The 8th CJK Dialogue

Session2 Joint efforts on building a secure, stable and clean supply chain by China, Japan and Korea

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Energy Systems in Japan for Achieving Carbon Neutrality

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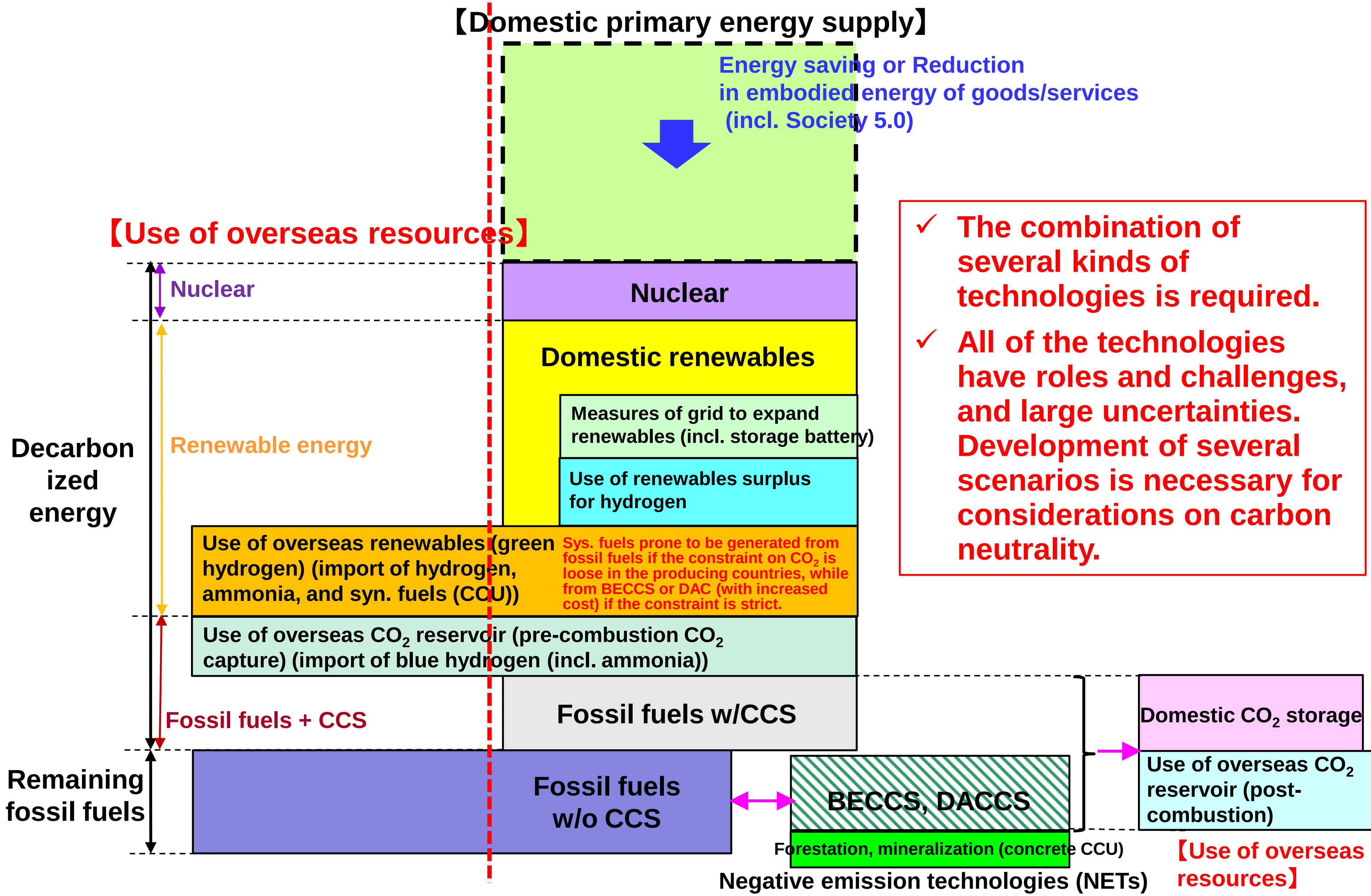
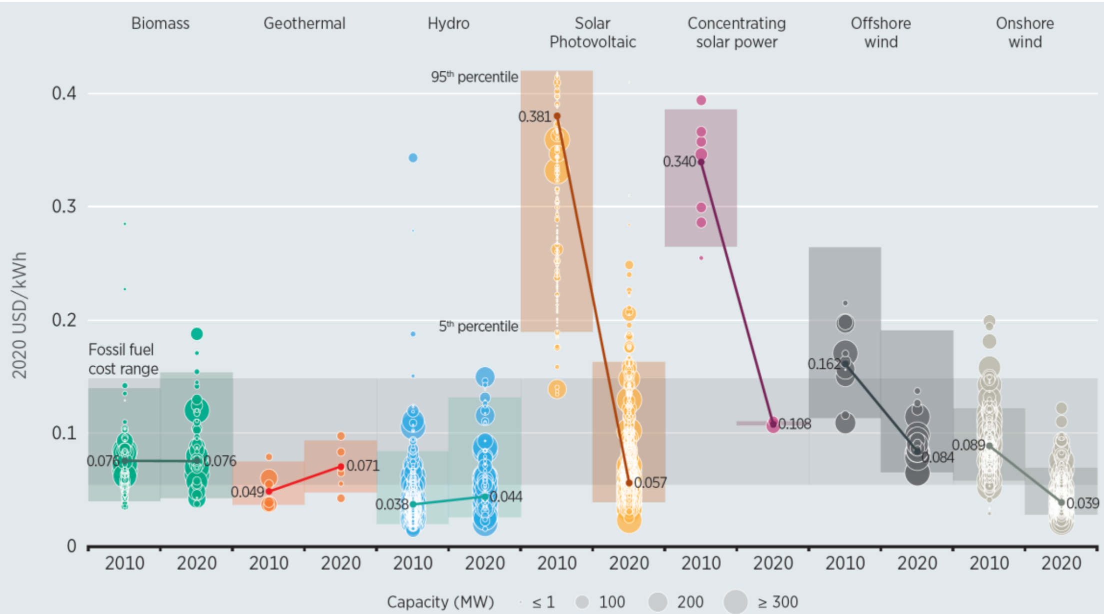
Image of Primary Energy in Japan for Net Zero Emissions

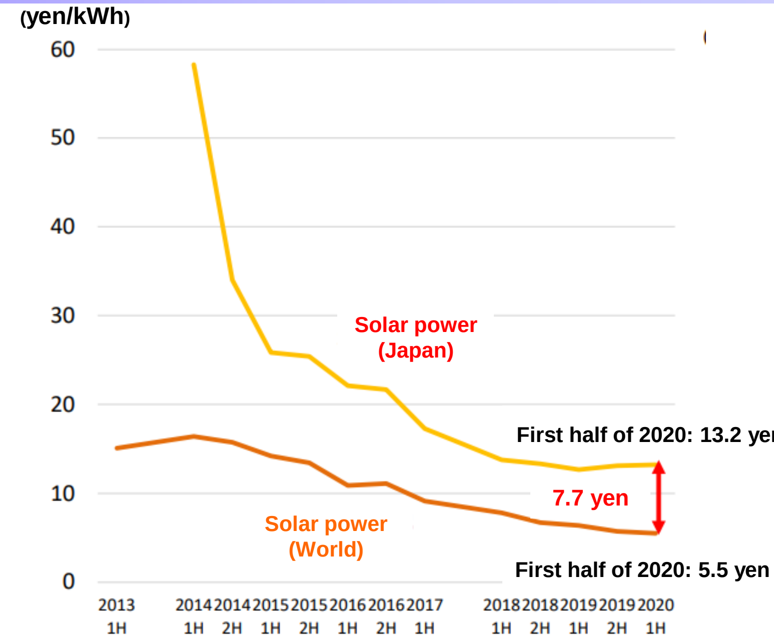


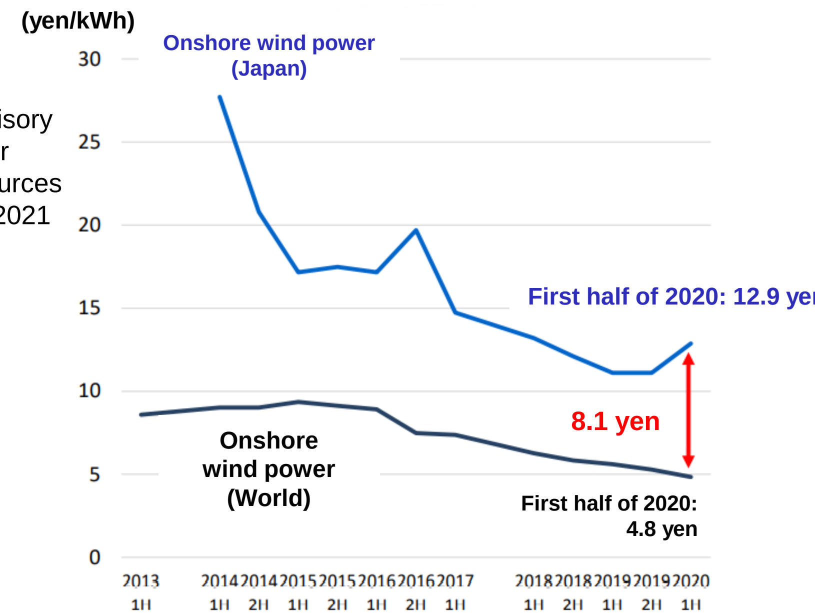
Trends of Renewable Costs in the World and Japan

RITE Research Institute of Innovative Technology for the Earth



Source) IRENA, 2021





(Source) Advisory Committee for Natural Resources and Energy, 2021

- ✓ **The costs of VRE have been greatly reduced.**
- ✓ **However, there are large differences in the costs among nations. The prices in Japan are considerably high compared with the average prices in the world.**

Current Conditions of Renewable Energies in Japan

Increase in renewables (except hydro power)

単位：億kWh

	2012年	2019年
Japan	309	→ 1,056 (3.4倍)
EU	3,967	→ 6,600 (1.7倍)
Germany	1,213	→ 2,227 (1.8倍)
UK	359	→ 1,146 (3.2倍)
World	10,586	→ 27,938 (2.8倍)

災害に起因した太陽光発電設備に係る被害例

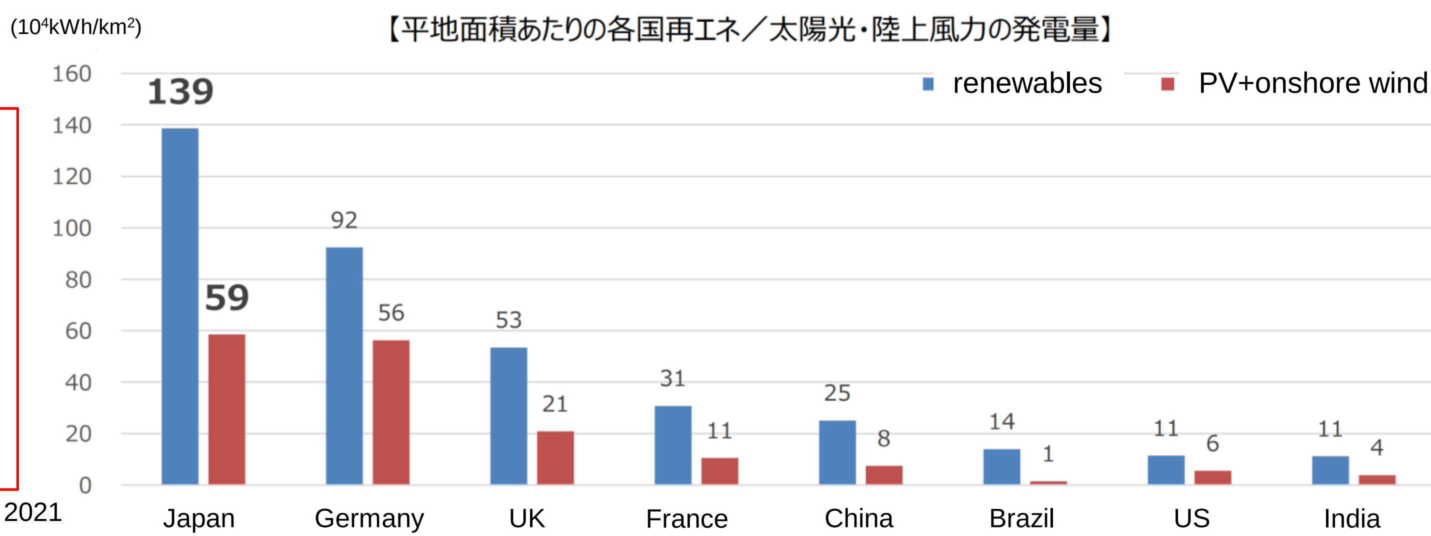
景観に影響を及ぼしている事例

観光地へのアクセス道路からの景観

Japan

Germany

- Installed renewables per flat land area in Japan is the largest in the world.



Renewables should be increased greatly to meet the emission targets, but it is very challenging issues in Japan.

Source) The Government of Japan, 2021

Energy Assessment Model: DNE21+
(Dynamic New Earth 21+)

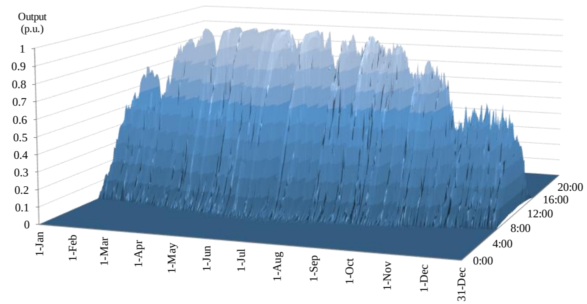
- Systemic cost evaluation on energy and CO_2 reduction technologies is possible.
- Linear programming model (minimizing world energy system cost; with 10mil. variables and 10mil. constrained conditions)
- Evaluation time period: 2000-2100
  Representative time points: 2005, 2010, 2015, 2020, 2025, 2030, 2040, 2050, 2070 and 2100
- World divided into 54 regions
  Large area countries, e.g., US and China, are further disaggregated, totaling 77 world regions.
- Interregional trade: coal, crude oil/oil products, natural gas/syn. methane, electricity, ethanol, hydrogen, CO_2 (provided that external transfer of CO_2 is not assumed in the baseline)
- Bottom-up modeling for technologies on energy supply side (e.g., power sector) and CCUS
- For energy demand side, bottom-up modeling conducted for the industry sector including steel, cement, paper, chemicals and aluminum, the transport sector, and a part of the residential & commercial sector, considering CGS for other industry and residential & commercial sectors.
- Bottom-up modeling for international marine bunker and aviation.
- Around 500 specific technologies are modeled, with lifetime of equipment considered.
- Top-down modeling for others (energy saving effect is estimated using log-term price elasticity.

- **Regional and sectoral technological information provided in detail enough to analyze consistently.**
- **For analyzing the 2050 carbon neutrality in Japan, the integration costs of VRE are estimated by using a generation mix model having five regions within Japan and interregional grid connections developed by the University of Tokyo and IEEJ, and they are integrated into the DNE21+.**
- **Analyses on non-CO_2 GHG possible with another model RITE has developed based on US EPA's assumptions.**

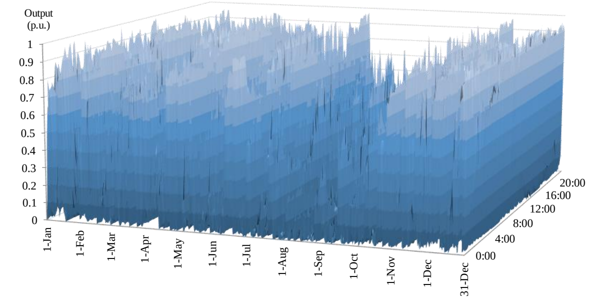
Assumptions for Estimating Integration Cost in the Univ. Tokyo - IEEJ Model

Regional aggregation

Divide Japan into 5 regions: [1] Hokkaido, [2] Northeastern area, [3] Tokyo, [4] Western area other than Kyushu, [5] Kyushu



Output example of PV



Output example of wind power

Considered in modeling･･･ Output control, power storage system (pumped hydro, lithium-ion battery and hydrogen storage), reduction of power generation facility utilization, inter-regional power transmission lines, electricity loss in storage and transmission

Not considered in modeling･･･ Intra-regional power transmission lines, power grid, influence of decrease of rotational inertia, grid power storage by EV, prediction error of VRE output, supply disruption risk during dark doldrums

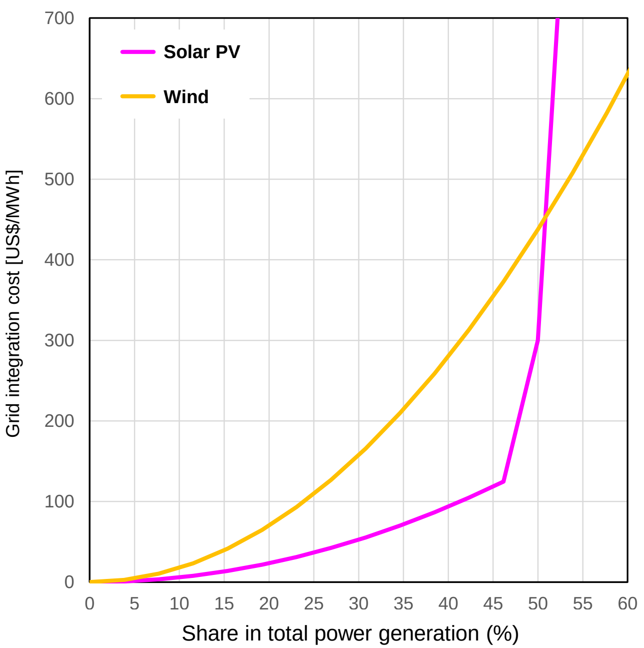
Power storage system

Mainly with Lithium-ion battery (setting 150$/kWh in 2050 based on estimation by the National Renewable Energy Laboratory (NREL)), it is assumed that existing pumped-storage hydropower and hydrogen storage will be used together.

Cost of interconnection lines

With reference to the plan by the Organization for Cross-regional Coordination of Transmission Operators, costs of interconnection lines are assumed to be 200,000 yen/kW between areas [1] [2] and [3][4], and 30,000 yen/kW in other areas, with an annual expense ratio of 8%. Underground transmission lines and submarine cables between Hokkaido and Tokyo are not considered.

Marginal cost of grid integration for VRE in Japan



Overview of Assumed Scenarios

		GHG emission reduction in 2050	Technology assumption (cost / performance)	Technology deployment scenario
Offset emission credits of overseas (The least-cost measures in the world = Equal marginal abatement costs among nations)		Domestic emission reductions are endogenously determined.	**Standard case** (Note: It is premised that RE is diffused due to suspected inertial force in high share RE scenario.)	**Determined endogenously (cost minimization), with constraints for nuclear power up to 10% and CO_2 storage.**
Reference case		**▲100%** (For other than Japan, ▲100% for each western country, and ▲100% for the others as a whole)		
Assuming high share of RE under Standard case	**1. Renewable Energy 100%**			**Renewable energy nearly 100%** **(Nuclear power 0%)**
Assuming each technology is further accelerated or expanded.	**2. Renewable Energy Innovation**		**Acceleration of RE cost reduction**	**Determined endogenously, with constraints for nuclear power up to 10% and CO_2 storage.**
	3. Nuclear Power Utilization		**Expansion of nuclear power deployment**	**Determined endogenously, with constraints for nuclear power up to 20% and CO_2 storage.**
	4. Hydrogen Innovation		**Acceleration of hydrogen cost reduction**	**Determined endogenously, with constraints for nuclear power up to 10% and CO_2 storage.**
	5. CCS Utilization		**Expansion of CO_2 storage potential**	**Determined endogenously, with constraints for nuclear power up to 10%. Large CCS storage potential assumed.**
	6. Synthetic fuel Utilization		**Acceleration of RE cost red. + Constraints of CO2 intern'l transportation**	**Determined endogenously, with constraints for nuclear power up to 10% and CO_2 storage. No intern'l transportation of CO_2.**
	7. Demand Transformation		**Expansion of car-/ride-sharing**	**Dramatic expansion of car-/ride-sharing due to fully autonomous car implementation assumed.** **Other assumptions are same as Reference case.**

Scenario Assumption and Share of Renewables in Total Electricity(in 2050)

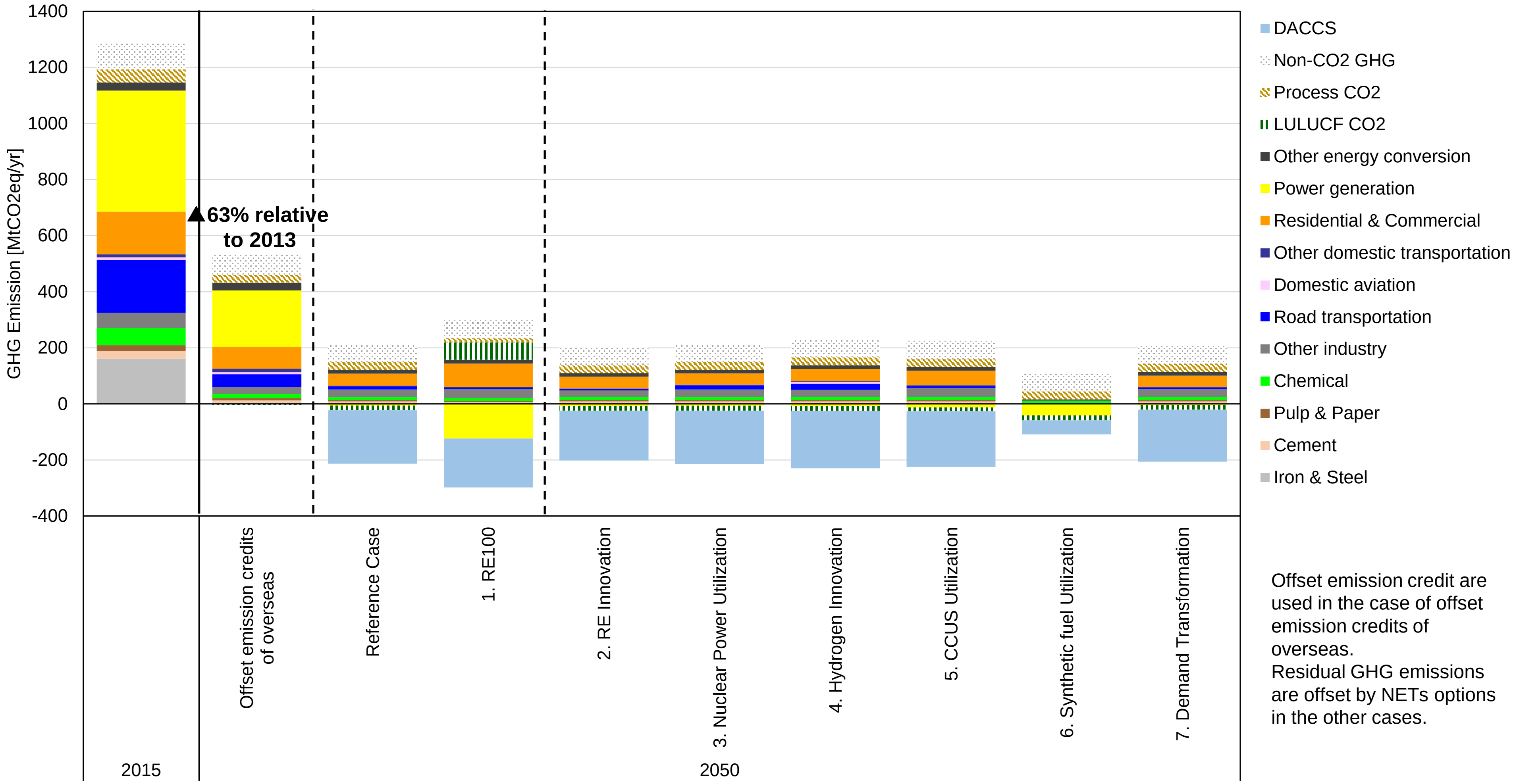
<table>
<tr><th>Scenario</th><th>Cost of renewable energy</th><th>Ratio of nuclear power</th><th>Cost of hydrogen</th><th>CCUS (Storage potential)</th><th>Fully autonomous driving (Car ride sharing)</th></tr>
<tr><td>Reference Case*1</td><td rowspan="2">Standard cost</td><td>Max. 10%</td><td rowspan="4">Standard cost</td><td rowspan="5">Domestic storage: max. 91MtCO_2/yr; Overseas transportation: max. 235MtCO_2/yr</td><td rowspan="7">Standard assumption (no fully autonomous cars)</td></tr>
<tr><td>1. Renewable Energy 100% (RE 100)</td><td>0%</td></tr>
<tr><td>2. Renewable Energy Innovation</td><td>Low cost</td><td>Max. 10%</td></tr>
<tr><td>3. Nuclear Power Utilization*2</td><td rowspan="3">Standard cost</td><td>Max. 20%</td></tr>
<tr><td>4. Hydrogen Innovation</td><td rowspan="4">Max. 10%</td><td>Hydrogen production such as water electrolysis, hydrogen liquefaction facility cost: Halved</td></tr>
<tr><td>5. CCS Utilization</td><td rowspan="3">Standard cost</td><td>Domestic: max. 273MtCO_2/yr; Overseas: max. 282MtCO_2/yr</td></tr>
<tr><td>6. Synthetic fuel utilization</td><td>Low cost</td><td>Domestic: max. 91Mt, Overseas: 0Mt</td></tr>
<tr><td>7. Demand Transformation</td><td>Standard cost</td><td>Domestic: max. 91MtCO_2/yr; Overseas: max. 235MtCO_2/yr</td><td>Realization and diffusion of fully autonomous driving and expansion of car ride sharing after 2030, and decrease in material production due to reduction of the number of automobiles</td></tr>
</table>

∗ Regarding changes on the demand side, further scenario analysis that takes into account factors other than car sharing will be conducted.

*1: There is no feasible solution without DAC, and DAC is assumed to be available in all scenarios.

*2: Nuclear power utilization scenarios up to a ratio of 50% are separately examined.

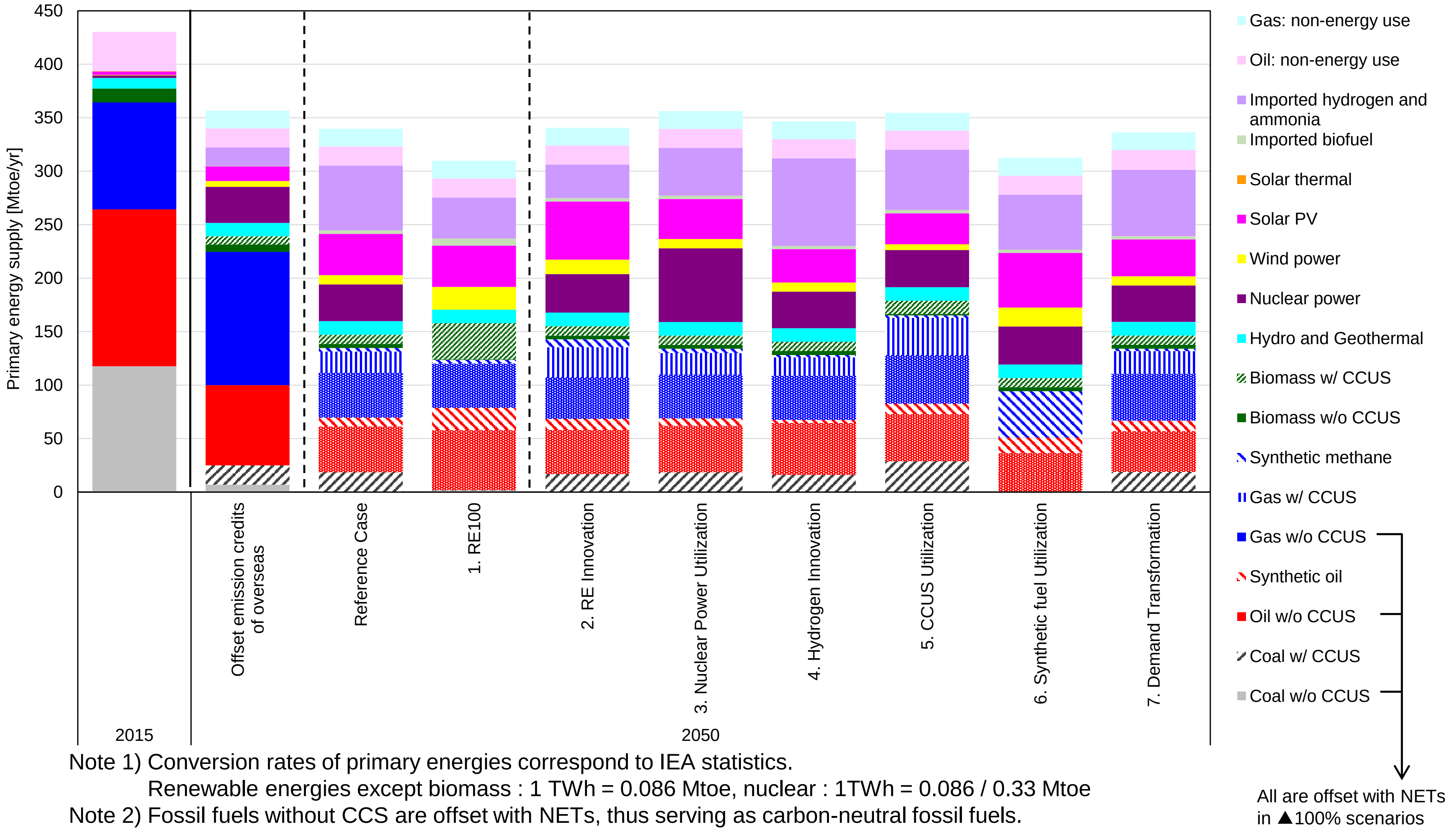
GHG Emissions by Sector in Japan in 2050



Offset emission credit are used in the case of offset emission credits of overseas.
Residual GHG emissions are offset by NETs options in the other cases.

- ✓ **In the case of offset emission credits of overseas, the emission reduction in 2050 is 63% relative to 2013 in Japan, because there are offset emission credit opportunities of cheaper NETs options such as BECCS and DACCS outside of Japan.**
- ✓ **For offset of residual GHG emissions, DACCS plays an important role.**

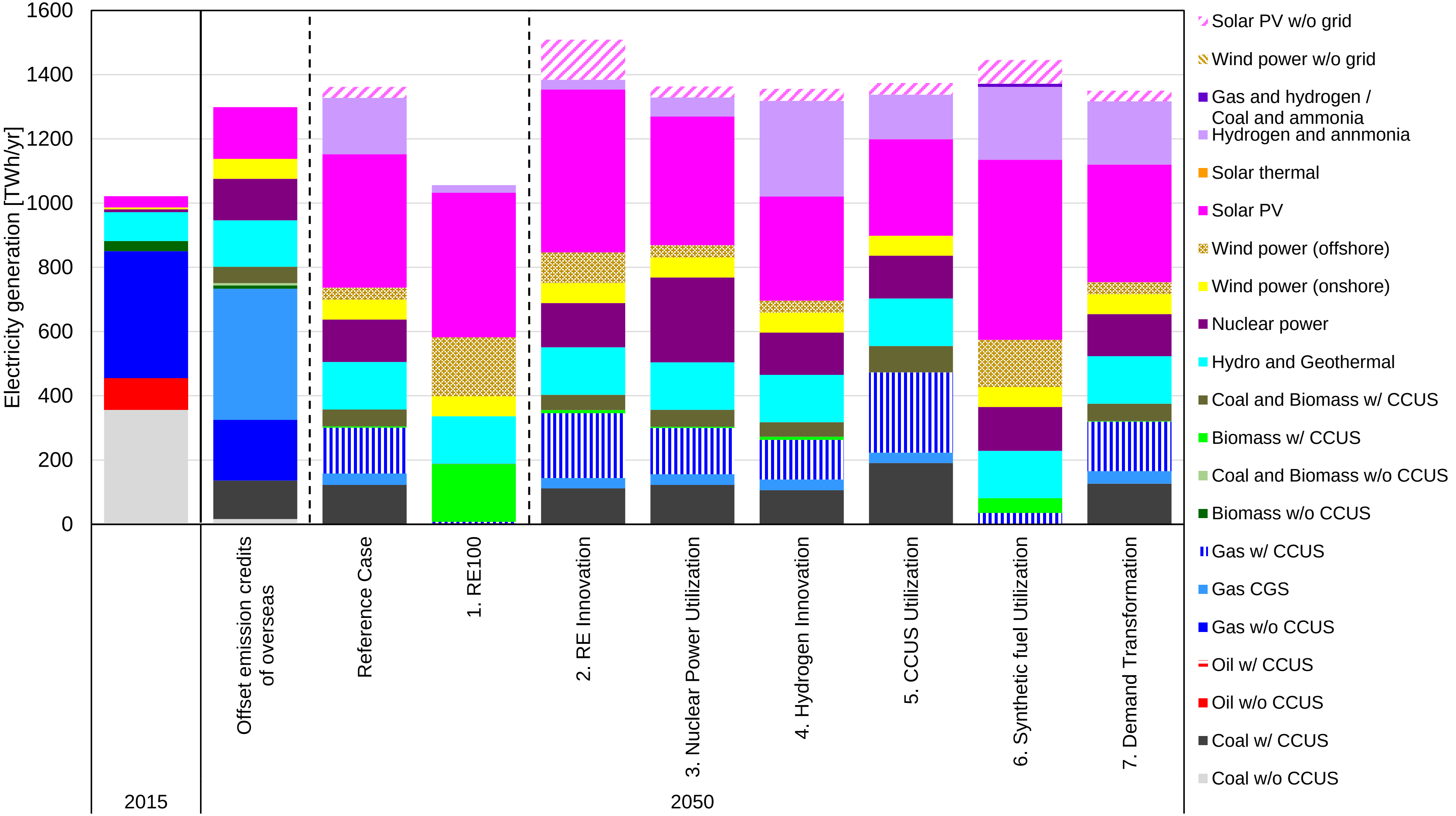
Total Primary Energy Supply in Japan in 2050



Note 1) Conversion rates of primary energies correspond to IEA statistics.
Renewable energies except biomass : 1 TWh = 0.086 Mtoe, nuclear : 1TWh = 0.086 / 0.33 Mtoe
Note 2) Fossil fuels without CCS are offset with NETs, thus serving as carbon-neutral fossil fuels.

- ✓ **For all of the scenarios, CCS is a cost-effective measures. Particularly in [6] syn. fuel case, large amounts of synthetic fuel supplies can be observed.**
- ✓ **A substantial amount of imports of hydrogen, ammonia and synthetic fuels are observed.**

Electricity Supply in Japan in 2050



- ✓ **In the case of offset emission credits of overseas, relatively large share of gas without CCS including co-generation can be seen in Japan.**
- ✓ **Especially for the RE100 case, a surge in integration costs significantly raises marginal cost of electricity supply, causing considerable decrease in electricity demand. CCS is important.**

Toward Carbon Neutrality

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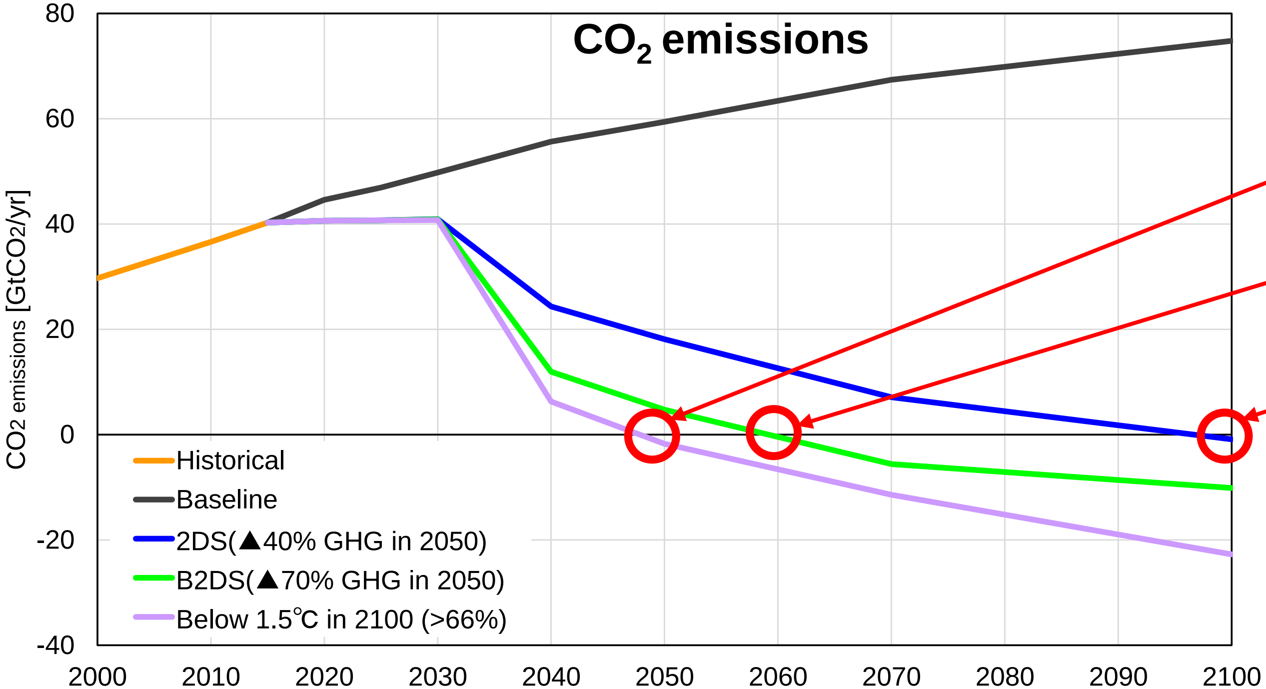
- **To achieve carbon neutrality (net-zero emissions), in principle, primary energy should consist of renewable energy, nuclear energy, and fossil fuels with CCS. The combination of an increase in electrification ratio and low-and de-carbonized power supply plays a vital role in achieving net-zero emissions.**
- **The increase in the further installations of renewable energy is a robust outlook. On the other hand, the increase in the grid integration costs is expected with the large deployments of VRE.**
- **Japan has a relatively high cost of renewable energy compared with other countries. Also, Japan has a relatively high cost of CCS and its potential is also relatively small. Therefore, a global strategy including the utilization of overseas-made renewable energy and CCS through hydrogen, ammonia, and e-fuels (synthetic gas and oil, one of CCU technologies) is needed.**
- **Not only Japan but also many Asian countries have a similar condition, and CCU will be also important as well as CCS for the net-zero emissions.**
- **Caron dioxide removal (CDR) (or NETs) such as DACCS will also play an important role in achieving net-zero emissions including the opportunities in the implementations overseas with emission credit transfer.**
- **Whole energy systems including electricity, carbon, and hydrogen will be required from a global viewpoint.**

Appendix

Global Baseline Emissions and Assumed Emissions Scenarios under 2°C and 1.5°C



Net zero CO_2 emissions around 2050

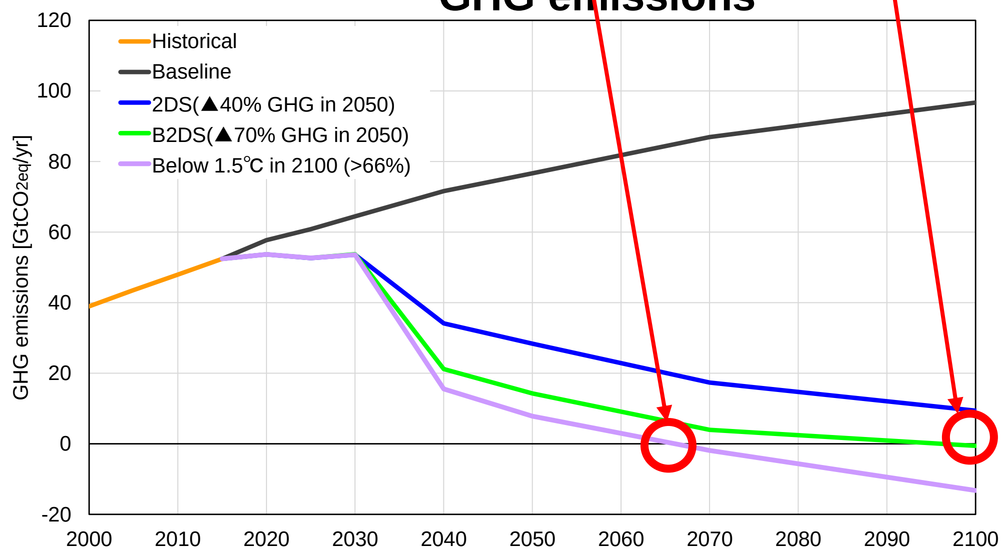
Net zero CO_2 emissions around 2060

Net zero CO_2 emissions around 2100

Net zero GHG emissions around 2065

Net zero GHG emissions around 2100

GHG emissions



Note) Emissions for baseline shows model estimates results under SSP2, not assumed scenario

※ 2DS, B2DS, B1.5OS scenarios assume emission constraints equivalent to NDCs of each nation up to 2030

In the scenario analyses of Japan's 2050 carbon neutrality, 1.5°C global scenarios are assumed in addition to Japan's emissions reduction scenarios, for the global competition for carbon neutral resources to be considered.

【ref.】Concept of Innovation in Power Supply Ref. Value

- Each power source must overcome a large hurdle to achieve the reference values for power sources in 2050 as presented at the Strategic Policy Committee.
- Under these conditions, for the 30 to 40% of nuclear power and fossil+CCUS, in case the upper limit of nuclear power is 10%, it is necessary to cover 20-30% with fossill+CCUS, thus it is assumed a considerable amount of CO2 is stored at home/abroad including CCUS required amount other than the electric power sector. For hydrogen/ ammonia and carbon recycled fuel, it is assumed that infrastructure development, etc. is expected to execute a large-scale transportation without setting the upper limit of supply on the model.
- It should be noted that in this analysis, the conditions were set by mechanically assuming such CCS storage amount based on the above reference values.

2020/12/21 Strategic Policy Committee Material

In order to aim for carbon neutrality in 2050, stable power supply from decarbonized power sources is indispensable. From the perspective of 3E+S, multiple scenarios will be analyzed without limiting to the following. In deepening the discussion, the positioning of each power source is suggested as follows.

Established decarbonized power source	Renewable Energy		・Continue to aim for maximum introduction as the main power source in 2050. ・Immediately work on issues to promote the maximum introduction such as adjustment amount, transmission capacity, ensuring inertial force, responding to natural conditions and social constraints, maximizing cost control, and increasing social transformation to cost increases. ・How about deepening discussions on covering 50-60%(approx.) of the generated power (* 1) with renewable energy in 2050 as a reference value (* 2)?
	Nuclear power		・As an established decarbonized power source, aim for a certain scale of utilization on the premise of safety. ・In order to restore public trust, make an increased effort to improve safety, gain understanding and cooperation of the location area, solve back-end problems, secure business feasibility, maintain human resources and technical capabilities, etc. How about deepening discussion on covering 30-40% (approx.) with nuclear power which is a carbon-free power source other than renewable energy and hydrogen/ammonia, along with fossil+CCUS/carbon cycle in 2050 as a reference value (* 2)?
Power sources required innovation	Thermal power	Fossil + CCUS	・While having the advantages of supply capacity, adjustment power, and inertial force, decarbonization of fossil-fired power is the disadvantage. ・Aim to utilize on a certain scale iimmediately by developing technology and suitable sites, expanding applications and reducing cost, etc., toward the implementation of CCUS / carbon recycling. How about deepening discussion on covering 30-40% (approx.) together with nuclear power which is a carbon-free power source other than renewable energy and hydrogen/ammonia in 2050 as a reference value (* 2)?
		Hydrogen, Ammonia	・While having the advantages of adjusting power and inertial force without emitting carbon during combustion, the challenges are establishing technology for large-scale power generation, reducing costs, and securing supply. Aim to build a stable supply chain immediately by promoting co-firing of gas-/coal-fired power, increasing supply and demand. ・Aim for a certain scale of utilization as a carbon-free power source, taking into account competition with industrial and transportation demand. Based on the fact that procurement required for future power generation is estimated to be 5-10-million ton as basic hydrogen strategy, how about deepening discussion on covering 10% (approx.) of generated power with hydrogen/ammonia in 2050 as a reference value (* 2)?

1: The amount of power generated in 2050 will be about 1.3-1.5 trillion kwh as a reference value (2) based on the power generation estimation by RITE presented at "the 33rd Strategic Policy Committee".

*2: This is not as a government goal, this is one guideline / option for future discussions. This will be the one of options to deliberate in considering multiple scenarios in the future.