An IPP's perspective on power plant flexibility – Focus on Japan

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J-POWER

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About J-POWER

J-POWER

(As of April 2017)

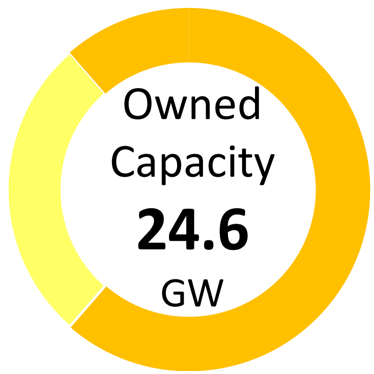
Corporate History

✓ Established as a state owned power generation company in 1952, and fully privatized in 2004.

Core Business

✓ Power generation and power transmission in Japan and power generation overseas.

Overseas
6.7 GW

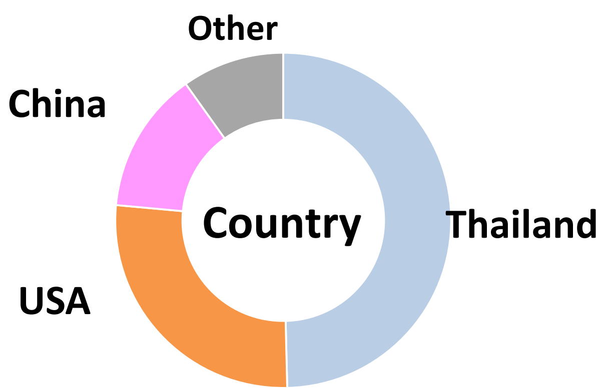


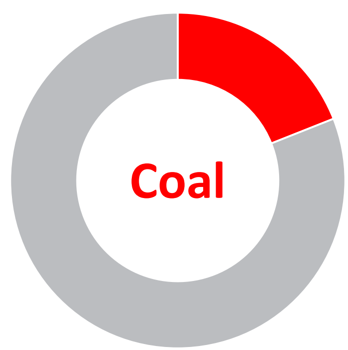
Japan
17.9 GW

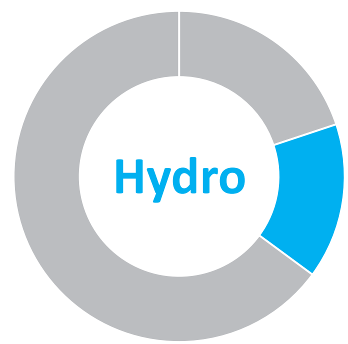
Growing significantly, especially in Thailand in recent years

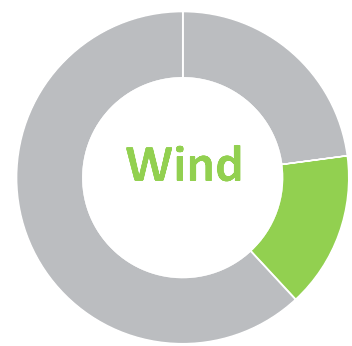
Leading shares in coal-fired, hydro and wind power generation

(Shares : As of March 2017)









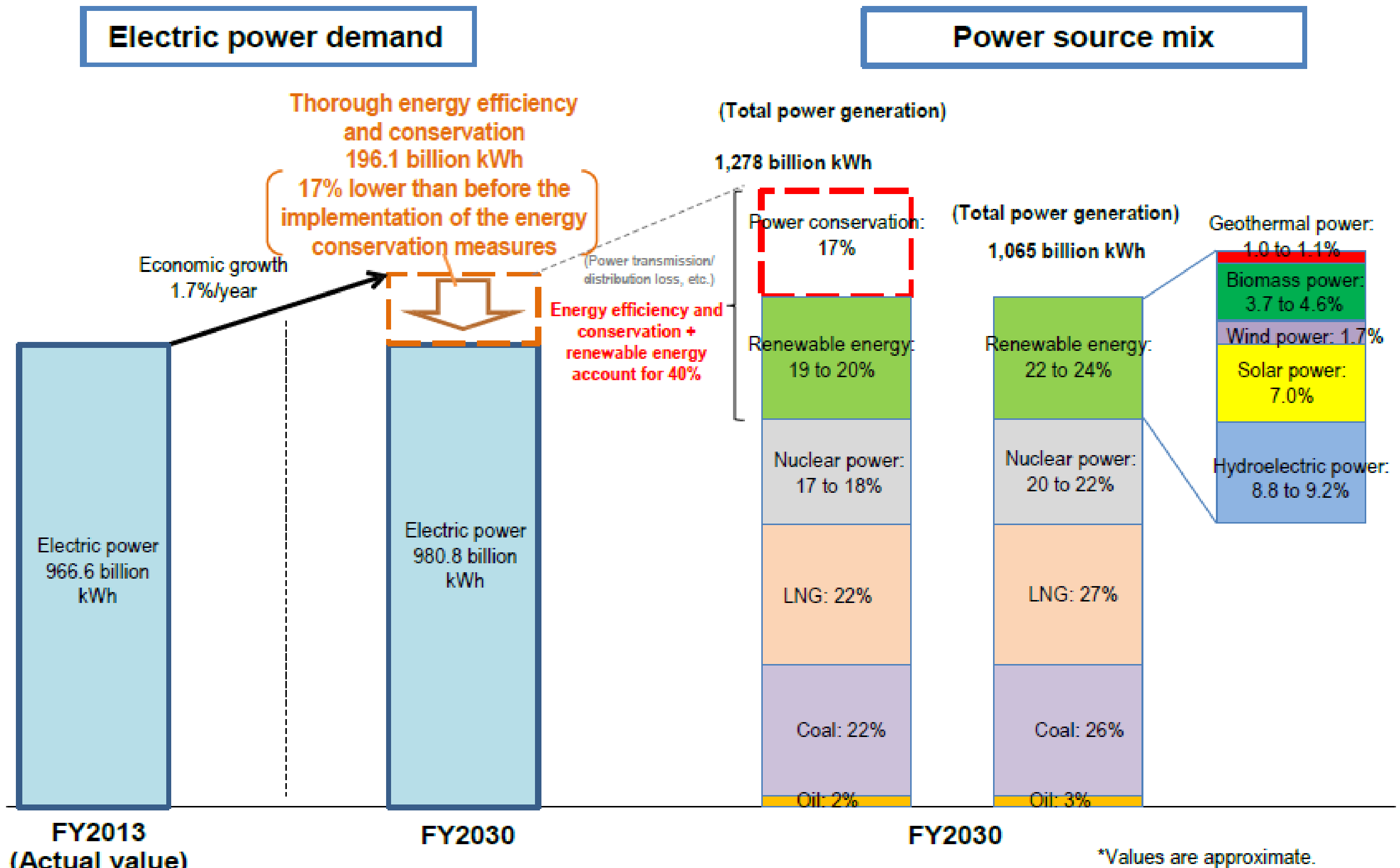
8.6GW　**8.6**GW　**0.4**GW

of which Pumped Storage Hydro 5.0GW

ELECTRIC POWER GENERATION IN JAPAN

Aimed Power Generation Portfolio in 2030

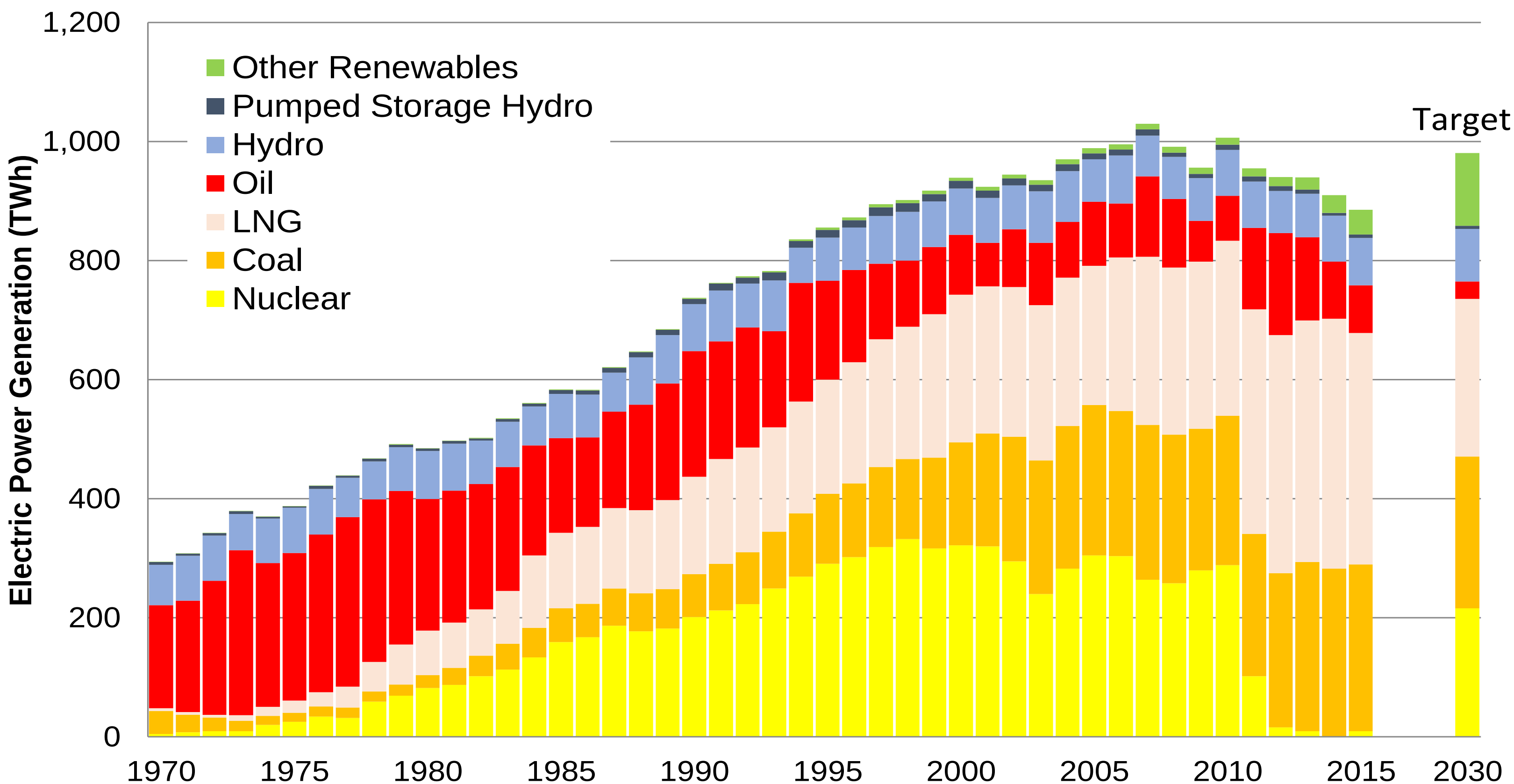
- Government of Japan (GOJ) set the 2030 target for power generation portfolio (in July 2015), which is underpinning Japan's INDC.
- This was developed for Japan's total energy mix to fulfill three conditions; 1) restoring energy self-sufficiency, 2) reducing electricity cost, 3) setting GHG reduction target comparable with other developed countries.



Source: Long-term Energy Supply and Demand Outlook 2015

Power Generation Resources, History and Target

- Since oil crisis in 1970s, the GOJ energy policy had been focusing on improving energy security by increasing the share of nuclear, coal and LNG in power sector.
- But it faced a big challenge again after Fukushima disaster.

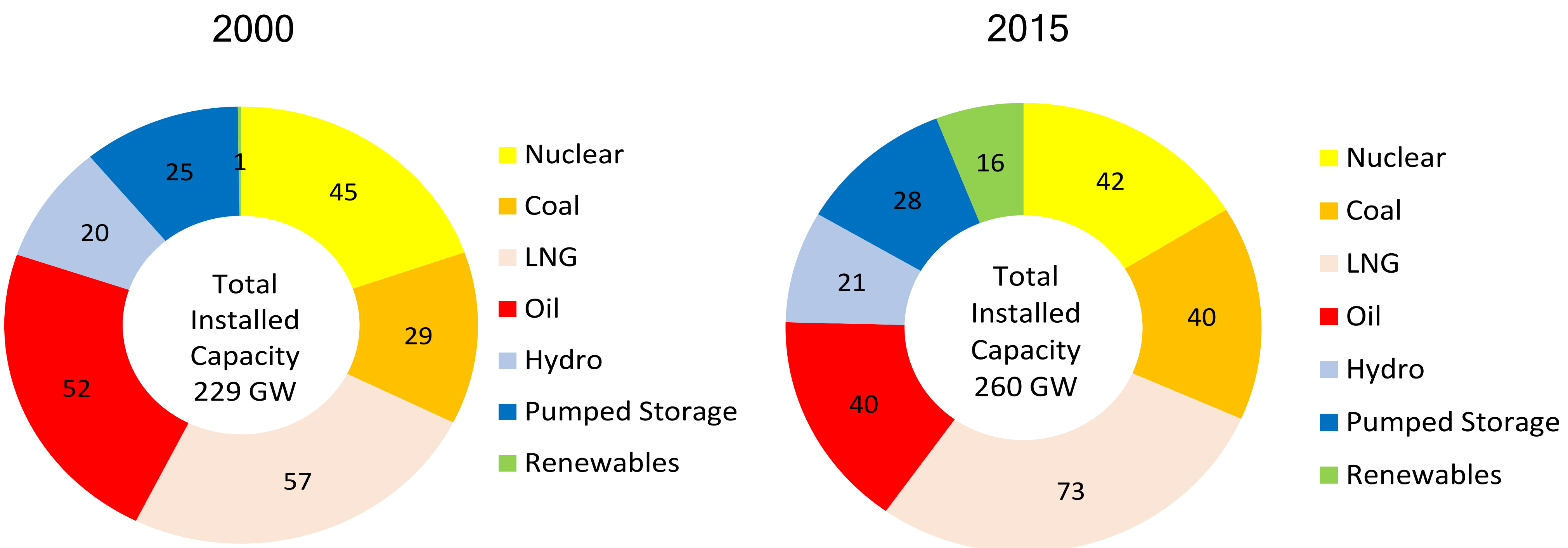


Electric power generation by energy resource in Japan (historical data exclude new entrants)

Source: Energy White Paper 2017

Power Generation Capacity Portfolio

- From 2000 to 2015, installed capacity of RE has remarkably increased, though most of solar PV and wind farms are owned by new entrants and not presented in the pie charts.
- Existence of 28GW pumped storage hydro (PSH) is a unique aspect of Japan's power generation capacity portfolio.



Power generation capacity by type in Japan (excluding new entrants)

Source: Energy White Paper 2017

Growth of Renewables

- RE promotion policy started with RPS in 2003 supplemented by Excess Electricity Purchasing Scheme in 2009. In 2012 they were replaced by Feed-in Tariff that triggered a surge of solar PV.

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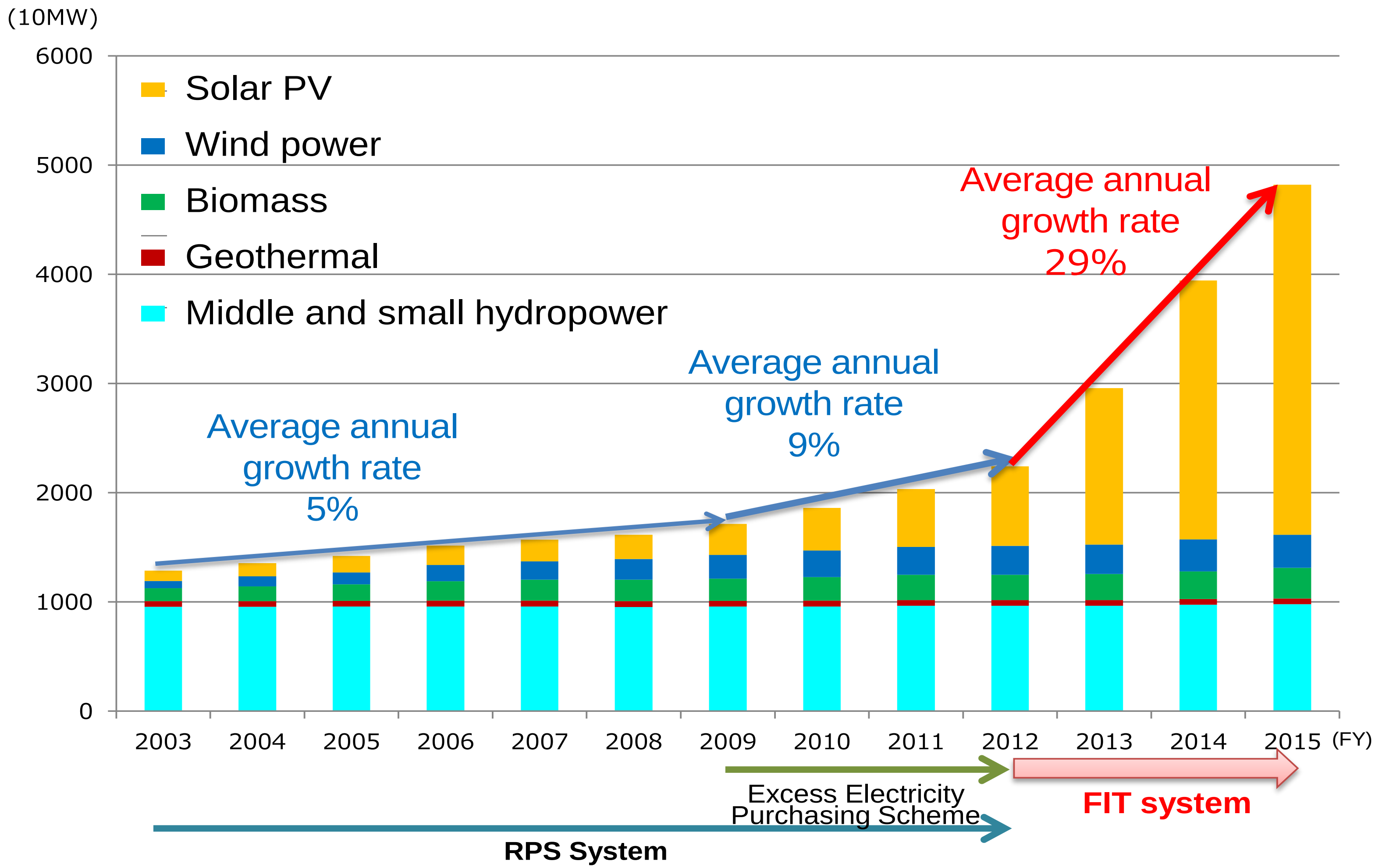
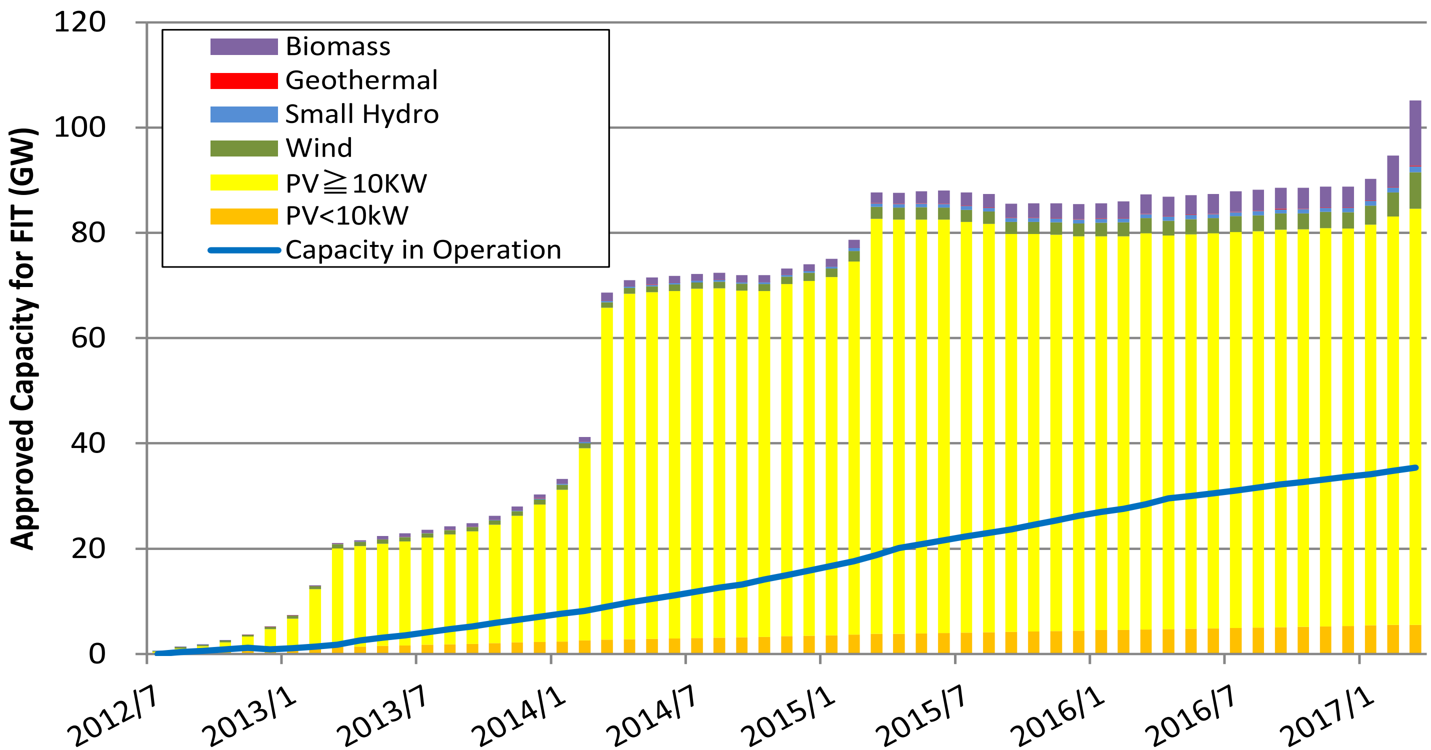


Source: presentation of Ministry of Economy, Trade and Industry

Growth of Renewables after FIT Started

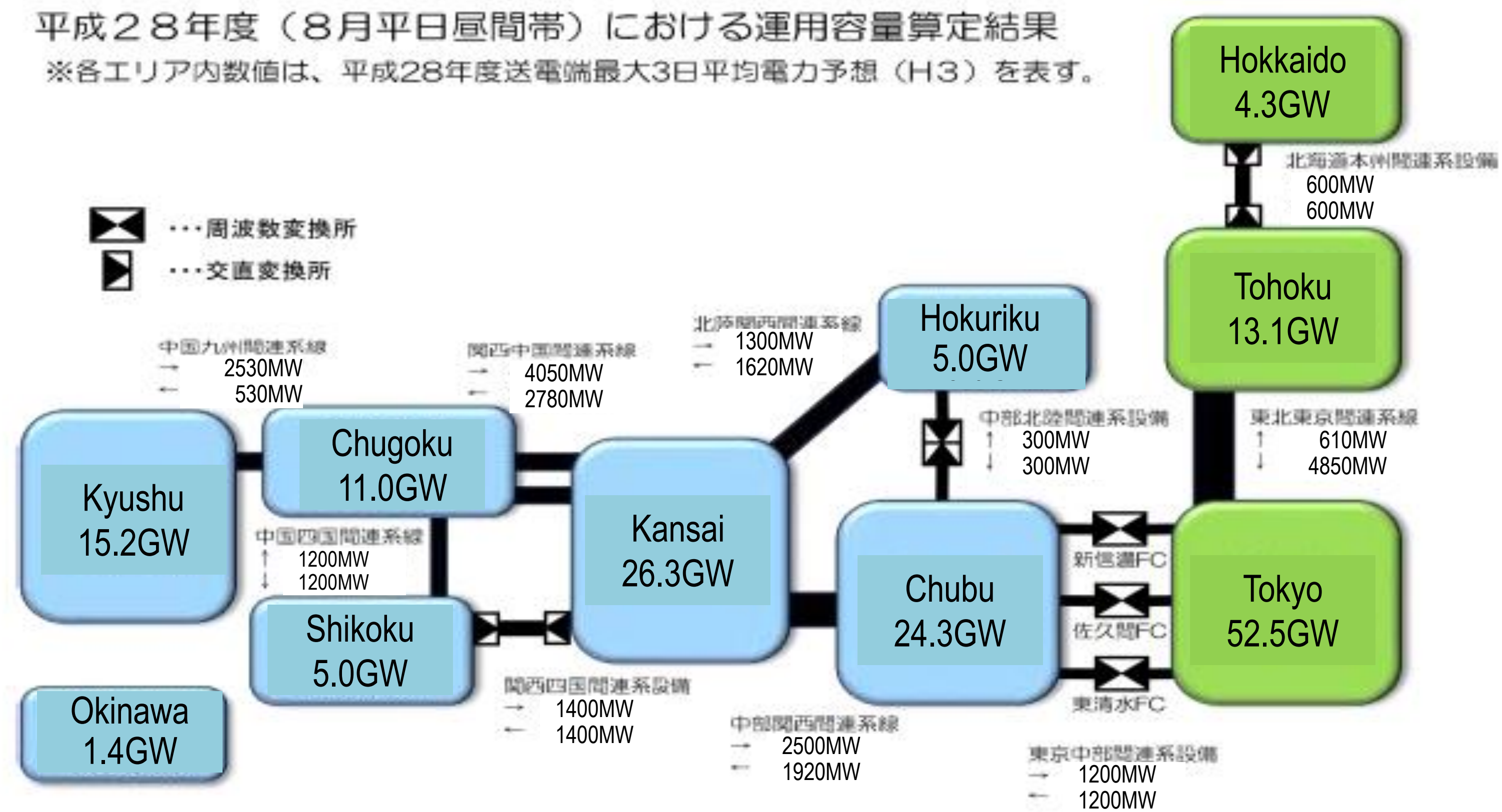
- In the latest data, as of the end of March 2017, FIT certified solar PV capacity reached 79 GW, of which 29 GW is in operation.
- Amended FIT law came in effect as from April 2017. Certificates of 28GW of solar PV were revoked for failing to fulfill newly imposed requirements.
- But there are still 22 GW of solar PV awaiting for operation.



Source: Ministry of Economy, Trade and Industry website

Power System in Japan

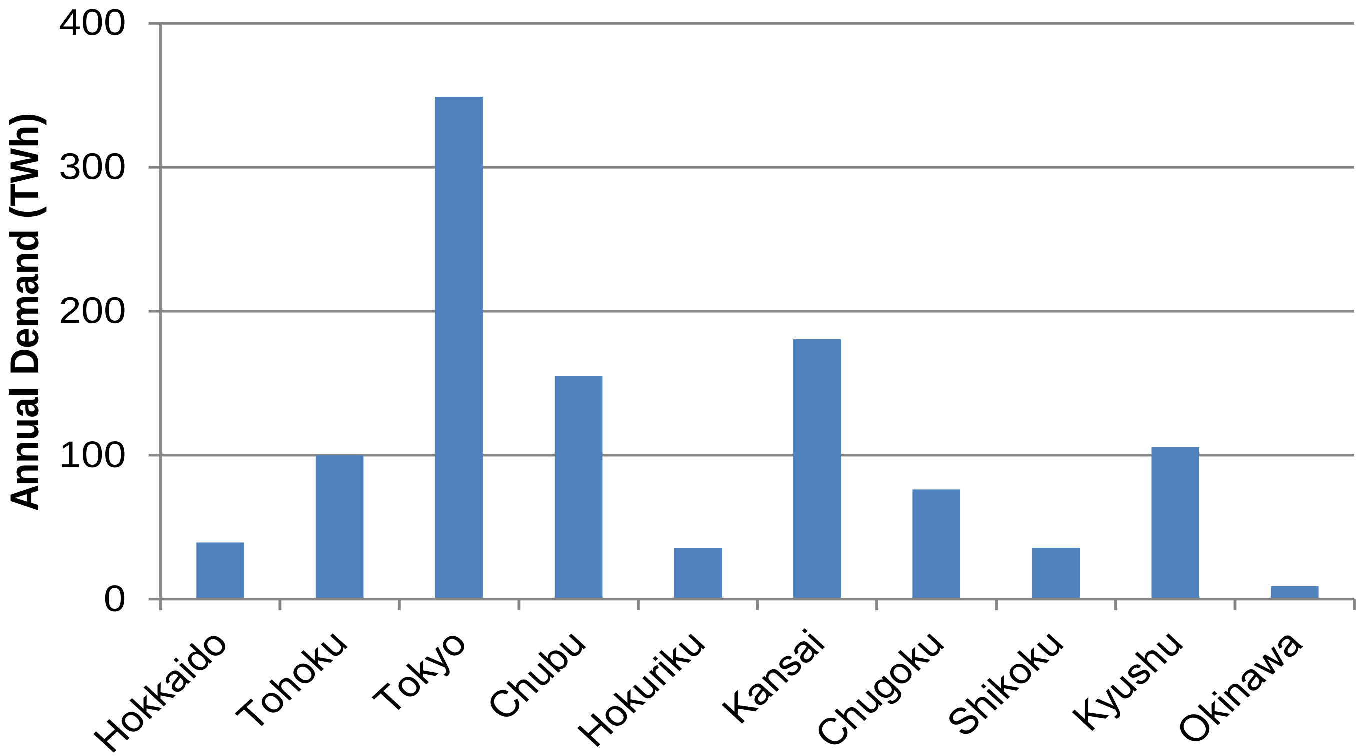
- Japan's power system consisting of 10 grids is divided between East (50Hz) and West (60Hz) in frequency and connected with FC(HVDC/AC converter)s.
- 9 grids going through four main islands are connected like "fishbone", which is totally different from the meshed network in the US or Europe.
- Interconnections between grids vary in number, capacity and type(AC/DC).



Operational Capacity of Interconnections (by OCCTO)

Power Demand by Grid

- The demand size of each grid varies depending on the regional population, industry structure and weather condition.
- The demand in Tokyo area accounts for one-third of Japan. Kansai (surrounding Osaka) and Chubu (surrounding Nagoya) are following.



Annual Power Demand by Grid in 2013

Source: website of power utilities

Uneven Distribution of VREs

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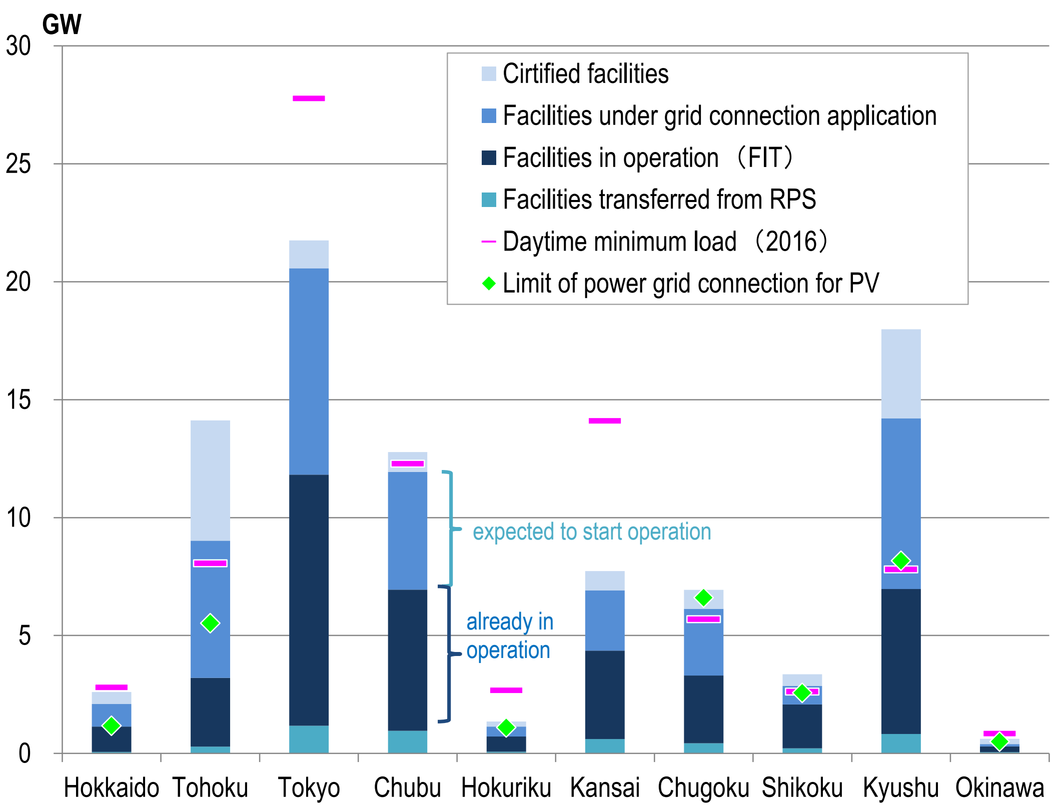
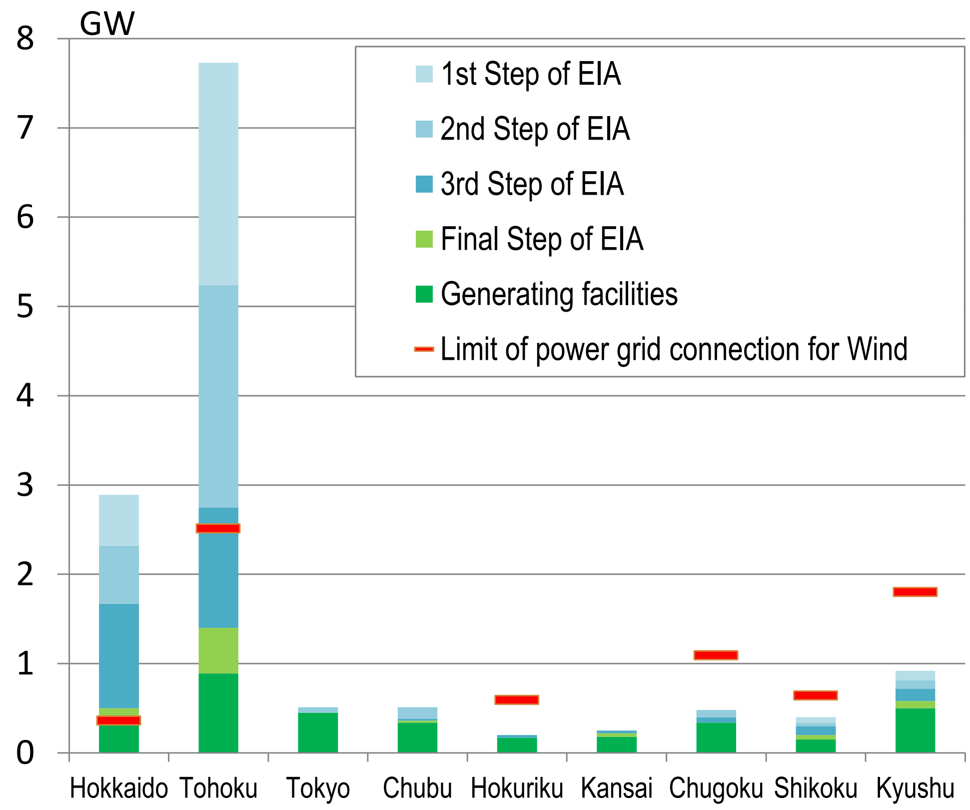
- ☐ The deployment of VREs by area is not proportional to demand size but rather concentrated in some areas.
- ☐ Solar PV (left figure) :intensively deployed in Kyushu area, followed by Tohoku area.
- ⇨ The highest hourly PV share of demand in Kyushu recorded 73% on April 30, 2017.
- ☐ Wind (right figure): intensively deployed in Tohoku area, followed by Hokkaido area.



Solar PV deployment by area

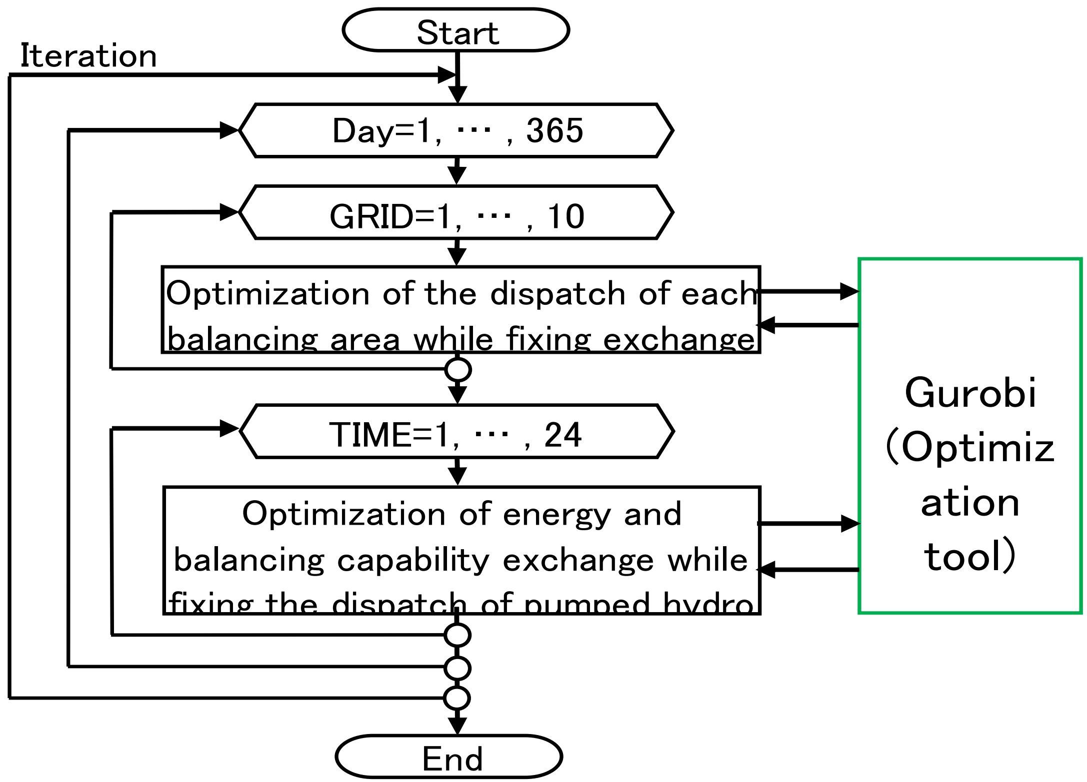


Wind deployment by area

VALUE OF FLEXIBILITY IN JAPAN
MODEL BASED ANALYSIS

Model Description

- Flexibility evaluation analysis for power system in 2030 was carried out with a production cost simulation model.
- The model was newly developed to simulate power demand and supply for interconnected grids with consideration of balance of balancing capacity (BC) and BC interchange as well as energy interchange at interconnection/frequency converter.



H. Azuma, S. Fukutome, S. Minotsu, S. Nonaka, K. Oigimoto, K. Kataoka:" Demand-Supply Analysis model with balancing capacity exchange by an interconnecti" IEEJ-B, No.137 (2017)

Model Description

- Objective function: Minimizing generation cost (consisting of fuel cost and start-up cost) of the total power system of interconnected 9 power grids and one isolated grid for 8760 hours.

$$\min\left(\sum_{ig=1}^{Ngrid}\sum_{i=idx_{ig}}^{idx_{ig}+NG_{ig}-1}\left(F(P_i)\right)\right)=\min\left(\sum_{ig=1}^{Ngrid}\sum_{i=idx_{ig}}^{idx_{ig}+NG_{ig}-1}\left(b_i\cdot P_i+c_i\cdot U_i+startup\cdot ST_i\right)\right)$$

- As a nature of production cost simulation, it does not take fixed cost into account.
- Limiting conditions
  - Balance between demand and supply
  - Balance between required variability and available balancing capacity for LFC
  - Upper and lower limit of hourly output in each power generation unit
  - Capacity of interconnection for energy interchange
  - Capacity of interconnection for balancing capacity interchange
- Priority dispatch of VRE is not assumed.

LFC (Load Frequency Control) balancing capacity able to regulate variability in a few to 20 minutes .

VRE Scenarios

- The total capacity of solar PV and wind
  - PV64 Scenario: consistent with the government's 2030 RE target
  - PV103 Scenario: massive VRE deployment far more than the target
- The distribution of solar PV and wind in grids: reflecting the current unevenness in both scenarios

Scenario	PV64 (national target)		PV103 (large VRE)	
GRID	PV(GW)	Wind(GW)	PV(GW)	Wind(GW)
A: Hokkaido	2.5	1.1	4.5	2.7
B: Tohoku	7.5	3.3	13.5	10.9
C: Tokyo	17.0	1.6	27.4	5.9
D: Chubu	8.6	1.1	12.9	3.7
E: Hokuriku	1.1	0.2	1.8	0.8
F: Kansai	8.7	0.9	14.2	2.1
G: Chugoku	4.8	0.6	7.5	2.1
H: Shikoku	2.4	0.6	3.6	1.1
I: Kyushu	11.2	1.2	17.3	2.4
J: Okinawa	0.5	0.1	0.6	0.4
Total	**64.3**	**10.6**	**103.4**	**32.2**

Consistent with the government's 2030 target

Massive VRE deployment scenario

Cases for Flexibility Evaluation

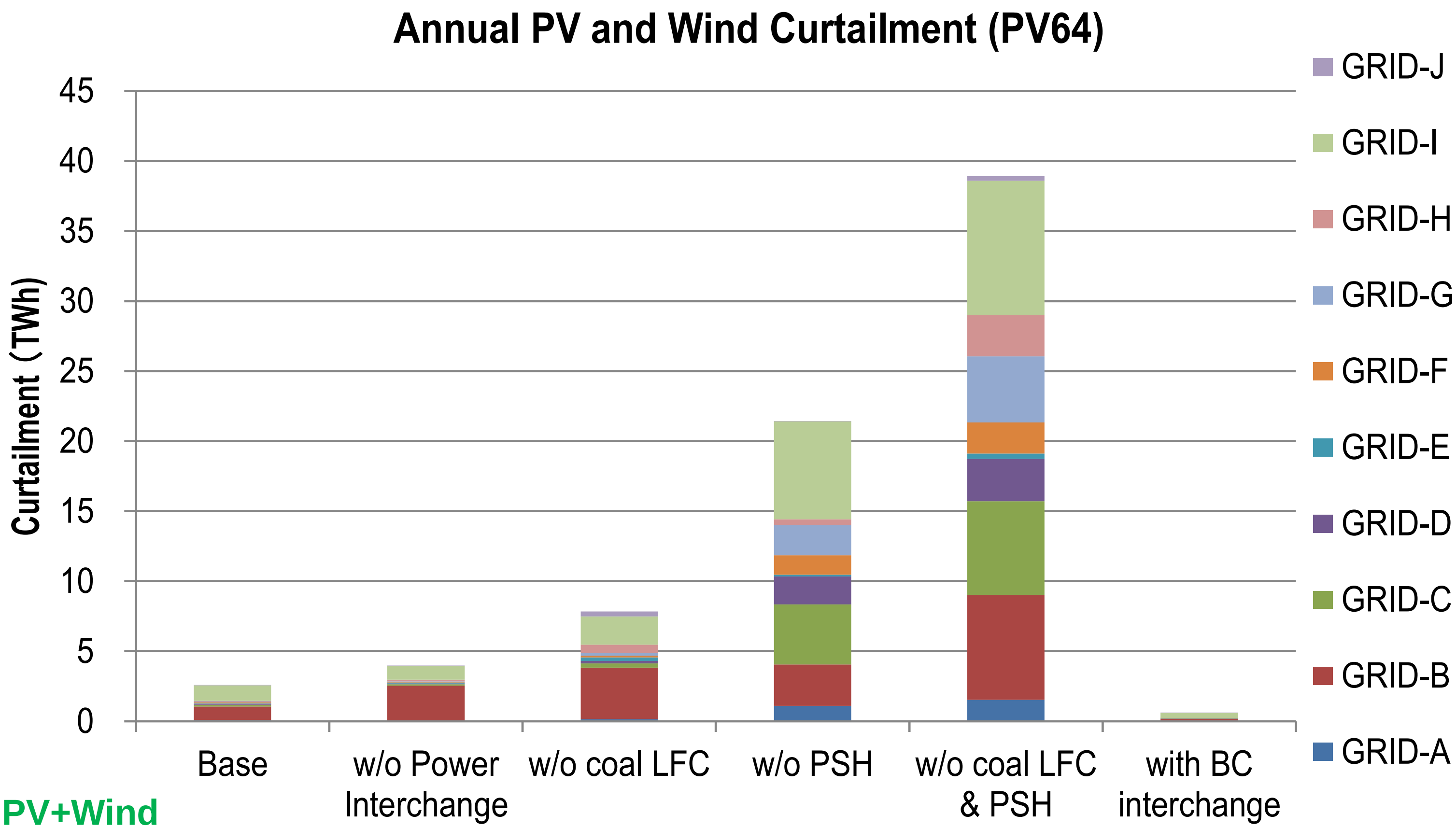
- Availability of following flexibility and their impacts were analyzed.
  - Energy interchange through interconnection
  - Coal-fired power plants' LFC service
  - Pumped storage hydro
  - Balancing capacity interchange through interconnection (limited to its 10% capacity)

Case	Energy Interchange	LFC service from Coal-fired PP	Pumped Storage Hydro	Balancing Capacity Interchange
Current situation in Japan	✔	*Not fully*	✔	
Base (assumed regular case in 2030)	✔	✔	✔	
w/o Energy Interchange		✔	✔	
w/o Coal LFC	✔		✔	
w/o PSH	✔	✔		
w/o PSH and Coal LFC	✔			
with BC Interchange	✔	✔	✔	✔

LFC (Load Frequency Control) service: balancing capacity able to regulate variability in a few to 20 minutes .

Result of Analysis: VRE Curtailment (PV64)

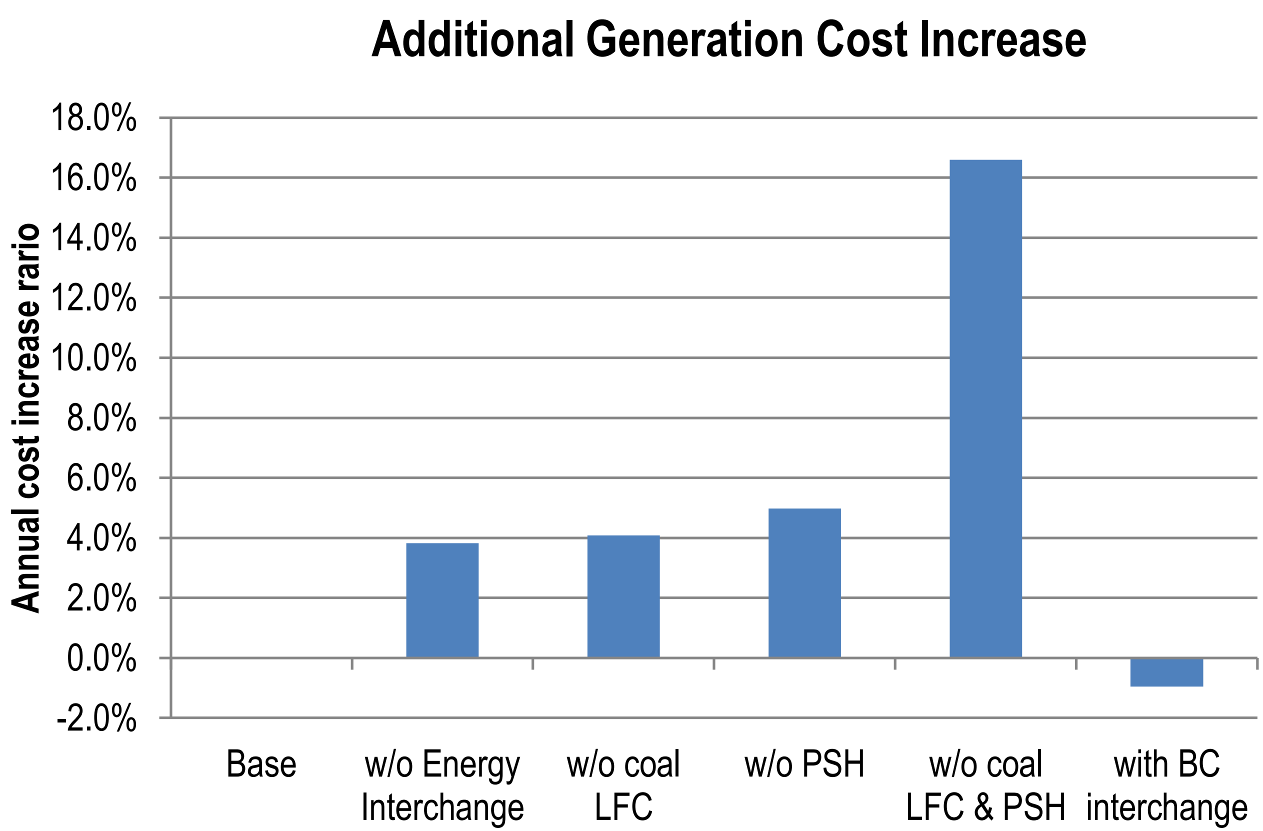
- All the sources of flexibility (energy interchange, coal LFC, PSH and BC interchange) are effective to reduce VRE curtailment compared with the Base Case.
- VRE curtailment is significantly high when neither of coal LFC nor PSH is available.
- BC interchange is effective to reduce VRE curtailment.



Share of PV+Wind In total power gen	Base	w/o Power Interchange	w/o coal LFC	w/o PSH	w/o coal LFC & PSH	with BC interchange
	8.2%	8.1%	7.6%	6.6%	4.9%	8.4%

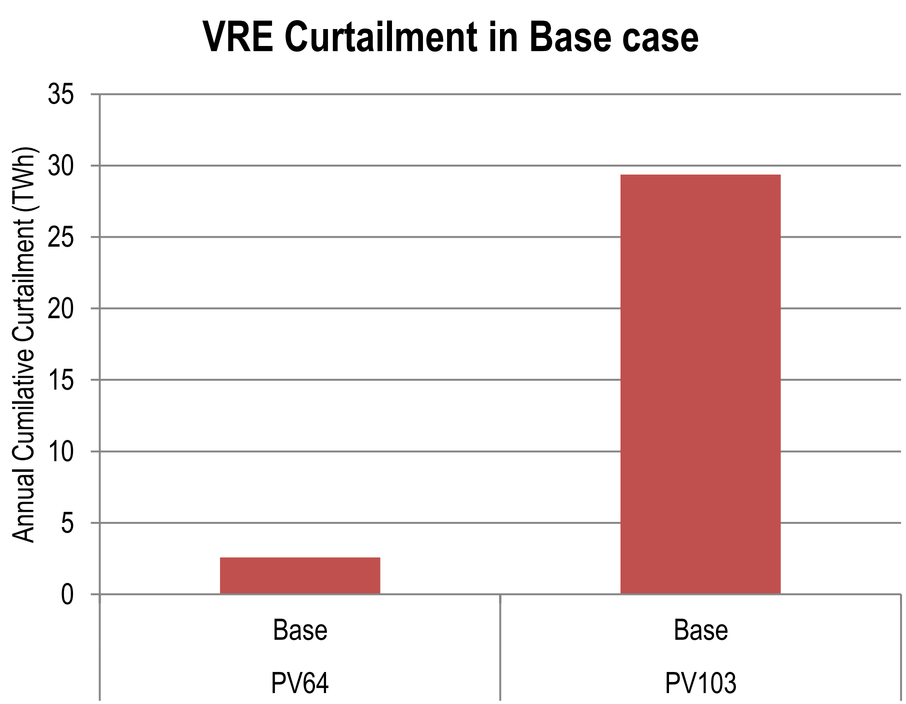
Result of Analysis: Generation Cost (PV64)

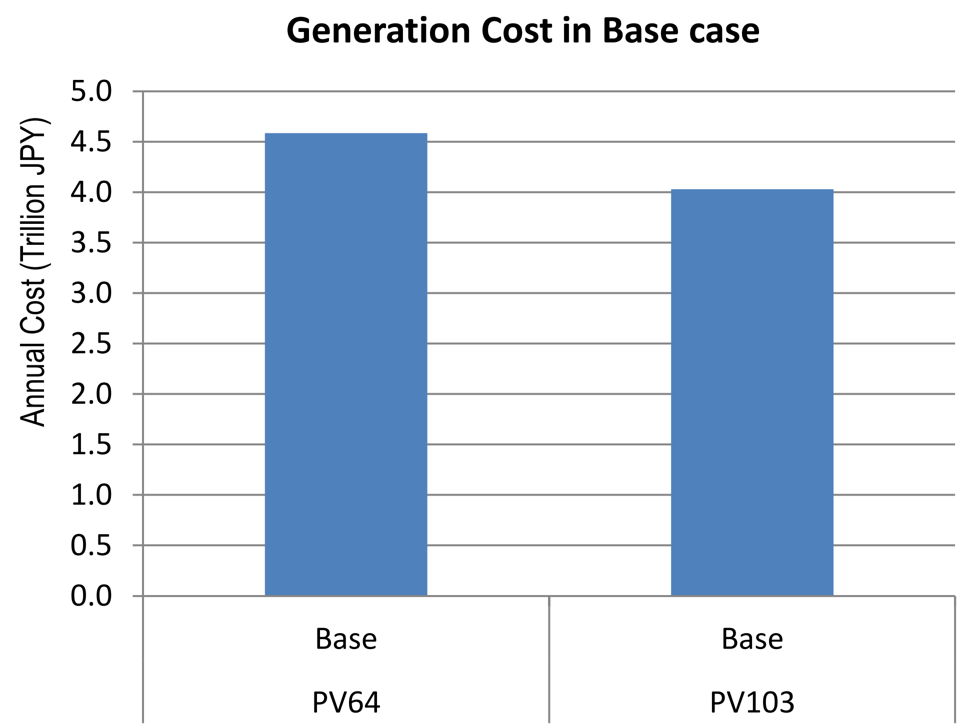
- All the sources of flexibility (energy interchange, coal LFC, PSH and BC interchange) are effective to reduce the cost compared with the Base Case.
- This is because lack of flexibility increases VRE curtailment while causing additional fuel cost and start-up cost.
- BC interchange is effective to reduce VRE curtailment.



Result of Analysis: PV64 vs PV103

- VRE curtailment of PV103 scenario is larger than that of PV64 scenario as the larger amount of PV and wind is deployed.
- The generation cost of PV103 scenario is smaller than that of PV64 in absolute value, as larger VRE power generation reduces conventional power generation.
- It should be noted that this analysis only optimizes variable generation cost but not fixed cost.

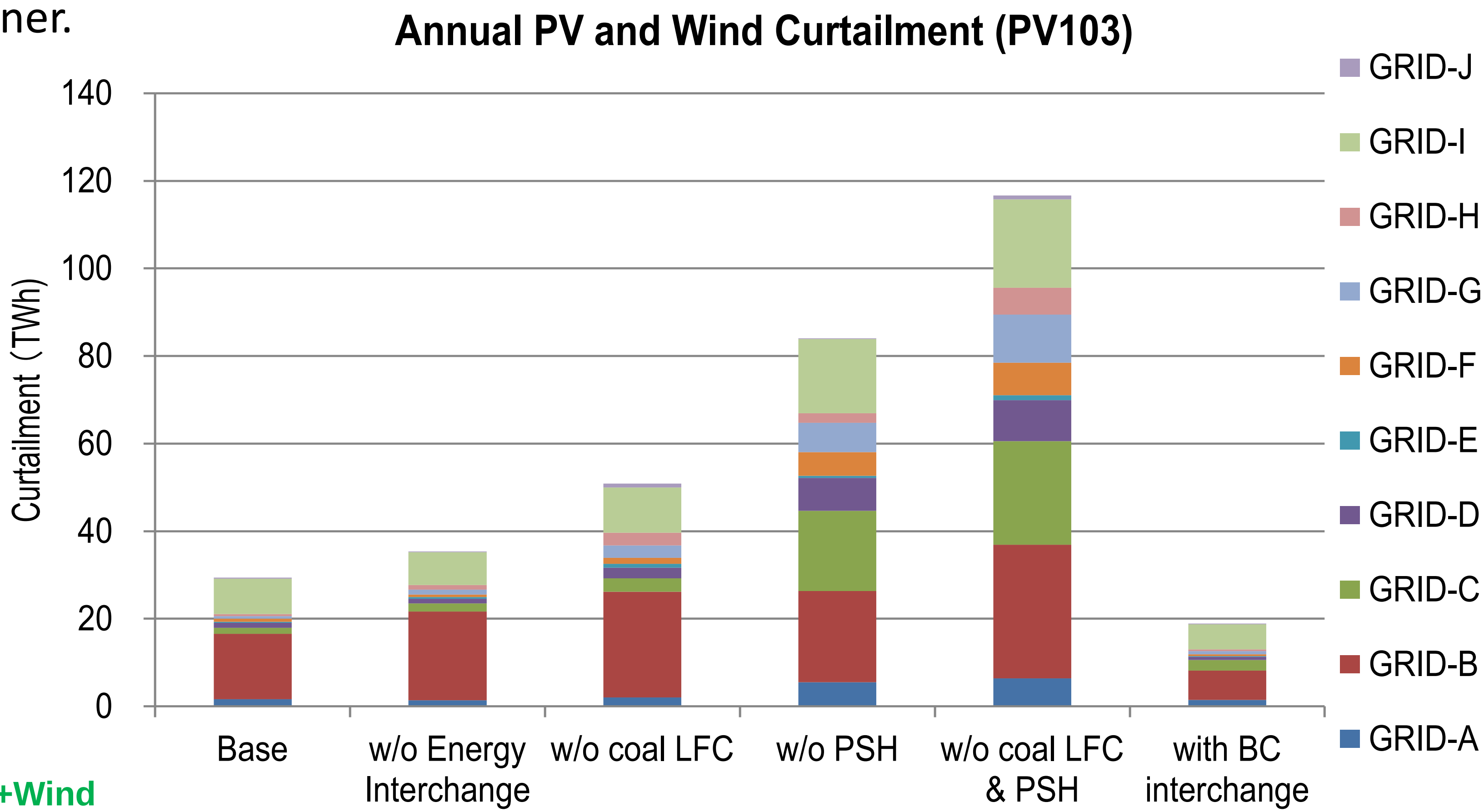




Share of PV+Wind In total power gen	8.2%	15.3.%

Result of Analysis: VRE Curtailment PV103

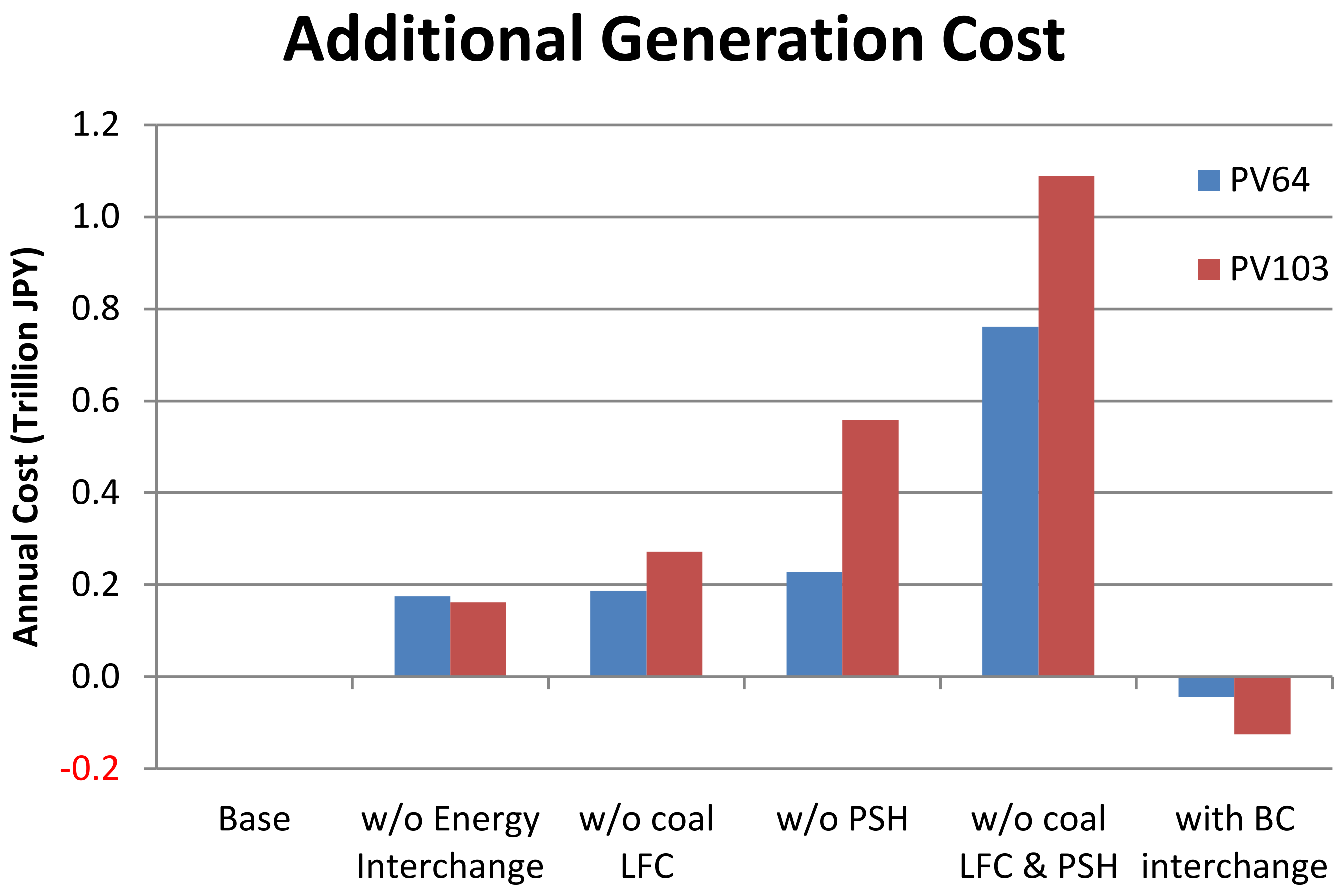
- All the sources of flexibility (energy interchange, coal LFC, PSH and BC interchange) reduce VRE curtailment.
- The level of curtailment in PV103 is larger than PV64, with higher share of VRE.
- The impact of PSH is significant in some areas especially in GRID-C, the largest PSH owner.



Ratio of PV+Wind In total power gen	**15.3%**	**14.8%**	**13.2%**	**10.7%**	**7.6%**	**16.2%**

Result of Analysis: Generation Cost PV103

- In PV103 scenario, the availability of flexibility options, Coal LFC, pumped storage hydro and BC interchange work more effectively compared to PV64 scenario due to massive VRE penetration.



Impact of Flexibility, Example of PSH

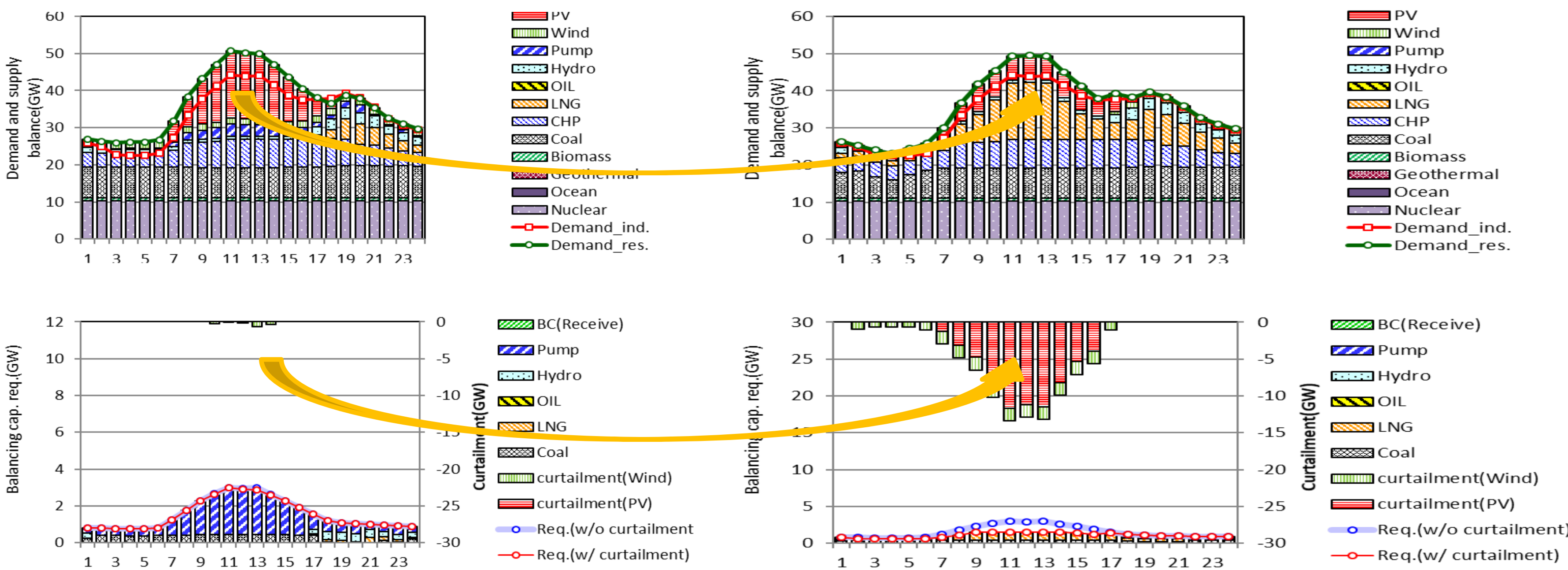
- Figures show hourly profile of power supply and demand, required and available balancing capacity, VRE curtailment in GRID-C, on May 17, a typical day with large PV and wind power generation as opposed to lower demand.
- Left figures show the case with PSH, and right figures the case without PSH.
- In the case without PSH, large curtailment of PV is necessary (below right) while PV power generation is displaced with LNG power generation (above right).
- Availability of PHS is effective to reduce VRE curtailment and fuel cost .

with PSH

w/o PSH

Electricity demand and supply balance

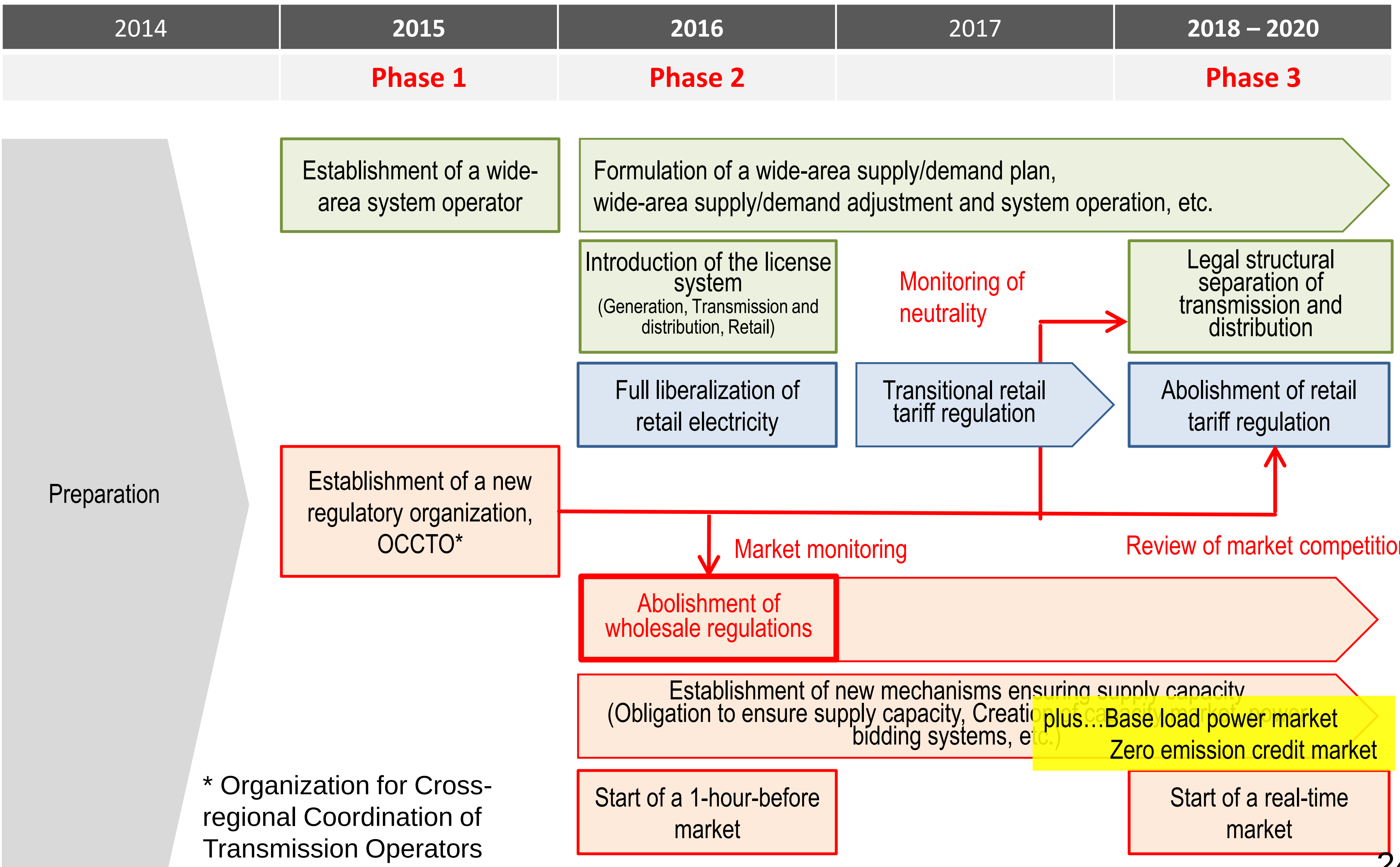
Variability and balancing capacity balance



Hourly demand and supply, required and available BC, VRE curtailment in GRID-C on May 17

MARKET DESIGN FOR FLEXIBILITY

Power Market Reform Time Schedule



Regulatory Framework for Flexibility

- Power market reform is underway aiming to complete the full deregulation by 2020
- Discussion on flexibility (balancing capacity) market design has just started in a dedicated committee under OCCTO.
- From an IPP's perspective, appropriate monetization of flexibility value is the key for fully realizing the flexibility potential.
- Quantitative evaluation of such value of flexibility by model based analysis is necessary to design effective market and regulatory structure.

電源開発

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