An IPP's perspective on power plant flexibility in Japan

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Global Attention to Power Plant Flexibility

- Advanced Power Plant Flexibility Campaign (APPF) was carried out as one of the activities of Clean Energy Ministerial from 2017 to 2018, coordinated by IEA.
- “Accommodating the growing shares of wind and solar power poses novel challenges for power systems”, “This raises the importance of power system flexibility”, “APPF seeks to build strong momentum and commitment from governments and industry to implement solutions that make power generation more flexible.”
- J-POWER participated in APPF as a private partner



About J-POWER

(As of April 2017)

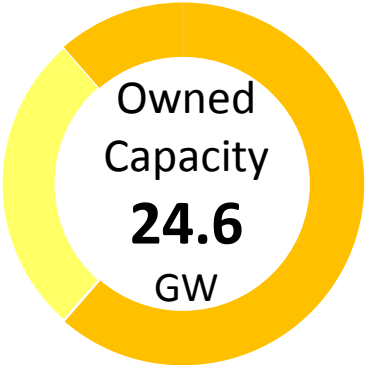
Corporate History

✓ 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

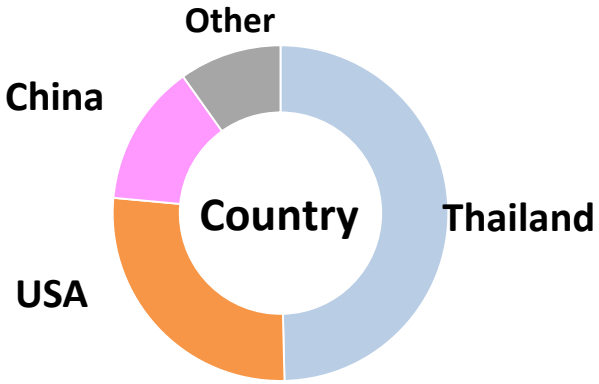


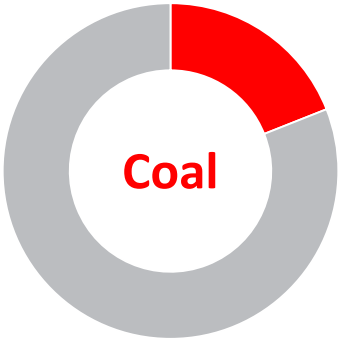
Japan
17.9 GW

Growing significantly, especially in Thailand in recent years

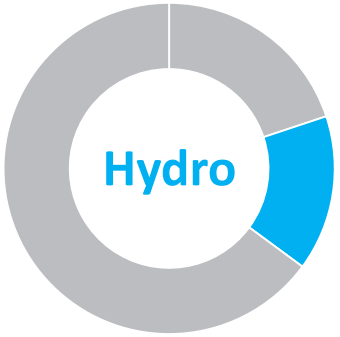
Leading shares in coal-fired, hydro and wind power generation

(Shares : As of March 2017)

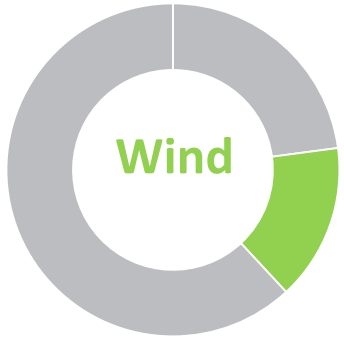




8.6GW



8.6GW



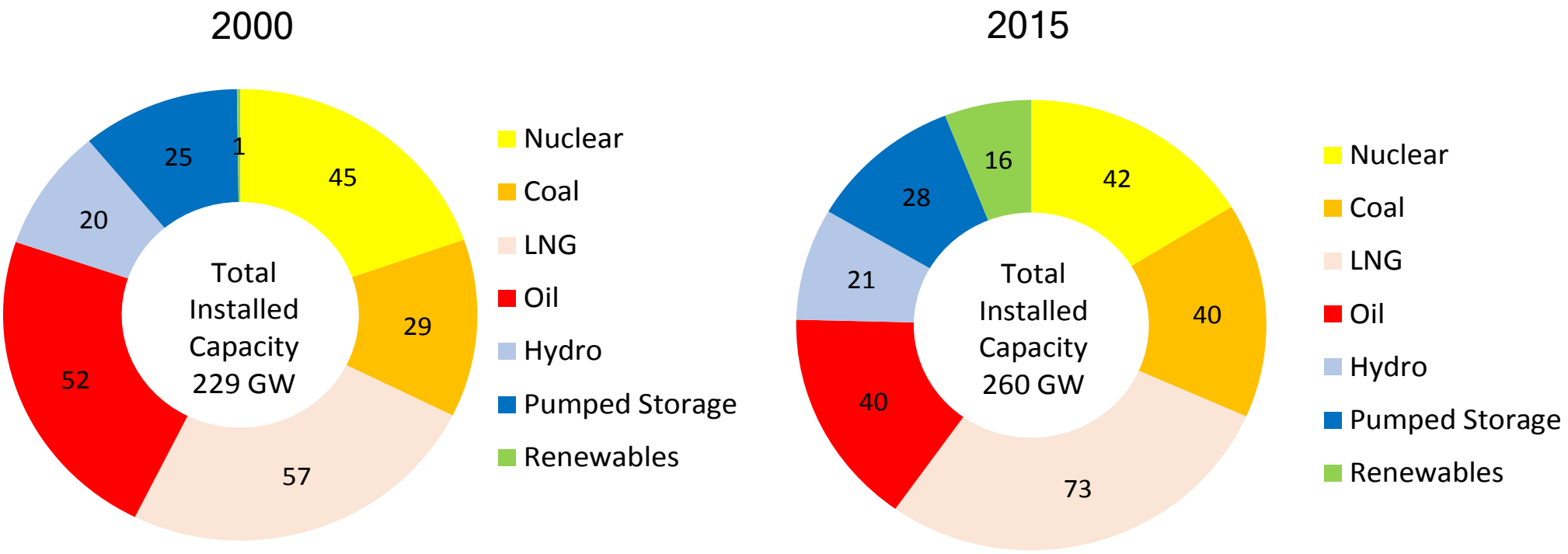
0.4GW

of which Pumped Storage Hydro 5.0GW

ELECTRIC POWER GENERATION IN JAPAN

Japan's 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.

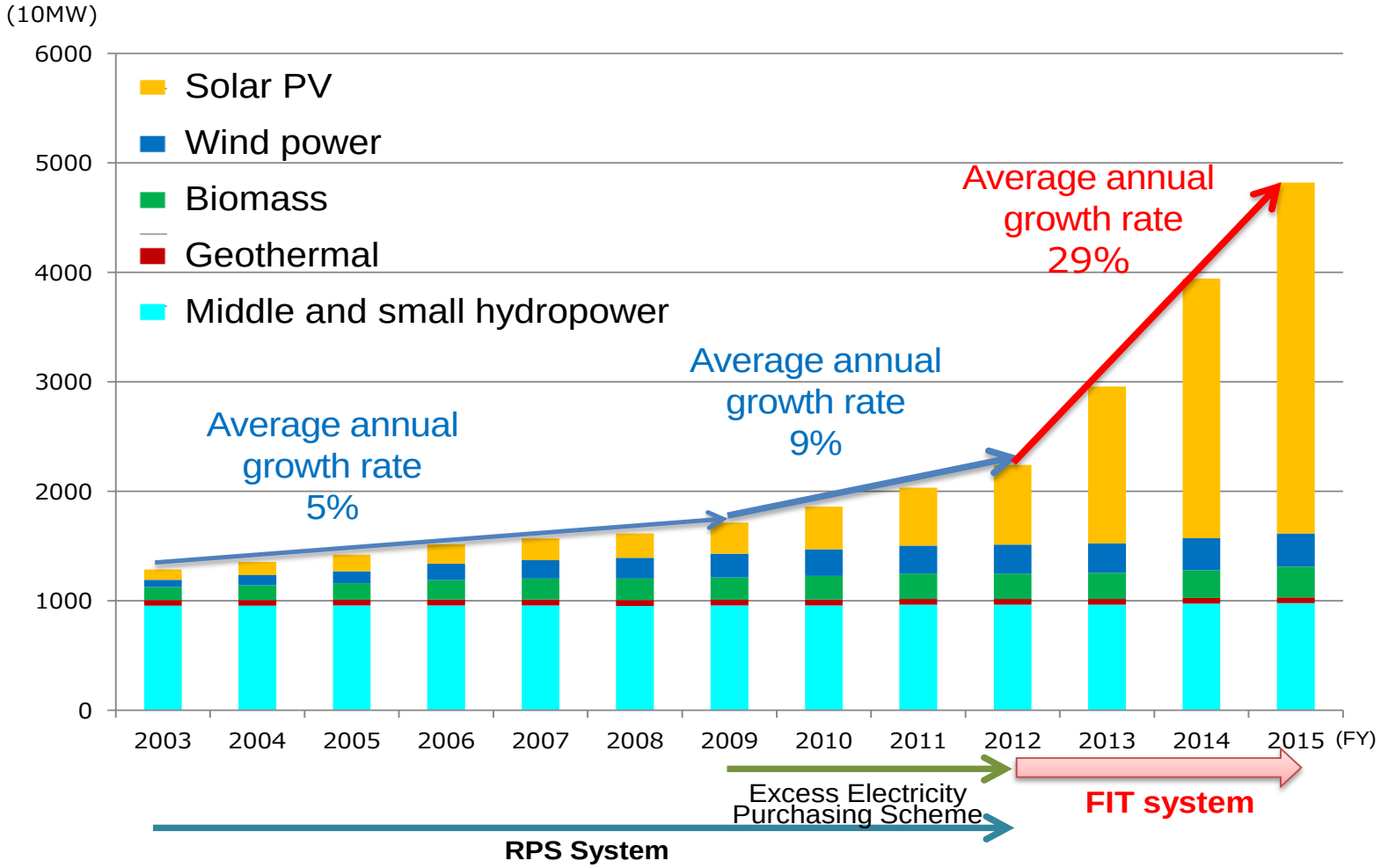


Power generation capacity by type in Japan (excluding new entrants)

Source: Energy White Paper 2017

Growth of Renewables

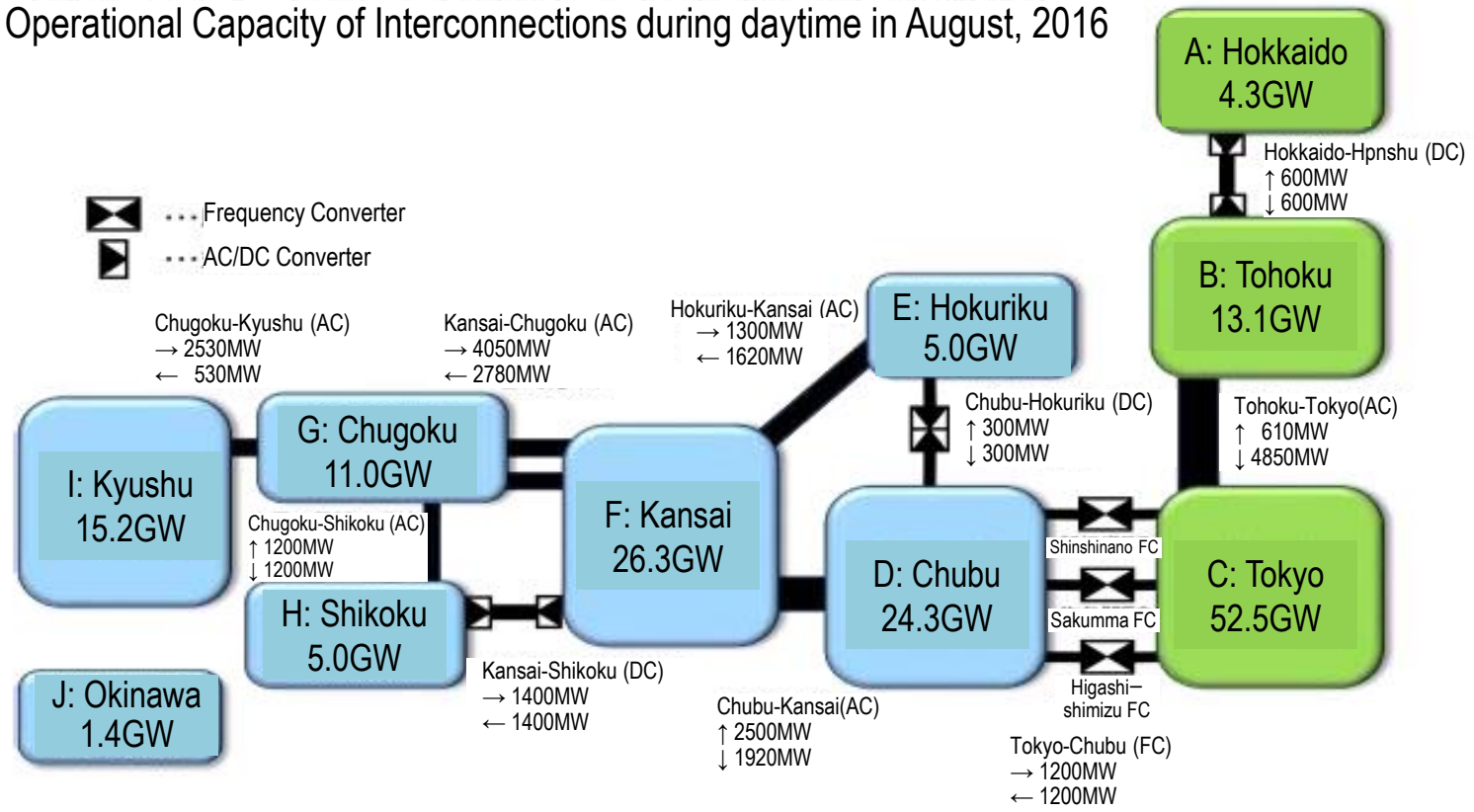
- RE promotion policy started with RPS in 2003 supplemented by Excess Electricity Purchasing Scheme in 2009. In 2012 they were replaced by Feed-in Tariff that triggered a surge of solar PV.



Source: presentation of Ministry of Economy, Trade and Industry

Power System in Japan

- Japan's power system consisting of 10 grids is divided between East (50Hz) and West (60Hz) in frequency.
- 9 grids going through four main islands are connected with interconnections and FCs 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).



VALUE OF FLEXIBILITY IN JAPAN MODEL BASED ANALYSIS

Model Description

- The analysis used a production cost model dedicated for Japan's power system.
- Objective function: Minimizing generation cost (fuel cost plus start-up cost) of the total power system of interconnected 9 power grids and one isolated grid for 8760 hours.

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

- As a nature of production cost simulation, it does not take fixed cost (capital cost nor depreciation) into account.
- Limiting conditions
  - Balance between demand and supply
  - Balance between variability and available flexibility (LFC* capacity)
  - Upper and lower limit of hourly output in each power generation unit
  - Capacity of interconnection for energy interchange

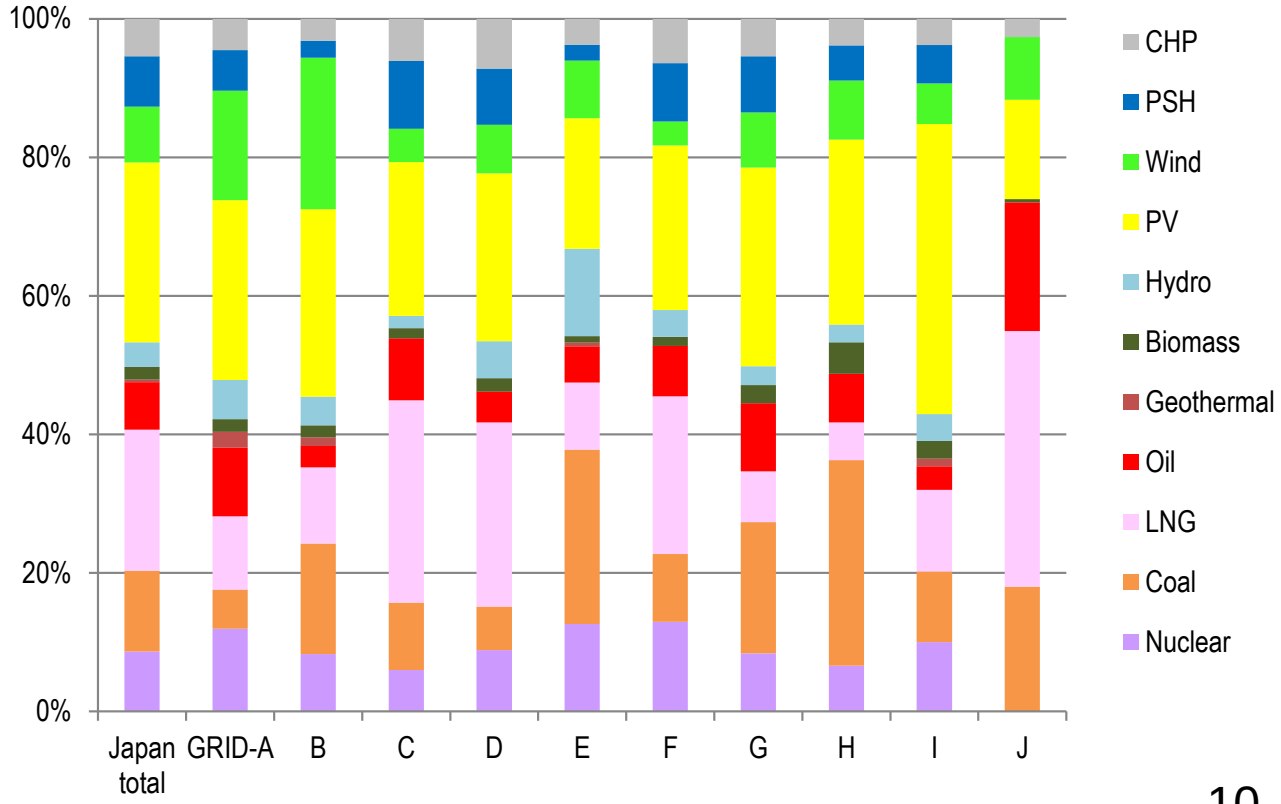
* LFC (Load Frequency Control) balancing capacity able to regulate variability in a few to 15 minutes .

Generation Capacity Portfolio in 2030

- The total capacity of solar PV (103GW) and wind (32GW) in 2030 assumed to represent “massive VRE deployment “
- Solar PV and wind distribution by grid assumed to reflect the current unevenness
- Other type of power generation capacity in 2030 assumed in line with Long Term Energy Demand and Supply Outlook 2015

VRE capacity by grid

GRID	PV(GW)	Wind(GW)
A: Hokkaido	4.5	2.7
B: Tohoku	13.5	10.9
C: Tokyo	27.4	5.9
D: Chubu	12.9	3.7
E: Hokuriku	1.8	0.8
F: Kansai	14.2	2.1
G: Chugoku	7.5	2.1
H: Shikoku	3.6	1.1
I: Kyushu	17.3	2.4
J: Okinawa	0.6	0.4
Total	**103.4**	**32.2**



Power generation capacity by type by grid

Cases for Flexibility Evaluation

- The impact by availability of source of flexibility to VRE utilization and operation cost were analyzed.
  - Coal-fired power plants' LFC capacity
  - Pumped storage hydro
- Priority dispatch for VRE, a known measure to support VRE, was also analyzed for comparison

Analyzed case and available source of flexibility

Case	Available Source of Flexibility			
	LFC service from Oil and Gas fired PP	LFC service from Coal-fired PP	Pumped Storage Hydro	Priority Dispatch of VRE
Current situation in Japan	✔	*Not fully*	✔	✔
Base Case	✔	✔	✔	
without Coal LFC (w/o C-LFC)	✔	No	✔	
without PSH (w/o PSH)	✔	✔	No	
with Priority Dispatch (PD)	✔	✔	✔	✔

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

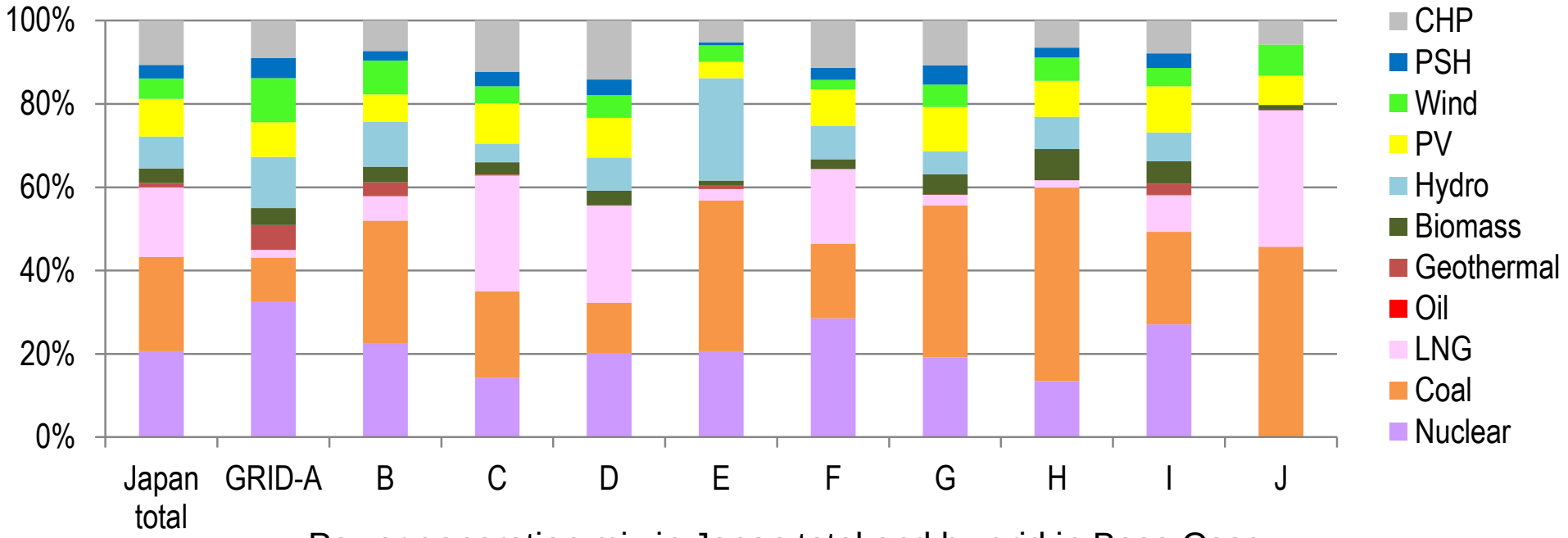
Result of Analysis: Power Generation Mix

- The power generation mix in Base Case by energy type shows;

  Nuclear: Coal: Gas: Oil: Renewables = 21%: 23%:27%:1%:28%

*Gas includes CHP, and Renewables includes PSH as in line with Long Term Energy Demand and Supply Outlook 2015

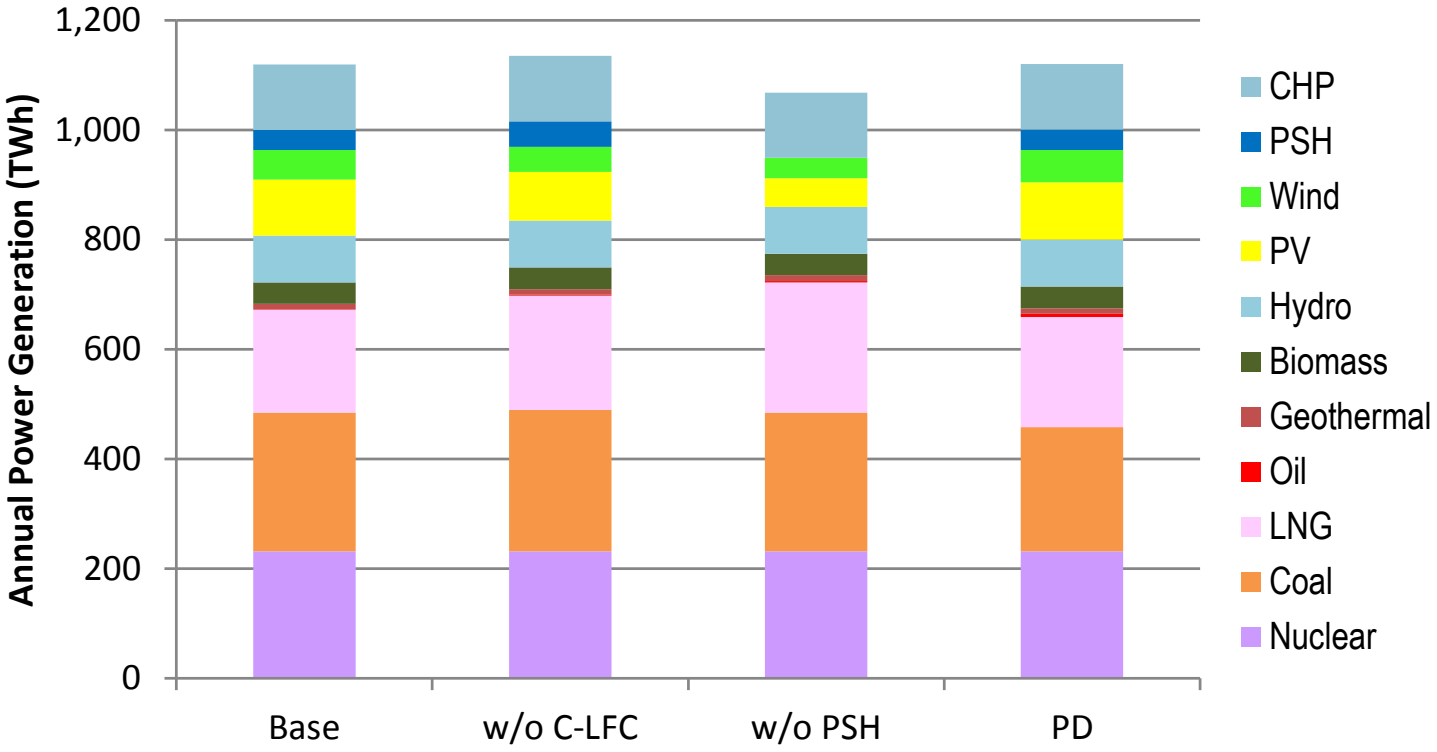
- The power generation mix varies by grid, mainly due to capacity portfolio in each grid but also due to conditions in neighboring grids.



Power generation mix in Japan total and by grid in Base Case

Result of Analysis: Power Generation Mix

- The power generation mix varies by case.
- When Coal LFC or PSH is not available, LNG power generation increase.
- When PSH is not available, total power generation is lower than the others as the power demand for pumping disappeared.

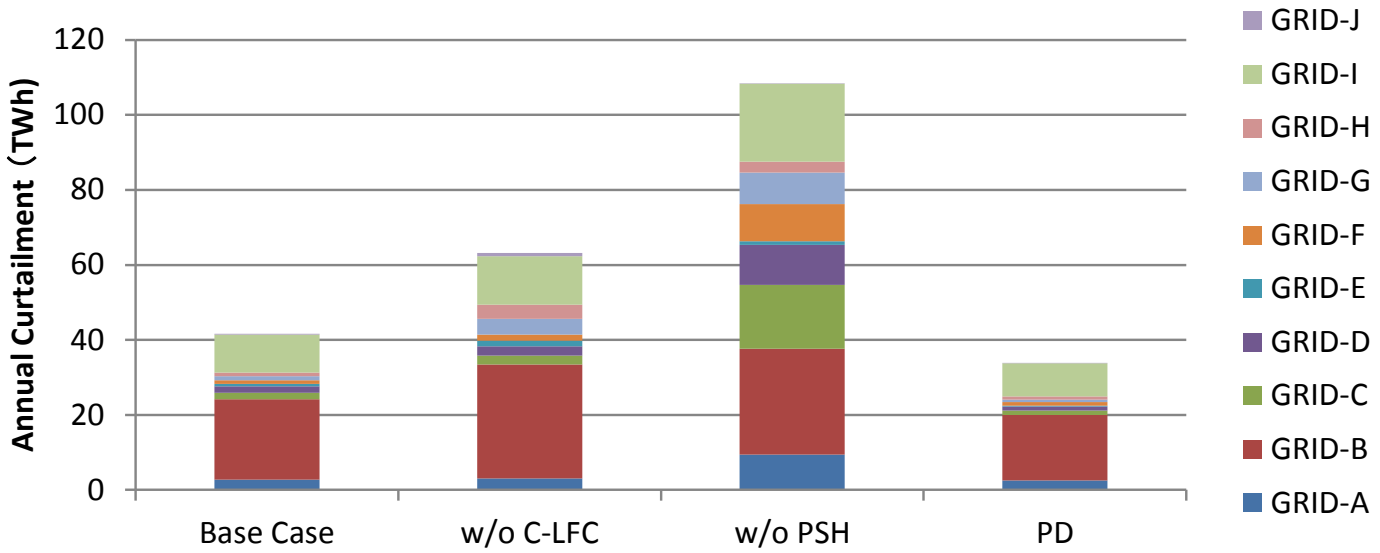


Power generation mix in Japan total by case

Result of Analysis: VRE Curtailment

- Unavailability of Coal LFC increases VRE curtailment to make VRE share 2% lower.
- Unavailability of PSH increases VRE curtailment to make VRE share 6% lower.
- Priority dispatch reduces VRE curtailment to make VRE share 1% higher.

⇨ Both sources of flexibility, Coal LFC and PSH, enable more efficient use of VRE power generation as (or more efficiently than) priority dispatch.

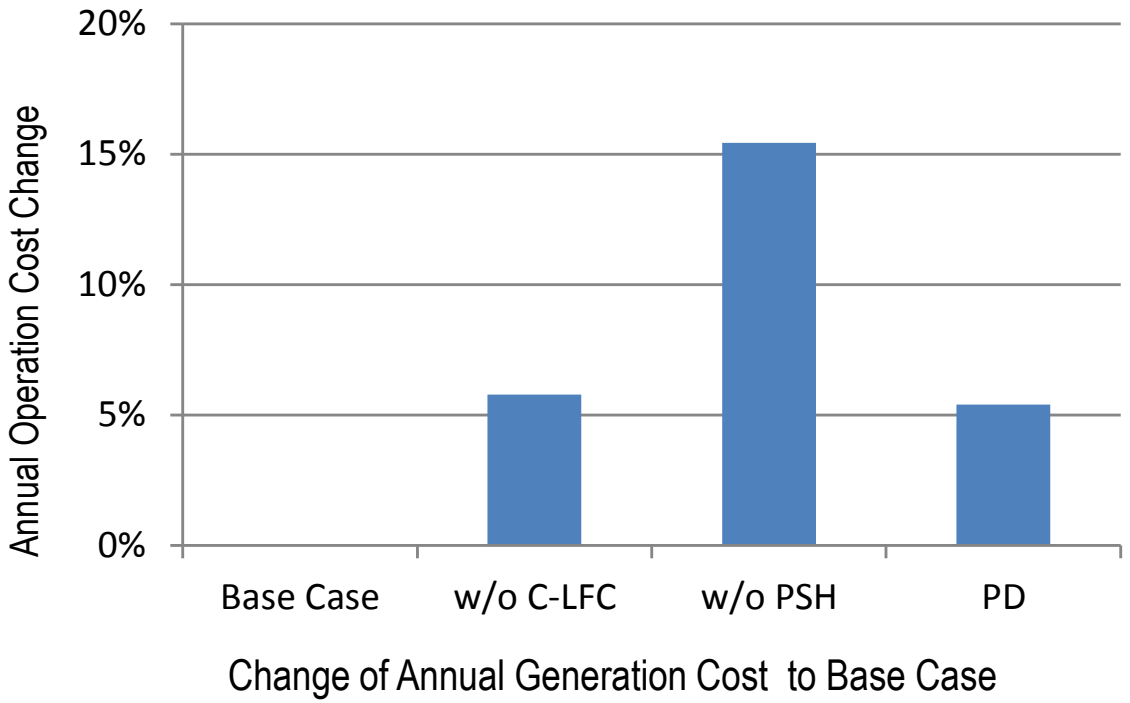


	Base Case	w/o C-LFC	w/o PSH	Peiority Dispatch
Share of VRE in total power generation				
VRE	14%	12%	8%	15%
Curtailment Ratio				
PV	17%	27%	57%	14%
Wind	27%	40%	51%	21%

VRE curtailment and VRE share in total power generation by case

Result of Analysis: Generation Cost

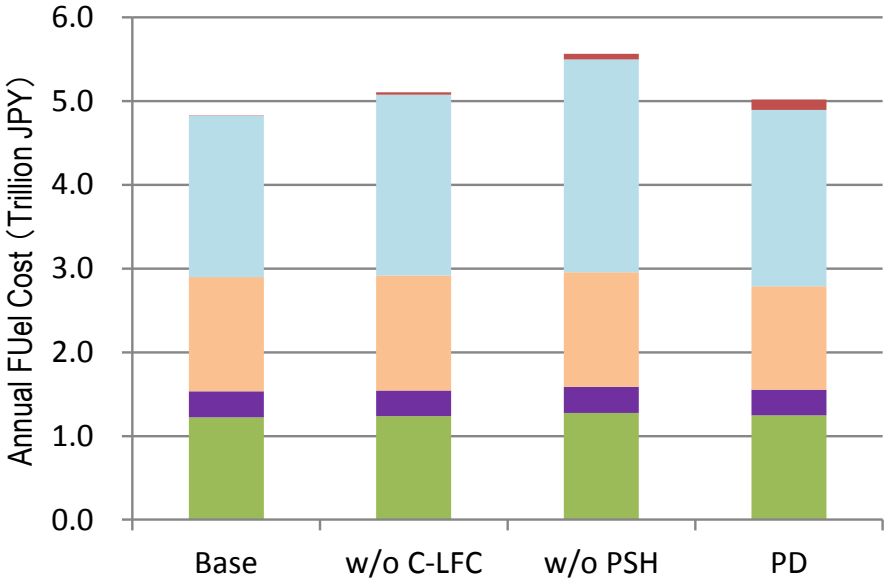
- Unavailability of coal-LFC increaces the generation cost by 6%.
  ⇨ Availability of coal LFC reduces VRE curtailment and cost
- Unavailability of PSH increases the generation cost by 9%
  ⇨ Availability of PSH reduces VRE curtailment and cost
- Priority dispatch increases the generation cost by 6%
  ⇨ Priority dispatch reduces VRE curtailment but increases cost

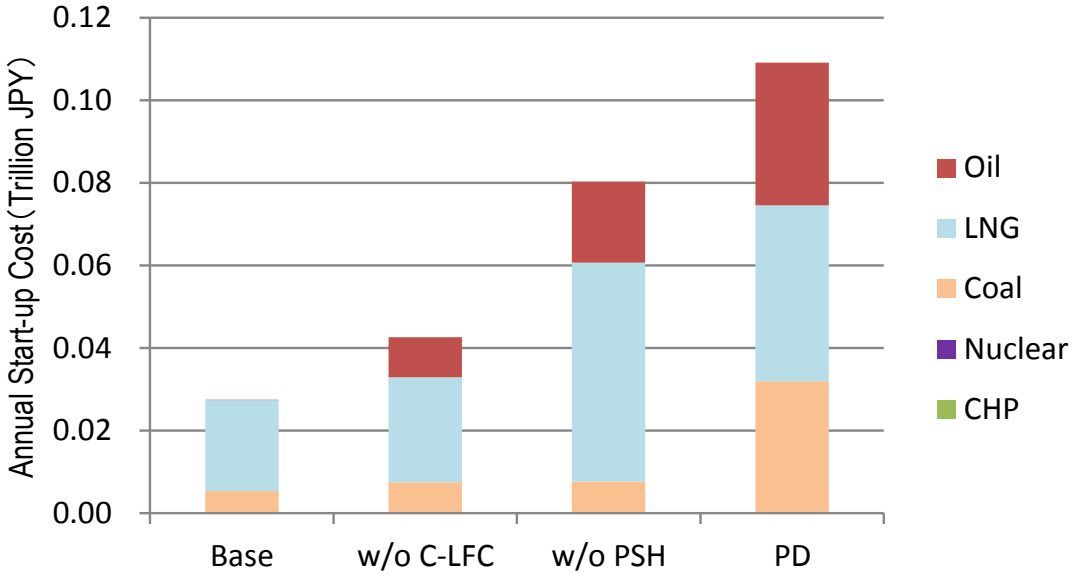


Result of Analysis: Generation Cost

- In case of coal LFC not available, the cost increase compared to Base is derived from increase of LNG PP's fuel cost and oil PP's start-up cost.
- In case of PSH not available, the large cost increase compared to Base is derived from increase of LNG PP's fuel cost and start-up cost, as well as oil PP's start-up cost .
- In case of priority dispatch, the cost increase compared to Base is derived from increase of start-up cost of coal PP, LNG PP and Oil PP.

⇨ Priority Dispatch increases start-up cost of all fossil fuel.





Annual fuel cost by fuel (left) and Annual start-up cost by fuel (right) by Case

Conclusion of Analysis

- Both of analyzed flexibility, coal LFC and pumped storage hydro, have effect to reduce VRE curtailment and generation cost.
- Compared to priority dispatch, the effect in reduction of VRE curtailment of coal LFC is same, and that of pumped storage hydro is larger.
- Priority dispatch increases the generation cost due to the raise of start-up cost.

⇨ Availability of coal LFC and pumped storage hydro is important for efficient use of VRE In Japan's power system.

- The cost reduction derived by the availability of flexibility indicates the value of flexibility.
- Quantitative evaluation combined with cost to realize flexibility helps to examine necessary payment for flexibility.

MARKET DESIGN FOR FLEXIBILITY

Framework for Flexibility

- Power market reform is underway in Japan that aims to complete the full deregulation of energy only market by 2020.
- Currently, procurement of balancing capacity is done through public tender annually for the next fiscal year in each grid .
- As the share of VRE increases in the power system, the awareness of the need of the market mechanism to ensure flexibility has increased, and discussion on the design of balancing capacity market started in a committee organized by OCCTO.
- The committee so far has identified 10 products ; (GF, LFC, EDC-H, EDC-L and Low Speed Tertiary Control Reserve) x (up and down)
- Market for Low Speed Tertiary Control Reserve (up and down) will be ready in 2021.
- Market(s) for the other 8 products is(are) planned to be ready in 2024.

Framework for Flexibility (continued)

- 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 essentially necessary to design effective market and such analysis is being spread with making progress.

- The flexibility mechanisms discussed here is effective to regulate short period variability, but it is not enough to address all the risks associated with increased share of VRE.
- Power system with larger share of VRE faces the potential risk of destructive damage by forecast error of VRE power generation.
- To ensure stable power system operation, forecast error should be addressed properly before VRE share increases to the concerned level.



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