Retirement of Nuclear and Coal Fired Plants in the Western Japan Grid: Focusing on Supply-Demand Power Balance

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Currently, Generation Companies are still Transmission System Operators.

Transmission Grids will be separated from Generation companies in **2020**.

Hokkaido
Demand
max 5.2 GW
min 2.4 GW

50Hertz regions

AC/DC converter
DC Link 600MW

Tohoku
Demand
max 13.7 GW
min 6.3 GW

60Hertz regions

Kansai
Demand
max 26.6 GW
min 10.3 GW

Hokuriku
Demand
max 5.2 GW
min 2.0 GW

300MW

Chugoku
Demand
max 10.6 GW
min 4.8 GW

AC/DC converter
DC Link

Tokyo
Demand max **53.3GW**
min 20.2MW

Shikoku
Demand
max 5.3 GW
min 2.3 GW

Chubu
Demand
max 24.9 GW
min 8.7 GW

Kyushu
Demand
max 15.5 GW
min 6.4GW

50Hz/60Hz convertor
1035MW

Japan's Grid Structure

Backgrounds: Japan's grid operations, the current rules 1

- 9 Transmission System Operators (TSO) are 9 Generation Companies.
- Unbundling of Generation and Transmission will be in 2020.
- TSOs are **not obliged to expand Grid Capacity for a**ccommodating RES power.
- Nuclear power has the **first priority** to be fed-into the grid.
- Generation companies **are only obliged to reduce Output levels of Fossil Thermal plants from the Current Capacity levels** for accommodating RES.
- Japan's FIT law does not regulate **the reduction of capacity of thermal power** in a time of power oversupply.

➢PV and Wind power has a 'limited' priority to access to the zone grids.

■Japan's grid operations of Inter-Regional Lines, the current rules 2

- **Nuclear power** has **the first priority** to be fed-in to **Inter-Regional lines.**
- A large capacity of Inter-Regional Lines **have been reserved by** large-scale of **Nuclear** . **'First come, First serve' rule.**
- Interzone tie-lines are operated according to **'Scheduled Power Flow'** .
- >>> PV and Wind power has difficulties to be transmitted to Inter-Regional Lines.
- No Control Reserve is activated through Inter-Regional lines beyond the zone.

  >>> There is **no Grid Control Cooperation** in Japan
- Power Supply-Demand is balanced in **Each grid zone**.

■Aim of the study

■Analyzing the impacts of PV and Wind power on **Supply-Demand Balance** in the Western Japan Grid in 2030.

■UC-ELD model:

We developed a simplified **Unit Commitment and Economic Load Dispatching model** for thermal power units (by Matlab optimization tool box).

■With the conditions of

- Zero Nuclear power
- Reduction of Coal power capacity
- PV and Wind power is transmitted to Inter-Regional Lines

■ Unit Commitment- Economic Load Dispatch model

Conventional Generator units are classified into **22 Subgroups**

Subgroup

Coal 1,2,3, Oil 1, 2, 3. LNG Thermal 1, 2, 3
Gas-CC 1, 2, 3. Independent Producers 1, 2, 3
Inter-Regional Transmission,
Nuclear, Pumped Storage, Reservoir (Hydro)

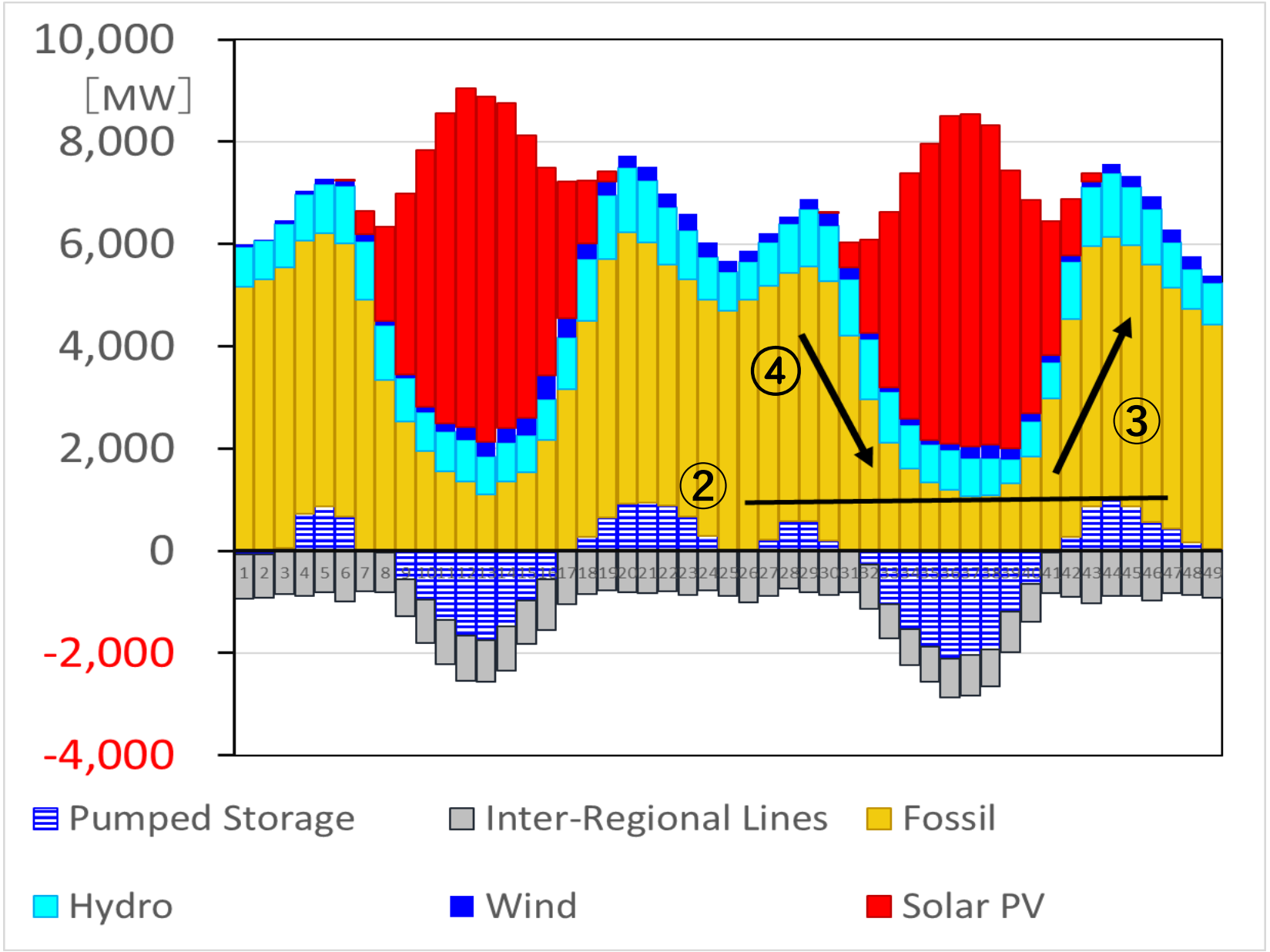
Priority Feed-in power

PV, Wind, Biomass, Geothermal, Hydro (Run of River)

■ Objective Function : Minimizing **hourly Fuel Cost** [JPY/h]

■ Endogenous Variables

Hourly power output of generator Subgroup k [MW]
to estimates Hourly Supply-Demand Balance in **May, August**



Technical limitations of fossil fired power plants in supply-demand balance

①Fossil power must satisfy residual load
Residual load = Demand- RES

②Fossil power plants have power output minimum, if continuous operation

③Fossil fired plants has speed limits for **ramp-up** of power output per minute.

④Fossil fired plants has speed limits for **ramp-down** of power output per minute.

■Constraints for UC-ELD Model

- **Minimum Output Limit:**

  Coal plants: **15%** - 30% of capacity,

  LNG Thermal, Gas-CC: 20% -30% of capacity

- **PV and wind is transmitted to Inter-Regional lines**

  < **80%*** Operational Capacity of Inter-Regional Lines

- **LFC Control Reserve (CR)**

  CR > 3% * Demand at every hour

  CRposi , CRnega > 5% * Capacity of Subgroup k

  Coal-fired units are not used for CR

  CR compensates for 1-hour ahead PV forecast errors.

  (max PV forecast error is 12% p.u)

■ High Case Assumptions for 2030

- **Capacity of Coal power** is reduced **as much as possible** with daily shut-downs
- **Zero nuclear is operated**.
- Demand is decreased -10%
- **HP**: Heat Pumps operation in daytime (household sector).
- **EV:** 20% of passenger vehicle charging in daytime
- **LFC Control Reserve** is activated beyond the control zone
- PV and wind power is transmitted to Inter-Regional Lines with a priority

High case in Kyushu zone

[MW], Base year= 2016

Kyushu	Base	**High**
PV Capacity	6,860	**18,200**
Wind Capacity	490	**4,700**
Nuclear Power	1,780	**0**
Inter-Regional Transmission Capacity	2,690	2,690
Inter-Regional Transmission from PV, Wind	No	**Yes**
Control Reserve through Inter-Regional Lines	No	**Yes**
Heat Pump	0	**810 MW *4 h * 2 sets**
Electric Vehicles	0	**700 MW* 8 h**
Pumped Storage Hydro Power	Pump-Up in Night, Daytime Generation	**PV Pump-Up, Evening Generation**
Pumped Storage Capacity	2,300	2,300
Demand (max)	15,500	**- 10%**
Demand (min)	6,400	**- 10%**

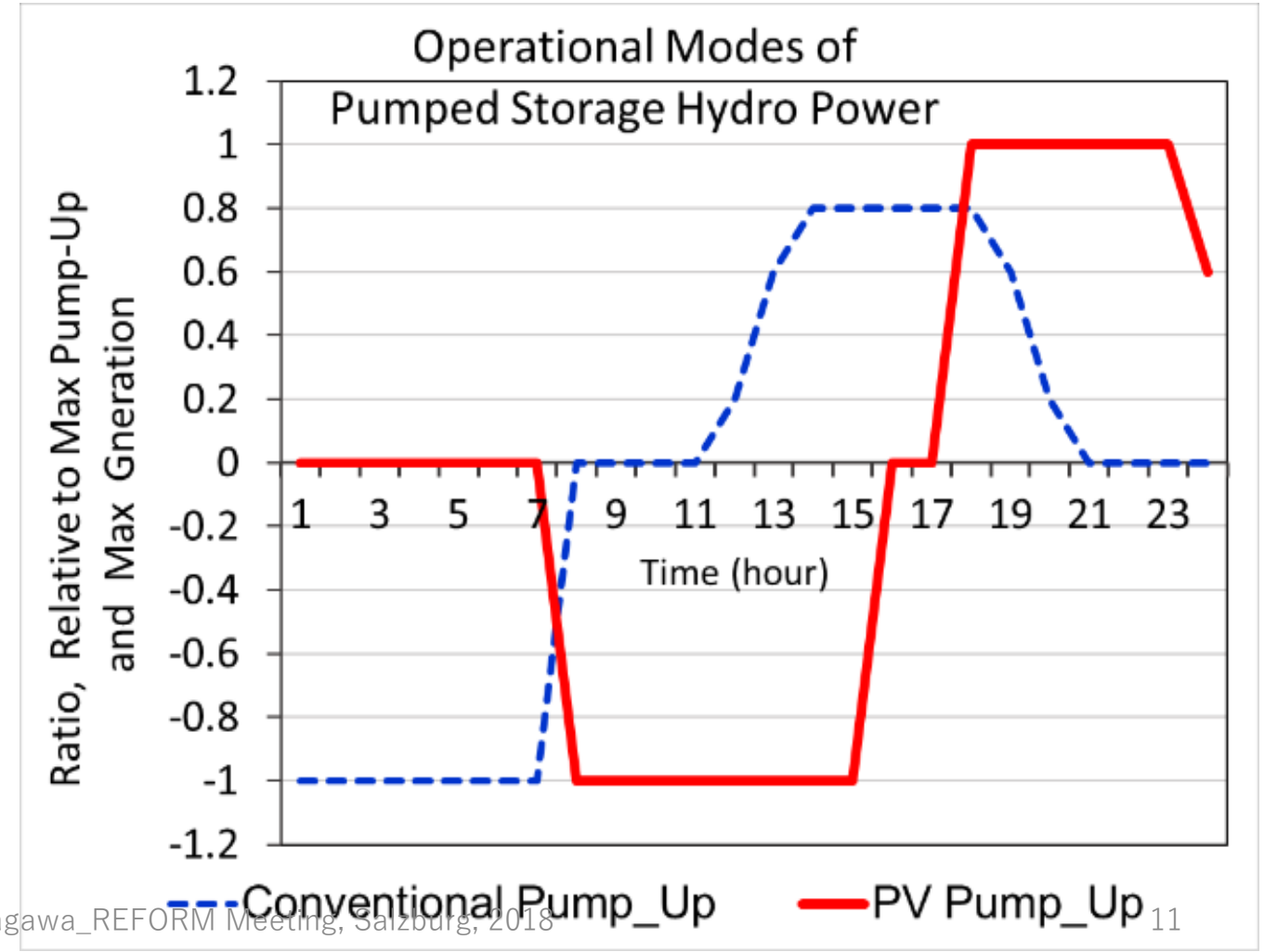
*Data for 2016 from METI, OCCTO and Kyushu Electric Power Company

2030 targets of Renewable energies

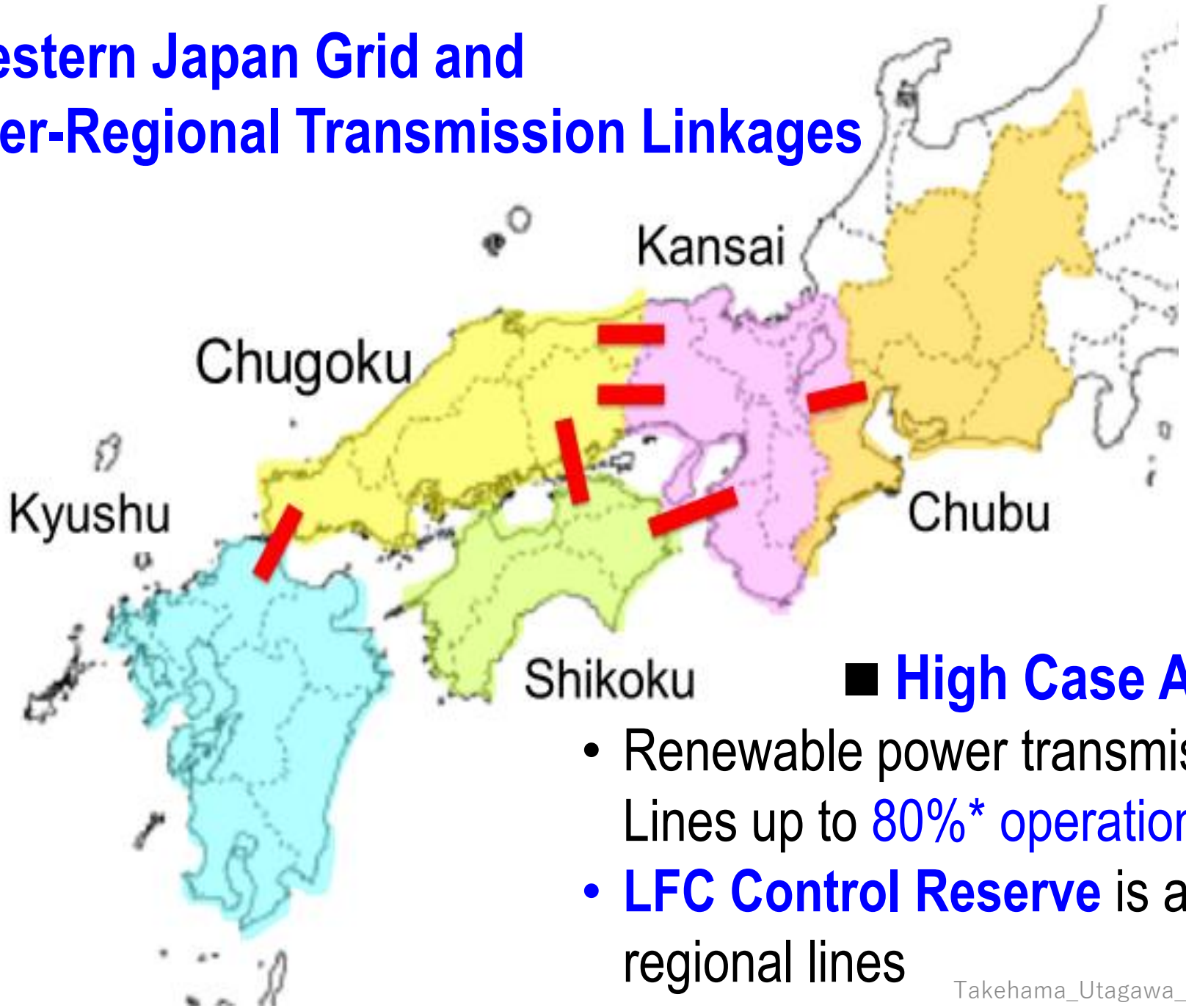
	Demand in 2016 [MW]		2030 Targets [MW]			
	Max	Min	PV	Wind	Heat Pump	EV
Chubu	25,000	9,000	17,400	10,400	1,350 MW*4h*2	1,120 MW*8h
Kansai	27,000	10,000	13,900	3,400	1,780 MW*4h*2	890 MW*8h
Chugoku	11,000	5,000	8,000	3,200	840 MW*4h*2	460 MW*8h
Shikoku	5,000	2,000	5,000	2,600	600 MW*4h*2	240 MW*8h
Kyushu	16,000	6,000	18,200	4,700	810 MW*4h*2	780 MW*8h

■ Assumptions for 2030 High Case :

- Pumped Storage: Pumping in daytime, Generating in evening **(PV Pump-UP)**
- **Heat Pump** loading in daytime
- **EV** charging in daytime



Western Japan Grid and Inter-Regional Transmission Linkages



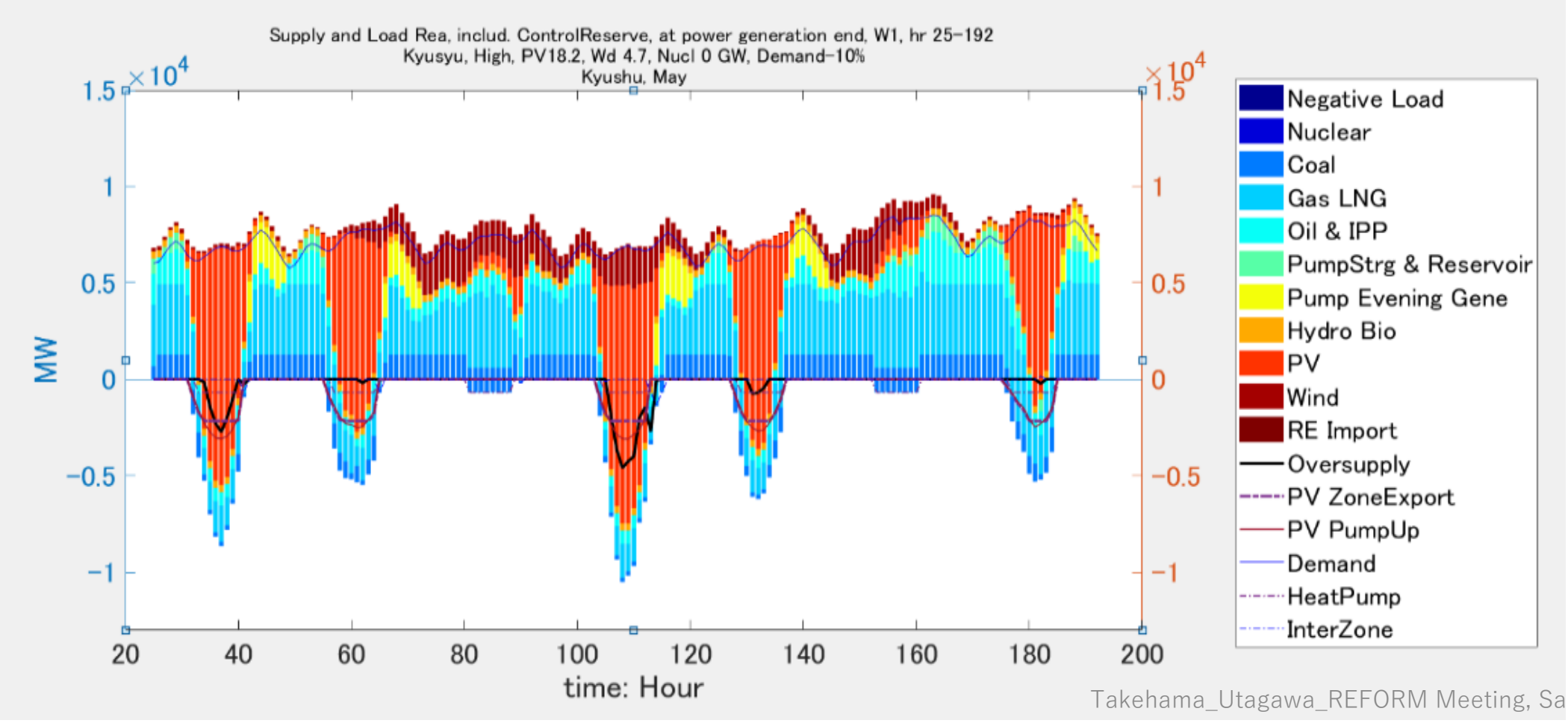
Kansai and Chubu zones are calculated as an integrated single zone

■ High Case Assumptions

- Renewable power transmission to Inter-Regional Lines up to 80%* operational capacity with a priority
- **LFC Control Reserve** is activated through inter-regional lines

●Simulation results in **Kyushu zone**, **High case in May**

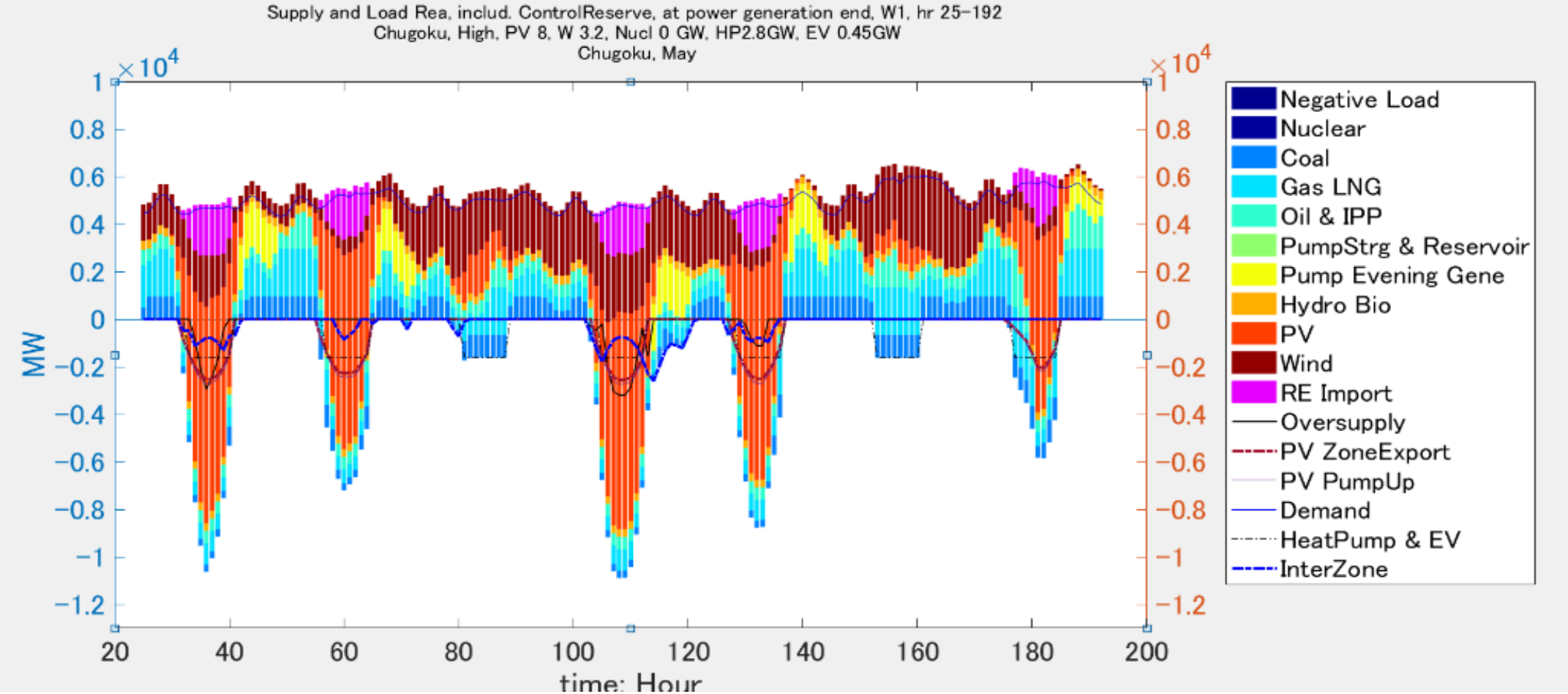
25% of PV power is absorbed by pumped storage,
27% of PV power is transmitted to Chugoku zone [% of MW] .
Flexible grid operations (Pumped Strg, Inter-regional lines, HP+ EV) can accommodate from 74% to 100% of VRE power (Variable Renewable Power).



■Chugoku zone, High case in May

Max transmission to Kansai zone is 3.3 GW.

Max power oversupply occurs in the first week of May (national holidays) .

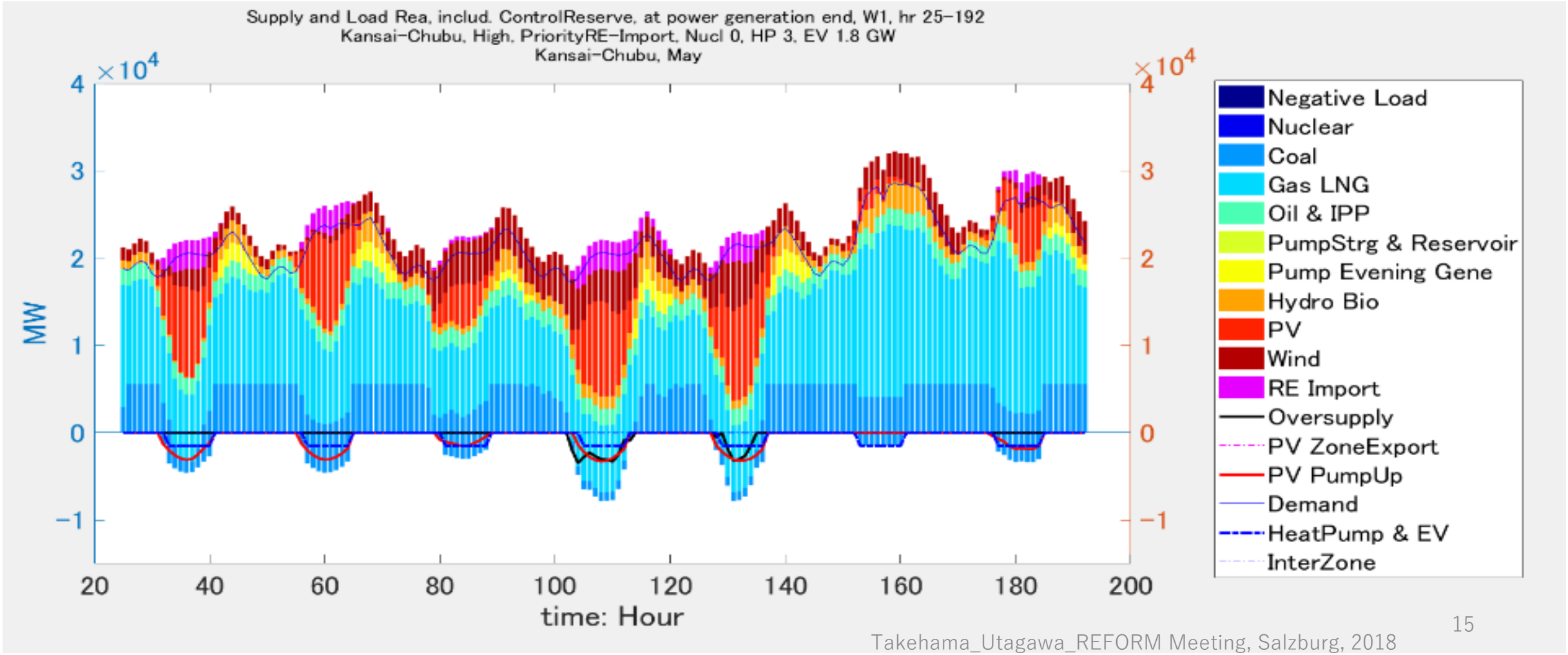


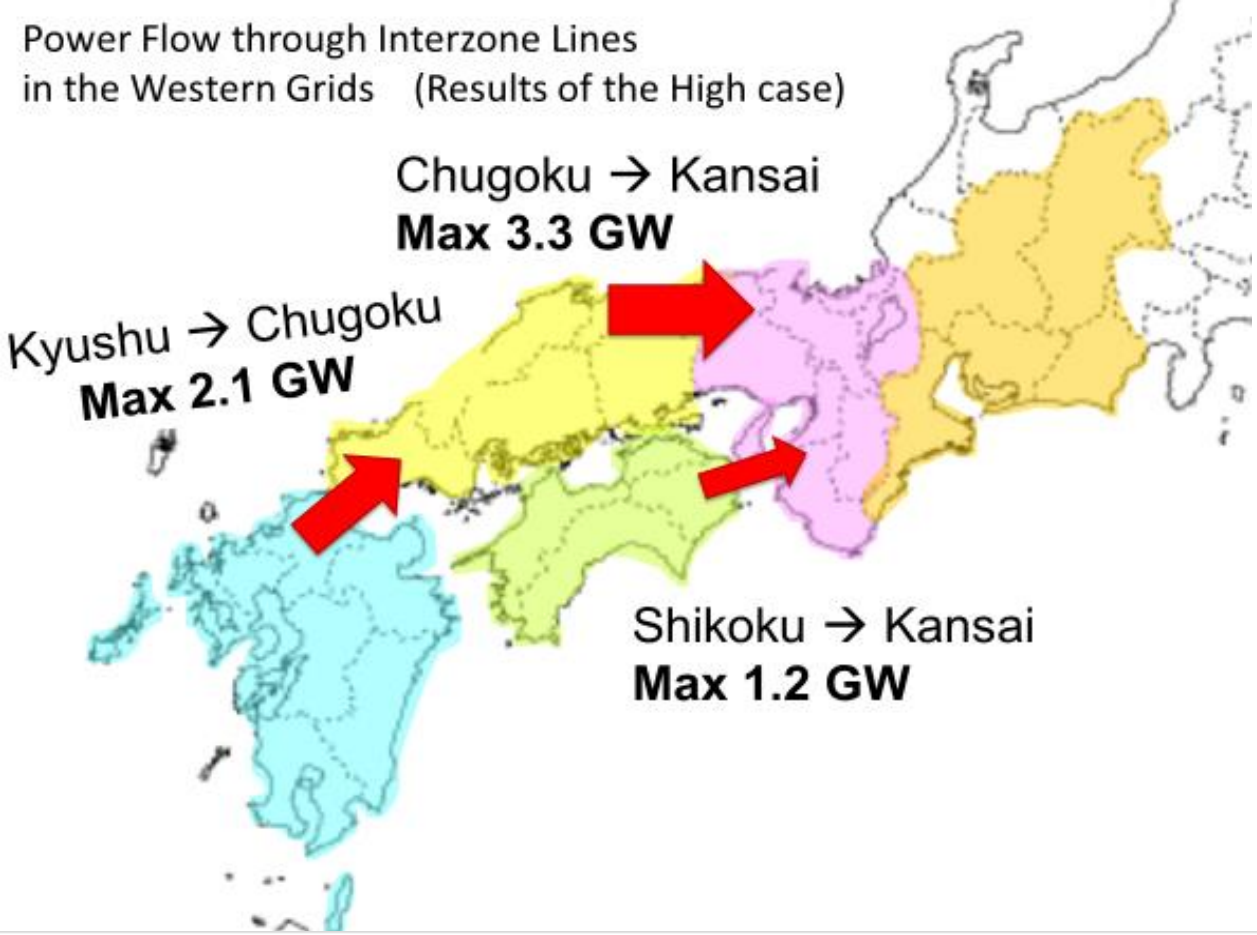
■Kansai-Chubu zone, High case, in May

Power oversupply is on a limited scale relative to its demand size.

RES electricity share 21 % of MWh, 50% of Coal power capacity is in operation

CO2 emission 410g_CO2 /kWh





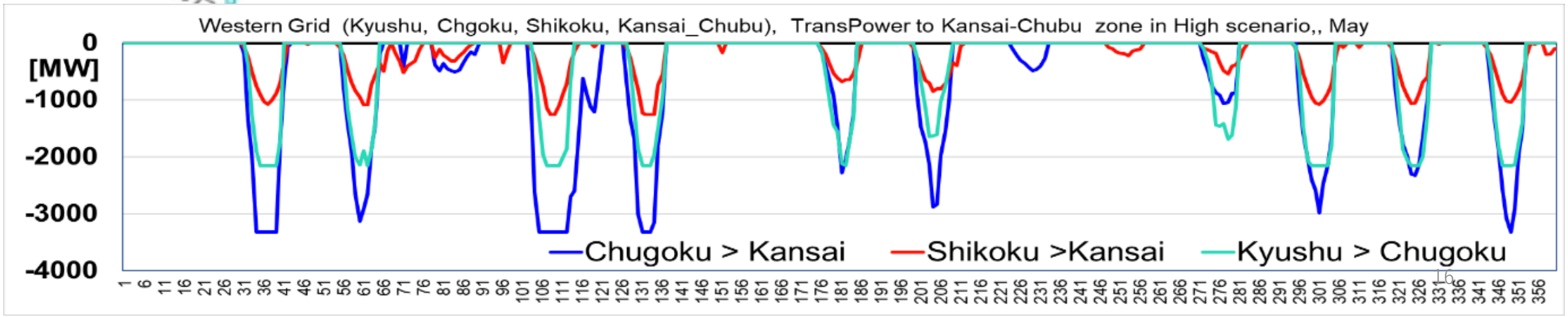
■Inter-Regional Lines

Max transmission in May

■Transmission of

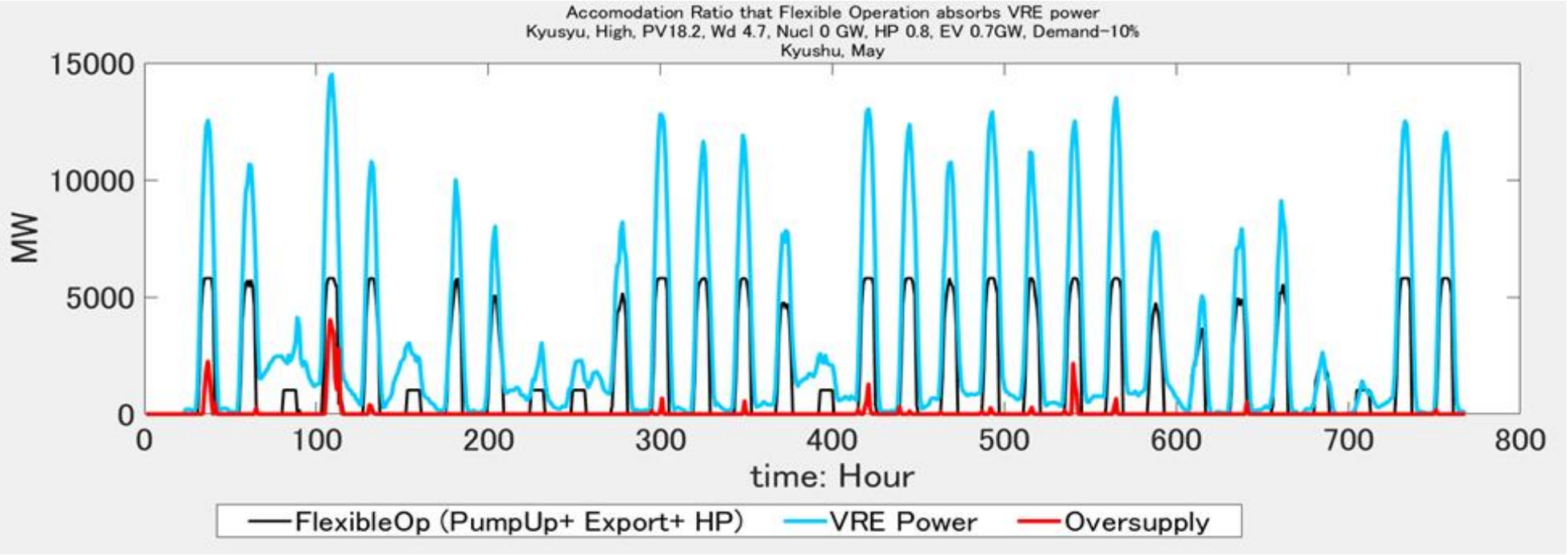
Kyushu >> Chugoku reaches its **capacity limit** on many days of **May**

Takehama_Utagawa_REFORM Meeting, Salzburg, 2018



■Results on Accommodation of VRE Power in Kyushu in May

- Flexible operation (Pumped Strg, Inter-Regional Transmission, HP and EV charging)
- **Flexible operations** accommodate the major portion of VRE power (75% to 100%)



■ **Large scales of oversupply** takes place **on several days, mainly** in the **first week** of May. Max oversupply: 4GW Kyushu, 3GW Chugoku, 0.8GW Shikoku.

■Kyushu: Oversupply occurs on holidays & weekends

■Kansai-Chubu : Oversupply is on **a limited scale** (relative to its demand size)

CO_2 emission and RE shares in High Case (in May)

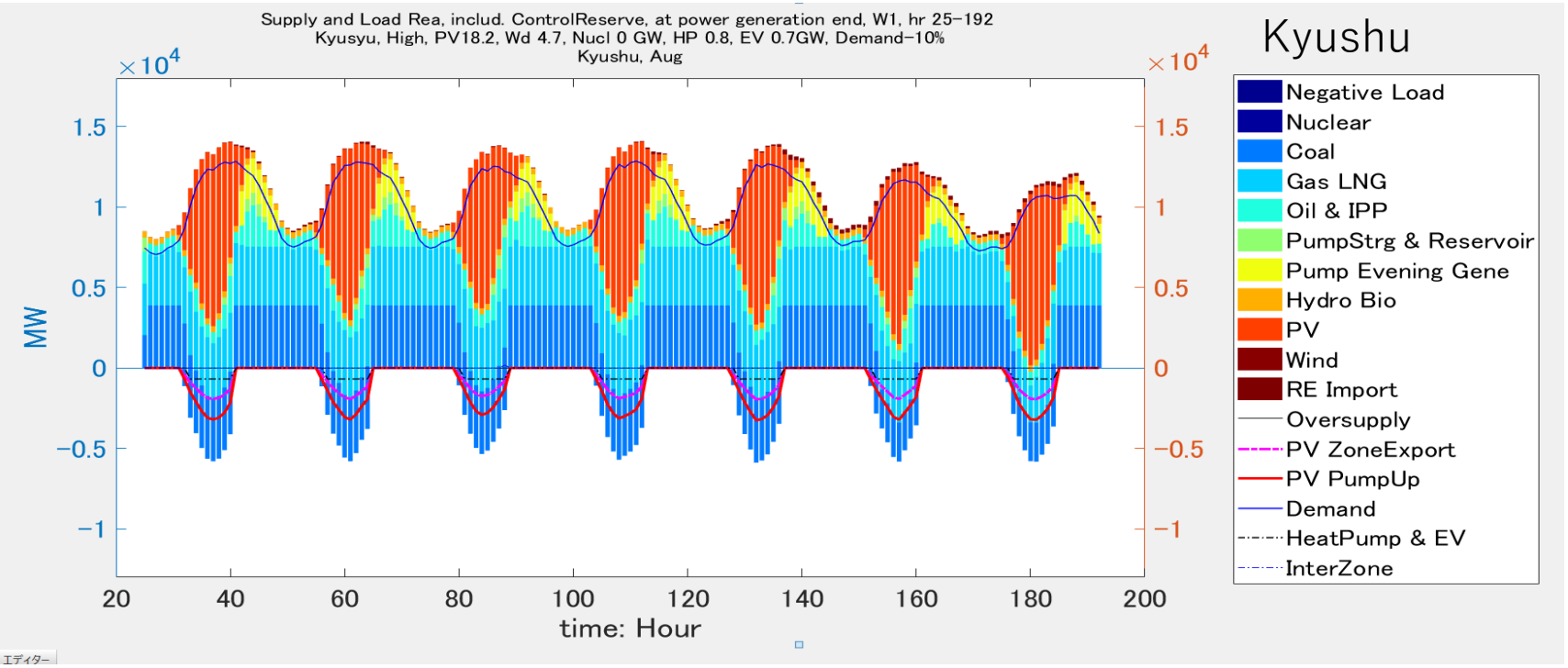
Kyushu zone	Base (with nuclear)	Middle	High
Renewable Share in Generation [% of MWh]	14.2%	29.3%	39.3%
CO_2 emission [CO_2_kg/kWh]	0.452	0.428	0.334
Fuel cost [USD/kWh]	0.066	0.075	0.076

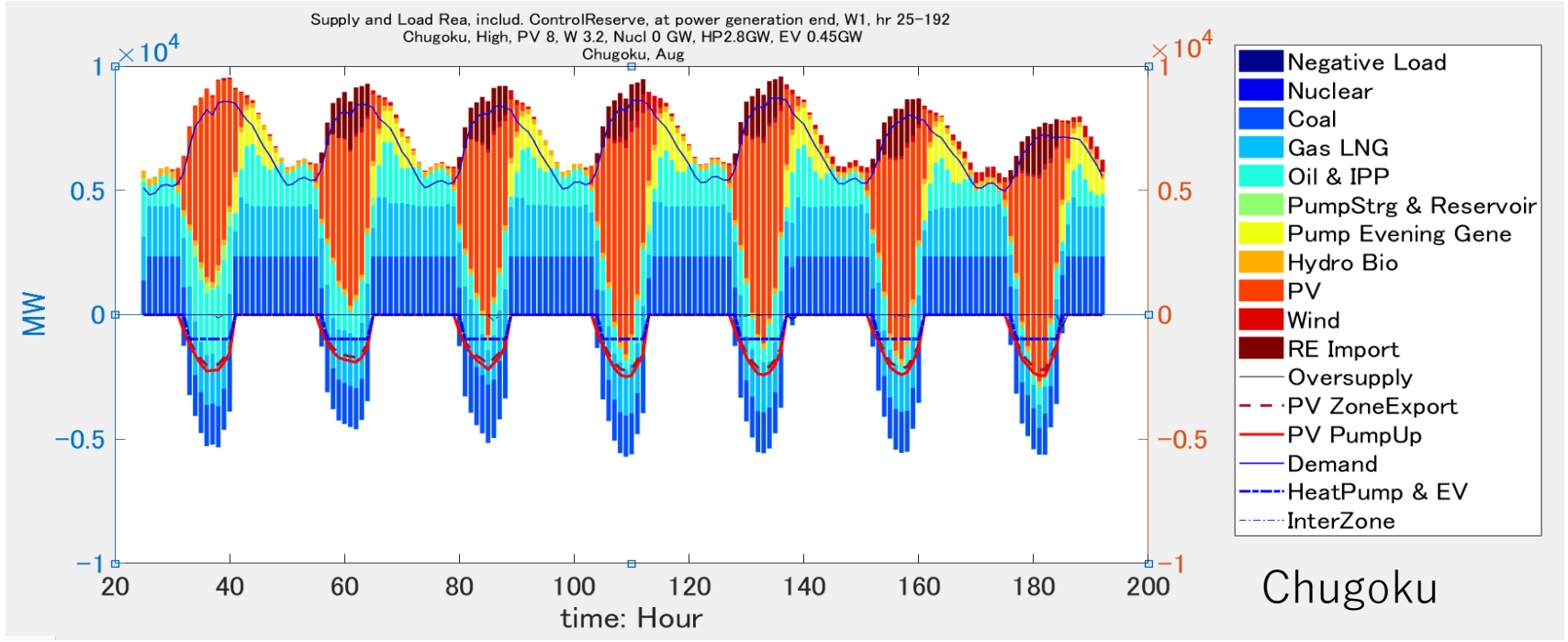
Chugoku zone	Base (with nuclear)	Middle	High
Renewable Share in Generation [% of MWh]	12.1%	33.1%	46.7%
CO_2 emission [CO_2_kg/kWh]	0.490	0.392	0.307
Fuel cost [USD/kWh]	0.074	0.092	0.072

Kyushu, Shikoku, Chugoku:
RE shares are
at 40%, 45%, 47% of total generation.

CO_2 emission decreases from the base level.

Shikoku
Emission 0.44 >> 0.40
RE Share 45 %





■Kyushu, Chugoku, Shikoku zone, in August (High load periods)

Risk of **Supply Shortage in August is limited in Kyushu, Shikoku, Chubu zones**,

due to a sufficient PV power and energy saving measures.

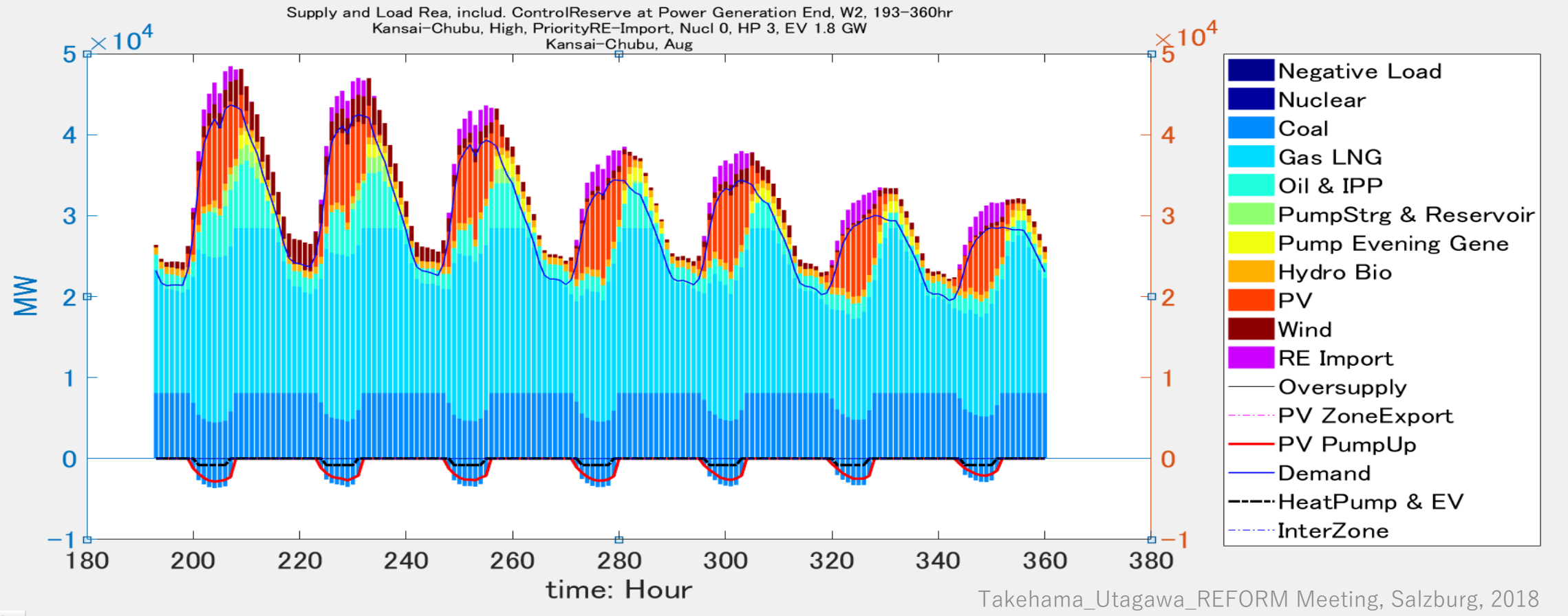
RES electricity share

33% in Kyusyu.

39% in Chugoku [% of MWh]

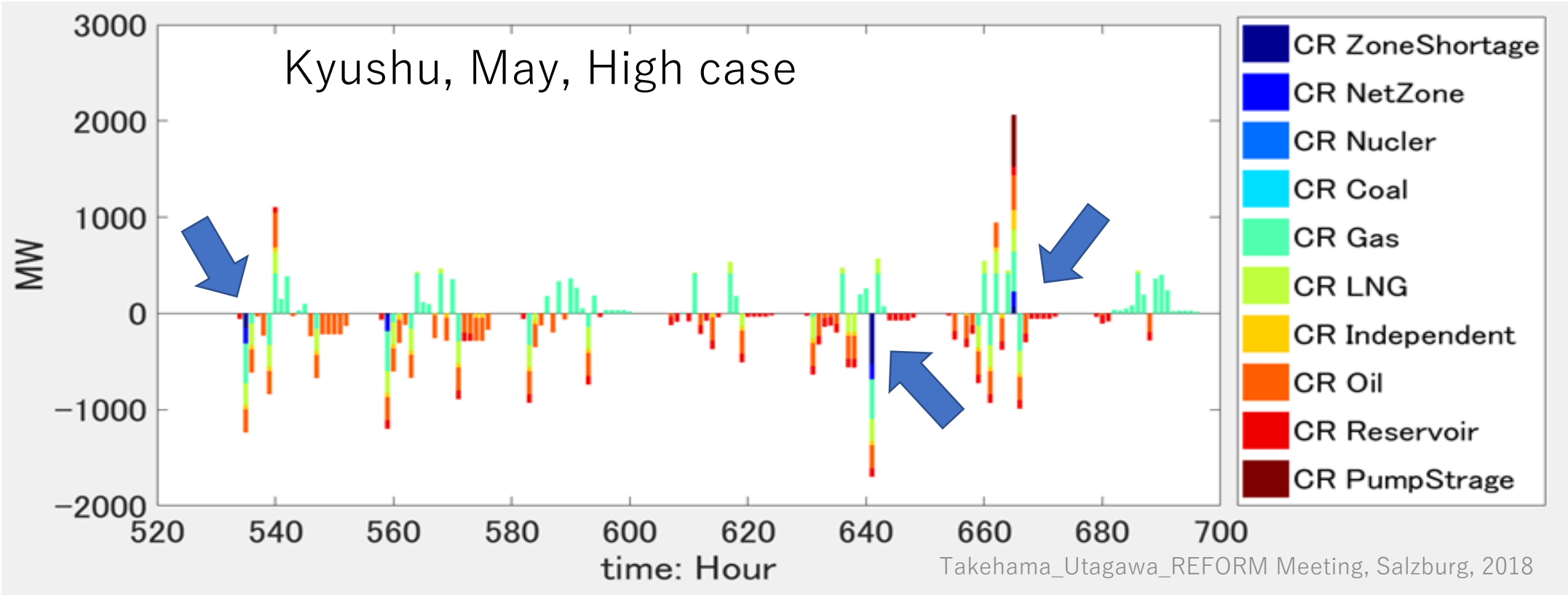
■Results in August (High load periods) in Kansai-Chubu zone

- The supply ability is **very tight in August (zero Nuclear) . A small risk** of **Supply Shortage in August due to steep ramp-up of residual load in the evening** (150MW in a few hours).
- **Additional energy saving measures are required in August**.
- Renewable share 15 % of MWh . Coal generation share 24 % of MWh.



■ Results on Control Reserve Activation

- Available capacity of **Negative Control Reserve** would be short in Kyushu, Shikoku, and Chugoku.
- However, **an increase in Negative Control Reserve** capacity could reduce grid capability to adapting to the **Down-Ramps** of LFC units.
- **Control Reserve activations through Inter-Regional Lines are required.**



Thank you for your attention

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