Posi-Watt Demand Response Utilizing Thermal Storage for Air-Conditioning Systems of Large Scale Buildings and Factories

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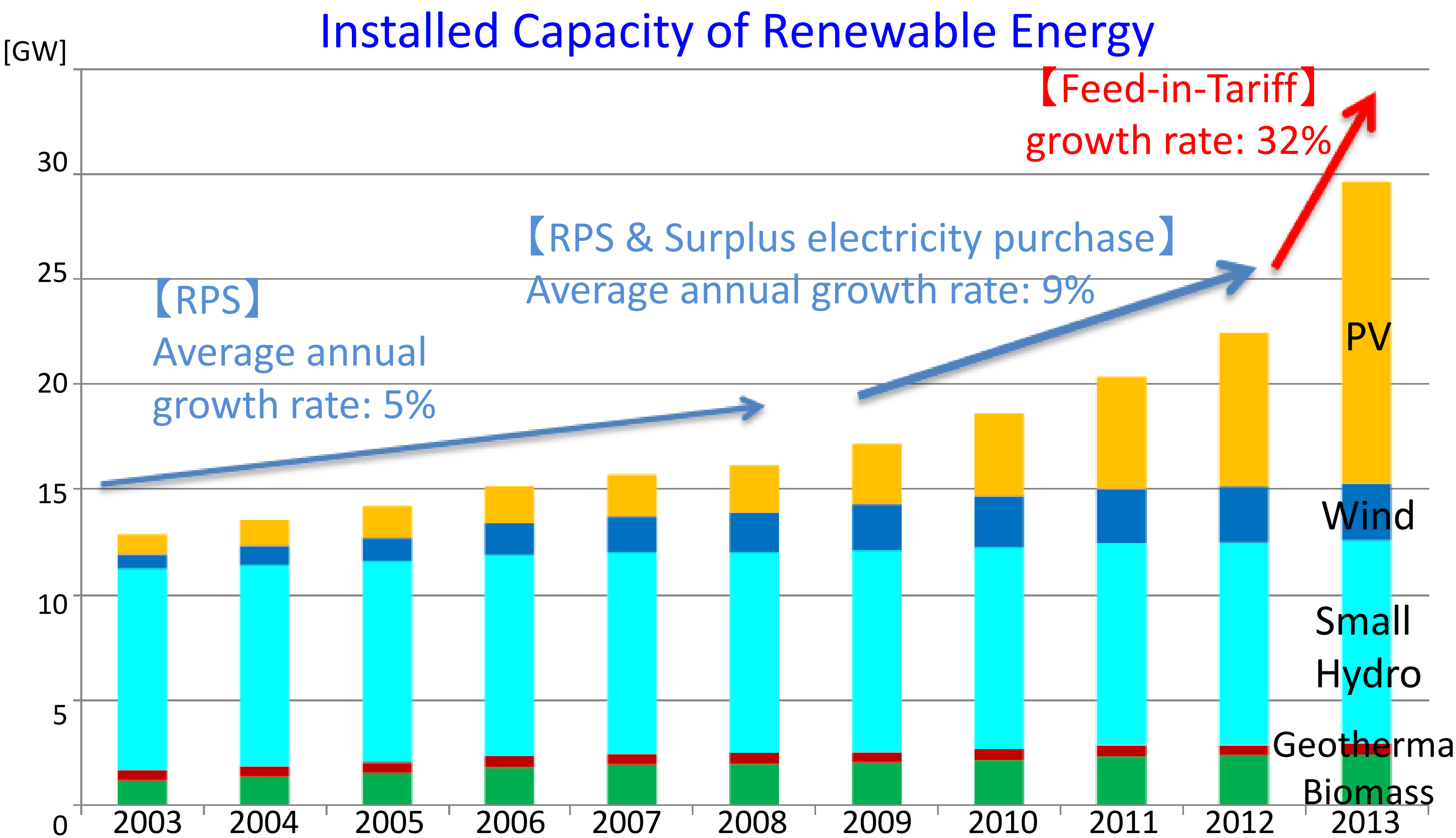
New Energy and Industrial Technology Development Organization（NEDO)

Technology Strategic Center

Renewable Energy/Energy System & Hydrogen Unit

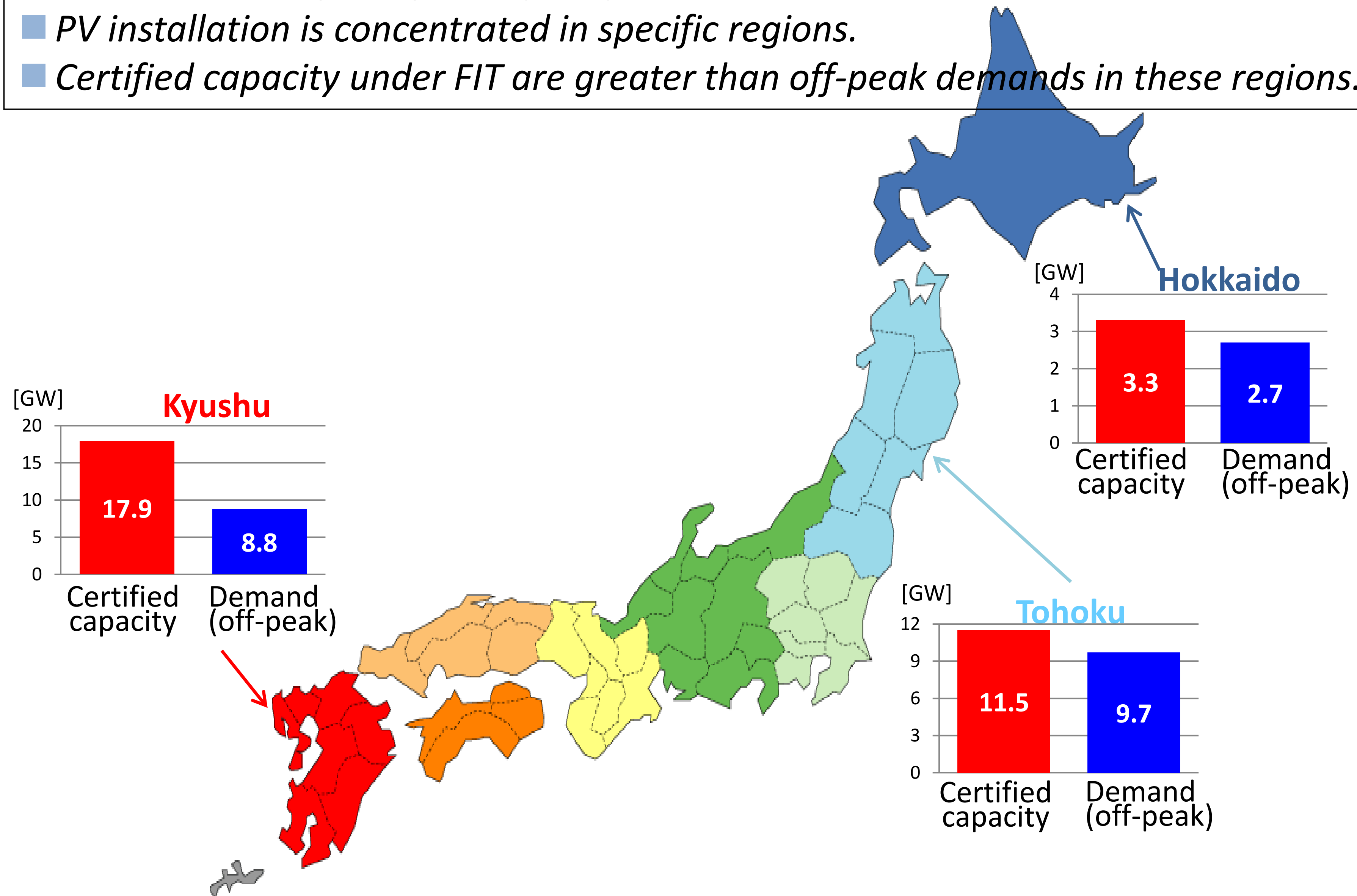
Feed-in-Tariff has accelerated renewable energy penetration

- *Installation capacity of PV has surpassed 20GW at the end of FY2014 and are expected over 60GW in 2030.*



PV installation > Off-peak demands

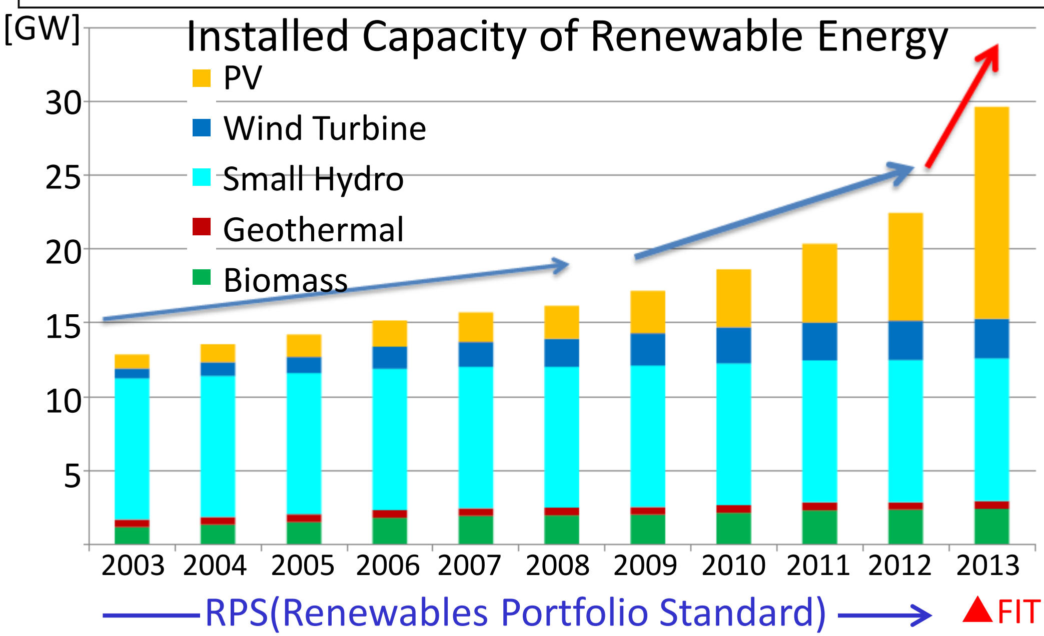
- PV shares 95% of certified capacity under FIT (82GW)
- PV installation is concentrated in specific regions.
- Certified capacity under FIT are greater than off-peak demands in these regions.

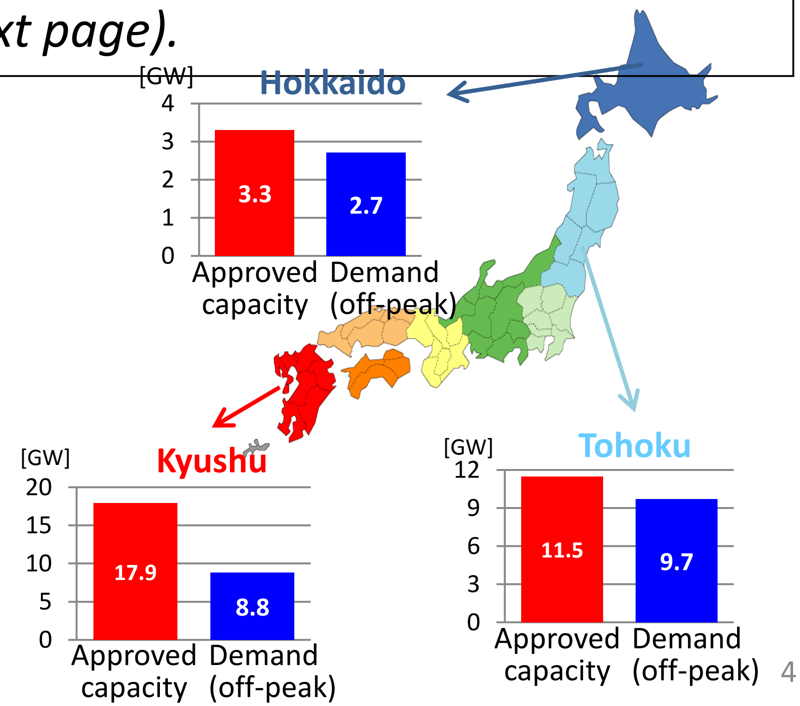


Why Energy Storage Technology ?

Trends on Renewable Energy in Japan

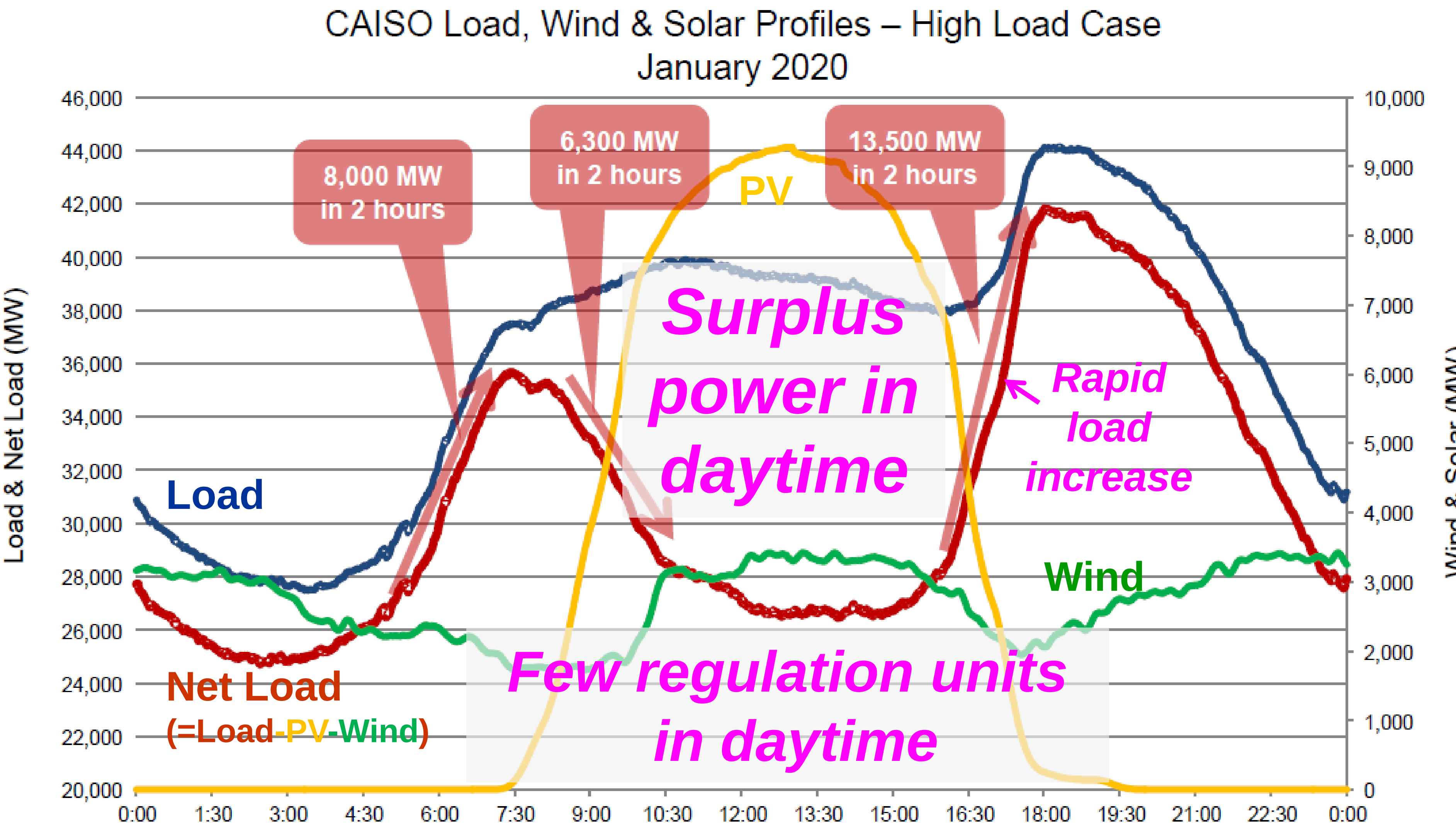
- *PVs have penetrated rapidly after introduction of Feed in Tariff (FIT) on July 2014.*
- *Installations of PVs have surpassed 20GW at the end of FY2014 and are expected over 60GW in 2030.*
- *PVs share 95% of certified capacity under FIT and are concentrated in specific areas such as Kyushu, Hokkaido and Tohoku. Approved capacity under FIT are greater than off-peak demands in these regions.*
- *We NEDO estimate around 10% of PVs generation would not be utilized because of generation suppression in off-peak periods when the installations of PVs reach70GW without any measures(listed in next page).*





Issues on power grid caused by variable generations

Load and Generation Curves of California



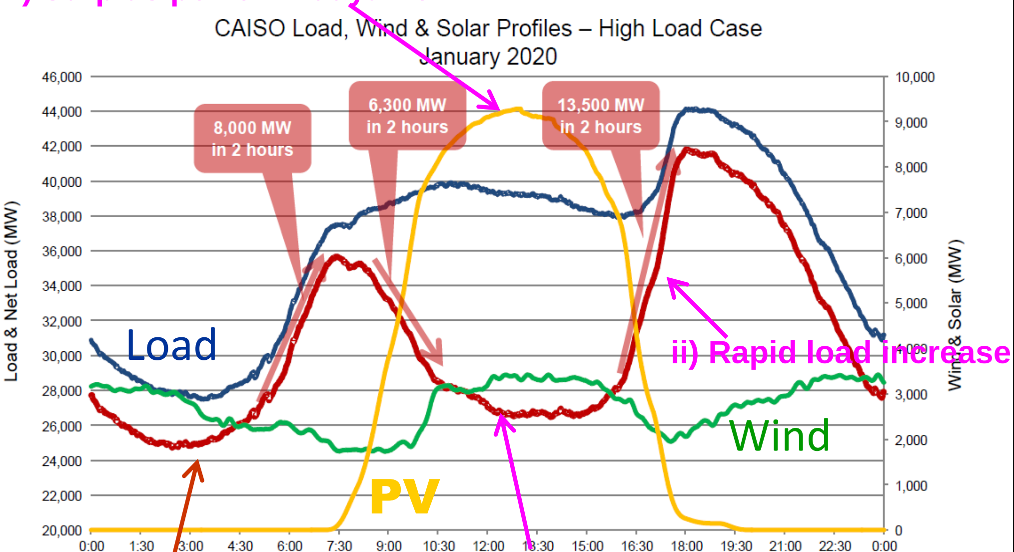
Source: California ISO

Why Energy Storage Technology ?

Future problem on power grid caused by variable generations

- *Large amount of variable power generation 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*

i) Surplus power in daytime



Net Load
(=Load-PV-Wind)

iii) Few regulation units such as thermal plant are operating in daytime

Source: California ISO

Measures against grid problem

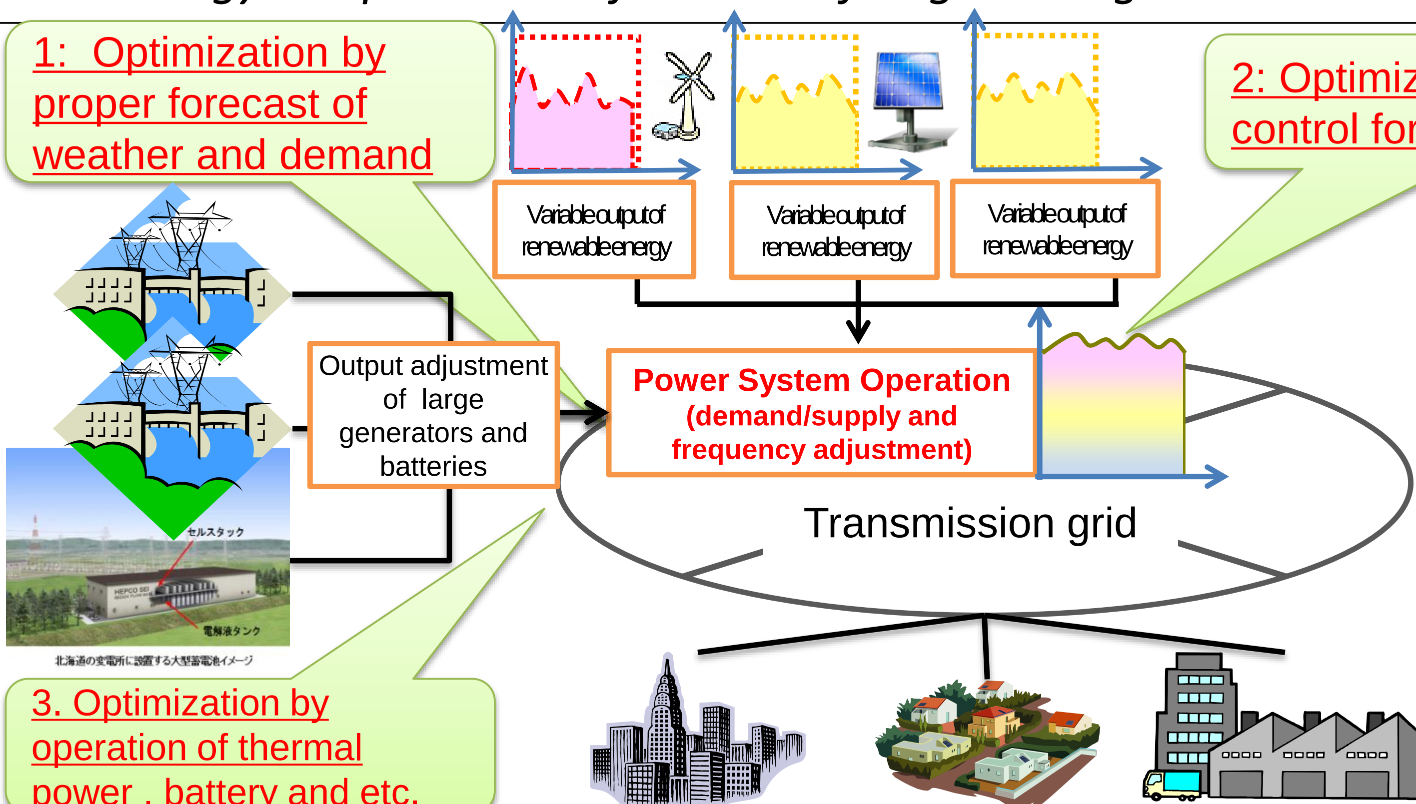
- *Generation management*
  - *Improvement of generation output forecast for variable generation*
  - *Generation suppression on light load*
  - *Improvement of thermal units' flexibility*
- *Demand side management*
  - *Improvement of thermal units' flexibility*
  - *Inter-regional operation of power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

Measures against issues on power grid

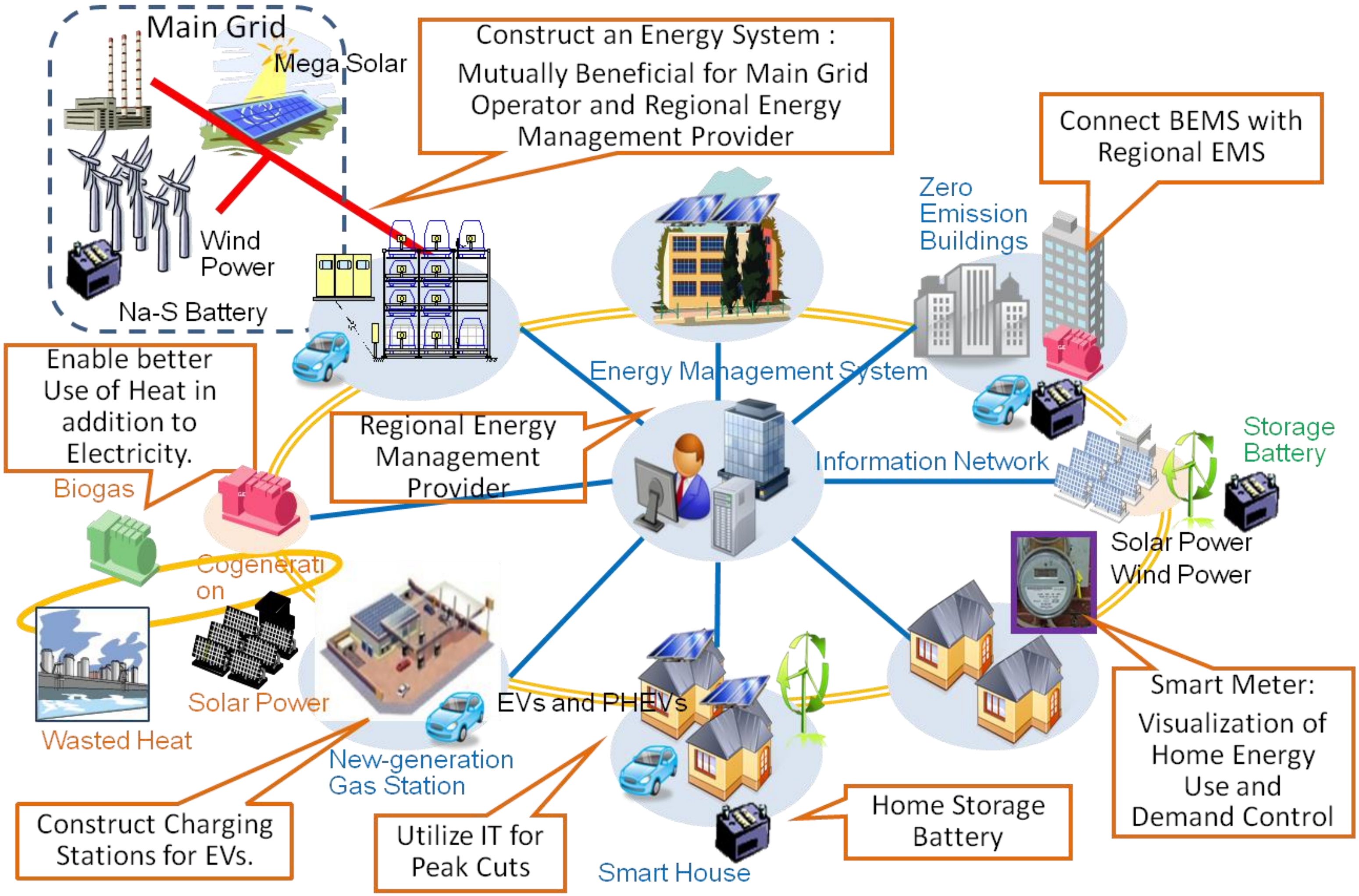
measures	Grid Side	Generation Side	Demand Side
Fluctuation reduction of variable generation		✓	
Improvement of generation output forecast for variable generation	✓		
Demand Response			✓
Energy storage	✓	✓	✓
Generation suppression on light load		✓	
Improvement of thermal units' flexibility	✓		
Inter-regional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

Network Stabilization - R&D Project on Grid Integration of Variable Renewable Energy

- *The purpose of the project is to optimize power system operation.*
- *There are three key technologies to develop*
- *Technology 1: Forecasting of variable power generation of renewable energies from weather and demand such as*
- *Technology 2: Controlling by generation plan with combination of output control and storage battery adjustment*
- *Technology 3: Operation adjustment of large scale generators and batteries*



- *Utilizing advanced ICT, a smart community is a new community which requires the participation of citizens and involves smart transportation, homes, office buildings and plants, while enabling the introduction of renewable energy.*



Types and characters of energy storage technology

Method	Unit capacity: 100kWh	MWh	10MWh	100MWh	GWh	Facility cost (USD/kWh)	Energy density (Wh/l)※3	Cycle life*3	Cycle efficiency*3 (%)	Application range: Stability	Supply & Demand Ctrl.: min	hr.	day	Mo.
Battery Storage	■	■	■	■		500-600 (NaS, past result in Japan) 1420*2 (VRFB) 900*2 (Li-ion)	10-400	-4,500 (NaS) >10,000 (VRFB) -10,000 (Li-ion)	70-85 (NaS) 60-75 (VRFB) 85-98 (Li-ion)		●	●	●	
Hydrogenation (Power to Gas)			□	□	□	200-400	550-650	1,000-10,000	34-44 (reconversion) 70 (electrolysis) 80-90*4 (SOEC)			●	●	●
LAES (Liquid Air Energy Storage)			□	□		400 (tankage・liquefaction)	>1,000		-70		○	●	●	
PHS (Pumped Hydro Storage)				□	■	510*2 200-300 (Past result in Japan)	1-2	> 15,000	70-80	●	●	●	●	
CAES (Compressed Air Energy Storage)			□	■ □	■	119*1 (underground storage) 2,200*1 (tankage)	2-6	>10,000	41-75	△	○	●	●	●
Flywheel Energy Storage	■					9,600*1 -17,200*2	20-80	20,000 – 1 millon	80-90		●	○		
SMES (Superconducting Magnetic Energy Storage)	■	■				700,000 (voltage sag compensation)	5-7	No record	75-80		●	○		
EDLC (Electric double-Layer Capacitor)	□					1,300,000 (voltage sag compensation)	10-20	>1 million	85-98		●			

Installation location… : power generation facility side : grid side : economic effects are expected

■ : Feasible □ : Feasible by R&D ●Applicable ○Possibly applicable by R&D △ Partly applicable

※1: Estimated from the total of DOE's demonstration projects ※2: DOE/EPRI reports ※3: IEC Whitepaper ※4: Interviews with companies

Worldwide energy storage technology trends

Method	Energy storage technology trends worldwide
Battery Storage	[JP] Sodium sulfur (NaS) batteries have been commercialized as large scale batteries and introduced more than 100 places in Japan. Typical price is about 500-600 USD/kWh. [JP] Vanadium redox flow battery (VFRB, 60MWh) and lithium ion battery (LIB, 20MWh) for frequency regulation are being tested in Japan (Ministry of Economy, Trade and Industry). [JP] Development of Cost reduction technology for LIB and nickel metal hydride (NiMH) is being implemented (NEDO). The targets are set to 500€/kW(670USD/kW, for regulation)and 140€/kWh(170USD/kWh, for surplus generation) ,and they are expected to achieve . [US] New methods of sodium ion and flow batteries are under development in ARPA-E program. [US] Tesla Mortors plans to sell low price batteries for household use.
Hydrogenation (Power to Gas)	[JP] NEDO has just started demonstration projects. [DE] Germany and the US are also conducting demonstration projects. [EU] It has been demonstrated that generated hydrogen is mixed into the gas pipeline directly or via methanation without reconversion. [JP] Solid polymer type water electrolysis(SOEC), the only method to achieve high cycle efficiency, is being developed.
LAES (Liquid Air Energy Storage)	[UK] LAES is developed in the UK. It uses existing mature components (liquefier, liquid air storage, power turbine), with proven performance, cost, lifetime.
PHS (Pumped Hydro Storage)	[JP] The method of using sea water in which the ocean is utilized as a lower reservoir is under operation in Okinawa. But this method doesn't be disseminated, because a corrosion-resistant material is expensive. [US] APRA-E plans to expand the R&D budget for developing power storage systems other than battery storage.
CAES (Compressed Air Energy Storage)	[US] Large facilities with underground storage space are in operation in the US and Germany. PG&E is planning to construct the large facilities of 300MW-10h(3GWh) in DOE project. [JP] The development and demonstration of tank storage (MW class) are considered (NEDO). [UK] Cryogenic energy storage method using liquid air(high density) in order to reduce cost has been developed.
Flywheel Energy Storatge	[JP] The target of 500€/kW is expected to achieved by using high-temperature superconductivity technology. [US] 100kW-25kWh*200units(20MW) systems for frequency regulation are in commercial operation. [US] ORNL in the US is developing a light and high-strength material.
SMES (Superconducting Magnetic Energy Storage)	[JP] SMES using low temperature superconductivity technology has been commercialized for voltage sag compensation. It has possibility to be used for frequency regulation if large capacity is realized.
EDLC (Electric double-Layer Capacitor)	[JP] It is already applied for regenerative power storage in railways. [JP] High energy density capacitor with CNT applied electrode was developed for automobile application (2010,NEDO).

Potential DR resources in Japan

Low-voltage customers	Heat pump	EV	Electric water heater	Total
(A) Number of machines	3.72M	0.056M	1.88M	5.65M
(B) Storing power[GW]	5.6 ((A)×1.5kW)	0.1 ((A)×2kW)	9.4 ((A)×5kW)	15
(C) DR resources ： (B)×1/3[GW]	1.9	0.03	3.1	5

High-voltage customers	Turbo refrigerator	Reciprocating liquid chiller	Total
(A) Number of machines	0.006M	0.14M	0.15M
(B) Storing power[GW]	12.4 ((A)×2057kW)	28.2 ((A)×200kW)	41
(C) DR resources ： (B)×1/3[GW]	1.0	2.4	3.4

◆Developments of heat pump devices which can control power fluctuation and maintain highly efficient operation at partial load

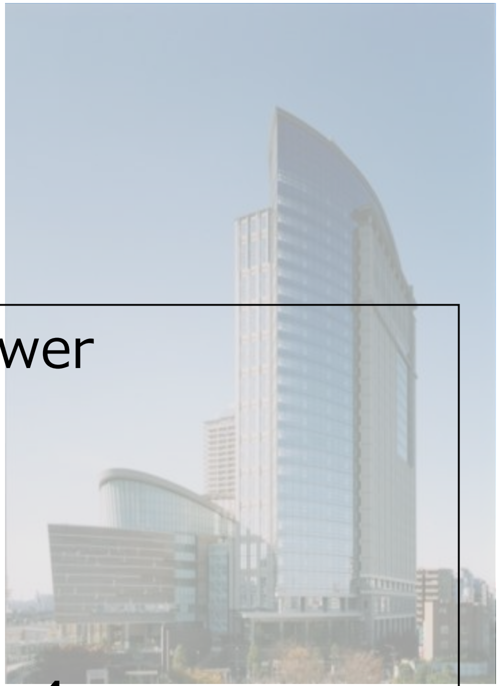
Technological problems of DR for business & industrial use

- **Increase the amount of devices & improvement performance of devices for DR**
- **Dispatchable control of DR resources**
- **Technologies for supervisory control, operation and sensing**

Case : NEDO Kawasaki Head Office

Composition

- Turbo refrigerator : 1,266kW×2
- Heat pump : 1,406kW×2
  - Heat storage water tanks 2,550m³
  - Ice storage tanks 218m³



- Drive the heat pumps with nighttime electric power
  ⇒ Produce heat:40℃, cold:7℃
  ⇒ Heat storage water tanks
  ⇒ Use for air conditioning in this building.
  ※ Supply the shortage: With turbo refrigerator
- Assumption: Heat & Electricity; 5,344kW COP＝4
  ⇒ The amount of electricity which can control power fluctuation:
  About 1,300kW
- Assumption: 1/3 of all power dissipation will available for DR
  ⇒ ***NEDO Kawasaki Head Office has 600kW DR resources***
  ⇒ **It corresponds to 400 heat pump type water heaters for home**

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Direction of NEDO TSC's strategy

- *Generation side*
  - *Household & Generation Utility*
    - » *It is important to develop storage systems which store surplus power of PV generation and utilize it basically for domestic electricity demands.*
    - » *It is also significantly important to explore various applications for load leveling; to explore smart system composed by generation, energy storage system and demand response.*
    - » *Batteries for electrical vehicle (EV) are supposed to be key devices for energy storage systems in houses.*
  - *Generation utility*
    - » *Storage devices of 10s MWh class are required.*

- *Grid side*
    - » *Variety of devices which are suitable for long duration and large capacity such as pumped hydro, liquid air and hydrogen should be developed.*

Conclusions

1. Posi-Watt Demand Response would become to be strongly requested due to the rapid and large amount of increase of fluctuating renewable energy.

2. As for the tools of Posi-Watt Demand Response, heat pump systems for air-conditioning and hot water supply in houses and the car batteries for Electric Vehicles would not be enough.

3. Large scale Heat pump systems for the air-conditioning of large business building and the large scale factories would become very important as the Posi-Watt Demand Response for controlling the electricity demand.

4.Large Scale Advanced Heat Pump Syetem with flexible thermal output control would be seriously important for controlling the electricity demand.