S.
72 GW Wind
15 GW Solar
50% Peak Load
27% Energy

2010 New England
12 GW Wind
39% Peak Load
24% Energy

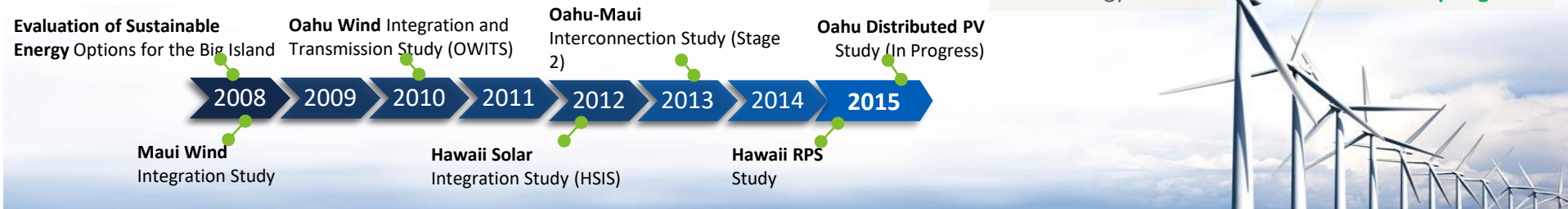
2012 Nova Scotia
~1500MW Wind
40% Energy

2013 PJM
96GW Wind
22GW Solar
30% Energy

2014 Minnesota
8 GW Wind
4.5 GW Solar
50% Energy

2016 Pan-Canadian
~72GW Wind
30% Energy

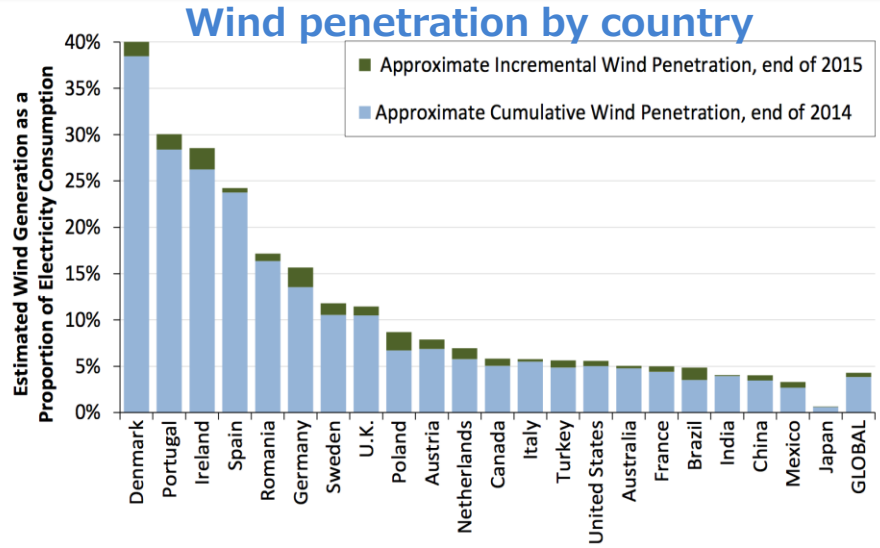
Underway
Saskatchewan
Colorado Springs



Conclusion

1. Renewable energy has already become a mainstream energy.

2. Wind power is an energy source **capable of dispatch and ancillary service** as well as output control. System operation and flexible power securement ignoring this function will cause unnecessary investment.



Source: Berkeley Lab estimates based on data from Navigant, EIA, and elsewhere

3. **Japan should learn even from other countries** to design power generation and system operation. First, outside perspectives should be considered with a view to **visualizing problems and challenges** for operation.

   (Learning case examples from Texas and Ireland, the improvement of flexible power should be systematically advanced in consideration of cost efficiency through not only storage of electricity but system operation methods and a wide range of technologies.)

4. A power transmission and distribution facility is defined by the maximum load in KW of a generator, while power generation and supply works by KWh.
   In the time of massive integration of renewable energy sources, existing power transmission and distribution facilities should be effectively utilized at first according to **Connect & Manage,** and flexible utilization of power transmission and generation should be demonstrated.