This research was performed by the Environment Research and Technology Fund (JPMEERF20201002 and JPMEERF20192008) of the Environmental Restoration and Conservation Agency of Japan.

# Challenges of Decarbonization Polices and Technological Innovation toward Carbon Neutral Society in Japan

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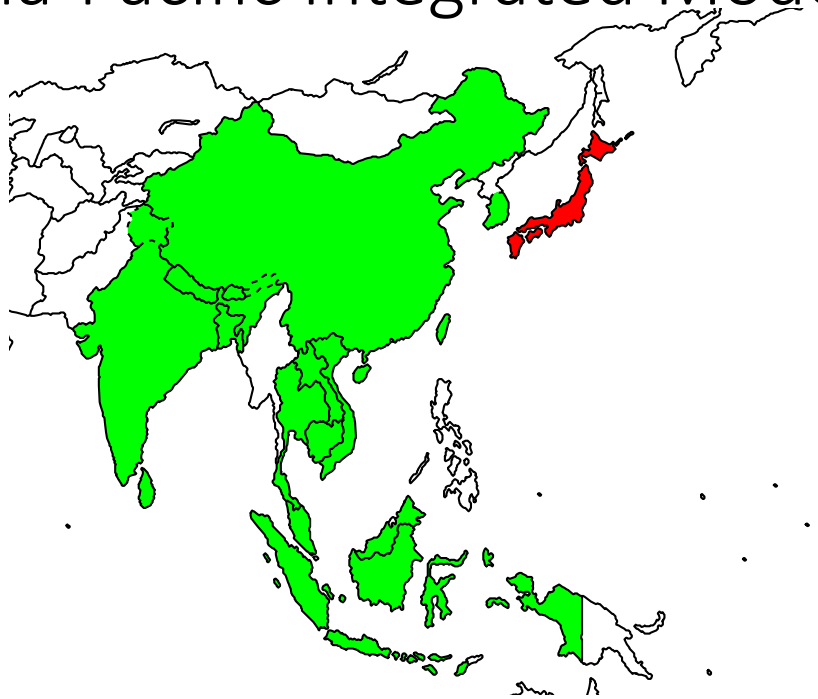
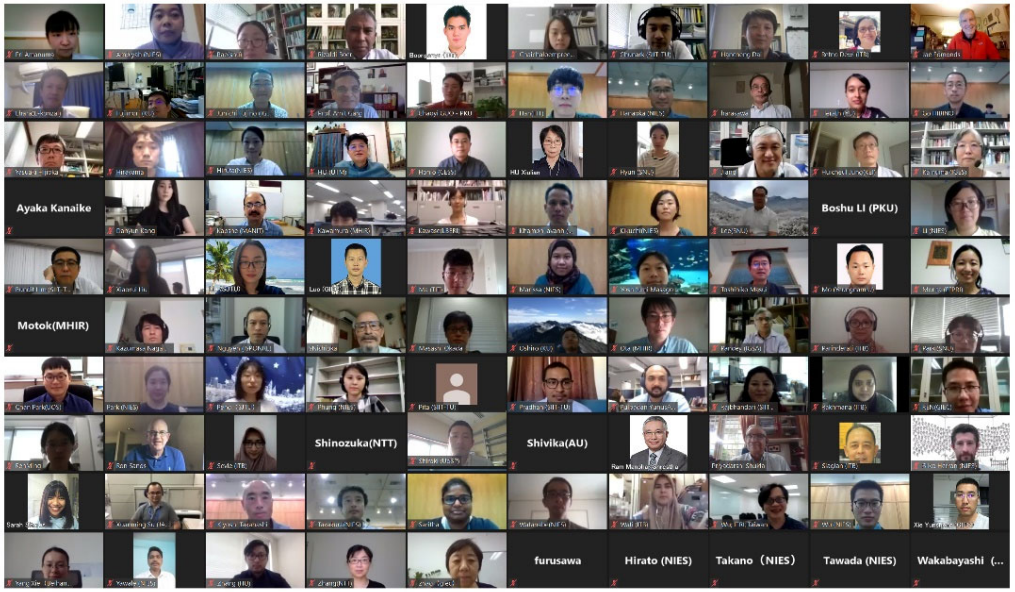
toward Carbon Neutral Societies in East Asia
Online
September 24, 2021

AIM ASIA-PACIFIC INTEGRATED MODEL
Asia-Pacific Integrated Model
http://www-iam.nies.go.jp/aim/index.html

NIES JAPAN

# International Network of AIM (Asia-Pacific Integrated Model)



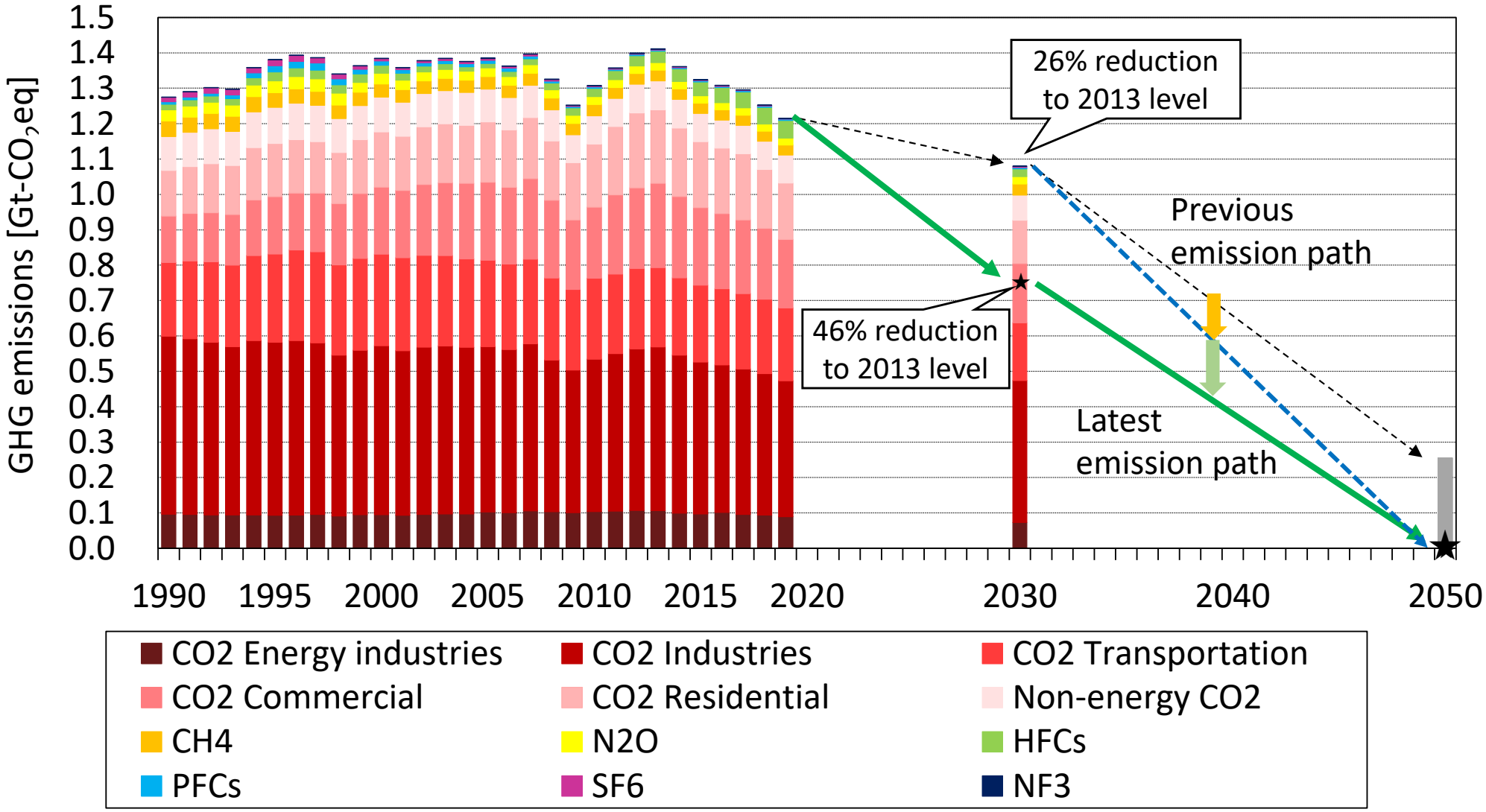



The 26th AIM International Workshop in 2020 (Online)

- Asian countries will update their mitigation target and roadmap to achieve the 2/1.5 degree target reflecting their issues to be solved and the resources to be endowed.
- Model can be a collaboration tool between science and decision making process. From the long-term viewpoint, each country will need the capacities to develop model and scenarios by itself.
- AIM (Asia-Pacific Integrated Model) has supported Asian countries to develop the integrated assessment model and their long-term low carbon/decarbonized scenarios.
- https://www-iam.nies.go.jp/aim/index.html

AIM ASIA-PACIFIC INTEGRATED MODEL

# Past trend and future targets of GHG emissions in Japan




Data source:

Greenhouse Gas Inventory Office of Japan, NIES, https://www.nies.go.jp/gio/en/index.html

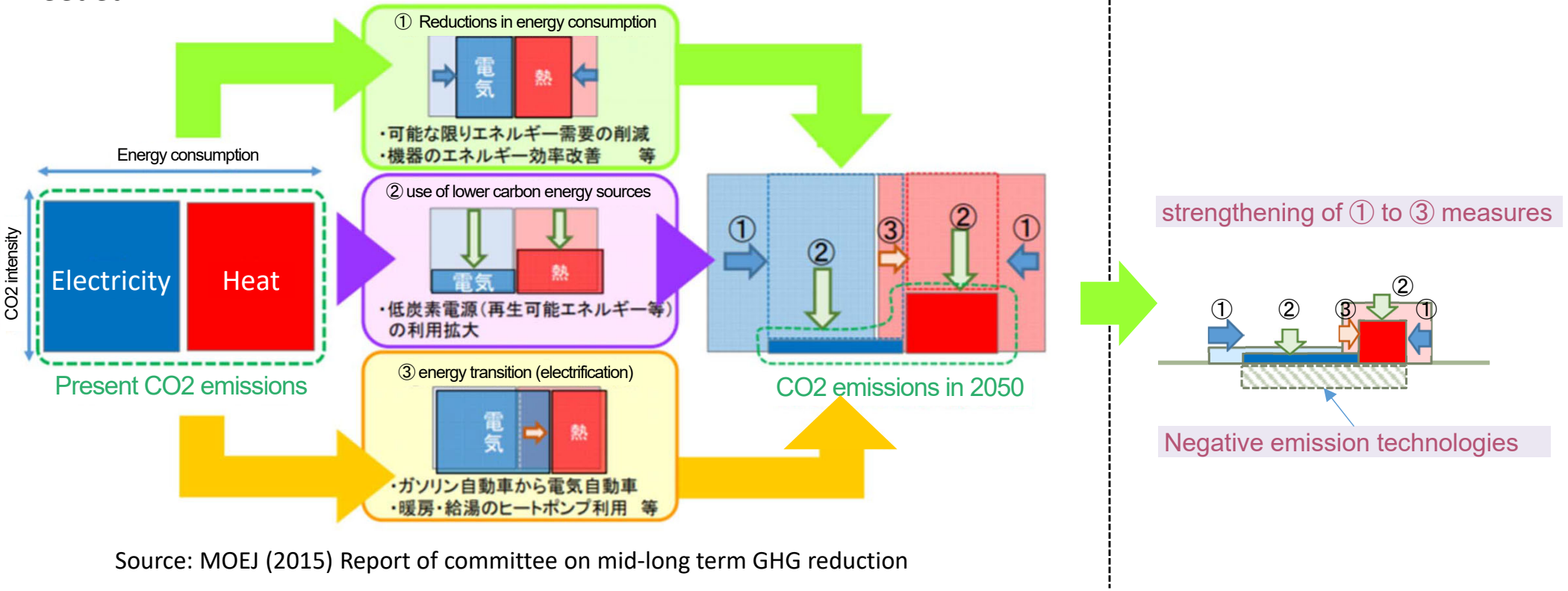
Japan's NDC, https://www.env.go.jp/press/files/en/828.pdf

# Present policies toward decarbonized society in Japan

- 2030: Nationally Determined Contribution
- 2050: Japan's Long-term Strategy under the Paris Agreement
  - ✓Individual vision toward carbon neutral in 2050
    - ➢Energy: Energy Basic Plan
    - ➢Economy: Green Growth Strategy
    - ➢Local: 2050 Zero Carbon Cities in Japan
    - ➢Food: Green Food System Strategy
    - ➢Land: Land Infrastructure and Transport Green Challenge
    - ➢Technology: Environment Innovation Strategy
  - ✓Keidanren and individual company show their own visions and strategies toward the net-zero emission by 2050

# Direction of actions to achieve a carbon neutral society

- Major directions toward low carbon society: **① Reductions in energy consumption**; **② use of lower carbon energy sources**; and **③ energy transition (electrification)**.
- To achieve carbon neutrality, in addition to ① – ③ measures, **negative emission technologies** will be needed.




Source: MOEJ (2015) Report of committee on mid-long term GHG reduction

※ Negative emission technologies are technologies, practices and approaches for artificially recovering or absorbing CO2 from the atmosphere and sequestering the CO2 in forms that will not be emitted again for the long term. These include afforestation and reforestation, biochar, soil carbon sequestration, wetland and coastal regeneration (blue carbon), bioenergy with carbon capture and storage (BECCS), accelerated weathering, direct air capture (DAC), ocean alkalinity enhancement, and carbon mineralization. (Reference: Minx et al. (2018), Negative Emissions—Part 1: Research Landscape and Synthesis, UNEP (2017), The Emissions Gap Report 2017)

# How to achieve the net zero GHG emissions in Japan in 2050

- Preliminary study: Assessment of 2050 using 4 scenarios
  1. LED: Social Transformation Scenarios for a Decarbonized Society in 2050
     Low energy and material consumption through changes in lifestyles, work styles, and material consumption and circular economy.
  2. ELE: Electrification Scenario
     The massive introduction of renewable energy generation and thorough electrification.
  3. H2: New fuel scenario
     The production of hydrogen through the massive introduction of renewable power generation, and synthetic fuels produced from hydrogen and CO2
  4. Zero: Net zero emission scenario
     Combining all above measures, including social transformation, electrification, and promotion of new fuels, as well as expansion of CO2 capture targets and negative emission technologies.
- Detailed analysis: Dynamic assessment considering local and 1 hour electricity supply and demand to assess availability of renewable energies

For more information, please visit the following URL;
https://www-iam.nies.go.jp/aim/projects_activities/prov/index_j.html

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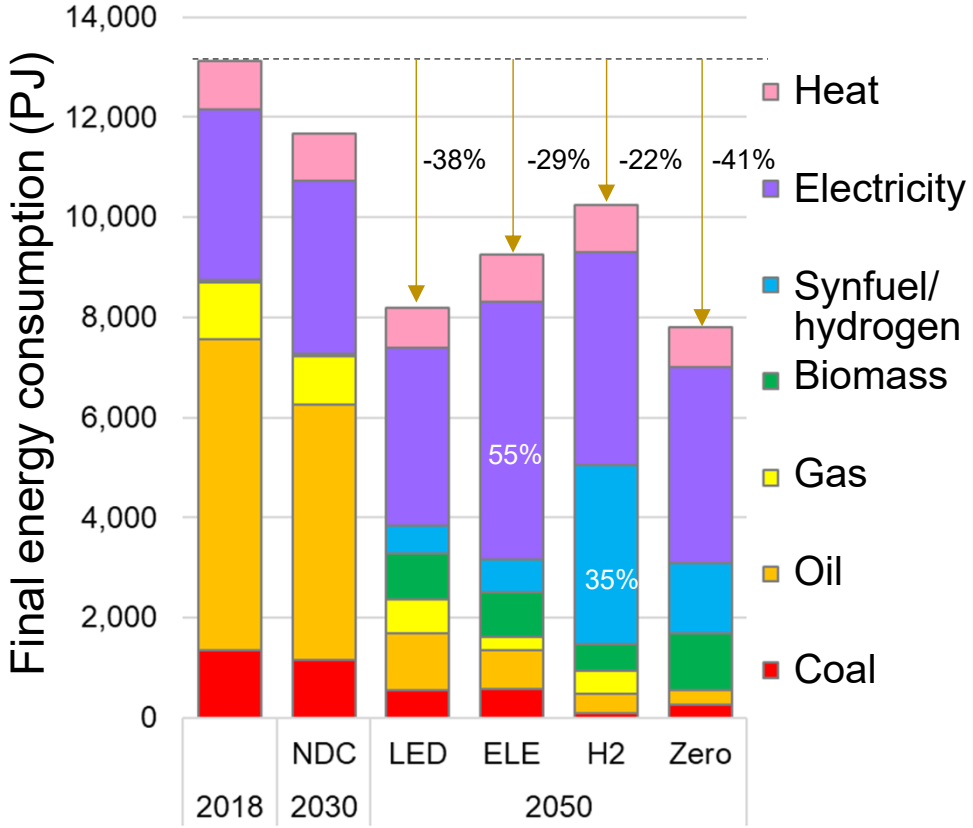
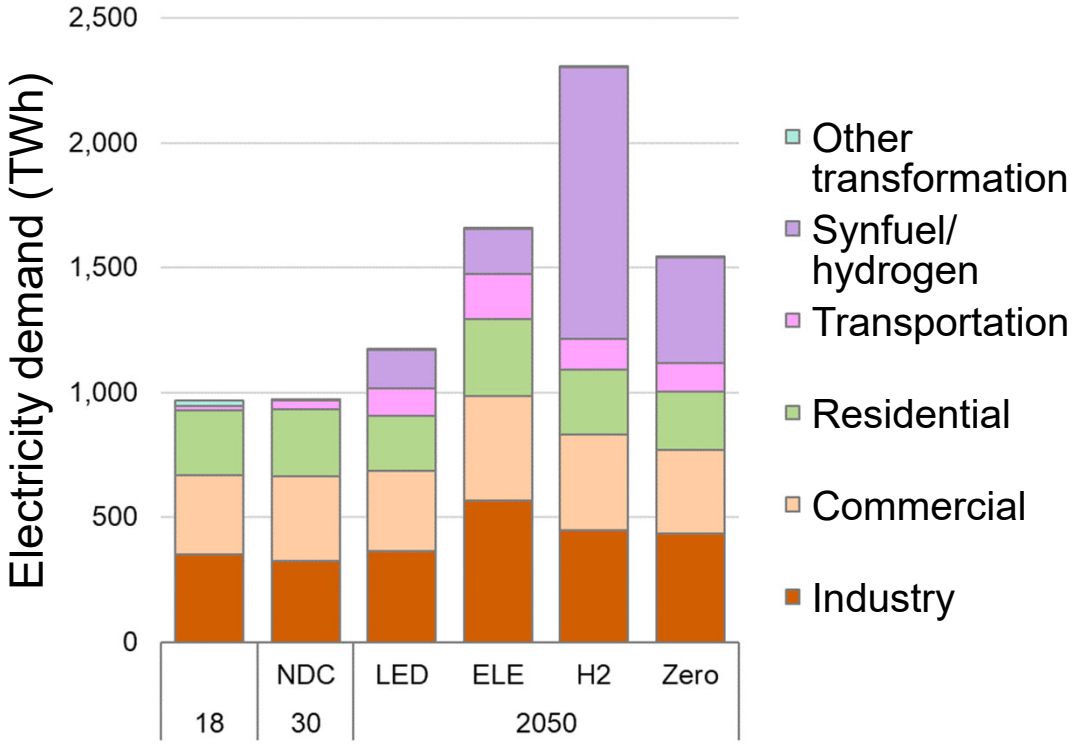
(Preliminary study)

# Final energy consumption and electricity demand

- By 2050, final energy consumption will be 22-41% lower than in 2018.
  Consumption of fossil fuels, especially petroleum products, decreases significantly.
  Electricity and synthetic fuels account for a large share: electricity accounts for 55% in ELE, and synthetic fuels, hydrogen, etc. account for 35% in H2.
- Electricity demand increases in all scenarios.
  In ELE scenario, electricity demand is larger than in the other scenarios.
  H2 scenario has a large electricity demand to produce hydrogen and synthetic fuels.




Final Energy Consumption

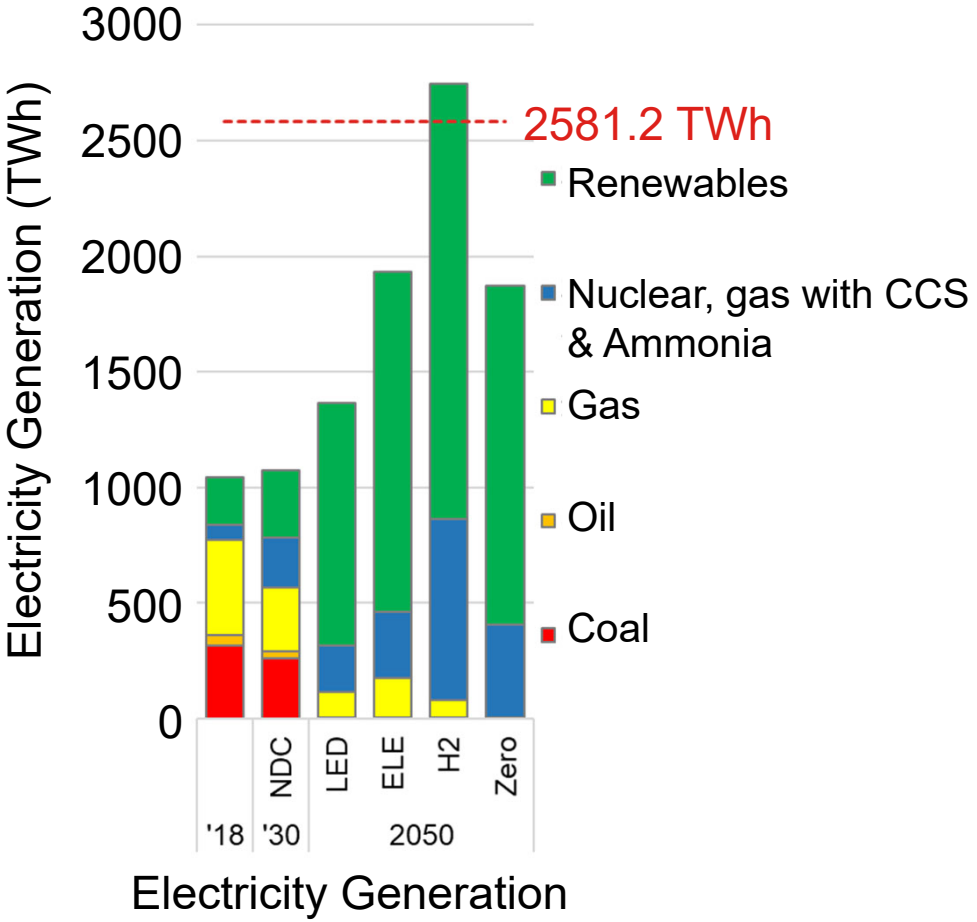



Electricity Demand

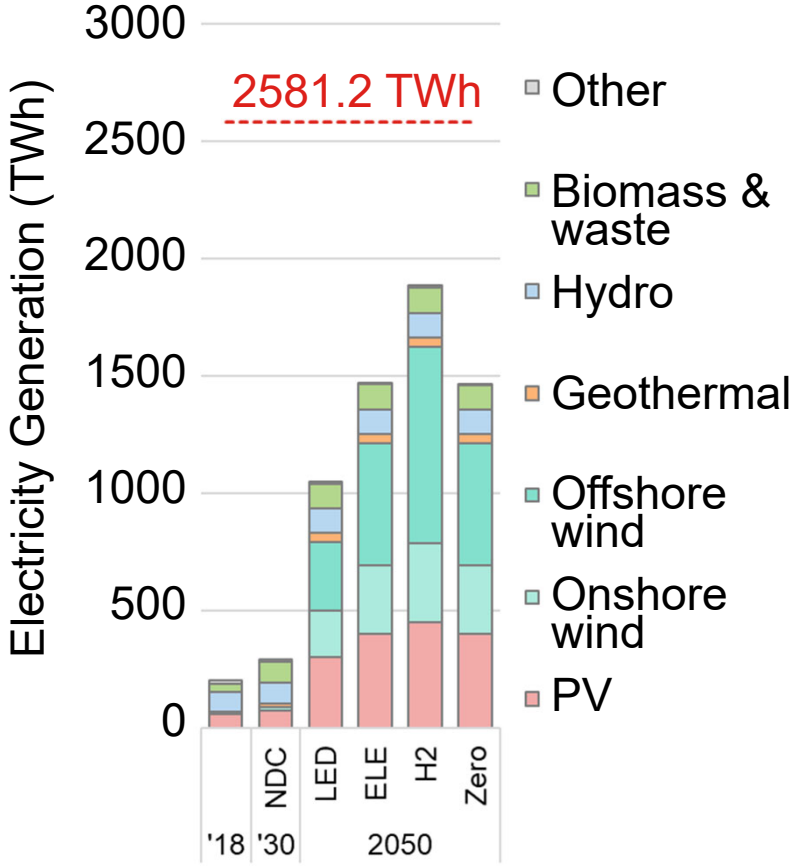
(Preliminary study)

# Electricity generation

- In 2050, almost all power sources are decarbonized in all scenarios.
- According to the Ministry of the Environment*, the economically viable amount of renewable energy power generation that can be introduced is up to 2581.2 TWh, which is more than the total amount of electricity generated in the Zero Scenario.
- In 2050, solar power and wind power will be the main sources due to their large potential.




Electricity Generation

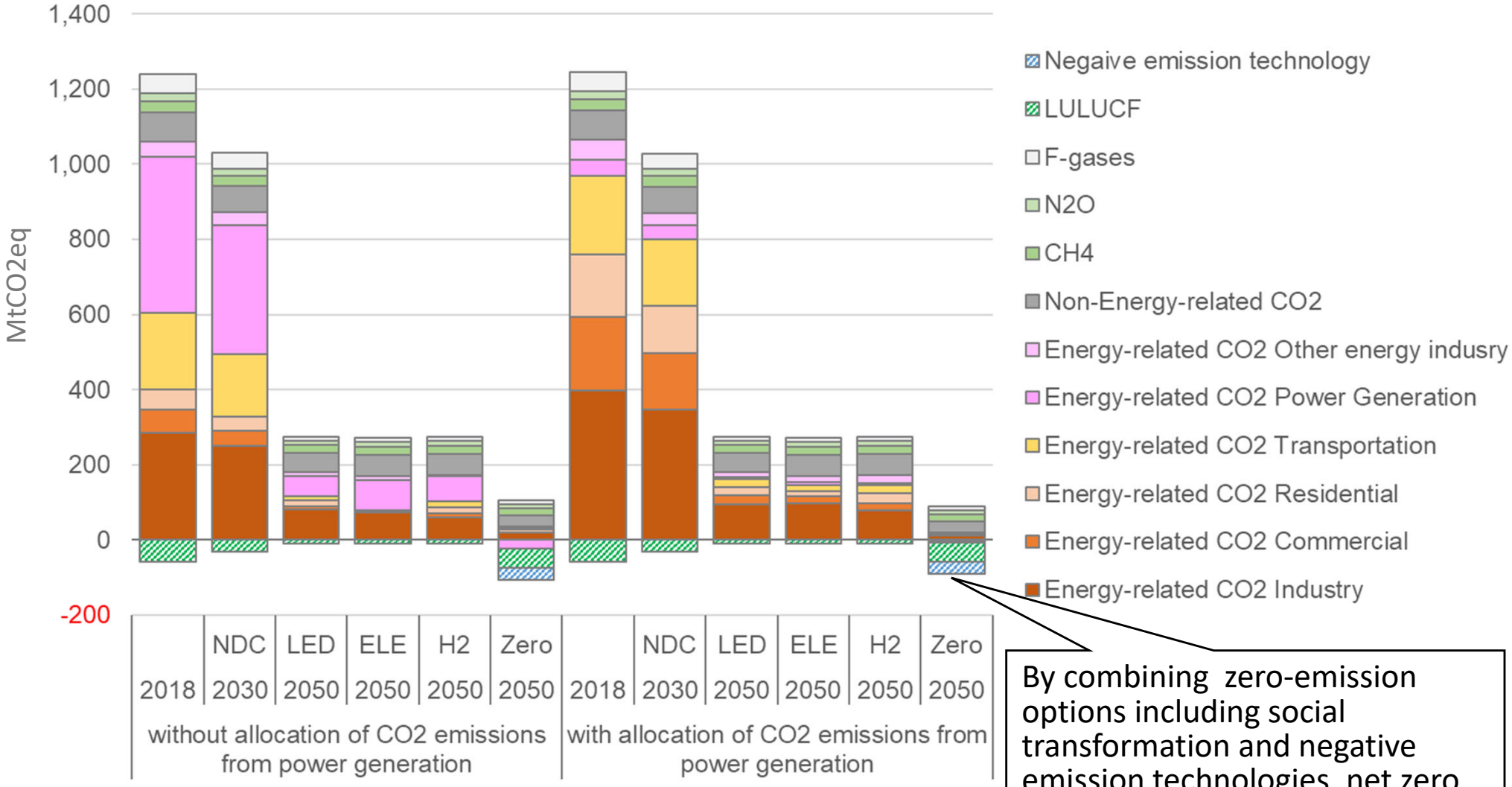



Electricity Generation from Renewables

* http://www.renewable-energy-potential.env.go.jp/RenewableEnergy/doc/gaiyou3.pdf

(Preliminary study)

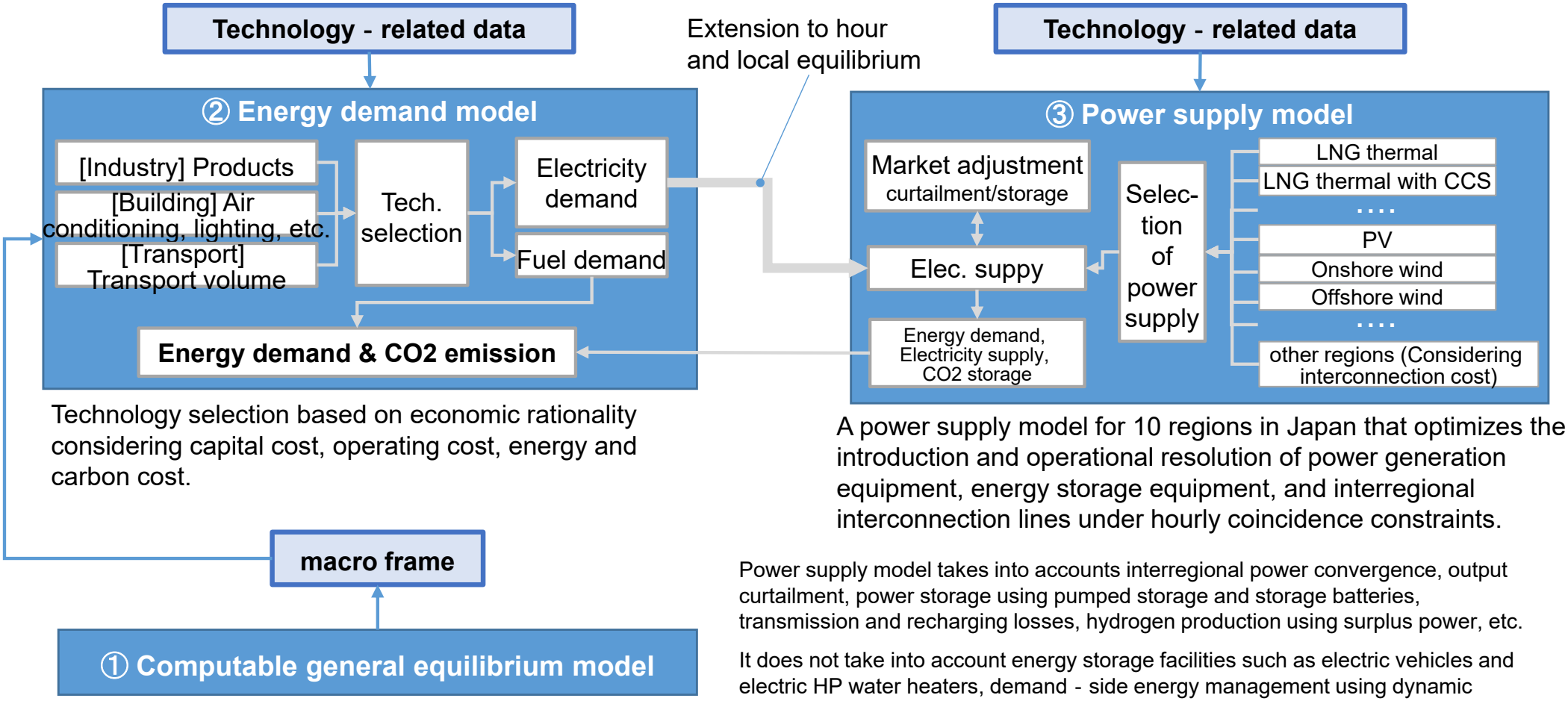
# GHG in Japan in 2050




By combining zero-emission options including social transformation and negative emission technologies, net zero emissions in 2050 will be realized.

# (Detailed analysis)

Given the assumptions of economic growth and population, the future macro frame is quantified using Computable general equilibrium model (①). Then, Energy demand model (②) is used to estimate the future energy demand. The annual electricity demand estimated in ② is extended to hourly demand by region, and the power generation facility configuration and supply configuration are estimated using Power supply model (③) that can take into account the coincidence and interregional interconnection constraints. The results are fed back to the energy demand model to calculate Japan's overall energy supply and demand and CO2 emissions.




Technology selection based on economic rationality considering capital cost, operating cost, energy and carbon cost.

A power supply model for 10 regions in Japan that optimizes the introduction and operational resolution of power generation equipment, energy storage equipment, and interregional interconnection lines under hourly coincidence constraints.

Power supply model takes into accounts interregional power convergence, output curtailment, power storage using pumped storage and storage batteries, transmission and recharging losses, hydrogen production using surplus power, etc.

It does not take into account energy storage facilities such as electric vehicles and electric HP water heaters, demand - side energy management using dynamic pricing, intra-regional power transmission and distribution networks,



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(Detailed analysis)

# Future scenario

"Technology" scenario: net-zero emissions are achieved through the diffusion of decarbonization technologies such as energy conservation, renewable energy, and electrification.

"Technology + social transformation" scenario: the diffusion of decarbonization technologies is combined with the progress of digitalization and circular economy.

| Technology | × | Social transformation |
|---|---|---|
| ○ Energy efficiency improvement technology<br>○ Renewable energy<br>○ Electrification (electric cars, heat pumps, etc.)<br>○ New fuels (hydrogen, synthetic fuels, ammonia, etc.)<br>○ CCUS<br>○ Negative emission technology | | ○ Efficient use of materials<br>• Improve product and material utilization rates through sharing and recycling.<br>• Reduction of production of mineral resource-derived products (steel, cement, etc.) through long service life, resource-saving design, and use of wood.<br>• Reduction of paper production by digitalization, etc.<br>⇒ Production in industrial in 2050: -15%<br>○ Reduction of work and commuting travel<br>• Transportation alternatives using virtual reality, etc.<br>○ Reduction of freight transportation and improvement of logistics efficiency<br>• Reduction of freight transportation through efficient use of materials.<br>• Improvement of logistics efficiency through utilization of advanced ICT and 3D printer.<br>⇒ Passenger & freight transport volumes in 2050: -20% |

AIM ASIA-PACIFIC INTEGRATED MODEL



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(Detailed analysis)

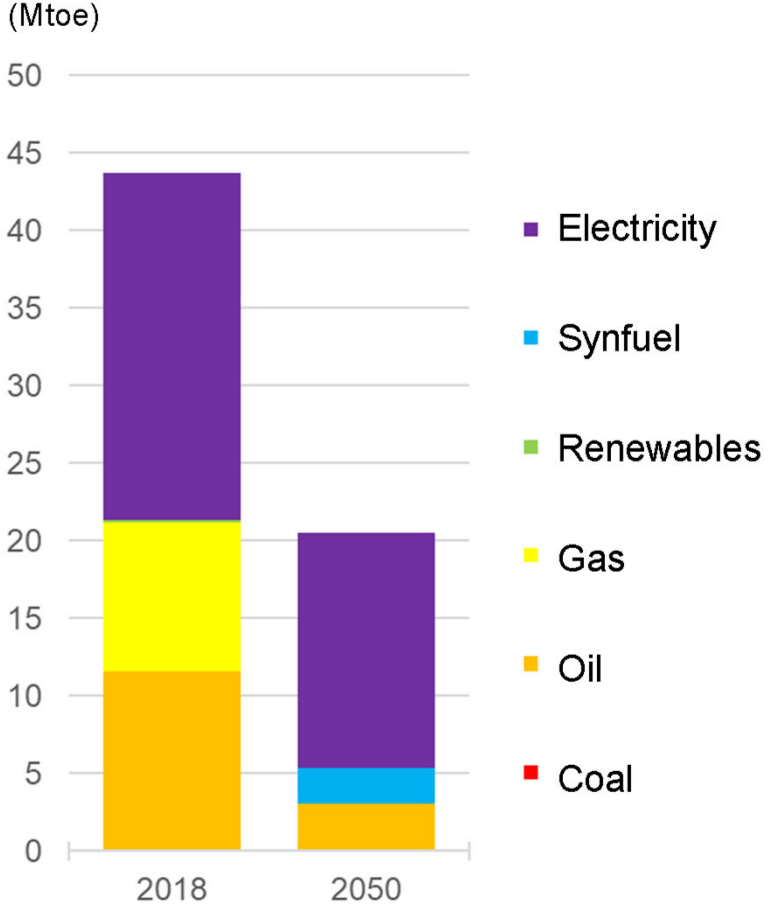
# Macro framework

| | Future outlook | Notes |
|---|---|---|
| Population | 126.440（2018）→ 101.923 (2050）mil. people | National Institute of Population and Social Security Research |
| Number of households | 53.889（2018）→ 47/241（2050）mil. households | National Institute of Population and Social Security Research and estimated based on its outlook |
| GDP growth rate | 1.7%/year (2020-2030)<br>0.5%/year (2031-2050) | 2020-2030: Estimated by Cabinet Office<br>2031-2050: SSP2 |
| Crude steel production | 102.89（2018）→ 85.70（2050）mil. ton | Estimated by AIM/CGE based on the above GDP assumptions. |
| Cement production | 60.23（2018）→ 60.39（2050）mil. ton | |
| Ethylene production | 6.18（2018）→ 5.41（2050）mil. ton | |
| Paper & paperboard production | 26.03（2018）→ 23.48（2050）mil. ton | |
| Machinery production | 100（2015）→ 141（2050）index | |
| Business floor space | 1903（2018）→ 1671（2018）mil. m2 | Estimated by AIM/CGE based on the above GDP assumptions and population structure |
| Passenger transport | 1,459（2018）→ 1,179（2050）bil. person-km | Estimated from population trend |
| Freight transport | 411（2018）→ 419（2050）bil. ton-km | Estimated by AIM/CGE based on the above GDP assumptions. |

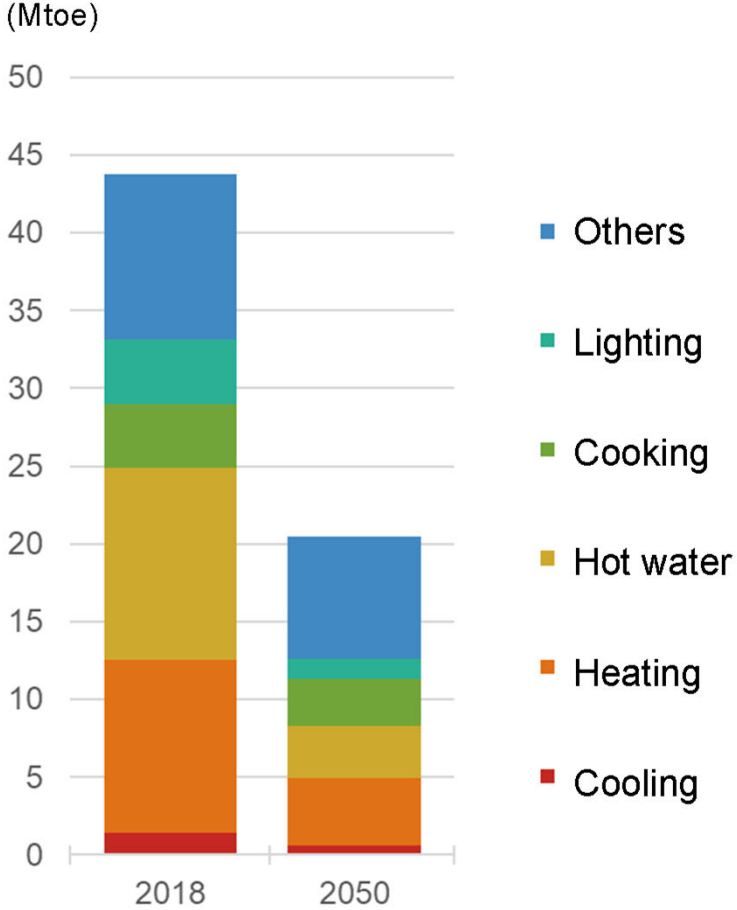
(Detailed analysis)

# Energy consumption in household sector

Energy consumption in household sector in 2050 will be 53% lower than in 2018.
The share of electricity will increase from 51% in 2018 to 74% in 2050 due to the promotion of electrification of air conditioning and hot water supply.
Energy consumption for heating, hot water supply, and lighting was significantly reduced.




Energy consumption by energy type




Energy consumption by enduse service

- Energy efficiency improvement
- Zero-carbon electricity
- Synfuels

Lighting & Others:
- HEMS
- LED: 100% in 2050

Hot water & cooking:
- Electric heat pump: 80% in 2050

Cooling & Heating:
- Highly insulation house: 40% (stock) in 2050
- Heating by Air conditioner: 80% in 2020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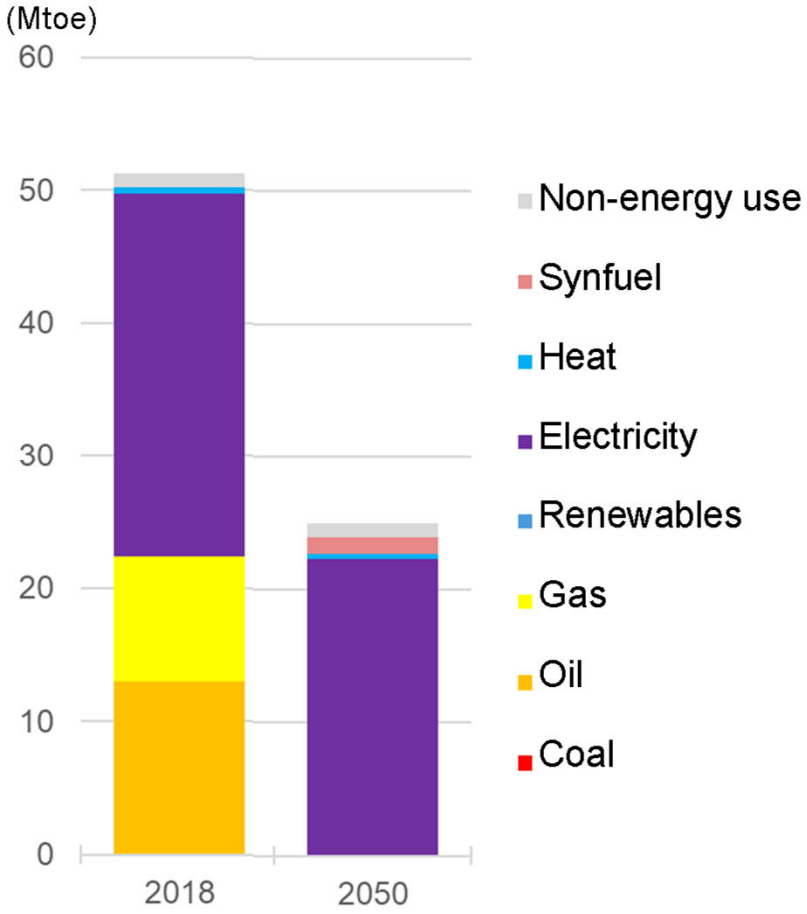
(Detailed analysis)

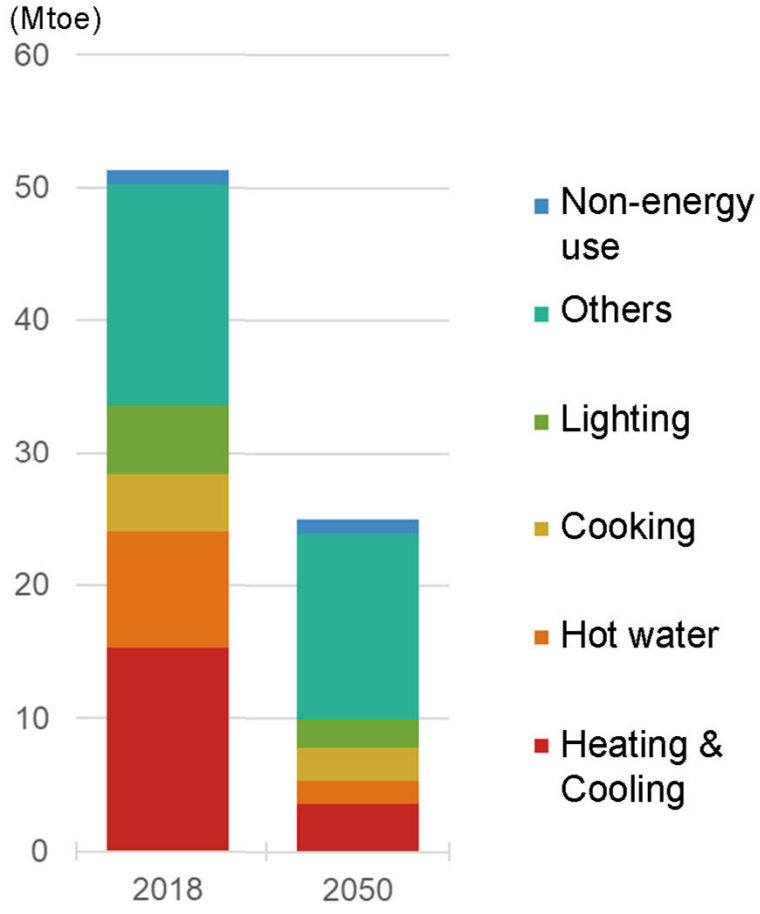
# Energy consumption in commercial sector

Energy consumption in commercial sector in 2050 will be 51% lower than in 2018.
The share of electricity will increase significantly from 54% in 2018 to 93% in 2050* due to the promotion of electrification of air conditioning and hot water supply.
Energy consumption for heating and cooling, hot water supply, and lighting was substantially reduced.

* The ratio of electricity to energy consumption for energy use excluding non-energy use.




Energy consumption by energy type




Energy consumption by enduse service

- Energy efficiency improvement
- Zero-carbon electricity
- Synfuels

Lighting & Others:
- BEMS
- LED: 100% in 2050

Hot water & cooking:
- Electric heat pump: 100% in 2050

Cooling & Heating:
- Highly insulation building: 70% (stock) in 2050
- Heating by Air conditioner: 100% in 2020



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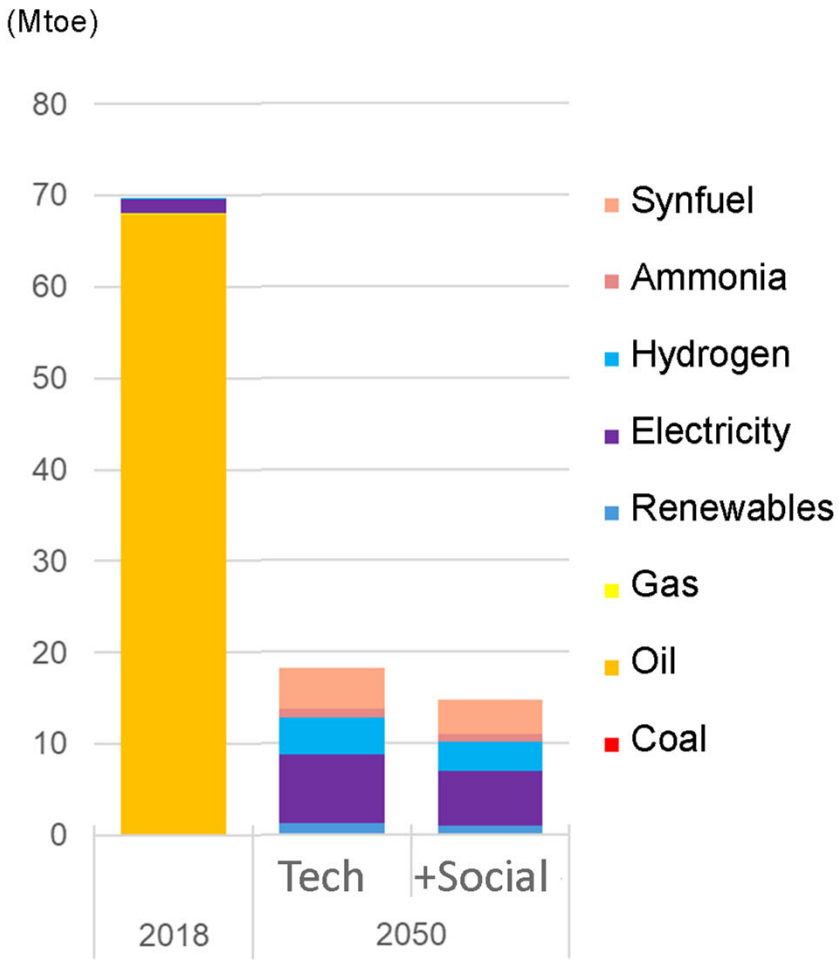
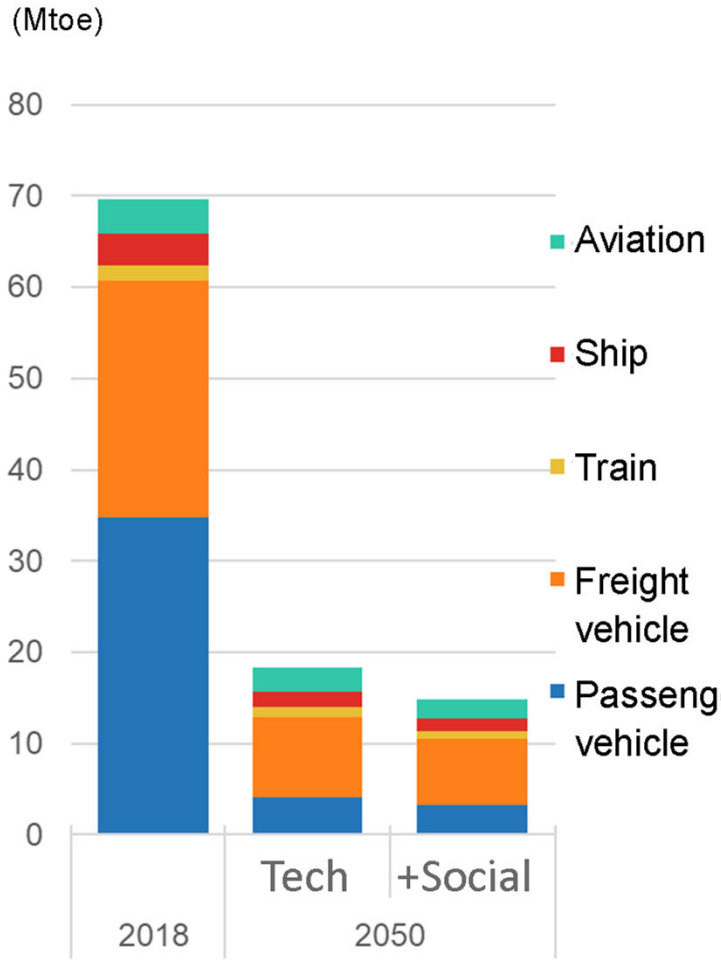
(Detailed analysis)

# Energy consumption in transportation sector

Energy consumption in transportation sector in 2050 will be -74% to -79% of that in 2018.
The share of electricity and hydrogen will increase significantly from 2% in 2018 to 62%-63% in 2050* due to the significant expansion of electric vehicles and fuel cell vehicles.




Energy consumption by energy type




Energy consumption by transportation mode

- Efficiency improvement
- Zero-carbon electricity (EV & train)
- Synfuel and bio-fuel

Passenger cars:
- Reduction of traffic volume (commuting etc.)
- BEV & FCV: 100% (stock) in 2050

Motor truck:
- Logistic efficiency improvement
- BEV & FCV: 80% (stock) in 2050

Train, ship & aviation:
- Improvement of travel distance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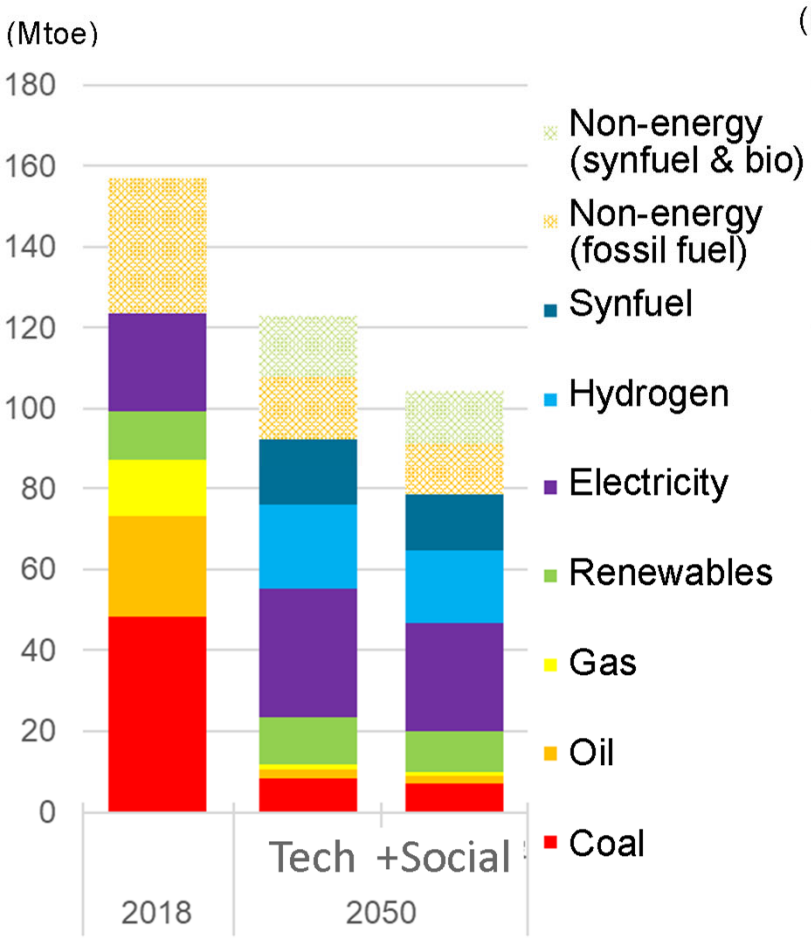
(Detailed analysis)

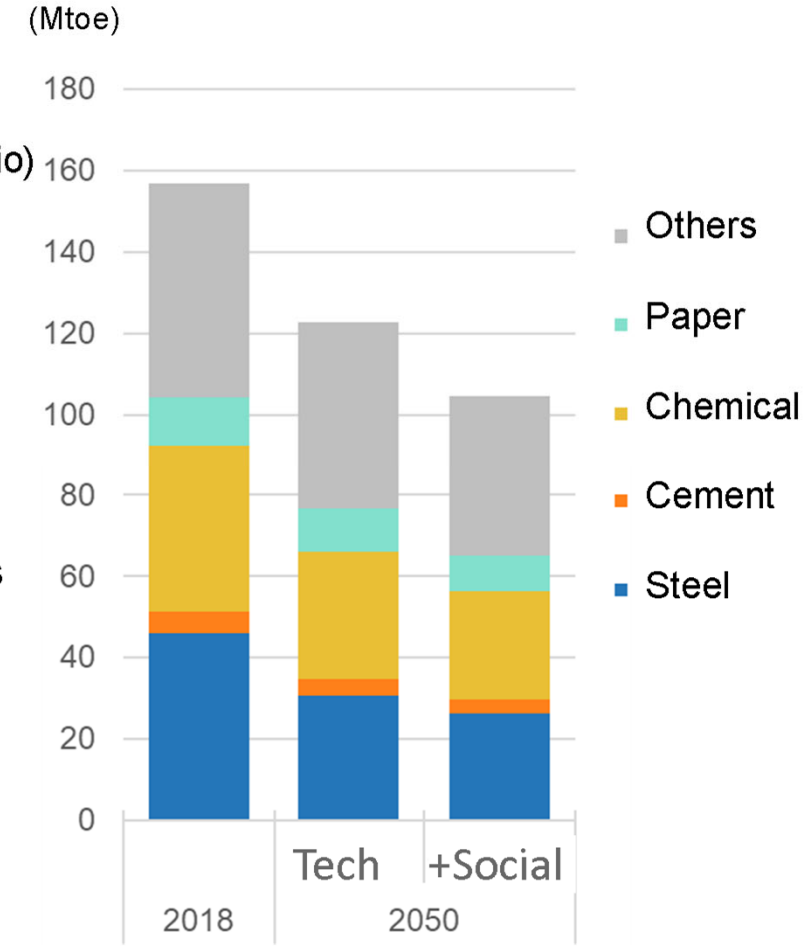
# Energy consumption in industry sector

Energy consumption in the industrial sector in 2050 will be 22-33% lower than in 2018. The share of electricity will increase significantly from 20% in 2018 to 34% in 2050*.

* The ratio of electricity to energy consumption for energy use excluding non-energy use.




Energy consumption by energy type




Energy consumption by sector

- Zero-carbon electricity (EV & train)
- Synfuel and bio-fuel
- BAT
- Demand reduction through efficient material use

Steel:
- Electric furnace
- Hydrogen reduction method
- Blast furnace with CCS

Chemical:
- Decarbonized organic chemical production process

Others:
- Reduction of cement & clinker use
- Electrification of heat
- Hydrogen burner



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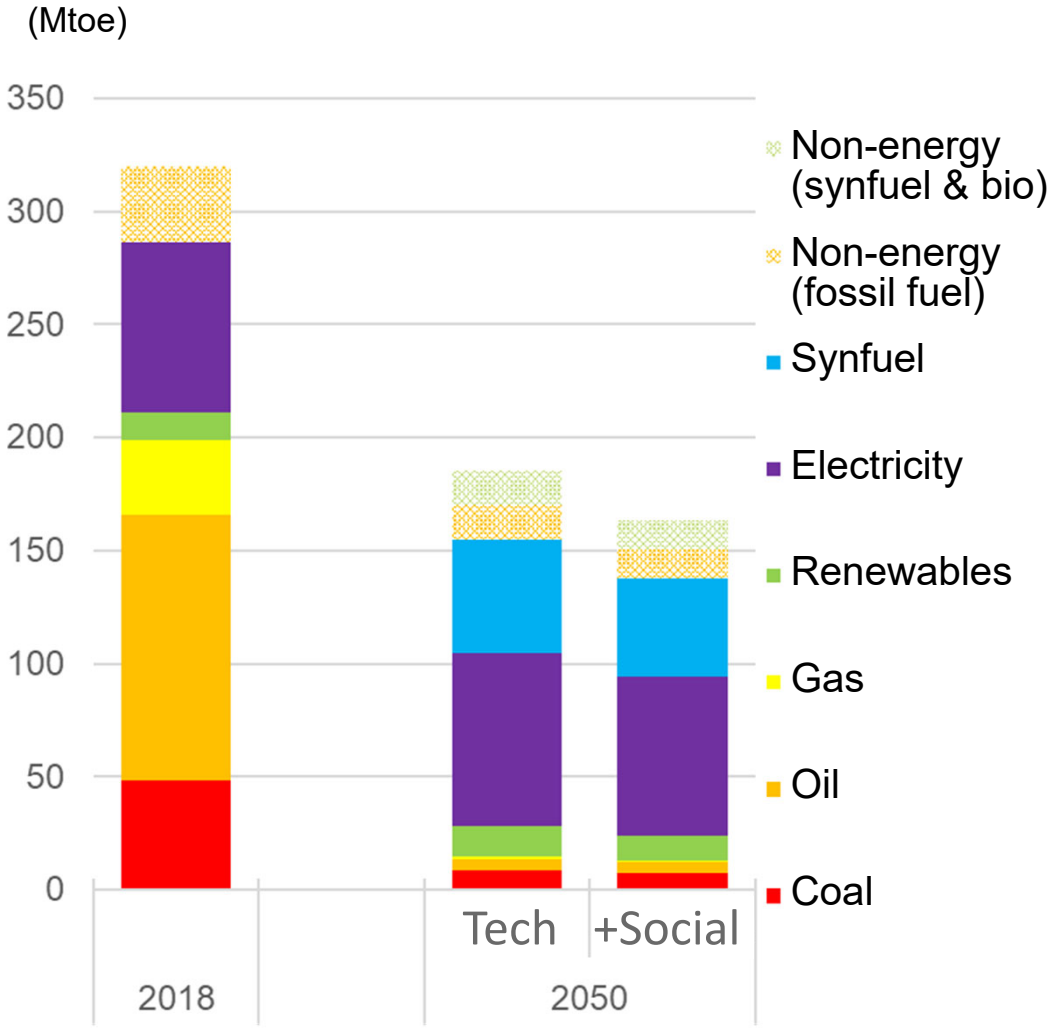
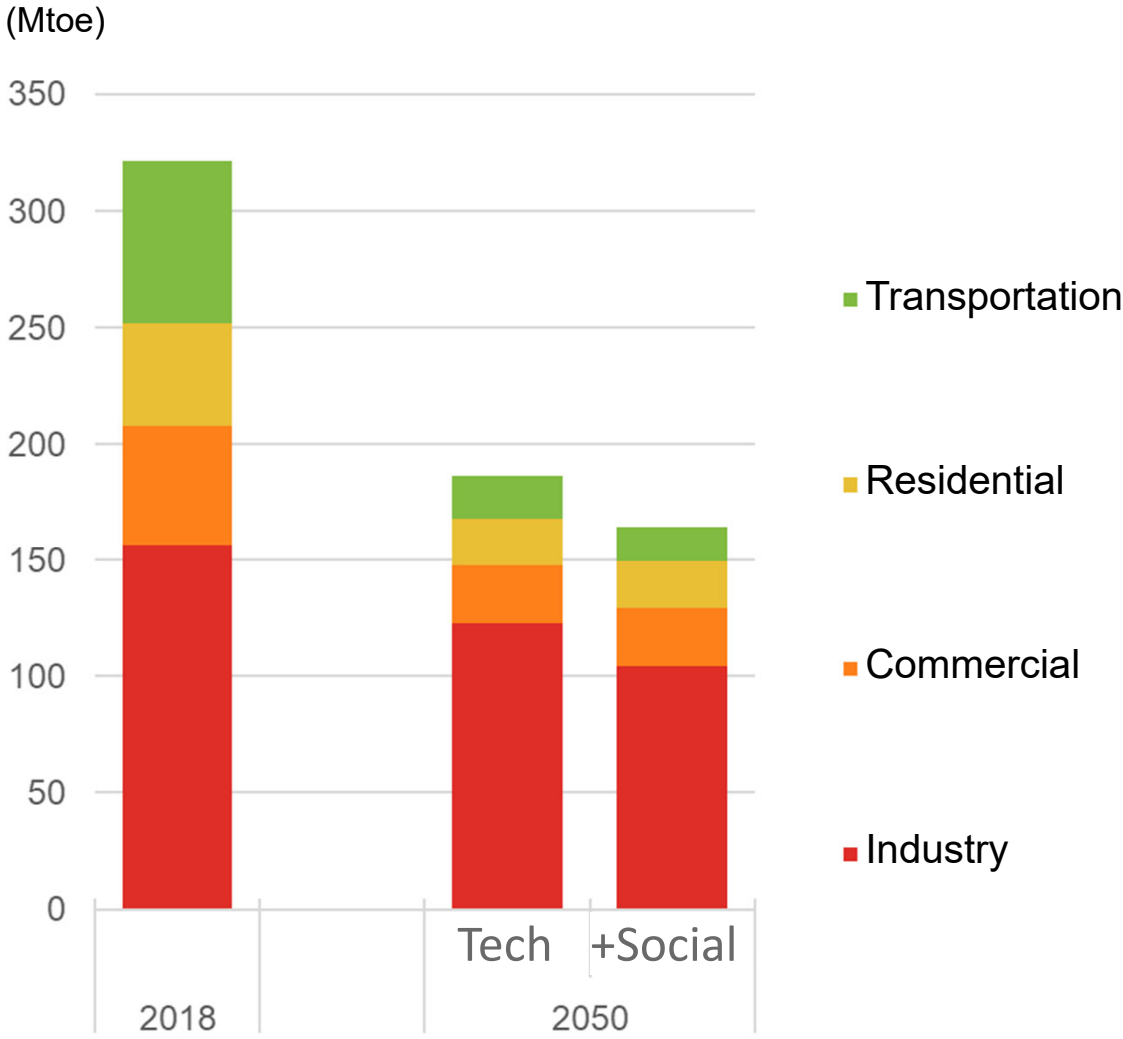
(Detailed analysis)

# Final energy consumption

Final energy consumption in 2050 will be -42% to -49% of that in 2018.
The share of electricity will increase significantly from 26% in 2018 to 49%-51% in 2050.
(Excluding non-energy use)




Energy consumption by energy type




Energy consumption by sector



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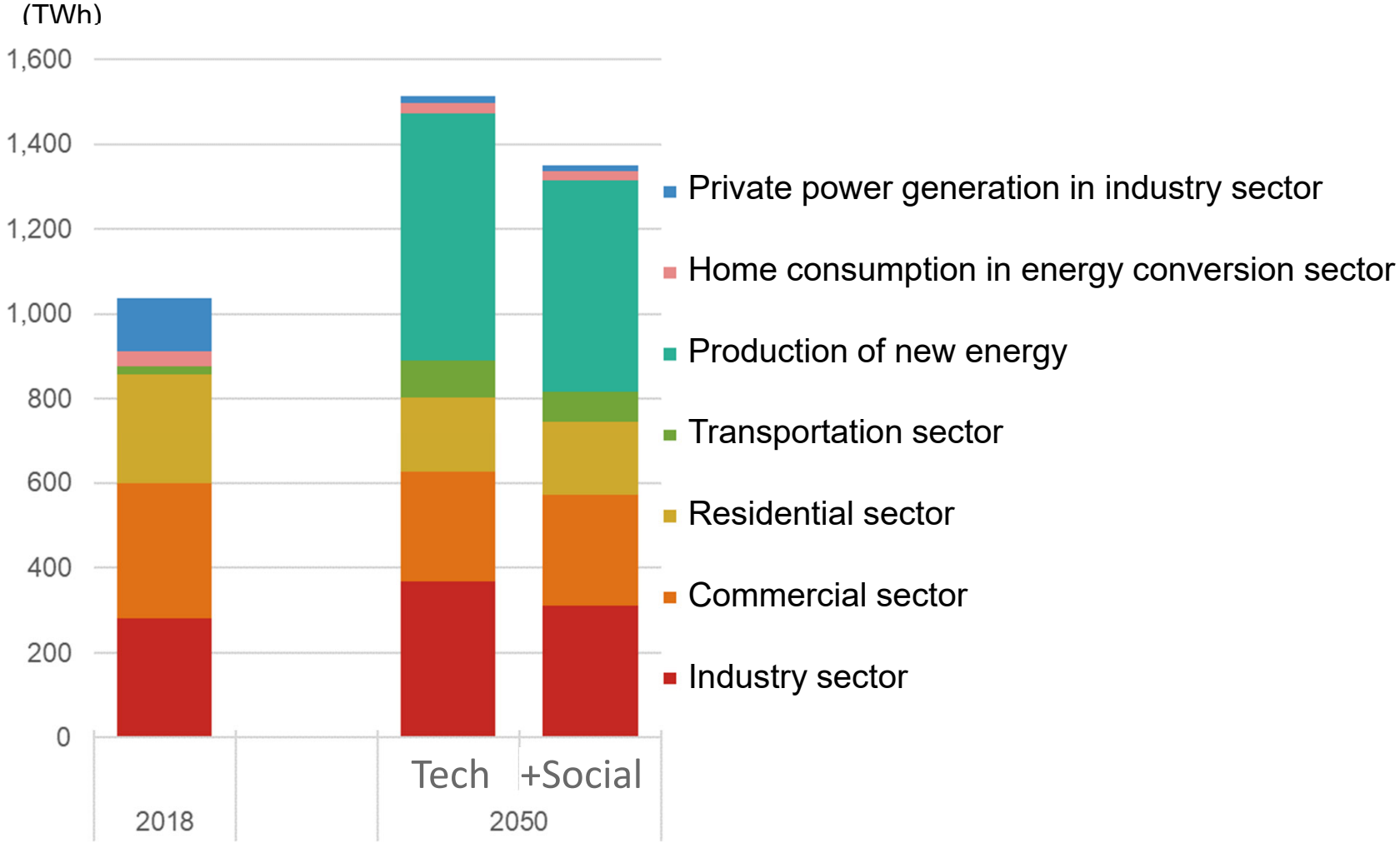
(Detailed analysis)

# Electricity demand

Electricity demand will increase substantially from 2030 onward, rising 30-46% in 2050 compared to that in 2018.
Demand in the final consumption sector will remain flat or decrease, but demand for new fuel production (mainly for electrolysis to produce hydrogen) will surge.




＜Electricity demand＞



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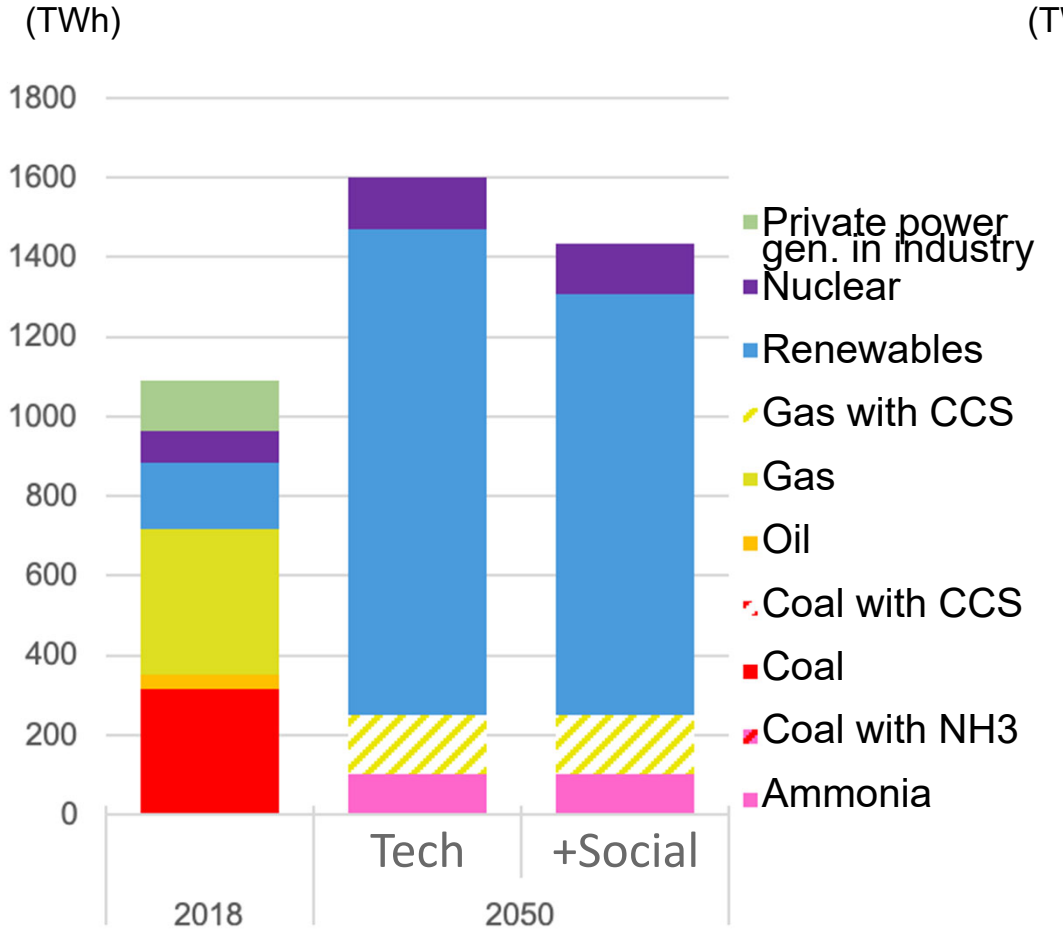
(Detailed analysis)

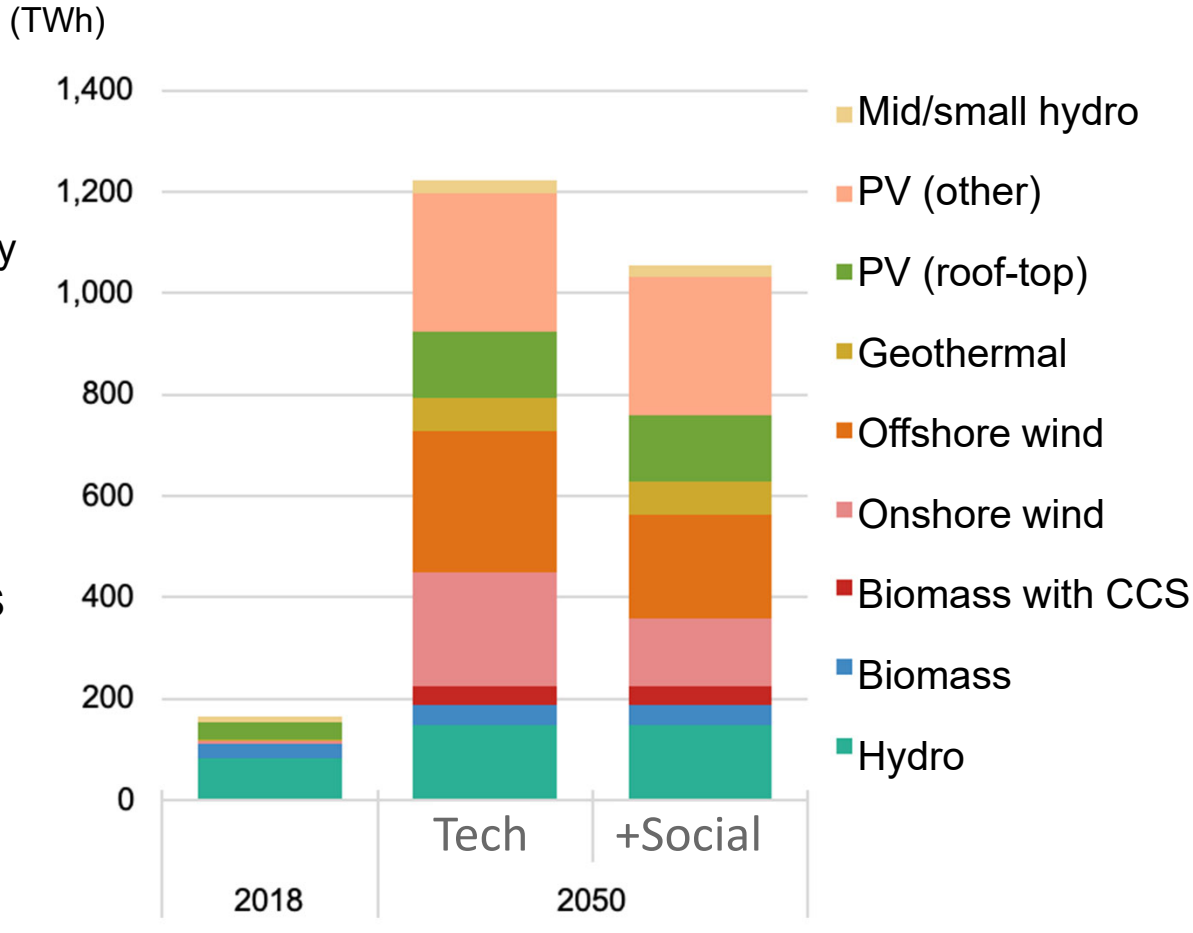
# Electricity supply

Share of decarbonized power sources in electricity supply changes from 25% in 2018 to 100% in 2050.

Share of electricity supply from renewable energy sources is expected to increase from 17% in 2018 to 73-76% in 2050. Solar and wind power will account for a large share of electricity generation, with solar power at 403-450 TWh in 2050, onshore wind power at 133-226 TWh in 2050, and offshore wind power at 205-276 TWh in 2050.




＜Electricity supply＞




＜Electricity from renewable source＞
(Breakdown of ■ in the left figure)



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(Detailed analysis)

# Electricity production cost

The average power generation cost in 2050 will be almost the same as the current level.

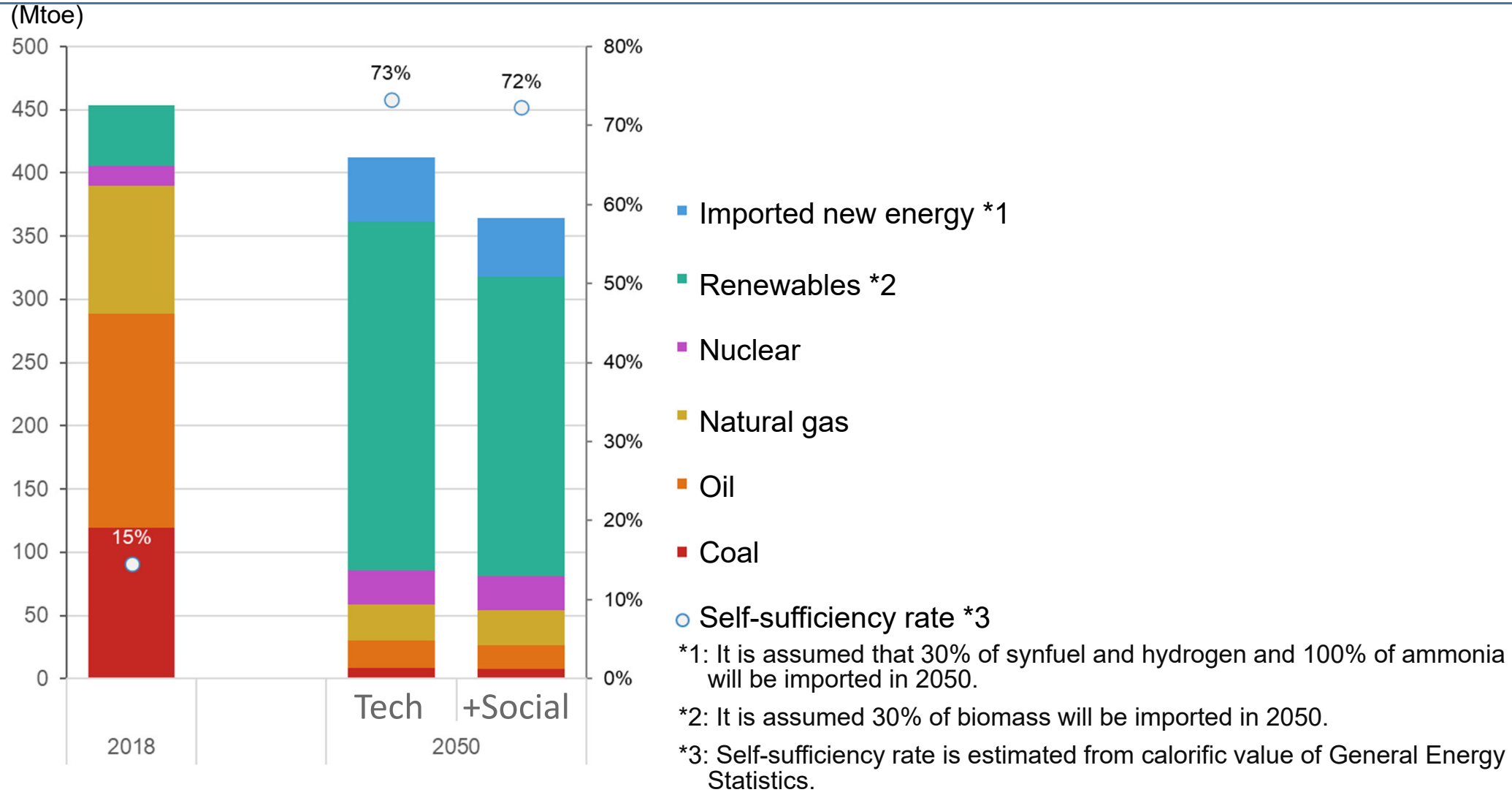
| | Average power generation cost* | |
|---|---|---|
| 2050 Technology scenario | 11.9 - 12.3 yen/kWh | Capital cost: 7.4 tri. yen<br>Maintenance cost: 7.8 tri. yen<br>Fuel cost: 2.2 - 2.7 tri. yen<br>Electricity generation: 1.5 TkWh |
| 2050 Technology + Social Transformation scenario | 11.8 - 12.2 yen/kWh | Capital cost: 6.5 tri. yen<br>Maintenance cost: 6.6 tri. yen<br>Fuel cost: 2.2 - 2.7 tri. yen<br>Electricity generation: 1.3 TkWh |
| 2018 | 11.5 yen/kWh | Capital cost: 3.3 tri. yen<br>Maintenance cost: 1.4 tri. yen<br>Fuel cost: 6.0 tri. yen<br>Electricity generation: 0.9 TkWh |

* The total capital cost (annual price), maintenance cost, and fuel cost of power generation facilities (including reserve power sources) and energy storage facilities in operation in 2050, divided by the amount of electricity generated.
The lower value of fuel cost for 2050 is based on sustainable development scenario of IEA WEO2020 , and the upper value is based on actual price for FY2018.
For coal- and gas-fired power generation in 2018, capital cost is calculated using 70% of capacity utilization rate for each type of power generation. For oil-fired power, no capital cost is accounted.
The average power generation costs for both years exclude the cost for nuclear power plants.

(Detailed analysis)

# Primary energy supply

Fossil fuels currently account for more than 80% of the domestic primary energy supply, but renewable energy will account for about 70% by 2050.
The energy self-sufficiency rate is improved from 15% in 2018 to over 70% in 2050.




*1: It is assumed that 30% of synfuel and hydrogen and 100% of ammonia will be imported in 2050.

*2: It is assumed 30% of biomass will be imported in 2050.

*3: Self-sufficiency rate is estimated from calorific value of General Energy Statistics.

＜Total primary energy supply and self-sufficient rate of energy＞



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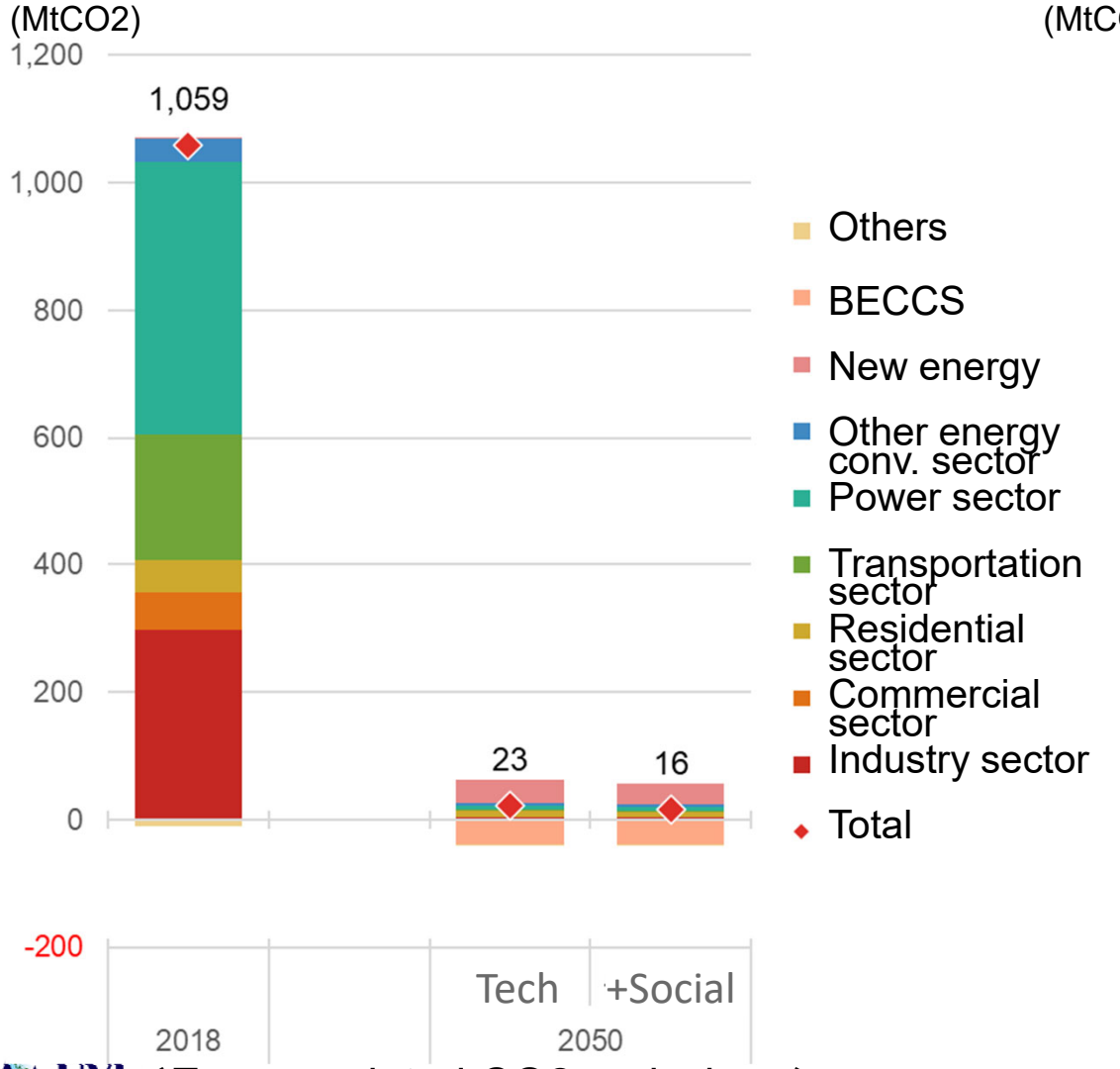
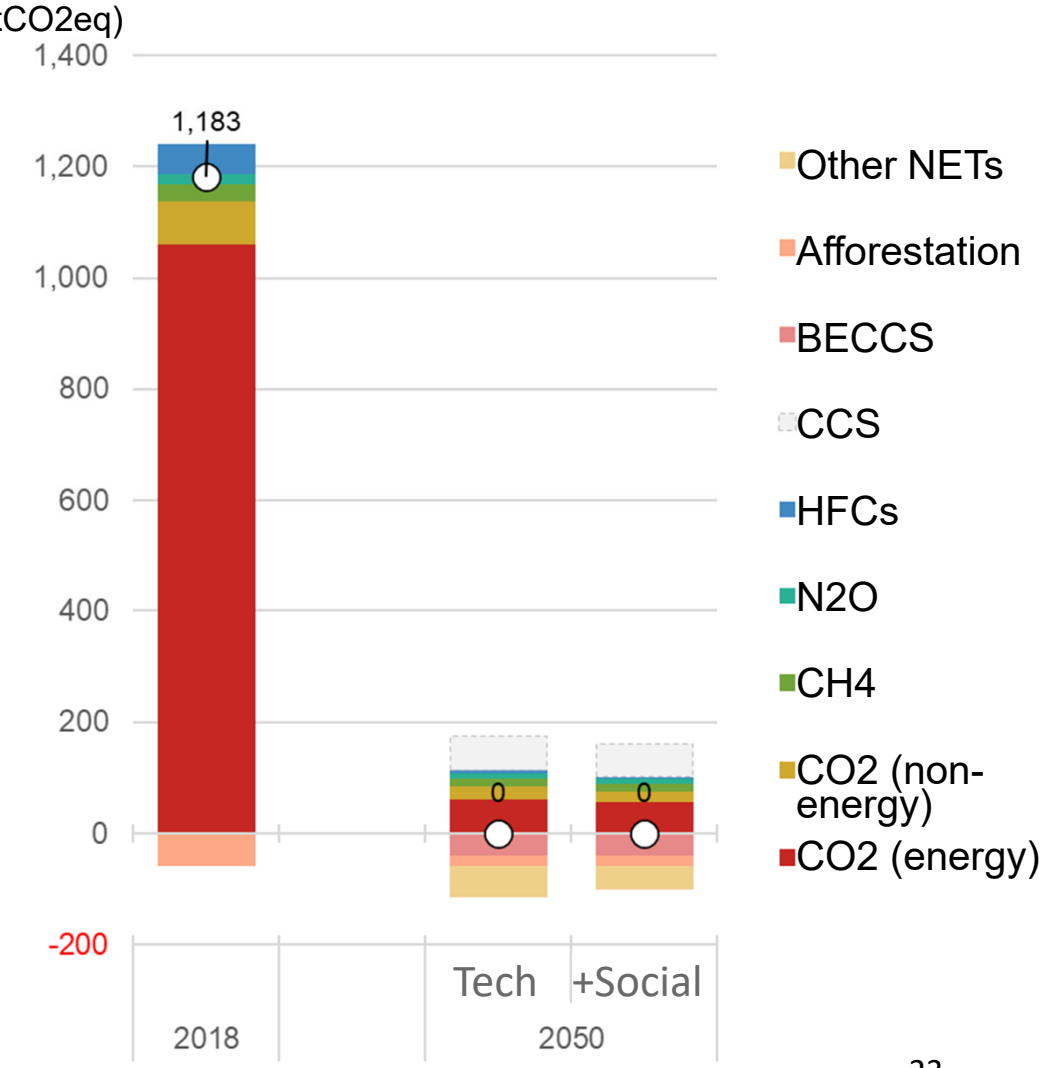
(Detailed analysis)

# Energy related CO2 and GHG emissions

Emissions from synthetic fuels (carbon from fossil fuels) will account for a large share of energy-related CO2 emissions in 2050.
In 2050, some level of emissions will be inevitable even if decarbonization measures are promoted. Therefore, negative emission technologies will be necessary to achieve net zero GHG emissions.




<Energy related CO2 emissions>




<GHG emissions>



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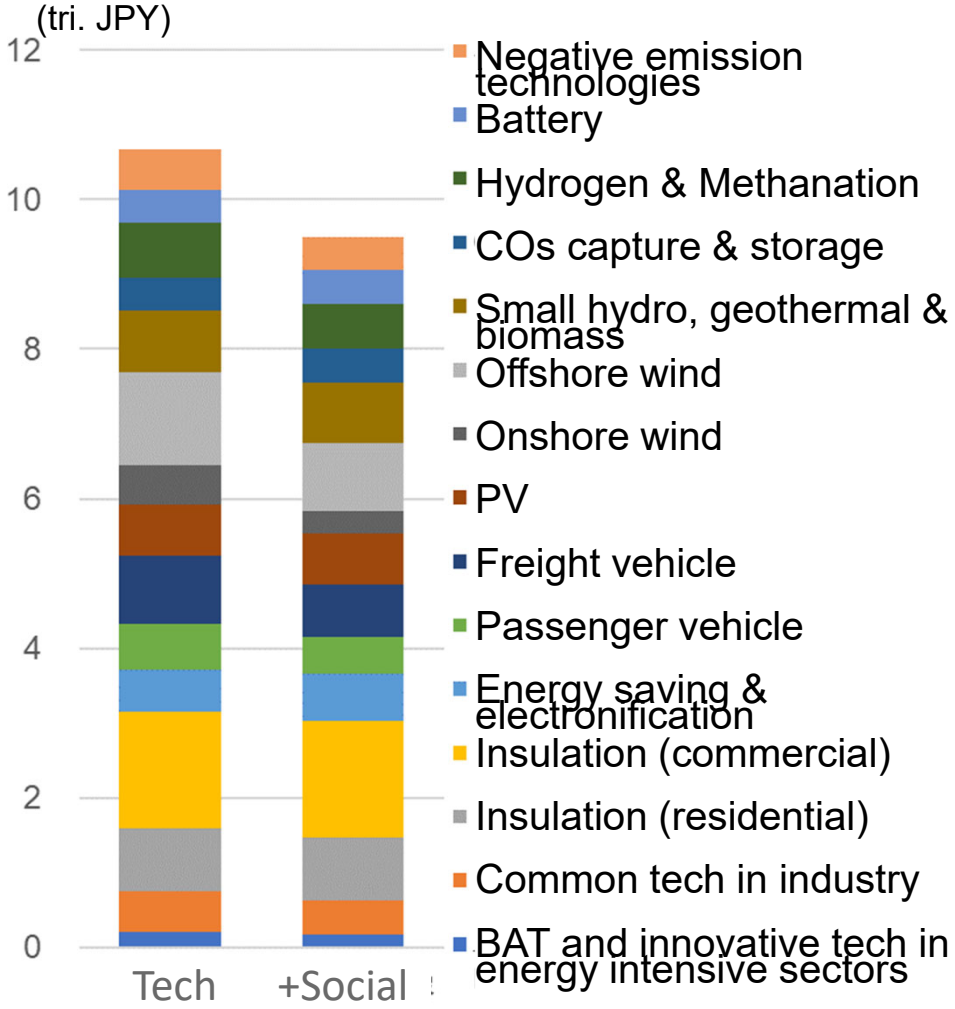
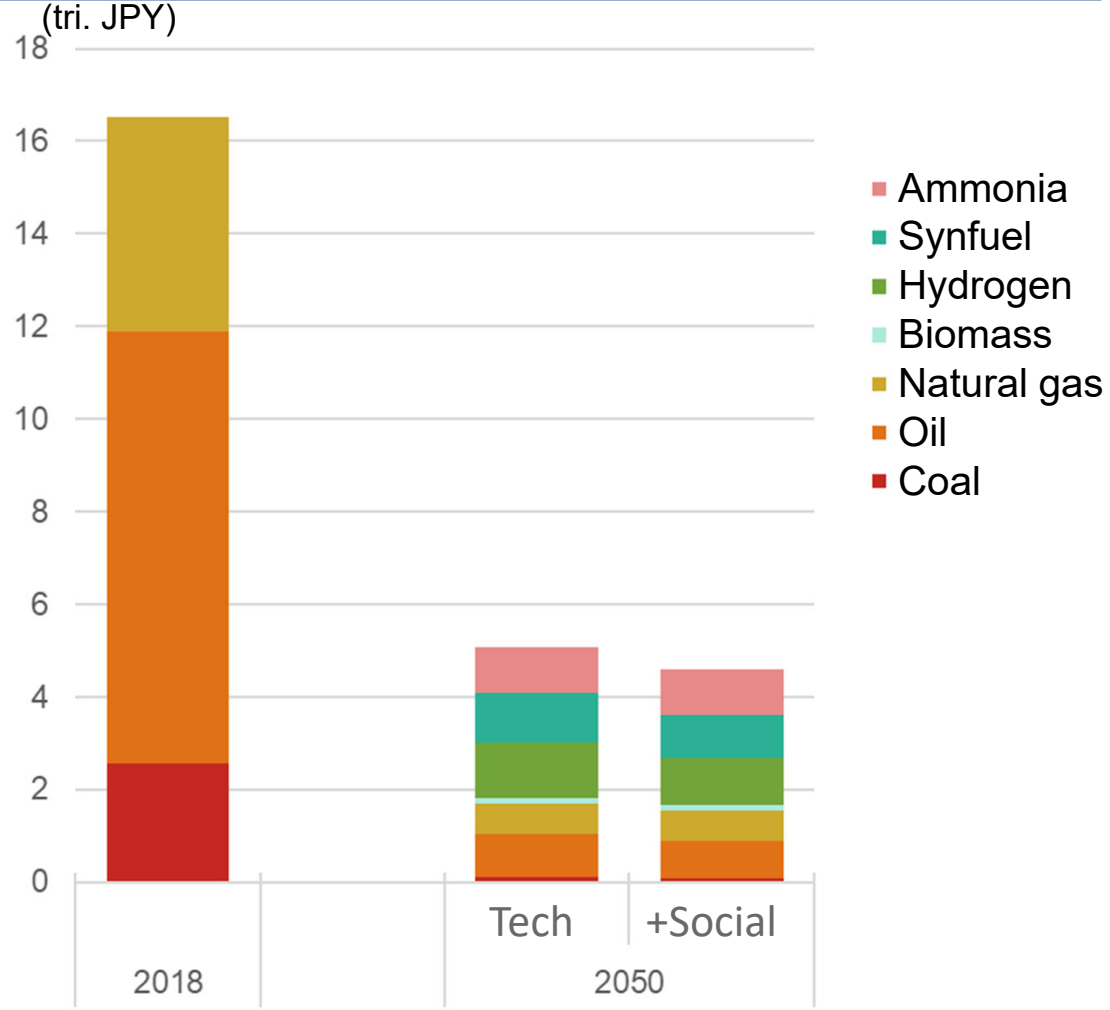
(Detailed analysis)

# Additional investment

In terms of the amount of additional investment needed to achieve a decarbonized society, investment in insulation of houses and buildings and in renewable energy accounts for a large share.
Net energy imports in 2018 were about 16 trillion yen, but imports will fall by about 12 trillion yen in 2050 due to reduced dependence on fossil fuels.




<Additional investment (average 2041-50)>




<Net import value of energy in 2050>

# Main implications of detailed analysis

**Reductions in energy consumption; use of lower carbon energy sources; and energy transition (electrification)**

Building sector:

- Electrification of heating and hot water supply is progressing, but this will not lead to an increase in electricity consumption due to higher insulation of houses and buildings and progress in energy conservation of equipment.
- For the remaining fuel consumption demand, synthetic fuels are supplied, and emissions are approaching zero*.

Transportation sector:

- It is necessary to promote use of electric vehicles (battery electric vehicles and fuel cell vehicles) as soon as possible.
- Cars with remaining internal combustion engines, trains in non-electrified areas, ships, and aviation use synthetic fuels, hydrogen, and biofuels. As a result, emissions are approaching zero*.

Industry sector:

- Innovative technologies such as hydrogen-reduced steelmaking in iron and steel industry, clinker substitute materials in cement industry, and CO2 feedstock conversion in chemical industry have been developed and spread. As for the consumption of remaining fossil fuels, CO2 capture is being carried out, synthetic fuels and products are being used, and geological sequestration is being carried out.
- In all sectors, BAT technology is widespread, and for heat use, industrial HP is widespread and electrification is progressing. For high temperature heat demand, synthetic fuels are being used.

**New fuel production**:

- Hydrogen is produced domestically by electrolysis to meet demand for hydrogen and synthetic fuels in the consumer, transportation, and industrial sectors. The electricity demand for hydrogen production is relatively unrestricted in terms of time, so it is possible to produce hydrogen at times when there is enough electricity supply.

* It should be noted that carbon content of synfuels includes a portion of fossil fuel origin, and thus CO2 emissions are associated with their use.

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# Main implications of detailed analysis

**Social transformation** could increase certainty of achieving decarbonized society.

- It is important to further study benefits and challenges of social transformation scenario. There are technical and social constraints and uncertainties regarding development and diffusion of new negative emission technologies and dependence on foreign countries for new fuels.
- Therefore, in order to increase feasibility of a decarbonized society, efforts to transform society into one that provides higher benefits and utility with less environmental impact through **digitalization** and promotion of **circular economy** will be important for the realization of a decarbonized society.

（Differences in social transformation）

・Negative emission technologies: 55 MtCO2 → 43 MtCO2 (about 22% reduction)

・Import of new fuels: 47 Mtoe → 42 Mtoe (about 10% reduction)

・Difference between reduction cost of net energy import and additional investment cost:
1 tri. yen/year → 2 tri. yen/year

Ratio of **renewable energy** to total power generation in 2050 will be around 70-80%. Average power generation cost will be almost the same as the current situation.

- Solar power and wind power, which will be main power sources in 2050, are highly variable power sources, but flexibility is ensured by combining various power sources, battery, and implementing inter-regional flexibility. In addition, when electricity supply exceeds its demand due to weather conditions, hydrogen and synfuel are produced using surplus electricity. The average cost of power generation in 2050 will increase by less than 10% from the current level, as declining costs of solar and wind power and the increasing share of their use offset the price increase to some extent, despite increasing investment for power stabilization.

Total required investment will be within range of reduction in fuel imports. Decarbonization may have a positive impact on reducing the outflow of national wealth.

- Annual required investment will be estimated to be about 10 - 11 trillion yen. This investment will significantly reduce fossil fuel demand. As a result, it is estimated that it will lead to a reduction in net energy imports of about 12 trillion yen in 2050.

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