Roadmap for "Transition Finance" in Oil Sector

February, 2022

Ministry of Economy, Trade and Industry

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1. Premise | Necessity for Roadmap for Oil Sector

- The sectors covered in The Roadmap for “Transition Finance” (hereinafter referred to as the Roadmap) have been selected for the following reasons: they are industries with high CO2 emissions, alternatives to zero emissions are technically and economically not available to them, and transitions are highly important for them.
- **Oil** accounts for approximately 40% of Japan’s primary energy supply. **It has a wide range of fuel applications such as for transportation and power generation and in the consumer sector, as well as material applications such as chemical products. In addition, it becomes the last bastion of energy supply in times of disaster.** As an energy source that contributes to energy supply not only in times of peace but also in emergencies, the government and private sector will continue to work together to ensure a stable supply of oil as an **energy source indispensable to people’s lives and economic activities.**
- In Japan, approximately 310 million tons of CO2 are emitted from the combustion of petroleum products. Due to the nature of the oil industry, it will be difficult for this industry alone to achieve carbon neutrality by 2050. To achieve net zero in the oil industry, **it is essential to make a transition with a full range of options in mind, to not only ensure a low-carbon and decarbonized petroleum refining process but also introduce decarbonization technologies such as CCS and CCU and shift to a supply system of decarbonized fuels such as biofuels and synthetic fuels.**
- Innovations in technology and business structure for decarbonization also are companies’ strengths. To attract global ESG funds, which grew to 3,500 trillion yen ($35 trillion according to the Global Sustainable Investment Alliance) in 2020, high-emission industries are also required to disclose their strategies as well as understand investors’ perspectives.
- Taking into account the energy situation in Japan and the characteristics of the oil industry, this roadmap was formulated through discussions involving experts in technology and finance and representatives of oil companies to **present a broad picture of the transition in the oil sector and a path of transition technologies based on the current outlook.**

1. Premise | Objectives and Positioning of the Roadmap

- Based on the Basic Guidelines on Climate Transition Finance (May 2021 by the Financial Services Agency, Ministry of Economy, Trade and Industry, and Ministry of the Environment), the roadmap will be formulated as follows: **Companies in the oil industry in our country can refer to it when considering climate change measures that utilize transition finance. For banks, securities companies, investors, and others, this roadmap will help them determine whether or not transition strategies and initiatives for decarbonization are eligible for transition finance in corporate funding in the oil industry in our country.**

- At present, the technology to realize carbon neutrality in the oil industry has not been established, and it is indispensable towerd 2050 that research and development of technology that has not yet been established.

- Looking ahead to 2030 and 2040, **during the transition period, not only research and development but also continued decarbonization of refineries is of paramount importance. Without waiting for the establishment of technologies to realize carbon neutrality, our country's oil industry is expected to make a "transition" toward decarbonization, including energy conservation, while referring to this roadmap.**

- This roadmap sets the ultimate goal of achieving carbon neutrality by 2050. Based on the information available at present, it provides a conceptualization of low-carbon and decarbonization technologies that are expected to be implemented by 2050 and the timing of their practical application.

- The Roadmap is consistent with the Nationally Determined Contribution[*1] established under the Paris Agreement, the Green Growth Strategy[*2], and the R&D and Social Implementation Plan[*3] of the Green Innovation Fund.

*1 — https://www.kantei.go.jp/jp/singi/ondanka/kaisai/dai41/siryou1.pdf
*2 — https://www.meti.go.jp/press/2021/06/20210618005/20210618005-3.pdf
*3 — https://www.meti.go.jp/press/2021/09/20210915001/20210915001-2.pdf

(Note)" Transition finance refers to a financing means to promote long-term, strategic GHG emissions reduction initiatives that are taken by a company considering to tackle climate change for the achievement of a decarbonized society" - *Basic Guidelines*

1. Premise | Basic Concept of the Roadmap for Oil Sector

- This roadmap, by showing **a broad picture of the transition in the oil sector,** will **guide the assessment of the adequacy of a company's transition strategy,** and **by showing the path of transition technologies based on the current outlook, it will guide the transition eligibility of specific projects that individual companies promote using these technologies.**
- Although **the main goal of achieving carbon neutrality by 2050 is common for many countries, the transition path may change depending on the circumstances of each,** and the approach to this transition in our country should be **advanced integrally with our country's energy policy, including the Strategic Energy Plan.** Therefore, the content of this roadmap is also consistent with our country's energy policy.
- In the transition process, **stable supply of oil is a major premise,** as it is regarded as an indispensable energy source for people's daily lives and economic activities. Oil is the "last bastion" of energy supply in times of disaster because of its advantages in terms of mobility based on the development of a supply system and a stockpiling system for final users. This should be taken into account when formulating transition strategies for each company and when financial institutions and third parties determine whether or not their strategies and individual funding are eligible for the transition.
- In this roadmap, **promising future technologies in the oil industry** will be **presented as quantitatively as possible** so as to contribute to the formulation of specific transition strategies and decisions on transition finance. It should be kept in mind that the technologies each company invests in will depend on the company's strategies, on the premise of achieving carbon neutrality by 2050.
- The Roadmap will be **revised as necessary in light of future trends in the development and practical application of decarbonization and transition technologies.**

1. Premise | Scope of the Roadmap for Oil Sector

- When it comes to assessing a transition strategy's appropriateness at the corporate level of each company, it is important to know whether a specific path to decarbonization has been laid out. In particular, **it is a major premise that individual initiatives are firmly linked to company-wide carbon neutrality initiatives.**
- In doing so, it is important to promote initiatives such as **steady decarbonization through various energy conservation and fuel conversion measures, decarbonization using CO2-free hydrogen, CCS, CCU, etc.,** and **a shift to a supply system of decarbonized fuels (hydrogen, ammonia, biofuels, synthetic fuels, etc.).** Efforts toward decarbonization may include not only the introduction of technologies but also the use of carbon credits and the purchase of carbon offset products.
- At the corporate level, efforts to **optimize fuel supply functions such as business reconstruction at refineries and service stations** and **develop into renewable energy businesses** are considered to be part of the transition.
- **Efforts to contribute to transitions in other industries,** such as the supply of fuel-efficient engine oil, can also be said to be transitions in the sense of indirectly promoting decarbonization.
- In addition, as indicated in the Basic Guidelines on Climate Transition Finance, transition includes not only direct efforts by businesses to reduce emissions but also **efforts for "a just transition,"** including support for those who are economically disadvantaged, and **support for decarbonization efforts of other companies.** For example, when consolidating refineries and service stations, it is necessary to proceed with the transition according to the actual conditions of the region, taking into account the **impact on the local economy and employment.**
- With this in mind, **the Roadmap will provide as quantitative a perspective as possible on promising technologies that will contribute to the promotion of transition finance in the oil refining industry, which plays a central role in ensuring a stable oil supply in our country.**

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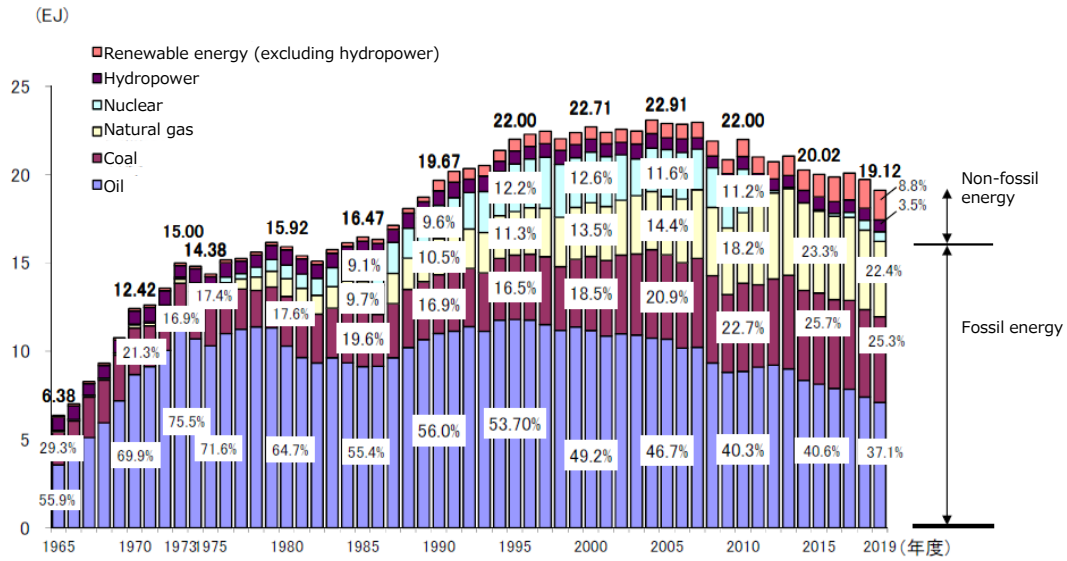
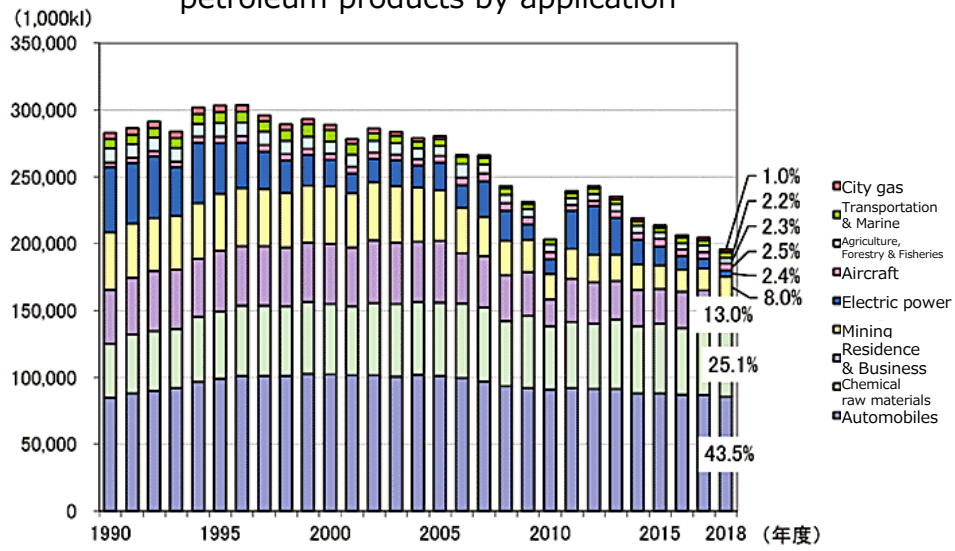
2. Overview of Oil Industry | Positioning and Importance of Oil

- Oil is **the largest energy source, accounting for approximately 40% of the domestic primary energy supply.**
- Gasoline (approx. 30%), naphtha (approx. 26%), and diesel oil (approx. 21%) are popular types of petroleum products. By application, products for automobiles have the largest share at approximately 44%.
- Oil has a high-energy density and is used in many fields from the viewpoint of economic efficiency and portability and mobility in times of disaster. **It will continue to be an important energy source during the transition to carbon neutrality.**

Trends in domestic primary energy supply



Trends in consumption of petroleum products by application

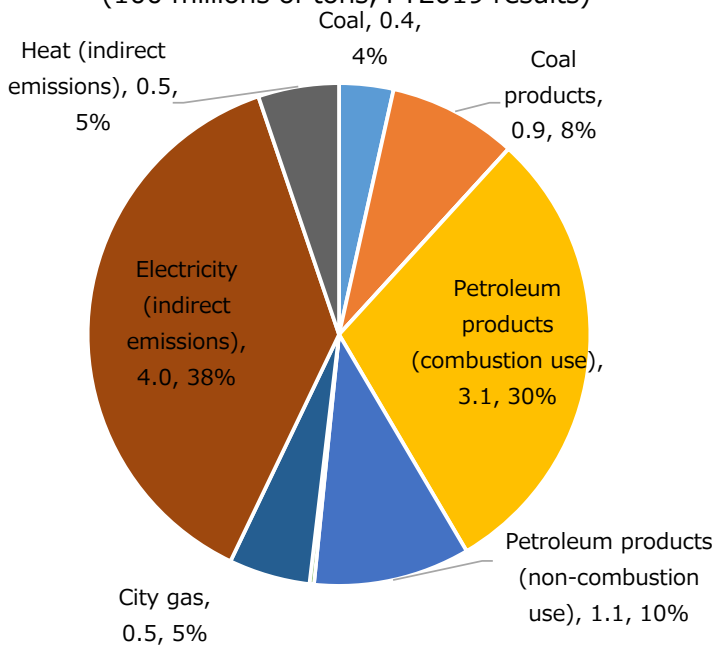


Source: The Ministry of Economy, Trade and Industry, "Energy White Paper 2021"

2. Overview of Oil Industry | CO2 Emissions

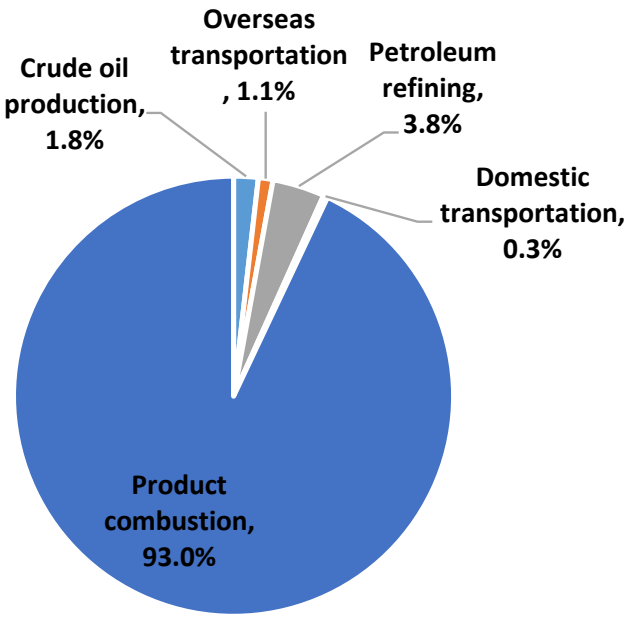
- Of our country's CO2 emissions per unit of final energy consumption in FY 2019, **emissions from petroleum products accounted for approximately 40%**. Of these, 30% (approx. 310 million tons) were from combustion applications and 10% (approx. 110 million tons) from non-combustion applications (chemical raw materials, etc.).
- In CO2 emissions over oil lifecycle, **emissions from oil production, transportation, and refining accounted for less than 10%. Thus, in addition to ensuring a low-carbon and decarbonized petroleum refining process, it is important to convert petroleum products into decarbonized fuels** to achieve carbon neutrality in the oil industry.

CO2 emissions per final energy consumption
(100 millions of tons, FY2019 results)



Source: The Ministry of Economy, Trade and Industry, "Comprehensive Energy Statistics" (FY 2019 figures)

An example of the oil life cycle inventory analysis results

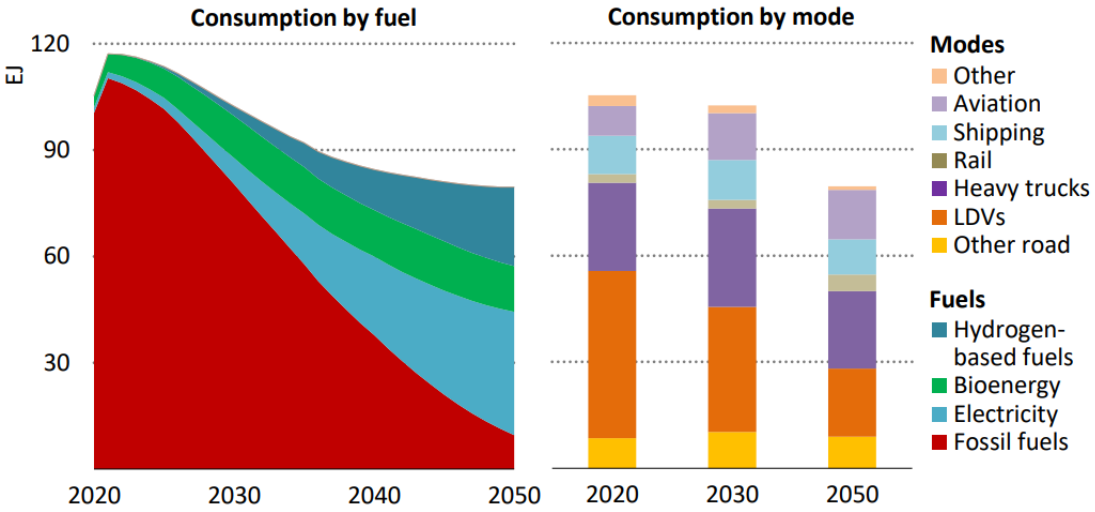


Source: The Institute of Energy Economics, Japan
"Life Cycle Inventory Analysis of Fossil Energy in Japan"

2. Overview of Oil Industry | Oil Demand Forecast, Movement toward CN

- While the world as a whole is moving toward carbon neutrality, demand for oil is expected to persist in some sectors, but **in most of them, it will be converted into biofuels and synthetic fuels.**
- Overseas oil companies are also **actively engaged in the development of technologies for biofuels, hydrogen, ammonia, etc.**

Prospects for fuel demand in the transport sector by fuel type and application



Source: IEA (International Energy Agency) "Net Zero by 2050"

Trends of Major Overseas Oil Companies

- BP will reduce Scope 1 and 2 emissions by 30–35% (compared with 2019 levels) by 2030 and aim to achieve net zero emissions by 2050. **The company will work on energy efficiency improvement, methane management, etc. The company will work on bioenergy, hydrogen, CCUS, etc.** with the aim of halving the carbon intensity of our products by 2050. (BP, UK)
- By 2030, Shell will reduce Scope 1 and 2 emissions by 50% (compared with 2016 levels) with the aim of achieving net zero by 2050. With respect to Scope 3 emissions, the company is aiming at net zero for all energy products sold by Shell. **The company will work on biofuels, hydrogen, CCS, etc.** (Shell, UK and Netherlands)
- By 2030, Woodside will reduce 30% of Scope 1 and 2 emissions (compared with the average between 2016 and 2020) according to the share of interests and aim to achieve net zero by 2050. **The company is working on the development of new energy technologies, including hydrogen, ammonia, and CCS,** and investing in afforestation activities. (Woodside, Australia)

Source: Prepared from materials published by each company

2. Overview of Oil Industry | Direction toward CN for Petroleum and Other Products

- To achieve carbon neutrality in the oil industry,*1 **(1) low-carbon and decarbonization of crude oil treatment and (2) decarbonization of product combustion by conversion to decarbonized fuels** are necessary. In particular, it is important to reduce emissions from product combustion, which is responsible for the most emissions, but it is also necessary to steadily promote low-carbon and decarbonization of crude oil processing (refining, etc.).

Major sources of emissions	Overview	Direction toward low carbonization and decarbonization
Approx. 4% ① Crude oil treatment	Use of heat during petroleum refining, and emissions from electricity self-generation	P25 • Energy conservation and higher efficiency • Conversion to low-carbon and decarbonized fuels • Introduction of CO2 capture, etc.
Approx. 93% ② Product combustion	Emissions from combustion of petroleum products produced by the oil industry	P 26–27 Conversion to low-carbon and decarbonized fuels • Hydrogen and ammonia P 14–15 • Biofuel P16 • Synthetic fuels P17 • Low-carbon fuel P19 etc.
Approx. 3% Other	Emissions from transportation and mining	• Not covered under this roadmap*1

% Percentage of emissions*2

*1: See page 6 for the scope of this roadmap
*2: Described with reference to “an example of the oil life cycle inventory analysis results,” page 9, figure on the right. Crude oil treatment is assumed to be applicable to the refinery process.

2. Overview of Oil Industry | Description of Petroleum in the Sixth Strategic Energy Plan

- **While ensuring a stable oil supply,** as a resource and fuel that will be needed continuously in the future, **the government will work to build a supply chain for hydrogen and ammonia.**
- With the aim of strengthening the fuel supply system, **in addition to improving the productivity of oil refineries, the government will also work on decarbonization, such as the use of CO2-free hydrogen.**
- In addition to **utilization of hydrogen overseas and establishment of hydrogen production bases in Japan** for a stable and large supply of hydrogen and ammonia, **promotion of greater utilization on the demand side, strategic establishment of hydrogen stations, etc.** will be worked on.

Points of policy responses towards 2030 [Resources/Fuels]

- **Stable and seamless procurement of necessary resources and fuels into the future** will be ensured while promoting smooth transition to carbon neutrality
  - In addition to ensuring stable supply of oil, natural gas and mineral resources, **"comprehensive resource diplomacy" will be newly deployed to integrally promote establishment of hydrogen/fuel ammonia supply chains and secure suitable sites for CCS advantage of the networks having been fostered with resource-rich countries in the past diplomacy.** In addition, active involvement in **realistic energy transitions in Asia** will be demonstrated.
  - **Functional enhancement of JOGMEC** will be considered so that it can **play a role in developing technology and supplying risk money** for **introduction of decarbonized fuels/decarbonization technology such as hydrogen, ammonia and CCS.**
  - Independent development ratio of **oil and natural gas** will be aimed to increase from 34.7% in FY2019 **to more than 50% in 2030** and **more than 60% in 2040**. Further, **domestic resource development including methane hydrate** will be addressed.
  - As to **mineral resources, financial support for Japan's interest in rare metals, etc.** with a concern of supply disruption **will be enhanced. By securing overseas interests and promoting base metal recycling**, **securing mineral resources of equivalent amount in domestic demand will be aimed by 2050.** In addition, **development of domestic marine mineral resources such as Sea-floor polymetallic sulphides and rare-earth yttrium rich mud, etc** will be addressed.
- **Resilience of the fuel supply system will be enhanced** and **efforts for decarbonization will be promoted** to cope with not only ordinary but also emergency situations.
  - In order to make energy supply solid in emergency situations such as disaster, **stockpiling function of oil and LP gas will be maintained; productivity of refineries will be improved** by cooperation between businesses inside and outside complexes; and **decarbonization such as use of CO_2 free hydrogen in the refineries** will be addressed.
  - Transition of **service stations supplying energy to the local community** to **"comprehensive energy hub" involved in supply, etc. of energy to EVs and FCVs** and **"local community infrastructure" providing services meeting local needs** will be addressed while supply of oil products being continued.
  - We will pursue **the shift to natural gas** on demand side and **decarbonization of gas through methanation** and other means, which play a significant role in **decarbonizing heat demand**. We will also work to further **strengthen the resilience of gas**.

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Points of policy responses towards 2030 [Hydrogen/Ammonia]

- Looking ahead to the carbon neutral, **hydrogen will be positioned as a new resource and its societal implementation will be accelerated.**
- In order to supply cost-effective hydrogen/fuel ammonia, **steadily and by large amount in the long term, inexpensive hydrogen from overseas will be utilized** and **hydrogen production base will be established by utilizing domestic resources.**
  - **Commercialization of hydrogen production utilizing international hydrogen supply chain and water electrolysis equipment using excess renewable energy, etc.; and development of innovative hydrogen production technology** utilizing high temperature heat sources **such as photocatalyst/high-temperature gas-cooled reactor** will be addressed.
  - **Supply amount of hydrogen will be increased** by **reducing its supply cost to the similar level to those of fossil fuels.**

    Cost: reduction from current 100 yen/Nm^3 to 30 yen/Nm^3 in 2030, and not more than 20 yen/Nm^3 in 2050.

    Supply amount: increase from current approx. 2 million tons/year to max. 3 million tons/year in 2030, and 20 million tons/year in 2050.
- Use of hydrogen on demand side (power, transport, industry and consumer sectors) will be expanded.
  - **In power generation sector** expected to large amount of hydrogen demand, aiming at **introduction/expansion of 30%-hydrogen co-firing in gas-fired power generation or hydrogen-fired power generation** and **20%-ammonia co-firing in coal-fired power generation, demonstration of co-firing/single fuel firing will be promoted** and the environment for appropriate assessment of non-fossil value will be prepared. In addition, **1% hydrogen/ammonia will be positioned in power generation mix in FY2030.**
  - **In transport sector, hydrogen station will be strategically streamlined for further expansion of FCVs and future FC trucks.**
  - **In industry sector, large scale diversion of manufacturing process such as** hydrogen-reduced iron making and **technology development of burners and large and highly functional hydrogen-fired boilers** based on its combustion characteristics will be addressed.
  - **In buildings sector, technology development towards cost reduction** will be addressed **for further introduction and expansion of stationary fuel cells** including pure hydrogen fuel cell.

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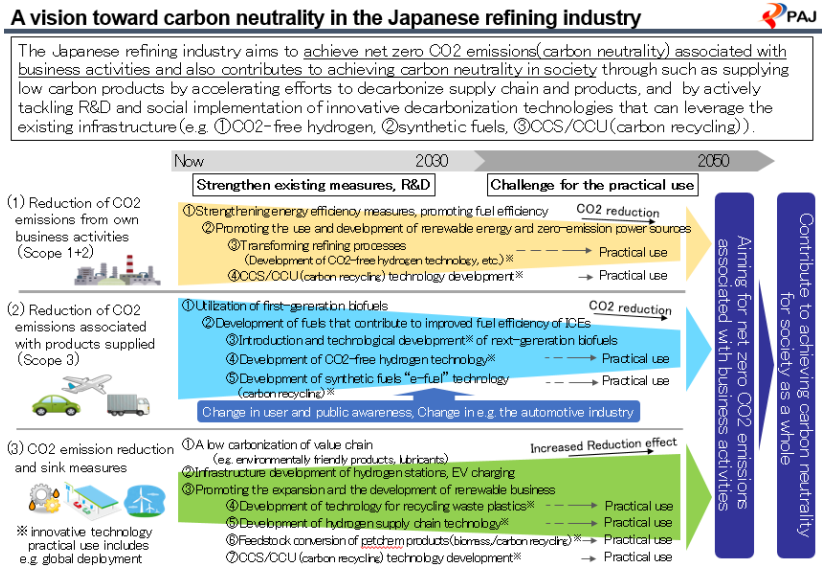
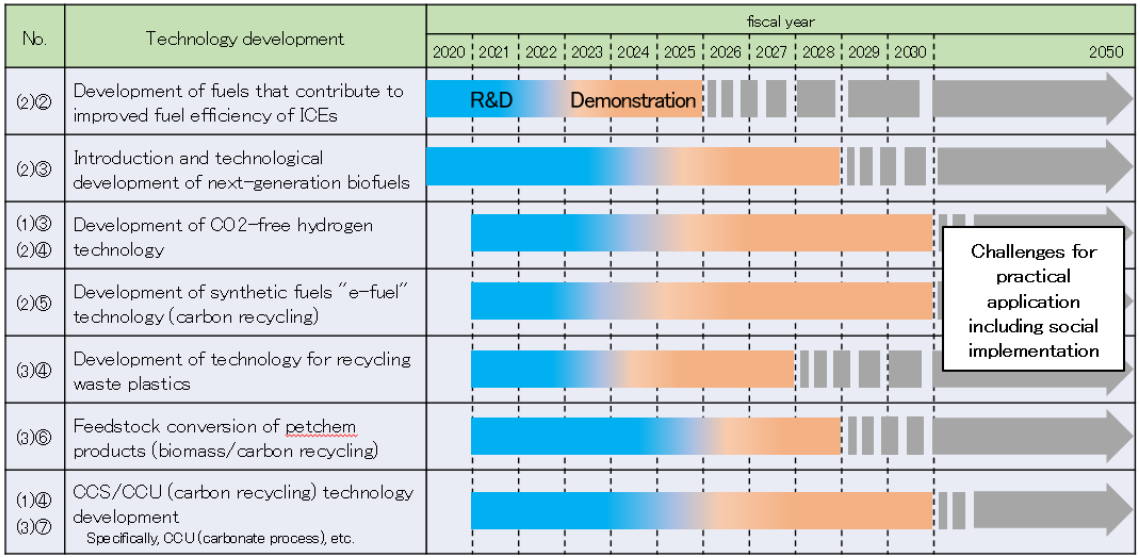
Source: Outline of the Sixth Strategic Energy Plan

2. Overview of Oil Industry | Efforts by the Oil Industry

- The Petroleum Association of Japan announced **its Vision toward Carbon Neutrality for the Oil Industry** (March 2021).
- It shows that the oil industry will work to achieve carbon neutrality based on the following three pillars: **(1) reduction of emissions associated with its business activities, (2) reduction of emissions associated with the products it supplies, and (3) measures to reduce CO2 emissions and carbon sinks**.





Source: The Petroleum Association of Japan: The Oil Industry's Vision toward Carbon Neutrality

2. Overview of Oil Industry | Prospects for Hydrogen Supply and Demand

- Regarding the supply of hydrogen, **in the short term, use of existing sources (by-product hydrogen, etc.), and in the medium to long term, use of imported hydrogen and new domestic sources (electrolytic hydrogen, etc.)** is expected.
- Demand covers a wide range of sectors such as transportation, power generation, and industry. **In the oil industry, it is expected to clean up the hydrogen used in refining processes.**

Assumptions of hydrogen supply sources and customers

Supply source	**Short term (until around 2025)**	**Medium term (until around 2030)**	**Long term (until around 2050)**
Actual and target values	Approximately 2 million tons	Up to 3 million tons	Approximately 20 million tons
Existing supply source (by-product hydrogen, etc.)	Largest use as a major source of hydrogen	Making supply sources cleaner (utilization of CCUS, etc.)	
Imported hydrogen	Knowledge accumulation and cost reduction through demonstration and semi-commercialization	Construction of large-scale international hydrogen supply chains on a commercial basis	Scale expansion through diversification of sources and suppliers
New sources of domestic supply (electrolytic hydrogen, etc.)	Knowledge accumulation and cost reduction through demonstration	Initiation of water electrolysis using surplus renewable energy	Expansion of the scale of electrolytic hydrogen production and the development of new manufacturing technologies

Demand destination	**Short term (until around 2025)**	**Medium term (until around 2030)**	**Long term (until around 2050)**
Division and target volume	Approximately 2 million tons	Up to 3 million tons	Approximately 20 million tons
Transportation sector	Expansion to FC trucks in addition to FCV and FC buses	Launch of vessels (FC vessels, etc.)	Use of hydrogen, etc. (synthetic fuels, etc.) in aircraft, etc.
Power sector	Regional expansion with a focus on stationary fuel cells and small turbines	Commercialization of large-scale hydrogen power generation turbines (integrated with SC)	Functions as an adjustment force supporting decarbonization of electric power
Industrial sector (industrial raw materials)	Clean-up of the hydrogen used in the desulfurization process of crude oil, and demonstration of manufacturing processes in the steelmaking and chemical industries		Hydrogen reduction steelmaking, green chemicals (MTO, etc.), etc.
Heat demand in the industrial, commercial, and household sectors	Replacement of fossil fuels through the introduction of water electrolysis equipment and decarbonization of supply infrastructure, including existing gas pipes		Supply expansion through infrastructure development and reduction in hydrogen costs

Source: Prepared based on the handouts of the Working Group on Energy Structure Conversion (2nd meeting), Green Innovation Project Subcommittee, Industrial Structure Council

2. Overview of Oil Industry | Hydrogen Carrier

- There are four types of hydrogen carriers for hydrogen transport: liquefied hydrogen, MCH (methylcyclohexane), ammonia, and methanation (synthethic methane).
- Because there are differences in characteristics, advantages, and technical problems, **it is necessary to aim for practical application of each technology without narrowing down carriers.**

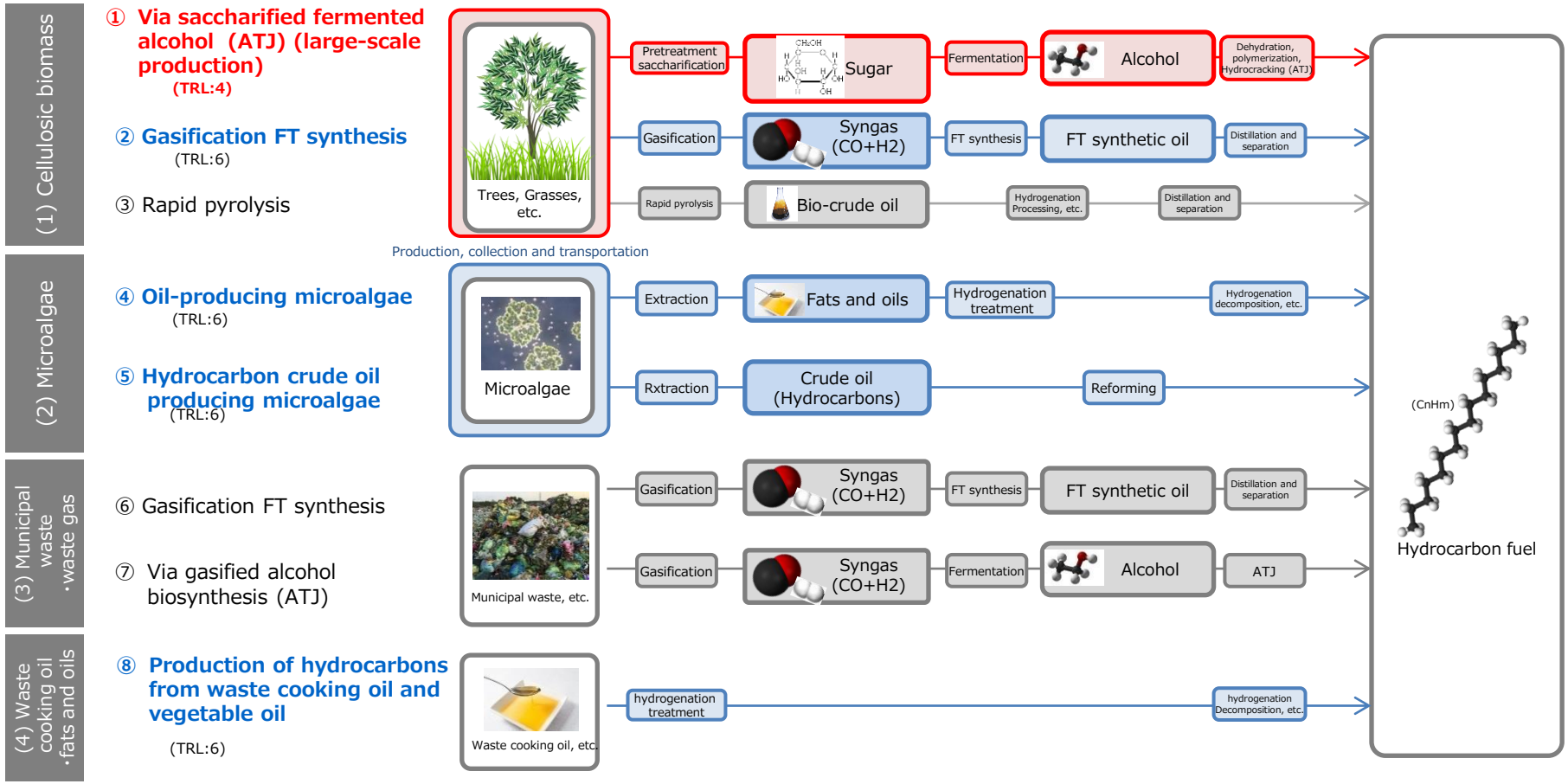
Carrier	Liquefied hydrogen	MCH	Ammonia	Synthethic methane
Volume (compared with hydrogen under atmospheric pressure)	Approximately 1/800	Approximately 1/500	Approximately 1/1300	Approximately 1/600
The conditions under which it becomes liquid; toxicity	-253 °C, atmospheric pressure; no toxicity	Normal temperature, normal pressure; toluene is toxic.	-33 °C, normal pressure, etc.; toxic, corrosive	-162 °C, atmospheric pressure; no toxicity
Availability of direct use	N.A. (no change in chemical properties)	Not current	Yes (coal-fired co-firing, etc.)	Yes (alternative to city gas)
Additional equipment for high purity	Not required	Required (during dehydrogenation)		
Energy loss for changes in the characteristics	Current: 25–35% Future: 18%	Current: 35–40% Future: 25%	Hydrogenation: 7–18% Dehydrogenation: not more than 20%	Current: -32%
Availability of use of existing infrastructure	International transportation is not available (new construction required). Domestic delivery is possible.	Yes (chemical tankers, etc.)	Yes (chemical tankers, etc.)	Yes (LNG tankers, city gas pipes, etc.)
Technical issues, etc.	Development of large-scale ocean transport technology (large liquefier, carrier, etc.) is required.	There is a need to further reduce energy loss.	It is necessary to develop technologies to expand the number of direct users and to develop technologies for dehydrogenation facilities.	Competitive supply of hydrogen from renewable energy sources and CO2 at manufacturing sites is essential.

Source: Handouts of the Working Group on Energy Structure Conversion (2nd meeting), Green Innovation Project Subcommittee, Industrial Structure Council

2. Overview of Oil Industry | Biofuels

- **Biofuels are carbon-neutral fuels made from plants and waste.** Currently, **bioethanol (gasoline substitute) and biodiesel (diesel oil substitute)** are being used worldwide.
- At the moment, to achieve the CO2 emission reduction framework of ICAO (International Civil Aviation Organization), it is said that **the introduction of sustainable aviation fuel (SAF) is necessary**, and the development of manufacturing technology and construction of supply chains are being actively considered in many countries.

< Major raw materials and types of manufacturing technologies for SAF >

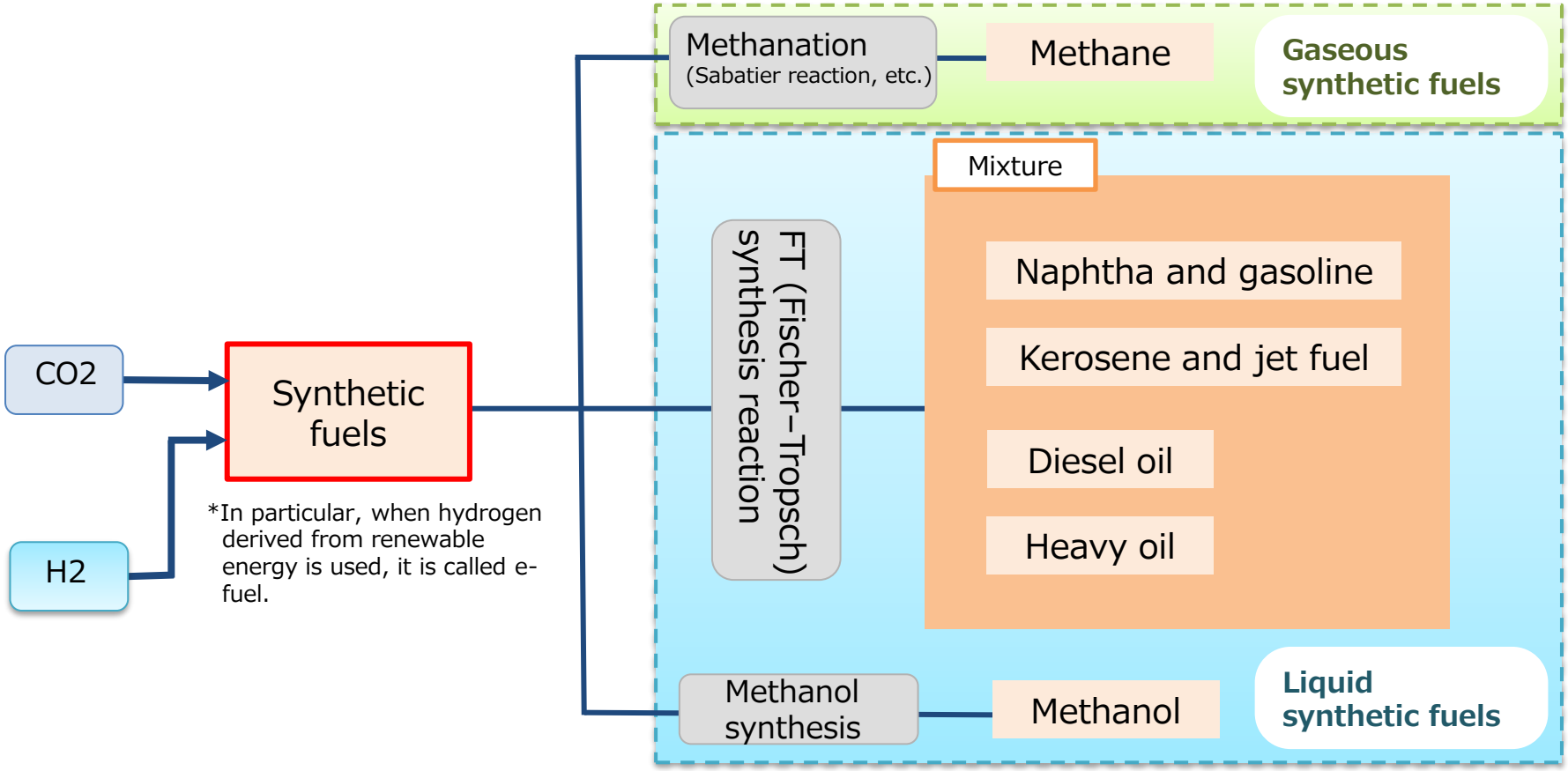


Red: Type of project to be supported **Blue: Types supported by existing projects** **Black: At present, businesses are considering the possibility of commercialization.**

Source: The Working Group on Energy Structure Conversion (7th meeting), Green Innovation Project Subcommittee, Industrial Structure Council

2. Overview of Oil Industry | Synthetic Fuels

- Synthetic fuels means **a fuel produced by combining CO2 and hydrogen.** The basic idea behind hydrogen as a raw material for synthetic fuels is **to use CO2-free hydrogen, which is produced through water electrolysis using renewable energy, etc.**



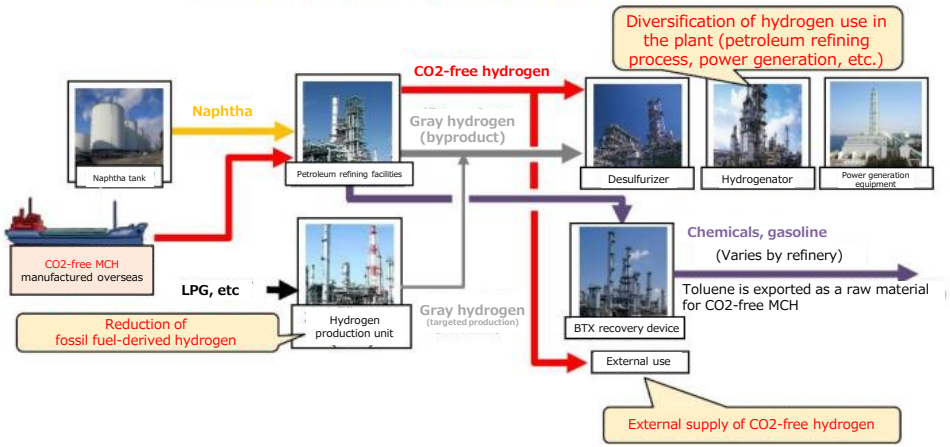
Source: The Working Group on Energy Structure Conversion (7th meeting), Green Innovation Project Subcommittee, Industrial Structure Council

2. Overview of Oil Industry | (Reference) Research and Development Trends in Japan

- In addition to projects related to the hydrogen supply chain, fuel ammonia, and synthetic fuels as GI Fund projects, research and development is also underway through NEDO and other projects, which the public and private sectors are working together to implement.

An example of the GI Fund's large-scale hydrogen supply chain construction project

< MCH dehydrogenation using existing refinery facilities >



NEDO Bio-Jet Fuel Production Technology Development Project

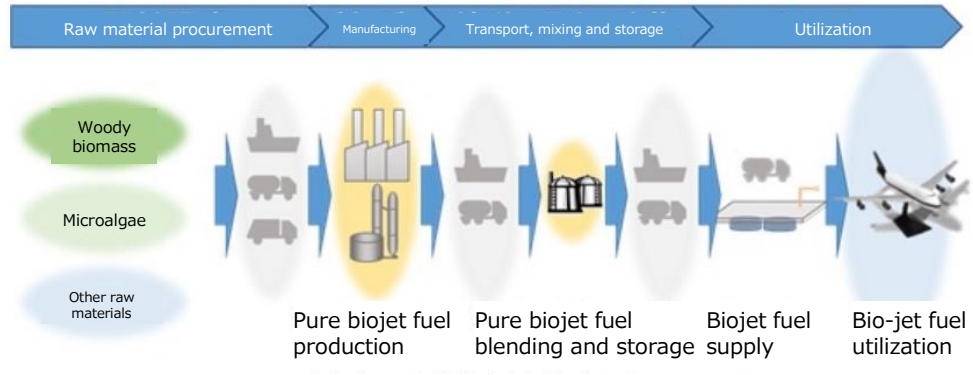


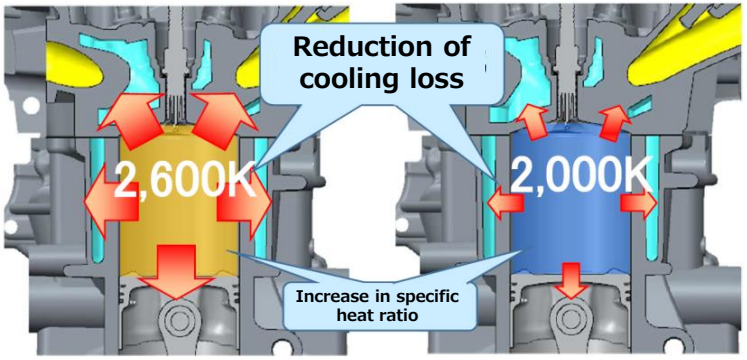
Image of bio-jet fuel production and supply chain

Source: GI Fund website, GI Fund summary materials, NEDO website

2. Overview of Oil Industry | New Fuel that Improves Fuel Efficiency of Internal Combustion Engines

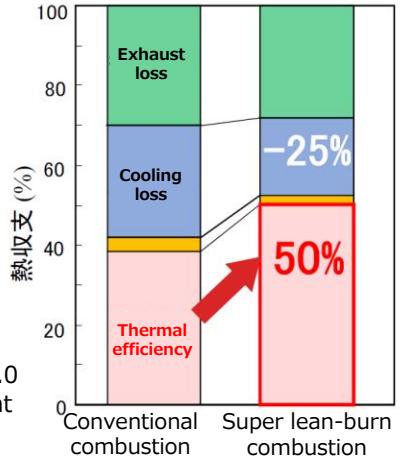
- According to a 2017 IEA analysis, 84% of vehicles will be powered by engines in 2040.
- In April 2020, the Petroleum Association of Japan and the Japan Automobile Manufacturers Association started a joint study to reduce CO2 emissions on a well-to-wheel basis and further improve emissions of vehicles with engines that can coexist with EVs (electric vehicles).
- The aim of this ongoing study is to clarify the optimum composition of liquid fuels for innovative high-efficiency combustion engines in the future (such as Super lean-burn combustion for gasoline engines), since the required fuel characteristics may differ from those of conventional engines, and to reflect this in the product standards for gasoline and diesel fuel after 2030.
- At first, mainly petroleum-based base materials are used, but gradually, biofuel base materials and synthetic fuel base materials will be used to produce fuel.

A representation of the future combustion system (example of a gasoline engine)



Conventional combustion
λ (excess air ratio) = 1.0

Super lean-burn combustion λ = 2.0
(combustion with twice the amount of air as shown in the left figure)

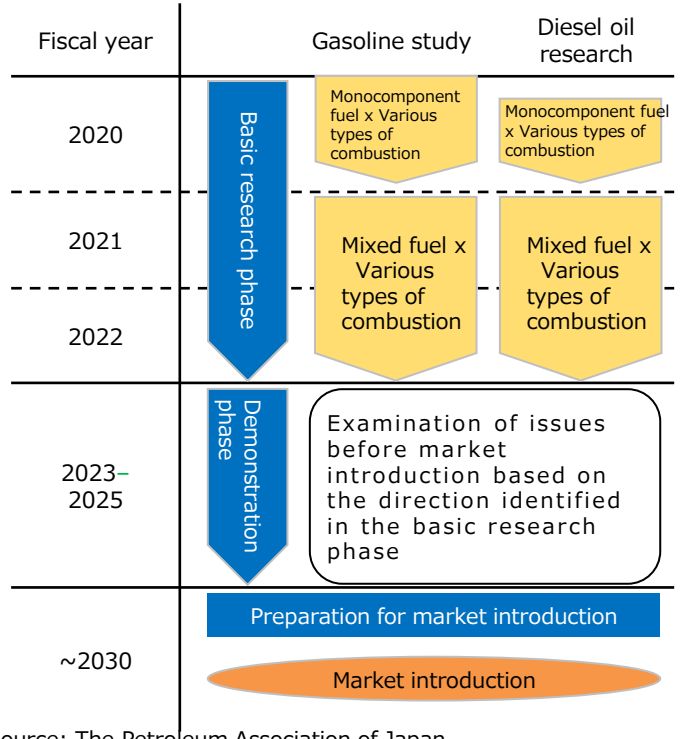


The future mainstream method for improving thermal efficiency is to reduce energy loss by lowering the combustion temperature while sufficiently controlling emissions (NOx, etc.) (similar studies are underway in Europe and the United States).

Fuel characteristics required for combustion are likely to vary.

Source: Compiled by the Petroleum Association of Japan from materials related to the Final Open Symposium on SIP, Innovative Combustion Technology

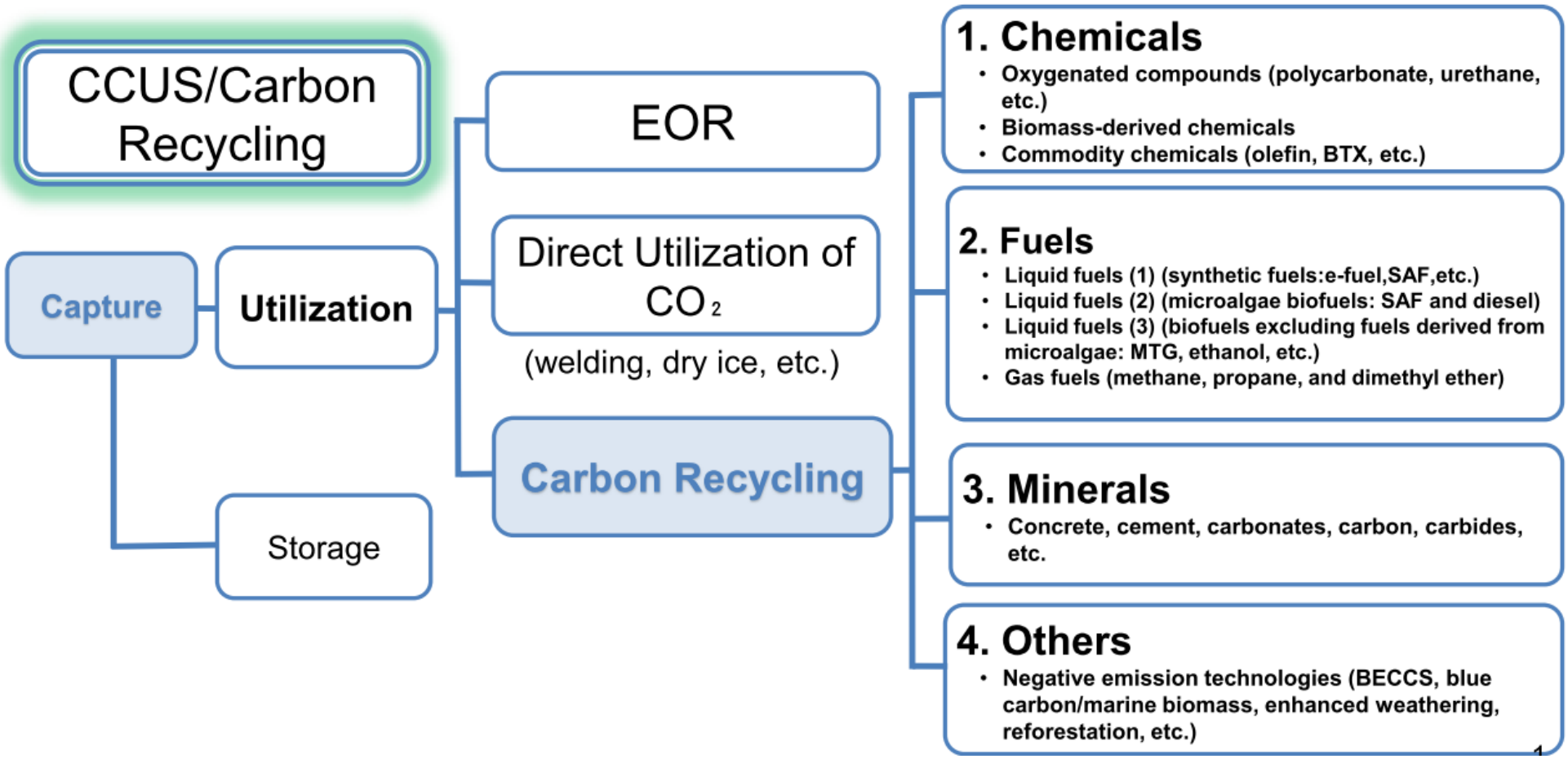
Study schedule



Source: The Petroleum Association of Japan

2. Overview of Oil Industry | Carbon Recycling and CCUS

- In carbon recycling, the recovered CO2 is reused as minerals (concrete), fuel, chemicals, etc. through chemical reactions with CO2-free hydrogen, etc.
- CO2 separation and recovery is a common technology for carbon recycling and an essential one for the social implementation of carbon recycling.

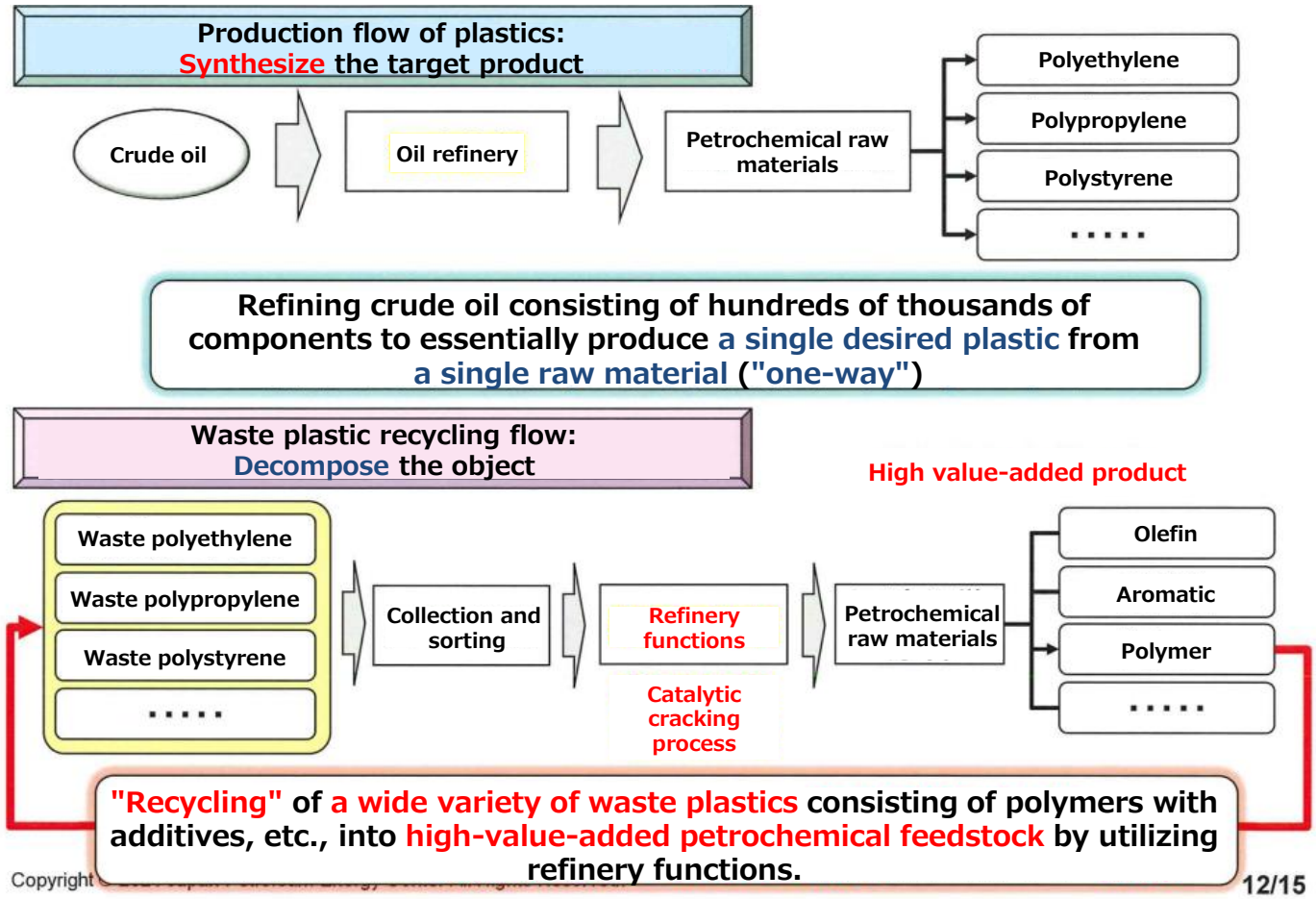


Source: Handout of the Working Group on Energy Structure Conversion (6th meeting), Green Innovation Project Subcommittee, Industrial Structure Council
(Source: (4) Direction of R&D and social implementation of the "Technology Development for CO2 Separation and collection, etc." Project)

2. Overview of Oil Industry | Waste Plastic Recycling in the Petroleum Refining Process

- Oil companies are engaged in chemical recycling, in which waste plastic is converted into oil and recycled into chemical raw materials through petroleum refining equipment.

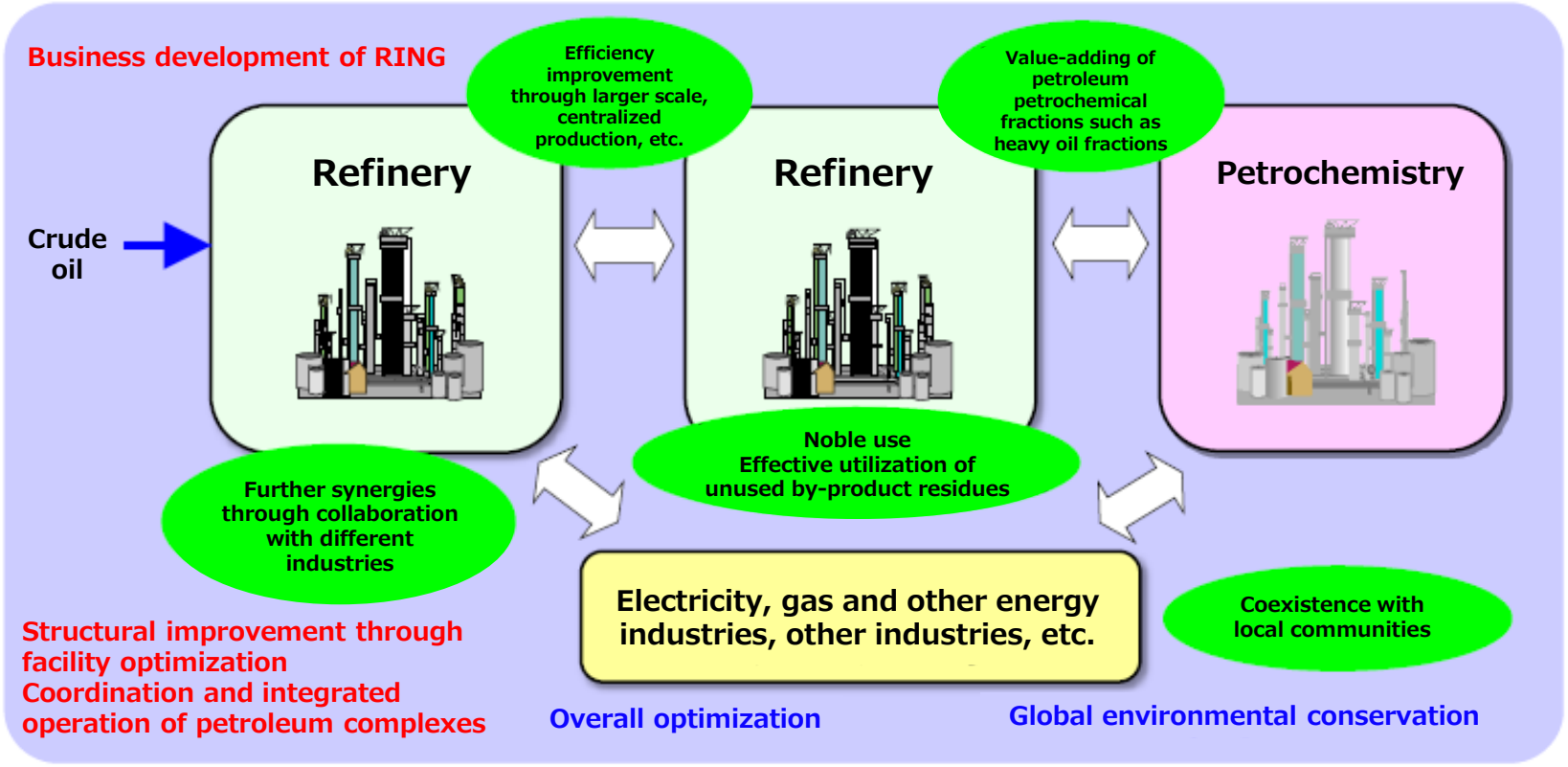
< Example of Waste Plastic Recycling Flow in the Petroleum Refining Process >



Source: FY 2021 JPEC Forum: Technology Development for Plastic Resource Recycling Process – Development for Petrochemical Raw Materials Process (May 12, 2021)

2. Overview of Oil Industry | (Reference) Integration and Cooperation of Refineries

- To achieve carbon neutrality in oil industry, in addition to upgrading of refining technology at refineries, **overall optimization through cooperation and integration between refineries** is also important.
- In addition, promoting the production of decarbonized fuels (biofuels, synthetic fuels, etc.) in the oil sector can also **contribute to decarbonization through the conversion of raw materials in the chemical sector,** which is downstream from the oil sector.



Source: Handout of the Working Group on Energy Structure Conversion (6th meeting), Green Innovation Project Subcommittee, Industrial Structure Council
Research Association of Refinery Integration for Group-Operation (RING), https://ring.or.jp/wp-content/uploads/2021/04/RINGの事業概要.pdf

2. Overview of Oil Industry | Examples of Products Contributing to Decarbonization

- The products manufactured by the petroleum businesses are used in the transportation field, such as in automobiles, and the electronics field, such as organic EL and battery materials, and contribute to reducing CO2 emissions from economic activities in other fields by improving efficiency, such as facilitating energy conservation.

Examples of Products Contributing to Decarbonization

Fuel-saving engine oil

The latest standard (ILSAC* GF -6) is over 1% more fuel-efficient than the previous standard.

*A gasoline engine oil standard established by an association of Japanese and U.S. automobile manufacturers. Comparison of GF -5 and GF -6

Carbon fiber composite

About 10 times stronger than steel; specific gravity is about 1/4 of iron's

Excellent wear resistance, acid resistance, thermal conductivity, etc.

OLED material

When an electric current is applied, it emits light by itself, eliminating the need to backlight the LCD panel, thus saving energy.

Battery material

① Anode material for lithium-ion batteries

② Development of all-solid-state battery with excellent energy density and charge/discharge performance

artificial graphite

Source: Data from the Petroleum Association of Japan

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3. Technology Pathways to Decarbonization | ① Low-Carbon and Decarbonization Technologies for Carbon Neutrality “Crude Oil Treatment”

Crude oil treatment

Technology	Overview	Emission Intensity[*1]	Implementation year[*2]	Main References[*3]
Strengthening energy efficiency measures	✓ Effective use of heat, introduction of advanced control and high-efficiency equipment, improvement in power system efficiency, large-scale improvement and upgrading of processes, etc.	-	Implemented	• Strategic Energy Plan • Commitment to a Low Carbon Society
Promoting fuel conversion	✓ Conversion from petroleum fuels to natural gas, etc.	-	Implemented	• Strategic Energy Plan
Conversion to decarbonized fuels	✓ Conversion from fossil fuels to decarbonized fuels such as CO2-free hydrogen	Up to 100% reduction	2030s	• Strategic Energy Plan • Green Innovation Fund - Social Implementation Plan[*4]
Promoting the use and development of renewable energy and zero-emission power sources	✓ Greening of electric power in the petroleum refining process	Up to 100% reduction	Implemented	• Strategic Energy Plan • Green Growth Strategy Through Achieving Carbon Neutrality in 2050
Transforming refining processes	✓ Decarbonization of refining processes by utilizing CO2-free hydrogen	Up to 100% reduction	2030s	• Strategic Energy Plan • Green Growth Strategy Through Achieving Carbon Neutrality in 2050
CCS/CCU	✓ CO2 recovery from refining processes ✓ Production of fuels and materials (e.g. carbonates) from the CO2 captured ✓ CCS introduction	Up to 100% reduction	2030s	• Strategic Energy Plan • Green Growth Strategy Through Achieving Carbon Neutrality in 2050 • Green Innovation Fund - Social Implementation Plan

*1: Calculated from the CO2 reduction by the target technology based on the existing emission intensity. The CO2 reduction is accounted only from the relevant process.
*2: Refers to the starting year of the *introduction and expansion/cost reduction phase* in the Social Implementation Plan.
*3: Underlined when referenced for implementation year.
*4: R&D and Social Implementation Plan in the Green Innovation Fund.

3. Technology Pathways to Decarbonization | ① Low-Carbon and Decarbonization Technologies for Carbon Neutrality “Low-Carbon and Decarbonized Fuel and Products”

Low-carbon and decarbonized fuels and products

	Technology	Overview	Emission Intensity[*1]	Implementation year[*2]	Main References[*3]
Improving the efficiency of existing fuels	Chemical recycling of waste plastic	✓ Production of fuel and chemical raw materials by converting waste plastic into oil and carrying out chemical recycling using petroleum refining equipment	-	2030s	• Green Growth Strategy Through Achieving Carbon Neutrality in 2050
	New fuel that contributes to improving the fuel efficiency of internal combustion engines	✓ Emission reduction through optimization of future innovative engine combustion methods and fuel combinations, etc.	-	Late 2020s	• The Petroleum Association of Japan’s “Vision for Carbon Neutrality in the Oil Industry”
Hydrogen and ammonia	Establishment of a CO2-free hydrogen and ammonia supply chain	✓ Higher efficiency of manufacturing and transportation technologies ✓ Dehydrogenation and storage using refinery facilities ✓ Domestic supply and in-house use (for power generation, automobile fuel, raw materials, etc.)	Up to 100% reduction	2030s	• Green Innovation Fund - Social Implementation Plan[*4] • Green Growth Strategy Through Achieving Carbon Neutrality in 2050 • Strategic Energy Plan
	Development of hydrogen stations, etc.	✓ Supplying hydrogen for fuel cell vehicles	-	Implemented	• Strategic Energy Plan • Green Growth Strategy Through Achieving Carbon Neutrality in 2050

*1: Calculated from the CO2 reduction by the target technology based on the existing emission intensity. The CO2 reduction is accounted only from the relevant process.
*2: Refers to the starting year of the *introduction and expansion/cost reduction phase* in the Social Implementation Plan.
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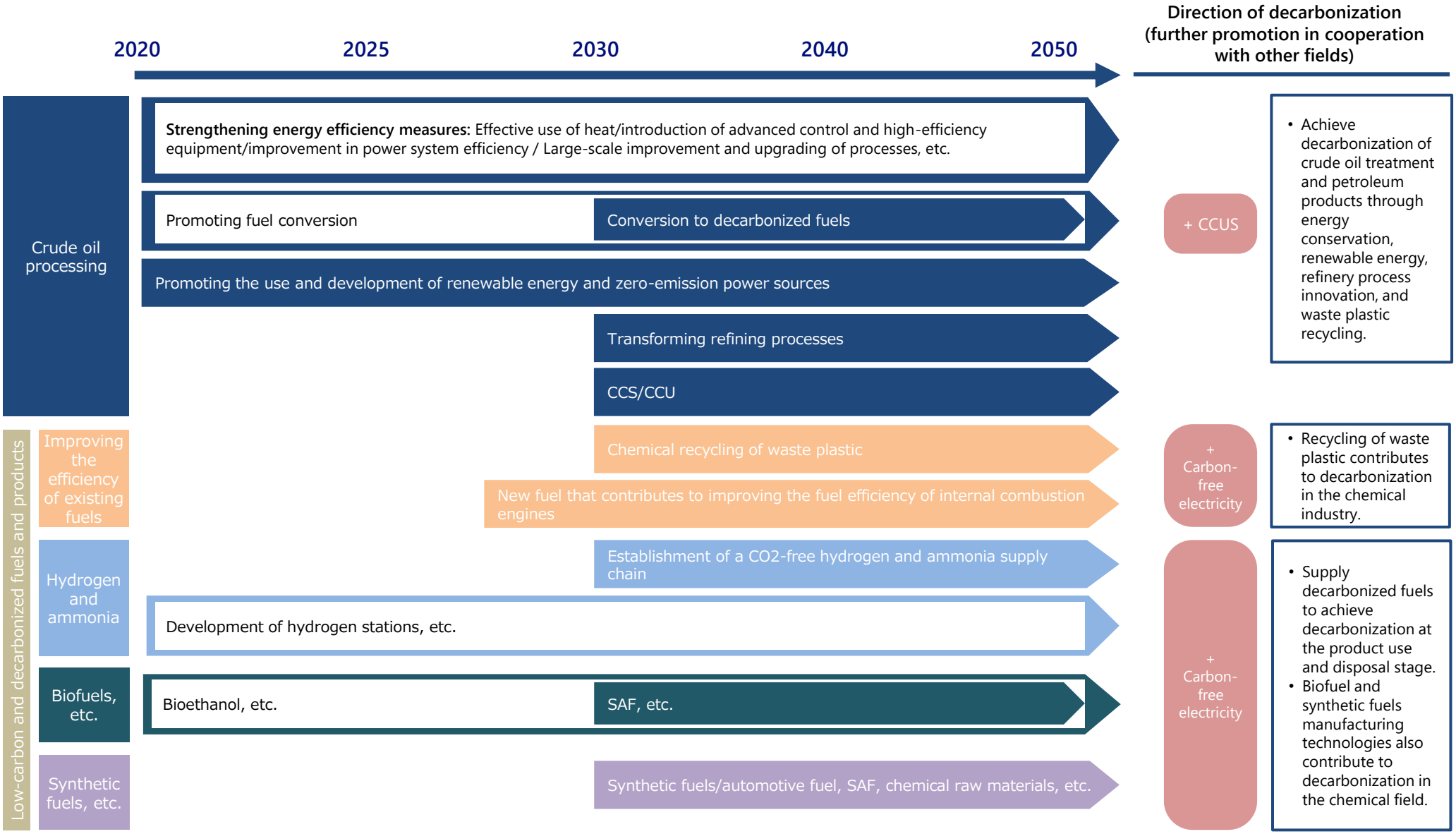
3. Technology Pathways to Decarbonization | ① Low-Carbon and Decarbonization Technologies for Carbon Neutrality “Low-Carbon and Decarbonized Fuel and Products”

Low-carbon and decarbonized fuels and products
- Biofuels, etc.
- Synthetic fuels, etc.

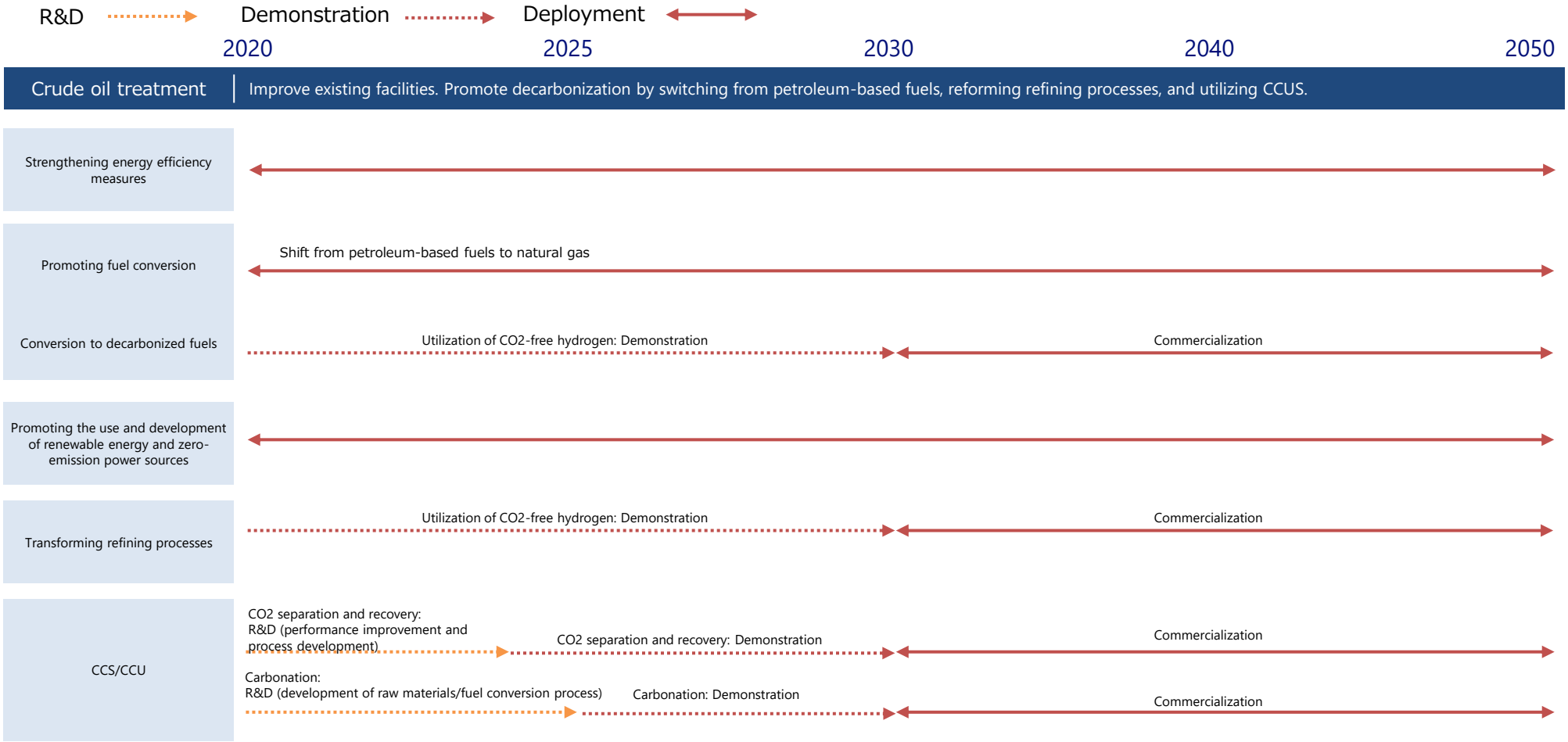
Technology	Overview	Emission Intensity[*1]	Implementation year[*2]	Main References[*3]
Biofuels, etc. (bioethanol, biodiesel, SAF, chemical raw materials, etc.)	✓ Production of liquid fuels and chemical raw materials from plants and waste materials	Up to 100% reduction	Partially deployed (implementation of SAF manufacturing technology around 2030)	• Green Innovation Fund - Social Implementation Plan[*4] • Green Growth Strategy Through Achieving Carbon Neutrality in 2050 • Commitment to a Low Carbon Society • Strategic Energy Plan • IEA-ETP 2020
Synthetic fuels, etc. (automotive fuel, SAF, chemical raw materials, etc.)	✓ Production of liquid fuels and chemical raw materials from hydrogen and CO2	Up to 100% reduction	2030s	• Green Innovation Fund - Social Implementation Plan • Green Growth Strategy Through Achieving Carbon Neutrality in 2050 • Strategic Energy Plan • IEA-ETP 2020

*1: Calculated from the CO2 reduction by the target technology based on the existing emission intensity. The CO2 reduction is accounted only from the relevant process.
*2: Refers to the starting year of the *introduction and expansion/cost reduction phase* in the Social Implementation Plan.
*3: Underlined when referenced for implementation year.
*4: R&D and Social Implementation Plan in the Green Innovation Fund.

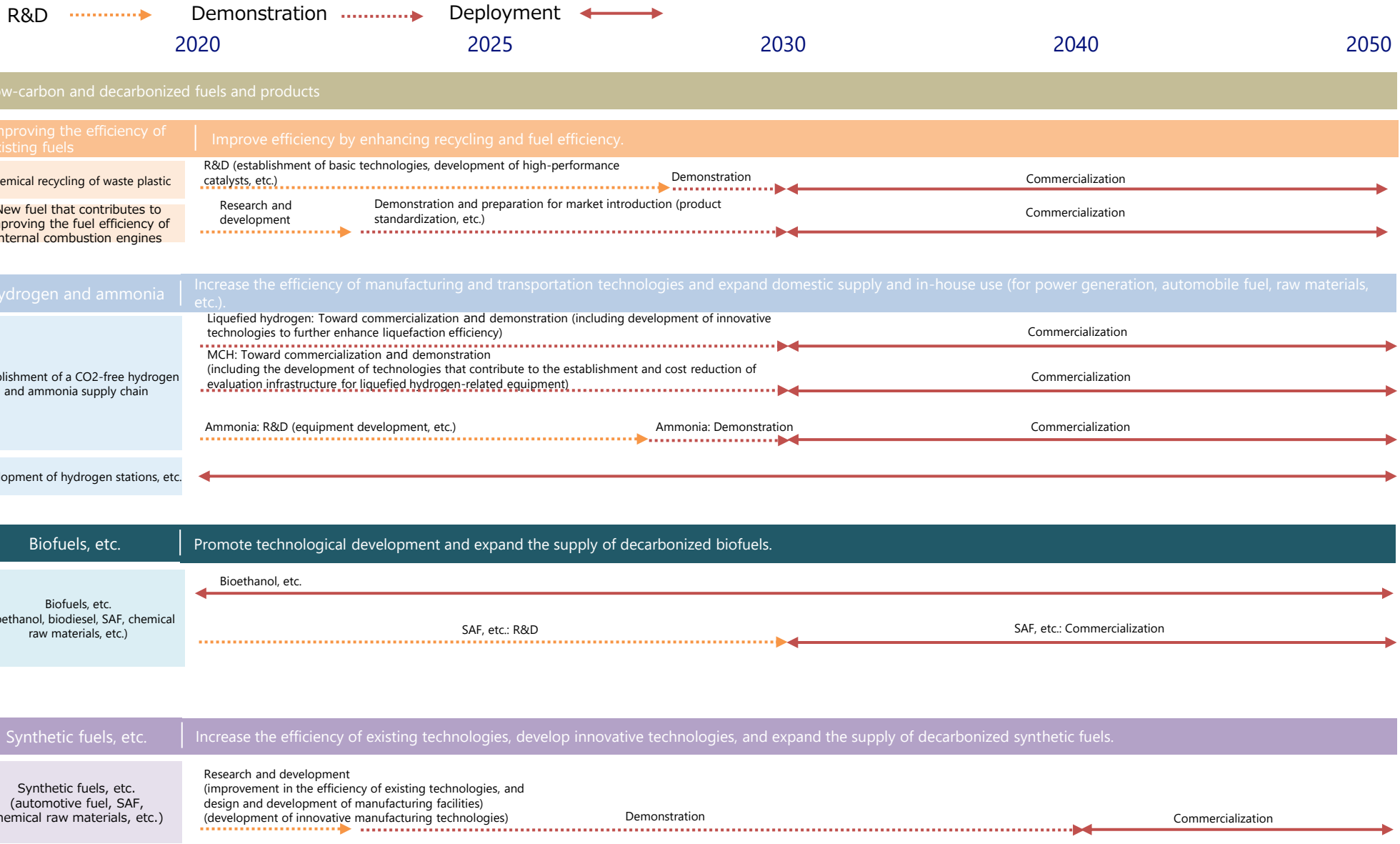
3. Technology Pathways to Decarbonization| ② Technology Roadmap



3. Technology Pathways to Decarbonization | ② Technology Roadmap【Appendix】



3. Technology Pathways to Decarbonization | ② Technology Roadmap【Appendix】



3. Technology Pathways to Decarbonization | ③ Scientific Basis/Alignment with the Paris Agreement

- The Technology Roadmap is aligned with the Paris Agreement, referring to various Japanese policies and international scenarios aimed at achieving carbon neutrality by 2050.
- With regard to crude oil treatment, in addition to steadily reducing CO2 emissions through various energy efficiency and fuel conversion measures, decarbonization by transforming refining processes and introducing innovative technologies such as CCS and CCU will be promoted. Furthermore, it is focused on achieving the 2050 carbon neutrality goal by shifting to a supply system of decarbonized fuels, including synthetic fuels.

Reference/Evidence

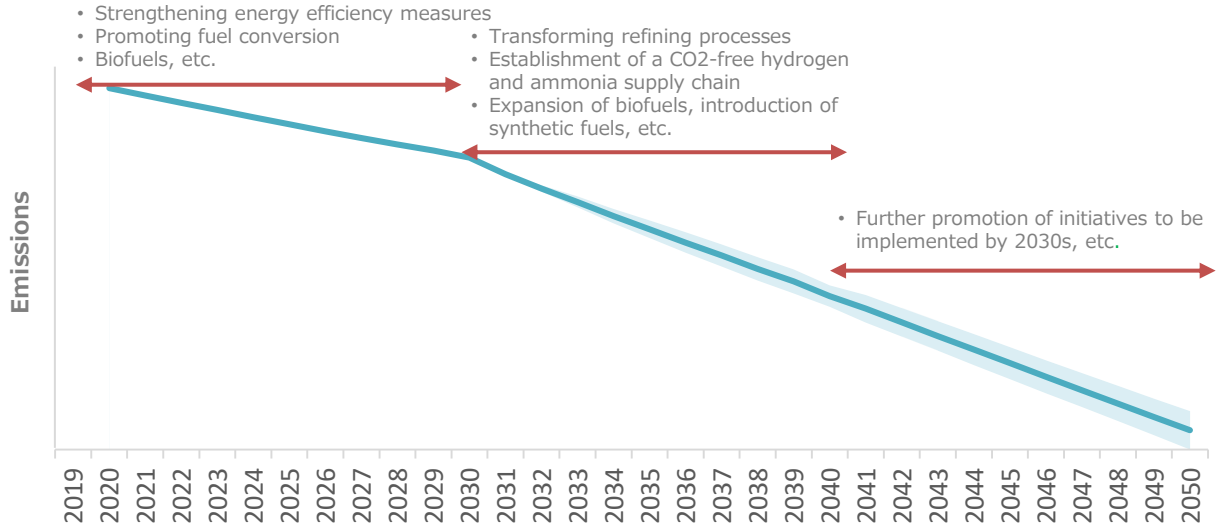
Government policies

- ✓ Basic Energy Plan and Strategic Policy Committee Materials
- ✓ Green Growth Strategy Through Achieving Carbon Neutrality in 2050
- ✓ R&D and Social Implementation Plan for the CO2 separation and recovery technology development project
- ✓ R&D and Social Implementation Plan for the fuel ammonia supply chain establishment project
- ✓ R&D and Social Implementation Plan for the hydrogen production through water electrolysis using electric power derived from renewable energy project
- ✓ R&D and Social Implementation Plan for the large-scale hydrogen supply chain establishment project
- ✓ R&D and Social Implementation Plan for the development of fuel manufacturing technology using CO2 project

International scenarios/roadmaps, etc. aligned with the Paris Agreement

- ✓ Clean Energy Technology Guide (IEA)
- ✓ World Energy Outlook 2021 (IEA)
- ✓ Science Based Target initiative

Assumed CO2 Reduction Pathway*1, 2



1 **2020~2030**
Work toward steady CO2 reduction by strengthening measures on energy efficiency in petroleum refining, and promoting fuel conversion; make efforts to expand the use of decarbonized fuels such as biofuels (SAF, etc.), which are already at the practical application stage.

2 **2030~2040**
Accelerate efforts toward carbon neutrality by reforming the petroleum refining process and establishing technologies related to decarbonized fuels such as CO2-free hydrogen, ammonia, biofuels, and synthetic fuels.

3 **2040~2050**
Achieve carbon neutrality by significantly reducing emissions through expanded use of decarbonized fuels and CCUS.

*1 It should be noted that this only illustrates the assumption of the overall Japanese oil sector's decarbonization pathway. In reality, decarbonization will be achieved based on each company's long-term strategy and therefore may not necessarily reflect this assumption.
*2 Achieving carbon neutrality by 2050 is based on the premise that CCUS and its related infrastructure, including DAC (direct air capture), will be developed in cooperation with other industries, and that the entire supply chain will become net zero.

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4. Toward Decarbonization and Achievement of the Paris Agreement

- The Roadmap is intended to exemplify low-carbon and decarbonization technologies envisioned today and indicate an estimation of when these technologies are to be established for commercialization.
- Technology development is assumed to require long-term development, and it is possible that other low-carbon and decarbonization technologies which are not described in the Technology Roadmap will be developed and adopted. In addition, there exists some uncertainties, including as economic feasibilities.
- Commercialization of low-carbon and decarbonization technologies in the oil sector will also depend on the development of societal systems, such as decarbonized power sources and CCUS. Carbon neutrality in the oil sector will be achieved in coordination with other sectors.
- Therefore, the Roadmap will be revised and updated regularly and continuously to maintain the credibility and usability of the Roadmap by considering the progress of other technologies, the trends of businesses and policies, and dialogues with the investors.
- The companies in the oil sector will aim to achieve carbon neutrality by making the best combination of technologies listed in the Roadmap according to their business decision based on long-term strategy.
- In addition, efforts for reducing CO2 emissions may include the utilization of carbon credits and the purchase of carbon offset products, not limited to “the technology” of the Roadmap.

Taskforce Formulating Roadmaps for Climate Transition Finance
Oil Sector: List of Committee Members

[Committee chair]	
Akimoto Keigo:	Research Institute of Innovative Technology for the Earth (RITE) Group Leader of Systems Research Group and Chief Researcher
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Kajiwara Atsuko:	Executive Officer, Head of Sustainable Finance Evaluation Department, Japan Credit Rating Agency, Ltd.
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Takamura Yukari:	Professor, Institute for Future Initiatives, The University of Tokyo
Takegahara Keisuke:	Executive Fellow/General Manager, Research Institute of Capital Formation and Head of Research Center on Financial Economics, Development Bank of Japan Inc.
Matsuhashi Ryuji:	Professor, Electrical Engineering and Information Systems, Graduate School of Engineering, The University of Tokyo
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