

Fact-Finding Surveys on PSH Business in Different Power Markets Accommodating Large Scale VRE

Koichi Ota
(Kansai Electric Power Co., Inc.)

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1. Research Project of Japan

Project Goal

To define common and different statuses and issues of pumped storage hydropower businesses in different power markets

Topics

- The needs for pumped storage hydropower as well as its functions expected to be delivered in the power system accommodating large scale VRE (Document research)
- Common and different roles and value of pumped storage hydropower in different power systems (Document Research & Fact-Finding Survey)
- Operational figures of pumped storage hydropower stations in service (Fact-Finding Survey)

1. Research Project of Japan (Timeline)

FY2017	FY2018	FY2019	FY2020
<p>Germany Austria</p> <p>-----></p>	<p>U.S.A</p> <p>Clarification of the design of each power market and technical & financial issues of pumped storage hydropower business</p>	<p>Document research</p> <p>←→</p> <p>Fact-Finding Survey</p> <p>Japan</p> <p>←→</p> <p>Portugal (Frades II, EDP, 19 Oct.)</p> <p>←→</p>	<p><i>Supplemental activities depending on the needs from the entire Annex IX programs</i></p> <p>←→</p>

2. Status of Japan

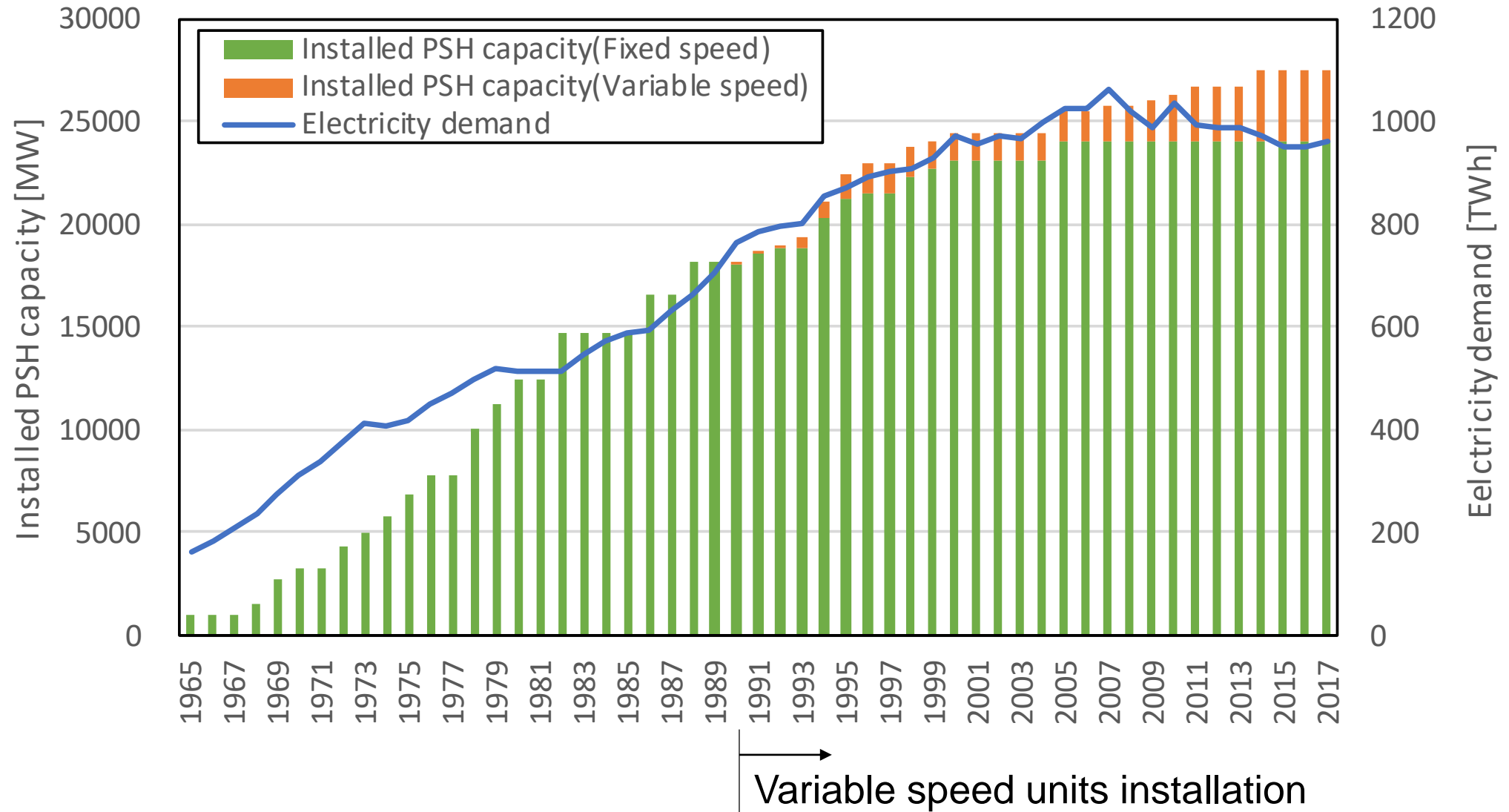
i. PSH Deployment

As of FY2018

Area	Fixed-speed PSH (kW)	Variable-speed PSH (kW)	Total (kW)
Hokkaido	300,000	500,000	800,000
Tohoku	712,340	0	712,340
Tokyo	10,435,500	1,080,000	11,515,500
Chubu	4,164,500	0	4,164,500
Hokuriku	110,000	0	110,000
Kansai	4,419,000	640,000	5,059,000
Chugoku	2,123,000	0	2,123,000
Shikoku	686,200	0	686,200
Kyusyu	1,100,000	1,200,000	2,300,000
Total	24,050,540	3,420,000	27,470,540

(Notes) The figures above include PSHs of J-Power and a local bureau of enterprise, on top of regional power utilities.

i. PSH Deployment

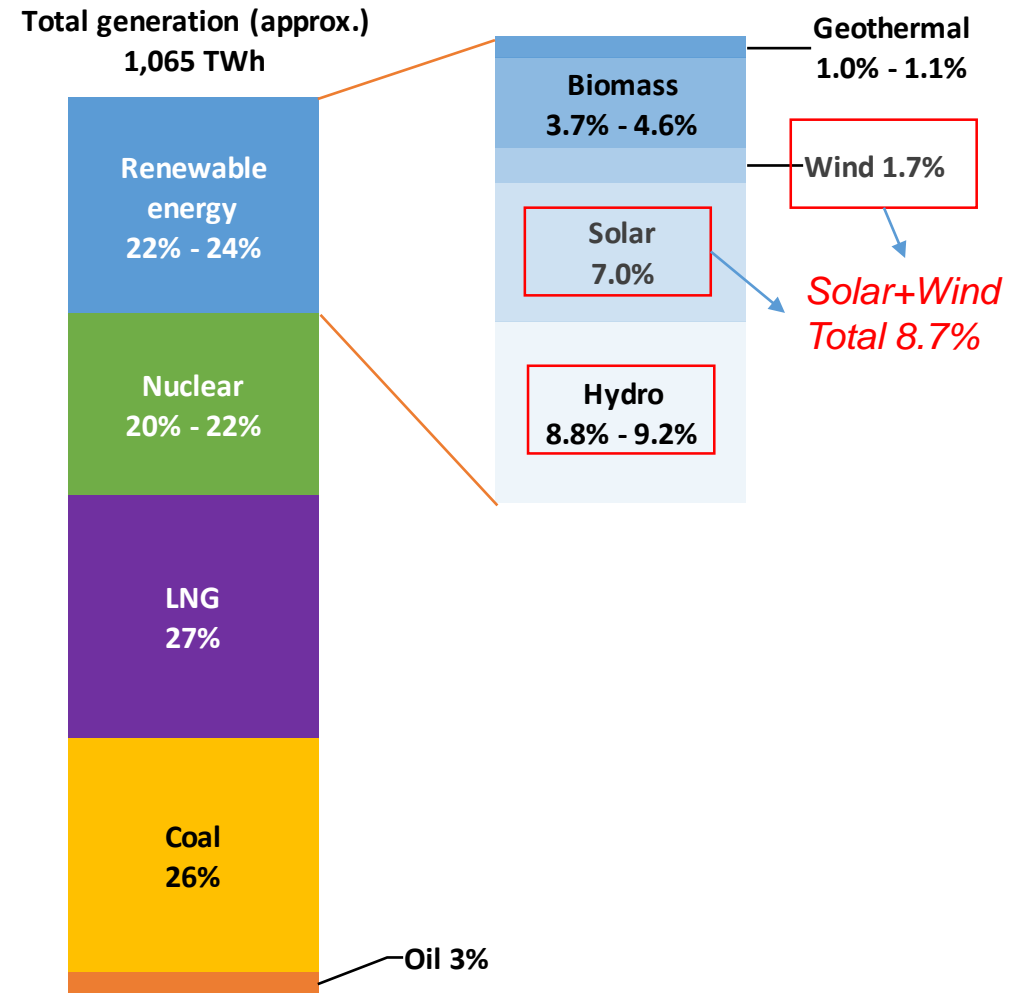


Source : Agency for Natural Resources and Energy

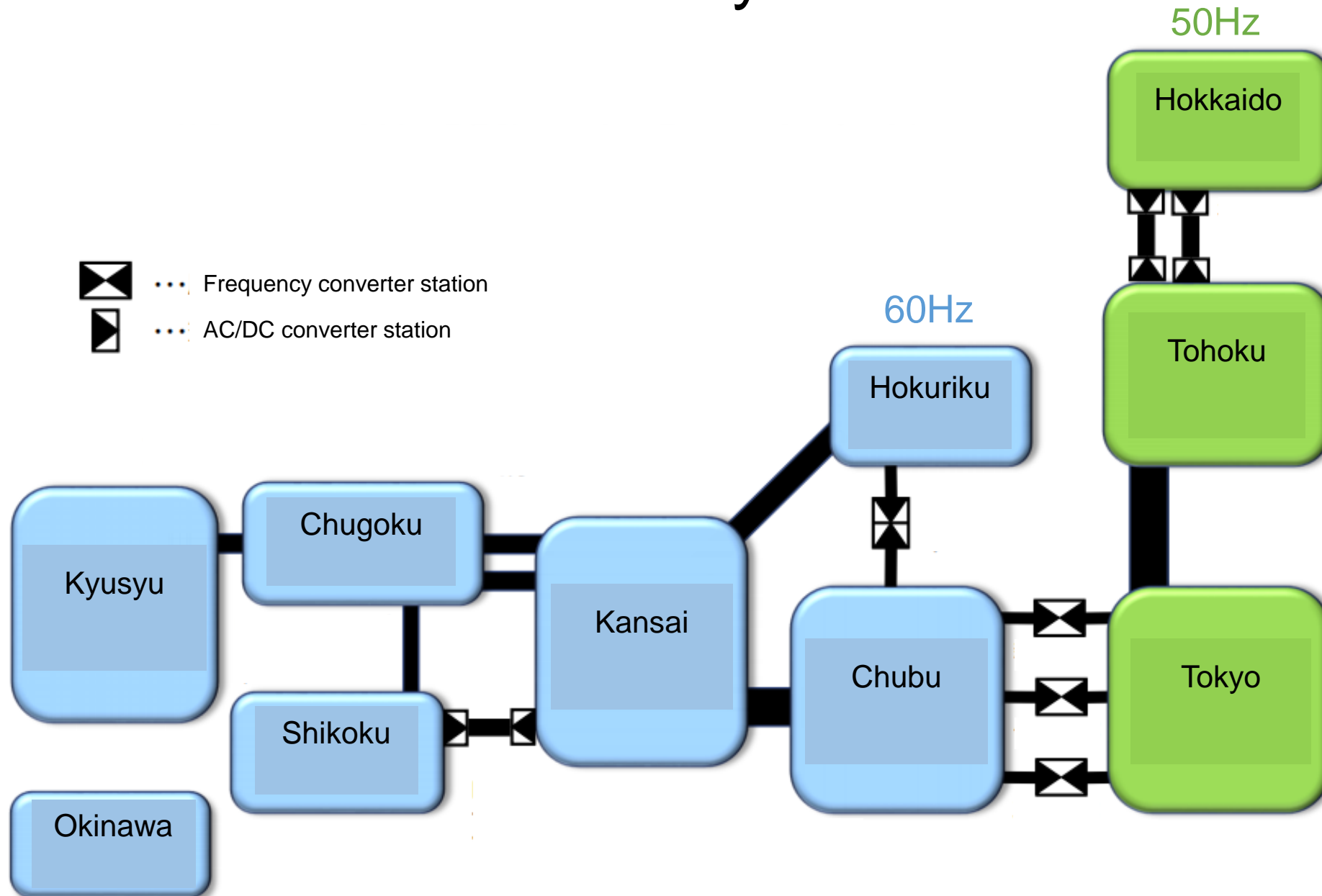
ii. Energy Policy

- To achieve energy mix target
- To lay foundation to use renewable energy as one of the major power sources
(Launched the Feed-In Tariff in 2012)
- To promote energy saving such as through introduction of EVs
- To lower dependency on nuclear power generation

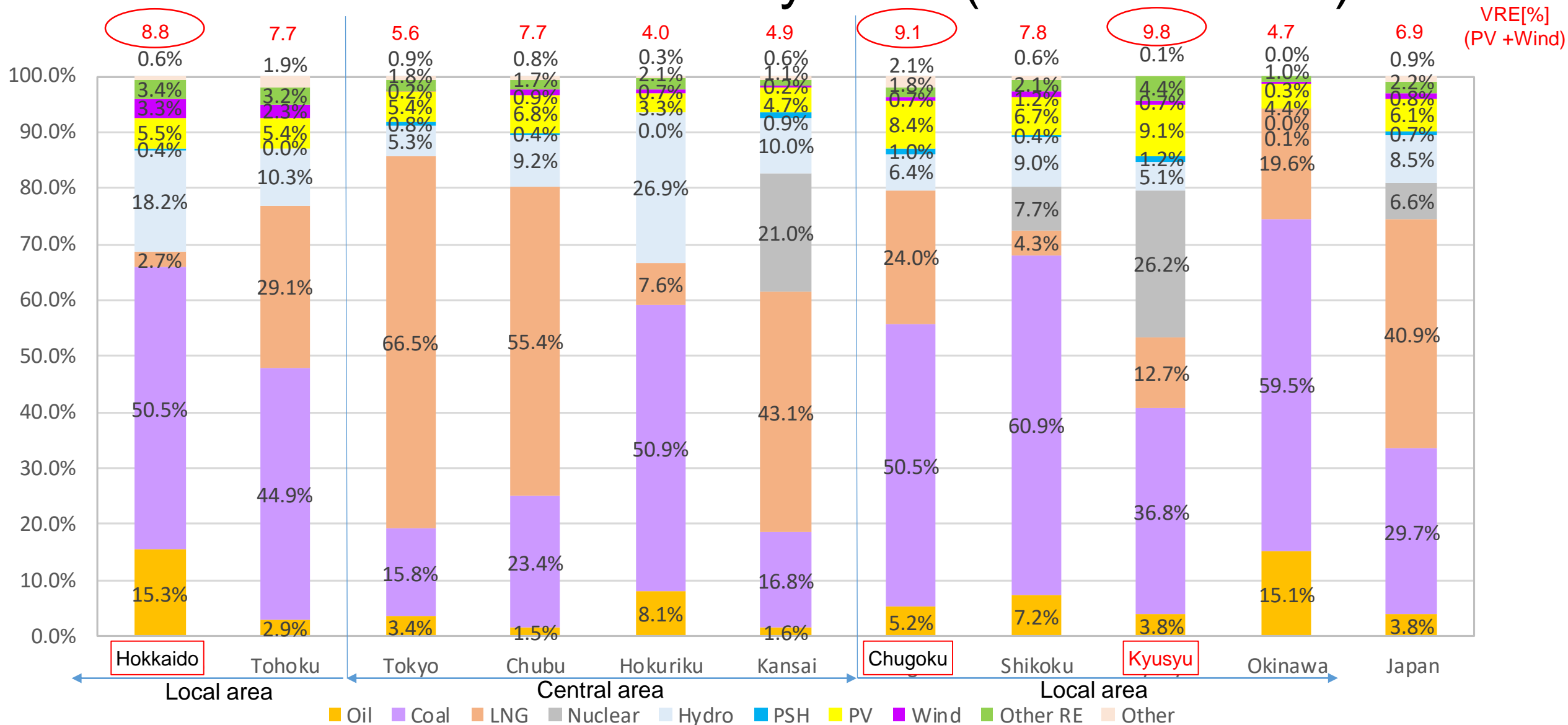
Power Generation Mix Target in FY2030



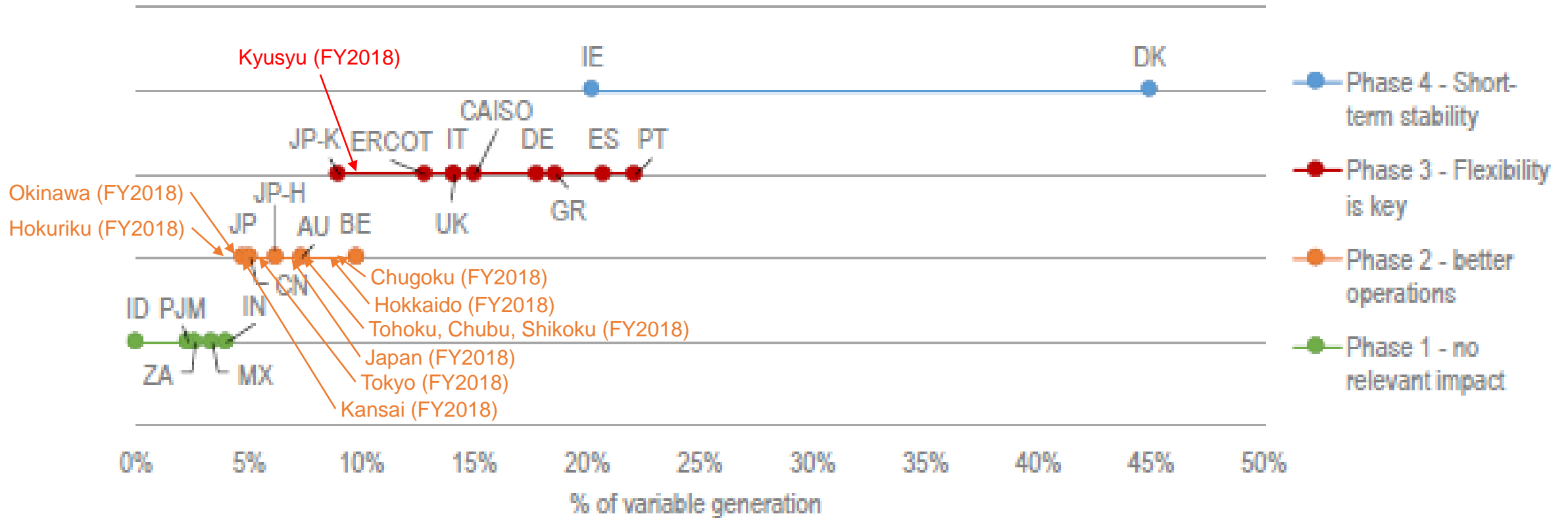
iii. Power Generation Mix by area



iii. Power Generation Mix by area (as of FY2018)



iii. Power Generation Mix by area (as of FY2018)



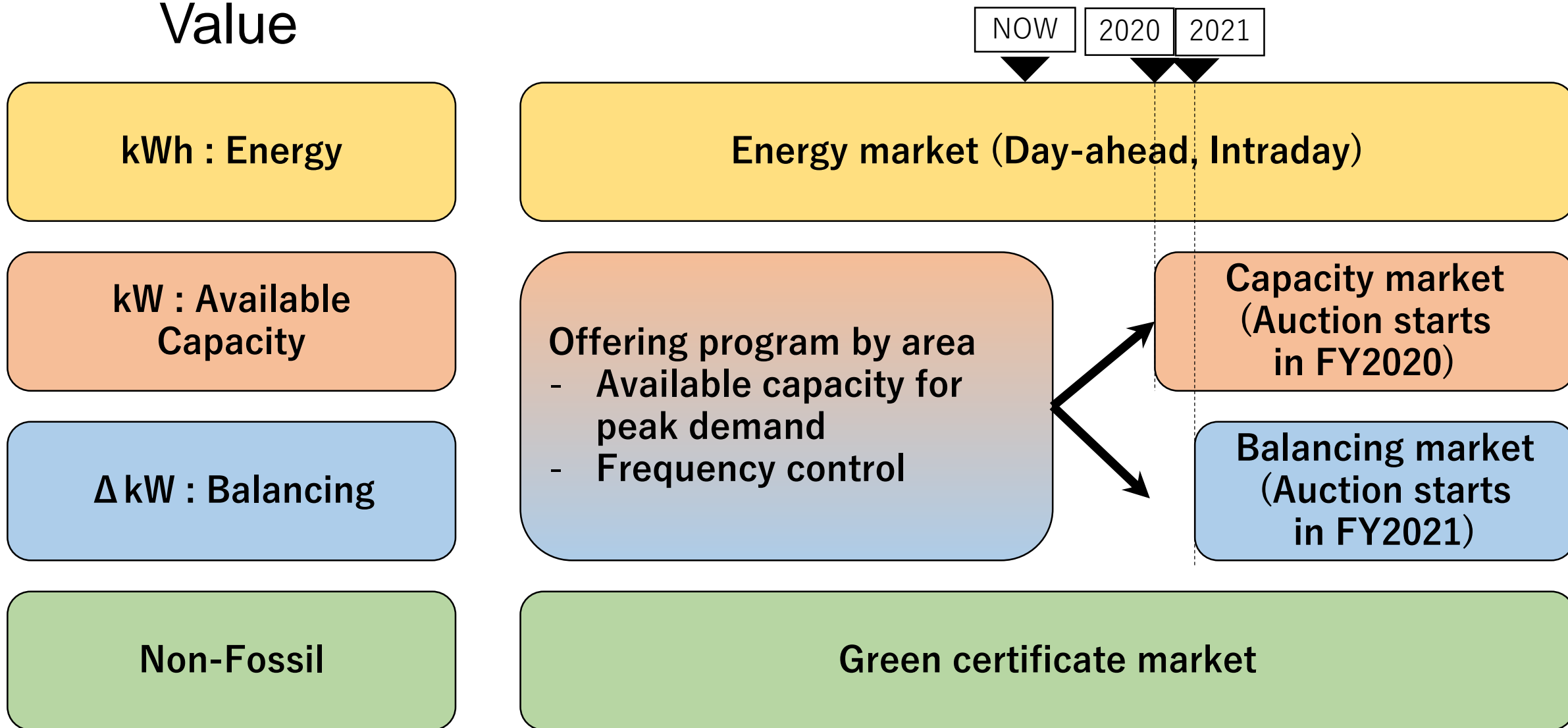
Notes: AT = Austria; AU = Australia; BR = Brazil; CL = Chile; CN = China; DE = Germany; DK = Denmark; ES = Spain; GR = Greece; ID = Indonesia; IE = Ireland; IN = India; IT = Italy; JP = Japan; JP-H = Hokkaido (Japan); JP-K = Kyushu (Japan); MX = Mexico; NZ = New Zealand; PT = Portugal; SE = Sweden; UK = the United Kingdom; ZA = South Africa. PJM, CAISO and ERCOT are US energy markets.

Source: Adapted from IEA (2017a), *Renewable 2017*.

iv. Market Design (being under review under OCCTO)

OCCTO: Organization for Cross-regional Coordination of Transmission Operators, JAPAN

Value



iv. Market Design (being under review under OCCTO)

OCCTO: Organization for Cross-regional Coordination of Transmission Operators, JAPAN

Offering program menu (Annual auction for next year)

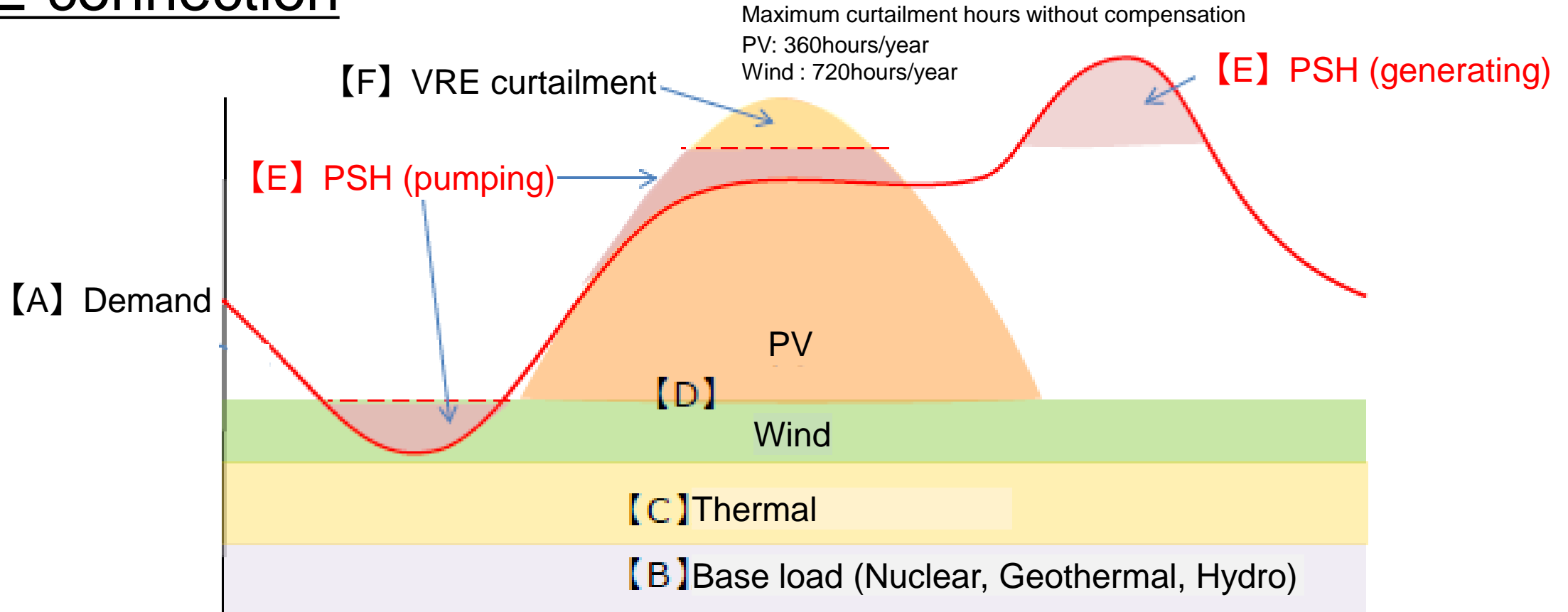
Category	Requirement					Offering capacity	Payment for	
	Response	Control		Capacity	Fixed cost		Variable cost	
I	I-a	5min	GF, LFC	Online	>5MW	7% of the average of 3 maximum annual demands in each area	Available	Depending on actual operation
	I-b	15min	-	Online	>5MW			
	I'	3hour	-	Off-line	>1MW			
II	II-a	5min	GF, LFC	Online	>5MW	Depending on each area	Not Available	
	II-b	15min	-	Online	>5MW			
	II'	1hour	-	Off-line	>5MW			

Source : Ministry of Economy, Trade and Industry

- Fixed remuneration for Category I supports PSH business.
- The offering capacity for Category I is limited.

v. Role of PSH for VRE Integration

VRE connection



Source : Agency for Natural Resources and Energy

Counts on:

- pumping to absorb VRE surplus in early morning and daytime
- generating in nighttime

v. Role of PSH for VRE Integration

Power curtailment procedure

Demand & VRE output forecast



- Thermal unit curtailment
- **Whole PSH units pumping**
 ※Regardless of electricity prices, PSHs require pumping to absorb VRE surplus and generating in nighttime to create an effective reservoir capacity for pumping for next daytime.
- Interconnection utilization

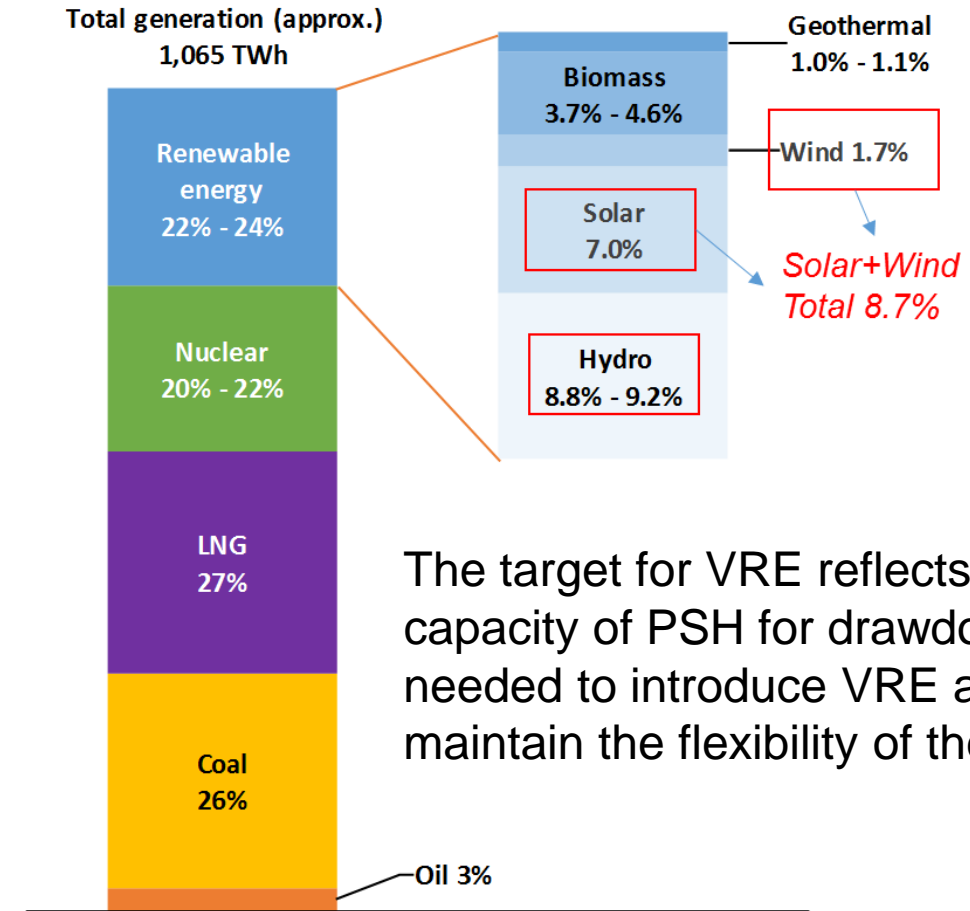


VRE curtailment



Base load curtailment

Power Generation Mix Target in FY2030

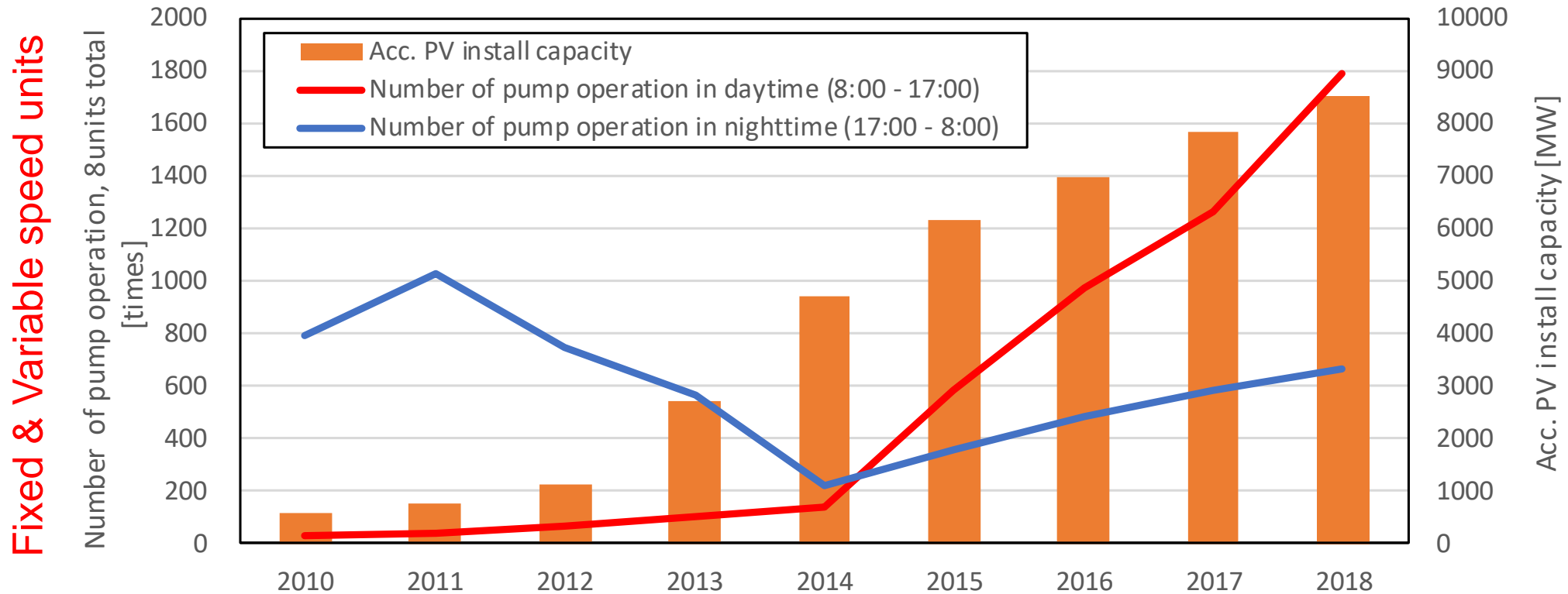


The target for VRE reflects the negative capacity of PSH for drawdown. PSH is needed to introduce VRE as planned to maintain the flexibility of the network.

Source : Ministry of Economy, Trade and Industry

vi. PSH Business in VRE-Highly-Shared Area (Kyusyu)

Number of pump operation & PV capacity (Kyusyu, FY2010 - FY2018)



Source : Kyusyu EPCO

the Great East Japan Earthquake
(Stopped Nuclear units)



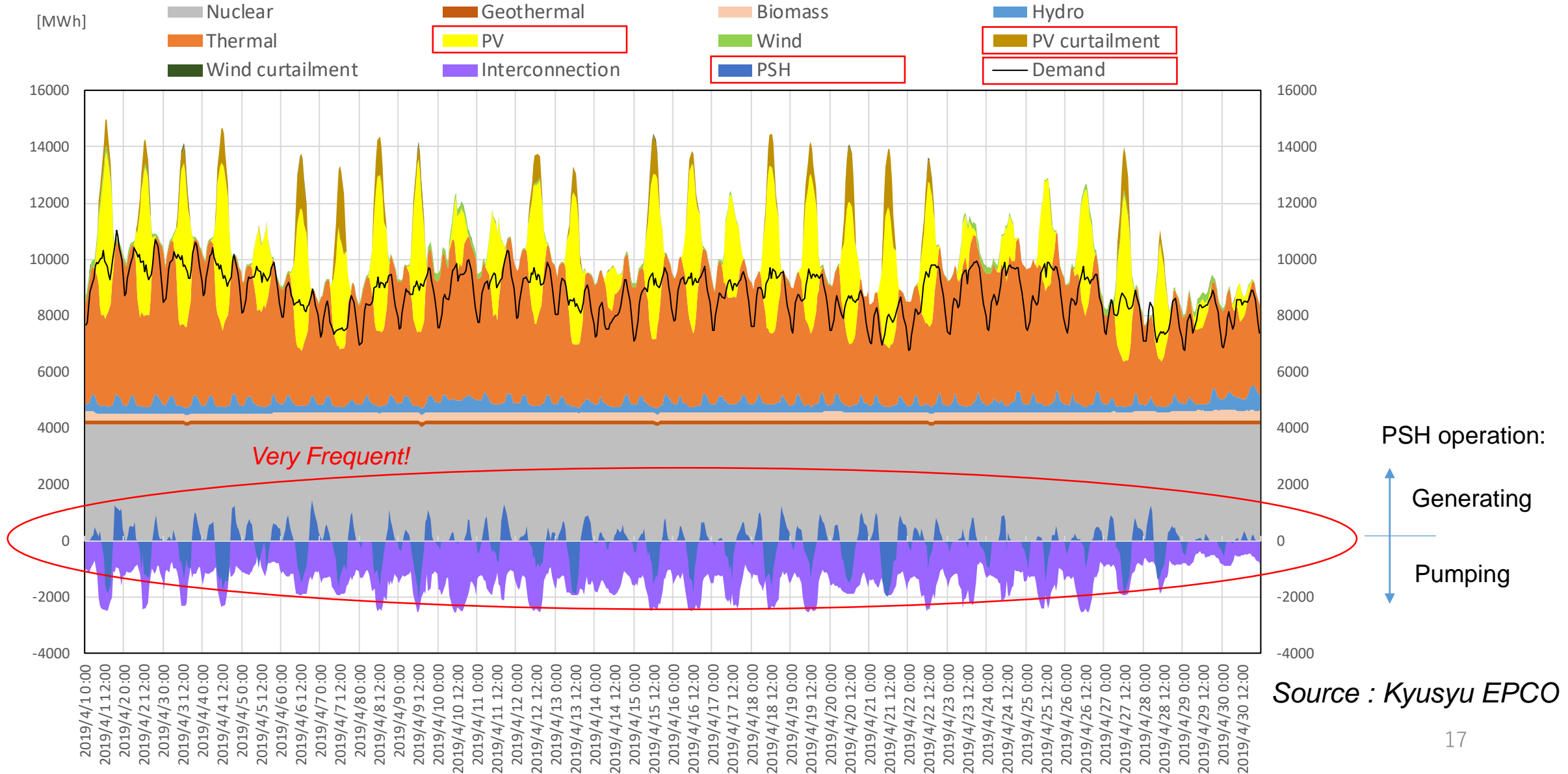
Launched FIT



Restarted Nuclear units

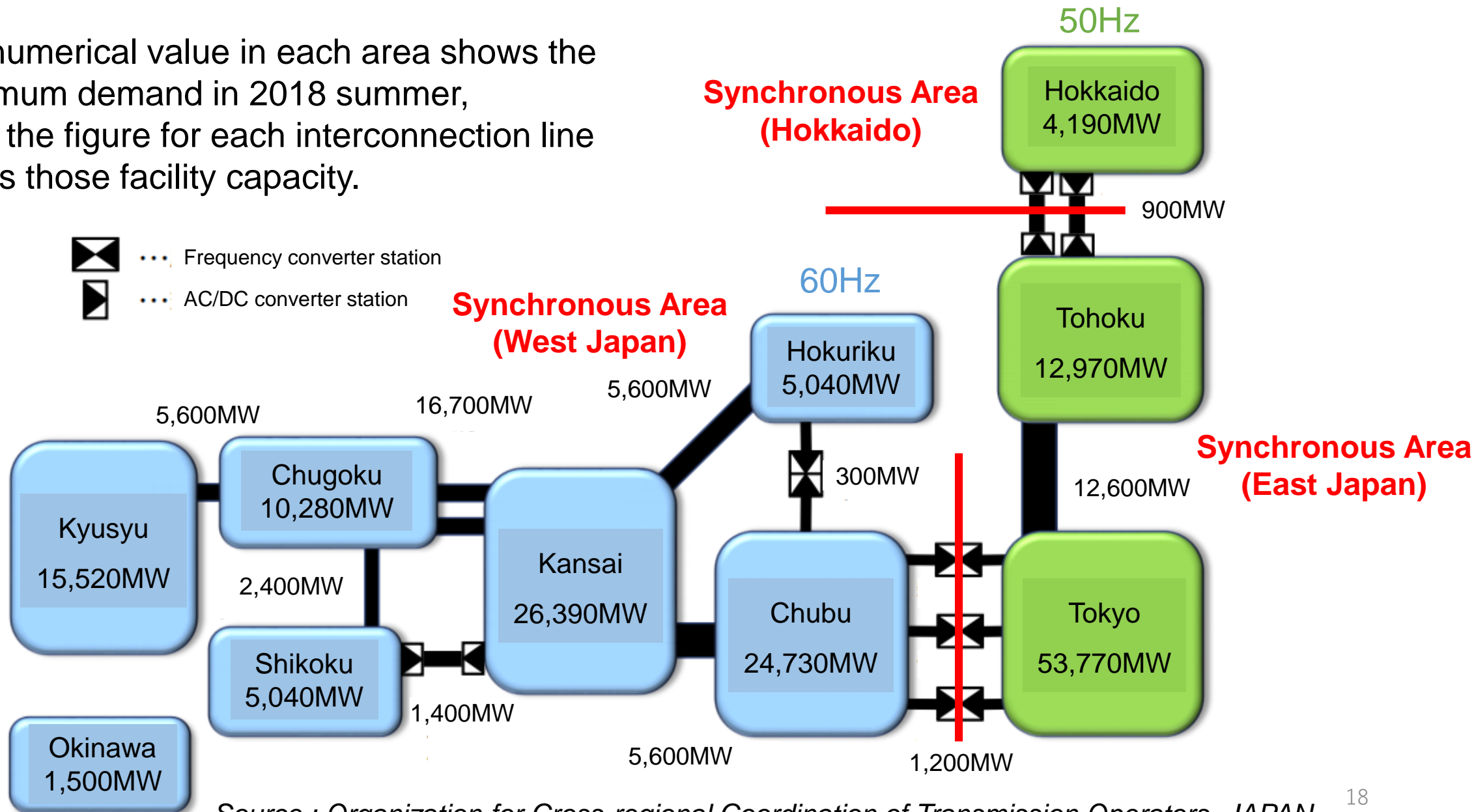
vi. PSH Business in VRE-Highly-Shared Area (Kyusyu)

Electricity demand & generation (Kyusyu, April 2019)



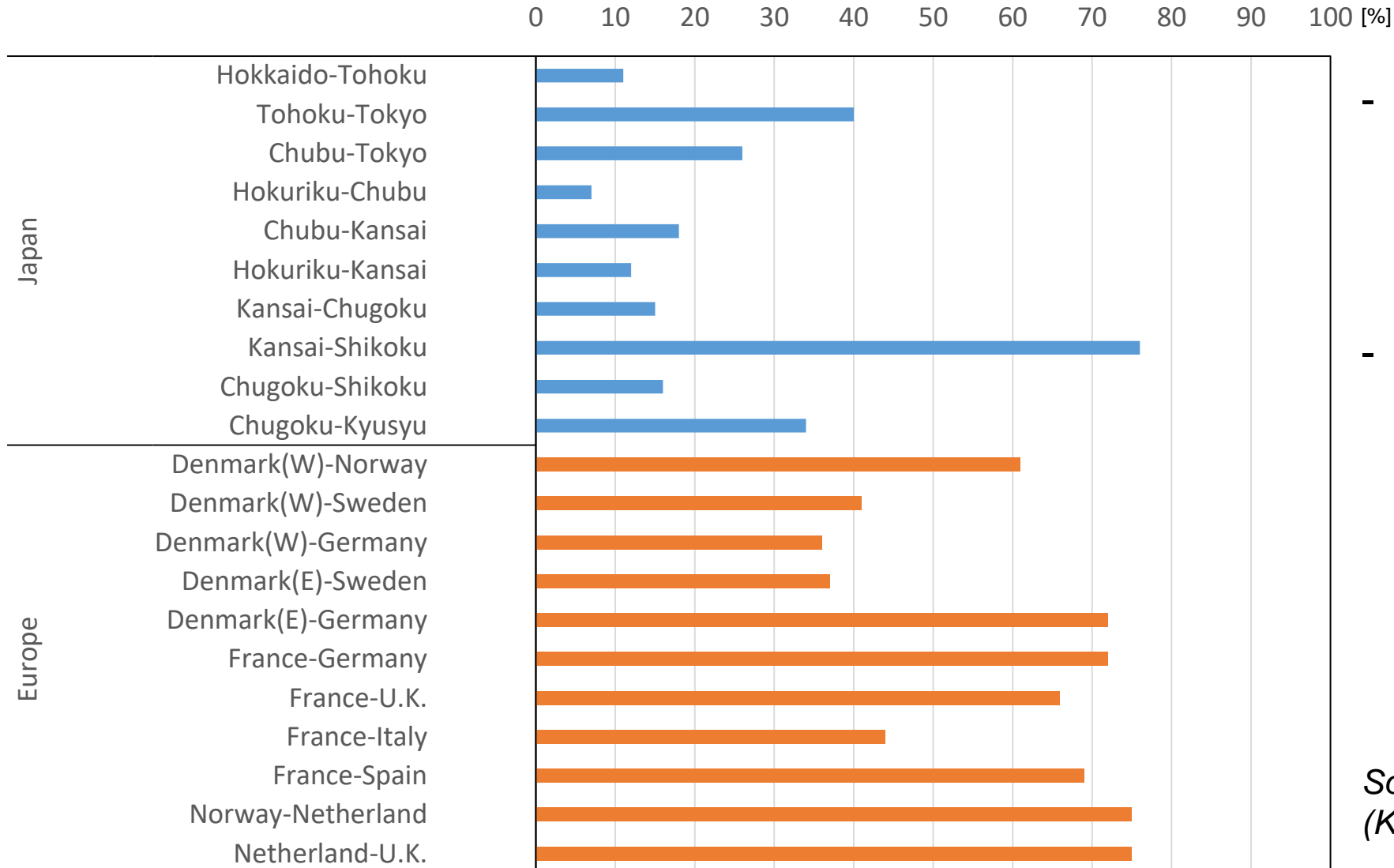
vii. Grid Interconnection

The numerical value in each area shows the maximum demand in 2018 summer, while the figure for each interconnection line shows those facility capacity.



vii. Grid Interconnection

Utilization Factor of Interconnection lines (Japan & Europe, 2014)



- A new regulation started in 2018 that would help promote flexible operation crossing an extensive area.
- More utilization of the interconnection lines may create more opportunities to use PSHs.

Source : Y. Yasuda
(Kansai University)

viii. Functions/Values of PSH

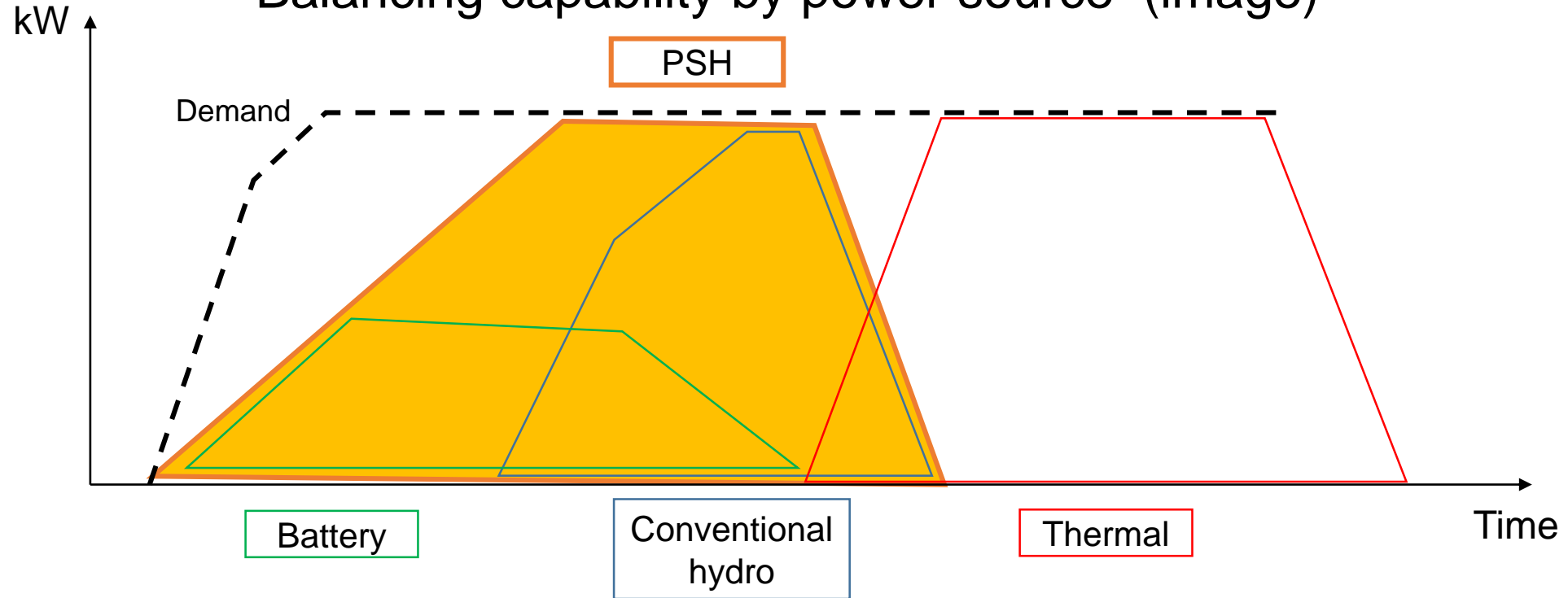
: Monetized in Japan

Value			Fixed-speed PSHS	Variable-speed PSHS
kWh : Energy			Available	Available
kW : Available capacity	Available capacity (Generating)		Available	Available
	Negative capacity for drawdown (Pumping)		Available	Available
ΔkW : Balancing	Frequency control (Spinning reserve)	GF, AFC (Generating)	Available	Excellent
		GF, AFC (Pumping)	N/A	Available
	Inertia response		Available	N/A
	Standing reserve (while network is available)		Available	Available
Non-fossil			Available(?)	Available(?)
Others	Voltage control		Available	Available
	Emergency	Black start※	Available	N/A
		Security	Available	Available

※Auxiliary diesel engines are only monetized.

viii. Functions/Values of PSH

Balancing capability by power source (image)



	Balancing speed	Balancing capacity
PSH	Excellent	Excellent
Battery	Excellent	Good
Conventional hydro	Good	Good
Thermal	Fair	Excellent

ix. Issues of PSH Business

Not all the PSH values are remunerated.

: Monetized in Japan

