Technology Roadmap for "Transition Finance" in Cement Sector

March, 2022

Ministry of Economy, Trade and Industry

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1. Premise | Necessity for Technology Roadmap for Cement Sector

- Technology Roadmap for "Transition Finance" (hereinafter, technology roadmap) selects sectors of high importance of transition and those with high emissions with no alternative measures of decarbonization available today (for technological and economic reasons).

- **The cement industry** is one of the few industries that can utilize limestone, a domestically produced raw material, without relying on imports. At the same time, it **is an industry that supplies materials essential for buildings, roads, and other infrastructure** due to its versatility and toughness. The industry **also plays a role in building a sound material-cycle society by effectively utilizing waste materials** such as waste tires **as a source of thermal energy and raw materials.**

- Since cement will continue to be **necessary for maintaining social functions**, such as a stable supply and contribution to waste disposal, **it is essential to take measures through transitions toward a net zero cement industry.**

- The transition will require the renewal and introduction of energy-saving equipment that will lead to low-carbonization, as well as the research and development of innovative technologies to become carbon neutral, such as technology to fix and carbonate the captured CO2 and reuse it as a raw material for cement, aggregate, etc., which will require significant funding for R&D and implementation.

- In the "Green Growth Strategy for Carbon Neutrality in 2050" (June 2021), it is stated that efforts toward carbon neutrality should be promoted in both the concrete and cement sectors. On the other hand, from the perspective of CO2 emissions, **it is extremely important to take measures through transitions in the cement sector, since the majority of CO2 emissions during concrete production come from cement, the raw material for concrete.**

- 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 cement industry, the Roadmap was developed through the discussion held with technology and finance experts and representatives of operators of cement sector.

1. Premise | Objectives and Positioning of Technology Roadmap①

- The Technology Roadmap is designed to serve as a reference for the **cement 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). In addition, **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 the Roadmap provides envisions of low-carbonization/decarbonization technologies that are expected to be deployed by 2050 and when these technologies will be deployed based on information currently available.

- 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].

- The technologies to realize carbon neutrality in the cement sector has not been established. Public and private sectors will collaborate to develop technologies that are not yet mature and indispensable toward 2050 carbon neutrality.

- The cement industry in Japan needs to work on “transition” including energy conservation and energy transition aiming at decarbonization without waiting for the establishment of decarbonizing technologies, while referring to the Technology Roadmap.

- Meanwhile, looking ahead towards 2030 and 2040, the transition period, it is important to further advance efforts on energy saving/efficient technologies in addition to R&D.

(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.meti.go.jp/policy/energy_environment/global_warming/gifund/pdf/gif_09_randd.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 for efforts/activities that contribute to the transition of other industries, cost of dismantlement/removal of existing facilities and response to other environment or social impact (such as land contamination associated with withdrawal from business, decommissioning of furnaces etc. and impact on employment) arising from activities to reduce emissions.

- **The Technology Roadmap will cover the “technologies” for low-carbonization/decarbonization mainly in the cement sector.** Since cement hydrates contained in concrete products have the ability to fix CO2, efforts to fix CO2, etc., in the concrete sector are being actively promoted. On the other hand, from the emissions point of view, as shown on P19, it is important to take actions in the cement sector, and this roadmap has been developed focusing on the cement sector.

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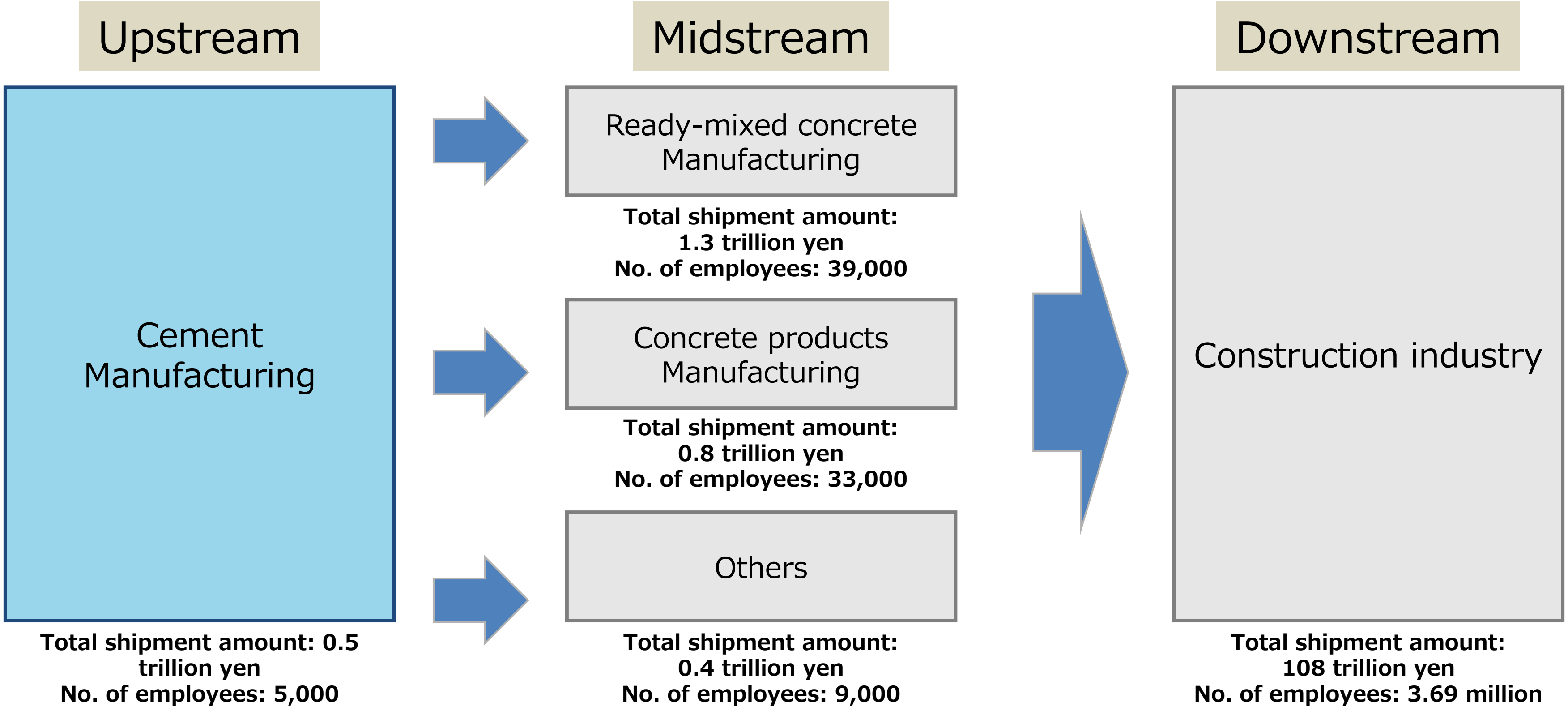
2. Overview of Cement Industry | Industry Size

- Cement as well as gravel and crushed stone are raw materials of concrete, which is supplied to the construction industry. **The demand for cement will be linked to the trend of construction investments**.
- **The cement industry important as it supports infrastructure. It is also important to sustain and develop the cement industry for the maintenance and development of the construction industry**, which employs about 3.7 million people, and related industries including ready-mixed concrete and concrete product manufacturers.



Upstream

Cement Manufacturing

Total shipment amount: 0.5 trillion yen
No. of employees: 5,000

Midstream

Ready-mixed concrete Manufacturing

Total shipment amount: 1.3 trillion yen
No. of employees: 39,000

Concrete products Manufacturing

Total shipment amount: 0.8 trillion yen
No. of employees: 33,000

Others

Total shipment amount: 0.4 trillion yen
No. of employees: 9,000

Downstream

Construction industry

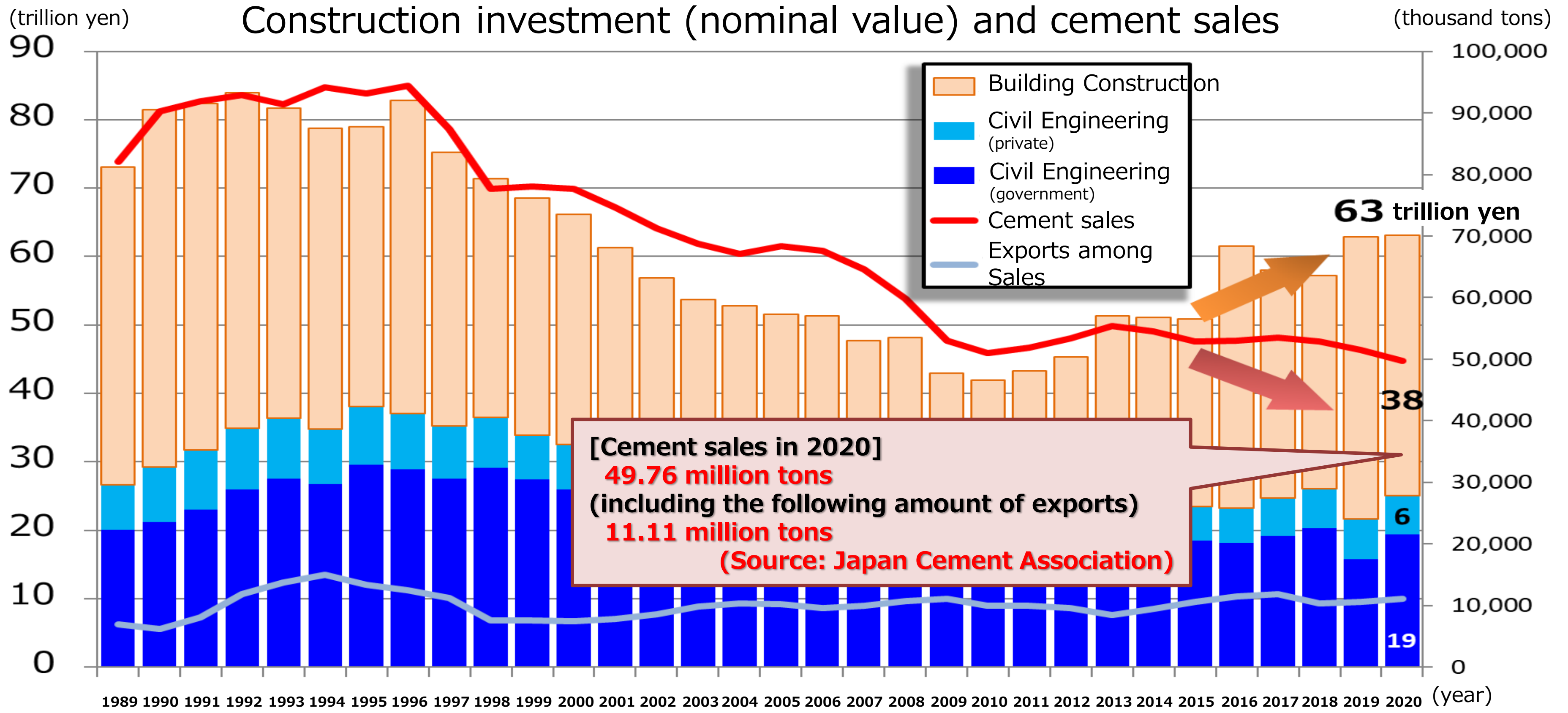
Total shipment amount: 108 trillion yen
No. of employees: 3.69 million

←Scope of this roadmap→

Source: 2019 Census of Manufacturers (Summary Version), 2016 Economic Census

2. Overview of Cement Industry | **Industry Size**

- The amount of construction investments in Japan has declined significantly since 1992. Though the amount has been increased in recent years due to measures to build national resilience, the **sales volume of cement has not increased due to rising costs such as labor costs, and has dropped by half from its peak.**
- However, it is an **essential industry and a certain level of demand is expected to continue to exist** thanks to **investments in disaster prevention and mitigation, renewal of public infrastructure (bridges, seawalls, and highways), and the aspect of the social value of accepting waste.**



Construction investment (nominal value) and cement sales

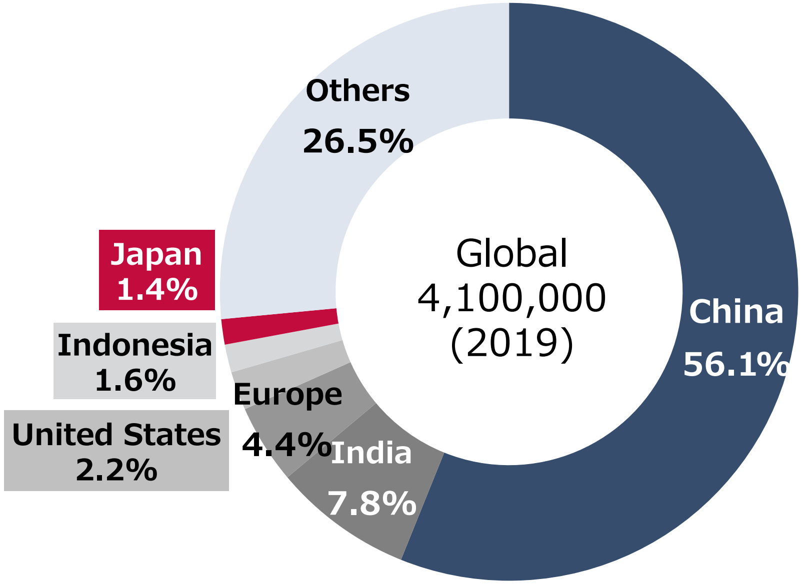
[Cement sales in 2020]
49.76 million tons
(including the following amount of exports)
11.11 million tons
(Source: Japan Cement Association)

Source: Prepared by METI based on the Outlook for Construction Investments of MLIT and Cement Handbook (Japan Cement Association)

2. Overview of Cement Industry | **Industry Size**

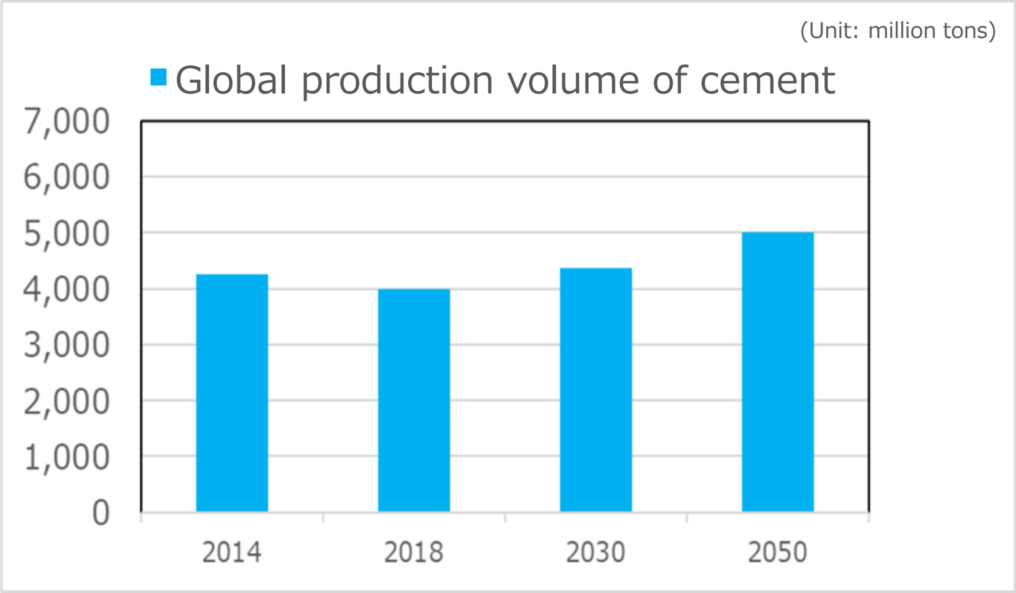
- The domestic cement industry produces 56 million tons and ships approximately 39 million tons of cement domestically*. **Though domestic demand is on the decrease**, maintaining a certain amount of capacity is essential. **Exports are increasing year after year** thanks to growing needs especially in Asia. **Increased demand in Asia and such like is offsetting the decline in domestic demand**.
- Considering the current situation where the Japanese cement industry is **contributing to the circular economy** by accepting waste, etc., it is **important to maintain the production system to meet the needs both in Japan and overseas, and to stably supply cement.** In addition, in order to win in overseas markets especially in Asia with carbon-neutral products, it is necessary to **develop technologies for CN while making responses with transitional technologies.**

Global production volume of cement



*Values for 2020.

Global cement production outlook



Source: Prepared based on IEA report (Technology Roadmap Low-Carbon Transition in the Cement Industry), Cement Handbook (Japan Cement Association), etc.

2. Overview of Cement Industry | Industry Size

- **There are 17 cement manufacturers and 30 plants in Japan.** Plants are located throughout Japan, mainly in mountainous areas where limestone mines are located.

Taiheiyo Group 🔵

①Taiheiyo Cement Corporation*
②Myojo Cement Co., Ltd.
③Tsuruga Cement Co., Ltd.
④DC Co., Ltd.
⑤Tosoh Corporation
⑥Hitachi Cement Co., Ltd.

Aso Group 🟠

⑪Aso Cement Co., Ltd.
⑫Kanda Cement Co.,Ltd.

Others
⑮Denka Company Limited ●
⑯Tokuyama Corporation** ○
⑰Ryukyu Cement Co., Ltd.* ⚫

*specialty manufacturer
**second-run manufacturer

Nippon Steel Group 🔴

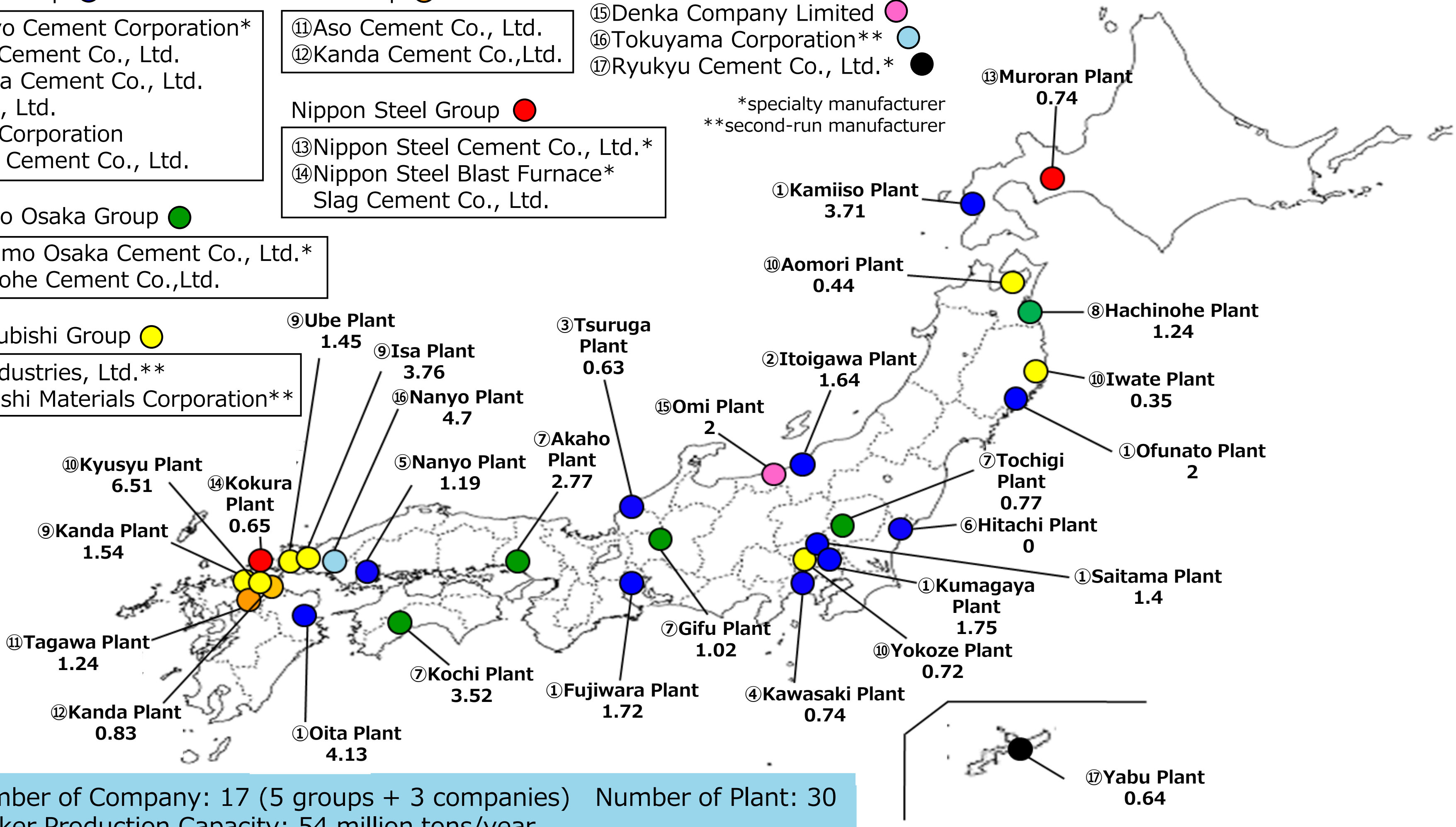
⑬Nippon Steel Cement Co., Ltd.*
⑭Nippon Steel Blast Furnace* Slag Cement Co., Ltd.

Sumitomo Osaka Group 🟢

⑦Sumitomo Osaka Cement Co., Ltd.*
⑧Hachinohe Cement Co.,Ltd.

Ube Mitsubishi Group 🟡

⑨Ube Industries, Ltd.**
⑩Mitsubishi Materials Corporation**



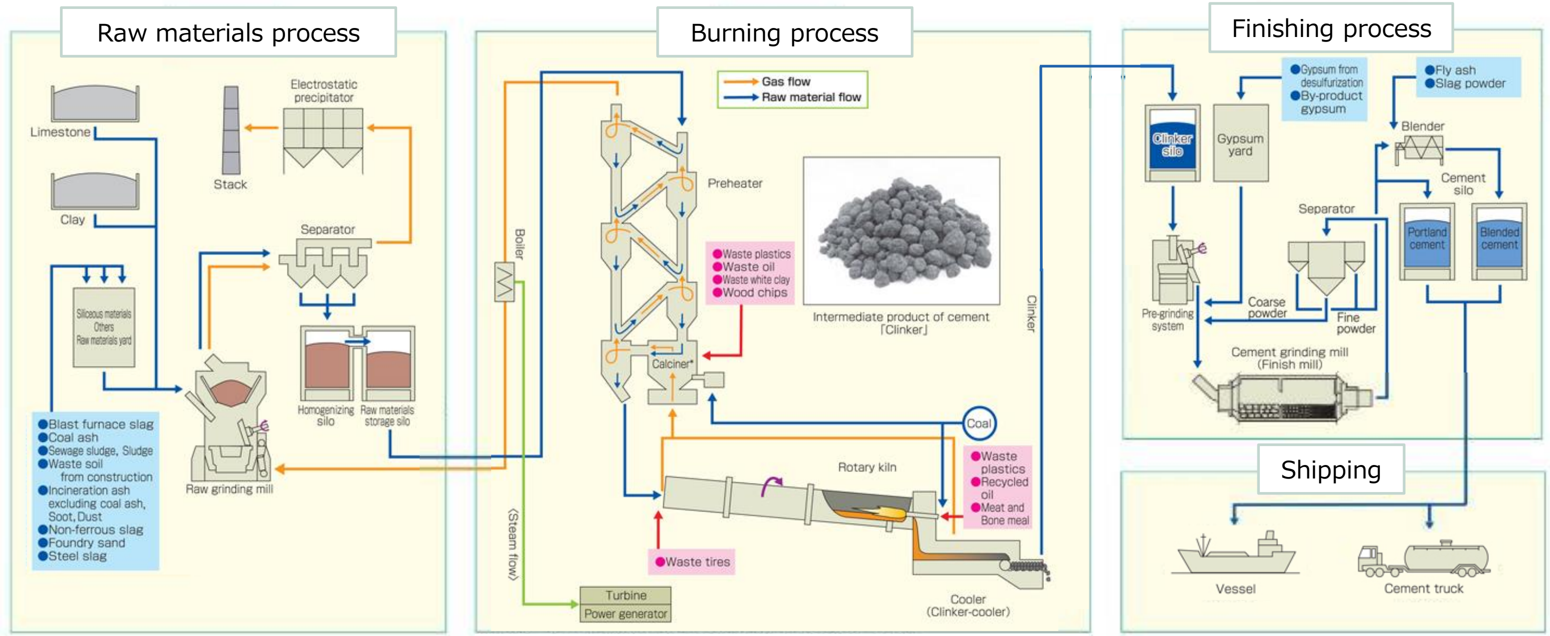
- Number of Company: 17 (5 groups + 3 companies) Number of Plant: 30
- Clinker Production Capacity: 54 million tons/year
- Sales: 2.5852 trillion yen Ordinary Income: 191 billion yen (FY2020)
- Ordinary Income Ratio: 7.4% Enrolled Employee: 7,714 (as of Dec 2020)

Unit = million tons

Source: Survey of the Japan Cement Association

2. Overview of Cement Industry | Cement Manufacturing Processes

- In the cement industry, **plants are constantly in operation, and each process requires electrical energy**.
- **In the burning process, the raw materials are fired at 1,450 degrees Celsius and a lot of energy is consumed.** From the viewpoint of efficiency including energy saving, it is **characterized by waste heat recovery for power generation, preheating and drying of raw materials, etc. using residual heat.**



*A suspension preheater kiln with a precalciner is called NSP kiln, and a suspension preheater kiln without a precalciner is called SP kiln.

Source: Material of the Japan Cement Association

Raw material mill

Crush the main raw materials including limestone using the raw material mill to produce powdered raw materials for the production of cement

Preheater

Preheat powdered raw materials with the preheater

Rotary kiln

Sinter raw materials at 1,450 degrees Celsius to produce compounds with hydraulicity

Clinker cooler

Cool the product compound to manufacture clinker

Finishing mill

Add gypsum and turn the cylindrical drum containing iron balls to crush clinker and gypsum

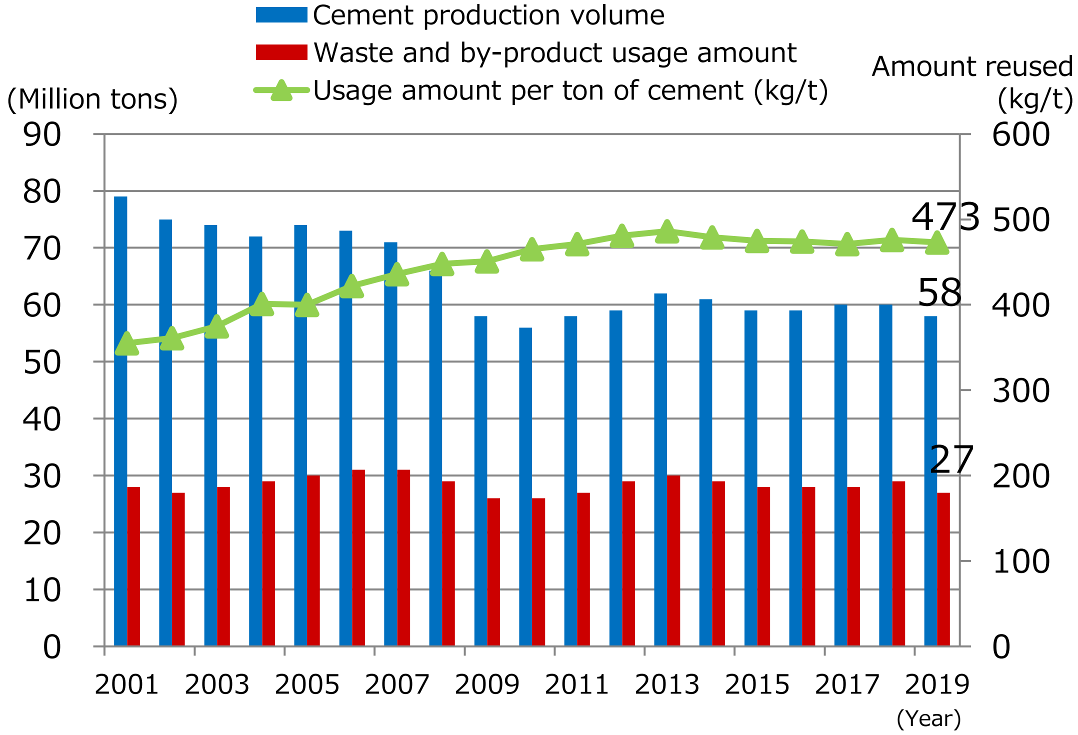
Separator and mixer

Separate fine and coarse powder with the separator
In the mixer, add fly ash and blast furnace slag to make the blended cement

2. Overview of Cement Industry | Waste used for Cement Production

- Cement industry accepts wide variety of waste and by-products as alternative to raw materials and energy. The industry uses about 500 kg of waste per ton of cement.
- After the Great East Japan Earthquake in 2011, the operation of cement plants **also contributed to disaster recovery by local governments, by utilizing disaster wastes for cement production.**

Transition in the amount of waste and By-products used for cement production



Source: Japan Cement Association

Examples of disaster wastes used for cement production

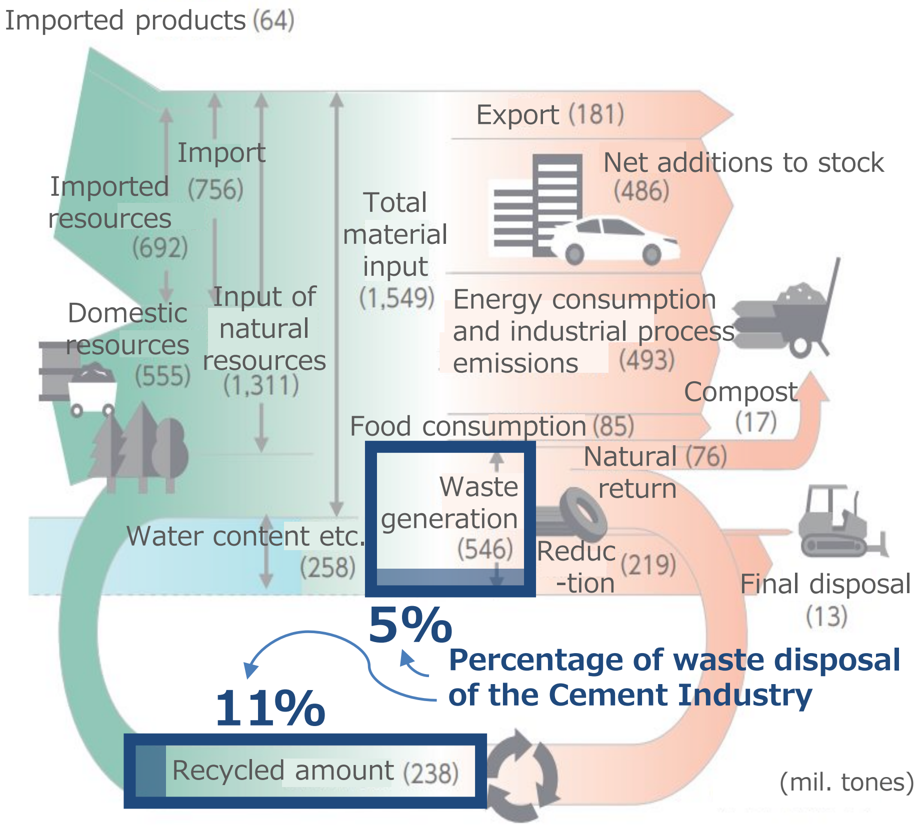
Year of occurrence	Natural disaster
2011	Great East Japan Earthquake
2014	Landslide disaster in Hiroshima
2015	Kanto and Tohoku heavy rains
	Joined D.Waste-Net
2016	Kumamoto earthquakes
2017	Heavy rain in northern Kyushu
2018	Heavy rain in western Japan
2019	Typhoon No. 19

(Reference) Amount of disaster waste accepted
- Great East Japan Earthquake 1.1 million tons
- Kumamoto earthquakes 220,000 tons

2. Overview of Cement Industry | **Waste Used for Cement Production**

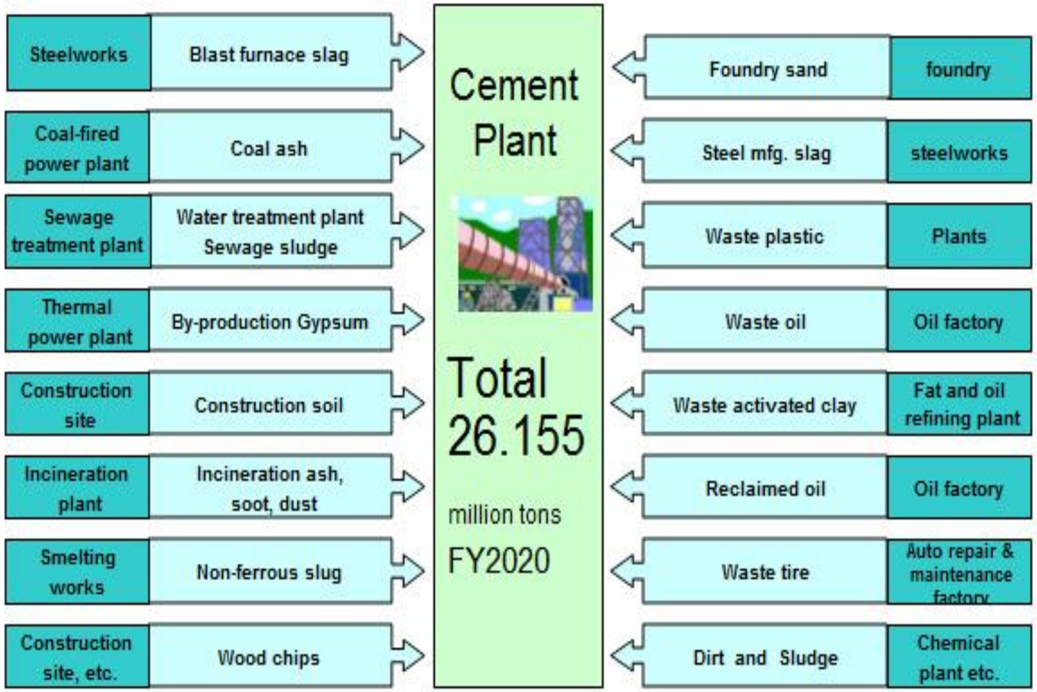
- The cement industry **receives approximately 26 million tons of waste and by-products annually** (about 5% of the total 546 million tons of waste generated in Japan, or about 11% of the total amount of recycled waste) and **effectively uses them as an alternative to natural resources.** This **contributes to a sound material-cycle society.**

Material flow in Japan



Source: Annual Report on the Environment, the Sound Material-Cycle Society and Biodiversity in Japan 2021 by the Ministry of the Environment

Breakdown of waste used in the cement industry



Steelworks	Blast furnace slag	Foundry sand	foundry
Coal-fired power plant	Coal ash	Steel mfg. slag	steelworks
Sewage treatment plant	Water treatment plant Sewage sludge	Waste plastic	Plants
Thermal power plant	By-production Gypsum	Waste oil	Oil factory
Construction site	Construction soil	Waste activated clay	Fat and oil refining plant
Incineration plant	Incineration ash, soot, dust	Reclaimed oil	Oil factory
Smelting works	Non-ferrous slug	Waste tire	Auto repair & maintenance factory
Construction site, etc.	Wood chips	Dirt and Sludge	Chemical plant etc.

Cement Plant

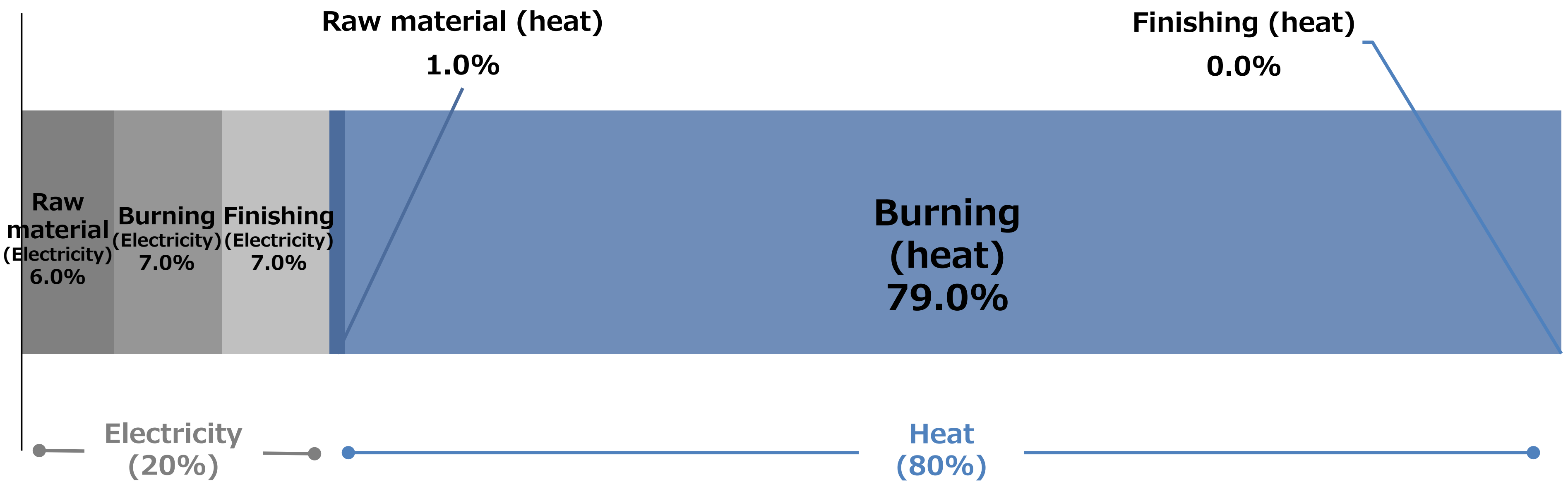
Total 26.155 million tons FY2020

Source: Japan Cement Association

2. Overview of Cement Industry | Breakdown of Energy Consumption in the Manufacturing Process

- **Most (80%) of the energy consumption** in the manufacturing process **is the heat energy of sintering raw materials such as limestone, which requires a high temperature of 1,450 degrees Celsius.**
- **Electricity is widely used in each process though,** the ratio of electricity to total energy consumption is low (20%) thanks to the effective use of heat such as for waste heat power generation equipment.

Breakdown of electricity and heat consumption in each process



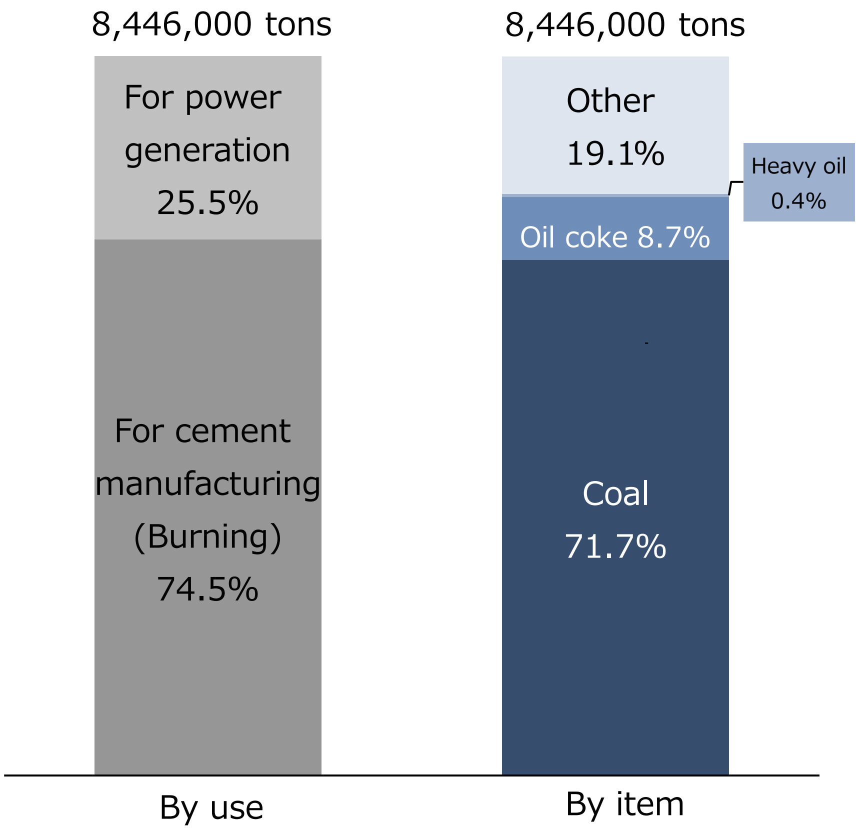
Source: Japan Cement Association

2. Overview of Cement Industry | Breakdown of Energy Consumption in the Manufacturing Process

- **Thermal energy**, which accounts for 80% of the energy consumption**, is mostly provided by coal** and **mainly used for the baking process, which requires a high temperature of 1,450 degrees Celsius**.
- **Electricity**, which accounts for 20% of the energy consumption, is provided **by private power generation and purchased power**, and is used in each process**. Private power generation is mainly based on coal and other fuels such as biomass and natural gas.**

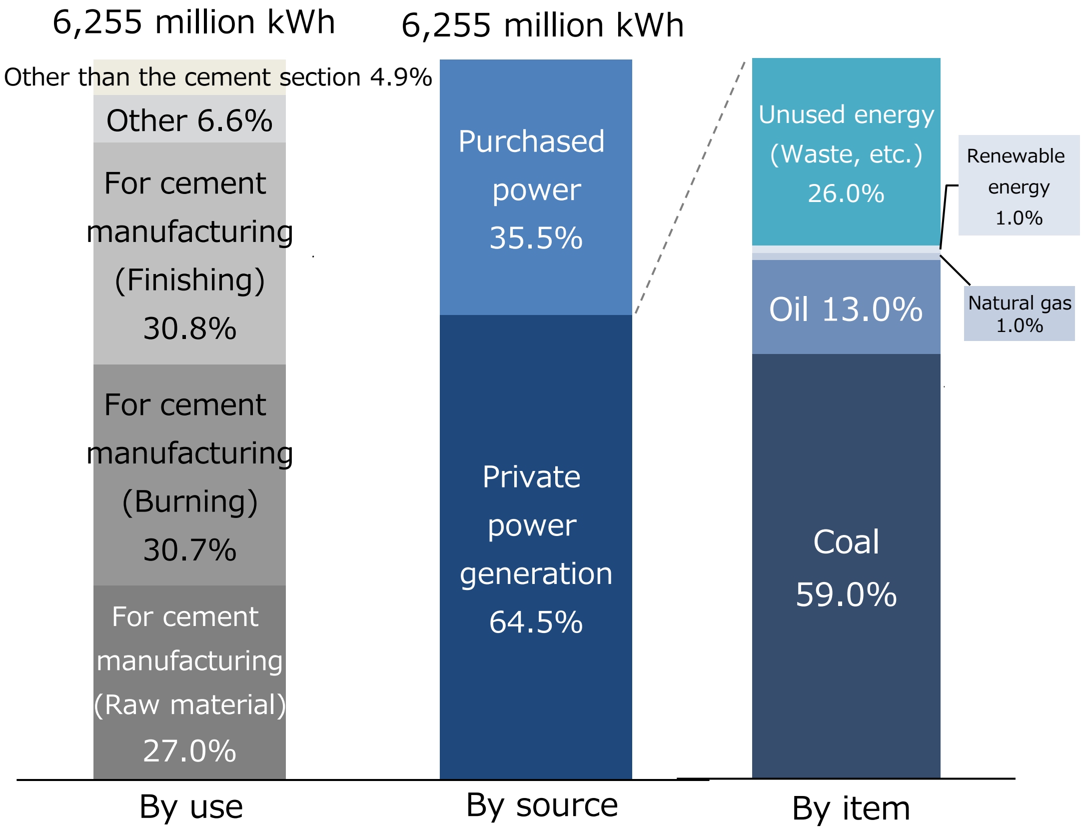
Thermal energy composition by application and item

80% of the energy consumption



Electricity composition by application and item

20% of the energy consumption

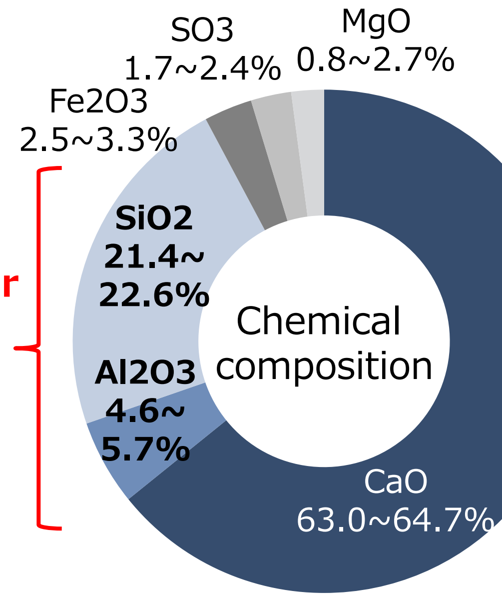


Source: "Comprehensive Energy Statistics" and Japan Cement Association

2. Overview of Cement Industry | Use of Coal, etc. in the Manufacturing Process

- **Coal is used as fuel and a raw material** in the cement industry. In addition to **being suitable for maintaining a high temperature of 1,450 degrees Celsius during the burning process**, the coal ash generated during the burning process is a valuable raw material of SiO2 (silica) and Al2O3 (alumina), which are cement components. In addition, from the viewpoint of substitution of natural raw materials, **coal has become the standard as one of the reasonable energy and raw material supply sources for the cement manufacturing process.**
- Other industries are switching fuel to natural gas, and while it is technically feasible in the cement industry, on the other hand, cement plants are located mainly in inland areas where limestone mines are located, which is **one of the reasons why pipeline installation and transport are difficult.**

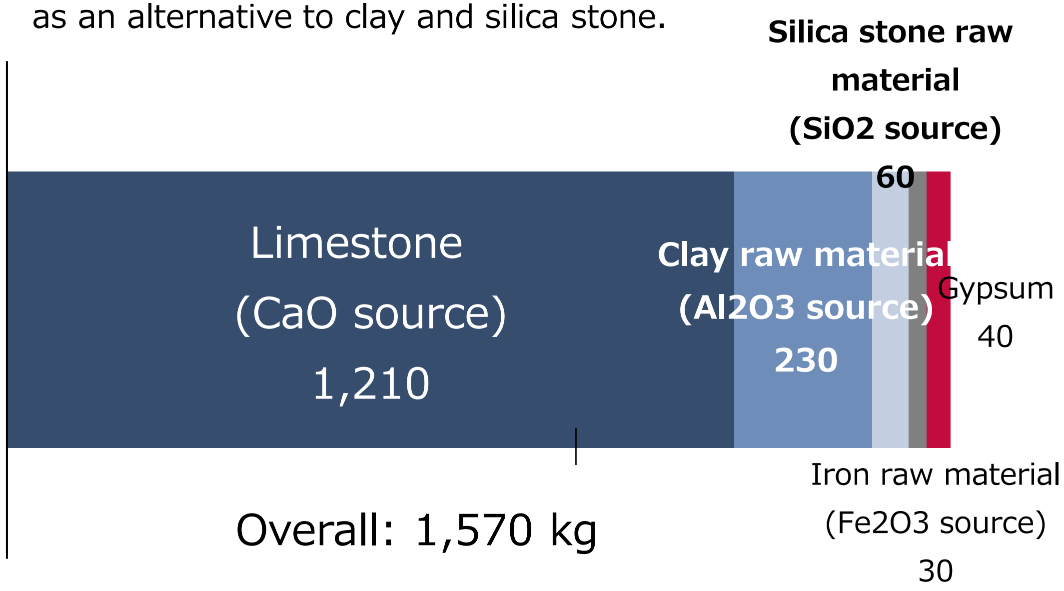
Chemical composition of ordinary portland cement



Substitute coal ash for part of the raw materials

Raw material composition per ton of ordinary portland cement (kg)

- Reduce the use of natural raw materials by utilizing coal ash as an alternative to clay and silica stone.



Source: Japan Cement Association

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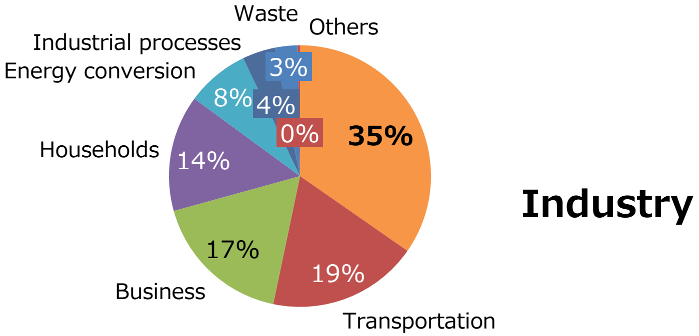
2. Overview of Cement Industry | CO2 Emissions Status

- CO2 emissions from the industrial sector accounted for 35% of Japan’s total CO2 emissions in FY2019. **Energy-derived CO2 emissions** from ceramic, stone, and clay products account for 8% of the industrial sector, in which **cement accounts for about 60%. (16.55 million tons)**
- In addition, the cement industry **emits about 25.33 million tons of non-energy-derived CO2 (= process-derived CO2) during the manufacturing process, for a total of approximately 42 million tons of CO2.**

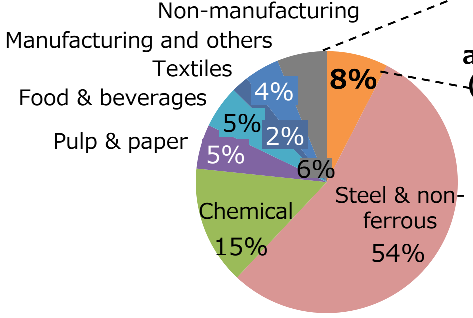
Japan as a whole (FY2019)

Approx. 1 billion tons of CO2



Industrial sector (FY2019)

Approx. 380M tons of CO2

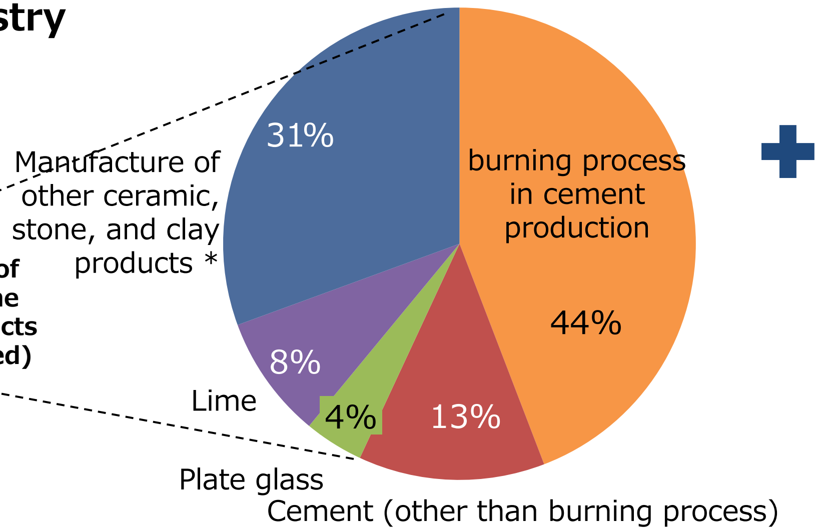


Manufacture of Ceramic, Stone and Clay Products (Energy-derived)

Ceramic, stone, and clay products: Breakdown of emissions (FY2019)

About 29 million tons of CO2
(including 16.55 million tons of CO2 from cement)

Energy-derived CO2 emissions



* Total of manufacturing of other products, other glass products, other ceramic, stone, and clay products in ceramic, stone, and clay product manufacturing

About 25.33 million tons of CO2

Non-energy-derived CO2 emissions

Since CO2 is generated from limestone in the cement manufacturing process, there are **approximately 25.33 million tons of non-energy-derived (= process-derived) CO2** emissions per year, which is equivalent to 60% of the emissions from the cement manufacturing process (approximately 42 million tons).

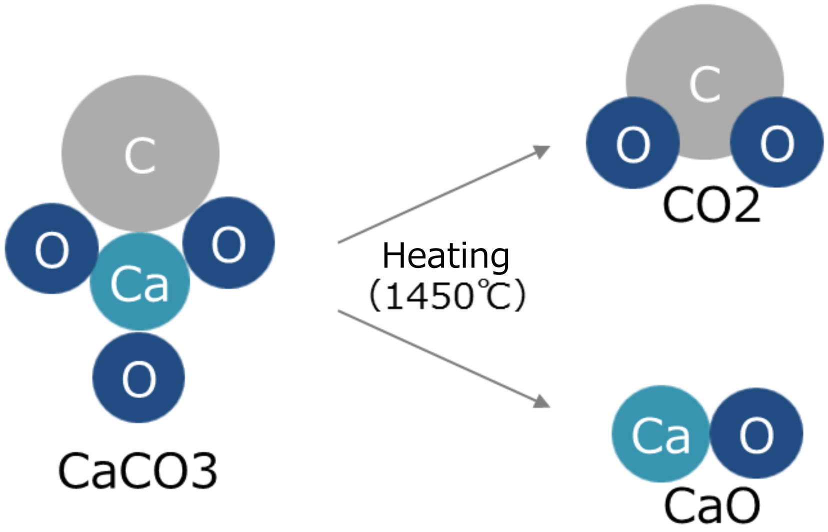
Source: National Institute for Environmental Studies “Japanese Greenhouse Gas Emissions Data” (FY2019 confirmed figures) and Ministry of Economy, Trade and Industry “Comprehensive Energy Statistics” (FY2019 confirmed figures)

2. Overview of Cement Industry | CO2 Emissions Status

- **Process-derived CO2 is inevitably emitted from limestone, which is a raw material for cement, through a decarboxylation reaction. In the burning process, coal is mainly used due to the need for a high temperature of 1,450 degrees Celsius, and this emits a large amount of energy-derived CO2.**
- **Process-derived CO2 and energy-derived CO2 account for 60% and 40%, respectively.** Countermeasures against emissions in the manufacturing process and from energy sources are necessary.

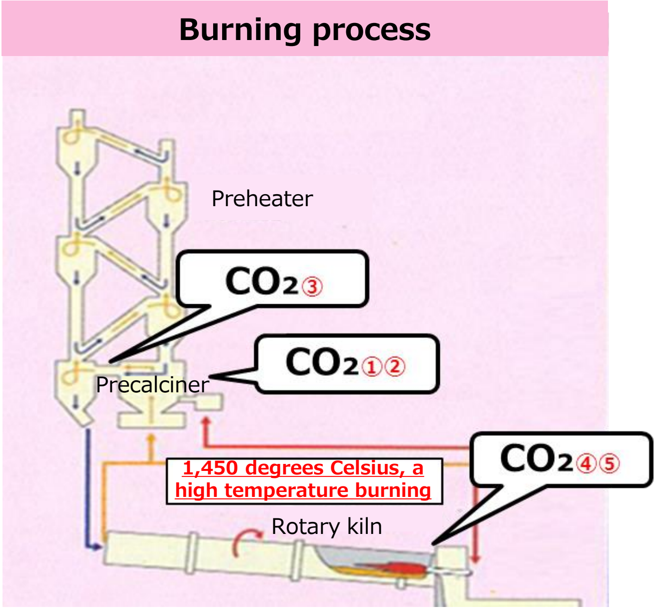
Process-derived CO2 emission principle

- CO2 is inevitably produced by the decarboxylation reaction when limestone, which is a raw material for cement, is heated at 1,450 degrees Celsius.
- The cement emission intensity is 763 kgCO2/t-cem.



Source: Japan Cement Association

Main sources of CO2 emissions during cement baking



CO2 emitted in the cement manufacturing process

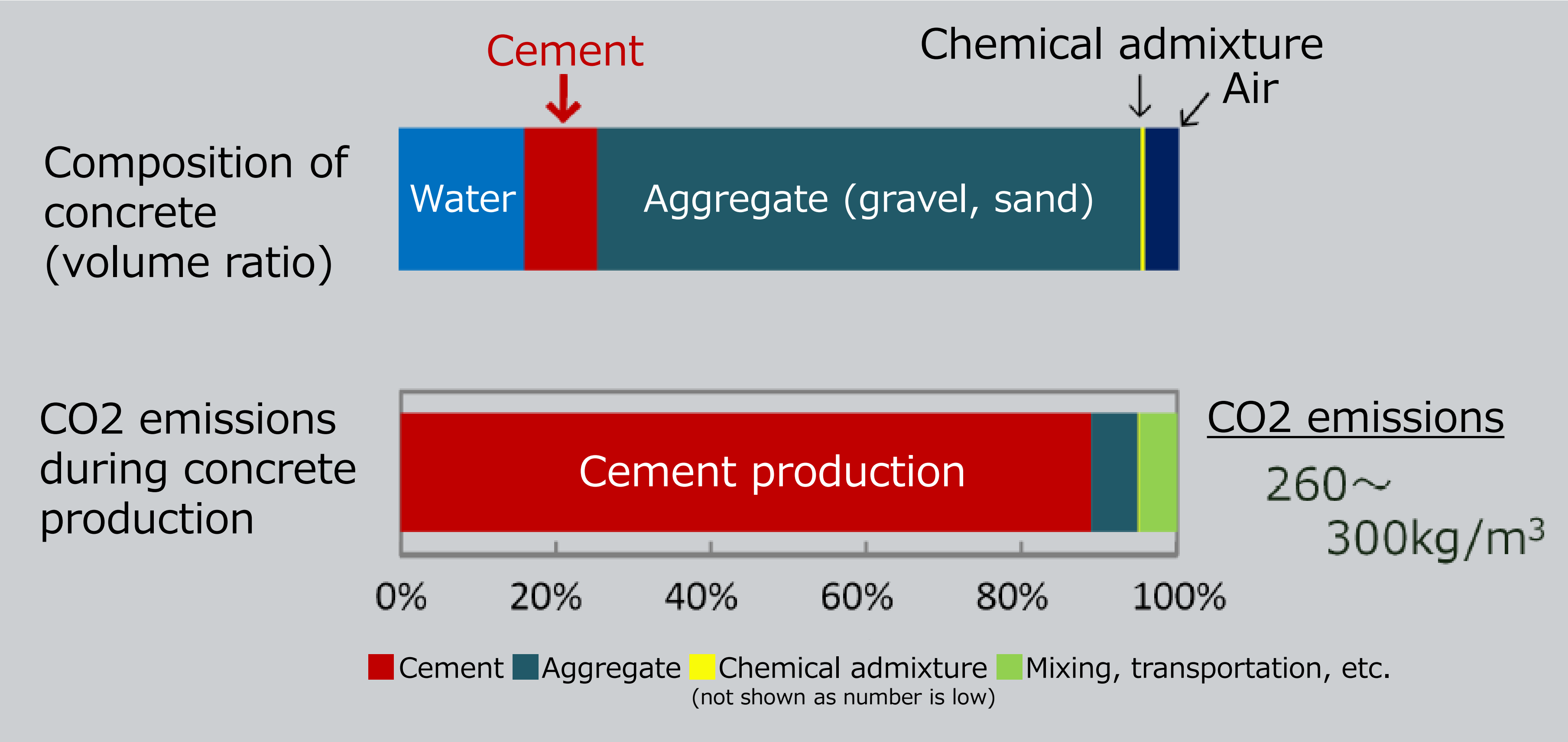
① Process-derived (precalciner)	About 48%
② Energy-derived (precalciner)	About 20%
③ Process-derived (preheater):	About 6%
④ Process-derived (kiln)	About 6%
⑤ Energy-derived (kiln)	About 20%

Blue: Process-derived CO2
Red: Energy-derived CO2

Prepared based on interviews with operators

Material Composition of Concrete and CO2 Emission Ratio

- **Even in the evaluation of concrete,** which is the product, **the main source of CO2 emissions is cement**, so it is important to strive to reduce CO2 emissions in the cement industry.



Prepared based on various pieces of published data

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2. Overview of Cement Industry | CO2 Countermeasures in the Domestic Cement Industry

- **Process-derived CO2 measures are done through innovation-based reductions. Innovative technologies are essential for CCUS including carbonate formation, cement development with a low clinker ratio, and technologies for efficient CO2 capture.** In addition to deepening existing R&D, it is also necessary to have R&D and capital investment through the Green Innovation Fund.
- **Energy-derived CO2 measures are taken by reducing CO2 emissions through fuel switching and other measures.** It is necessary to promote efforts such as **introducing energy-saving equipment, expanding the use of energy substitute waste, switching fuel for private power generation equipment, and converting kiln fuel for clinker production to clean energy.**
- Furthermore, in cooperation with related parties, a system to recycle waste into raw materials and fuel (i.e., circular economy) will be further established, and implement the above smoothly and surely to achieve net zero in the cement industry.

CO2 emission reduction methods

Process-derived CO2 countermeasures

Recycling of CO2

- Research **CCUS technologies** such as carbonation by incorporating CO2 from the cement manufacturing process into the calcium source.
- The Green Innovation Fund is implementing projects related to **"design and demonstration of CO2 capture technologies in manufacturing processes" and "establishment of carbonation technologies using various calcium sources."**

Low carbonization of cement

- **Development of** cement with low clinker ratio**, increased use of** blended cement**, and development of** cement with high blended material ratio.

Energy-derived CO2 countermeasures

Use energy-saving equipment and alternative fuel to reduce fossil fuel

- Promote the reduction of fossil fuel through energy saving by **introducing various energy-saving technologies and equipment** in the manufacturing processes of raw materials, baking, and finishing.
- **Effectively use waste as energy and raw materials** during clinker production.

Fossil fuel reduction Low carbonization

- In private power generation in the manufacturing process, **promote switching from fossil fuel to biomass, hydrogen, etc.**
- Promote research and development to **switch the thermal energy** of the rotary kiln **into ammonia and other products**.
- Promote the **generation (methanation) and utilization of synthetic methane** using CO2.

Source: "Green Innovation Fund" by the Ministry of Economy, Trade and Industry and "Initiatives toward the Construction of Sustainable Society" by the Japan Cement Association

2. Overview of Cement Industry | Long-term Vision toward Decarbonization in the Cement Industry

- In March 2020, **the Japan Cement Association announced its "Long-Term Vision for the Cement Industry toward a Decarbonized Society" to reduce greenhouse gas emissions by 80%**.
- Among some initiatives, **it announced ones for low carbonization of input raw materials and used energy and CO2 capture, utilization, and storage (CCUS/carbon recycling), etc. as countermeasures to be taken by 2050.**

Long-Term Vision for the Cement Industry toward a Decarbonized Society (excerpt)

1. Background and objective of this vision

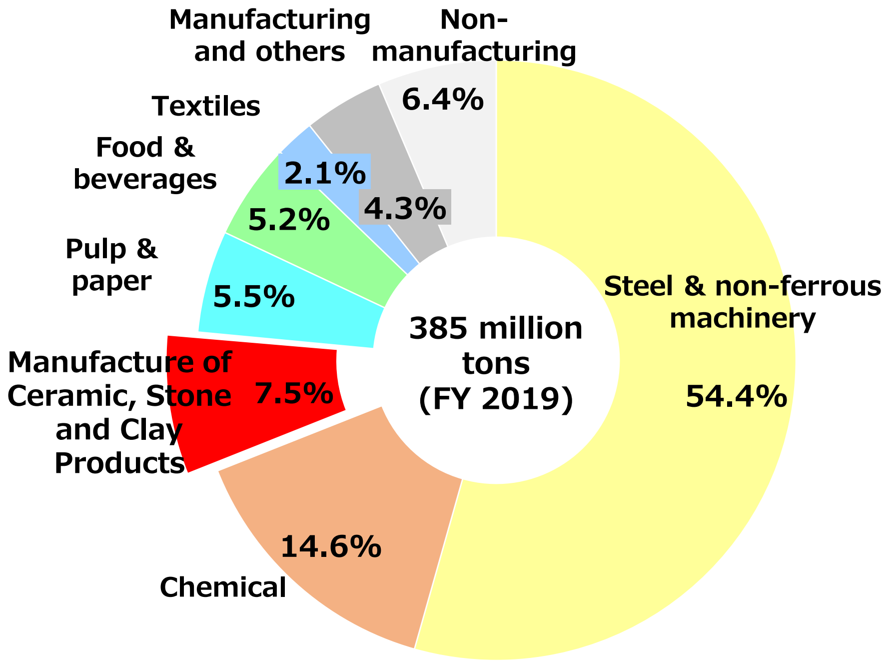
2. Estimated Domestic demand in 2050
Domestic demand in the broad sense (public and private demand for cement and cement base agent) in 2050 is expected to be about 34 to 42 million tons.

3. Role of the cement industry
(Omitted) The cement industry will continue to play the following roles in the future:
[Supplier of basic materials], [Contribution to an establishment of a sound material-cycle society], [Contribution to the local community], and [Contribution to disaster debris management]

4. Direction of countermeasures to be taken and issues to be overcome
Most of the countermeasures to be aimed at have difficult issues to overcome and require "discontinuous innovation" for their realization.

- Reduction of the clinker to cement ratio
- Switching to Low carbon raw materials
- Improving energy efficiency
- Improving thermal energy efficiency using mineralizers, etc.
- Switching to Low carbon thermal energy
- Developing low-carbon binding materials and new cement
- Challenging to carbon capture, utilization, and storage (CCUS)
- Taking up carbon dioxide by cement carbonation
- Reduction in carbon dioxide emissions by promoting concrete pavement to improve fuel efficiency of heavy vehicles

CO2 Emission Ratio by Industry (FY2019)



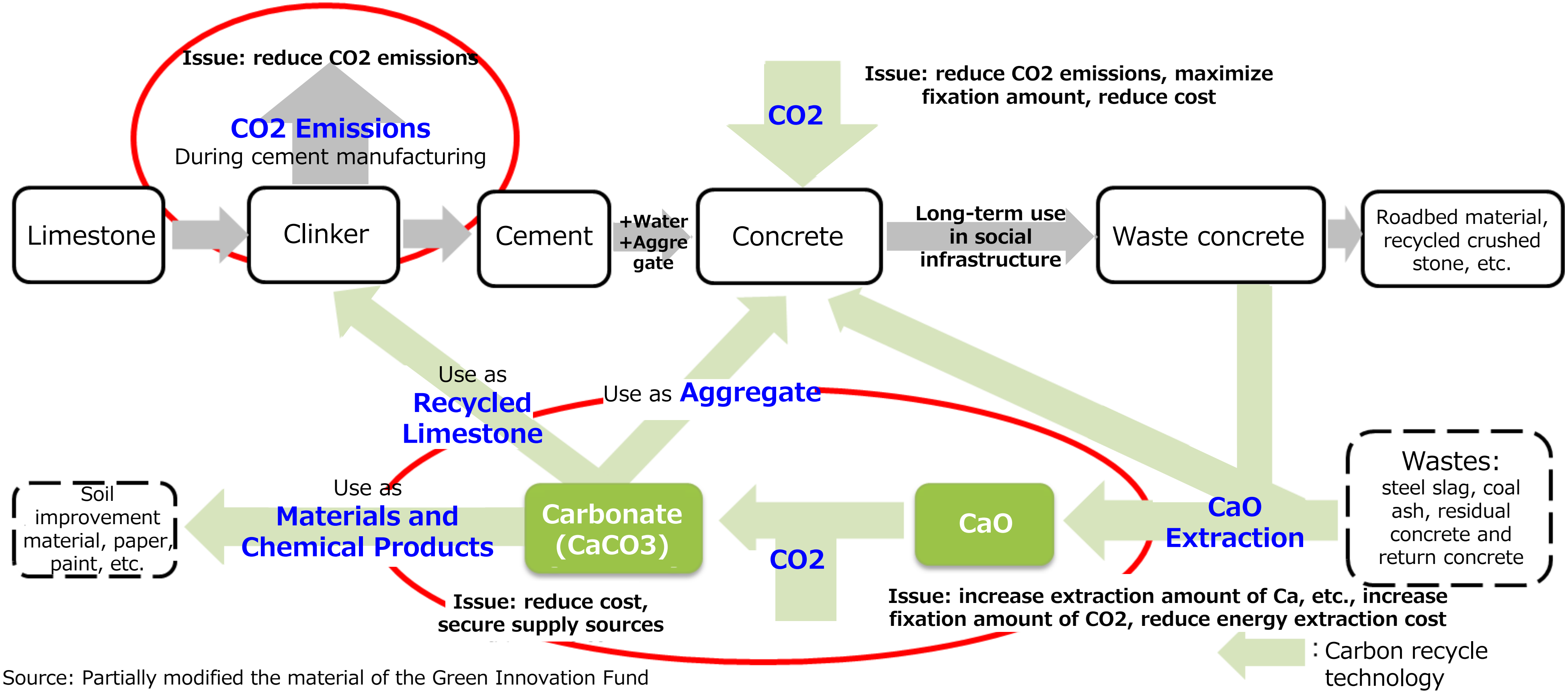
CO2 emissions during cement manufacturing: 41.47 million tons in Japan (FY2019)

- **Derived from limestone (raw material): 60% 25.33 million tons/CO2**
- **Derived from fossil fuel (energy): 40% 16.14 million tons/CO2**

2. Overview of Cement Industry | Initiatives for Process-derived CO2 Countermeasures (GI Fund Project①)

- In order to **reduce process-derived CO2,** which is indispensable for decarbonization, **the public and private sectors will work together to promote initiatives through the Green Innovation Fund project.**
- In this project, **new cement manufacturing processes with increased CO2 yield will be developed while utilizing the existing efficient manufacturing processes, and technologies to carbonate and reuse the recovered CO2 with calcium sources such as various types of waste, will be developed.** This will reduce CO2 emissions from new limestone and reduce the use of domestic limestone, thereby helping to secure domestic resources.

Overview of the Green Innovation Fund project



Source: Partially modified the material of the Green Innovation Fund

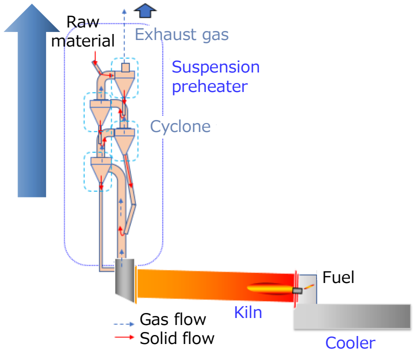
2. Overview of Cement Industry | Initiatives for Process-derived CO2 Countermeasures (GI Fund Project②)

- Since most of the process-derived CO2 is generated inside the preheater, it can be recovered efficiently, but cost is an issue in recovering nearly the entire amount. From now on, promote **development of a low-cost and efficient production process for CO2 capture by retrofitting the existing NSP kiln.**
- In order **to reduce process-derived CO2, an urgent task is also to establish a carbonation technology as a substitute for limestone .** In addition to the above-mentioned CO2 recovery cement manufacturing process technology**, carbonation technologies using CO2 and a CO2 recycling model in the cement manufacturing process will be developed and demonstrated.**

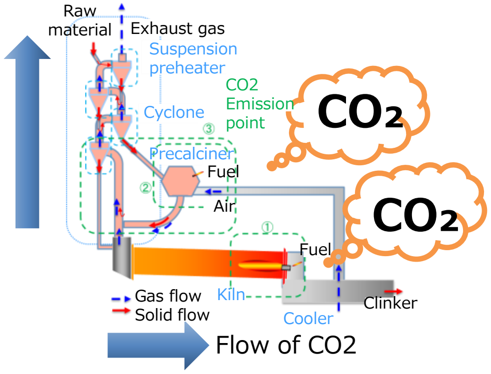
CO2 capture in manufacturing processes

- ✓ SP kiln: Has a system that sends high-temperature gas from the kiln to the preheater for limestone preheating in order to make effective use of exhaust heat.
- ✓ NSP kiln: Kiln (developed in Japan) that achieves further energy saving by installing additional combustion equipment (precalciner) in the preheater to increase the total combustion efficiency. It is the de facto of the world today.

Conventional: SP kiln



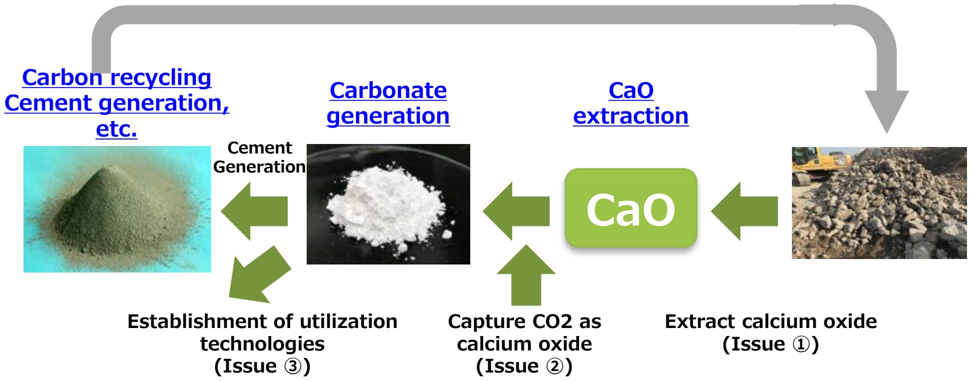
Current: NSP kiln



The issue is to achieve a large amount of CO2 capture at low cost.

Technology for cement manufacturing using recycled CO2 and waste, etc.

- ✓ Develop technologies of mineral carbonation with appropriate calcium component. There are issues in terms of the capacity of the carbonation, etc., and practical application has not been achieved so far, and development and demonstration of new CO2 recycling models are in progress.



Issues
① Expansion of the CaO extraction amount
② Expansion of the CO2 fixation amount
③ Establishment of utilization technologies
Common issue: Low-cost treatment

CO2 recovered by the CO2 recovery-type cement manufacturing technologies (Shown on the left)

Research and development matters in the GI Fund

Source: Partially modified the material of the Green Innovation Fund

2. Overview of Cement Industry | Initiatives for Process-derived CO2 Countermeasures (Current Initiatives)

- Process-derived CO2, which accounts for 60% of emissions from the cement industry, is generated by heating limestone, which is a raw material, so it is difficult to eliminate completely.
- **Innovative technologies, such as the utilization of carbonates, are needed to achieve a complete reduction of process-derived CO2**. **In addition to reducing the amount of waste by substituting raw materials, initiatives with carbonate formation (CCUS) and technological development are in progress for technologies such as cement with a low clinker ratio.**

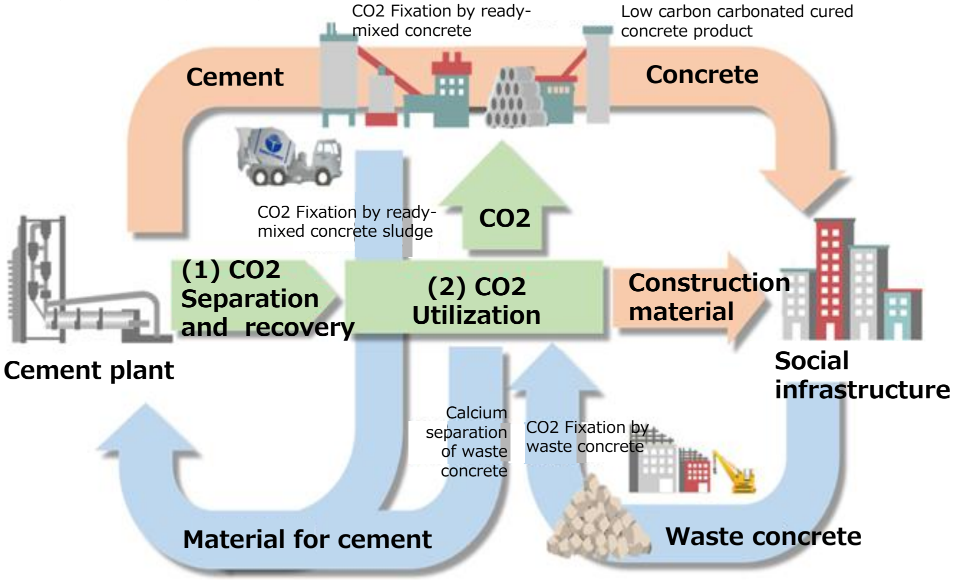
Substitution of waste for raw materials for clinker production

- Waste can be substituted as a raw material for clinker production because its chemical composition is close to that of natural raw materials.
- The estimated amount of CO2 reduction in FY2019 is 848,000 t-CO2. This is equivalent to a reduction of about 1.9 million tons of limestone.

Raw materials	Calcium oxide (CaO)	Silicon dioxide (SiO2)	Aluminum oxide (Al2O3)	Iron oxide (Fe2O3)
Clay (Natural)	~5%	40~80%	10~30%	3~10%
Coal ash (Waste)	5~20%	40~65%	10~30%	3~10%
Incinerated ash (Waste)	20~30%	20~30%	10~20%	~10%
Sewage sludge (Waste)	5~30%	20~30%	20~50%	5~10%

Development of carbon-recycling cement manufacturing process technology

- In Japan, mainly the NEDO project has been conducting demonstration experiments on the separation and recovery of CO2 from kiln exhaust gas and fixation of the recovered CO2 in cement products in order to reduce process-derived CO2 emissions.
- However, no technology to recover nearly the entire amount of CO2 contained in the exhaust gas in the cement industry has been established.

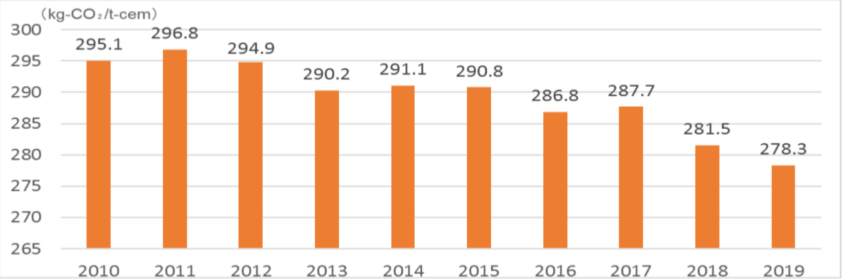


Source: Japan Cement Association, NEDO

2. Overview of Cement Industry | **Current status of Energy-derived CO2 Countermeasures**

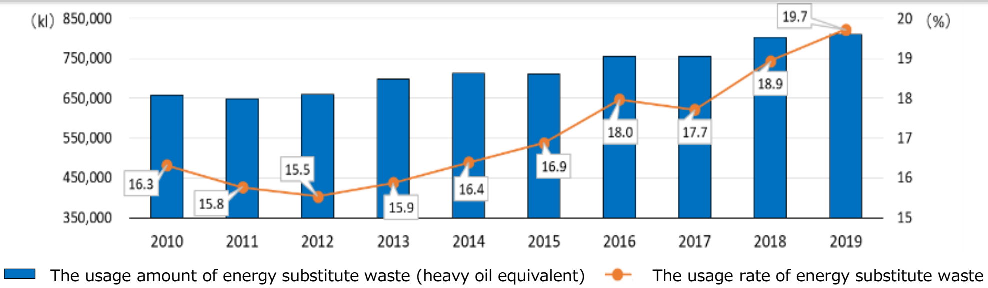
- Based on the Plan for Global Warming Countermeasures, the cement industry is **implementing measures to reduce CO2 through the introduction of energy-saving equipment and the reduction of fossil fuel through the use of waste for cement production, etc.**
- **As for private power generation equipment**, initiatives to reduce energy-derived CO2 are in progress **such as switching to renewable energy from fossil fuel to biomass.**

Transition in the CO2 emission intensity



*The CO2 emission intensity is the energy-derived CO2 emissions per ton of cement (kg)

Transition in the amount of waste used for thermal energy



Transition in the energy-saving capital investment amount

(Million yen)

Investment year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Cumulative
Investment amount	5,144	749	1,807	2,356	3,634	8,744	3,469	889	2,975	11,256	41,023

Initiatives for fuel switching

Ofunato Biomass Power Plant (funded by Taiheiyo Cement Corporation)

Tochigi Plant biomass power generation equipment (Sumitomo Osaka Cement Company, Limited)

◆ Introduced waste heat recovery for power generation in 31 of 50 kilns.
*190,000 kW/700,000 kW (output basis)

◆ Renewable energy (including co-combustion) in private power generation is about 40%.
*280,000 kW/700,000 kW (output basis)

2. Overview of Cement Industry | Future Issues and Countermeasures of Energy-derived CO2 Countermeasures

- **The Green Innovation Fund is intended to promote process-derived CO2 countermeasures, but issues remain in energy-derived CO2 countermeasures generated from coal, heavy oil and the like to operate kilns, etc.**
- Initiatives are underway to reduce energy-derived CO2 emissions by expanding the use of renewable energy such as biomass and introducing energy-saving equipment. **Though certain results have been achieved, further research and development, fuel switching initiatives, etc. are necessary to achieve carbon neutrality in the future.**

Conceptual image of future countermeasures

- Continue the ongoing **expansion of the use of renewable energy and introduction of energy-saving equipment.** In addition, promote **the switching of energy sources used for private power generation from fossil fuel to natural gas and biomass (including improving the co-combustion rate).**
- While **developing infrastructure** such as the pipelines necessary for natural gas combustion, promote the introduction of **private power generation equipment necessary for fuel switching to clean energy** such as hydrogen, ammonia, and synthetic fuel (synthetic methane*).

  *As a part of fuel switching, we are promoting the use of methanation such as methane generation (synthesis gas or syngas) using CO2 emitted from cement plants and hydrogen, but it is necessary to **introduce equipment and demonstrate technologies for methane generatio**n.
- As a measure for fuel to be used in cement kilns, promote **development and demonstration toward switching to and introducing decarbonized fuel** such as hydrogen, ammonia* and synthetic methane.

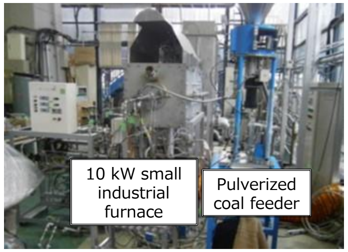
  *Though a burner using ammonia and other devices have already been developed, the ammonia co-combustion ratio is only about 30%, so an **ammonia burning technology with a high co-combustion ratio** will be required.
- In order to improve the profitability of the business, it is necessary to **develop an effective production system** suitable for the production volume. For example, the development of production facilities such as hydrogen and ammonia complexes for joint use.

2. Overview of Cement Industry | Reference: Initiatives by Cement Manufacturers to Reduce Energy-derived CO2 Emissions

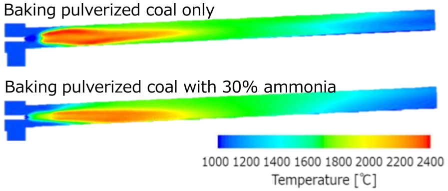
- As part of initiatives by domestic cement manufacturers to address energy-derived CO2 emissions through fuel switching, **the development of burning technologies that use a mixture of fossil fuel and ammonia for combustion in cement kilns** is in progress.
- In addition, **the development and demonstration of technology to utilize synthetic methane, which is produced by separating and recovering CO2 from the exhaust gas of cement plants, as fuel** is also in progress.

Switching of thermal energy for clinker production

- ○ Development of a technology to switch burners for cement manufacturing to ammonia (Cabinet Office SIP)
  Aim to establish a technology to reduce energy-derived CO2 emissions from fossil fuels by replacing the heat energy of the burner in the rotary kiln with ammonia (conducted by Ube Industries, Osaka University, etc.).
- ○ Conducted experiments on the co-combustion of heavy oil or pulverized coal with ammonia using a model combustion furnace test to obtain guidelines for achieving low NOx emissions.
- ○ Experiments for clinker production were conducted by co-combustion of ammonia with heavy oil, and the quality of the obtained samples was evaluated and the impact of co-combustion with ammonia was predicted in a simulation.
- ○ At the experimental furnace level, achieved an increase in the ratio of ammonia co-combustion to 30%.



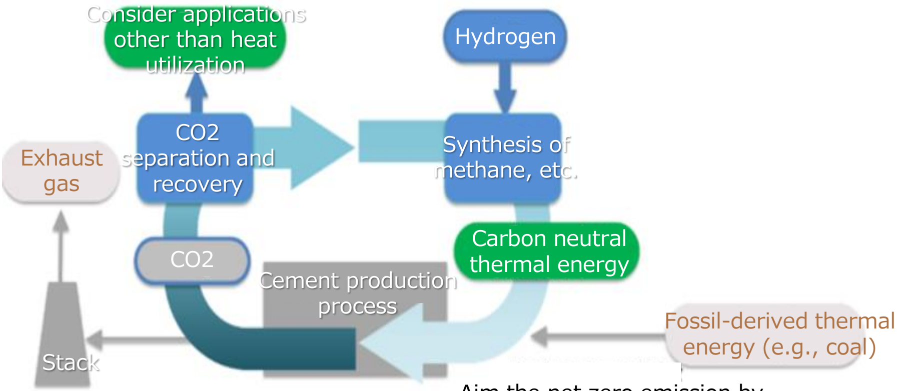
Clinker test baking



Fuel switching for plant operation energy (Use of synthetic methane by methanation)

- ○ The development of a **technology to manufacture synthetic methane by separating and recovering CO2 from the exhaust gas** of cement plants, **and to utilize the synthetic methane as a decarbonized fuel** is in progress (conducted by Mitsubishi Materials).
- ○ The demonstration test was started in FY2021.
- ○ It is necessary to secure inexpensive hydrogen, calculate the cost in the future, etc.

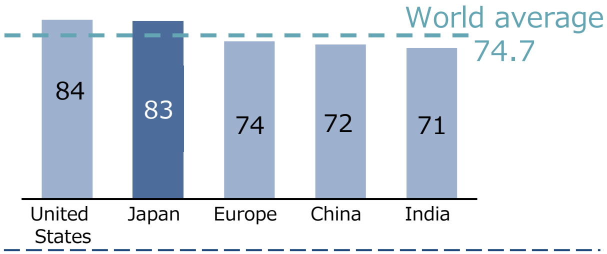
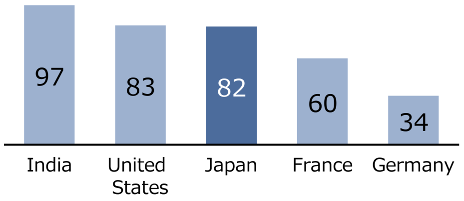
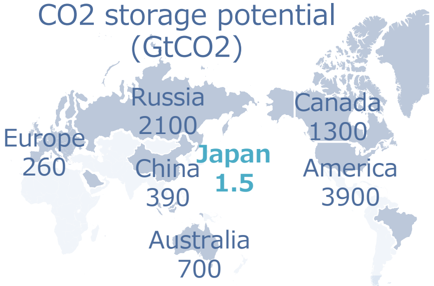
Conceptual diagram of the exhaust gas recycle of cement plants



Aim the net zero emission by combining energy savings and offsets

2. Overview of Cement Industry | Comparison between Domestic and Overseas Cement Industries

- There are no big differences in the **use of raw materials and fuel** between the domestic and overseas cement industry, though there are some differences in the clinker to cement ratio and fossil fuel utilization rate. We will **promote efforts taking into consideration Japan's unique circumstances**, such as the need for strength and durability of concrete due to high earthquake frequency **while in line with global trends.**
- On the other hand, as Japan has a low storage potential for CO2 unlike other countries, as for the **direction of CCUS**, recycling CCUS technology that **reuses waste or recovered CO2 may be suitable for Japan**.

	Domestic	Overseas	Reference
Clinker/cement ratio (related to process-derived CO2)	• **The clinker/cement ratio is about 83%, which is higher than the global average**, and the CO2 emission factor is correspondingly high. • There is a difference in the operation of the required level of compressive strength for cement among countries, and this is reflected in the result. • **Reduction of the clinker to cement ratio, etc.**to reduce CO2 emissions. (Long-term vision of the Japan Cement Association)	• **In Europe, the rate is 74%, and in China it is relatively low at 72%**. For example, Chinese cement is characterized by a low clinker/cement ratio. (The CO2 emission factor is also low.)	Clinker/cement ratio in major regions* 
Fossil fuel Utilization rate (Related to energy-derived CO2)	• **The utilization rate of fossil fuel** in heat energy **for clinker manufacturing is 82.1%.** • In Japan, **waste is being used as a substitute for energy and raw materials**. • Promote continuous initiatives and **low carbonization of energy used**. (Long-term vision of the Japan Cement Association)	• Europe is **expanding the use** of waste and **biomass fuel** for thermal energy , and the utilization rate of fossil fuel is low. • On the other hand, in emerging countries such as India, the use of alternative fuel has not expanded and the utilization rate of fossil fuel is high.	Fossil fuel ratio (%) (FY2016) 
Storage potential (related to process-derived CO2)	• Currently, there are limited CO2 storage areas in Japan, and for the captured CO2, it is **more reasonable to take a recycling approach** to utilize CO2 in the cement manufacturing process rather than storing it. • Promote CCUS initiatives. (Long-term vision of the Japan Cement Association)	• **In Northern Europe and the U.S.,** where the CO2 storage potential is high thanks to the large number of oilfields**, technologies for storing captured CO2** have become mainstream.	CO2 storage potential (GtCO2) 

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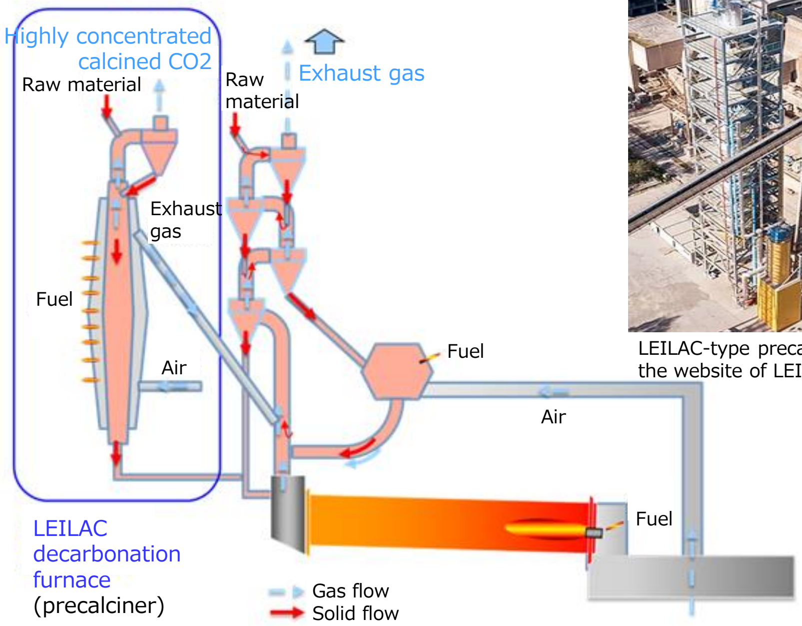
*The clinker ratio is excerpted from the 2016 METI report, except for Europe. For the values of Europe, refer to the data of Cembureau. The year is unknown.

Source: Surveys and reports of Global CCS Institute, Cembureau, GTSP, GNR, and METI related to measures to diffuse and expand energy-saving manufacturing processes in the cement industry

2. Overview of Cement Industry | Trend of the Global Cement Industry (Initiative Examples)

- As an international technology trend, the LEILAC project has started to demonstrate a technology to capture process-derived CO2 by indirectly heating limestone in a precalciner. It is possible to capture high-concentration CO2, but **the issue is to enlarge the scale of the equipment**.
- HeidelbergCement announced it would aim for decarbonization at its Swedish plant by 2030. It plans to capture the process-derived CO2 by chemical absorption, and compress, cool, and store it at the sea bottom (CCS). However, the CO2 capture energy is estimated to be five times higher than the energy for cement production. In addition, **the cost of sea bottom storage must also be considered**.
- In Japan, it is currently difficult to widely implement CO2 storage at low cost, so it may **be more realistic to work on the recycling CCUS technology** to reuse the captured CO2 by utilizing the existing know-how in conventional waste utilization, etc.

Combustion method by LEILAC




LEILAC-type precalciner (from the website of LEILAC)

■LEILAC project

○ With financial support from EU Horizon 2020, the world's leading manufacturers such as HeidelbergCement (Germany), CEMEX (Mexico) and CALIX (USA) have participated in the project.

- LEILAC I 2019 and onward 30,000 tons - CO2/year
- LEILAC II 2025 and onward 100,000 tons - CO2/year

○ The equivalent of 20% of the CO2 derived from limestone is captured.

(from the website of LEILAC)

■HeidelbergCement data (CCS)

- CO2 capture energy 3.0 GJ/t *1
- Cement production 0.6 GJ/t *2

*1 「CO2 Capture, Use, and Storage in the Cement Industry: State of the Art and Expectations」 (AuthorMarta G. Plaza,Sergio Martínez, and Fernando Rubiera)
*2 Calculated based on the electricity consumption in "Cement Handbook" (Japan Cement Association)

2. Overview of Cement Industry | Summary of the Trends toward Decarbonization of the Cement Industry

- Cement, which is an important building material for social infrastructure, will continue to be important in the future, and we need **to strive to reduce both process-derived CO2 and energy-derived CO2** in order to achieve a decarbonized society while seeking quality and stable supply.

- Innovative technologies will be necessary to reduce **process-derived CO2**. **While promoting use of wastes for raw material substitution and carbonate generation as a transition and the development of cement with a low clinker ratio, it is necessary to develop technologies for CO2 capture and utilization mainly through GI Fund projects in order to achieve carbon neutrality in the future.** In addition, it is necessary to cooperate with users and related ministries and agencies, deepen understanding among all parties, and gradually develop a social system to promote recycling.

- To reduce **energy-derived CO2 emissions, in the short term, continue to expand the use of wastes for thermal energy and introduce energy-saving and high-efficiency equipment while, in the long term, aiming to switch to decarbo**nized fuel such as hydrogen and ammonia for private power generation equipment and kilns.

- Overseas, the development of CCS and other technologies is proceeding, but issues remain in terms of equipment scales, costs, etc. In addition, the potential for storage in Japan is lower than overseas, and in view of economic efficiency, it is **important to steadily promote technological development, mainly the development of recycling CCUS technology, which reuses captured CO2, while utilizing existing know-how such as waste utilization**.

- In the future, proceed with initiatives toward decarbonization mainly through the GI Fund project while also utilizing technologies in the transitional period.

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3. Technology Pathways to Decarbonization | ①Low-Carbon and Decarbonization Technologies for Carbon Neutrality

	Technology	Overview	Emission factor/ reduction range*1	Implementation year*2	References*3
Manufacturing process	**Energy saving and high efficiency (Best practices)**	✓ Waste heat recovery for power generation ✓ Efficiency improvement of clinker coolers ✓ Introduction of vertical coal mills ✓ Verticalization of blast furnace slag mills ✓ NSP kiln ✓ Introduction of IoT and automated driving	Energy intensity approx. 5.7% reduction※3 (compared to 2019, as of 2030)	Already implemented	✓ Low-Carbon Society Action Plan, etc. ✓ Material Economics
	Decrease in the sintering temperature of clinker	✓ Contribute to a reduction in the energy intensity by lowering the sintering temperature using mineralizers, etc.		2020s	✓ Action Plan for Low-Carbon Society
Raw materials	**Reduction of the clinker ratio**	Reducing emissions by reducing the proportion of clinker in cement through the following measures: ✓ Increase the amount of minor additional constituent used by increasing the amount of tricalcium aluminate ✓ Increase the amount of blast furnace slag added to Portland blast furnace slag cement type B	―※4	Already partly implemented	✓ Action Plan for Low-Carbon Society ✓ Material Economics ✓ IEA ETP2020
	Substitution of waste for raw materials	✓ Contribute to the reduction in process-derived CO2 by using waste as part of raw materials	―※4	Already implemented	✓ Action Plan for Low-Carbon Society
	Recycling of concrete	✓ Use sludge and other materials from concrete manufacturing or waste concrete as raw materials for clinker	―※5	2030s	✓ Long-term vision for the cement industry ✓ Material Economics
	Development of new low-carbon materials	✓ Contribute to the reduction in non-energy emissions by developing materials with new compositions to replace existing binders	―※6	2040s	✓ Long-term vision for the cement industry ✓ Material Economics

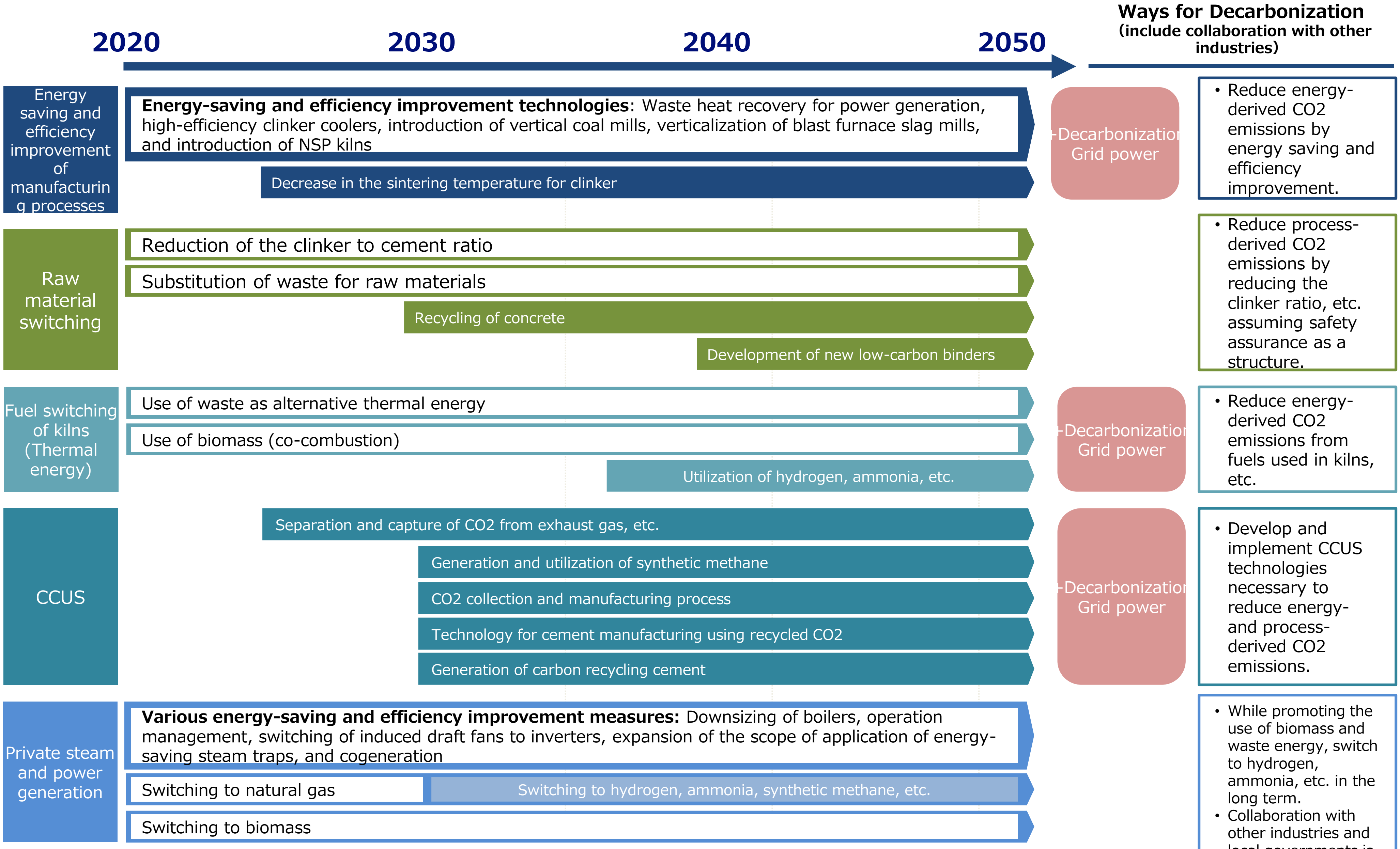
*1: Emission factors are calculated based on the emission factors of existing technologies and the reduction range of the target technologies. The emission reduction range is the range of reduction in the relevant process.
*2: Regarding the Social Implementation Plan, see the start year of the introduction expansion and cost reduction phase, and for the IEA, see the available year.
*3: Reduction rate with reference to the 2030 review target and 2019 actuals in the Carbon Neutral Action Plan.
*4: Emission factors vary depending on the clinker ratio and the substitution ratio by waste.
*5: For reference, Material Economics states that this technology can reduce non-energy emissions by up to 20%. However, this report is based on the EU, and it is currently difficult to assume similar reductions in Japan because the clinker ratio and standards used in the report differ from those used in the EU.
*6: For reference, Material Economics states that the use of currently available alternative binding materials can reduce non-energy emissions by up to 10% compared to Portland cement. However, the reductions are based on a comparison of pure Portland cement, and it is difficult to make a simple comparison, as the reductions are different for cements containing mixed materials such as blast furnace slag. The report also states that there are challenges for adoption in terms of technology, such as setting time and strength, in addition to the limited availability of alternative raw materials.

3. Technology Pathways to Decarbonization | ①Low-Carbon and Decarbonization Technologies for Carbon Neutrality

	Technology	Overview	Emission factor/ reduction range*1	Implementation year*2	References*3
Fuel switching	**Use of wastes for thermal energy**	✓ Use waste plastics, sludge, wood waste, etc. from various industries for thermal energy	Energy-derived emissions ～100% reduction ※3	Already implemented	✓ Action Plan for Low-Carbon Society
	Utilization of biomass	✓ Contribute to the reduction in energy-derived CO2 by reducing the amount of fossil fuel used and using biomass during combustion.		Already implemented	✓ Green Innovation Fund: Social Implementation Plan ✓ IEA ETP2020
	Utilization of hydrogen, ammonia, etc.	✓ Contribute to the reduction in energy-derived CO2 using hydrogen, ammonia, etc., which do not emit CO2 during combustion		2030s	✓ Cabinet Office SIP
CCUS	**Separation and capture of CO2 from exhaust gas, etc.**	✓ Separate and capture CO2 from exhaust gas emitted outside plants using existing technologies such as the chemical absorption method	– ※4	2020s	✓ IEA ETP2020 ✓ Roadmap for Carbon Recycling Technologies
	CO2 collection and manufacturing process	✓ Develop a technology to capture process-derived CO2 from inside a preheater using the existing cement manufacturing process	– ※4 ※5	2030s	✓ Green Innovation Fund: Social Implementation Plan
	Generation of carbonate	✓ Contribute to CO2 reduction by capturing and uptaking CO2 in calcium sources and storing and using it as carbonate	– ※5	2030s	✓ Green Innovation Fund: Social Implementation Plan ✓ Roadmap for Carbon Recycling Technologies
	Technology for cement manufacturing using recycled CO2	✓ A technology to produce cement from carbonates using CO2-captured contributes to CO2 emission reduction	– ※5	2030s	✓ Green Innovation Fund: Social Implementation Plan
	Generation and utilization of synthetic methane	✓ Contribute to the reduction in CO2 emissions in cement manufacturing by recovering CO2 in exhaust gas and generating and using synthetic methane	– ※4	2030s	✓ Green Growth Strategy

*1: Emission factors are calculated based on the emission factors of existing technologies and the reduction range of the target technologies. For fuel switching, energy-derived emissions are listed, and for CCUS, both energy-derived and non-energy-derived emissions are listed.
*2: Regarding the Social Implementation Plan, see the start year of the introduction expansion and cost reduction phase, and for the IEA, see the available year.
*3, *4: Reduction due to CO2 capture depends on the capture performance. In the case of hydrogen and ammonia dedicated combustion, energy emissions are zero, and the extent of reduction varies depending on the co-combustion ratio and other factors. In the case of co-combustion in the utilization of waste and biomass, it also depends on the co-combustion rate.
*5: In the Green Innovation Fund: Social Implementation Plan, the goal is to recover at least 80% of the CO2 generated in the preheater and fix at least 400kg of CO2 per ton of carbonate.

3. Technology Pathways to Decarbonization | ②Technology Roadmap



Ways for Decarbonization
(include collaboration with other industries)

Energy saving and efficiency improvement of manufacturing processes

- **Energy-saving and efficiency improvement technologies**: Waste heat recovery for power generation, high-efficiency clinker coolers, introduction of vertical coal mills, verticalization of blast furnace slag mills, and introduction of NSP kilns
- Decrease in the sintering temperature for clinker

+Decarbonizatio
Grid power

- Reduce energy-derived CO2 emissions by energy saving and efficiency improvement.

Raw material switching

- Reduction of the clinker to cement ratio
- Substitution of waste for raw materials
- Recycling of concrete
- Development of new low-carbon binders

- Reduce process-derived CO2 emissions by reducing the clinker ratio, etc. assuming safety assurance as a structure.

Fuel switching of kilns (Thermal energy)

- Use of waste as alternative thermal energy
- Use of biomass (co-combustion)
- Utilization of hydrogen, ammonia, etc.

+Decarbonizatio
Grid power

- Reduce energy-derived CO2 emissions from fuels used in kilns, etc.

CCUS

- Separation and capture of CO2 from exhaust gas, etc.
- Generation and utilization of synthetic methane
- CO2 collection and manufacturing process
- Technology for cement manufacturing using recycled CO2
- Generation of carbon recycling cement

+Decarbonizatio
Grid power

- Develop and implement CCUS technologies necessary to reduce energy- and process-derived CO2 emissions.

Private steam and power generation

- **Various energy-saving and efficiency improvement measures:** Downsizing of boilers, operation management, switching of induced draft fans to inverters, expansion of the scope of application of energy-saving steam traps, and cogeneration
- Switching to natural gas → Switching to hydrogen, ammonia, synthetic methane, etc.
- Switching to biomass

- While promoting the use of biomass and waste energy, switch to hydrogen, ammonia, etc. in the long term.
- Collaboration with other industries and local governments is also important.

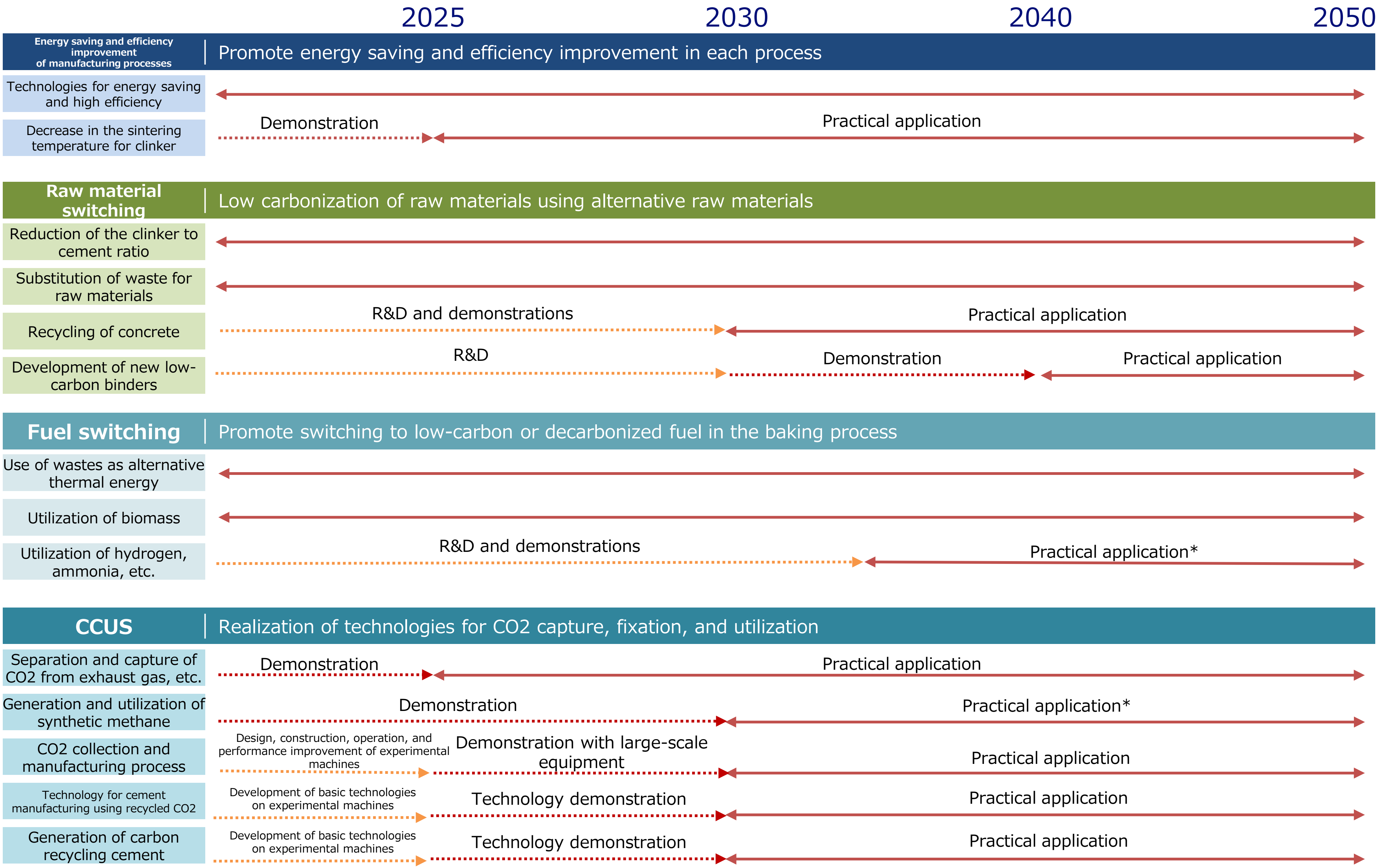
*In the cement industry, about 80% of energy consumption is heat energy.
*Regarding fuel switching, it is assumed that conversion to waste and biomass will proceed underway, followed by switching to natural gas and other fuels. In the future, switching to hydrogen, ammonia, etc. using pipelines laid for natural gas, etc. is also possible.

3. Technology Pathways to Decarbonization |
②Technology Roadmap (reference)

R&D ⇢

Demonstration ⇢

Deployment ⟷



2025 2030 2040 2050

Energy saving and efficiency improvement of manufacturing processes | Promote energy saving and efficiency improvement in each process

- Technologies for energy saving and high efficiency
- Decrease in the sintering temperature for clinker: Demonstration; Practical application

Raw material switching | Low carbonization of raw materials using alternative raw materials

- Reduction of the clinker to cement ratio
- Substitution of waste for raw materials
- Recycling of concrete: R&D and demonstrations; Practical application
- Development of new low-carbon binders: R&D; Demonstration; Practical application

Fuel switching | Promote switching to low-carbon or decarbonized fuel in the baking process

- Use of wastes as alternative thermal energy
- Utilization of biomass
- Utilization of hydrogen, ammonia, etc.: R&D and demonstrations; Practical application*

CCUS | Realization of technologies for CO2 capture, fixation, and utilization

- Separation and capture of CO2 from exhaust gas, etc.: Demonstration; Practical application
- Generation and utilization of synthetic methane: Demonstration; Practical application*
- CO2 collection and manufacturing process: Design, construction, operation, and performance improvement of experimental machines; Demonstration with large-scale equipment; Practical application
- Technology for cement manufacturing using recycled CO2: Development of basic technologies on experimental machines; Technology demonstration; Practical application
- Generation of carbon recycling cement: Development of basic technologies on experimental machines; Technology demonstration; Practical application

*For practical application, it is necessary to establish conditions such as a stable supply of inexpensive hydrogen and the development of social systems such as the establishment of infrastructure.

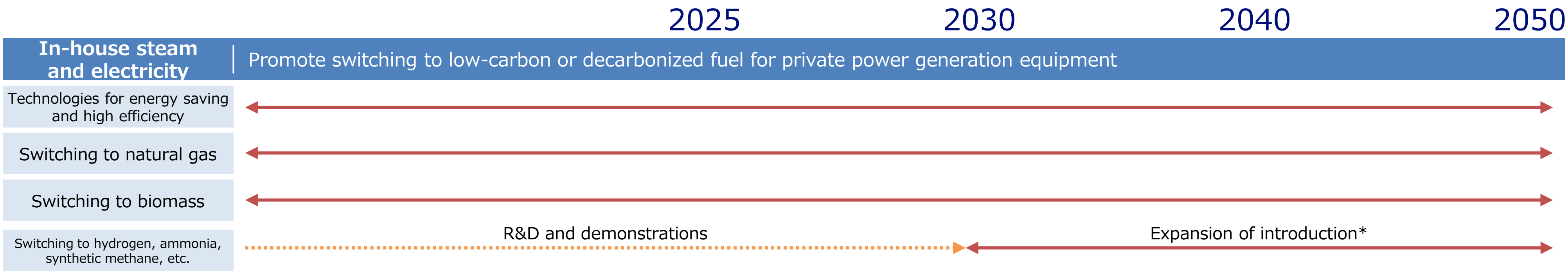
3. Technology Pathways to Decarbonization |

②Technology Roadmap (reference)

R&D

Demonstration

Deployment



In-house steam and electricity | Promote switching to low-carbon or decarbonized fuel for private power generation equipment

Technologies for energy saving and high efficiency

Switching to natural gas

Switching to biomass

Switching to hydrogen, ammonia, synthetic methane, etc.

R&D and demonstrations

Expansion of introduction*

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*For practical application, it is necessary to establish conditions such as a stable supply of inexpensive hydrogen and the development of social systems such as the establishment of infrastructure.

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

- 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.
- Specifically, carbon neutrality will be achieved by 2050 through the active introduction of innovative technologies such as CCUS, in addition to the steady achievement of low-carbon operations through various energy-saving and efficiency improvements, and fuel switching.

Main references/evidence

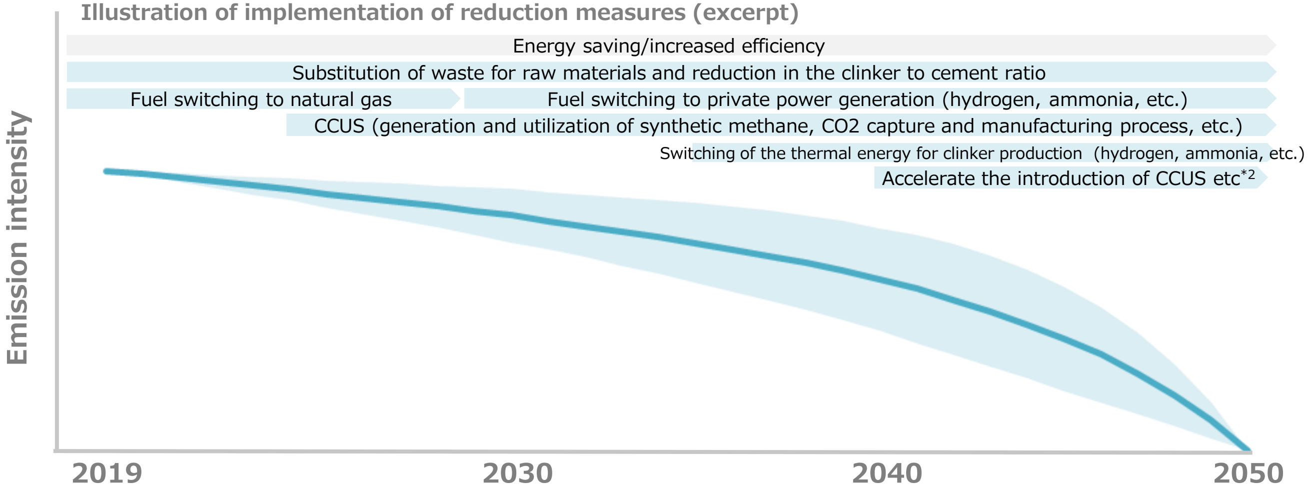
Government Policies

- ✓ 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 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



Main reduction methods	Overview
2020s	• Promote the introduction of energy-saving equipment and fuel switching to biomass, waste, etc. • Promote the development of technologies for CO2 capture, etc., reduction in the clinker ratio, the use of waste as raw material, etc.
2030 to 2040	• In addition to the initiatives in the 2020s, promote the implementation of technologies such as CO2 capture. • Promote switching to decarbonized fuels such as hydrogen for private power generation and kilns for clinker production.
After 2040	• Aim to decarbonize by implementing technologies such as CO2 capture, promoting fuel switching to decarbonized fuels for private power generation and kilns, developing new low-carbon binders, etc.

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*1 This only illustrates the assumption of the overall cement sector’s decarbonization pathway in Japan.
In reality, decarbonization will be achieved based on each company’s long-term strategy and hence, will not necessary be a reflection of this assumption.

*2 Implementation of CCUS, hydrogen/ammonia etc. are of extreme importance to achieve 2050 carbon neutrality. On the condition of developing new societal such as promotion of energy-saving technologies, supply of affordable hydrogen/ammonia, development of related infrastructure, CCUS and circular economy through supply chain collaboration.

Table of Contents

Chapter	Section	Overview
1. Premise		Necessity for Technology Roadmap for Cement Sector Objectives and Positioning of Technology Roadmap
2. Overview of Cement Industry		About the Cement Industry (Industry Size, Cement Manufacturing Processes, Energy Consumption Breakdown) CO2 Emissions Status Measures against CO2 Emissions
3. Technology Pathways to Decarbonization	①Low-Carbon and Decarbonization Technologies for Carbon Neutrality	Details of Short, Medium, and Long-term Technological Options for Achieving Carbon Neutrality
	②Technology Roadmap	Mapping of Technological Development Assumed to Be Required in Japan to Realize 2050 Carbon Neutrality
	③Scientific Basis/Alignment with the Paris Agreement	Confirmation of the Alignment with the Paris Agreement in Terms of the Technologies and CO2 Emissions Assumed in the Technology Roadmap
4. Toward Decarbonization and Achievement of the Paris Agreement		Coordination with Other Fields Including Decarbonized Power Source Future Development of the Technology Roadmap

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 in the cement sector 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 such as economic feasibilities.
- Commercialization of low-carbon and decarbonization technologies in the cement sector will also depend on the development of societal systems including linkages with other sectors, such as decarbonized power sources, hydrogen supply, infrastructure, and CCUS. In addition, it is necessary to gain the understanding of society as a whole, including users, regarding the increased use of carbon-neutral cement and technologies and the recovery of the added value created by technological development, therefore, efforts to achieve carbon neutrality will be made in cooperation with other sectors and related ministries and agencies.
- 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.
- Cement manufacturers 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” of this technology roadmap.

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

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