Technology Roadmap for “Transition Finance” in Pulp and Paper Sector

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Ministry of Economy, Trade and Industry

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1. Premise | Necessity of Roadmap for Pulp and Paper Sector

- Technology Roadmap for "Transition Finance" (hereinafter, technology roadmap) selects fields based on reasons including the importance of transition and an industry with high-emissions with no alternative measures of decarbonization available today (for technological and economic reasons).
- The pulp and paper industry stably and at low cost **provides paper and paperboard products that are daily necessities**, such as paper for newspapers, copy paper, and publishing paper for communication, corrugated boards, kraft paper for packaging, and toilet paper, tissue paper, and toweling paper for sanitation, **people come into contact with them on a daily basis** and the industry permeates widely and deeply into people's lives, supporting industrial activities and domestic life.
- **The industry has also become indispensable to the formation of a sound material-cycle society**, using renewable resources as raw materials, recovering and reusing used paper as much as possible, utilizing black liquor, a byproduct of pulp making, as a biomass fuel, and using construction waste and waste as fuel.
- On the other hand, the pulp and paper industry emits large amounts of CO2 at the present time and is the 4th largest CO2 emitting manufacturing industry in Japan. Due to the high dependency on fossil fuels, **transition toward net zero in the pulp and paper sector is essential** and a large amount of funding will be required for the effective use of existing facilities and related equipment, R&D/implementation of innovative technologies for low-carbonization, as well as updating/introduction of energy-saving facilities. In this regard, we examined domestic and overseas technologies and developed a pathway to 2050.
- Technology innovation and structural change of business for decarbonization will become advantages of companies. To attract world’s ESG investments which grew to ¥3,500 trillion ($35 trillion : by GSIA) as of 2020, high-emitting industries are required to disclose their strategies with the understanding of investors’ perspectives.
- In terms of contributing to increase the international competitiveness of Japanese pulp and paper industry, the Technology Roadmap was developed through the discussion held with technology and finance experts and representatives of the pulp and paper companies in Japan.

1. Premise | Objectives and Positioning of Roadmap①

- The Technology Roadmap is designed to serve as a reference for **the pulp and paper companies in Japan, when investigating measures against climate change using transition finance (Note)** based on "the Basic Guidelines on Climate Transition Finance" (Financial Services Agency, Ministry of Economy, Trade and Industry, Ministry of the Environment, May 2021).
- **It is intended to help** banks, securities companies and investors **to assess the eligibility of the fundraiser's decarbonization strategies and approaches.**
- **The final goal of the Technology Roadmap is to achieve 2050 carbon neutrality** and based on information currently available, the Technology Roadmap provides envisions of low-carbonization/decarbonization technologies that are expected to be deployed by 2050 and when these technologies will be deployed.
- The Technology Roadmap is aligned with Nationally Determined Contribution (NDC) based on Paris Agreement*1, Green Growth Strategy*2, and R&D and Social Implementation Plan using Green Innovation Fund*3.
- Fuel switching is the key to achieve carbon neutrality in the pulp and paper industry, and innovative technologies such as new carbon-neutral fuels are drawing attention, but early application is difficult. Therefore, looking ahead towards 2030 and 2040, **the transition period, it is essential to further advance efforts on "transition" from fossil fuels to renewable energy sources such as woody biomass, natural gas with low CO2 emissions and waste fuels.**

(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 : https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Japan%20First/JAPAN_FIRST%20NDC%20(INTERIM-UPDATED%20SUBMISSION).pdf
* 2 : https://www.meti.go.jp/english/policy/energy_environment/global_warming/ggs2050/pdf/ggs_full_en1013.pdf
* 3 : https://www.nedo.go.jp/content/100932374.pdf

1. Premise | Objectives and Positioning of Roadmap②

- Transition finance includes not only the investment on facilities and R&D toward low-carbonization/decarbonization within the company but also cost of dismantlement/removal of existing facilities and response to outside environment or social impact (such as land contamination associated with withdrawal from business, decommissioning of furnaces etc. and impact on employment), efforts/activities that contribute to the transition of other industries arising from activities to reduce emissions.

- In the pulp and paper sectors, **products contribute to decarbonization (eco products**, noted in P22**) for other industries can be subject to transition finance.** Moreover, Basic Guidelines on Climate Transition Finance (noted in P8) states ”Transition finance is **available for not only entities with strategies and plans for reducing emissions associated with their corporate economic activities, but also entities that plan to take initiatives that enable others to implement transition strategies through their own products and services”.**

- These are important elements for the decarbonization of whole society and economy. At the same time, as these efforts/activities are extremely broad, **the Technology Roadmap will cover the “technologies” for low-carbonization/decarbonization mainly in the pulp and paper sector.**

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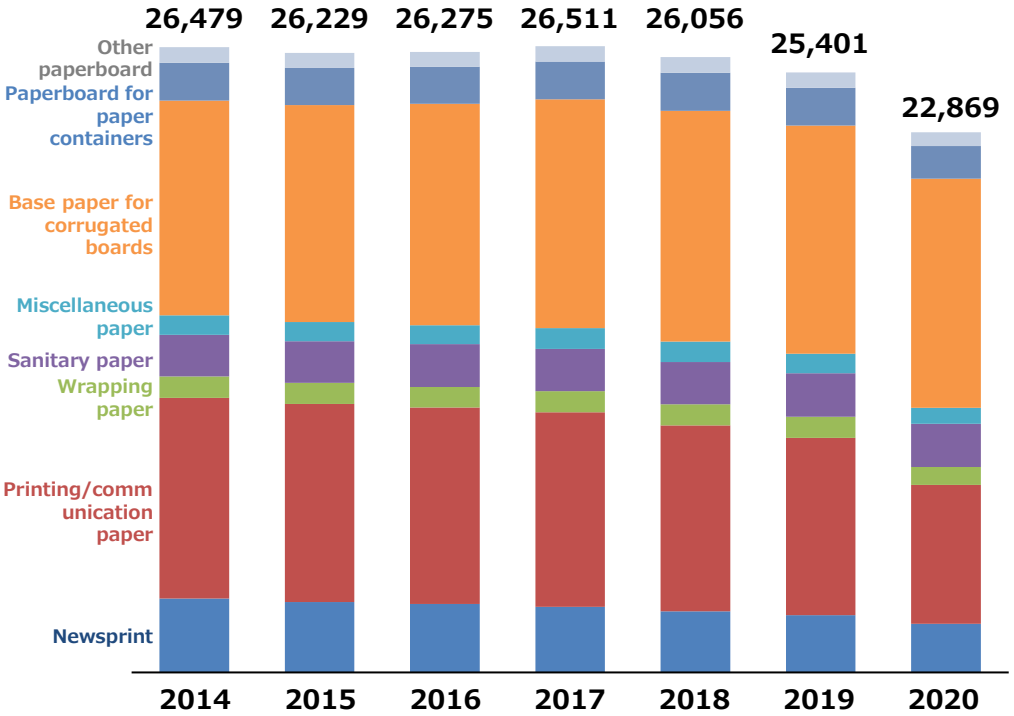
2. Overview of Pulp and Paper Industry | Industrial Scale

- **Total gross domestic shipments is about 7.5 trillion yen** (about 2.3% of the whole manufacturing industry). **The companies employ about 187,000 people.**
- **Domestic demand is on the decrease mainly for printing and communication paper** due to structural factors such as digitization and the declining birth rate.
- The industry manufactures pulp and **paper/paperboard products from wood that support industrial activities and domestic life such as paper for communication, packaging, and sanitation** using various processing technologies.

Paper/paperboard production volume (thousand tons)

- The production volumes of newsprint and paper for printing/communication are on the decrease due to digitization
- On the other hand, that of base paper for corrugated board is on a slight increase thanks to the expansion of e-commerce (EC), etc.



Main types and purposes of paper/paperboard

- Paper/paperboard is used for various purposes such as communication, packaging, and sanitation and it supports diverse industrial activities and domestic life.

Paper/paperboard

Communication

For newspapers
- Newsprint

For communication
- Communication paper

For printing
- Uncoated wood free printing and writing paper
- Thin printing paper
- Special printing paper
- Wood containing paper, middle grade
- Wood containing paper, low grade
- Art coated paper
- Other coated paper
- Ultra light weight coated paper

...And others

Packaging

For bags and packaging bags
- Unglazed kraft paper
- Machine glazed poster paper

...And others

For corrugated container
- Kraft liner board
- Jute liner board for interior
- Corrugating medium

...And others

For paper containers
- White liner board
- Manila board
- Straw boards
- Colored paperboard

..And others

Sanitation

For sanitation
- Toilet paper
- Tissues
- Towel paper

...And others

Others

For industrial use
- Wallpaper
- Laminated plate
- Tableware/ containers
- Electrical insulating paper
- Glassine paper
- Rice paper
- Building paper board
- Mill wrapper
- Paper tubes

..And others

For domestic use
- *Shodo* (calligraphy) paper

...And others

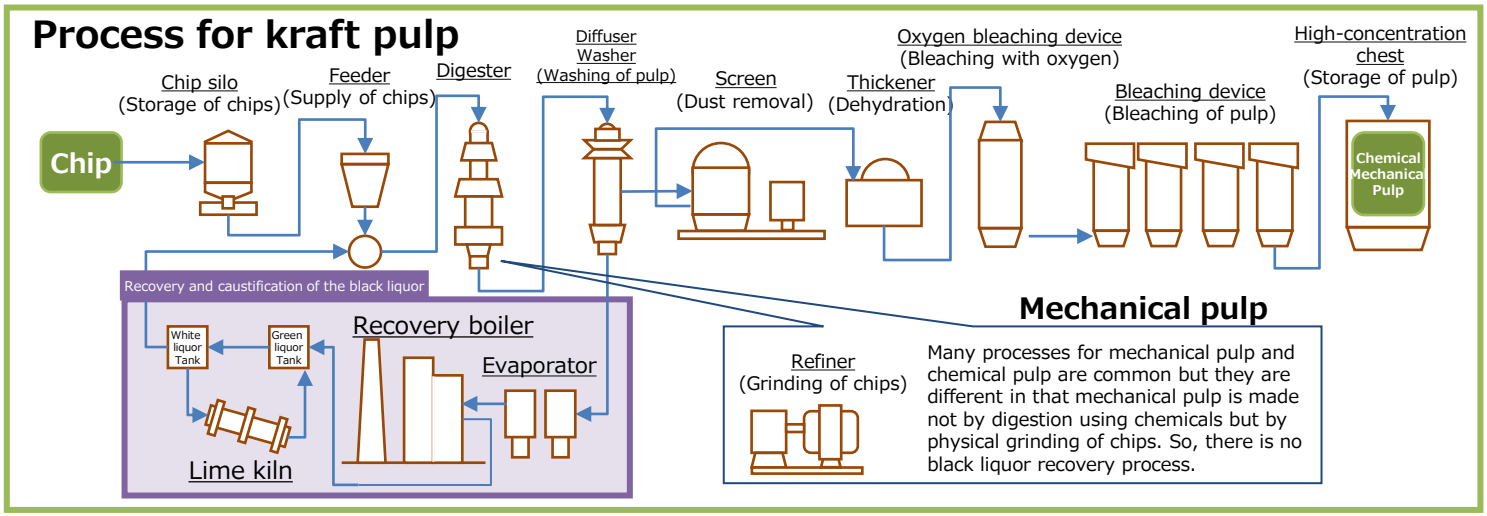
Source: Website of the Japan Paper Association

- Manufacturing process consists of **the preceding process of producing pulp using wooden chips and waste paper as raw materials** and **the following process of producing paper from pulp,** and requires **much heat and electricity for the digestion and drying processes**.

Pulp manufacturing

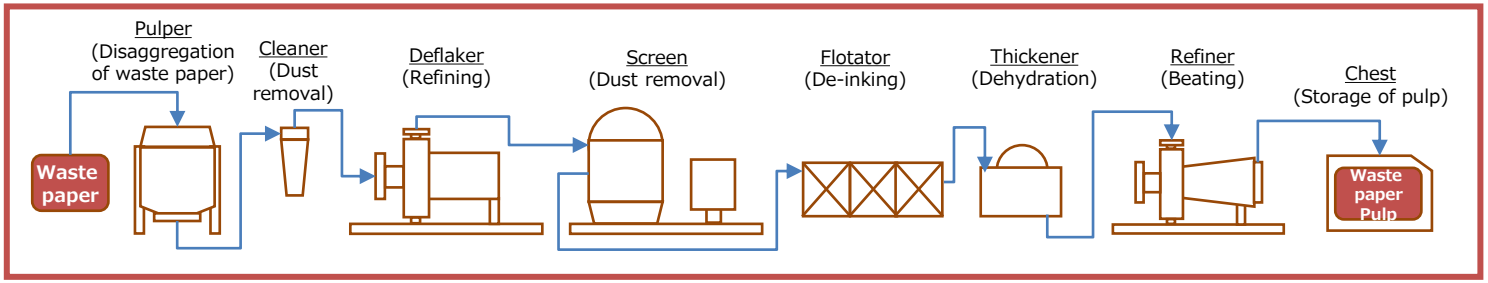
Chemical and mechanical pulp

- Process to manufacture pulp using wooden chips as material.
- Kraft pulp made by digestion of chips with chemicals and mechanical pulp made by physical grinding.
- The black liquor generated in manufacturing chemical pulp is collected and used as an energy source and the recycled chemicals are also collected and reused.



Deinked pulp

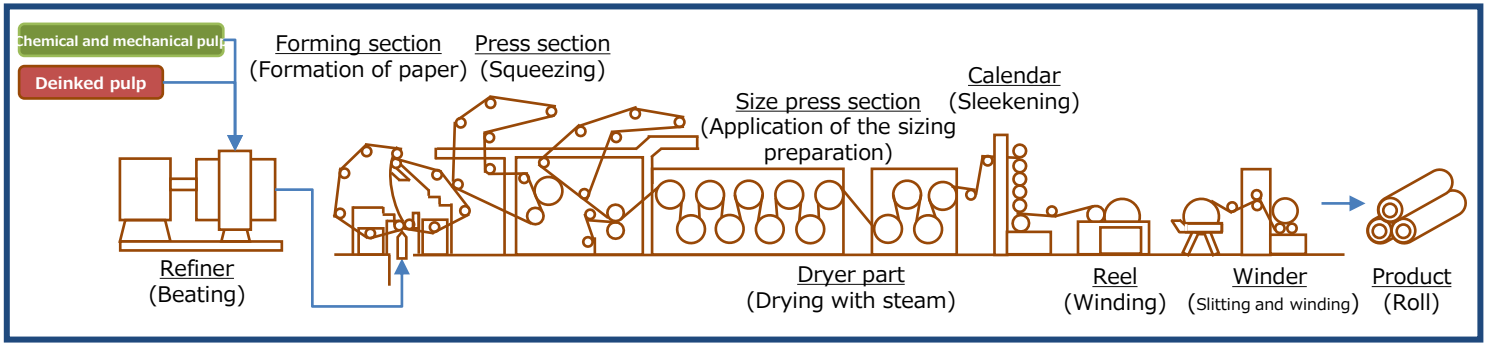
- Process to manufacture pulp using waste paper as raw material.
- Pulping by disaggregation, dust removal, de-inking, etc.



Paper manufacturing

Papermaking/coating

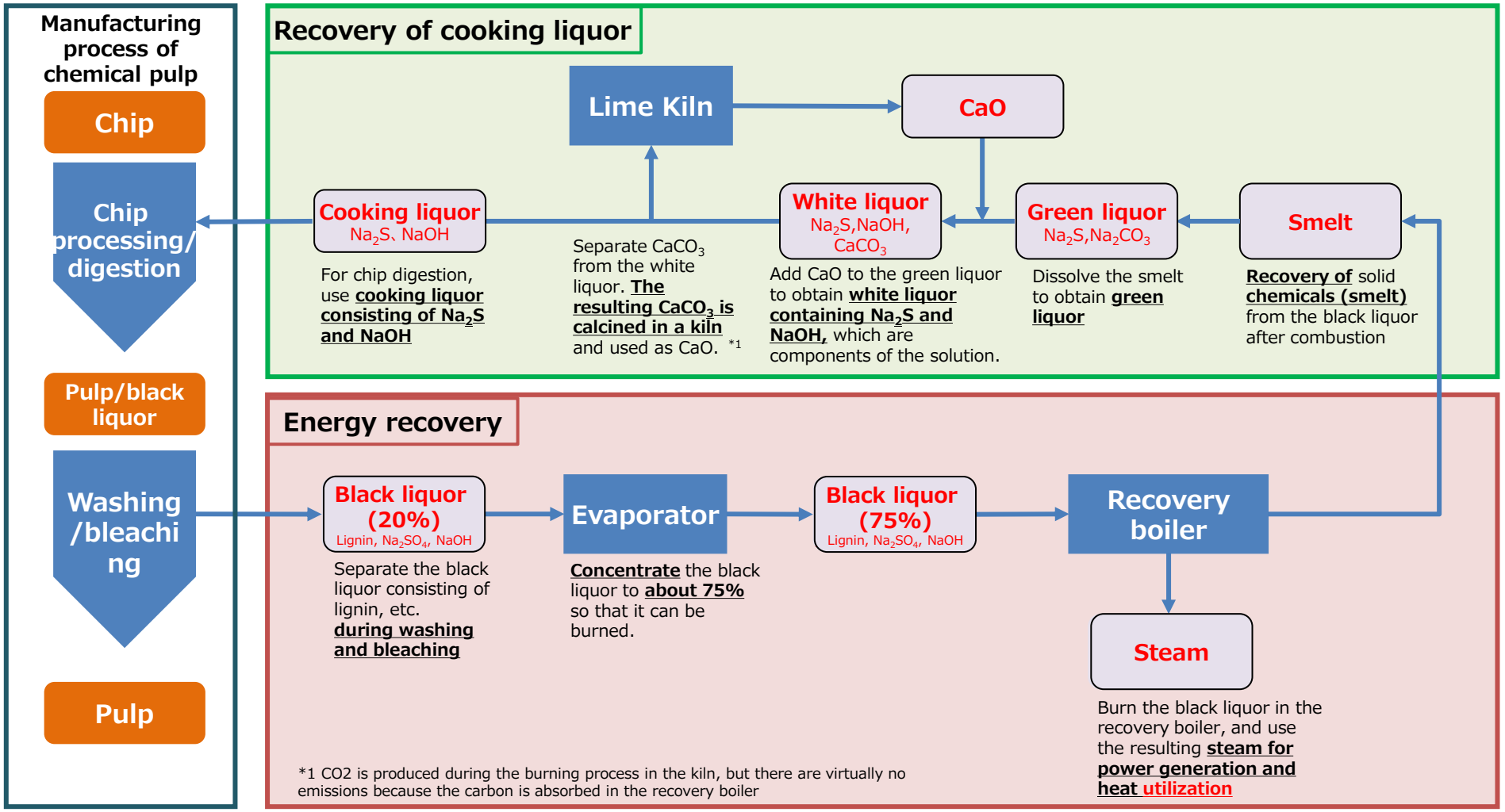
- Process to manufacture paper from pulp.
- Making paper by drying pulp which contains 99% water by pressing, heating, etc.
- Coat the paper surface with additives, etc.



Source: Prepared by referring to the website of the Japan Paper Association

 Effective Use of Energy and Used Chemicals Associated with Chemical Pulp Manufacturing

- **The black liquor** (side product with lignin as its main component) **produced in the chemical pulp manufacturing process** is concentrated and **used as fuel in the recovery boiler**. In addition, after combustion in the boiler, **the chemicals are recovered from the black liquor and causticized to produce components to be used for digestion** for **effective use of energy and efficient circulation of chemicals**.

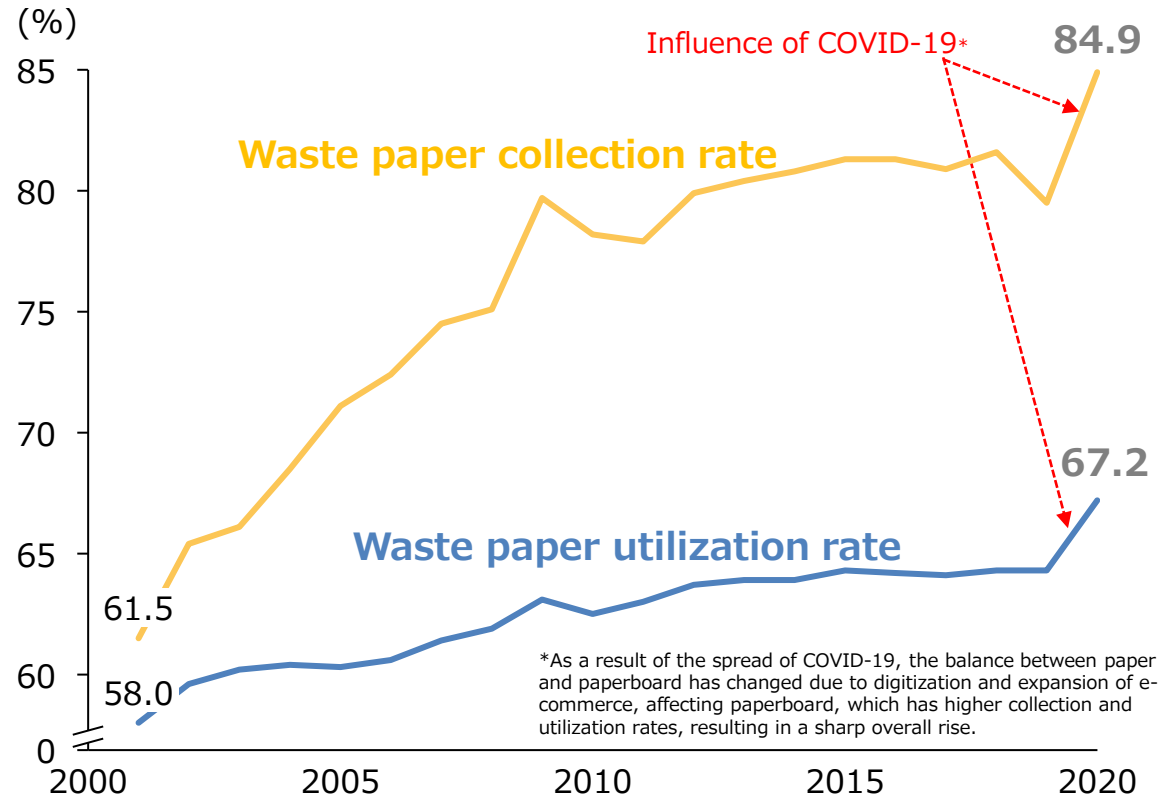


Source: Prepared based on M. R. Mobarakeh et al. 2021, etc.

Resource Recycling through Waste Paper Recycling

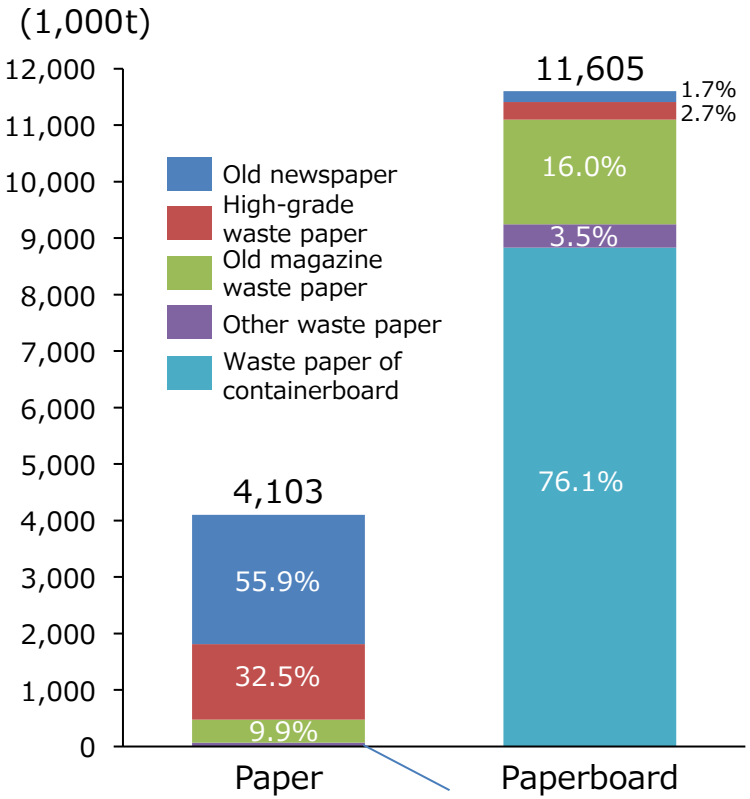
- Japan's waste paper collection and utilization rates are among the highest in the world, and they **form a sound material-cycle society.** As a producer of paper and a consumer of waste paper, Japan is **promoting the use of waste paper,** and from the viewpoint of securing raw materials, **also striving to expand the use of difficult-to-process waste paper (paper garbage that was difficult to collect and use in the past)**.
- On the other hand, **it is important to use the most appropriate raw materials for each paper variety, and to balance on demand and price while maintaining quality.** The surplus waste paper in Japan is exported to Southeast Asia, etc.

Transition in the collection and utilization rates of waste paper



Consumption of waste paper by paper/paperboard (2020)

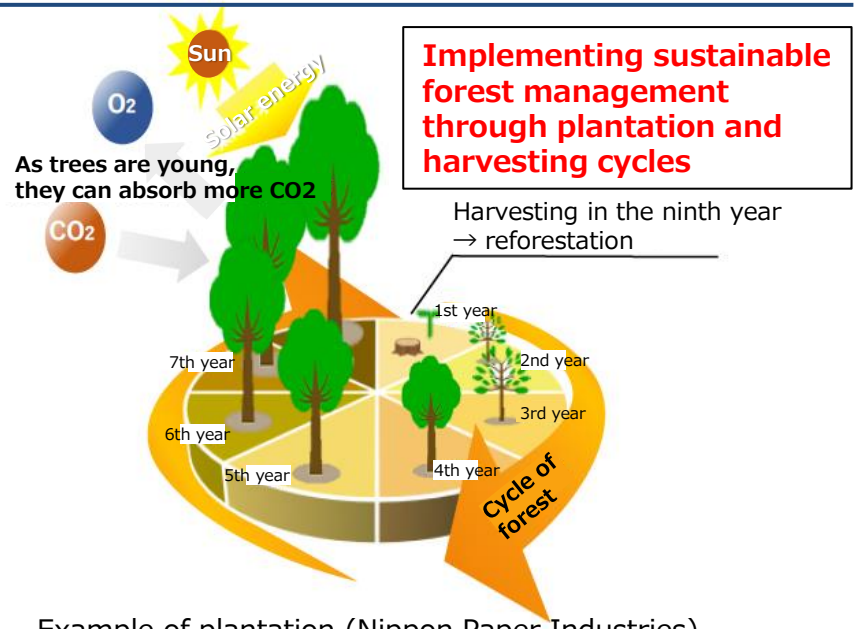
It is necessary to use raw materials adapted to the variety, e.g. chemical pulp for high-quality white paper and deinked pulp for containerboard.



Source: Prepared based on paper, printing, plastic products and rubber products statistics of Yearbook/Monthly report of current production statistics and Trade Statistics of Japan

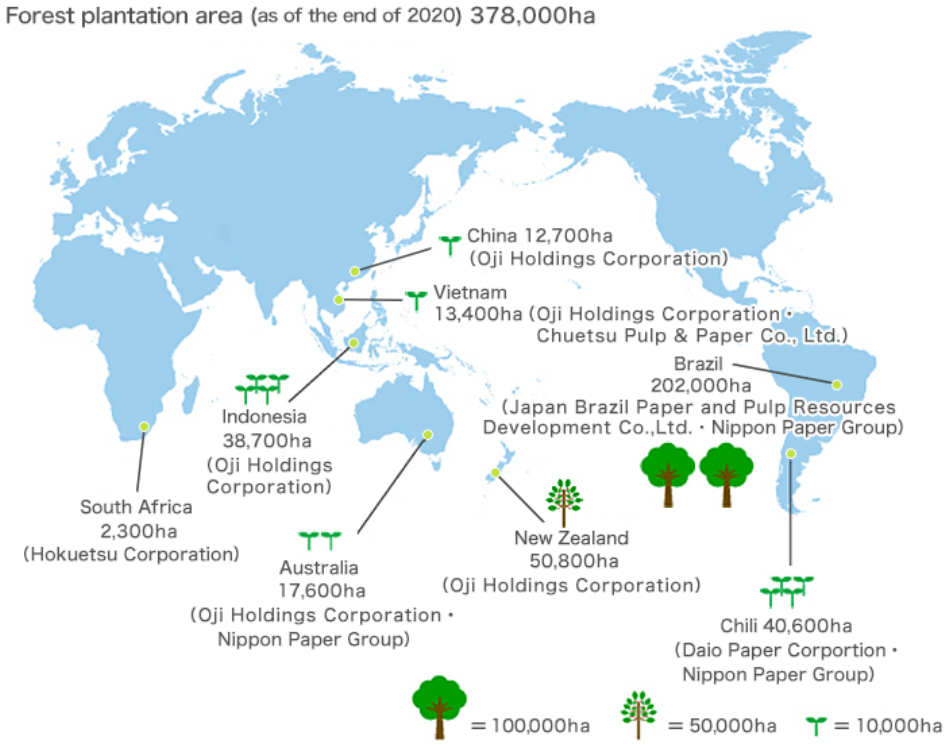
- The pulp and paper industry owns forests, which are used as raw materials and fuels, **promotes sustainable forest management through appropriate management**, including the conservation of biodiversity and respect for human rights, and **contributes to the absorption and sequestration of CO2**.
- **The pulp and paper industry contributes** to carbon neutrality of the entire society by **the expansion of CO2 absorption and sequestration through systematic harvesting and reforestation, expansion of the plantation area, and promotion of forest tree breeding with high environmental adaptability and growth increment.**

Conceptual image of industrial plantation



Example of plantation (Nippon Paper Industries)

Overseas plantation in the pulp and paper industry



*Brazil's Japan Brazil Pulp and Paper Resource Development Co.,Ltd. is a consolidated subsidiary of Oji Holdings Corporation as of March 2022.

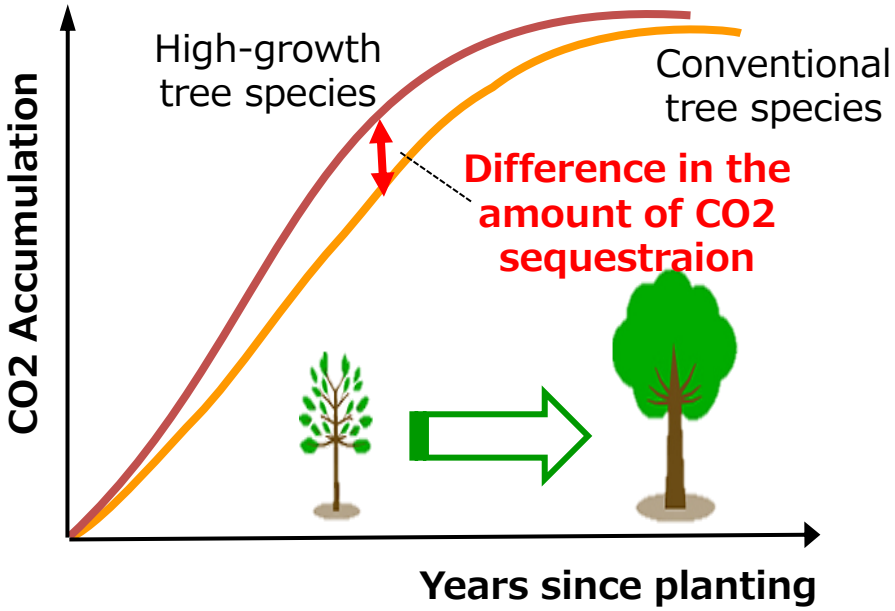
Source: Website of the Japan Paper Association and Nippon Paper Industries

 # Fast-growing Trees (Elite Trees)

- Planting fast-growing forest tree species (elite trees, etc.) **increases the amount of growth and CO2 absorption (1.5 times or more) for the same forest area**, contributing to carbon neutrality for society as a whole, and **might also contribute paper companies, which own and manage vast domestic forests, to achieve net zero emissions**[*1].

*1: The adjustment of schemes, etc. associated with offsets is a prerequisite.

Conceptual image of growth potential of planted trees and CO2 accumulation



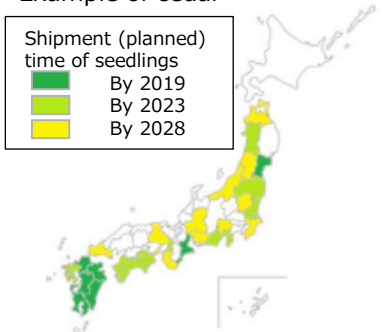
*Assumption that the total sequestration amount will constantly increase by reforesting elite trees after harvesting.

Fast-growing trees (elite trees)

The shipment of elite trees, etc. (planned)

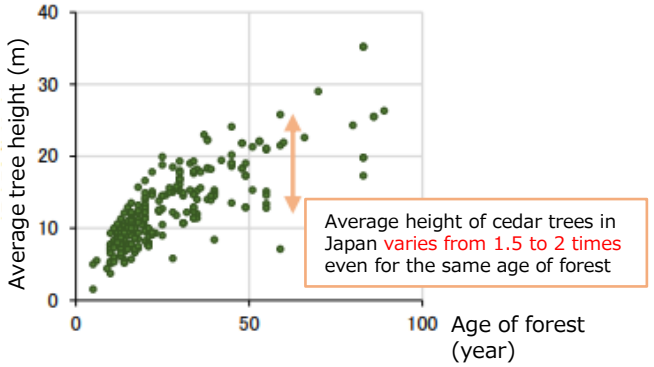
Seedlings derived from specified mother trees of cedar in 29 prefectures are expected to begin shipment by 2028.

<Example of cedar>



*Forestry Agency work data (as of end of March 2020)

Suitable planting areas



*Forestry Agency work data (based on a survey of 250 sites of cedar plantations throughout Japan)

Planting elite trees, etc. in suitable planting areas may provide more growth volume.

*Specified mother trees: Trees that are particularly suitable for the collection of seed scions for the production of quality seedlings and have particularly excellent growth characteristics, according to Article 2, Paragraph 2 of the Amending Part of the Act on Special Measures for the Promotion of Thinning, etc. in Forestry. (Meeting the designated criteria for growth (1.5 times or more compared to native strains), wood stiffness, trunk straightness, pollen content, etc.)

Source: Materials provided by the Japan Paper Association and Forestry Agency (October 2020), website

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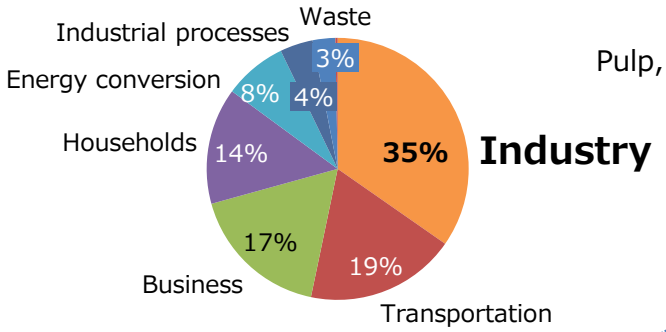
2. Overview of Pulp and Paper Industry | CO2 Emissions

- The **industrial sector accounted for 35% of the CO2 emissions** in Japan in FY2019
- **About 5% of this is accounted for by the pulp and paper industry**, where **reducing CO2 emissions is an urgent issue**.
- Since the raw materials for pulp and paper are ligneous resources, **the majority of emissions come from energy sources** such as private power generation.

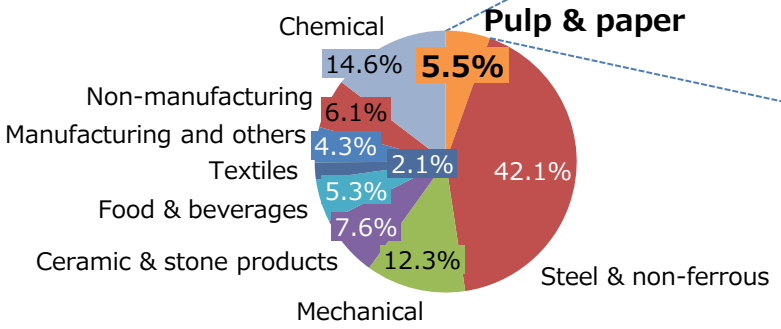
Japan as a whole (FY2019)

About 1 billion tons of CO2



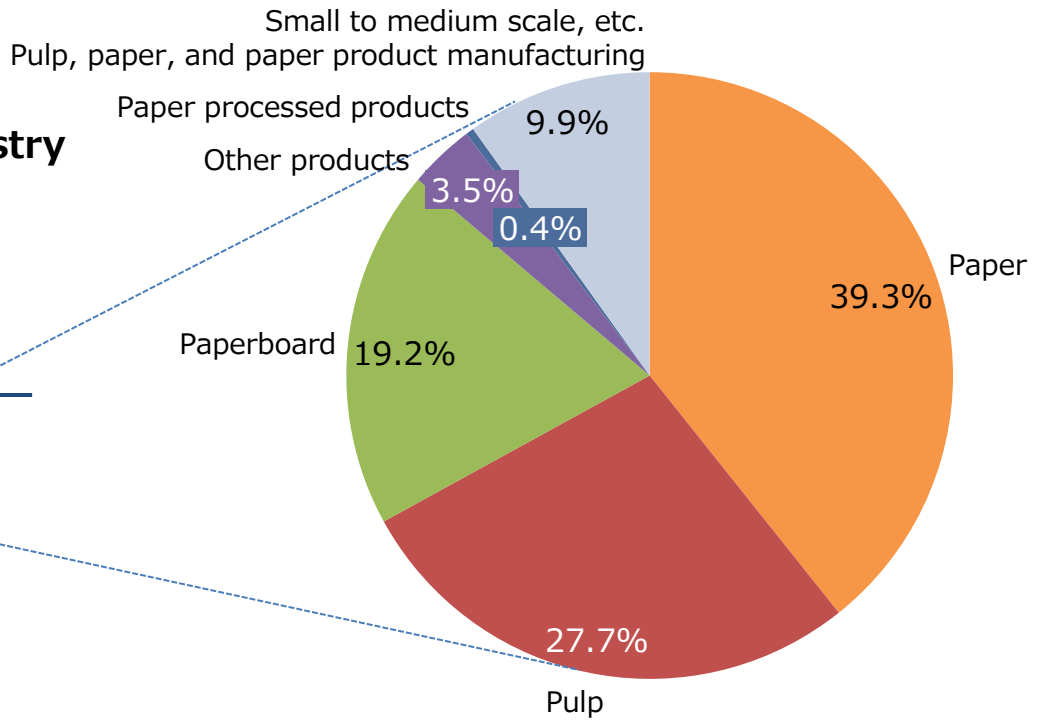
Industrial sector (FY2019)

Approx. 380M tons of CO2



Pulp and paper industry: Breakdown of emissions (FY2019)

About 21 million tons of CO2



Source: National Institute for Environmental Studies "Japanese Greenhouse Gas Emissions Data" (FY2019 confirmed figures)

Source: METI, "Comprehensive Energy Statistics" (FY2019 confirmed figures)

2. Overview of Pulp and Paper Industry | Energy Consumption

- In the pulp and paper manufacturing processes, **electricity is used as the power source**, and **a lot of steam (heat) is used in processes such as digestion and drying**. **The black liquor recovery process** can **generate more energy than it consumes.**

Outline of pulp and paper manufacturing process and energy intensity(energy consumption per product-ton)

Power consumption*5 GJ/t | Heat consumption GJ/t

Pulp manufacturing process

Chemical pulp

Chip processing/digestion

- Adjust the sizes and thicknesses of wood chips
- Add chemicals to wood chips and boil them in a high-temperature, high-pressure digester to dissolve the resin (lignin) and extract the fiber components

1.5 | 4.4

Washing/Bleaching*1

- Wash the removed fibers to remove residual lignin, etc.
- Use chemicals such as oxygen to remove residual lignin, and bleach and wash

1.0 | 4.8

Black liquor concentration, recovery boilers and lime kilns

- Concentrate the black liquor obtained from digestion and recover energy in a recovery boiler.
- After combustion in a recovery boiler, recover and causticize the chemicals in a lime kiln, etc., and utilize them again for digestion.

Liquor evaporation		Recovery boiler		Lime Kiln/recausticization		Recovered energy*2
0.1	4.4	0.2	1.1	0.2	1.2	19GJ/t

Mechanical pulp

Chip processing and grinding*3

- Physically grind the chips

5.9~7.3 | 0.0~0.9

Washing/Bleaching*1

- After grinding, wash and bleach them

0.2 | 0.0

*The mechanical pulp process consumes more electricity than the chemical pulping process.

Waste paper pulp

Disaggregation

- Gently loosen waste paper and make it gruel-like

1.4 | 0

Screening

- Remove foreign matter and trash from gruel-like waste paper pulp

0.2 | 0

De-inking

- Separate ink adhering to pulp with other chemicals such as surfactant for separation and removal

0.3 | 0

*The energy used in the waste paper pulp process is smaller than in the chemical pulp process

Paper manufacturing process

Paper manufacturing (papermaking, coating, etc.)

- Manufacture paper*4 from pulp by pressing, drying, coating, etc.

Forming, pressing, etc.		Drying	
1.0~1.9	0.0	0.1~0.5	4.2~5.5

①Head Box

Use a refiner to fuzz fibers so that they can easily tangle with one another. Blow the slurry evenly over the moving fabric.

②Former

Filter and squeeze the water from the slurry through a plastic net via gravity and vacuum pressure to form a continuous sheet.

③Press

Place the sheet on felt, sandwich it between press rolls, and further press to remove water.

④Dryer

Press the wet sheet against a cylinder heated by steam (metal cylinder) and further dry it through evaporation.

⑤Calendar

Pass the sheet between hard and soft rolls to smooth the surface and make it shiny

⑥Coater

Coat them with pigment and binder, and dry them with infrared rays, hot air, etc. to make the sheet suitable for printing

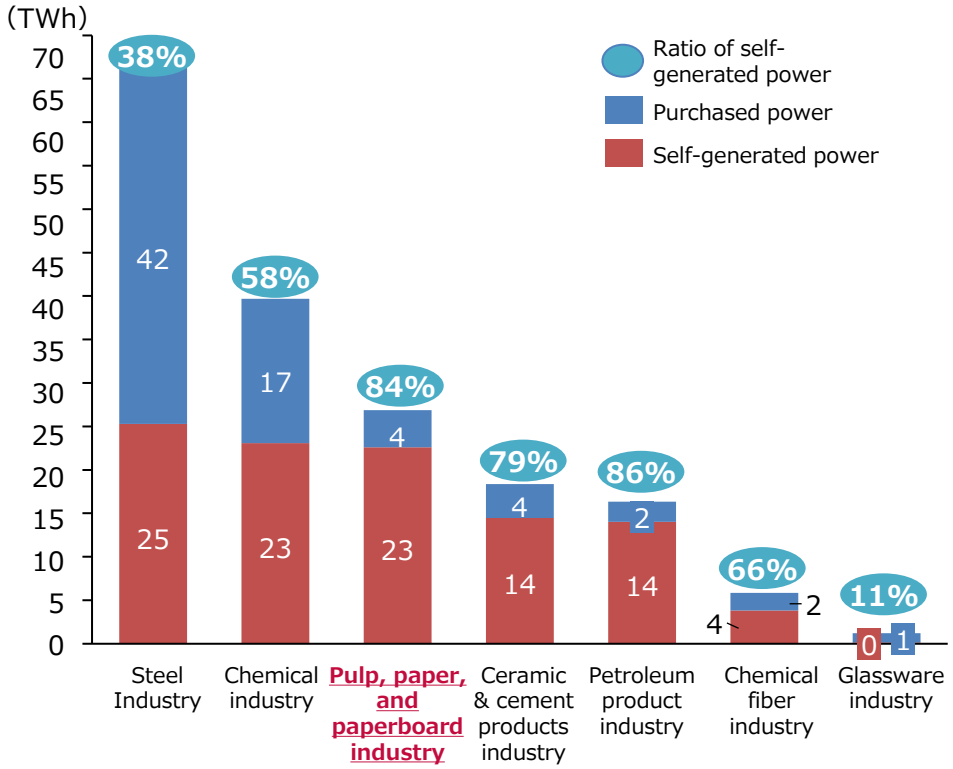
*1 Bleaching is only required for some paper products.
*2 Black liquor energy per ton of pulp (IEA ETP2017)
*3 Multiple methods are available with different energy consumptions
*4 Energy consumption depends on the type of the paper product to be manufactured
*5 Electricity consumption is converted with 1Wh=3,600J

Source: Prepared from "Paper Manufacturing Process" of the Japan Paper Association, M. R. Mobarakeh et al. 2021, IEA ETP2017, etc.

 # Ratio of Self-generated Power and Energy Consumption

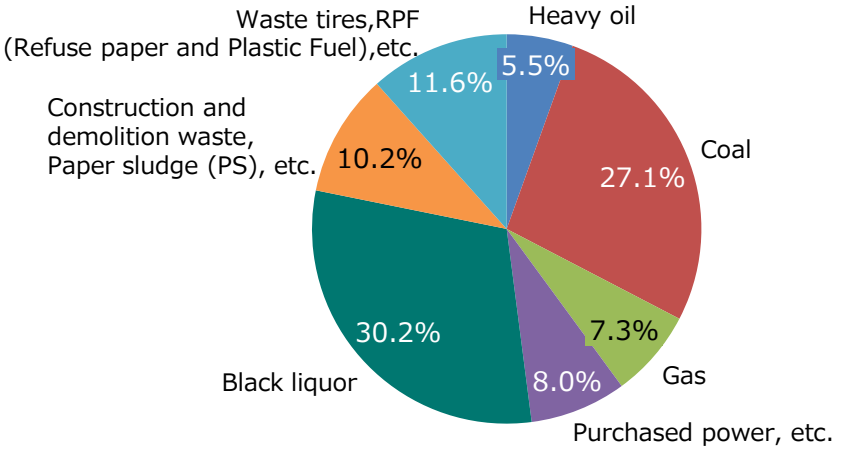
- Paper production **requires a large amount of heat and electricity, because pulp diluted with a large amount of water (pulp 1 : water 99) is skimmed, squeezed, and dried**. To get the required energy, boilers are used to burn fuel to generate heat and electricity, and **the ratio of self-generated power** to electricity consumption **is high**. Pulp and paper mills around Japan are supplying electricity to surrounding areas, including in the event of natural disasters.
- **The biggest** energy source is **the black liquor generated during the chemical pulp production**, and though the amount of black liquor generated depends on the demand for pulp, the whole amount is used as fuel. On the other hand, **a high proportion of energy from fossil fuels such as coal and heavy oil** requires huge investments for fuel switching.

Electricity consumption by industry and ratio of self-generated power generation (2020)



Energy consumption by type in the pulp and paper industry (2020)

Total: About 437 PJ



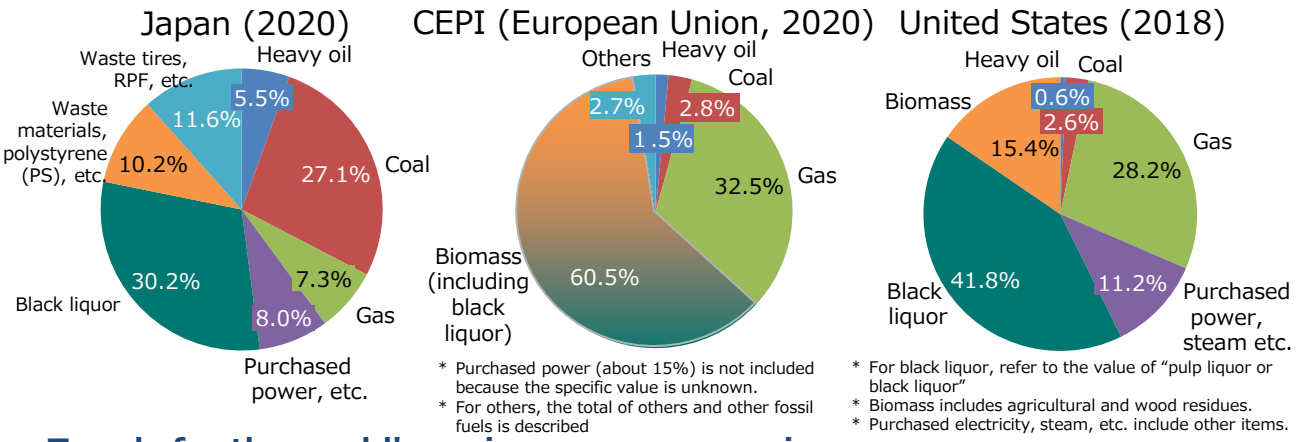
Energy consumption breakdown of the pulp and paper industry (2020)

Heat 2 : 1 Electricity

Source: Compiled from Statistical Survey on the Dynamics of Petroleum Consumption, etc., and material of the Japan Paper Association

- Paper mills in Europe and the U.S. make the best use of the **abundant forest resources to produce large amounts of inexpensive pulp, which yields large amounts of black liquor,** as well as **biomass fuels, which are available at low cost.**
- On the other hand, because **domestic lumber is relatively expensive,** Japan **uses a lot of lumber imported from overseas at great expense for shipping,** and has been promoting the use of waste paper to compensate for this cost. Therefore, **the amount of black liquor generated is limited,** and **dependence on other fuels such as coal, which is inexpensive, is high**.
- Referring to companies in Europe and the U.S. that are making efforts focusing on energy saving, higher efficiency, and fuel switching to renewable energy, etc., it is necessary to consider and promote measures that are appropriate for Japan's circumstances.

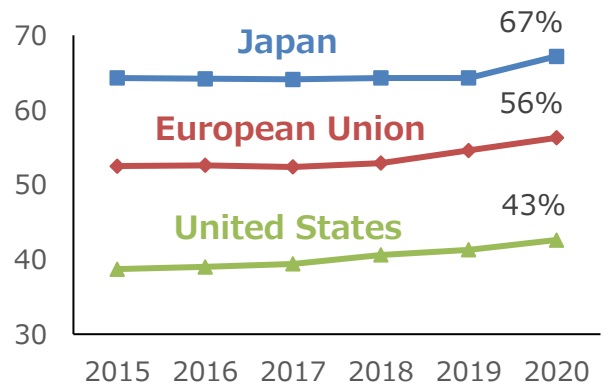
Energy composition of the global pulp and paper industry



* Purchased power (about 15%) is not included because the specific value is unknown.
* For others, the total of others and other fossil fuels is described

* For black liquor, refer to the value of "pulp liquor or black liquor"
* Biomass includes agricultural and wood residues.
* Purchased electricity, steam, etc. include other items.

World utilization rate of waste paper



Trends for the world's major paper companies

- We will achieve a 65% reduction in emissions by 2030 compared with 2015 by achieving a 1% energy efficiency improvement every year, using wood-based biomass and cost-effective hydrogen power generation, and purchasing electricity from CO2-free energy sources including nuclear power. (Finnish company)
- In addition to the introduction of LED electricity and the cutting-edge biomass boiler equipment, we will aim to achieve a 40% reduction by 2030 compared with 2019 and net zero by 2050 by shifting to renewable energy electricity and waste to energy and introducing anaerobic gas turbines, etc. (UK company)
- In addition to energy-saving practices, we will replace all of coal-fired boilers in the Dongguan area with gas-fired boilers by the end of 2025 to meet the national goal of carbon neutrality by 2060 (Chinese company)

Source: Prepared based on various published materials

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Long-term Vision toward Decarbonization in the Paper Industry

- **In January 2021, the Japan Paper Association announced "Long-Term Vision 2050 to address Climate Change." Major papermakers** also **declared that they will be carbon neutral by 2050**.
- To date, fuel switching and energy saving efforts have **reduced CO2 emissions by approximately 3.2 million t-CO2 in FY2020 compared to FY2013**, and further measures will be taken with the additional new technologies.

Target and method to reduce CO2 emissions in the production activities of the Japan Paper Association (reduction target of 21 million t-CO2 emissions in FY2013)

Promotion of energy saving by proactive introduction of cutting-edge energy-saving equipment and technologies, etc.

4.2 million t-CO2 reduction
(20% of FY2013 emissions)
- Introduction of cutting-edge energy-saving equipment and technologies
- Review of manufacturing processes
- Thorough energy management

* Do not install conventional coal boilers as new equipment or for replacement of aged equipment.

Challenge practical application of innovative technologies related to paper manufacturing (Innovation)

2.1 million t-CO2 reduction
(10% of FY2013 emissions)
- Electrification of paper machine dryers and lime kilns
- Improvements in drying efficiency of dryers by reducing moisture in the press section
- Development of a highly efficient pulp manufacturing method
- Development of an energy-efficient black liquor evaporation equipment
- Development of waste heat recovery technologies for dryer hoods, effluent treatment facilities, etc.

Increase in the ratio of renewable energy used in self-generated power generation equipment

8.4 million t-CO2 reduction
(40% of FY2013 emissions)
- Securing a stable supply of domestic and foreign woody biomass for fuel
- Development of biomass-fuel-conversion technology
- Introduction of renewable energy equipment such as hydro, solar, wind, and geothermal

Proactive adoption of innovative energy-related technologies

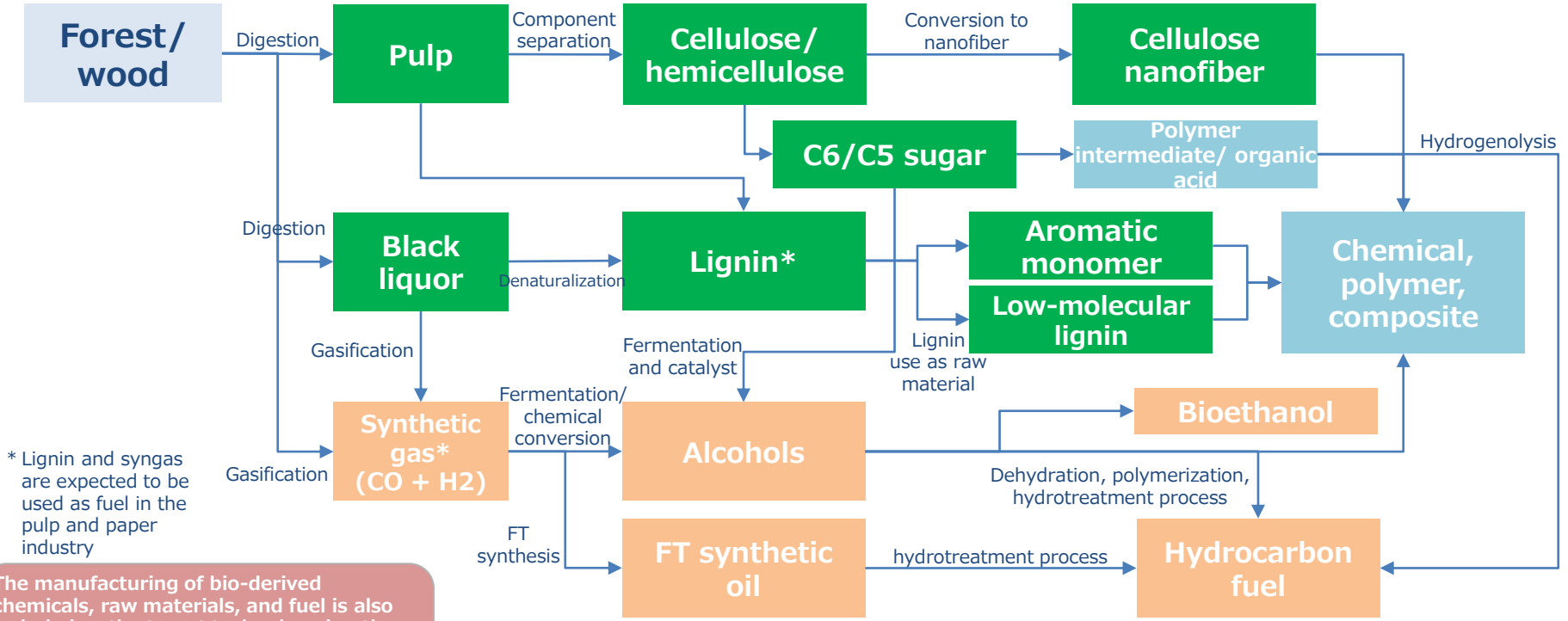
6.3 million t-CO2 reduction
(30% of FY2013 emissions)
- CCS、CCUS
- Use of carbon-neutral gas and energy from waste such as plastics
- Use of carbon-neutral purchased electricity

Source: Prepared based on "Long-Term Vision 2050 to address Climate Change" and "Energy Status of the Pulp and Paper Industry" of the Japan Paper Association

- To achieve carbon neutrality by 2050, we will **introduce energy-saving equipment and develop innovative energy-saving technologies** focusing on the drying process, which uses a lot of electricity and heat, in the manufacturing process.
- With a view to 2030, it is necessary to **shift from coal to renewable energy sources such as woody biomass as the fuel for self-generated steam and electricity generation**, which are the main sources of CO2 emissions. Toward 2050, we will promote a further fuel shift, and in preparation for the possibility that fossil fuels remains, **also consider introducing technologies for carbon capture, fixation, and utilization.** Pulp and paper mills, small and medium-sized companies, etc. that don't produce chemical pulp and cannot obtain black liquor will also **promote fuel switching to natural gas, waste, and renewable energy such as solar power, etc**.
- In addition, the paper industry owns a large area of forests, and can **increase the amount of the absorption and fixation of CO2 by forests through the promotion of sustainable forest management and the development of fast-growing tree species** to contribute to the carbon neutrality of society as a whole, as well as to promote the offsetting of the companies' own CO2 emissions. Furthermore, the **adjustment of a credit system will enable more advanced forest management by appropriately valuing CO2 absorption by forests**.
- The pulp and paper industry's technologies for separating pulp, lignin, and other components from wood will **contribute to the carbon neutrality of society as a whole by being deployed as "biorefinery" technologies for manufacturing chemical products from woody resources** instead of chemical products derived from fossil resources. In addition, by **providing products made of carbon-neutral and environmentally friendly materials derived from woody resources, the industry will contribute to a reduction in CO2 emissions throughout the supply chain**. Examples include cellulose nanofiber composites, paper products as plastic substitutes, bioplastics and cellophane made from woody resources.
- The pulp and paper industry will **contribute to a reduction in CO2 emissions in the entire region by developing a system and technology to collect and reuse difficult-to-process waste paper and general waste as fuel**, which have conventionally been incinerated as private waste.

- The pulp and paper industry is developing technologies to manufacture chemical products from woody biomass, and promoting them as a part of biorefinery initiatives that will contribute to the realization of a carbon-neutral society.
- Among them, cellulose nanofiber (CNF) is a biomass-derived, high-performance material with characteristics of light weight and high strength, and is expected to be used in a wide range of fields such as automobiles and construction materials. Many paper companies are developing and utilizing it for various purposes.

Conceptual image of wood utilization

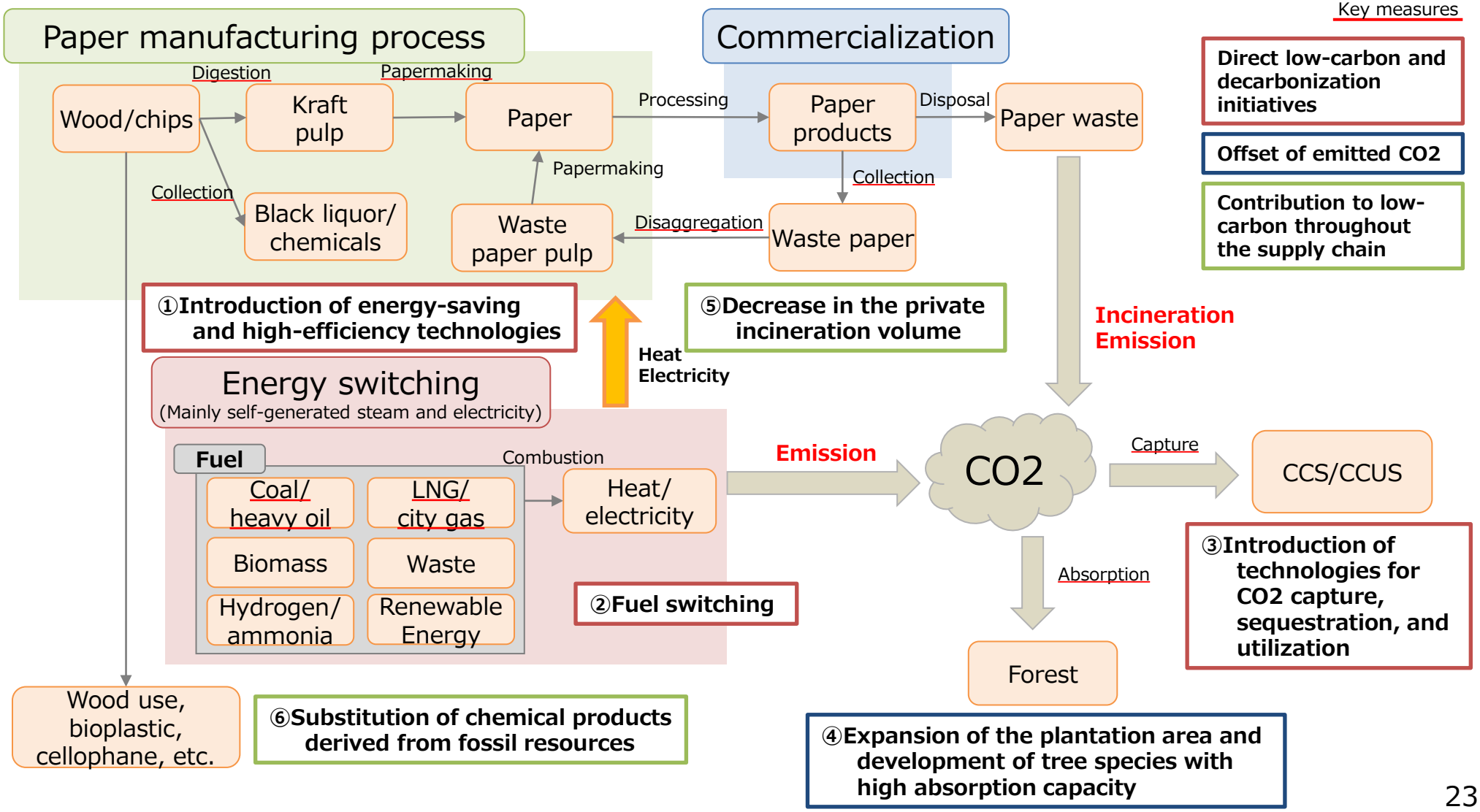


* Lignin and syngas are expected to be used as fuel in the pulp and paper industry

The manufacturing of bio-derived chemicals, raw materials, and fuel is also included as the target technology in other sector's roadmap such as the chemical sector, etc., and we will promote initiatives in collaboration with other relating fields.

Source: Prepared based on the Roadmap for Carbon Recycling Technologies, etc.

- Promote ①, ②, and ③**direct low-carbon and decarbonization** associated with paper manufacturing, ④**offset of** emitted **CO2**, and ⑤, ⑥**contribution to low-carbon throughout the supply chain.**



Summary of CO2 Emission Sources and Decarbonization Methods

Initiatives in existing processes in the pulp and paper industry (scope of this technology roadmap)

	Main emission sources	Methods for decarbonization
①②③ Pulp and paper manufacturing	• **Emissions from energy use, mainly self-generated power**	• **Utilization of energy-saving technologies, etc.** • **Fuel switching and electrification during heat and energy use** • **Implementation of CCS/CCUS**
④Plantation	• **–**	• **Increase CO2 absorption and fixation by forests through plantation and the development of fast-growing tree species**, thereby contributing to the carbon neutrality of society as a whole and promoting the companies' own CO2 offsetting
⑤Waste paper recycling	• **Emissions from incineration as waste instead of being collected as waste paper**	• Contribute to the carbon neutrality of society as a whole by **expanding systems and technologies to recover and reuse difficult-to-process waste paper and other materials that are** conventionally considered waste

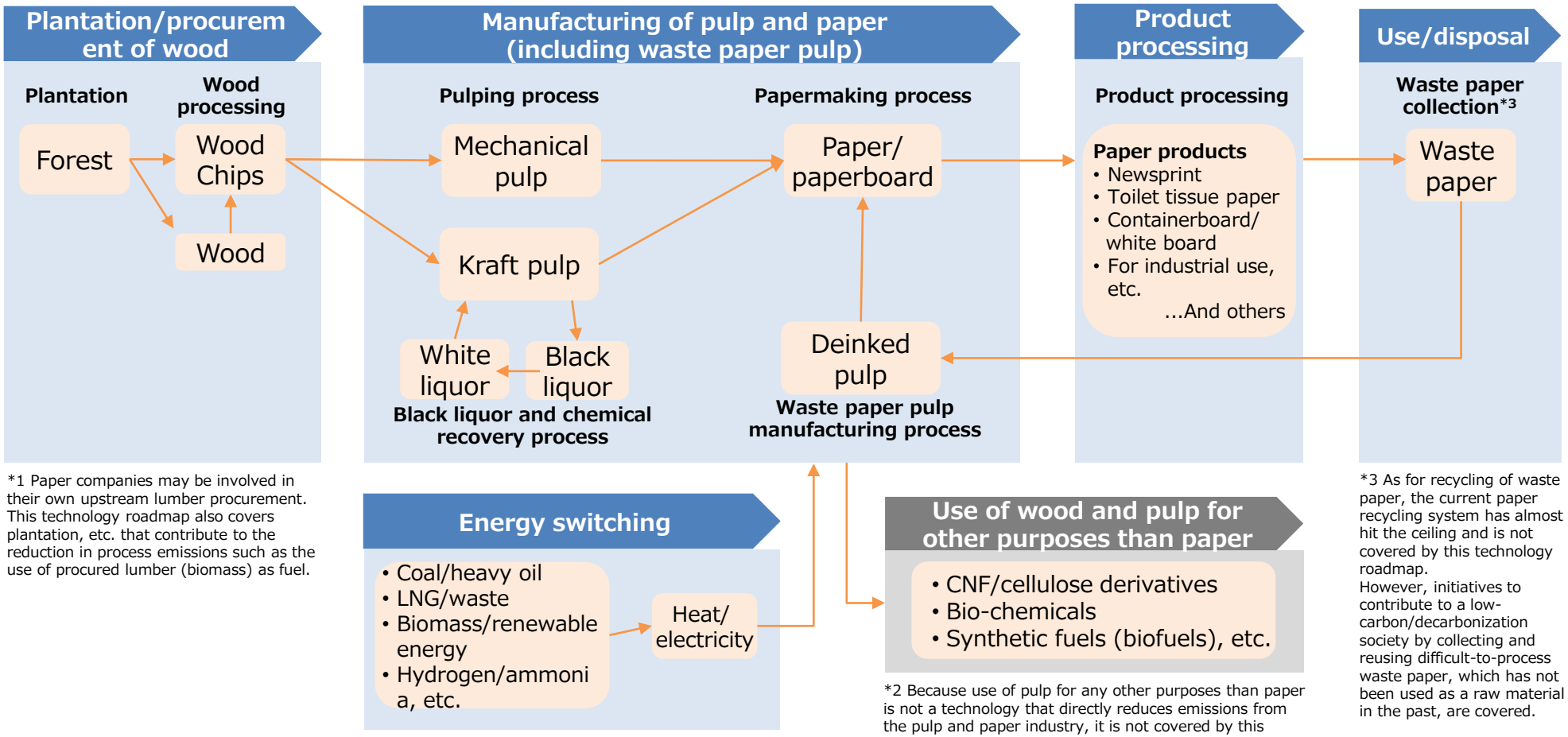
Other initiatives (initiatives contributing to the decarbonization of other industries/included in the other sector's roadmap)

⑥Utilization of pulp for other purposes than paper (Biorefinery)	• The pulp and paper industry's technologies for separating pulp, lignin, and other components from wood will **contribute to the carbon neutrality of society as a whole by being deployed as a "biorefinery" technologies for manufacturing chemical products from woody resources** instead of chemical products derived from fossil resources. • By **providing products made of carbon-neutral and environmentally friendly materials derived from woody resources, the company will contribute to a reduction in CO2 emissions throughout the supply chain**. Examples include cellulose nanofiber composites, paper products as plastic substitutes, and bioplastic made from woody resources.

- The technology roadmap is applicable to **the procurement of wood and waste paper as raw materials and fuels' the pulping and papermaking processes that form the basis of the pulp and paper industry and the energy switching that is important in these processes**, as initiatives that contribute to decarbonization. *1, 2

Overview of the pulp and paper industry and the scope of this technology roadmap

Scope of this technology roadmap | Outside the scope of this technology roadmap



*1 Paper companies may be involved in their own upstream lumber procurement. This technology roadmap also covers plantation, etc. that contribute to the reduction in process emissions such as the use of procured lumber (biomass) as fuel.

*2 Because use of pulp for any other purposes than paper is not a technology that directly reduces emissions from the pulp and paper industry, it is not covered by this technology roadmap. However, as it is an important technology for the transition, it may be applicable to transition finance.

*3 As for recycling of waste paper, the current paper recycling system has almost hit the ceiling and is not covered by this technology roadmap.
However, initiatives to contribute to a low-carbon/decarbonization society by collecting and reusing difficult-to-process waste paper, which has not been used as a raw material in the past, are covered.

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Technologies for CN①

	Technology	Overview	Emission intensity*1	Implementation year*2	Main References
Manufacturing process	Energy saving and high efficiency (Best practices)	✓ Review of manufacturing processes (integration, shortening, etc.) ✓ Thorough energy management (introduction of energy management systems, review of management methods, etc.) ✓ Renewal of aged equipment to save energy and increase efficiency, and adoption of LED lighting	–	Already implemented	✓ Carbon Neutral Action Plan, etc.
	High-efficiency pulp manufacturing, etc.	✓ Washing of chemical pulp produced by digestion with steam instead of water, etc.	Energy saving: 30 to 40%	2020s	✓ M.R. Mobarakeh, etc.
	Decarbonization of lime kilns	✓ Electrify the lime calcination process in pulp manufacturing ✓ New chemical recovery technology that does not require a lime kiln	0.0~	2030s	✓ Long-Term Vision to addresses Climate Change
	Dry sheet forming	✓ Use air instead of water to reduce energy consumption in the drying process. Wastewater reduction is also possible	Energy saving: 50%	2030s	✓ M.R. Mobarakeh, etc.
	High-efficiency press technology	✓ Energy-saving technologies such as hot pressing to reduce the heat demand in the drying section. The technologies are combination of mechanical pressure and air pressure.	Energy saving: 8 to 40%.	2030s	✓ M.R. Mobarakeh, etc.
	High consistency forming	✓ Technology to increase the consistency of pulp from the conventional 0.5~1% to about 3% at the forming section which contributes to improved forming speed and energy saving in the pressing process.	Energy saving: 8%	2030s	✓ M.R. Mobarakeh, etc.
	Electrification of paper machine dryer	✓ Electrify the drying equipment in stead of using fossil fuel in the papermaking process (CN electricity supply is a prerequisite)	0.0~	2030s	✓ Long-Term Vision to addresses Climate Change
	High-efficiency drying technology	✓ Improved dehydration technology using heat and pressure, and drying using steal belts. They contribute to improved product quality and productivity*3	–	2030s	✓ M.R. Mobarakeh, etc.
	Gas drying	✓ Hot gas combustion is used instead of steam leading to improve energy efficiency. May contribute to improved productivity	Energy saving: Up to 20%	2030s	✓ M.R. Mobarakeh ✓ Lingbo Kong et al. and others
Fuel manufacturing	Isolation of lignin	✓ Separate lignin from lumber, etc. and use it as biofuel (it can also be used for chemicals)	–	2020s	✓ IEA ETP2020 ✓ M.R. Mobarakeh
	Gasification of black liquor	✓ Gasify black liquor, a byproduct of the chemical pulping process, for efficient energy recovery	Emission reduction 10%	–	✓ IEA ETP2020 ✓ M.R. Mobarakeh
	Smart forestry	✓ Development of ICT production management systems, etc., consistent with automated machinery and forest cloud, and reduction of the cost and labor of plantation using sensing technologies	–	Already partly implemented*4	✓ Environment Innovation Strategy, etc. ✓ Green Growth Strategy ✓ The Development of Smart Agriculture, Forestry, and Fisheries

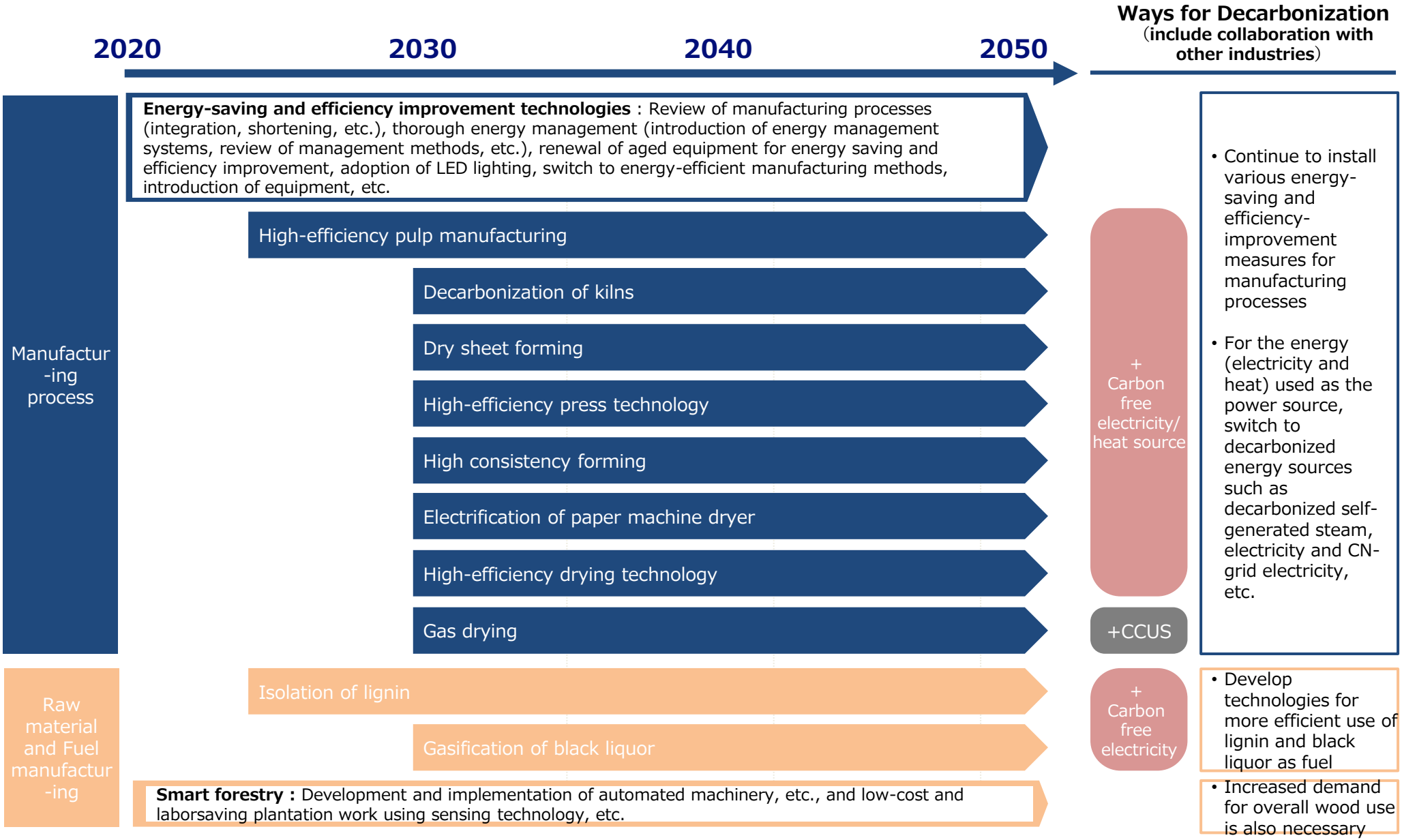
*1: Emission factor also includes the downstream section Calculated from the reduction range of the target technology based on the emission factor of the existing technology. The reduction range is shown as the amount of reduction in the relevant section.
*2: For the social implementation plan, refer to the starting year of the expanded deployment and the cost reduction phase, and for IEA, refer to Available Year.
*3: Impulse Drying uses the heat and pressure in mechanical dewatering before the drying section, leading to improved drying rate, productivity, and quality. Condebelt Drying is a drying method using two steel belts, leading to improve drying efficiency and quality. It is suitable for paperboard production.
*4: Some technologies are already in the implementation phase, while others are under development.

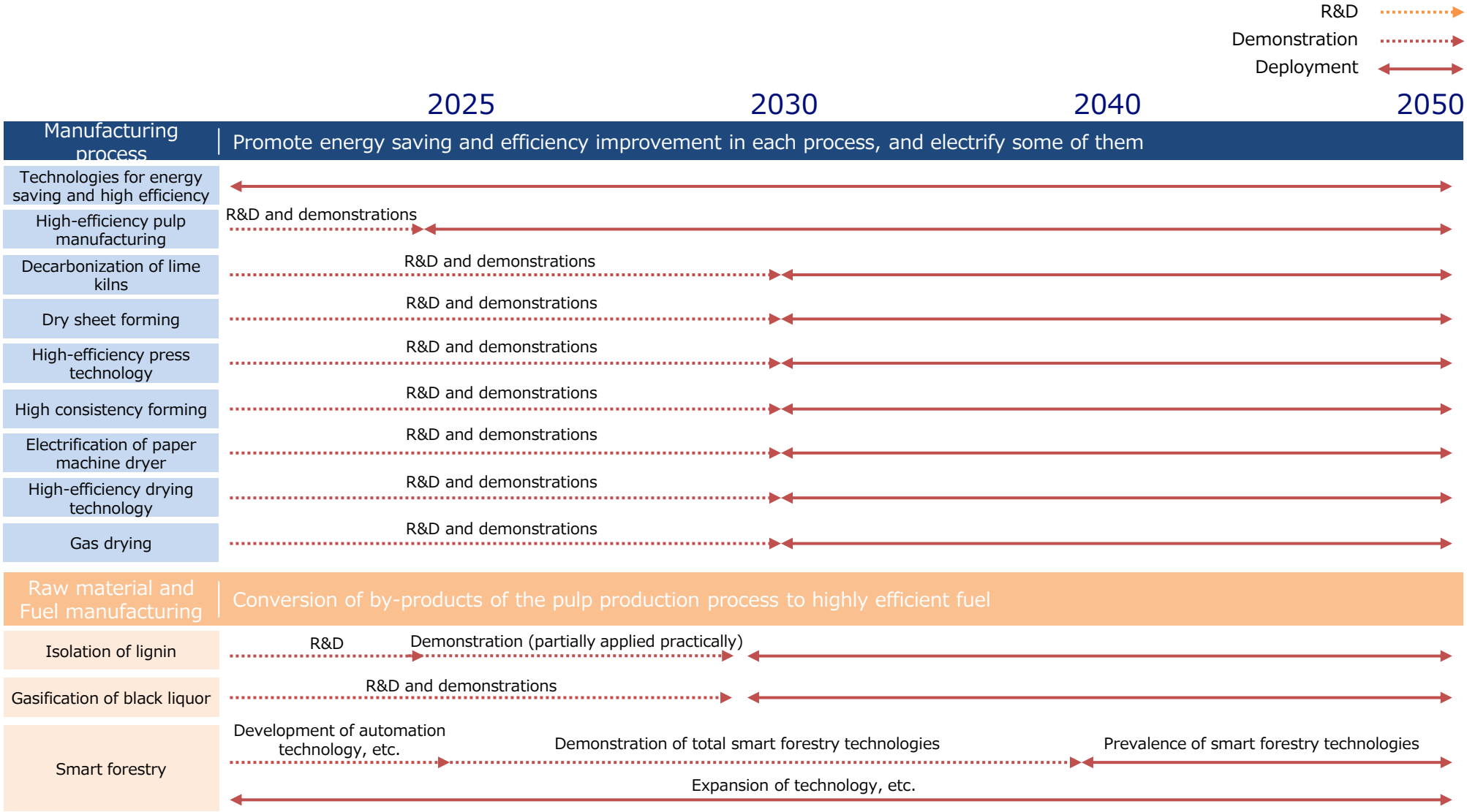
Technologies for CN②

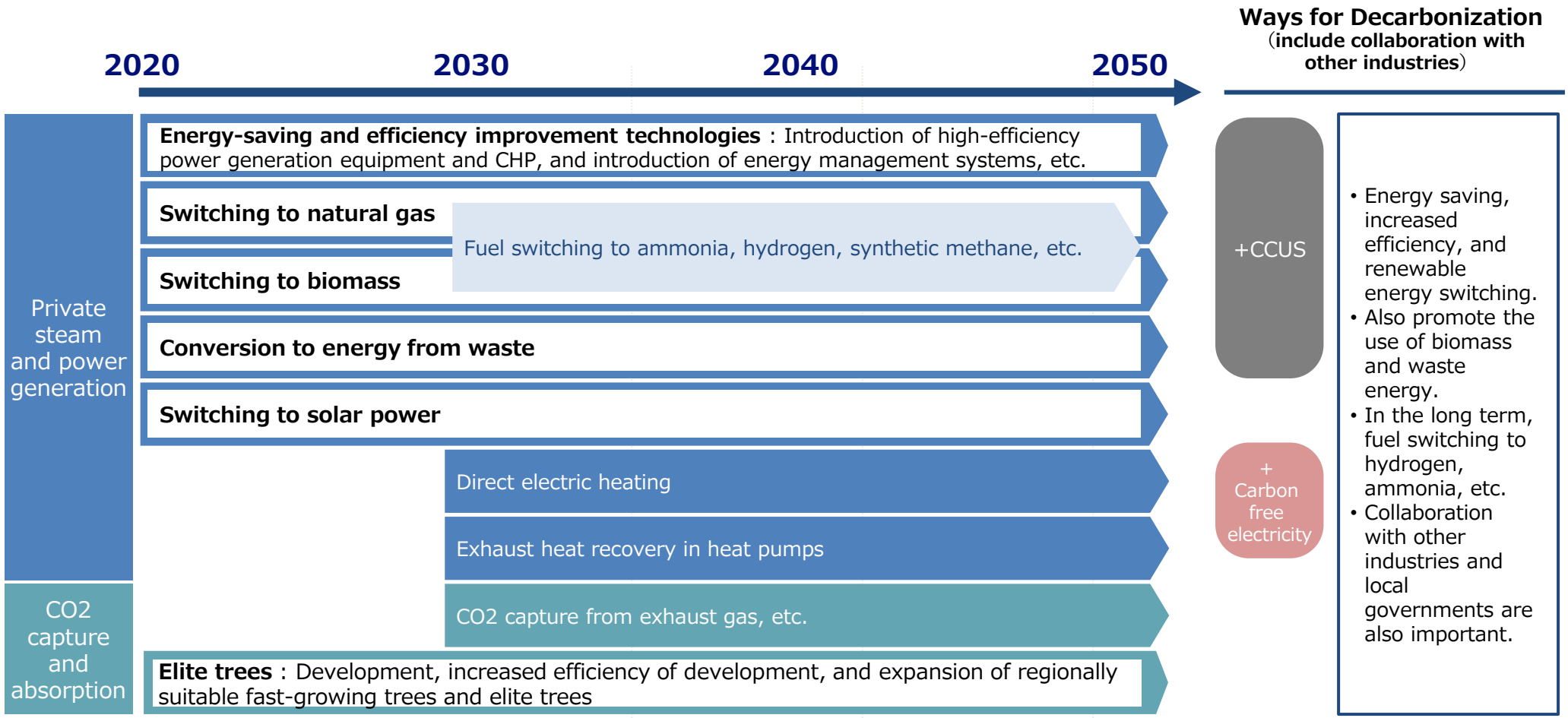
	Technology	Overview	Emission intensity*1	Implementation year*2	Main References
Self-generated power and steam	Energy saving/high efficiency	✓ Introduction of high-efficiency power generation equipment and combined heat and power (CHP) ✓ Introduction of energy management systems, etc.	–	Already implemented	✓ Carbon Neutral Action Plan ✓ Green Growth Strategy
	Fuel switching to natural gas	✓ Switch fuel to natural gas (co-combustion and mono-fuel combustion)	0.32~0.415 *3 (kgCO2/kwh)	Already implemented	✓ Carbon Neutral Action Plan ✓ Green Growth Strategy, etc.
	Fuel switching to biomass	✓ Switch fuel to biomass (co-combustion and mono-fuel combustion)	0.0~ (kgCO2/kwh)	Already implemented	✓ Carbon Neutral Action Plan ✓ IEA ETP2020
	Use of energy from waste	✓ Utilize waste energy from plastics, tires, refuse paper and plastic fuel (RPF), refuse derived fuel (RDF), etc.	–*4 (kgCO2/TJ)	Already implemented	✓ Carbon Neutral Action Plan ✓ Green Growth Strategy
	Switching to solar power	✓ Switch the energy source from thermal power generation to solar power	0.0 (kgCO2/kwh)	Already implemented	✓ Green Growth Strategy ✓ IEA ETP2020
	Fuel switching to hydrogen, ammonia, etc.	✓ Hydrogen power generation in gas turbines, ammonia mixed-fuel firing, ammonia mono-fuel firing in coal boilers , etc.	0.0~	2020s and beyond	✓ Green Innovation Fund: Social Implementation Plan ✓ Green Growth Strategy ✓ IEA ETP2020
	Direct electric heating	✓ Generate steam from electric boilers	0.0~ (kgCO2)	2030s	✓ M.R. Mobarakeh, etc.
	Exhaust heat recovery in heat pumps	✓ Recover waste heat from the process and convert it to medium temperature (about 160°C)	0.0~ (kgCO2)	2030s	✓ M.R. Mobarakeh, etc.
Capture and absorption	CO2 separation and capture from exhaust gas, etc.	✓ CO2 capture from exhaust gas of natural gas, biomass combustion, etc. ✓ Introduction of carbon capture and storage (CCS), carbon capture utilization and storage (CCUS), etc. (including bioenergy with carbon capture and storage (BECCS), etc.)	–	2020s	✓ Green Growth Strategy ✓ Green Innovation Fund: Social Implementation Plan ✓ IEA ETP2020
	CO2 absorption from the atmosphere (fast-growing trees, elite trees)	✓ Development and plantation of superior tree species that are highly adaptable, quick to grow, and capable of absorbing more CO2 (1.5 times or more) ✓ Direct absorption of CO2 from the atmosphere	–	Already partly implemented*5	✓ Environment Innovation Strategy, etc. ✓ Green Growth Strategy

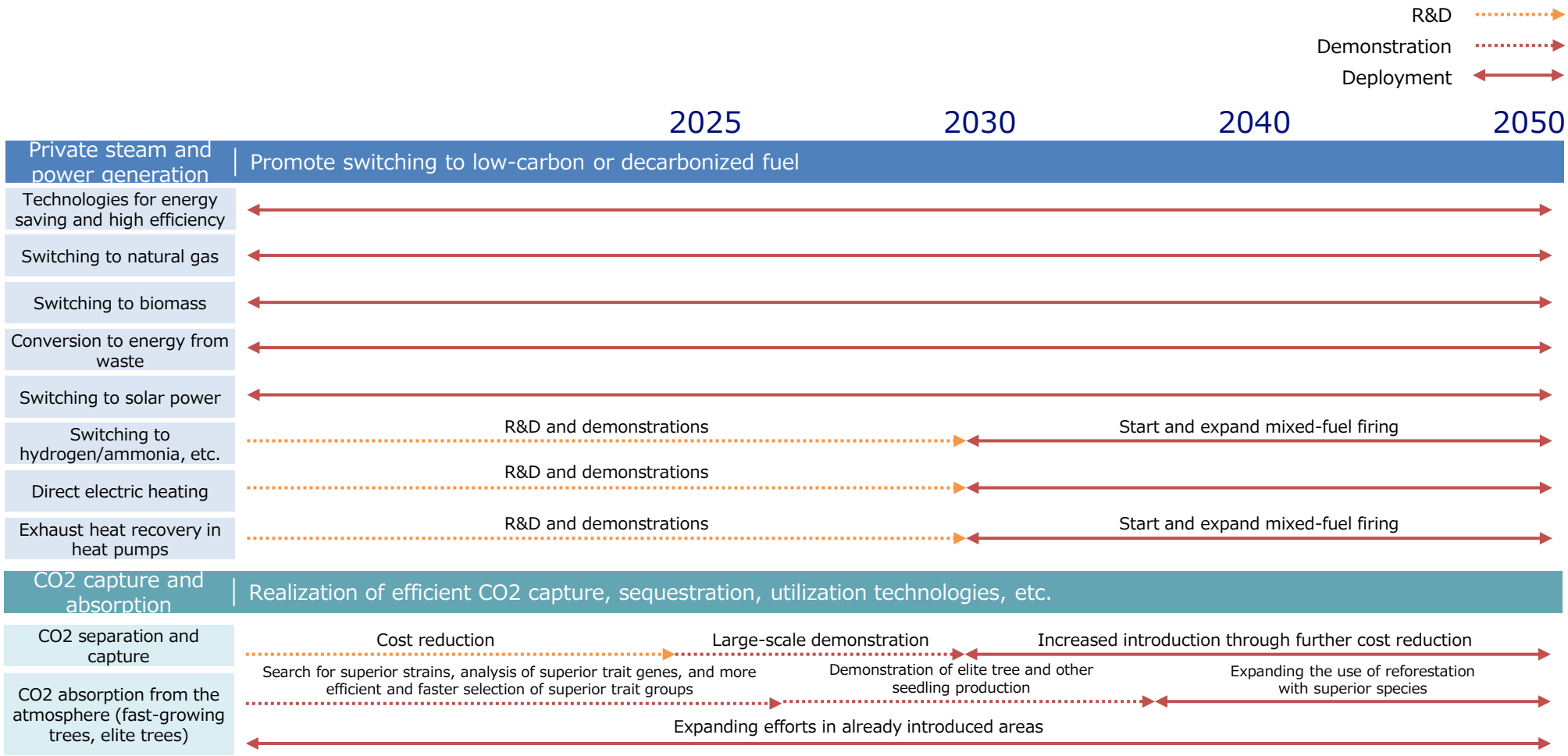
*1: Emission factor also includes the downstream section. Calculated from the reduction range of the target technology based on the emission factor of the existing technology. The reduction range is shown as the amount of reduction in the relevant technology.
*2: "Implementation year" means the starting year of the expanded deployment and the cost reduction phase, except for "Available year" in case of IEA ETP2020.
*3: CO2 emissions per unit of electricity generated from natural gas-fired power generation (conventional LNG-fired and GTCC).
*4: The emission factor varies depending on the type of waste used, etc.
*5: Although in some regions, this method have already been implemented, Japan's long north-south geography requires the selection and development of tree species suited to each region, and some aspects of the method are still in the demonstration stage.

3. Technology Pathways to Decarbonization | Technological Roadmap①




R&D
Demonstration
Deployment
2025
2030
2040
2050
Manufacturing process
Promote energy saving and efficiency improvement in each process, and electrify some of them
Technologies for energy saving and high efficiency
High-efficiency pulp manufacturing
R&D and demonstrations
Decarbonization of lime kilns
R&D and demonstrations
Dry sheet forming
R&D and demonstrations
High-efficiency press technology
R&D and demonstrations
High consistency forming
R&D and demonstrations
Electrification of paper machine dryer
R&D and demonstrations
High-efficiency drying technology
R&D and demonstrations
Gas drying
R&D and demonstrations
Raw material and Fuel manufacturing
Conversion of by-products of the pulp production process to highly efficient fuel
Isolation of lignin
R&D
Demonstration (partially applied practically)
Gasification of black liquor
R&D and demonstrations
Smart forestry
Development of automation technology, etc.
Demonstration of total smart forestry technologies
Prevalence of smart forestry technologies
Expansion of technology, etc.


2020
2030
2040
2050
Ways for Decarbonization
(include collaboration with other industries)
Private steam and power generation
CO2 capture and absorption
Energy-saving and efficiency improvement technologies : Introduction of high-efficiency power generation equipment and CHP, and introduction of energy management systems, etc.
Switching to natural gas
Fuel switching to ammonia, hydrogen, synthetic methane, etc.
Switching to biomass
Conversion to energy from waste
Switching to solar power
Direct electric heating
Exhaust heat recovery in heat pumps
CO2 capture from exhaust gas, etc.
Elite trees : Development, increased efficiency of development, and expansion of regionally suitable fast-growing trees and elite trees
+CCUS
+ Carbon free electricity
• Energy saving, increased efficiency, and renewable energy switching.
• Also promote the use of biomass and waste energy.
• In the long term, fuel switching to hydrogen, ammonia, etc.
• Collaboration with other industries and local governments are also important.


R&D
Demonstration
Deployment
2025
2030
2040
2050
Private steam and power generation
Promote switching to low-carbon or decarbonized fuel
Technologies for energy saving and high efficiency
Switching to natural gas
Switching to biomass
Conversion to energy from waste
Switching to solar power
Switching to hydrogen/ammonia, etc.
R&D and demonstrations
Start and expand mixed-fuel firing
Direct electric heating
R&D and demonstrations
Exhaust heat recovery in heat pumps
R&D and demonstrations
Start and expand mixed-fuel firing
CO2 capture and absorption
Realization of efficient CO2 capture, sequestration, utilization technologies, etc.
CO2 separation and capture
Cost reduction
Large-scale demonstration
Increased introduction through further cost reduction
CO2 absorption from the atmosphere (fast-growing trees, elite trees)
Search for superior strains, analysis of superior trait genes, and more efficient and faster selection of superior trait groups
Demonstration of elite tree and other seedling production
Expanding the use of reforestation with superior species
Expanding efforts in already introduced areas

- The technology roadmap is based on Japan's various policies and international scenarios aimed at achieving carbon neutrality by 2050, and is aligned with the Paris Agreement.
- Carbon neutrality will be achieved by 2050 through the use of decarbonized fuel such as hydrogen/ammonia and the introduction of CCUS, in addition to the steady achievement of low-carbon operations through various energy-saving and efficiency improvements, and fuel switching.

Main references/evidence

Government Policies

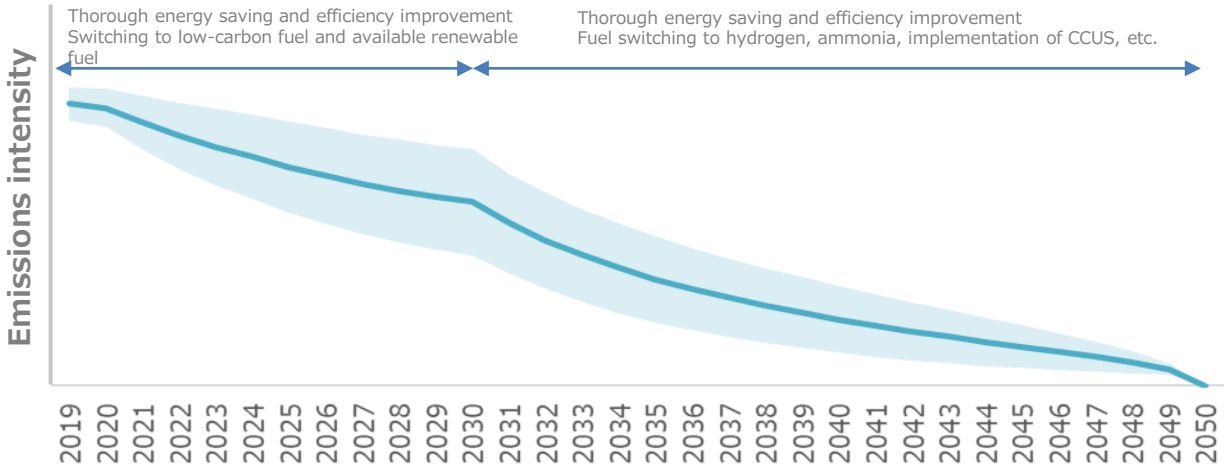
- ✓ Green Growth Strategy through Achieving Carbon Neutrality in 2050 (Carbon recycling, materials industry)
- ✓ "Carbon recycling-related" project related R&D and Social Implementation Plan
- ✓ Environment Innovation Strategy
- ✓ Strategic Energy Plan
- ✓ Global Warming Prevention Plan
- ✓ Roadmap for Carbon Recycling Technologies

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

- ✓ Clean Energy Technology Guide (IEA)
- ✓ Energy Technology Perspective 2020 (IEA)
- ✓ Industrial Transformation 2050 (Material Economics)
- ✓ Science Based Target initiative

Assumed CO2 Reduction Pathway*1, 2

Illustration of implementation of reduction measures (excerpt)



2020s	• Shift fuel from coal and oil to natural gas and biomass while promoting energy saving and efficiency improvement
2030s	• Switch from coal, oil, and natural gas to decarbonized fuel such as hydrogen, ammonia, and biomass, while promoting energy saving and efficiency improvement. Also promote the introduction of the CCUS technology.
2040s	

*1: Expected reduction in emissions in Japan's pulp and paper industry as the sector covered by this roadmap. To be precise, paper companies will all aim to achieve carbon neutrality under their own long-term strategies, so they are not required to be in accordance with the above path.

*2: Advances in energy-saving technologies, a stable and inexpensive supply of new fuels such as hydrogen and ammonia, CCUS and related infrastructure including direct air capture (DAC) and others in collaboration with other industries, and the establishment of new social systems such as a circular economy are assumed to be in place. Although CO2 absorption by plantation, etc. is not included in the above image, paper companies managing forests may include absorption as shown on pages 21 and 24 in their efforts to achieve net zero emissions in 2050.

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4. Toward Decarbonization and Achievement of the Paris Agreement

- The Technology 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 pulp and paper industry will also depend on the development of societal systems, such as decarbonized power sources, hydrogen/ammonia fuel supply, and CCUS. Carbon neutrality in the pulp and paper sector will be achieved in coordination with other sectors.
- Therefore, the Technology Roadmap will be revised and updated regularly and continuously to maintain the credibility and usability of the Technology Roadmap by considering the progress of other technologies, the trends of businesses and policies, and dialogues with the investors.
- The pulp and paper companies will aim to achieve carbon neutrality by making the best combination of technologies listed in the Technology 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” indicated in this technology roadmap.

Taskforce Formulating Roadmaps for Climate Transition Finance
Pulp and Paper 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

[Committee member]

Oshida Shunsuke: Managing Director, Head of Credit Research, Japan, Manulife Investment Management (Japan) Limited

Kajiwara Atsuko: Executive Officer, Head of Sustainable Finance Evaluation Department, Japan Credit Rating Agency, Ltd.

Sekine Yasushi: Professor, Faculty of Science and Technology, School of Advanced Science and Engineering, Waseda University

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

[Expert committee member]

Akira Isogai: University Professor, The University of Tokyo

Hiromi Uchimura: Distinguished Professor, Ehime University

Yoshinori Matsubara: Chairman, Energy Committee, Japan Paper Association