Temporary Version

The Challenge to Carbon Neutrality in 2050
-Issues for Japan and CRIEPI's Undertaking-

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4th IERE Webinar

November 18, 2021

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4 Questions to be touched upon.

1. What is ‘Carbon Neutrality’?

2. What are the official views and plans by the Japanese government?

3. How and to what extent can VRE be introduced?

4. What and how is CRIEPI planning to achieve?

VRE : Variable renewable energy.

The Essences of Lecture.

- Carbon neutrality (CN, hereafter) is, fundamentally, achieved through thorough electrification of demand and decarbonization of power sources, while remaining positive emissions must be canceled by negative emissions, i.e. removal.

- The Japanese government has published their views and plans for CN in 2050, though substantive uncertainties lie ahead.

- CRIEPI, as a research organization on energy and electricity, strives for contributing to Japan's challenge for CN in 2050, through optimizing stable supply and active demand managements.

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Fundamental Equation of CO_2 Deep-cut.

$$CO2 = CO2_{EE} + CO2_{NE}$$

$$= \left\{ \alpha \times \left(\frac{CO2_{EE}}{EE_p} \times \frac{1}{\eta_{EE}} \right) + (1-\alpha) \times \left(\frac{CO2_{NE}}{NE_p} \times \frac{1}{\eta_{NE}} \right) \right\} \times E_S$$

Rate of Electrification

CO_2 coefficient of Energy Service Demand E_S supplied by electricity.

CO_2 coefficient of Energy Service Demand E_S supplied by non-electricity.

Direct reduction of E_S ('bad energy cut') could reduce CO_2 emission.

CO_2 Reduction achieved by Electrification ($\alpha\uparrow$) is realized as the synergy of;

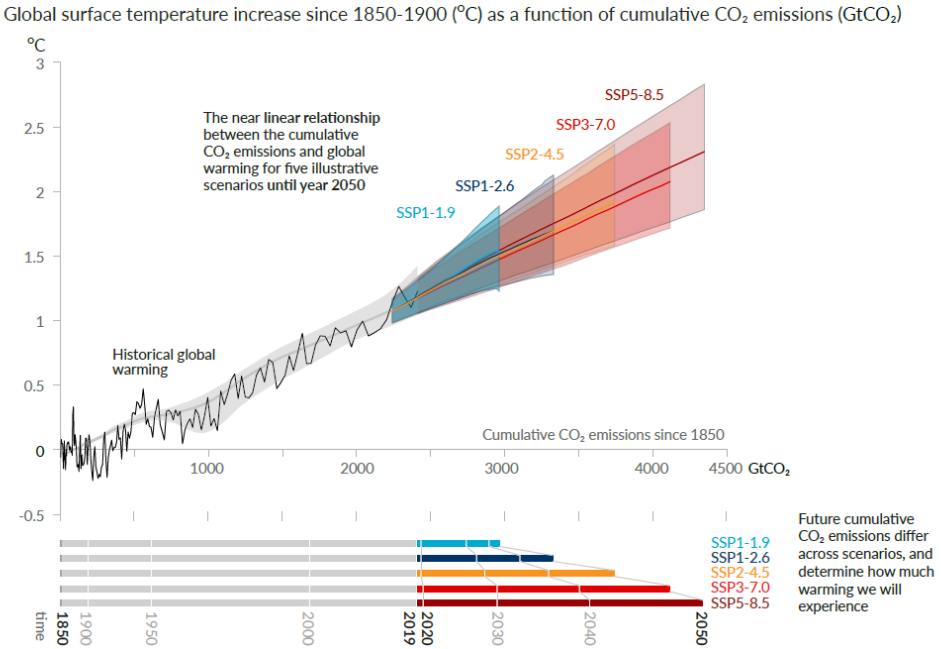
- **Higher Exergy of electricity ($\eta_{EE} > \eta_{NE}$)**
- **Power generation shift to Low/Zero carbon emitting sources ($CO2_{EE}/EE_p \to 0$)**

Ref : Nagano (2020)

What is Carbon Neutrality?

- **Air temperature increase is proportional to cumulative CO_2 emissions.**
  - Presented in IPCC-AR5, confirmed in AR6.
  - To limit temperature increase, cumulative CO_2 emissions must be limited.

  ⇒ Paved way to Net-Zero Emissions.



Ref : IPCC Working Group I (2021)

- **Article 4, Item 1 of the Paris Agreement dictates:**

"… achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century …"

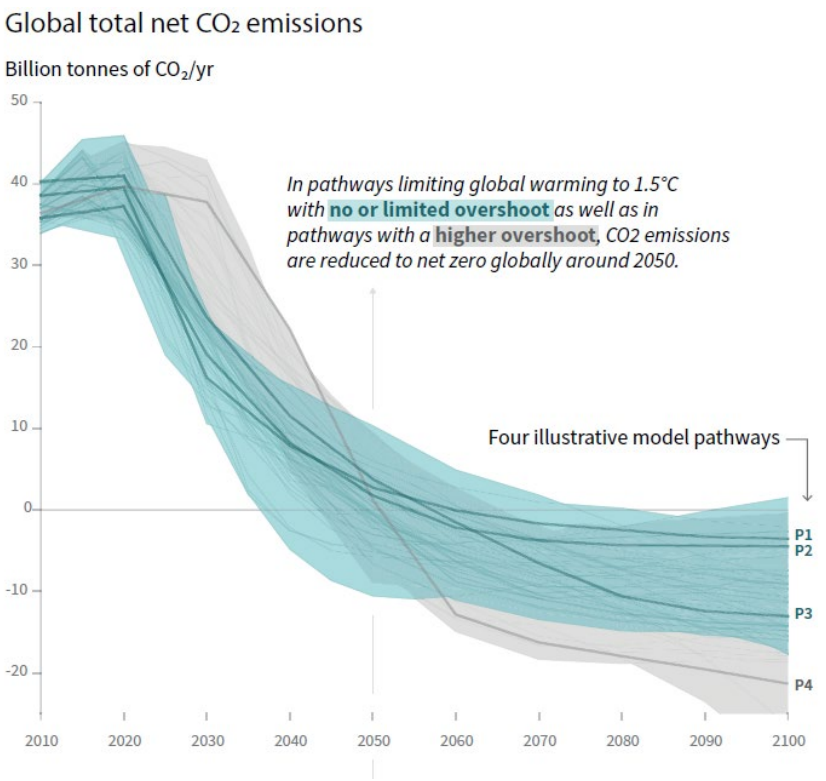
Scenarios in IPCC SR15.

- IPCC special report “Global Warming of 1.5℃” (SR15, 2018)
  - Provided global emission pathways and timings to achieve CO_2 net-zero consistent with 1.5℃ increase.
  - Analyzed 411 scenarios presented by research entities worldwide.
- **CRIEPI meta-analyzed the SR15 scenarios.**
  - 205 scenarios achieving CO_2 net-zero.

Timings of global CO_2 net-zero.

1.5 degree C : around 2050

2 degree C : around 2070



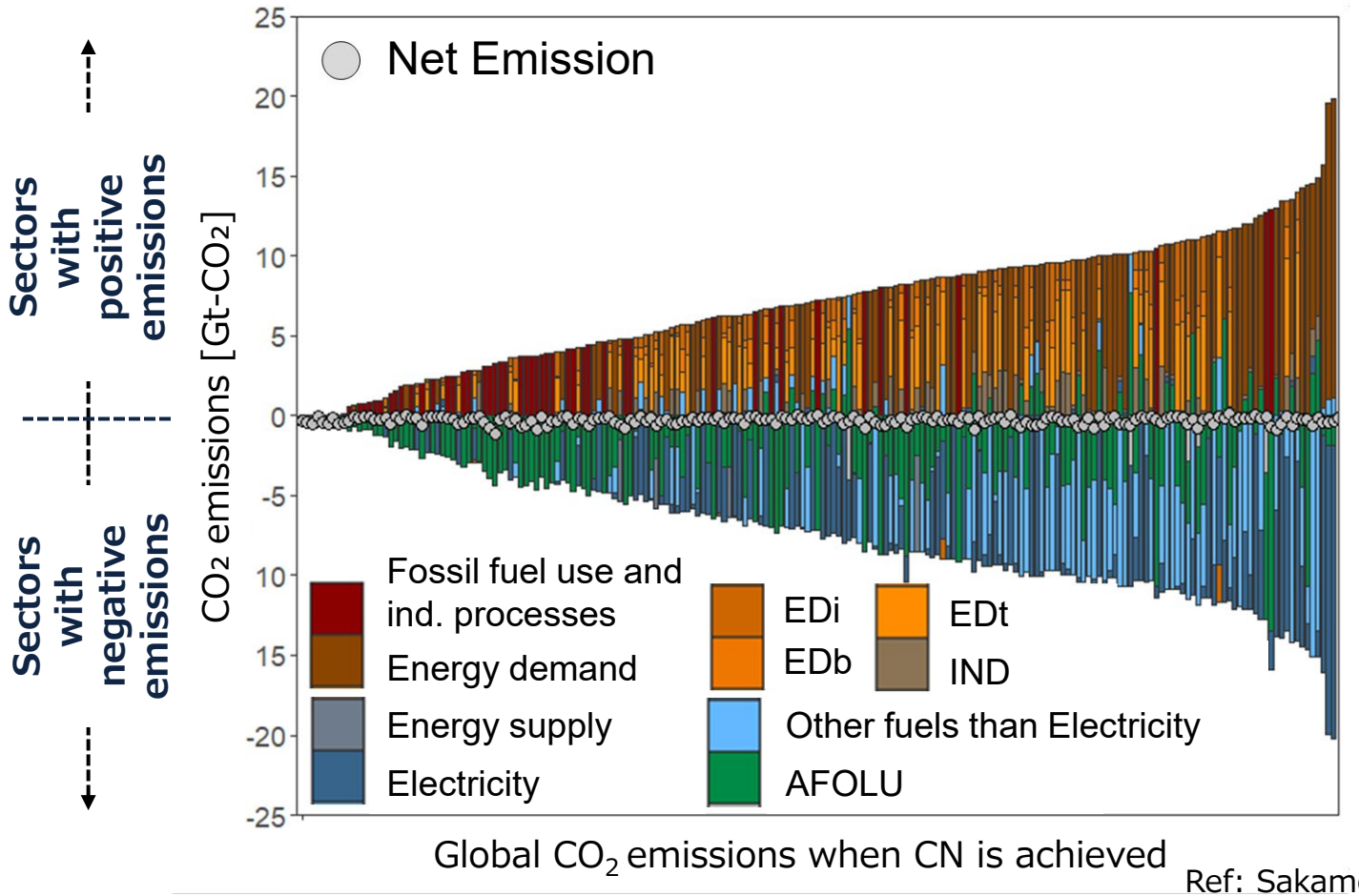
Ref: IPCC (2018), Sakamoto and Horio (2020)

Meta-analysis of IPCC CN Scenarios.

- For the 205 scenarios of CN achieved, CRIEPI looked at CO_2 emission balances in amount (positive/negative) and sectors.
- CO_2 emitting sector category:
  - Fossil fuel use and industrial processes:
    - Energy Demand: Industry(EDi), Buildings (EDb), Transport (EDt).
    - Energy Supply: Electricity (ESe), Liquid Fuel (ESl), Gaseous Fuel (ESg), Heat (ESh), Solid Fuel (ESs).
  - Other industrial Processes (IND),
  - Agriculture, forestry and other land use (AFOLU).

Pathways to CN Vary significantly.

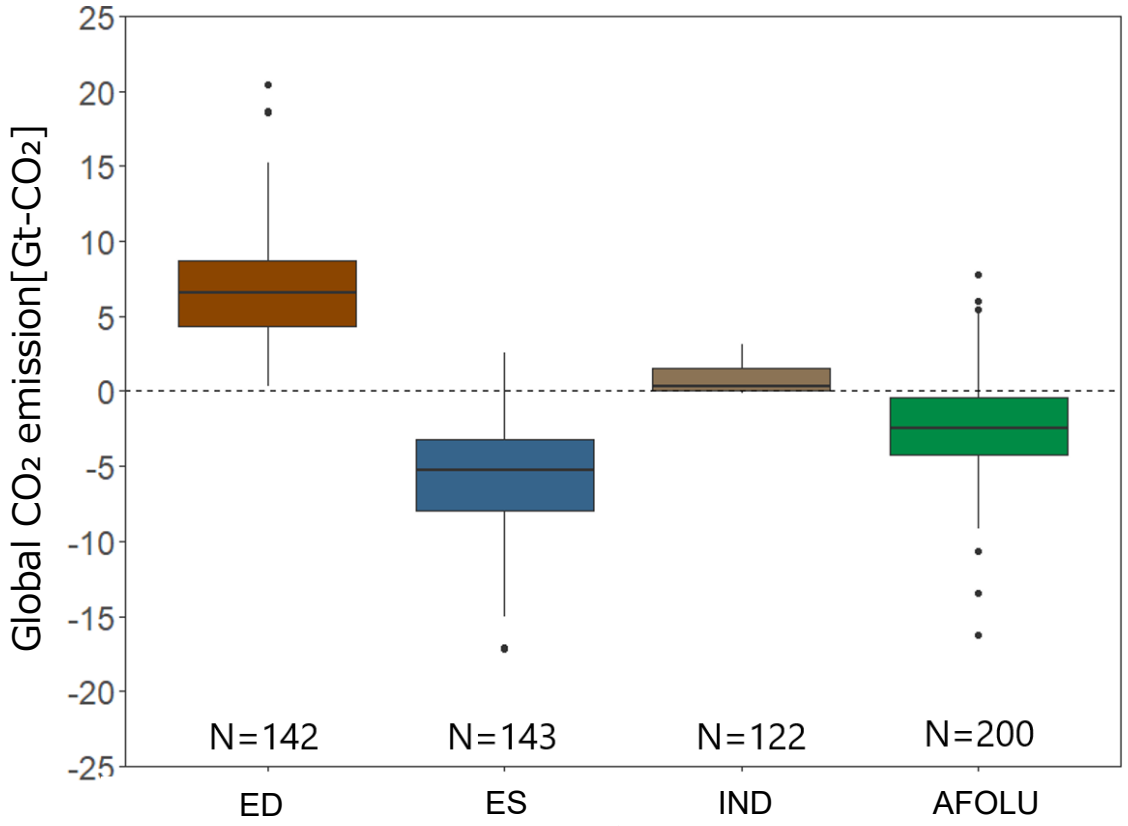
- Positive/negative CO_2 emissions when CN achieved, in both amounts and distribution, are in an enormous variety.



Ref: Sakamoto and Horio (2020)

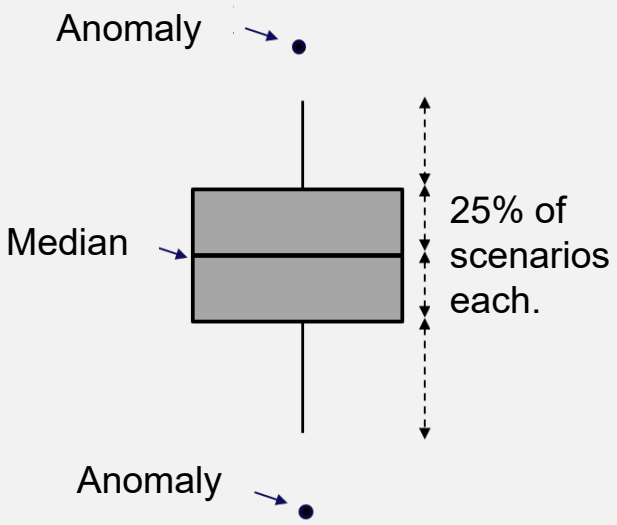
CN Varies: CO_2 Emissions/Removals

- Emissions from ED and IND are positive in all the scenarios.
- Emissions from ES and AFOLU can be positive or negative.



* As some scenarios didn't show sectoral details, N is lower than 205.

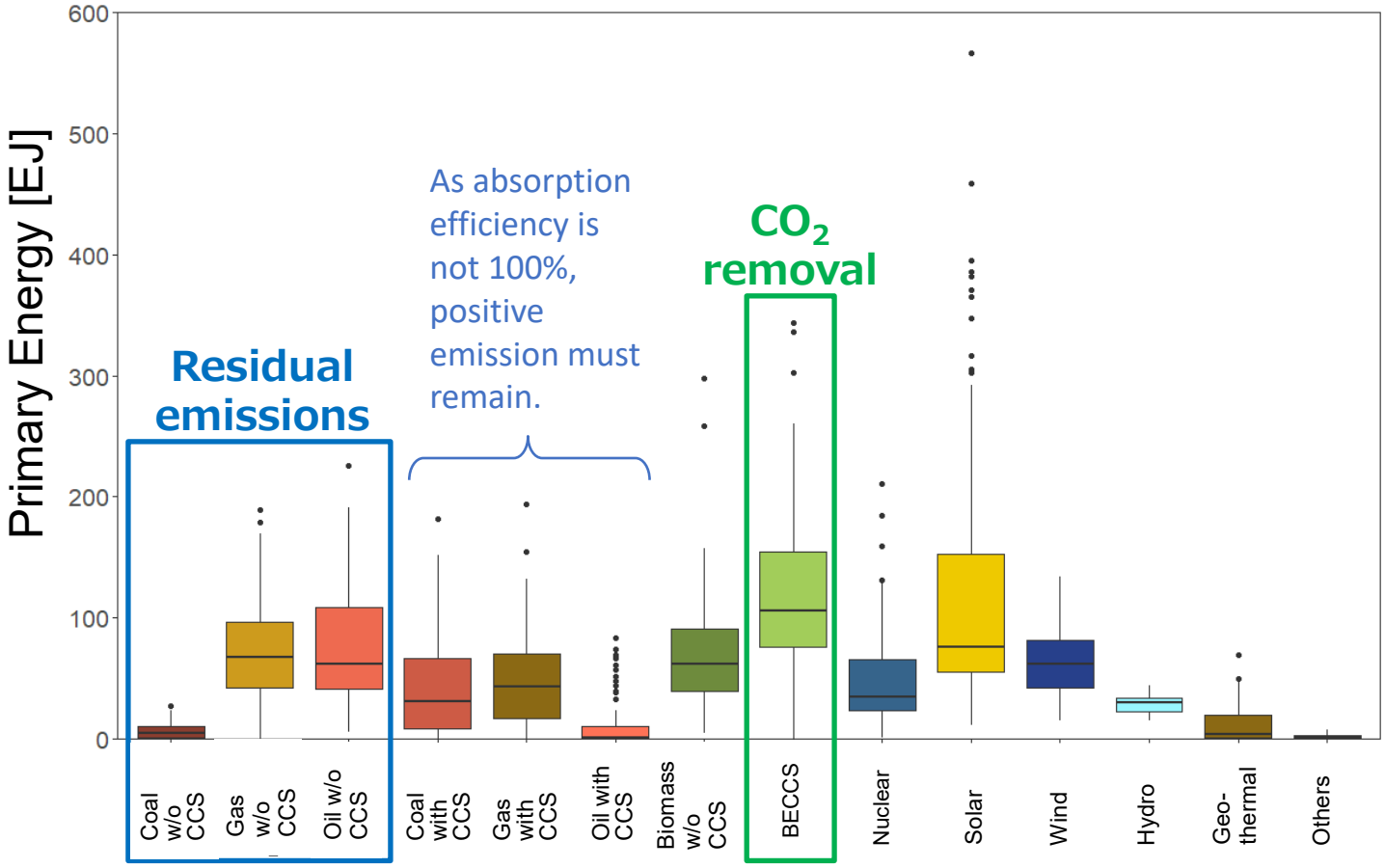
This graph shows data distribution visually. The wider the boxes and bars, the more dispersed data.



Ref: Sakamoto and Horio (2020)

CN Varies: Primary Energy Supply.

- Residual emission by 'Fossil w/o CCS' offset by 'Biomass w/ CCS (BECCS)'.

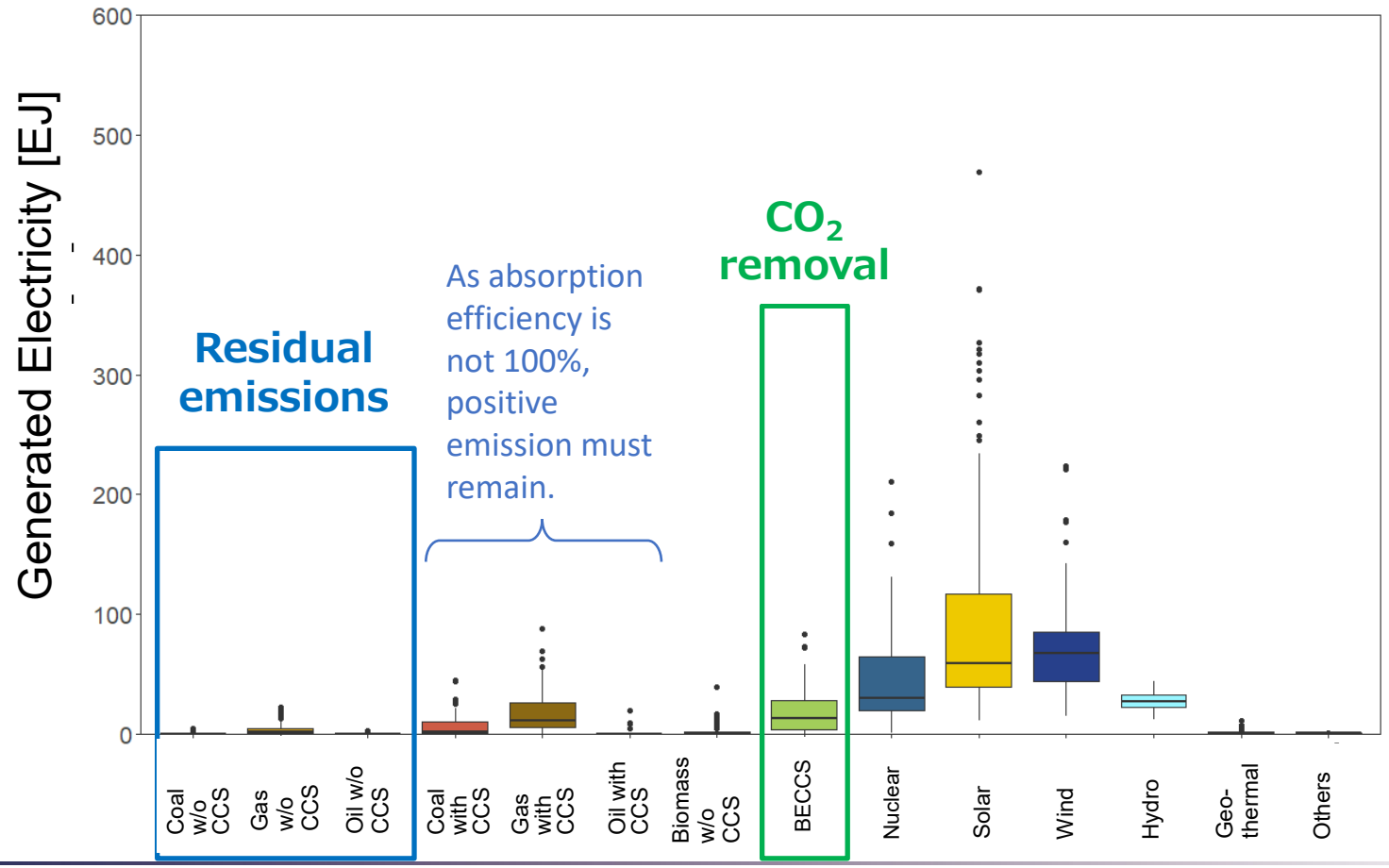


※Based upon the 138 scenarios with those detailed data are presented.

Ref: Sakamoto and Horio (2020)

CN Varies: Power Generation Mix.

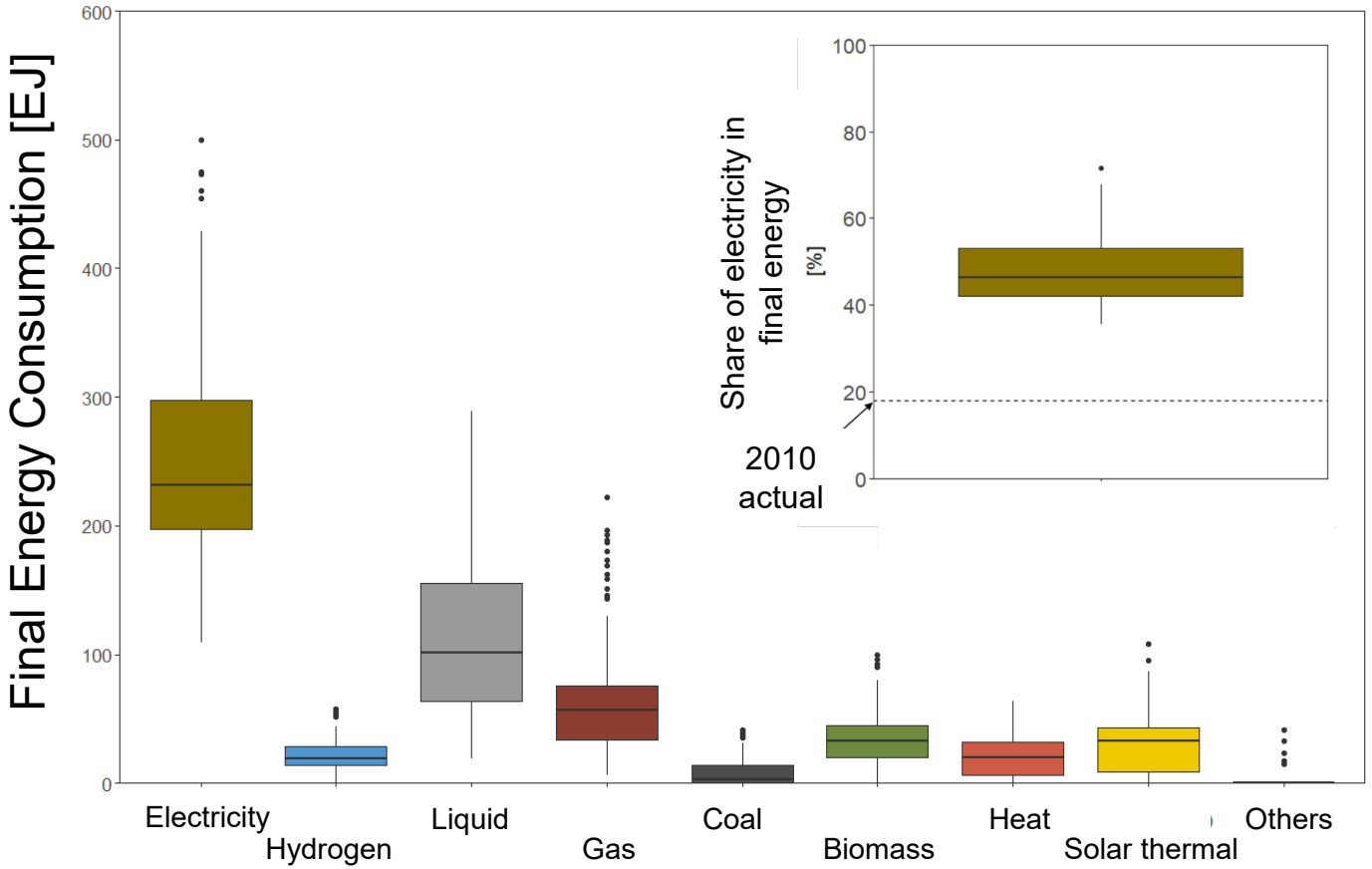
- Numerous patterns of combination.
  - Renewables, Nuclear, Fossil with and without CCS.



Ref: Sakamoto and Horio (2020)

CN Varies: Final Energy Demand and Electrification Rate.

- The energy carrier with the largest share is electricity.
  - The median value of electrification rate is about 46%.
- Remaining emissions are from gaseous/liquid fuels and coal.



Ref: Sakamoto and Horio (2020)

Insights from IPCC SR15 Scenarios.

- **Pathways to CN vary significantly.**
  - Various combinations of emission/removal.
  - Besides supply-side, demand-side measures are indispensable.
- Key technologies for CN will include …
  - Renewable energy : PV, wind, biomass, hydro …
    - ✓ Grid stabilization against their fluctuating power output.
  - Nuclear Power, and
  - Efficient fossil fuel uses including power generation.
- CO_2 removal technologies are the final weapon.
  - ✓ While BECCS seems most promising, DACCS will show up?
- **Final energy demand must be thoroughly electrified.**
  - ✓ **CO_2 deep-cut through 'electrification times decarbonization of power sources'.**

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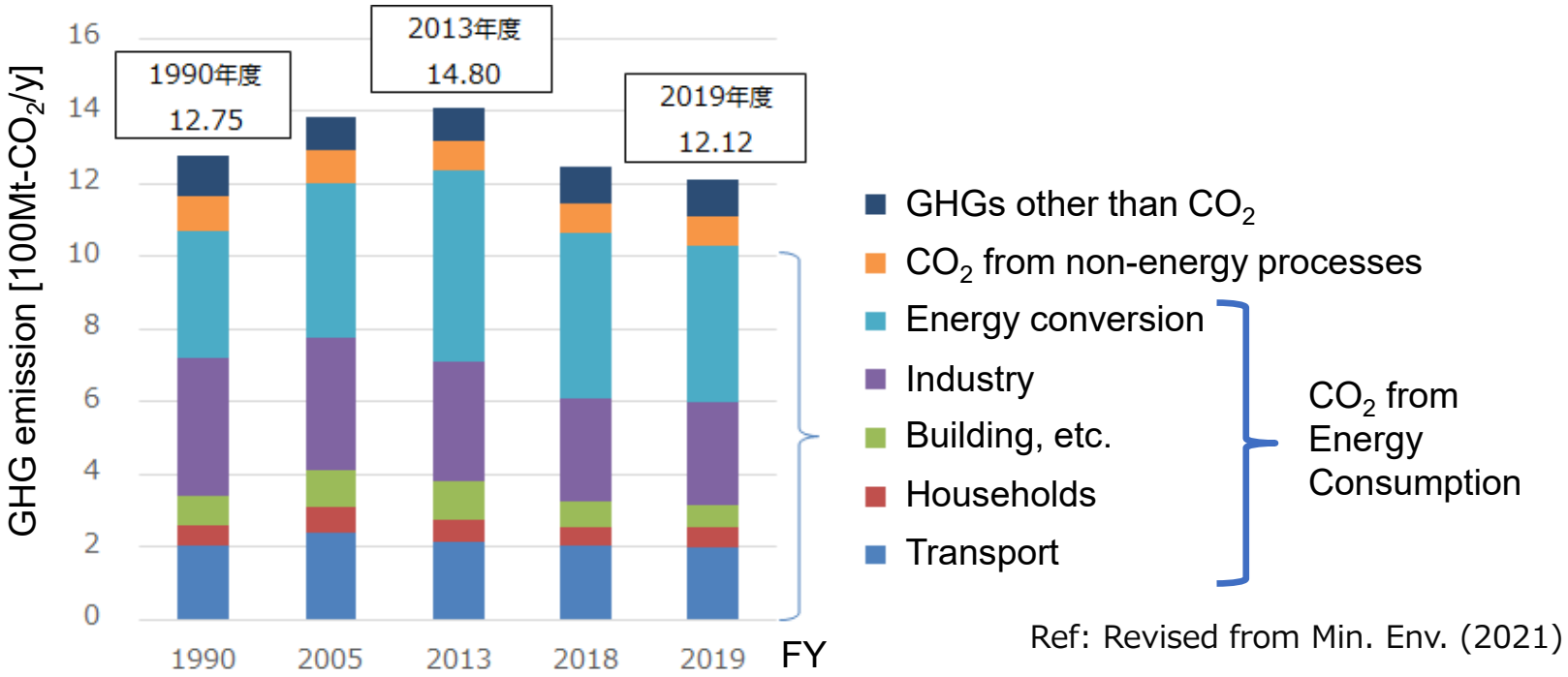
Japan's CN Targets.

- In Oct. 2020, then-PM Yoshihide Suga announced 'CN in 2050'.
  - "I herewith declare that Japan will make total GHG emissions zero, i.e. CN or realization of decarbonized society, by 2050.
- Article 2, (2) 'Basic principle' of Act on Promotion of Global Warming Countermeasures (revised in May, 2021)
  - "Aiming at realization of decarbonized society (which a balance between anthropogenic GHG emission and absorption through preserved and enhanced sequestration is maintained) by 2050."

⇒ Japan aims at not net-zero emission of CO_2 but GHG.

Japan's GHG emissions.

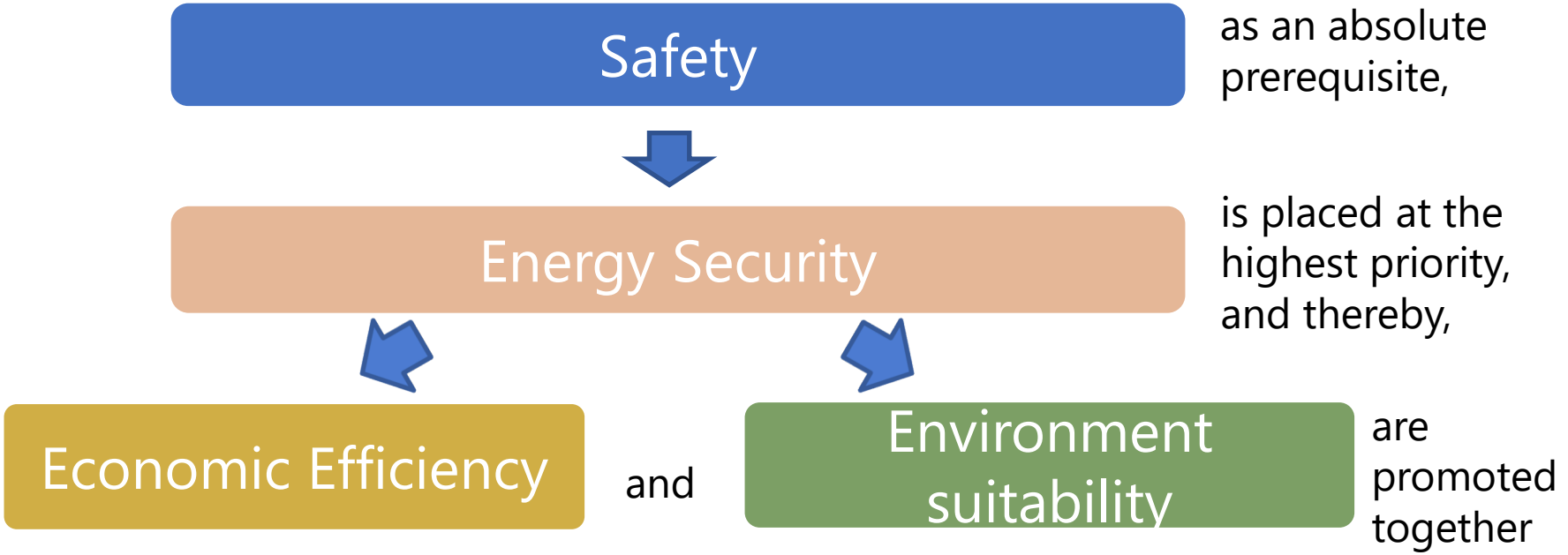
- After its historical high in FY2013, downward trend.
  - FY2019 -14% than FY2013.
    - Among all, CO_2 occupies 91%, with CO_2 by energy uses 85%.
    - Absorption in FY2019 was 46Mt-CO_2 (Forestry 43Mt-CO_2)
- CO_2 by energy uses peaked out in FY2013 at 1.235Bt-CO_2.
  - 1.029Gt-CO_2 in FY2019, -17% than FY2013.



Ref: Revised from Min. Env. (2021)

The 6th Strategic Energy Plan.

- The Cabinet adopted Oct. 22, 2021.
- Basic principle of energy policy 'S+3E' is held unchanged.

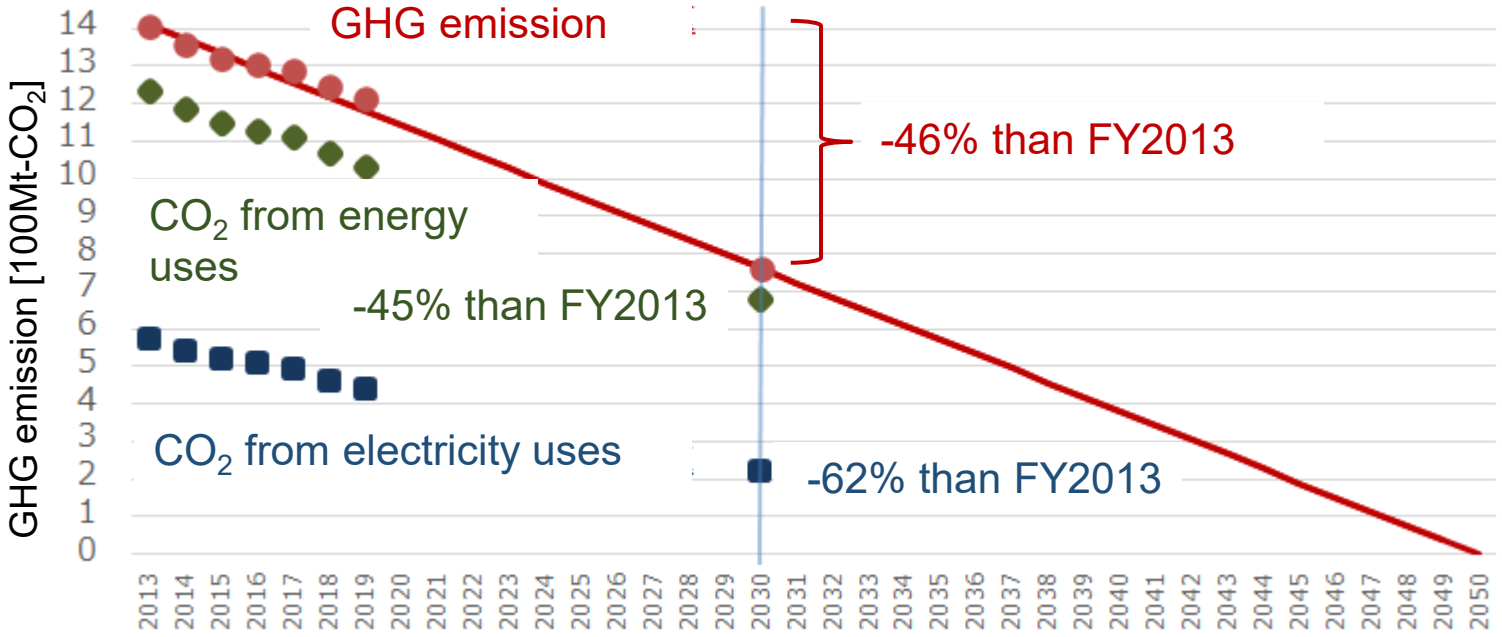


Newly adopted viewpoint

Based upon experiences obtained from the coronavirus infection, energy security overlooking entire energy supply chain is recognized.

The 6th Strategic Energy Plan: Ambitious Target in FY2030

- For GHG emission -46% than FY2013 in FY, every technology options currently available will be utilized at their maximum.
- Towards CN in 2050, further efforts, such as development and introduction of innovative technologies, are in want.



Ref : revised from Min. Env.(2021), ANRE(2021a, 2021b)

The 6th Strategic Energy Plan: Efforts needed for power sector to 2050.

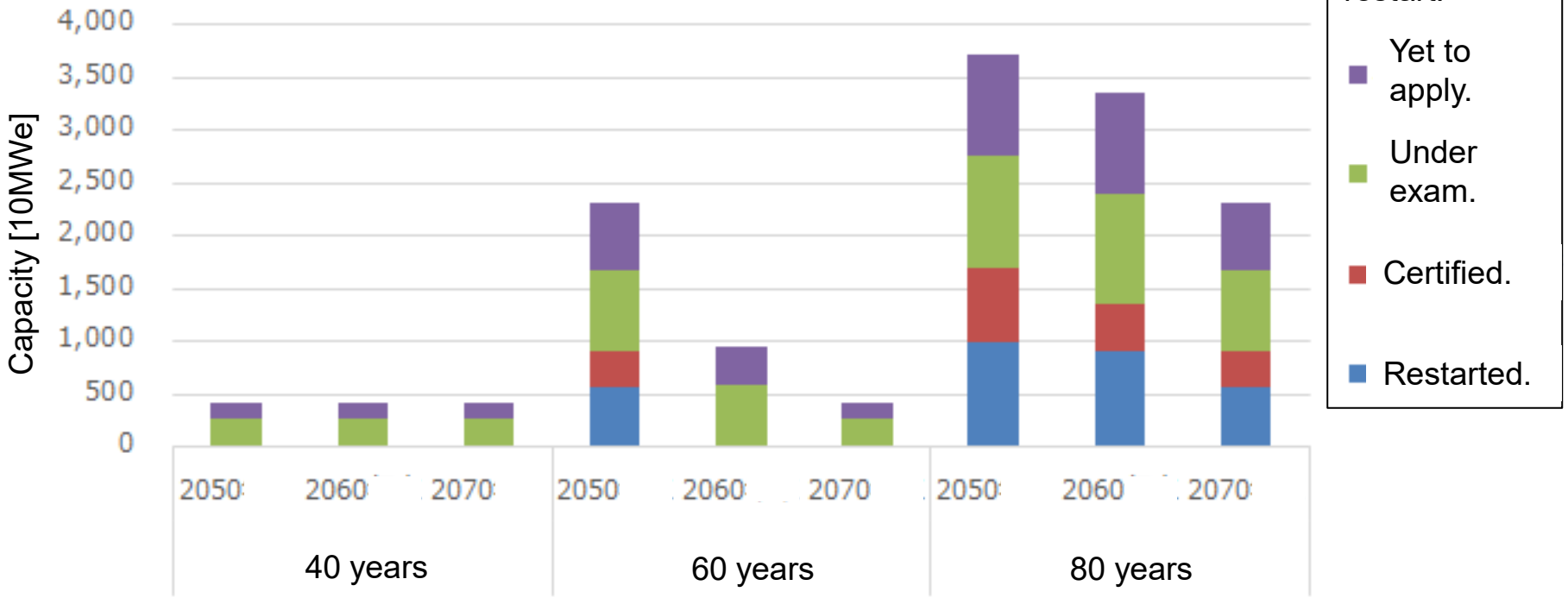
■ While steady decarbonization is secured with currently available sources, new options should be pursued.

①Renewable Energy, incl. power grid measures.	• With S+3E as prerequisite, strong priority is given to introduce to their maximum. • Adequate management of grid is indispensable, such as capacity, measures for fluctuation and grid stability. • Cost reduction to push down economic burdens.
②Nuclear Power	• While reliance should be pushed down as much as possible, required capacity is used at a sustainable manner. • For better public trust, human/technological/industrial resource bases are strengthened. Promotion of new reactors with better safety/economy/mobility. R&D to solve the back-end issues.
③Hydrogen, Ammonia, CCS and Carbon recycle.	• H_2, NH_3: Technology development to build them to major supply/adjustment options. • CCS: Technology development and cost reduction. Social adjustments for actual introduction. • CR: Advantages are pursued in the international competition. R&D for cost reduction and new uses.

Uncertainties Lie Ahead: Can Nuclear Energy Play a Key Role?

- The 36 units, including those under construction, are considered.
  - Their operating periods are mechanically assumed as 40, 60 and 80 years*, and see how it looks like after 2050...

⇒ Proper maintenance of resource bases necessary.



* Under the current legal framework, operating period of these nuclear power units is 40 years, with an extension up to 20 years can be certified after examination by regulatory authority.

The 6th Strategic Energy Plan: Viewpoint on technology R&D.

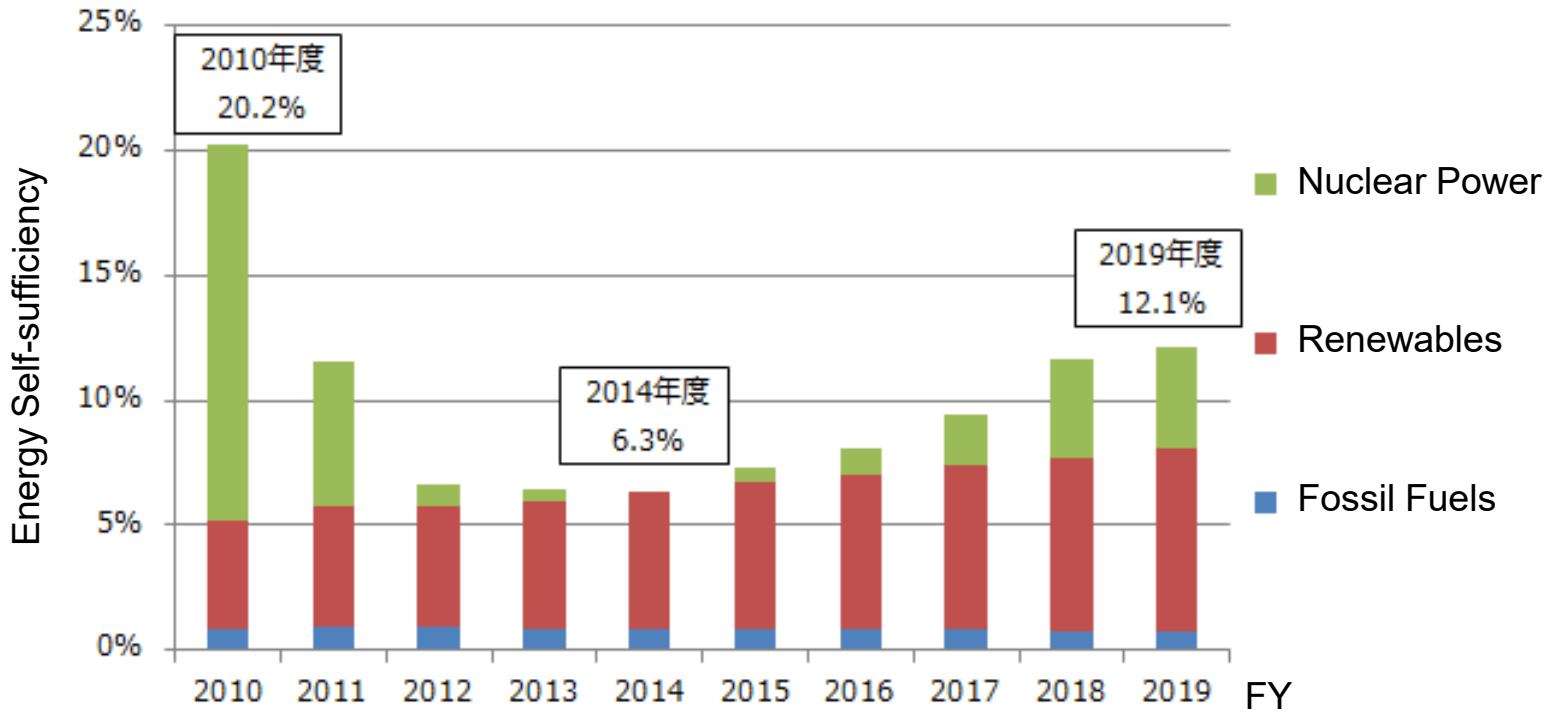
- **Need to improve 'Technology Self-Sufficiency'.**
  - Reliable and affordable energy supply is indispensable to maintain and strengthen the national power.
  - Not just energy supply, but also variety of decarbonization technologies must be procurable domestically.
- **Importance of periodic survey of technology trends.**
  - Technology trends with surrounding environmental changes should be regularly reviewed under transparent mechanisms.

□ What is 'Technology Self-Sufficiency'?

- Defined as the share of domestically available technology in national energy consumption.
- The 5th Strategic Energy Plan presented:
  - ✓ The core technologies in supply chain must be secured domestically, thus lead the innovation worldwide.

Energy Self-sufficiency in Japan

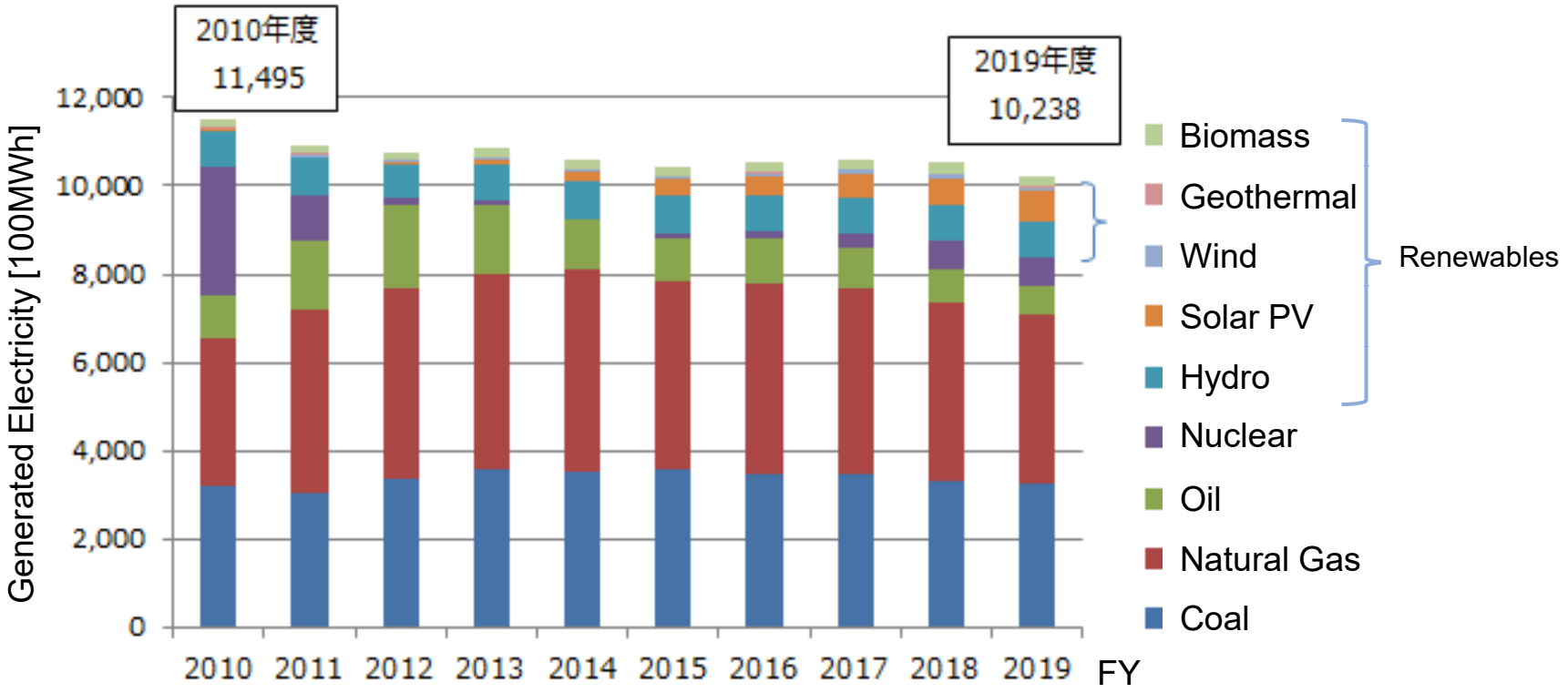
- After going down to 6.3% in FY2014, rebound due to introduction of renewable energy and restart of nuclear power.
- Even so, it stays as low as 12.1% in FY2019.



Ref: revised from ANRE (2021)

Power Generation Mix in Japan.

- Pushed back by FIT, solar PV explosively introduced.
  - All renewable sources combined, 185.2GWh（18.1%, Hydro: 79.6GWh, PV: 69.0GWh）in FY2019.
- After Fukushima, the loss of nuclear was filled by LNG.



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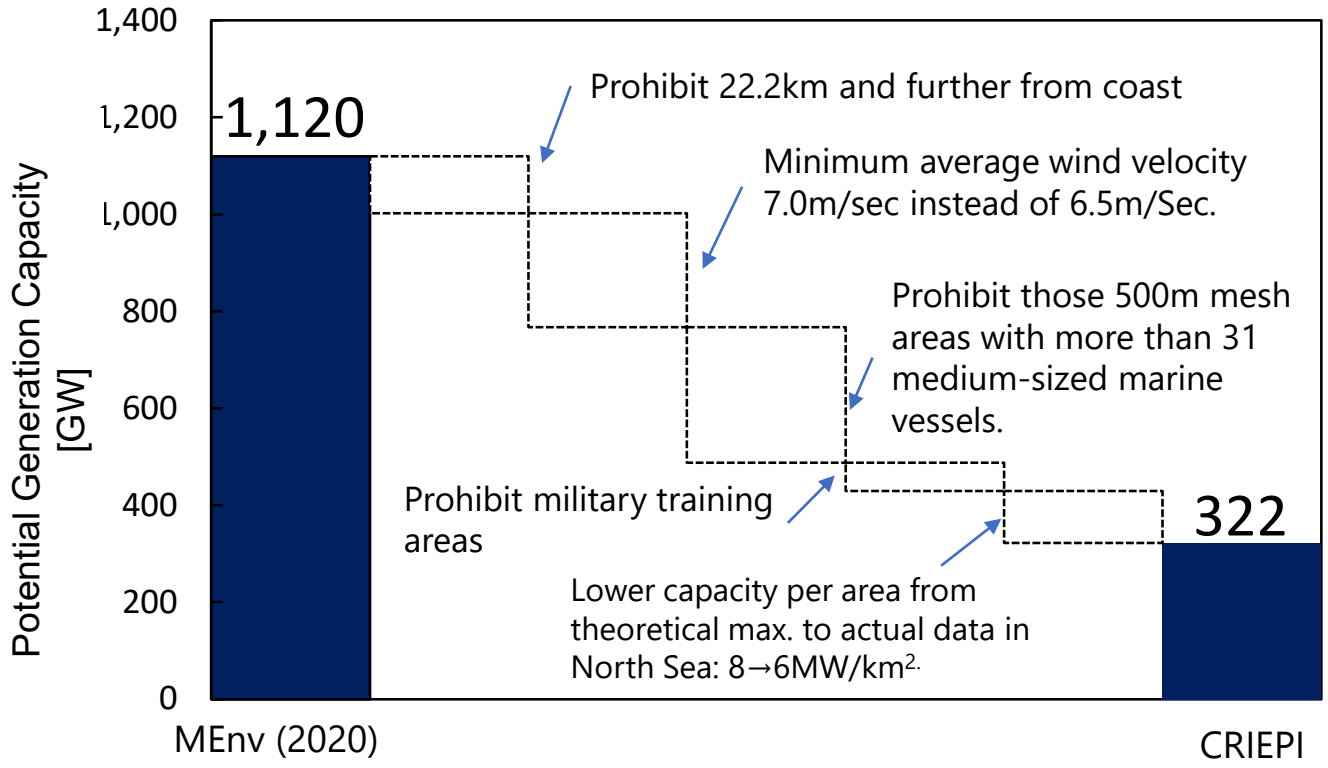
Assessing Potentials of Solar and Wind.

- Introduction potentials of solar and wind are assessed ...
  - Theoretical values based on installable areas and physical conditions such as average wind velocity are corrected with natural constraints and regulatory requirements.
  - Judgment, for social conditions in particular, is difficult and delicate: will make differences among studies.
- CRIEPI analyzed Japan's potentials using Geographical Information System (GIS).
  - Ground PV, onshore and offshore wind are assessed.
  - Social constraints, such as legal specifications and recent increase of conflicts with local residents, are reflected.

Ref: Obane et al. (2018), Obane et al. (2019)

Potential for Offshore Wind Power.

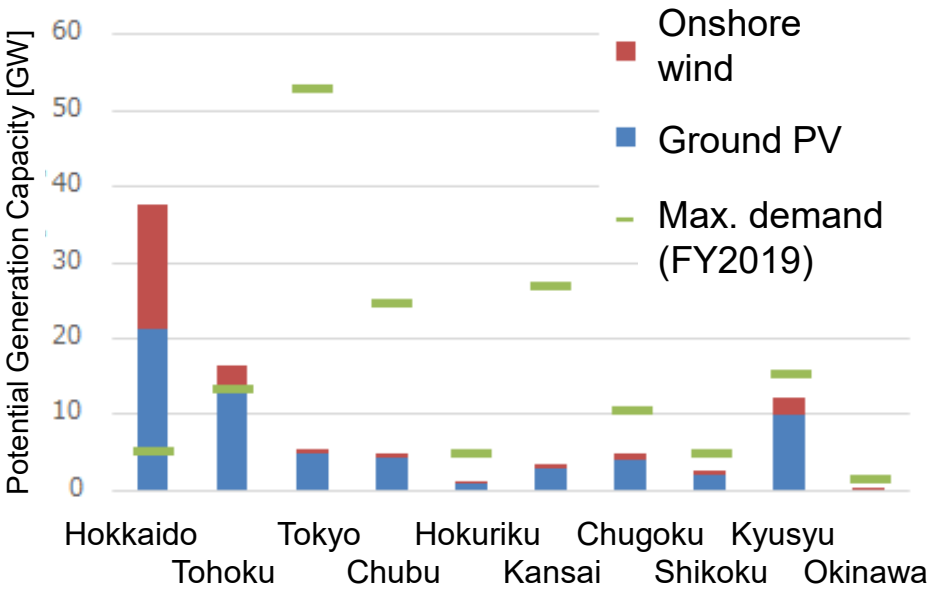
- MEnv (2020) assessed 1,120GW.
- Reflecting requirements by the legal Framework, such as natural conditions and disturbance to maritime transportation, CRIEPI scrutinized those potentials in detail.



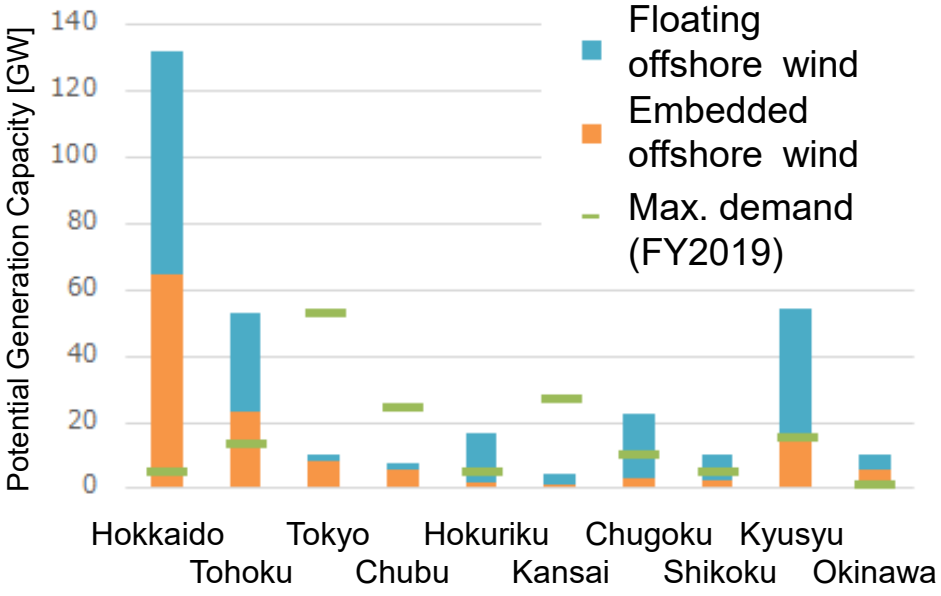
Ref: Obane et al. (2019), Asano et al. (2020)

Potentials are Highly Localized.

- Potentials for ground PV and onshore wind surpass maximum power demand in Hokkaido and Tohoku areas.
- Potentials for offshore wind, both embedded and floating, exist in Hokkaido, Tohoku and Kyusyu areas.



Ground PV and onshore wind



Offshore wind

Ref: Obane et al. (2018), Obane et al. (2019), Asano et al. (2020)

Maximum demand refers to OCCTO (2021).

PV/Wind Scenario Analysis by CRIEPI.

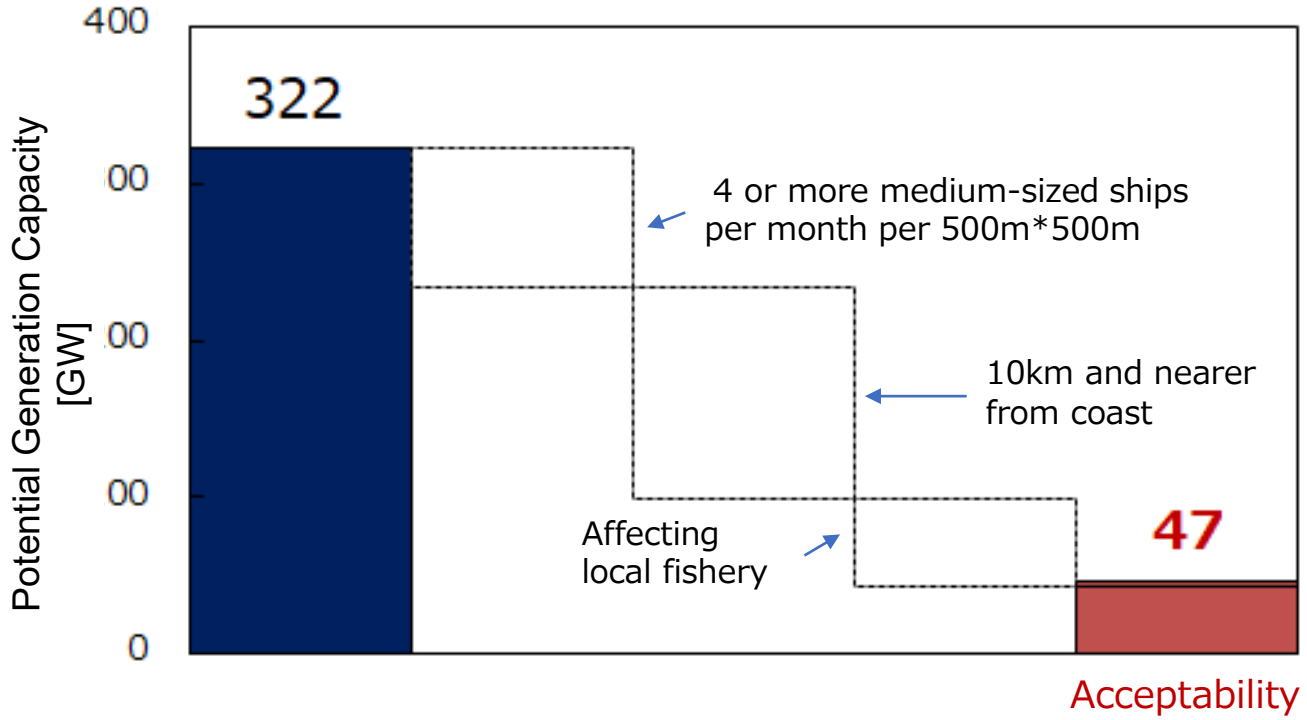
- Towards 2050, two scenarios are defined and analyzed.
  - Acceptability Scenario
    - Maximum introduction is pursued while avoiding negative influences, such as interferences to local residents and conflicts on land uses.
  - Treand Scenario
    - Simply extrapolate the trend at present.

Scenario	Description
Acceptability	• Those areas with less binding by regulation are prioritized. • Foreseeable deregulation actions, such as utilization of unrestorable farmland, are taken into account.
Trend	• The trend since FIT is assumed to continue. • Lifetime of equipment 20 years.
Factors yet to be considered	• Grid constraints, economics and technological progresses.

Ref: Asano et al. (2020)

Acceptability Scenario for Offshore Wind.

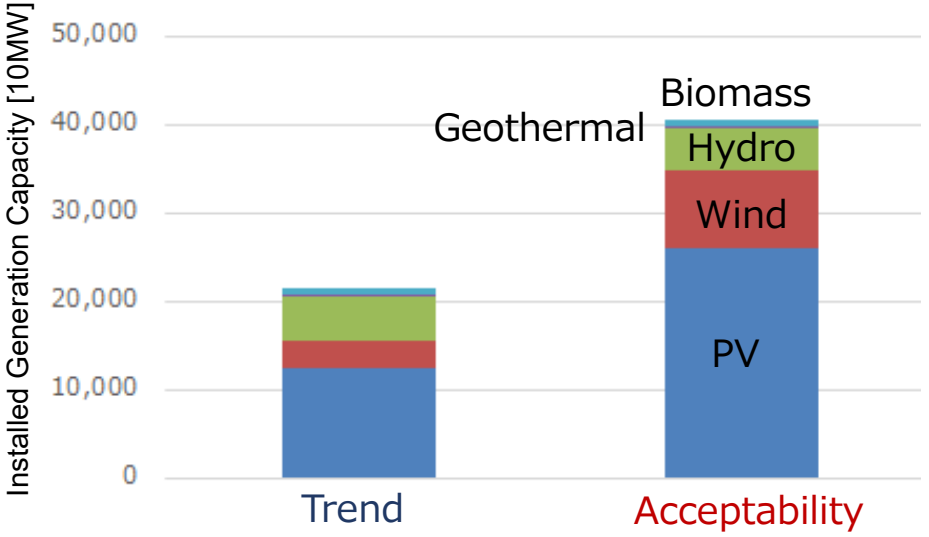
Scenario	Description
Acceptability	• Around 4GW which are already determined or regarded as promising by the Promoting Act. • Around 43GW avoiding violating those criteria below. ✓ 4 or more medium-sized ships running per month per 500m mesh, ✓ 10km and nearer from coast, and ✓ Affecting local fishery.

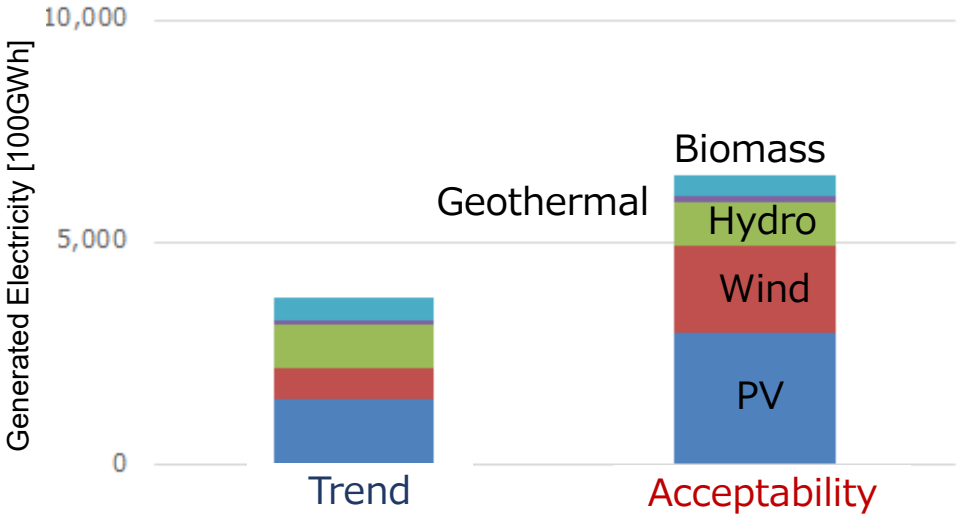


Ref: Asano et al. (2020), Obane et al. (2020)

Magnitudes of VRE Introduction.

- Generation capacities of PV and wind while their standard capacity factors are assumed.
- Hydro, geothermal and biomass refer to those in the 24% case as ANRE (2015).
- Capacity and kWh by all renewable sources combined:
  - Acceptability Scenario: Around 400GW, 650TWh.
  - Trend Scenario: Around 210GW, 400TWh.

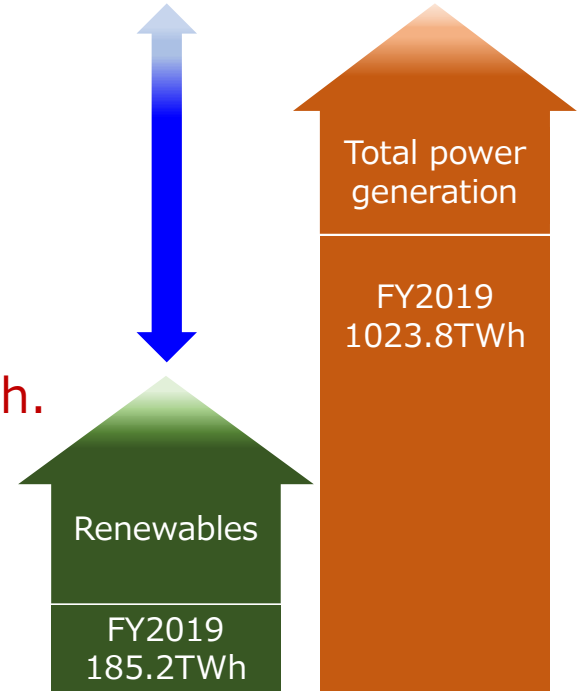




Ref: Asano et al. (2020)

Implications from Acceptability Scenario.

- To make renewable sources core of generation mix, acceptances in the installed areas, such as cares for fishery and visual esthetics are indispensable.
- Localized potentials may cause severe problems to transmission grid.
- To decarbonize the entire power generation, sources other than renewables and their technology developments should also be pursued.
  - Great expectations, huge uncertainty.



Acceptability:650TWh.
Trend: 400TWh.

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The 7 research goals towards 2050.

- In the Medium-Term Management Plan adopted Nov. 2019, CRIEPI defined 'Energy Systems for Sustainable Society' as the goal for 2050, and thereby determined the 7 goals for our research strategy.

CRIEPI's Undertaking for CN.

- For CN in 2050, we concentrate our efforts to ...
  - At supply side, innovations for VRE and grid stabilization, nuclear power, fossil-fired power, CO_2 removal and sequestration,
  - At demand side, rigorous electrification, while,
  - Cost sharing and public understanding also important.
- Efforts to the 7 goals will contribute to CN.
  - Concrete research themes directly targeting at CN are picked up and promoted more aggressively.
- While co-operating with the power utility industry, CRIEPI strives for ...

"Co-optimize CN and harmonious supply-demand by technologies and insights."

ご清聴ありがとうございました。
Thanks for your kind attention.

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References.

Agency of Natural Resources and Energy (ANRE) (2015) : Related material for Long-term Energy Supply and Demand Outlook, Paper No.2, 10th Long-term Energy Outlook Subcommittee, Research Committee on Natural Resources and Energy (in Japanese).

ANRE (2021): Comprehensive Energy Statistics – The Time Series of Energy Supply and Demand in FY2019 (Confirmed Values) (in Japanese).

Asano, K., Y. Nagai and H. Obane (2000): A Study on the Large-scale Introduction Scenarios for Wind and Solar Power Generation Towards Net-zero Emission, Paper No.3-4, 34th Basic Policy Subcommittee, Research Committee on Natural Resources and Energy, Agency of Natural Resources and Energy (in Japanese).

IPCC Working Group I (2021): Climate Change 2021: The Physical Science Basis, Sixth Assessment Report.

IPCC (2018): Global Warming of 1.5℃, Special Report.

Ministry of Environment (MEnv) (2020) : Report for the FY2019 Contract Research on Development and Distribution of Zoning Basic Data on Renewable Energy (in Japanese).

MEnv (2021): On Japan’s GHG Emission in FY2019 (Confirmed Values) (in Japanese).

Nagano, K. (2020): The Fundamental Law of De-carbonization, Energy And Resources Vol.41, No.3, p.70-71, Japan Society of Energy and Resources (in Japanese).

References (Cont'd).

Obane, H., Y. Nagai and K. Asano (2018): Evaluating Technical Potential of Ground-mounted Solar and On-shore Wind Energy in Japan, CRIEPI Report No.Y18003 (in Japanese).

Obane, H., Y. Nagai and K. Asano (2019): A Study on Available Sea Areas for Offshore Wind Power Generation against the Act on Promoting Marine Renewable Energy, CRIEPI Research Paper No.Y19502 (in Japanese).

Obane, H., Y. Nagai and K. Asano (2020): A study on level of possible conflict for developing offshore wind energies in Japanese territorial waters, SERC Discussion Paper 20005, CRIEPI.

OCCTO (2021): Electric Power Demand Nationwide and each Supply Areas for FY2021 (in Japanese).

Sakamoto, S. and K. Horio (2020): State of CO_2 Emissions and Removals at the time of Achieving Net Zero Emissions -Examination of the IPCC SR15 and other scenarios-, CRIEPI Report No.Y20001 (in Japanese).