25th CEE Symposium with NEDO **October 19th, 2016**

Grid Integration Strategy for Variable Renewable Energy Highly Penetrated Energy System – Japanese Case-

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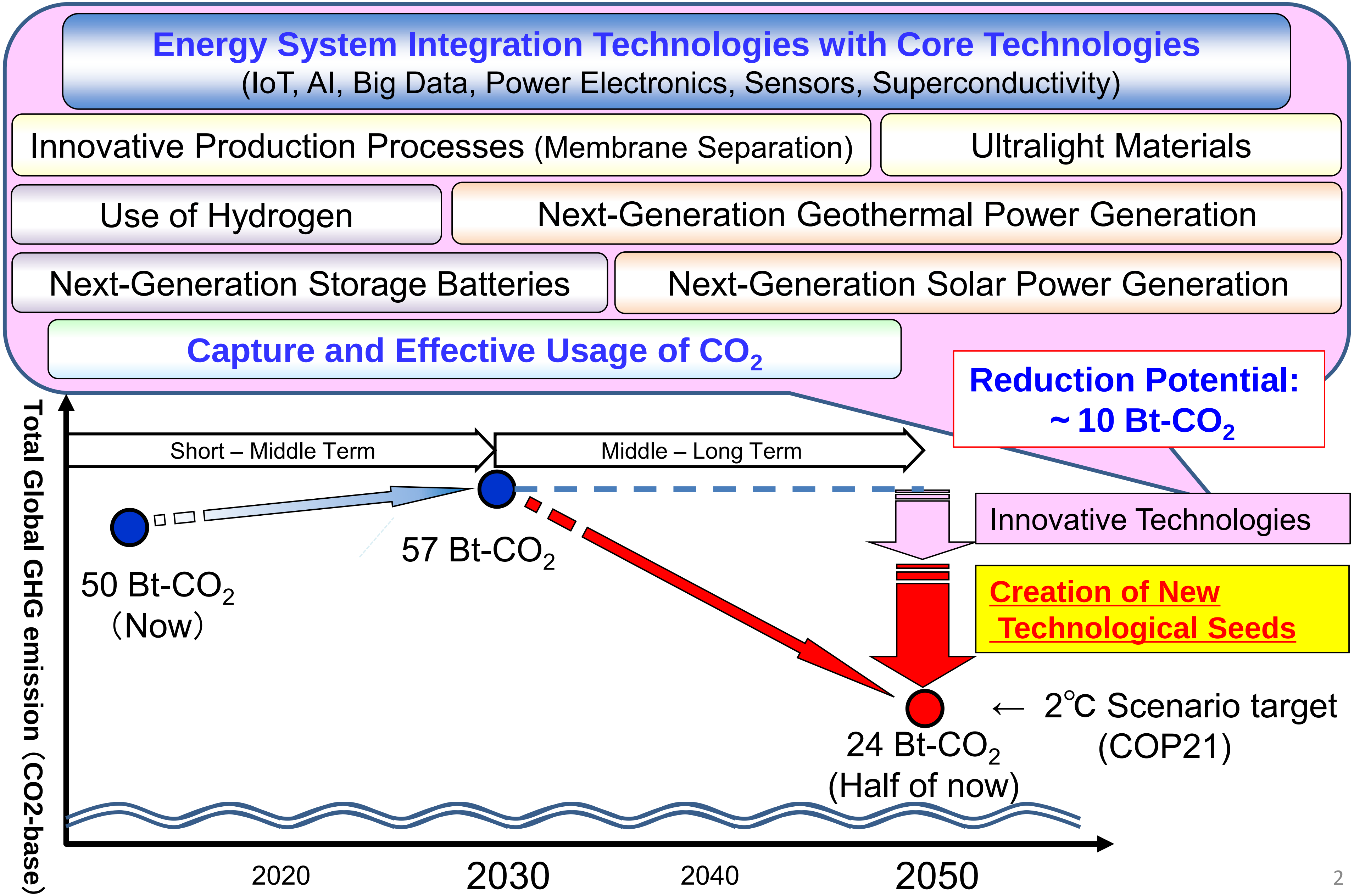
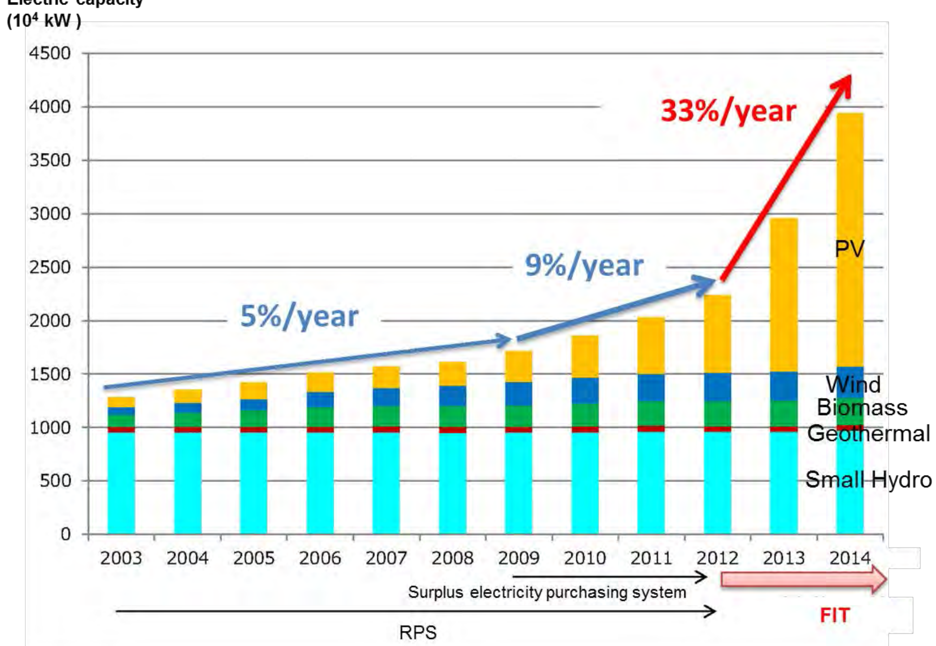
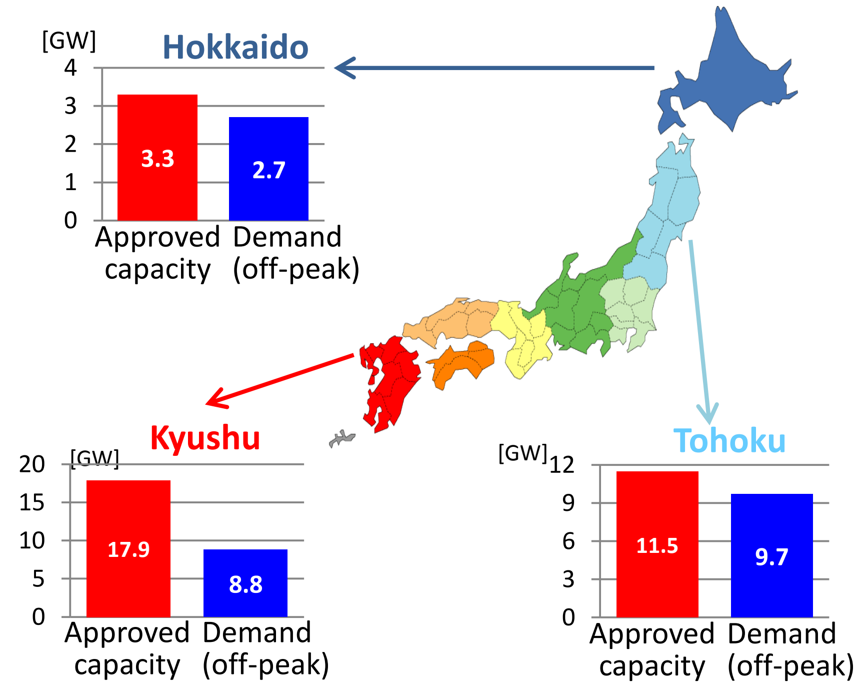

Energy System Integration Technologies with Core Technologies
(IoT, AI, Big Data, Power Electronics, Sensors, Superconductivity)
Innovative Production Processes (Membrane Separation)
Ultralight Materials
Use of Hydrogen
Next-Generation Geothermal Power Generation
Next-Generation Storage Batteries
Next-Generation Solar Power Generation
Capture and Effective Usage of CO_2
Reduction Potential: ~10 Bt-CO_2
Short – Middle Term
Middle – Long Term
Innovative Technologies
Creation of New Technological Seeds
50 Bt-CO_2 (Now)
57 Bt-CO_2
24 Bt-CO_2 (Half of now)
← 2℃ Scenario target (COP21)
Total Global GHG emission (CO2-base)
2020
2030
2040
2050

Trends on Renewable Energy in Japan

- PVs have penetrated rapidly after the introduction of Feed in Tariff (FIT) in July 2012.
- Installed capacity of PVs have surpassed 20GW at the end of FY2014 and is expected over 60GW in 2030.
- PVs account for 95% of certified capacity under FIT and are concentrated in specific areas such as Kyushu, Hokkaido and Tohoku. Approved capacity under FIT is greater than off-peak demand in these regions.
- We NEDO estimate around 10% of PVs generation would not be utilized if installed PV capacity reaches 70GW without any measures due to output suppression in off-peak period .

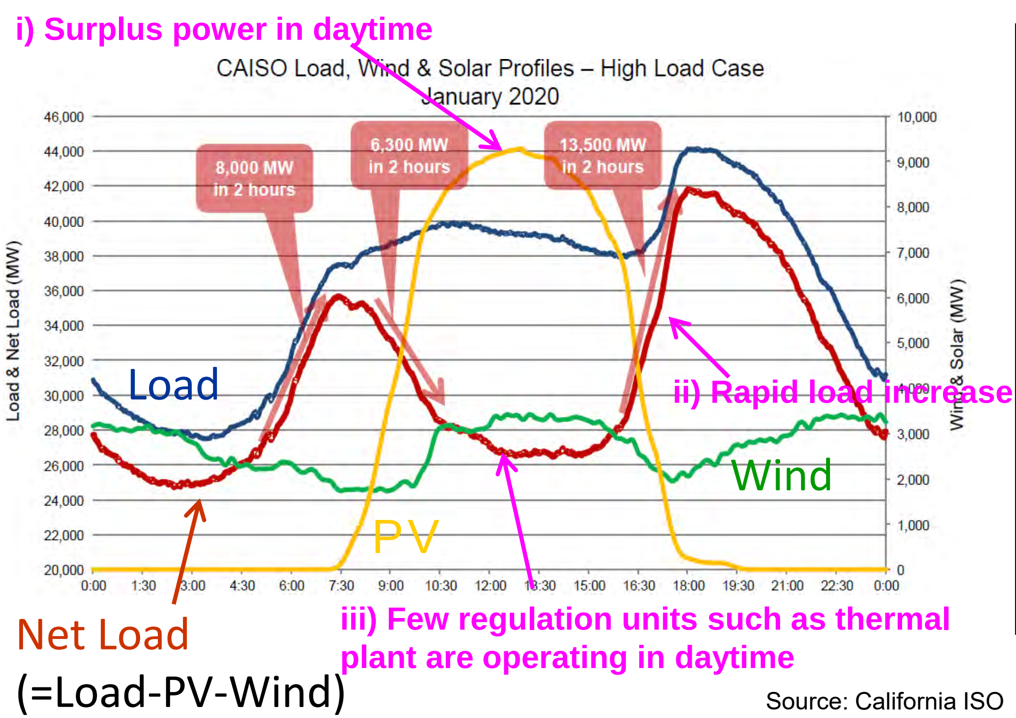
Installed Capacity of Renewable Energy





Future Problem on Power Grid caused by VRE

- *Large amount of variable renewable energy (VRE) may cause problems on power grid such as*
  - *i. Surplus power in daytime of off-peak period*
    - *hours to day time-domain*
  - *ii. Rapid variation of net load especially in evening time*
    - *10 minutes to hours time-domain*
  - *iii. Lack of regulation and/or load following capacity in daytime on sunny day*
    - *10s seconds to hours time-domain*



Source: California ISO

Measures against grid problem

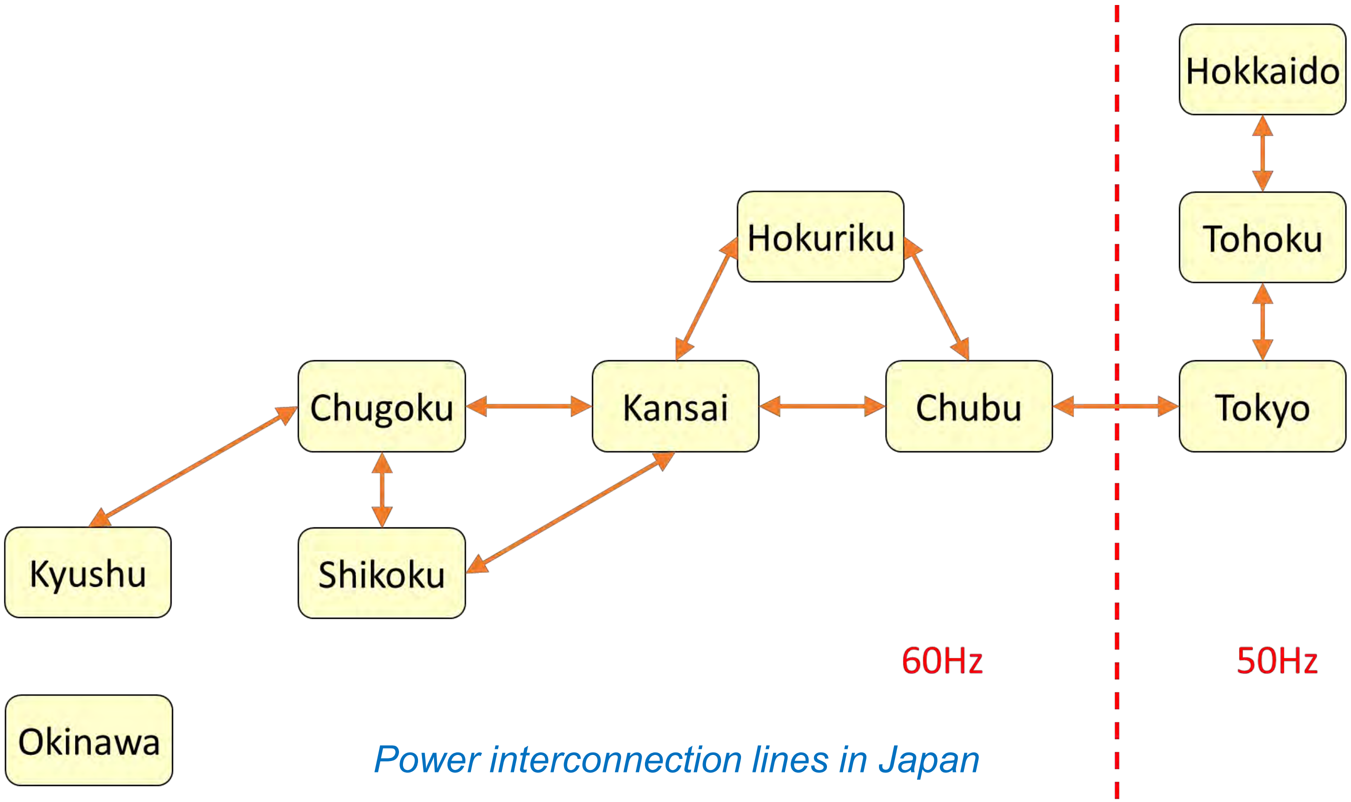
- *Generation management*
  - *Improvement of generation output forecast for variable generation*
  - *Generation suppression on light load*
  - *Improvement of thermal units' flexibility*
- *Demand side management*
  - *Improvement of thermal units' flexibility*
  - *Inter-regional operation of power grid*
- *Energy storage*

Measures against Issues on Power Grid

Measures	Grid Side	Generation Side	Demand Side
Fluctuation reduction of variable generation		✓	
Improvement of generation output forecast for variable generation	✓		
Demand Response			✓
Energy storage	✓	✓	✓
Generation suppression on light load		✓	
Improvement of thermal units' flexibility	✓		
Inter-regional operation of power grid	✓		

Simulation of Variable RE Highly Penetrated Energy System

- Based on the "the Outlook", evaluate the system operation issues of various further deployment scenarios of PV (64GW->103GW) and wind (11GW->32GW).
- Evaluate flexibility measures to overcome the integration issues.
- This study focuses on batteries, DR and load dispatch.
- In this study, we focused on Japan's power system as a whole.
- Japan's power system is composed of 10 balancing areas. The 9 areas in the four main islands are interconnected by AC and DC interconnections.



Power interconnection lines in Japan

Conditions of the Simulation

Object of This Study	Japan's power system as a whole (10 balancing areas)
Objective Function	Minimization of fuel cost for thermal power generation
Demand Curve	Actual results of energy demand in 2013
Composition of Power Sources	Composition in 2030 (Source: Long term energy demand and supply outlook, METI)
Power Grid	Considered only interconnection lines by AC or DC between 9 areas
Installed Capacity of PV and Wind	Case1) PV: 64GW, Wind: 10GW (Source: Long term energy demand and supply outlook, METI) Case2) PV: 103GW, 32GW (Source: RTS Corporation and JWPA)
Forecast Accuracy of Power Output of PV and Wind	Actual results of power output in 2013 Assumed 0% of prediction errors
Capacity of DR Resources	0, 10, 22 GW (Breakdown: DR potential of heat pump, EV, electric water heater, turbo refrigerator, reciprocating liquid chiller, and so on in 2015: 10.4 GW, EV/PHEV for DR in 2030: 12.1 GW)
Capacity of Battery for Frequency Trimming	0, 0.3, 1.5, 3.0 GW

Effect of Batteries and DR in 2030 (1/2)

- Fuel costs of entire Japan for the thermal power generation can be reduced by the battery introduction for the frequency trimming.
- Pay out time of battery 3GW is about 6 years since the annual amount of the fuel cost reduction is 60 billion Yen.
- Fuel costs for power generation in Japan decrease with increasing the amount of DR resources. DR is applicable not only to nega-watt regulation but also to posi-watt regulation.

① Fuel Cost Reduction by batteries in 2030

PV: 103 GW Wind: 32GW

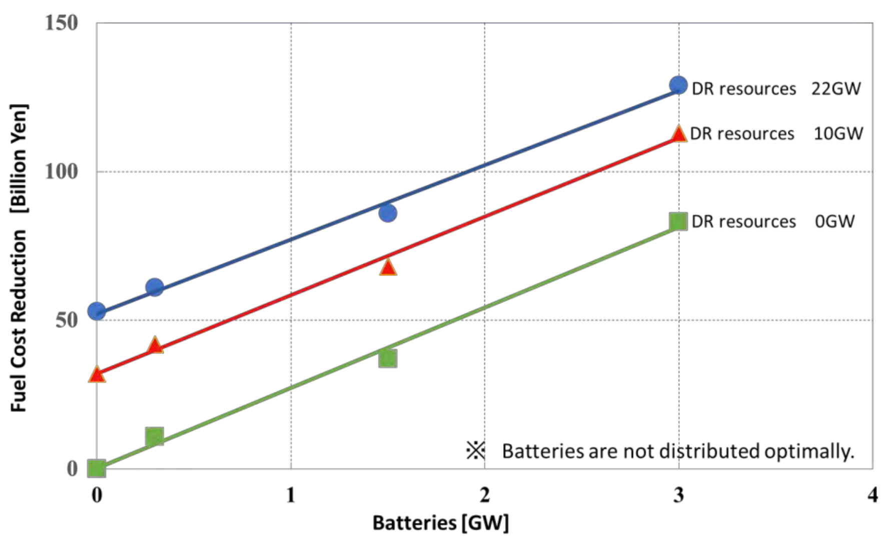


Fig.1 Fuel cost reduction as a function of battery power.

② Fuel Cost Reduction by DR in 2030

PV: 103 GW Wind: 32GW

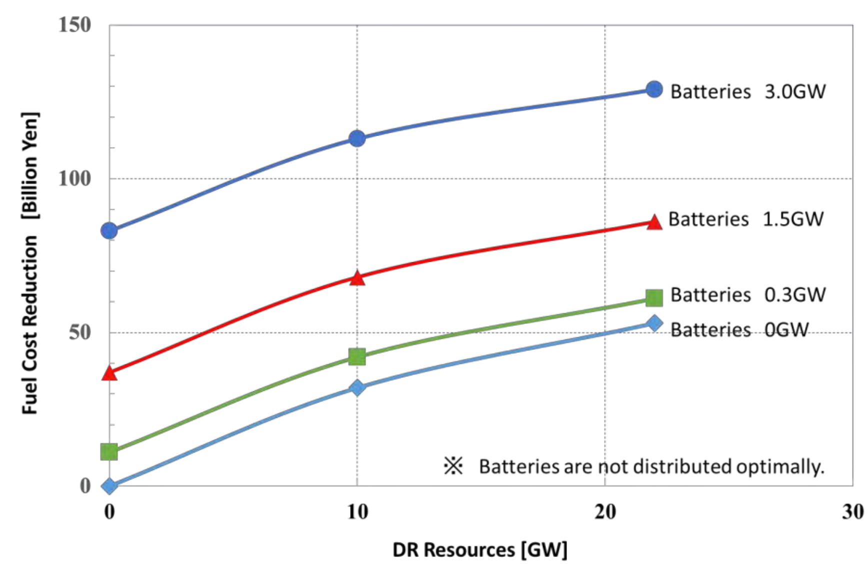


Fig.2 Fuel cost reduction as a function of DR resources.

Effect of Batteries and DR in 2030 (2/2)

- Curtailment of variable power generations such as PV and wind would be required at above the some level of renewable energies deployment.
- The curtailment of PV and wind power generations increased to about 15% at about 2 times penetration of the PV and wind prospect in 2030 based on the Long-term Energy Demand and Supply Prospects published in 2015.

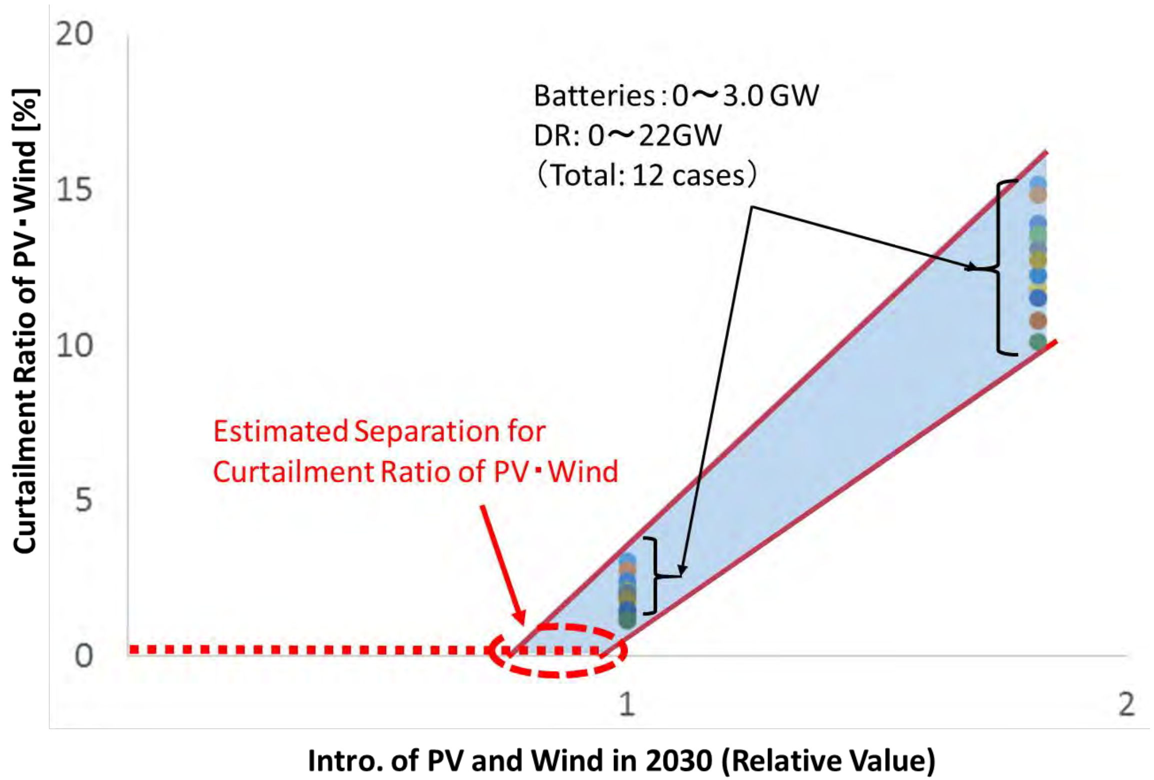


Fig.3 Estimated curtailment ratio of PV and wind.

Potential of DR resources in Japan

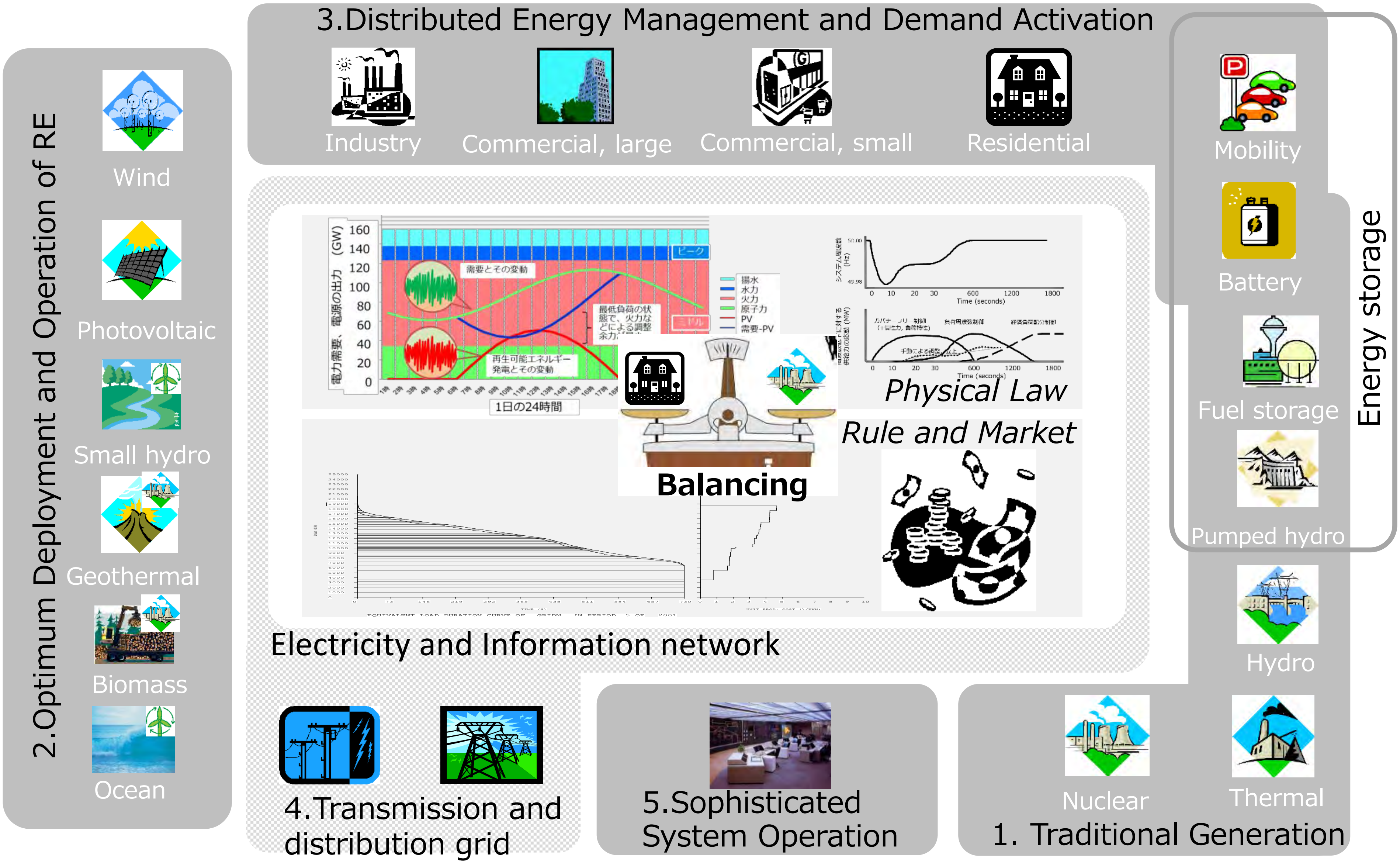
- Not only Nega-watt but also Posi-watt Demand Response would become to be strongly requested due to a large amount of variable renewable energy
- The potential of Posi-watt DR now is as follows;
  - Low-voltage customers: 5.0GW
  - High-Voltage customers (air conditioners etc.): 5.4GW

Low-voltage customers	Heat pump (P)	EV/PHV (P/N)	Electric water heater (P/N)	Total
(A) Number of machines	4.38M	0.1M	1.62M	6M
(B) Storing power[GW]	6.57 ((A)×1.5kW)	0.2 ((A)×2kW)	8.1 ((A)×5kW)	15
(C) DR resources ：(B)×1/3[GW]	2.19	0.07	2.7	5.0

High-Voltage customers	Water thermal storage type air conditioning (Heat pump) (P/N)	Industrial electric oven (P/N)	Others (P/N)	Total
(A) Number of machines	0.08M	-	-	-
(B) Storing power[GW]	10.7 ((A)×1336kW)	-	-	-
(C) DR resources ：(B)×1/3[GW]	3.7	1.1	0.56	5.4

P: Posi-watt N:Nega-watt

Optimum Integration of Flexibility Resources



Direction of NEDO TSC's Strategy 1/2

Modeling & Simulation

1. *To efficiently utilize power systems having a large amount of fluctuating power generation due to variable renewable energies and minimize the social cost, we have to prove integrated optimization methods in combination of thermal power generations, pumping power generations, energy storages , DR, and so on.*

   — *Technologies of processing for a large amount of data and modeling to choose optimizing methods against grid problem in view of electric power transaction market*

2. *We will develop software integrating grid operation system as facility planning and SOP (sales and operations planning) methods and stable operation of the systems*

R&D for DR

1. In order to obtain effects of Posi-watt DR, equipment for DR including heat pump systems for low-voltage and high-voltage customers would not be enough.
2. Large scale equipment for DR of large business building and the large scale factories would become very important as the Posi-watt DR for controlling the electricity demand.

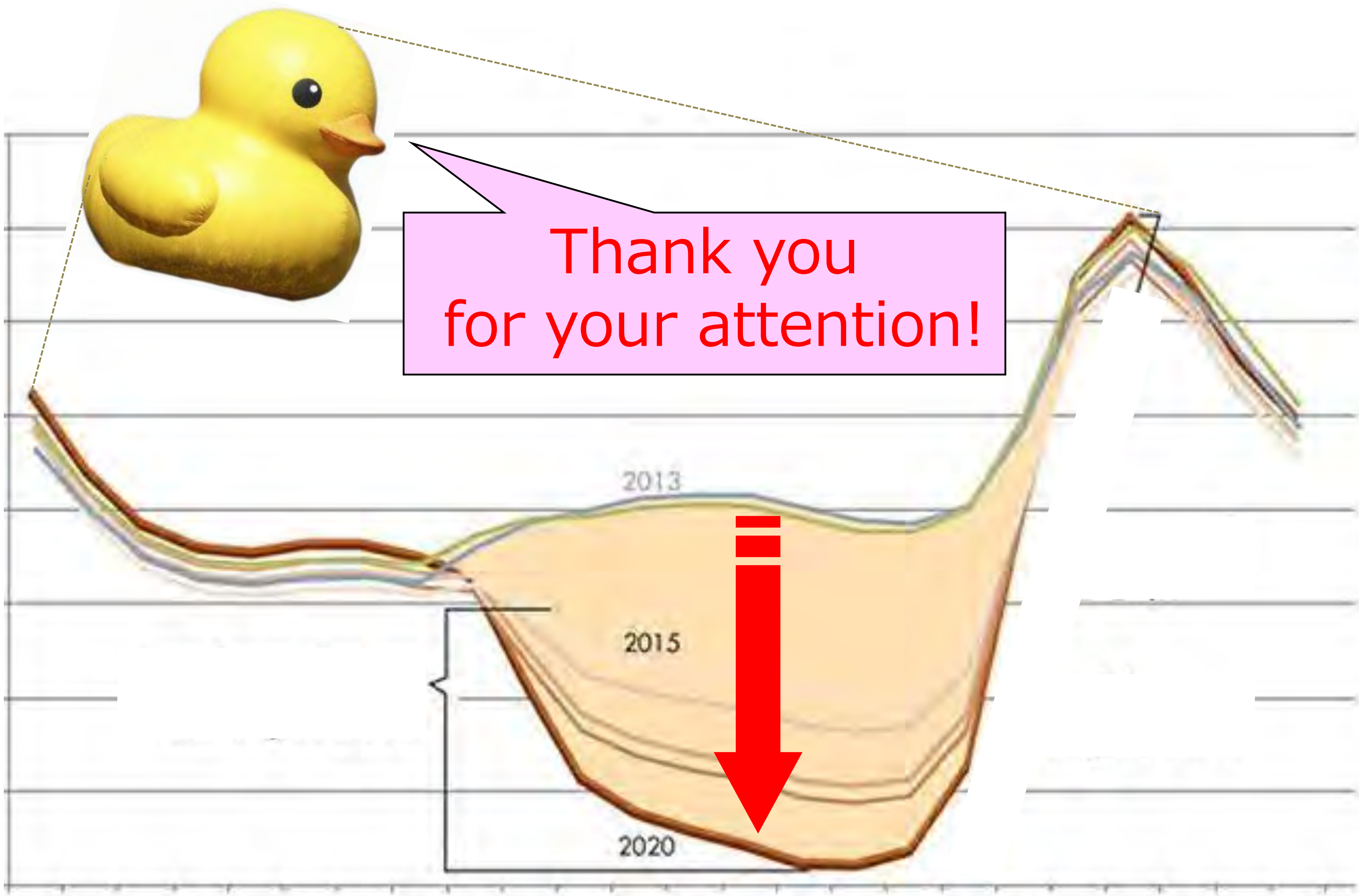
   — Large scale equipment with flexible thermal / electrical output (sec.-hr.) control would be seriously important for controlling the electricity demand.

【Technological problems of DR for business & industrial use】
- **Increase the amount of devices & improvement performance of devices for DR**
- **Dispatchable control of DR resources**
- **Technologies for remote control, operation and sensing**

Cybersecurity

1. Risk assessment and prevention for cyber attacks etc.

   (including measures to minimize damages even when accidents)
2. To ensure security for different systems between information and energy in a comprehensive way .


Thank you
for your attention!
2013
2015
2020