Japan's challenges for boosting renewable energy

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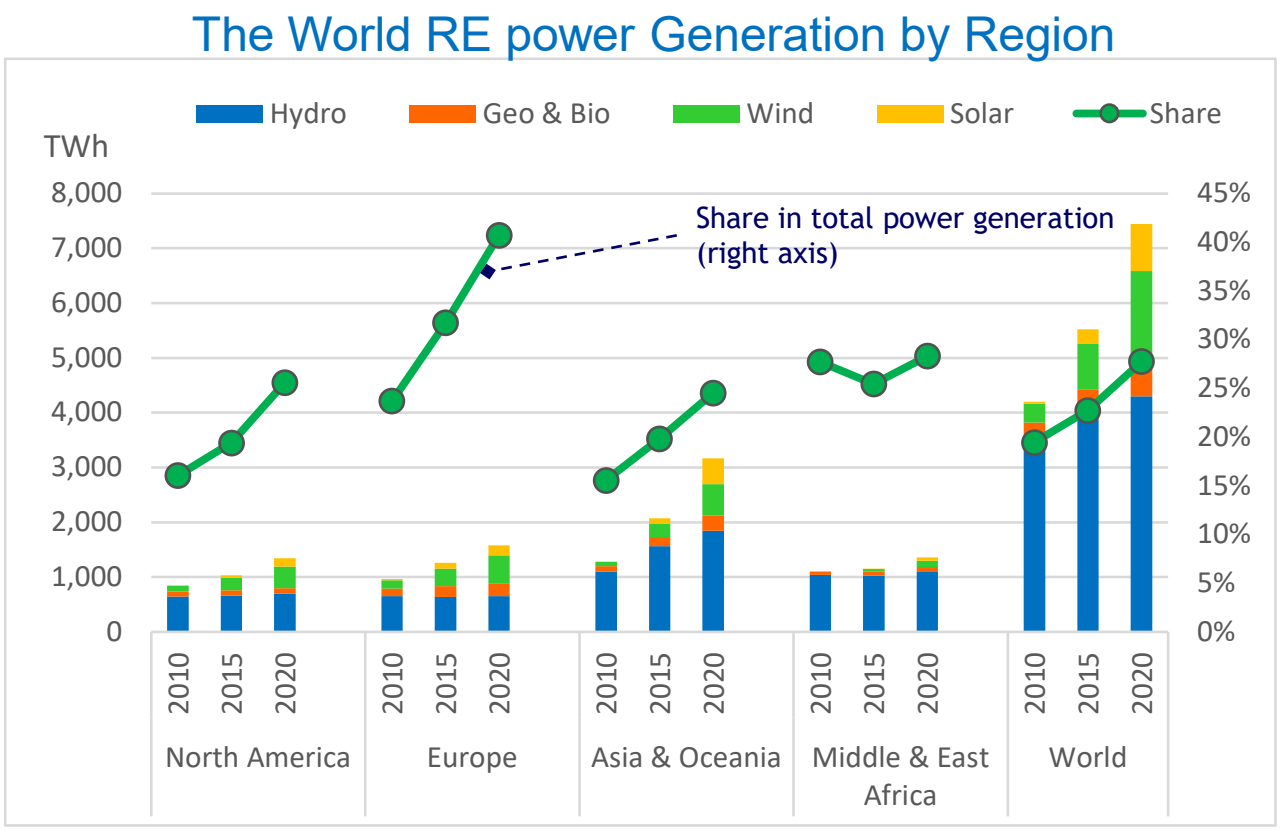
Historical trend of global RE

- The global RE (including large-scale hydro) accounts only for 28% in 2020 (Wind is 6% and solar PV in 3%).
- Regional difference: 41% in Europe, 25% in Asia & Oceania



Source: BP Statistics

Note: Large-scale hydro is included.

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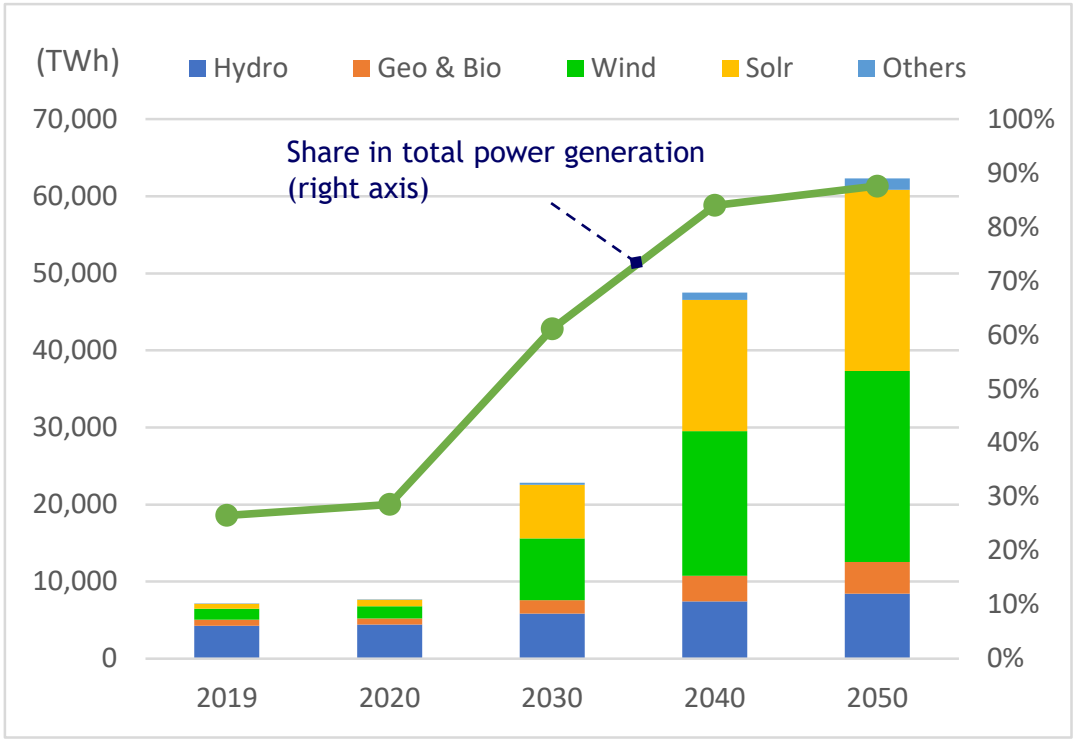
NZE scenario of IEA

- Net - Zero Emissions by 2050 Scenario (NZE) of IEA requires 62,000 TWh of RE in 2050 (RE=88%, VRE=68%), 9 times the current scale. The 80% of additional RE come from wind and solar PV. Battery should also be largely deployed.

Global RE Power Generation in IEA NZE



Cumulative Capacity: GW

	2019	2050
Solar PV	600	14,500
Wind	620	8,300
Hydro	1,300	2,600
Biomass	150	640
Others	22	610
Battery*	11	3,100

* The world pumped-storage hydro is 120GW in 2019

Source: Net Zero by 2050 A Roadmap for the Global Energy Sector, IEA Note: Large-scale hydro is included.

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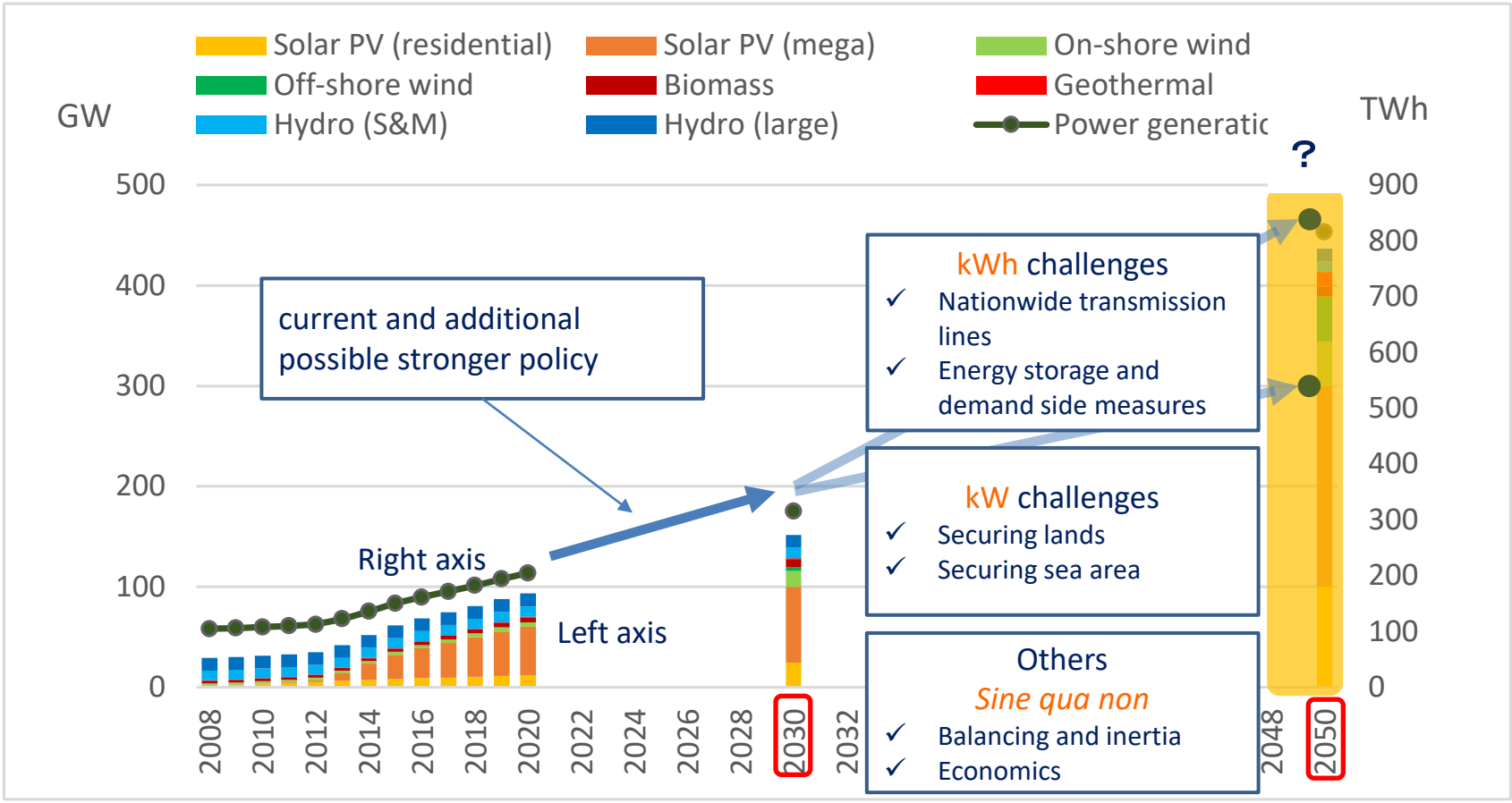
Challenges in large-scale deployment of RE in Japan

- 330~350TWh in 2030 by the current and the additional stronger policies
- Toward 2050 is unknown horizon. A variety of challenges face, kW and kWh.



Source: Assumed by discussions in Councils of METI

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Policy vector through 2030

	Current Measures	Probable Stronger Measures
Solar PV	More than annual 1.5 GW of FIT-approval	✓ Zoning for RE ✓ Installation to public buildings ✓ Repurposing agricultural land ✓ Revising rules of grid connection ✓ ZEB/ZEH ✓ Rule making for PPA
Wind	On-shore: 1.3 GW/year of FIT-approval Off-shore: 1.0 GW/year of zone selection	✓ Deregulation for environmental assessment (10MW to 50MW) ✓ Grid strengthening
Geothermal	Present FIT-approval	✓ Acceleration of ongoing projects ✓ Technologies to increase & stabilize steam flow
Hydro	Present FIT-approval	✓ Optimization of existing plants
Biomass	Present FIT-approval	✓ Updating biomass fuel supply target

Source: Committees for RE of METI

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Challenges toward 2050: *how to find sites*

	Options	Challenges
Solar PV (ground-mounted)	✓ Utilization of desolated farmland, unknown-owner land, local government land	✓ Rule-making ✓ Cost of leveling/preparing the desolated farmland
Solar PV (roof-top)	✓ Obligation/incentives to newly-built houses ✓ Obligation to public buildings (19GW of potential)	✓ New installation method for existing houses. Development of lighter PV cells ✓ Roof space restriction
Wind	✓ Utilization of security forest zone	✓ Rule-making
Geothermal	✓ Shortening lead time by further deregulation	✓ Opposition from local residents and hot spring business
Hydro	✓ Repurposing flood-control dams to power plants ✓ Repowering	✓ Further interior land, high cost of smaller-scale
Biomass	✓ Expected decrease in biomass fuel import price	✓ Development and utilization of domestic resources ✓ Sustainability of biomass

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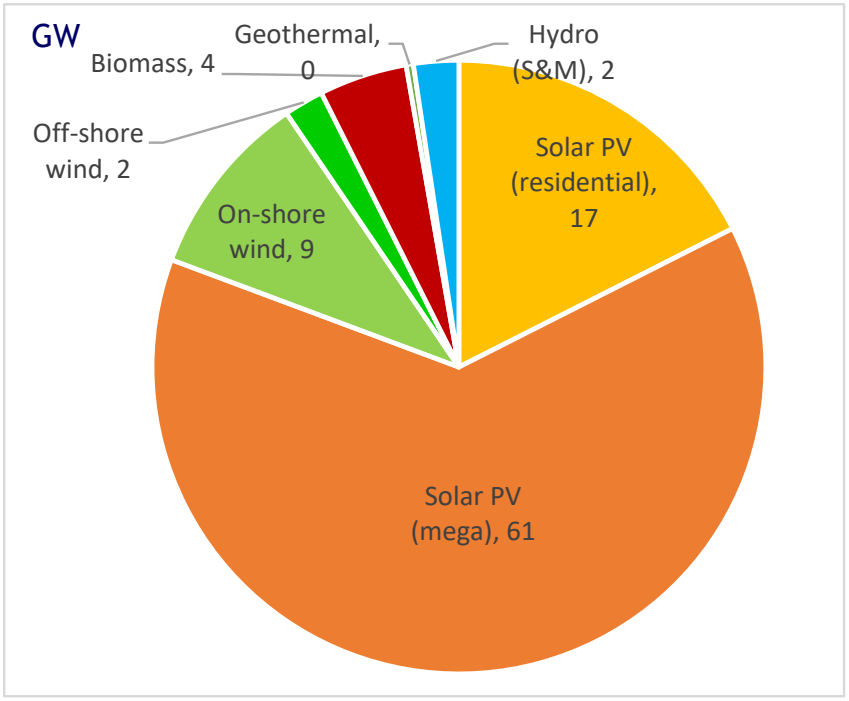
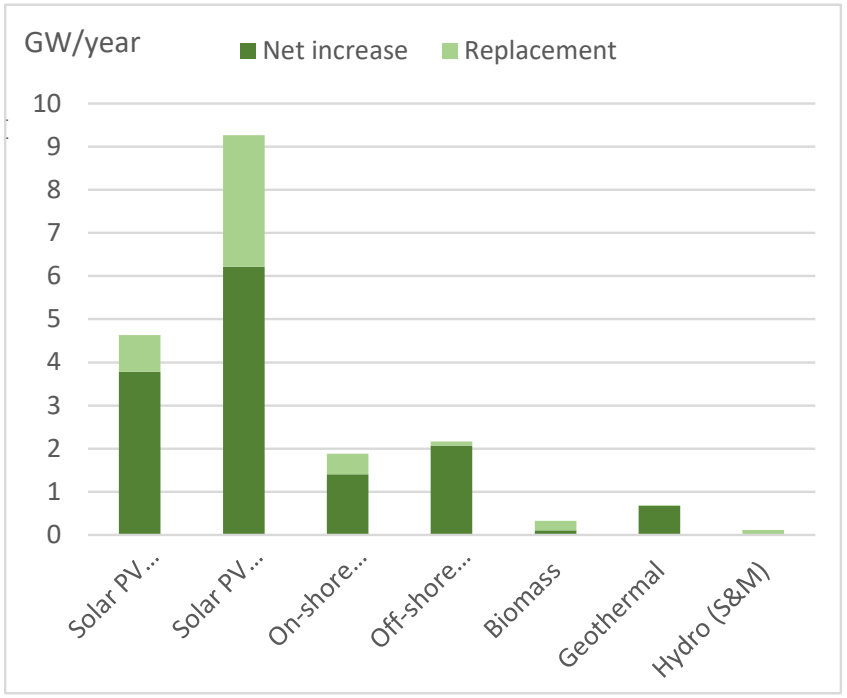
Challenges toward 2050: *replenishing the retired*

- Replenishment of the retired capacity is required to realize net increase.
- Measures to promote replacement should be made.
- Repowering is also an option.

Cumulative Retired Capacity during 2031~2050



Required Annual Additional Capacity 2031~2050



Note: RE is assumed to be 50%~60% in power generation.

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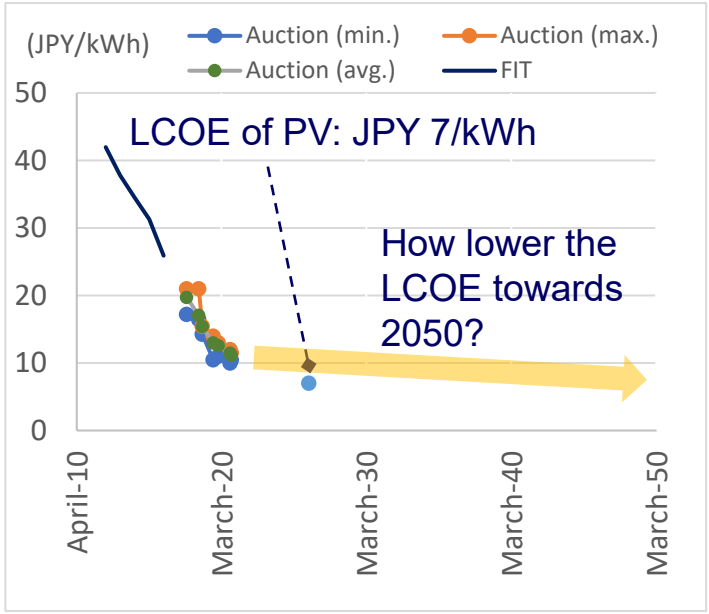
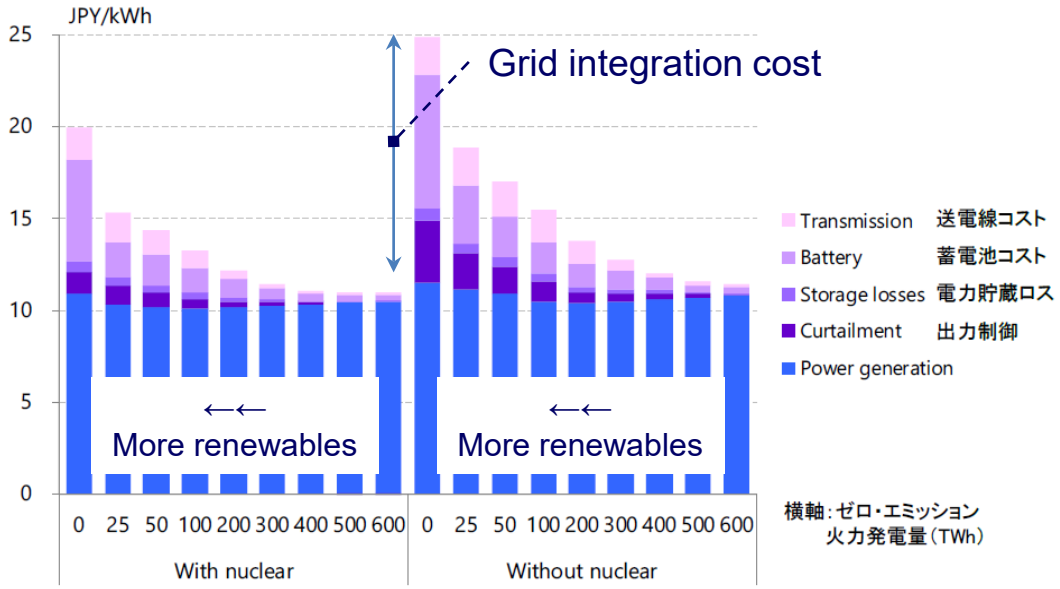
Challenges toward 2050: *economics*

- LCOE of mega-solar PV in 2030 will be JPY 8~11/kWh, lowest among power generation options (METI's committee), but cannot reach the target JPY 7/kWh. LCOE of the off-shore wind will be JPY 26/kWh, which is far higher than the target JPY 8~9/kWh.
- Grid integration cost should also be evaluated, including cost required for inertia decrease issue.

Solar PV FIT-level



Larger-scale of VRE = Increase in Grid Integration cost



Source: Matsuo, et. Al., "Estimation of 2050-Carbon-Neutral", Advisory Council for METI, June, 2021.

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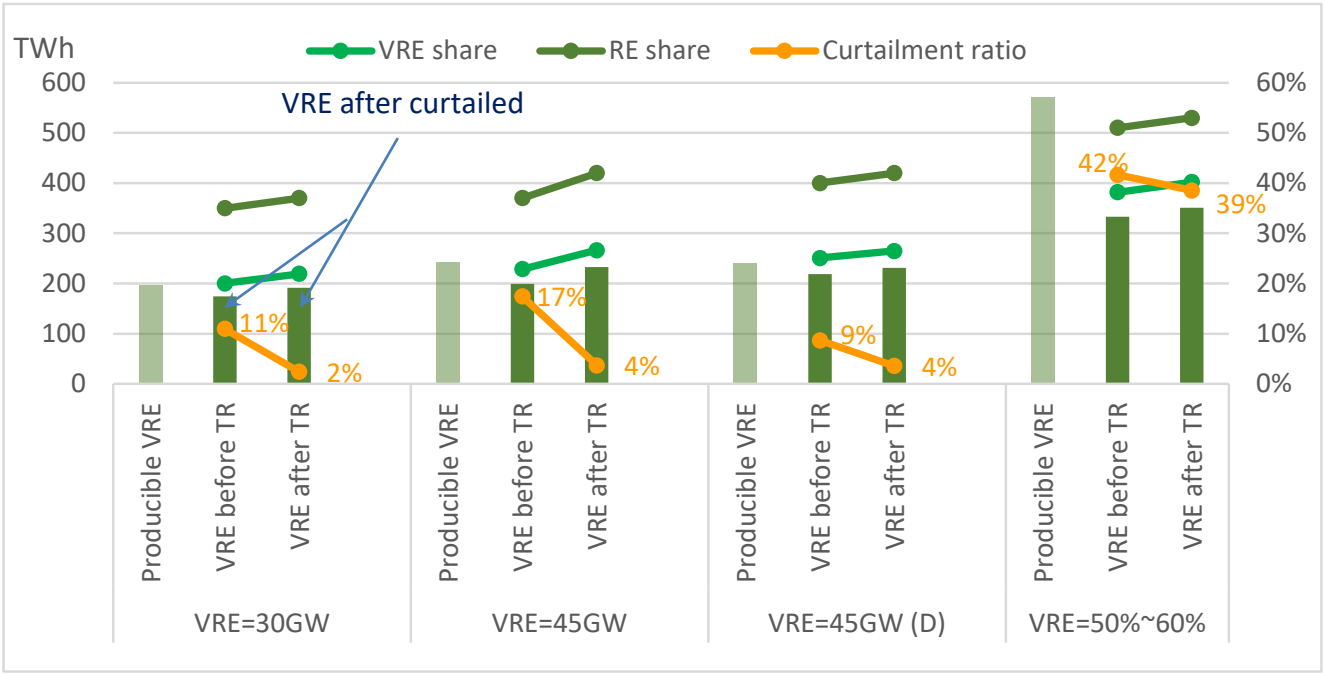
Challenges toward 2050: *nationwide transmission lines*

- Masterplan for Nationwide Transmission Line (June 2021) shows that large part of curtailed VRE cannot be saved only by nationwide transmission lines expansion in 50%-60% VRE scenario and that demand side measures, battery and Power to Gas are needed.



	VRE=30GW	VRE=45GW	VRE=45GW (D)	VRE=50%~60%
Benefit/cost=	1.07 ~ 1.35	1.13 ~ 1.44	1.29 ~ 1.53	0.95 ~ 1.21
Solar PV =	76GW	76GW	76GW	304GW
On-shore wind=	11GW	11GW	11GW	44GW
Off-shore wind=	30GW	45GW	45GW	45GW

In "VRE=45GW (D)" scenario, more VREs are deployed nearby electricity mass-consuming region.

Note: "Masterplan for Nationwide Transmission Line"

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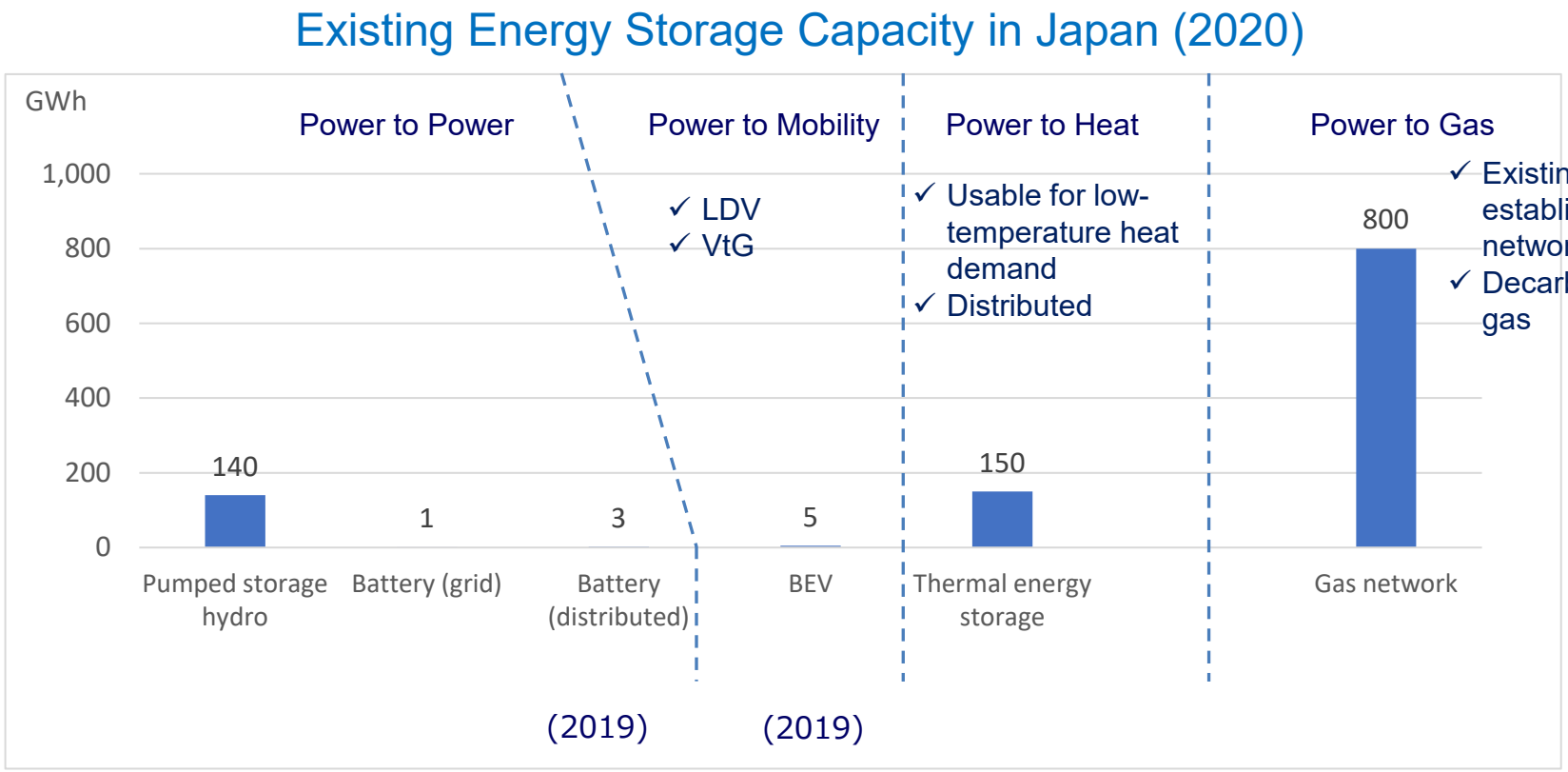
A variety of energy storage are already there

- Already-existing thermal energy storage capacity at demand side is huge.
- Storage capacity of gas network (storage tank and linepack) is also remarkable.



Storage capacity is expressed by physical maximum capacity, not taking into account of the availability.

Note: Based on; Committees of METI, DOE Global Energy Storage Database, JEMA (The Japan Electrical Manufacturers' Association), New Generation Vehicle Promotion Center, JARIA (The Japan Refrigeration and Air Conditioning Industry Association), HPTCJ (Heat Pump & Thermal Storage Technology Center of Japan) , Statistics of Machinery (METI), Gas Statistics.

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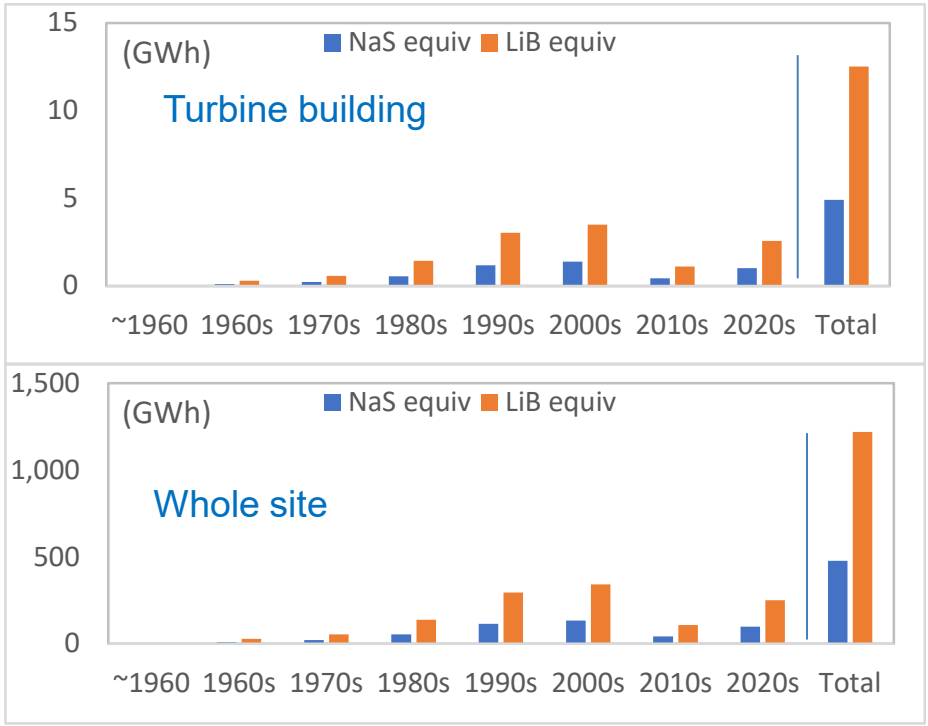
Repurposing coal-fired power plants

- Repurposing of retiring coal-fired power plants for energy storage facility
- Not only battery, but synchronous energy storages are expected to mitigate grid inertia decrease issue; compressed/liquified-air energy storage and Carnot-battery that may be able to use steam turbines of coal-fired power generation.

Battery Capacity Potential using Coal-fired Power Plants



Note: Horizontal axis represents vintage of coal-fired power plants

Cases

Location	Description
Elverlingsen, Germay 2018	✓ Battery for balancing at retired coal-fired power plant ✓ Reuse of BEV battery ✓ Daimler, Mercedes-Benz Energy, Getec Energie, The Mobility House ✓ 9MW/9.8MWh
NSW, Australia 2021	✓ Battery installing at planned-to-retired coal-fired power plant in 2032 (2,880MW) ✓ Surplus electricity to battery ✓ Origin Energy ✓ 700MW×4h

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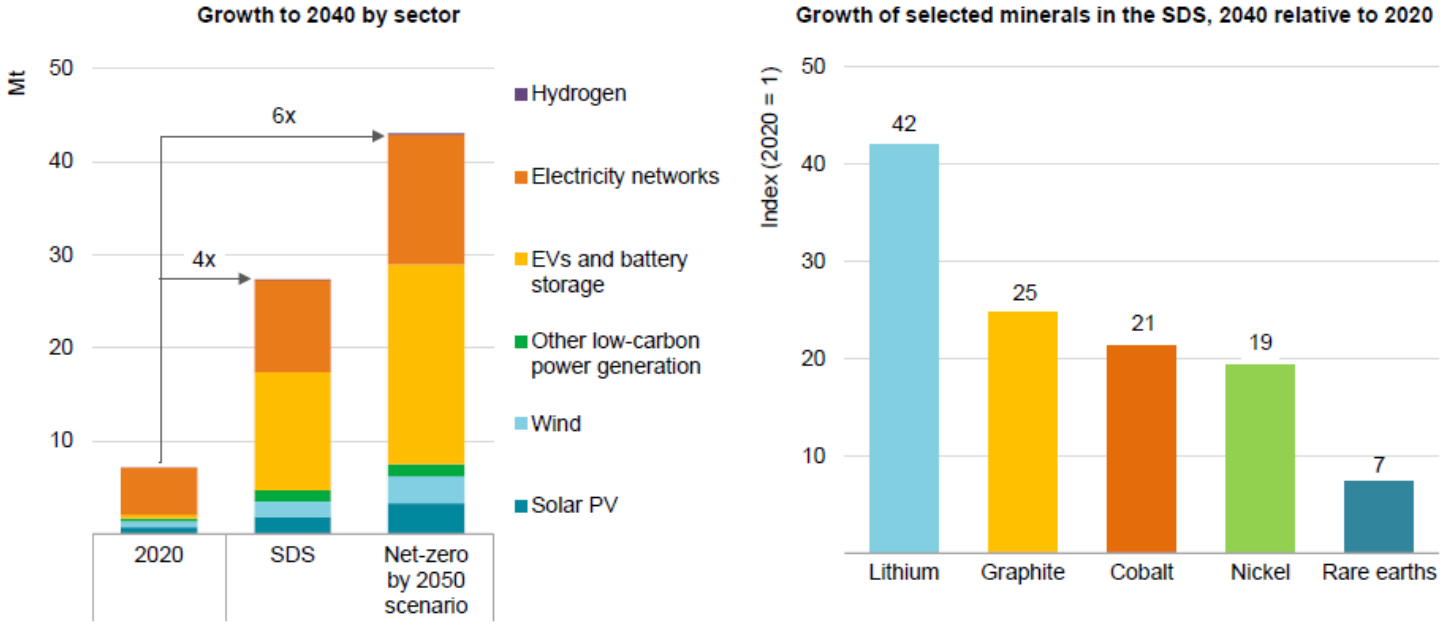
Concerns on critical minerals supply

- The global demand of critical minerals like lithium will increase, due to battery and BEV. Concerns on economic security by higher-dependency on suppliers like China.
- Other options should be on the table; vanadium RedOx flow battery, Power to Gas.
- "Energy Storage Best Mix", based on technology performance and mineral supply security

Global Critical Mineral Requirement towards Decarbonization



Source: "The Role of Critical Minerals in Clean Energy Transitions", IEA

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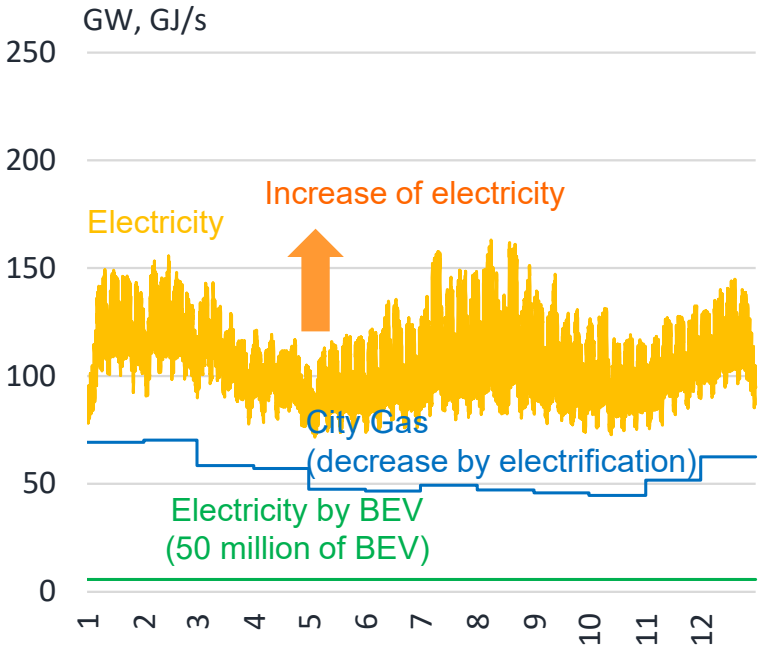
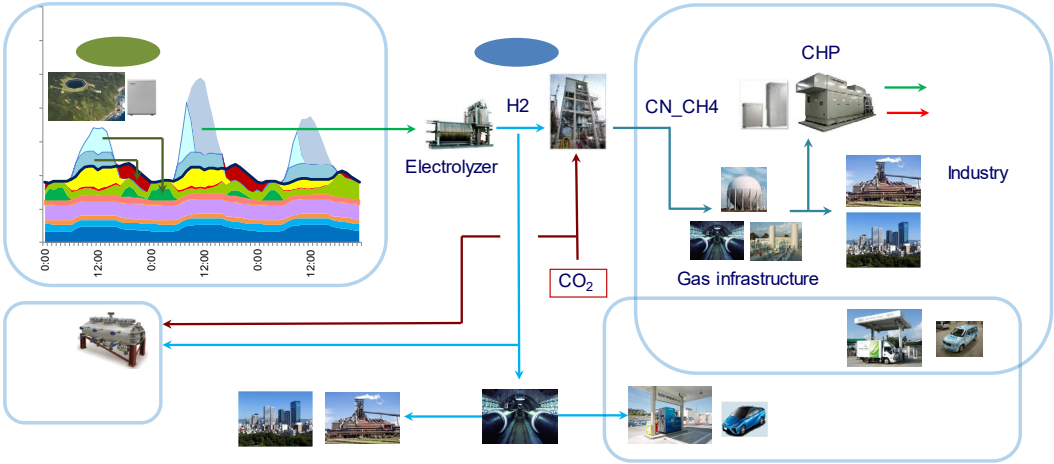
Energy System Integration (Sector Coupling)

- Energy System Integration (Sector Coupling) contributes to expansion of accommodation capacity of renewables, which means minimizing required energy storage capacity.
- Power to Gas (PtG) allows city gas and mobility sector to use renewables. Electrolyzers play a role of balancing in the power grid.

Comparative Hourly Demand Scale



Energy System Integration by Power to Gas



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How to redevelop/develop related-Industry

- It is not sustainable to focus only on deployment of renewables (lessons learnt from solar PV by FIT in Japan). Redevelopment and development of related-industry are required.
- Venous industry, reuse and recycle, is also required with an aim of material security

Solar PV

- ✓ Redevelopment of industry
- ✓ Recycling of mass-disposal of solar PV panel

Wind

- ✓ Industry development
- ✓ Recycling of mass-disposal of blades

Biomass

- ✓ Domestic resource utilization
- ✓ Collaboration with forestry
- ✓ CO2 from biomass for synthetic fuel production

Energy Storage

- ✓ A variety of energy storage should be considered.
- ✓ Reuse and recycling of battery

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Summary

- RE large-scale deployment beyond 2030 faces a number of challenges
- Harmonization with environment and consensus with local residents are essential
- Besides nationwide transmission lines expansion, discussion on Energy System Integration is also needed.
- A variety of energy storage technology. Analyses on energy storage mix based on techno-economic characteristics and critical minerals supply security are needed.
- Existing infrastructure and facilities should be used efficiently.
- For domestic economy, redevelopment and new development of RE-related industry is required.
- Reuse and recycling industry will be needed, preparing for mass disposal of RE facilities and supply risk of critical minerals for energy storages.

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