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WORLD
ECONOMIC
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Industrial Decarbonization in Japan
2023 Edition

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Contents

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Executive summary

The decarbonization of industry is pivotal in achieving Japan's net-zero target by 2050, and will have significant impacts on the nation's environmental, energy and economic landscape.

Industrial decarbonization in Japan

Japan has pledged to reduce its greenhouse gas (GHG) emissions by 46% by 2030 (from 2013 levels) and achieve carbon neutrality by 2050. As the country is among the world's top five energy consumers and is the third-largest economy, its transition towards net zero will be significant for global efforts to achieve the Paris Agreement targets.

Industrial decarbonization is essential if Japan is to achieve its net-zero target, as industries are responsible for 36% of the country's GHG emissions and 42% of its final energy consumption. From an economic perspective, there is also the challenge of how best to maintain or even enhance the competitive edge of Japan's industries while reducing emissions, given that the industrial sector employs 15% of the nation's workers and contributes to 22% of gross domestic product (GDP).

Report objectives and foundational initiatives

This report was prepared by the World Economic Forum in collaboration with Accenture and supported by expert input from the steel and chemical industries, the financial sector, and national and local government offices in Japan. It analyses the progress of Japan's industries, mainly steel and chemicals, towards net zero, based on the framework established by the Forum's July 2022 *Net-Zero Industry Tracker* report. The report also places a spotlight on industrial clusters, which play a critical role in promoting the cross-sectoral collaboration of industries, as set forth in the Forum's *Transitioning Industrial Clusters towards Net Zero* initiative, assessing the opportunities and potential risks of Japan's industrial clusters in the path towards net zero.

Focus sectors: steel and chemicals

To provide an in-depth analysis of Japan's net-zero performance and readiness, this report focuses on the steel and chemical sectors, which are responsible for nearly half (32% and 14% respectively) of Japan's industrial emissions. It is worth noting that oil, natural gas and aluminium, which are among the top industrial sectors in terms of

GHG emissions globally, have a relatively small impact in Japan, because most of the emissions-intensive processes in the upstream (e.g. well delivery of oil and gas, smelting for aluminium production) are not conducted in Japan.

Sources: National Institute for Environmental Studies (NIES), *The GHG Emissions Data of Japan (1990-2020)*, 19 April 2022, https://www.nies.go.jp/gio/en/archive/ghgdata/index.html; Ministry of Economy, Trade and Industry (METI), *Energy White Paper 2022: Section 212-1-1 (Trends in Energy Consumption of Enterprises, Establishments, and Other Sectors)*, n.d., https://www.enecho.meti.go.jp/about/whitepaper/2022/html/2-1-2.html (in Japanese); METI, *2021 Economic Census – Activity Survey: Summary of the Preliminary Results*, 31 May 2022, https://www.meti.go.jp/statistics/tyo/census/r3result/pdf/r3_sokuhogaiyo.pdf (in Japanese); Cabinet Office, *National Accounts for 2021: Gross Domestic Product Classified by Economic Activities (in Real Terms, Calendar Year)*, n.d., https://www.esri.cao.go.jp/en/sna/data/kakuhou/files/2021/2021annual_report_e.html

36%

Industries are responsible for 409 Mt CO_2e, or 36%, of Japan's GHG emissions

42%

Industries consume ~5 EJ of energy, or 42%, of Japan's final energy consumption

15%

Industries employ ~9 million workers, or 15%, of Japan's total labour force

22%

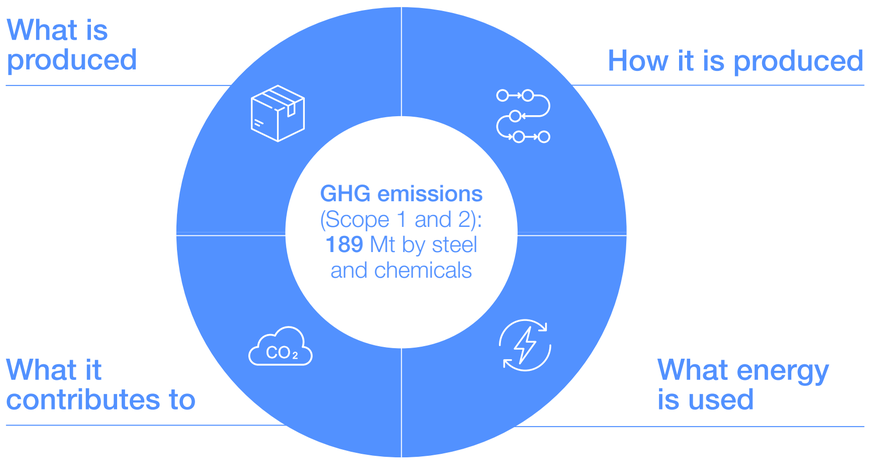
Industries contribute to 22% of Japan's GDP

Despite various efforts already under way by Japan's steel and chemical industries, neither sector is anywhere near where it needs to be to achieve carbon neutrality by 2050.

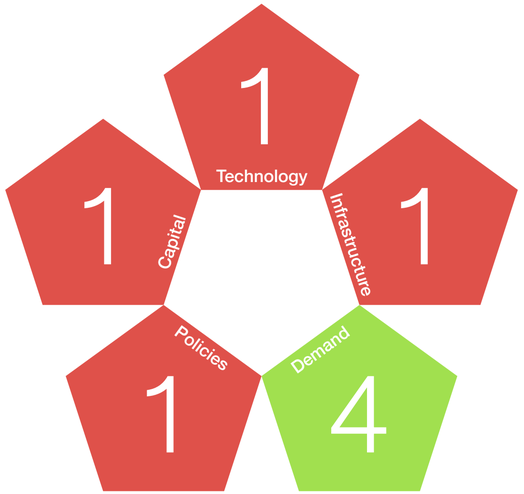
Net-zero performance of the steel and chemical sectors

Both the steel and chemical sectors have improved their energy efficiency by introducing various technologies (e.g. use of waste heat and by-product gases). However, 80–90% of their energy consumption comes from fossil fuels, and significant CO_2 emissions are still being released not only from production processes but also from captive power generation. These factors are largely influenced by the product portfolio and the availability of energy and materials at the location. For example, Japan's steel production is highly dependent on the blast furnace (BF) route, which is more emissions-intensive than the scrap-based electric arc furnace (EAF) or direct reduced iron (DRI) routes, because of the high-quality output required by steel buyers and limited access to resources (e.g. natural gas, DRI-grade iron ore).

Net-zero performance of steel and chemicals



Net-zero readiness of steel and chemicals



Net-zero readiness of the steel and chemical industries

For both sectors, the demand enabler has relatively high readiness due to the minimal impact of green premiums on end consumers, but each of the other enablers (technology, infrastructure, policies and capital) is at the lowest stage of readiness. Immediate action by both the private and public sectors is needed in terms of cross-sectoral priorities as follows:

1. Accelerate the development of innovative production technologies, which are largely at the early prototype stage today.
2. Develop the infrastructure for clean hydrogen, clean electricity and CO_2 handling at scale and speed.
3. Promote buyers' confidence to pass on the green premiums for steel and chemicals, as their impact on end consumers is lower than most people would assume, although still noticeable.
4. Direct more capital towards low-emission production assets. In total, investments of $134–152 billion (JPY 17.4–19.7 trillion) are required to transform the steel and chemical asset base by 2050.
5. Develop policies to support the priorities above and strengthen the business case for low-emission production.

Sources: METI, *Comprehensive Energy Statistics (Fiscal Year 2020)*, n.d., https://www.enecho.meti.go.jp/statistics/total_energy/results.html (in Japanese); Japan Iron and Steel Federation (JISF), *Efforts towards Carbon Neutrality*, 21 February 2022, https://www.meti.go.jp/shingikai/sankoshin/seizo_sangyo/pdf/011_03_02.pdf (in Japanese); Japan Chemical Industry Association (JCIA), *Efforts of the Chemical Industry towards Carbon Neutrality and Utilization of Hydrogen and Ammonia*, 16 November 2022, https://www.meti.go.jp/shingikai/enecho/shoene_shinene/suiso_seisaku/pdf/006_01_00.pdf (in Japanese)

While industrial clusters provide opportunities, a robust and multifaceted approach is needed to accelerate the transition towards net zero and maximize its positive impact.

Industrial clusters in Japan

Geographic areas where industries are co-located – generally defined as industrial clusters – provide "opportunities for scale, sharing of risk and resources, aggregation and optimization of demand". In the context of Japan's industrial decarbonization, nine areas have traditionally been developed as industrial complexes, or kombinat; these have an oil refinery and a petrochemical plant at the core, and are often co-located with other energy-intensive sectors such as steelmaking and thermal power generation. Section 4 of the report, "Net-zero industrial clusters", considers the decarbonization of these industrial complexes in Japan.

Recommendations for net-zero industrial clusters in Japan

As the momentum for decarbonization gathers pace at each of the industrial complexes in Japan, the following key considerations/requirements are emphasized in designing solutions:

1. Accelerate the development of hydrogen and ammonia supply chains by intensively supporting first movers.
2. Strengthen the competitiveness of industrial clusters by promoting cross-sectoral and extensive collaboration.
3. Transform the value recognition of decarbonized goods and services throughout the entire value chain.

Various actions are needed in each of the four strategic approach areas – partnership, policy, financing and technology – to accelerate the decarbonization of industrial complexes. In particular, many of the actions related to partnership and financing, such as embedding mechanisms in subsidy/grant programmes to incentivize collaboration and engaging local financial institutions, have just started and need to build up speed.

The actions related to policy and technology are essentially in progress, but policy-makers still need to develop and implement mechanisms to level the playing field for decarbonized products/services (e.g. carbon pricing). In addition, standards on safety and the environmental values of hydrogen (including its derivatives) and low-emission industrial products need to be developed as soon as possible to support the deployment of low-emission technologies.

The outlook

More than ever, Japan's industries face increased uncertainty, partly due to the recent energy crisis and the constantly changing competitive environment. Each sector and company has its own unique constraints and needs, making it impossible to apply a single strategy or solution across the board. However, multistakeholder collaboration, such as that seen in industrial clusters globally, could be a key accelerator in the path towards net zero. With this in mind, the World Economic Forum continues to provide a platform for collaboration to support the decarbonization of Japan's industries.

Sources: Accenture, *Achieving Net-Zero Future with Industrial Clusters*, 1 March 2021, https://www.accenture.com/us-en/insights/utilities/industrial-clusters-net-zero-future; METI, *Organizing Key Issues for the Realization of Carbon-Neutral Industrial Complexes*, March 2022, https://www.meti.go.jp/shingikai/energy_environment/carbon_neutral_complex/20220324_report.html (in Japanese)

Abbreviations and acronyms

BF-BOF	Blast furnace-basic oxygen furnace
Bt	Billion tonnes
BTX	Benzene, toluene and mixed xylene
CapEx	Capital expenditure
CCS	Carbon capture and storage
CCU	Carbon capture and utilization
CCUS	Carbon capture, utilization and storage
CfD	Contract for difference
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CTO	Coal to olefin
DBJ	Development Bank of Japan
DRC	Dialkyl carbonate
DRI	Direct reduced iron
EAF	Electric arc furnace
EJ	Exajoule
ESG	Environmental, social and governance
ETO	Ethanol to olefin
GDP	Gross domestic product
GW	Gigawatt
GX	Green transformation
H_2	Hydrogen
HVC	High-value chemical
IEA	International Energy Agency
IEEJ	Institute of Energy Economics, Japan
IFA	International Fertilizer Association
JAA	Japan Aluminium Association
JCIA	Japan Chemical Industry Association
JH2A	Japan Hydrogen Association

JISF	Japan Iron and Steel Federation
JOGMEC	Japan Organization for Metals and Energy Security
kWh	Kilowatt-hour
LNG	Liquified natural gas
LPG	Liquified petroleum gas
MDI	Methylene diphenyl diisocyanate
METI	Ministry of Economy, Trade and Industry
MOF	Ministry of Finance
MPP	Mission Possible Partnership
Mt	Million tonnes
MTA	Methanol to aromatics
Mt CO_2e	Million tonnes of carbon dioxide equivalent
MTO	Methanol to olefin
MTPA	Million tonnes per annum
NH_3	Ammonia
NIES	National Institute for Environmental Studies
NRI	Nomura Research Institute
NSRI	Nippon Steel Research Institute
PDH	Propane dehydrogenation
PJ	Petajoule
PPE	Plant, property and equipment
PWMI	Plastic Waste Management Institute
R&D	Research and development
REI	Renewable Energy Institute
RITE	Research Institute of Innovative Technology for the Earth
SME	Small and medium enterprise
tCO_2	Tonne of carbon dioxide
tCO_2e	Tonne of carbon dioxide equivalent

1 Scope of work and research approach

This report analyses the performance and readiness of Japan's industries towards net zero, using the framework developed by the World Economic Forum's July 2022 *Net-Zero Industry Tracker* report. While the *Net-Zero Industry Tracker* covers global industries, this report focuses on Japan, its purpose being to provide both domestic and international stakeholders (e.g. companies, investors, financial institutions, governments, policy-makers) with a better understanding of the country's progress in industrial decarbonization and the priority areas to accelerate it.

Steel and chemicals are the focus sectors of this report, as they contribute to almost 50% of Japan's industrial emissions. In addition to presenting an in-depth sector-by-sector analysis, the report examines the opportunities and challenges of net-zero industrial clusters, focusing mainly on areas called industrial complexes or kombinat in Japan, by leveraging the framework developed by the World Economic Forum's *Transitioning Industrial Clusters towards Net Zero* initiative.

The report was developed through a review of public documentation issued by governments and businesses in Japan. Furthermore, experts in the steel and chemical industries, the financial sector, and national and local government offices in Japan were interviewed to gain a better view of their priorities for industrial decarbonization.

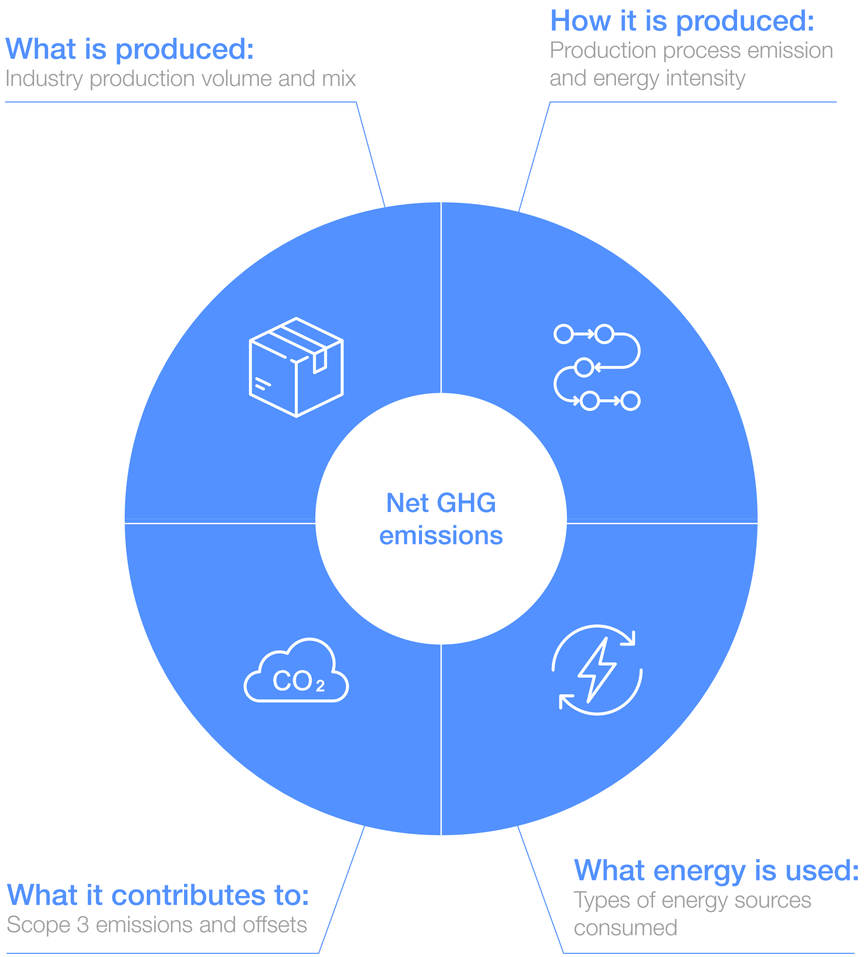
Sources: World Economic Forum, *The Net-Zero Industry Tracker,* 28 July 2022, https://www.weforum.org/reports/the-net-zero-industry-tracker/; World Economic Forum, *Industrial Clusters: The Net-Zero Challenge*, n.d., https://initiatives.weforum.org/transitioning-industrial-clusters/home

Net-Zero Industry Framework

The Net-Zero Industry Framework combines two complementary lenses to track industries' progress on the ground.

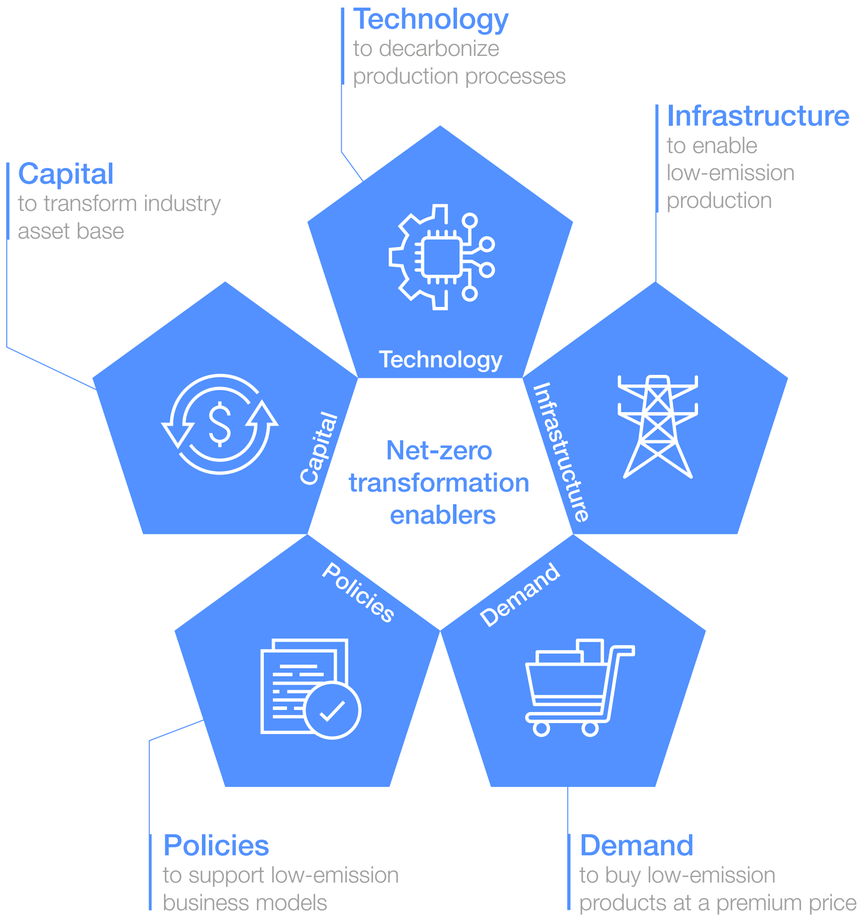
Net-zero industry performance

The four drivers of industry net greenhouse gas (GHG) emissions:



Net-zero industry readiness

The five enabling dimensions of industry net-zero transformation:



Source: World Economic Forum, *The Net-Zero Industry Tracker*, 28 July 2022, https://www.weforum.org/reports/the-net-zero-industry-tracker/

Five stages of readiness

Transformation enablers are assessed against five stages of readiness.

Key readiness questions	Technology Is the technology to produce low-emission product at competitive cost available?	Infrastructure Is the infrastructure to enable use of low-emission technologies available?	Demand Can the market pay the required green premium for the low-emission product?	Policies Are supporting policies to enable the growth of a low-emission industry in place?	Capital Are returns sufficient to drive investments towards low-emission assets?
Stage 5	The low-emission production technologies are **fully available and competitive with high-emission alternatives.**	The necessary infrastructure required by the low-emission industry **is fully in place.**	**The whole market** can pay the required green premium.	Policies **fully** complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.	Low-emission investments generate sufficient return for **all** CapEx to flow towards low-emission production assets.
Stage 4	The low-emission production technologies are **largely commercial and competitive with high-emission alternatives.**	The necessary infrastructure required by the low-emission industry **is largely in place.**	**Most of** the market can pay the required green premium.	Policies **strongly** complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.	Low-emission investments generate sufficient return for **most** CapEx to flow towards low-emission production assets.
Stage 3	The low-emission production technologies are **largely demonstrated in commercial conditions.**	The necessary infrastructure required by the low-emission industry **is partially in place.**	**Some of** the market can pay the required green premium.	Policies **moderately** complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.	Low-emission investments generate sufficient return for **some of** CapEx to flow towards law-emission production assets.
Stage 2	The low-emission production technologies are **largely prototyped at scale.**	The necessary infrastructure required by the low-emission industry **is emerging.**	**A limited portion of** the market can pay the required green premium.	**Limited** policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.	Low-emission investments generate sufficient return for a **minority of** CapEx to flow towards low-emission production assets.
Stage 1	The low-emission production technologies are **largely at concept or early prototype stage.**	The necessary infrastructure required by the low-emission industry **needs to be developed almost entirely.**	**Only very early adopters** in the market can pay the required green premium.	**Very limited** policies complement current environment (technology, infrastructure, demand, capital), to support growth of the low-emission industry.	Low-emission investments generate sufficient return for **barely any** CapEx to flow towards low-emission production assets.

Source: World Economic Forum, *The Net-Zero Industry Tracker*, 28 July 2022, https://www.weforum.org/reports/the-net-zero-industry-tracker/

2

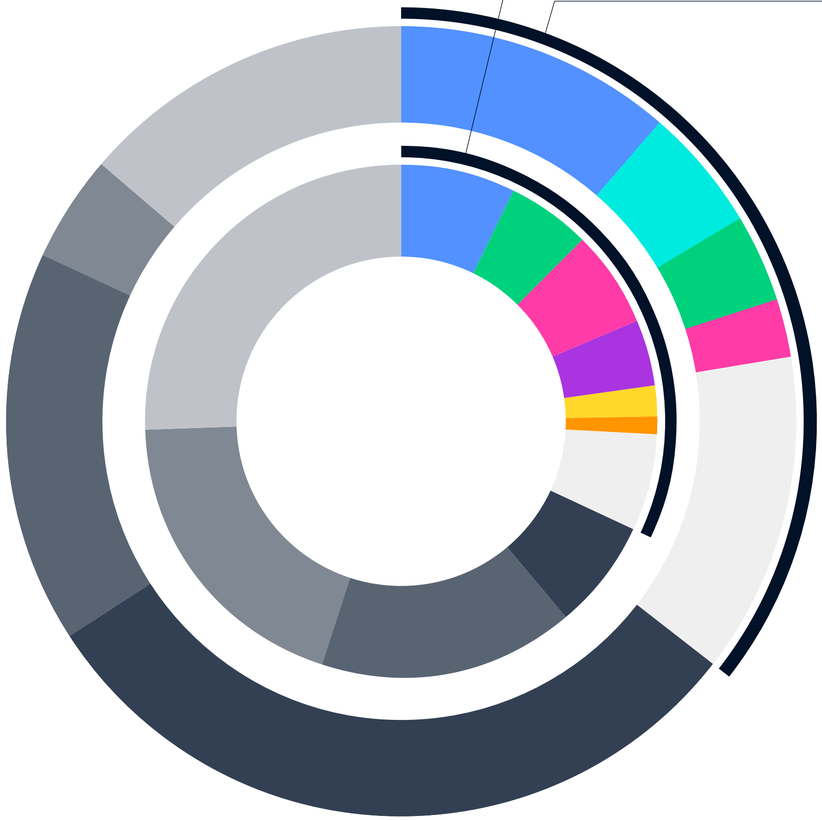
Overview of Japan's industries

Industrial emissions by sector

The decarbonization of industries is essential for Japan's pathway to net zero as industries account for 36% of total GHG emissions. Crucially, the steel and chemical sectors are responsible for almost half of Japan's industrial emissions.

Japan's GHG emissions by sector (Scope 1 and 2), 2020

Global GHG emissions by sector (Scope 1 and 2), 2020



Global industrial emissions

32% of total GHG emissions

Japan's industrial emissions

36% of total GHG emissions

Industrial emissions

Steel · Chemical · Cement · Oil · Natural gas · Aluminium · Ammonia · Other industries

Non-industrial emissions

Buildings · Transport · Agriculture · Other

Sources: World Economic Forum, *The Net-Zero Industry Tracker*, 28 July 2022, https://www.weforum.org/reports/the-net-zero-industry-tracker/; NIES, *The GHG Emissions Data of Japan (1990-2020)*, 19 April 2022, https://www.nies.go.jp/gio/en/archive/ghgdata/index.html

Hard-to-abate industry value chains conducted in Japan

Emissions-intensive processes in the upstream for the aluminium, oil and gas sectors are not conducted in Japan. In addition, ammonia production, which contributes significantly to global industrial emissions, occurs on a very small scale in the country. Such differences between global and Japanese industries affect how the nation deals with industrial emissions reductions.

All virgin **aluminium** ingots used in Japan are imported from overseas, meaning that the smelting process, which contributes to more than 80% of total aluminium production GHG emissions, is not conducted in Japan.

The Japanese **oil** industry imports crude oil from overseas, mainly from the Middle East (Saudi Arabia, UAE, etc.), so the well delivery and production process, which emits more than half of oil production emissions, does not take place in Japan.

Gas companies in Japan import LNG from various countries such as Australia and Malaysia and distribute gas after regasification, so most of the emission-intensive processes are not conducted in Japan.

While **ammonia** accounts for 28% of global primary chemical production, it accounts for only 3% in Japan. High-value chemicals account for the remaining 97%, which requires different decarbonization solutions.

Note: 1. Refers to the proportion of emissions by process for the BF-BOF route.

Sources: Carbon Trust, *International Carbon Flows - Steel*, 2011, https://ctprodstorageaccountp.blob.core.windows.net/prod-drupal-files/documents/resource/public/International Carbon Flows - Steel - REPORT.pdf; McKinsey & Company, *Laying the Foundation for Zero-Carbon Cement*, 14 May 2020, https://www.mckinsey.com/industries/chemicals/our-insights/laying-the-foundation-for-zero-carbon-cement; JAA, *Aluminium Vision 2050*, September 2020, https://www.aluminum.or.jp/vision2050/pdf/VISION2050_main.pdf (in Japanese); World Economic Forum, *The Net-Zero Industry Tracker*, 28 July 2022, https://www.weforum.org/reports/the-net-zero-industry-tracker/; *Sustainable Gas Institute, Methane and CO_2 Emissions from the Natural Gas Supply Chain*, September 2015, https://www.imperial.ac.uk/media/imperial-college/research-centres-and-groups/sustainable-gas-institute/SGI_White_Paper_methane-and-CO2-emissions_WEB-FINAL.pdf

3

In-depth industry analysis

3.1

Steel industry
Industrial decarbonization in Japan

Steel
Key takeaways

The outcome of the steel in-depth industry analysis can be summarized in five key takeaways:

1	Japan's steel production ranks among the world's most **energy-efficient,** when evaluating the production methods BF-BOF and EAF separately, mainly due to the **widespread adoption of existing energy-efficiency technologies.** A more drastic change in production processes, such as the introduction of **hydrogen reduction and increased use of scrap,** is essential if it is to further improve.
2	Japan's steel industry is **pursuing multiple options for low-emission production technologies,** including not only DRI and scrap-EAF but also BF-BOF hydrogen reduction, mainly due to resource constraints (e.g. iron ore, scrap, natural gas) and the need to maintain the competitive edge it has because of its high-quality steel. There is a big hurdle to overcome, as the sector aims to produce **high-quality steel from low-quality feedstock.**
3	To deploy low-emission steel-production technologies at scale, **massive investments in infrastructure,** such as **clean hydrogen, electricity** and **CO_2 transport and storage,** will be required. In particular, hydrogen supply chains need to be built almost entirely in Japan, to supply as much as **20 MTPA of hydrogen** to the sector by 2050, which will necessitate investment of **$130–230 billion[1] (JPY 17–30 trillion).**
4	**The total investment required to transform Japan's steel industry asset base by 2050,** including research and development (R&D), is estimated at **$77 billion (JPY 10 trillion).** To finance the necessary capital, the business case needs to be **more attractive for private investors/financiers;** establishing a **green steel market** is also imperative, and will ensure steel buyers feel more confident that they can **pass on the cost increase to end consumers.**
5	The government has been supporting the sector's transition through various measures, including providing **$1.5 billion (JPY 0.2 trillion) for the development of innovative steelmaking technologies** (as part of the $15 billion (JPY 2 trillion) **Green Innovation Fund**). However, **more robust policy measures can help to accelerate the transition** by mitigating the sector's unique potential risks, such as technological difficulties and the long asset life cycle.

Note: 1. Assumes the required CapEx to be $6.5–11.5 billion (JPY 0.8–1.5 trillion)/MTPA.

Steel

Performance of Japan's steel sector: towards net zero

The steel sector is responsible for 32% of Japan's industrial emissions. With the existing technologies mostly implemented, the deployment of more innovative technologies to transform today's blast furnace-centered assets will be the key to achieving net zero, reducing both energy- and non-energy-derived GHG emissions.

What is produced

Domestic steel production was 83 Mt in 2020, expected to decrease by 10% by 2050.

It is competitive in high-grade steel.

The automotive sector accounts for 27% of production output.

How it is produced

75% of crude steel is made in blast furnaces.

Japan's steel production is evaluated as the world's highest level of energy efficiency for both BF-BOF and scrap-EAF routes.

DRI is not deployed due to the difficulty in procuring high-grade iron ore and natural gas.

What it contributes to

GHG emissions by the steel sector were 112 Mt for Scope 1, and 19 Mt for Scope 2 (2020).

The steel industry is responsible for 11% of Japan's GHG emissions, or 32% of industrial emissions – the biggest emissions by a single sector.

What energy is used

~80% of energy consumption comes from fossil fuels.

Significant emissions come from captive power plants, but most of these use off-gases from steelmaking processes, contributing to high energy efficiency.

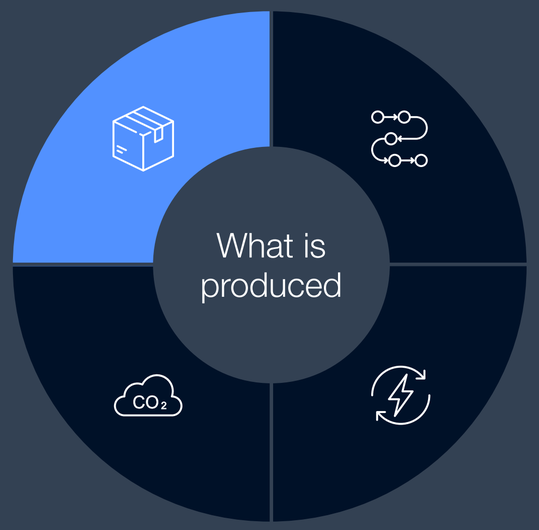
Sources: worldsteel, *2021 World Steel in Figures*, 2021, https://worldsteel.org/wp-content/uploads/2021-World-Steel-in-Figures.pdf; RITE, *Estimates of Energy Intensity for the Iron and Steel Sector*, May 2022, https://www.rite.or.jp/system/en/latestanalysis/2022/05/Comparison_EnergyEfficiency2019steel.html; NIES, *The GHG Emissions Data of Japan (1990-2020)*, 19 April 2022, https://www.nies.go.jp/gio/en/archive/ghgdata/index.html; METI, *Comprehensive Energy Statistics (Fiscal Year 2020)*, n.d., https://www.enecho.meti.go.jp/statistics/total_energy/results.html (in Japanese)

Steel

Production volume

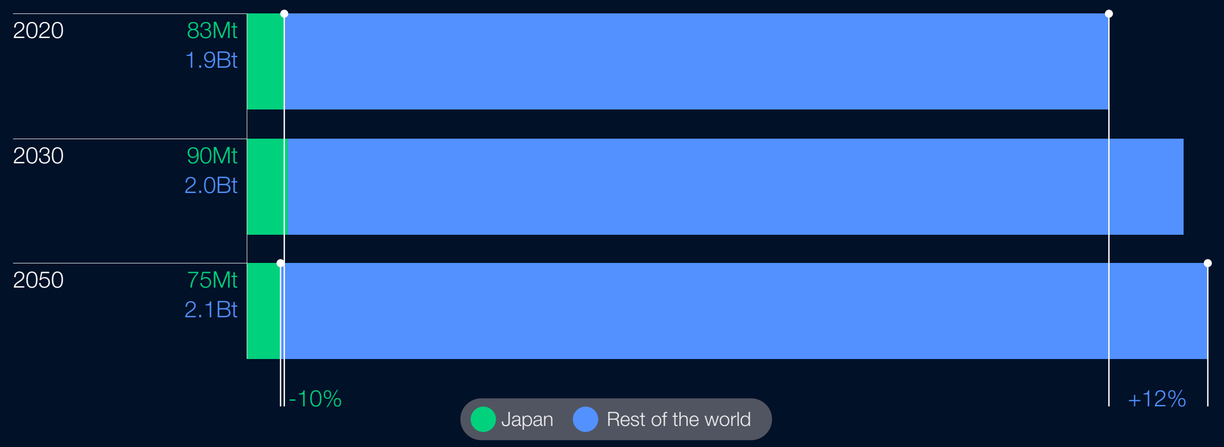
Japan produces 4% of the world's crude steel and is the largest producer after China, the 27 countries of the European Union (EU27) and India. Japan's steel production is expected to decline along the pathway towards 2050.

Click on an icon
below to find out more.



Steel production by country/region in 2020: Crude steel production, Mt

Steel production outlook by 2050



Global steel production is expected to grow by 12% from 2020 to 2050 under the IEA Net Zero by 2050 Scenario.

On the other hand, Japan's Ministry of Economy, Trade and Industry (METI) estimates that the country's crude steel production in 2030 will be 90 Mt ± 10 Mt. This is based on the consolidation of domestic production facilities and globalization, due to structural factors (e.g. declining domestic demand as a result of depopulation, intensifying international competition).

Domestic production in 2050, estimated by the Nippon Steel Research Institute (NSRI) based on the above METI forecast, will be around 75 Mt, which is 10% lower than today's production.

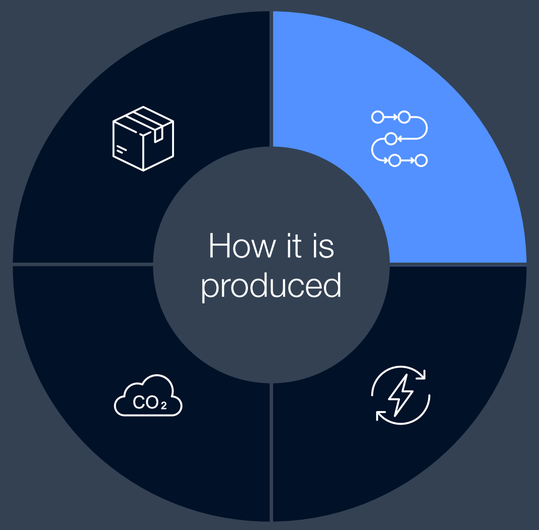
Sources: worldsteel, *2021 World Steel in Figures*, 2021, https://worldsteel.org/wp-content/uploads/2021-World-Steel-in-Figures.pdf; IEA, *Net Zero by 2050*, May 2021, https://www.iea.org/reports/net-zero-by-2050; METI, *Energy Supply and Demand Outlook for Fiscal Year 2030*, October 2021, https://www.enecho.meti.go.jp/category/others/basic_plan/pdf/20211022_03.pdf (in Japanese); NSRI, *Report on Investigative Project towards Sustainable Development of Japan's Metal Industry Based on Carbon Neutrality*, February 2022, https://www.meti.go.jp/meti_lib/report/2021FY/000080.pdf (in Japanese)

3.1.1 **Steel performance tracker:**
In-depth review: How it is produced

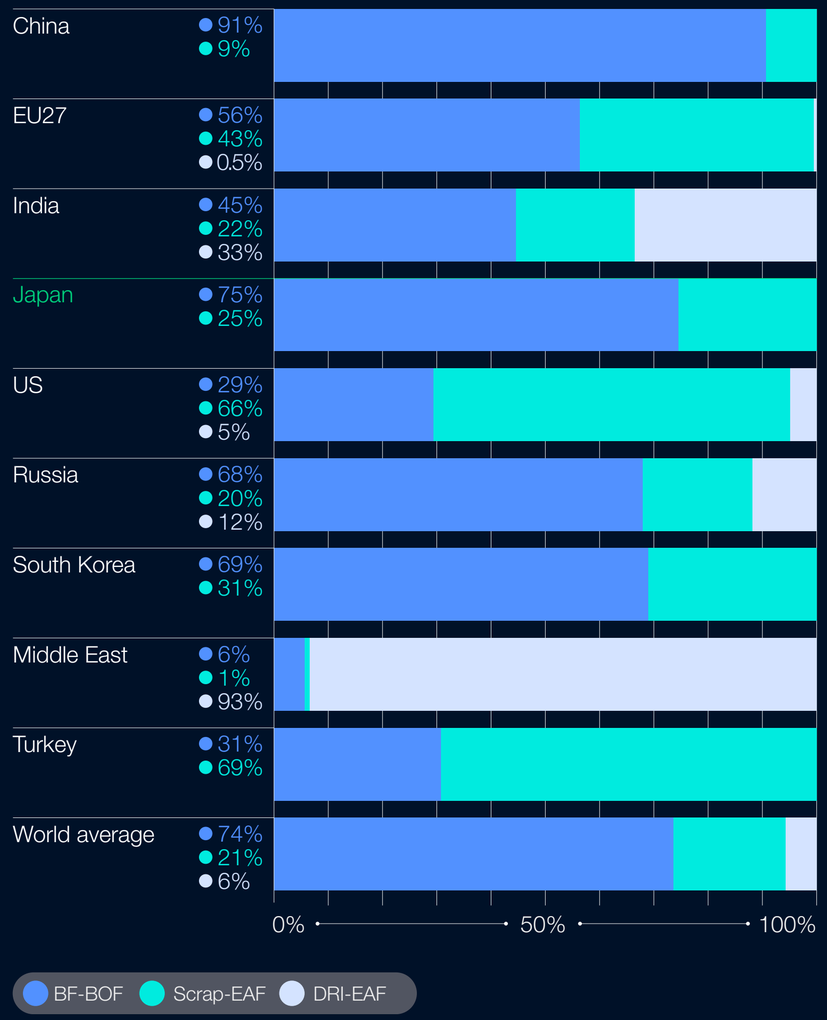
Steel

Production processes

Japan's steel production is highly dependent on the BF-BOF route, compared to other major steel-producing countries/ regions. While the BF-BOF route releases more than four times the CO_2 emissions compared to scrap-EAF, Japan's BF-BOF steel production is evaluated as the world's highest level of energy efficiency.



Crude steel production by process (2020)



Comparison of energy intensity by country (BF-BOF route)

The high diffusion rate of the best available energy efficiency technologies is considered as the key factor for the energy efficiency of Japan's BF-BOF route, leaving little potential for improvement without innovative technology.

Production emission and energy intensity in Japan

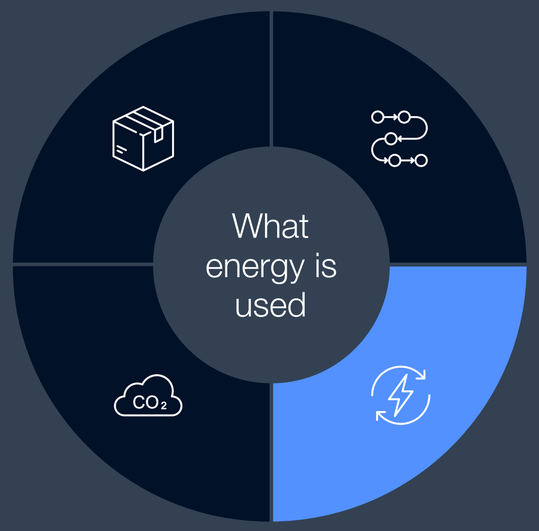
	Percentage of production	Emissions intensity (tCO_2e/t)	Energy intensity (GJ/t)
BF-BOF	75%	2.06	22.9
Scrap-EAF	25%	0.44	8.3
	Japanese average	1.65	19.2

Sources: worldsteel, *2021 World Steel in Figures*, 2021, https://worldsteel.org/wp-content/uploads/2021-World-Steel-in-Figures.pdf; RITE, *Estimates of Energy Intensity for the Iron and Steel Sector*, May 2022, https://www.rite.or.jp/system/en/latestanalysis/2022/05/Comparison_EnergyEfficiency2019steel.html; JOGMEC, *Research on Trends in Reducing CO_2 Emissions in the Iron and Steel Industry and its Impact on Raw Material Coke Demand*, March 2022, https://coal.jogmec.go.jp/content/300377648.pdf (in Japanese)

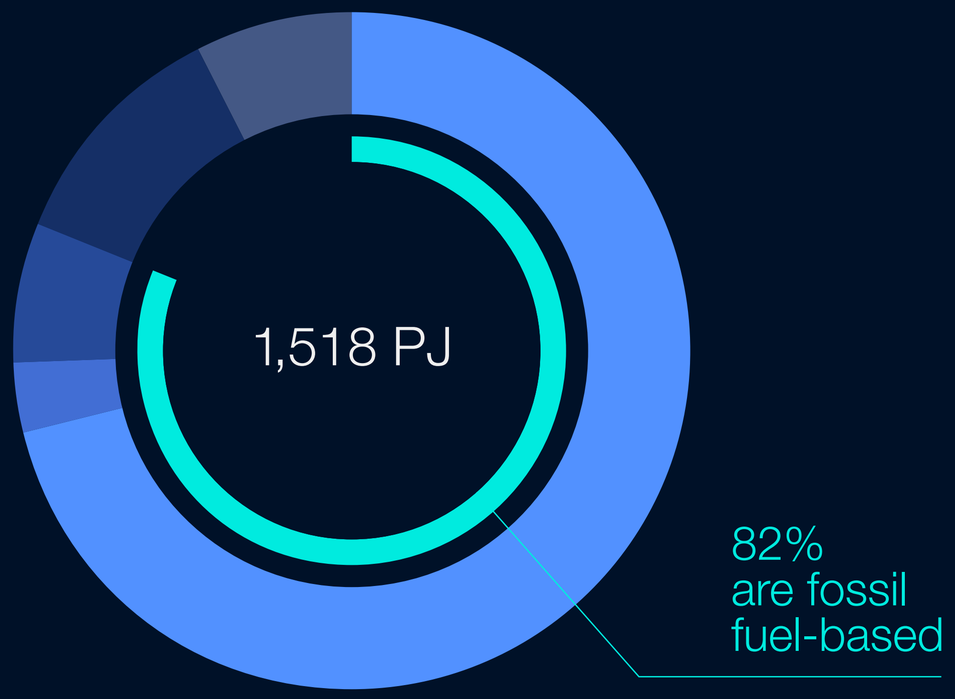
Steel

Fuel use in Japan's steel industry

In Japan's steel industry, more than 80% of the energy consumption came from fossil fuels in 2020.



Energy input in 2020[1]



Fuel use		% of total
Coal	1,084 PJ	72%
Oil	49 PJ	3%
Gas	102 PJ	7%
Purchased electricity	173 PJ	11%
Other[2]	112 PJ	7%

Notes: 1. Includes the energy input for captive generation of power and heat; **2.** Other energy sources include energy recovery and renewables.

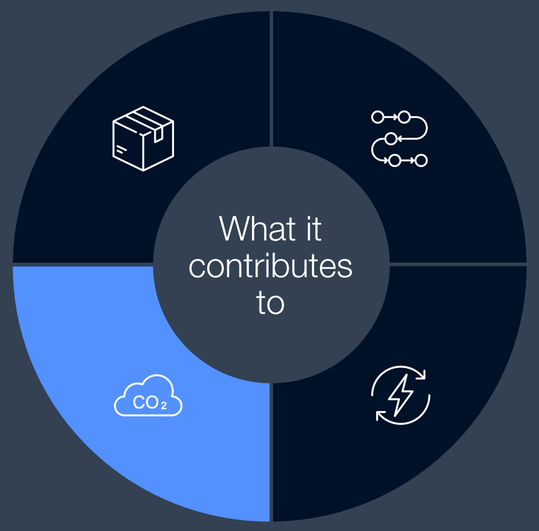
Source: METI, *Comprehensive Energy Statistics (Fiscal Year 2020)*, n.d., https://www.enecho.meti.go.jp/statistics/total_energy/results.html (in Japanese)

3.1.1 **Steel performance tracker:**
In-depth review: What it contributes to

Steel

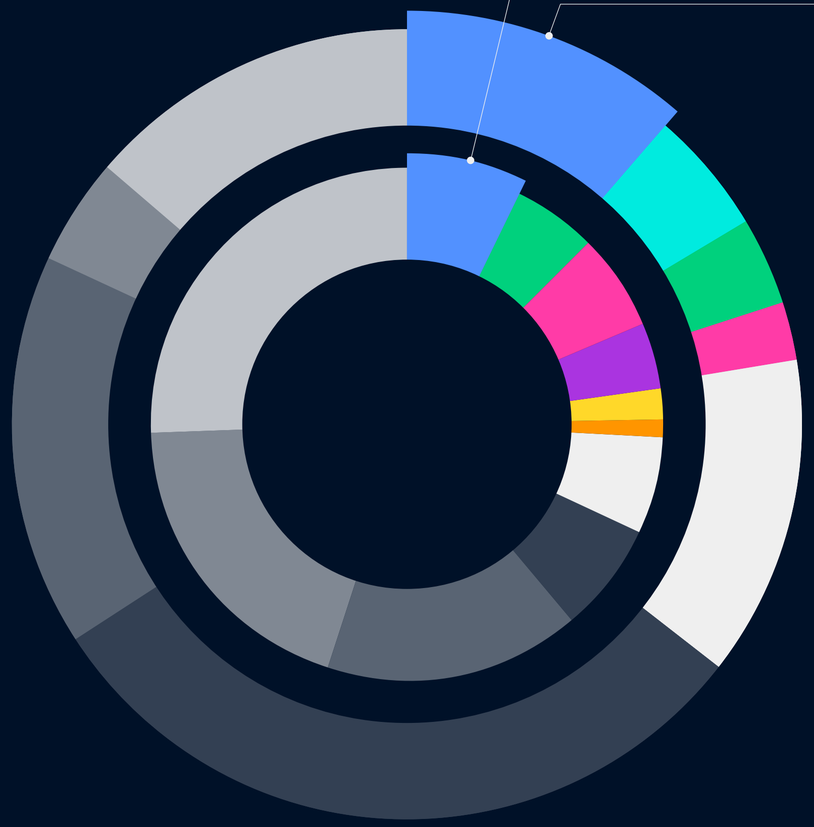
Global and Japanese GHG emissions

GHG emissions from Japan's steel production in 2020 were 131 Mt CO_2e (Scope 1 and 2). This accounts for 32% of industrial emissions, or 11% of the country's total GHG emissions.



Japan's GHG emissions by sector (Scope 1 and 2)

Global GHG emissions by sector (Scope 1 and 2)



Global **steel** GHG emissions

~23% of industrial emissions

Scope 1 and 2: 3,700 Mt CO_2e
Scope 3: 700 Mt CO_2e

Japan's **steel** GHG emissions

~32% of industrial emissions

Scope 1 and 2: 131 Mt CO_2e
Scope 3: *Data not available*

Industrial emissions

Steel · Chemical · Cement · Oil · Natural gas · Aluminium · Ammonia · Other industries

Non-industrial emissions

Buildings · Transport · Agriculture · Other

Sources: World Economic Forum, *The Net-Zero Industry Tracker*, 28 July 2022, https://www.weforum.org/reports/the-net-zero-industry-tracker/; NIES, *The GHG Emissions Data of Japan (1990-2020)*, 19 April 2022, https://www.nies.go.jp/gio/en/archive/ghgdata/index.html

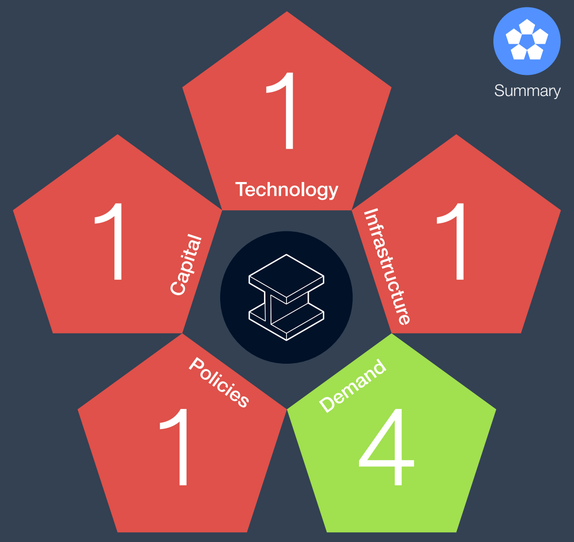
Steel Summary

Steel benefits from the minimal cost impact on end consumers, but it requires more investment in innovative production technologies and hydrogen infrastructure, as well as improvements in supporting policies.

Readiness stage, on a scale 1 (low) – 5 (high)[1,2]

1 2 3 4 5

Click on the enablers below to find out more.



Readiness of Japan's steel industry to achieve net zero

Technology

1 Readiness Stage

The low-emission production technologies are **largely at concept or early prototype stage.**

Key metrics

Late 2020s

Expected year of commercial readiness of first key technology.

Infrastructure

1 Readiness Stage

The necessary infrastructure required by the low-emission industry **needs to be developed almost entirely.**

Key metrics

$21 billion (JPY 3 trillion)

Investment required in low-emission power generation.

$130–230 billion (JPY 17–30 trillion):

Investment required in low-emission hydrogen production.

$4–8 billion (JPY 0.5–1.0 trillion):

Investment required in CO_2 transport and storage.

Demand

4 Readiness Stage

Most of the market can pay the required green premium.

Key metrics

The impact on end consumers is expected to be limited

as +25–50%[3] green premium of steel would lead to +0.5–0.7%[3] cost increase for end consumers of cars and buildings.[4]

Policies

1 Readiness Stage

Very limited policies complement current environment (technology, infrastructure, demand, capital), to support the growth of the low-emission industry.

Key metrics

$2 (JPY 249)/$tCO_2e$

direct carbon price in Japan.

Capital

1 Readiness Stage

Low-emission investments generate sufficient return for **barely any** CapEx to flow towards low-emission production assets.

Key metrics

$77 billion (JPY 10 trillion)

Cumulative CapEx required to transform industry asset base by 2050, or **~$2.5 billion (JPY 0.3 trillion)/year.**

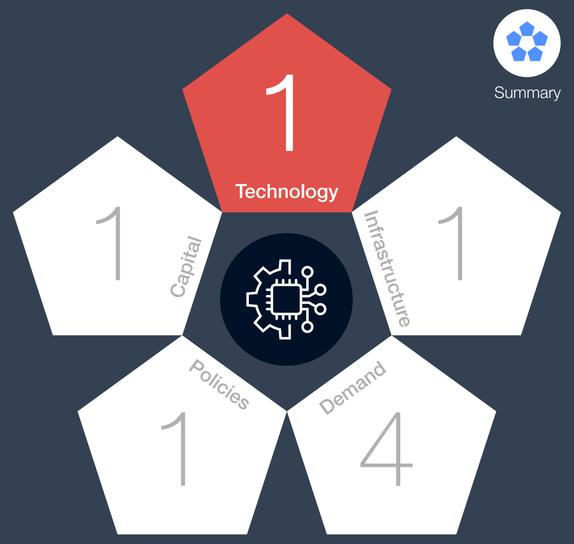
Notes: 1. As defined in the World Economic Forum's *Net-Zero Industry Tracker*. For the definition of all stages, see "Scope of work and research approach" section of this report;
2. This assessment is an absolute evaluation of the readiness of Japan's steel industry towards achieving net zero, rather than a relative comparison with other countries;
3. Assumes the same green premium of steel and its impact on end consumer sectors as in the World Economic Forum's *Net-Zero Industry Tracker report*, as Japan-specific data is not available;
4. Cars and buildings/infrastructure sectors consume nearly 70% of Japan's steel production.

Source: World Economic Forum, *The Net-Zero Industry Tracker*, 28 July 2022, https://www.weforum.org/reports/the-net-zero-industry-tracker/

Steel

Key technologies for achieving net-zero steel in Japan

Japan's steel industry focuses on: (1) hydrogen reduction in blast furnace; (2) hydrogen direct reduction; and (3) large-scale EAF for producing high-grade steel, but the technologies with more than 50% emission reduction impact potential are largely at the early prototype stage.



Key technologies		Expected year of commercial readiness[1]	Emission reduction limit (%)	Description
Blast furnace hydrogen reduction	**COURSE50 (use of on-site hydrogen)**	Late 2020s	30%	– Use of hydrogen (by-product hydrogen generated on-site) as a reducing agent in blast furnaces, partially replacing the coke (contributing to 10% emissions reduction) – Capture of CO_2 from the waste gas from blast furnaces, using the waste heat for the capturing process (contributing to 20% emissions reduction)
	SuperCOURSE50 (use of external hydrogen)	2040s	50% or more	– Maximizing the use of hydrogen (procured from external suppliers) as a reducing agent to minimize the use of coke. Specifically, hydrogen could be blown into blast furnaces directly, or it could be blown in as methane (produced from hydrogen and CO_2 captured from the furnaces) – Considering other options, such as the use of biomass to replace the coke, to optimize the processes and minimize the emissions
Direct reduction 100% hydrogen		2040s[2]	95%	– Directly reducing iron ore in the solid state, using hydrogen as a reducing agent (globally, DRI is conducted with natural gas as a reducing agent today)
Large-scale EAF for high-quality steel		2030s	90–95%	– Removal of impurity included in DRI produced from low-quality iron ore or scrap, to produce high-quality steel – Scaling up the size of EAF to that of basic oxygen furnaces (300 tonnes), which is twice as large as today's average EAF

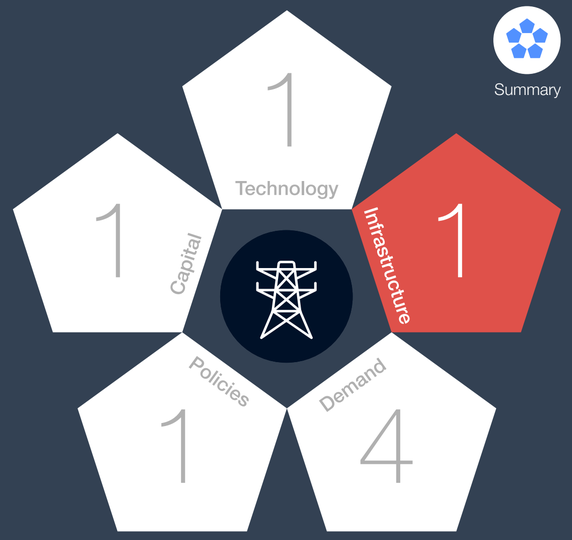
Notes: 1. Refers to the year of commercialization in METI's *Technology Roadmap for "Transition Finance" in Iron and Steel Sector;* **2.** Globally, direct reduction 100% hydrogen technology is expected to be ready for commercialization by 2028, but Japanese steelmakers are working on direct reduction technology that enables the use of low-grade iron ore, such as that used for the BF-BOF route today, making the technology development more time-consuming; 2040s also takes into account the pace of development of hydrogen infrastructure in Japan.

Sources: METI, *Technology Roadmap for "Transition Finance" in Iron and Steel Sector*, August 2021, https://www.meti.go.jp/policy/energy_environment/global_warming/transition/transition_finance_technology_roadmap_iron_and_steel_eng.pdf; METI, *Direction of R&D and Social Implementation of Use of Hydrogen in Steelmaking Processes*, August 2021, https://www.meti.go.jp/shingikai/sankoshin/green_innovation/energy_structure/pdf/005_03_00.pdf (in Japanese); MPP, *Net-Zero Steel: Sector Transition Strategy*, October 2021: https://missionpossiblepartnership.org/wp-content/uploads/2021/10/MPP-Steel-Transition-Strategy-2021.pdf

Steel

Required infrastructure for net-zero steel

More than $150 billion (JPY 20 trillion) will need to be invested in low-emission power, clean hydrogen and CO_2-handling infrastructure to enable low-emission steel production technologies.



Product	Low-emission production routes	Estimated infrastructure needs by 2050					
		Low-emission power generation[1]		Low-emission hydrogen production		CO_2 transport and storage	
		Capacity required	CapEx/unit	Capacity required	CapEx/unit	Capacity required	CapEx/unit
Primary steel	BF-green H_2-based routes with CCS			20 MTPA[4]	$6.5–11.5 billion/MTPA[5]	47 MTPA[6]	$80–175 million/MTPA[7]
	DRI-green H_2-based routes						
Secondary steel	EAF with green power	8.1 GW[2]	$2.6 billion/GW[3]				
	Total investment	$21 billion (JPY 3 trillion)		$130–230 billion (JPY 17–30 trillion)		$4–8 billion (JPY 0.5–1.0 trillion)	

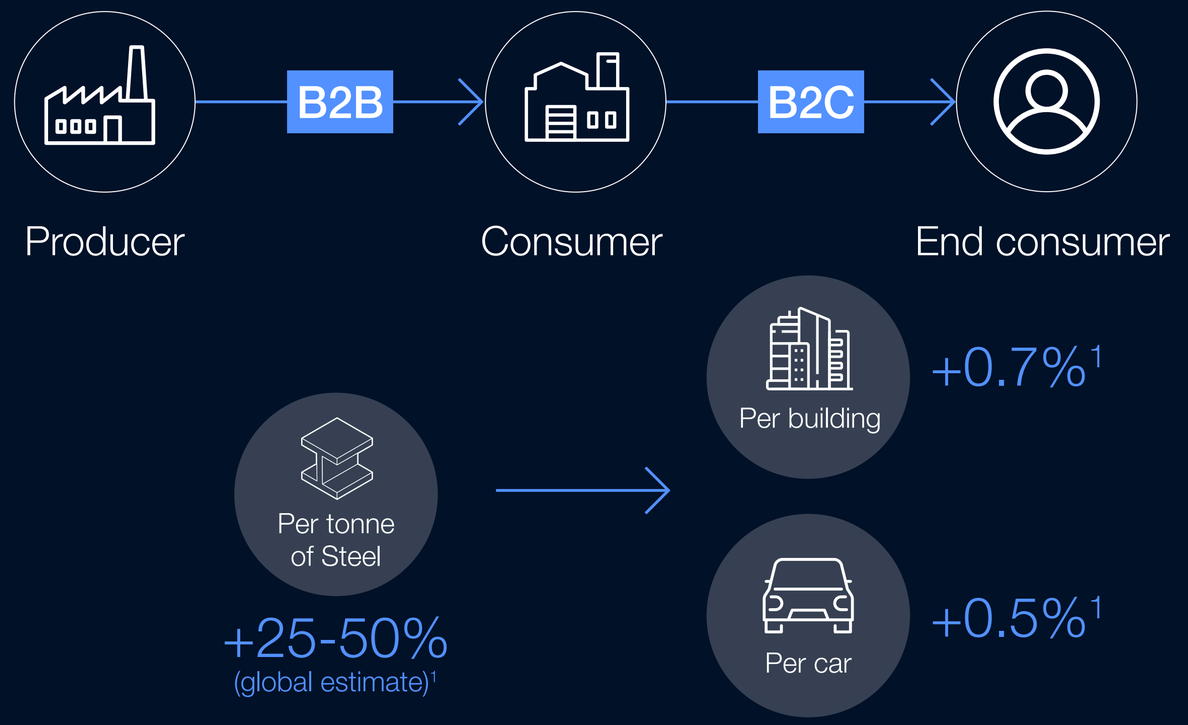
Notes: 1. Assumes a capacity factor of 30%; **2.** Assumes that 700 kWh is required for 1 tonne of crude steel made in EAF, and that 30 Mt-crude steel will be produced by EAF in 2050 based on the medium scenario in a NSRI report; **3.** Weighted average of today's installed costs of renewable and nuclear power generation (as estimated by METI's Power Generation Cost Verification Working Group), based on the IEEJ's power generation mix in 2050 (the 60-year nuclear power plant lifetime scenario); **4.** Potential hydrogen demand in the steel industry, not only for steelmaking processes but also for low-emission captive power generation, CCU and high-temperature heat, estimated by JH2A; **5.** Includes CapEx only for renewable electricity generation and electrolysers; **6.** Estimated by the REI, assuming that COURSE50 and SuperCOURSE50 account for 33% each among primary ironmaking, and that the former reduces 10% and the latter reduces 25% of CO_2 emissions through hydrogen reduction, with the rest of the CO_2 captured at a rate of 90%; **7.** Based on carbon capture infrastructure networks and includes CapEx only for compression, pipeline and well development.

Sources: NSRI, *Report on Investigative Project towards Sustainable Development of Japan's Metal Industry Based on Carbon Neutrality,* February 2022, https://www.meti.go.jp/meti_lib/report/2021FY/000080.pdf (in Japanese); REI, *The Path to Green Steel: Pursuing Zero-Carbon Steelmaking in Japan,* February 2023, https://www.renewable-ei.org/en/activities/reports/20221118.php; Global CCS Institute, *Technology Readiness and Costs of CCS*, March 2021, https://globalccsinstitute.com/wp-content/uploads/2021/04/CCS-Tech-and-Costs.pdf; Nippon Steel, *Efforts towards Utilization of Hydrogen in the Steelmaking Process,* 7 October 2022, https://www.meti.go.jp/shingikai/enecho/shoene_shinene/suiso_seisaku/pdf/005_01_00.pdf (in Japanese); IEEJ, *Model Calculation for Decarbonization by 2030 and 2050,* 28 September 2022, https://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/2022/050/050_005.pdf (in Japanese); METI, *Power Generation Cost Verification Working Group,* September 2021, https://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/#cost_wg (in Japanese); Accenture analysis

Steel

Green premiums

Using low-emission steel in buildings or cars would increase the cost of the final product by 0.7% or 0.5%, respectively,[1] with these sectors consuming nearly 70% of Japan's steel production.



Estimated green premium for steel buyers[1]	Annual shipment value of Japan-made steel products (2020)	Additional value with green premium	Estimated green premium for end consumers		
			Product	Share of output[2]	Green premium[1]
25–50%	$116 billion (JPY 15 trillion)	$29–58 billion (JPY 4–8 trillion)	Buildings and infrastructure	41%	0.7%
			Cars	27%	0.5%

Notes: 1. Assumes the same green premium of steel and its impact on end consumer sectors as in the World Economic Forum *Net Zero Industry Tracker* report, as Japan-specific data is not available; **2.** Share of order booked for ordinary steel products by consuming sector in 2020, where the tonnage of those with identifiable consuming sectors serves as the denominator.

Sources: World Economic Forum, *The Net-Zero Industry Tracker*, 28 July 2022, https://www.weforum.org/reports/the-net-zero-industry-tracker/; METI, *2021 Economic Census – Activity Survey: Summary of the Manufacturing Sector,* 30 September 2022, https://www.meti.go.jp/statistics/tyo/census/r3result/pdf/r03_seizogaiyo_giy.pdf (in Japanese); JISF, *Regional and Application-Based Order Statistics for Ordinary Steel: Reference Statistics Table IV for Fiscal Year 2020,* n.d., https://www.jisf.or.jp/data/yoto/documents/FY2020r.pdf (in Japanese)

Steel

Supporting policies for a net-zero steel industry

The Japanese government has implemented a wide range of policies, but further robust measures will help to create a more economically viable market for low-emission steel.

General policies (non-exhaustive) **red bold indicates new policies under consideration**

Carbon pricing:

- Japan's direct carbon price is **$2 (JPY 249)/t$CO_2$,**[1] among the lowest in the advanced economies. However, fuel excise taxes are imposed on all types of fossil fuels. Adding up these **indirect carbon prices,**[2] the **effective carbon price** in Japan reaches **~$28 (JPY 3,659)/t$CO_2$.**
- The METI's carbon pricing study group suggested in 2021 that the government should carefully consider the impacts on **total energy costs** for the industry and consumers in planning additional carbon pricing instruments. The study group also suggested that the government should **clearly communicate to the international community** details of the financial burdens borne by its energy consumers as they are not necessarily proportional to emissions.
- **GX-ETS:** Under the Green Transformation (GX) League,[3] an **emissions trading system** that uses a **baseline-and-credit system** will be introduced. Companies participating in the GX League will set **voluntary targets,** report the actual emissions data, trade earned emission credits and disclose the information in a mutual database called the "GX Dashboard". After the trial phase, starting in 2023, the system will enter the full-operation phase in 2026, with measures to improve the fairness and effectiveness of the mechanism. Furthermore, electricity companies with large emissions will need to purchase the emission allowance through auction from 2033.
- **Carbon surcharge:** From 2028 onwards, importers of fossil fuels will be charged a new surcharge, with a gradually increasing rate of burden.

Technology support:

- **Green Innovation Fund:** This public fund, worth $15 billion (JPY 2 trillion), will provide consistent support over the next 10 years to businesses that undertake ambitious innovations in various areas, including renewables, hydrogen and industrial decarbonization.

Regulations:

- **2022 Revised Energy Conservation Act:** Large energy consumers are mandated to submit their mid- to long-term plans for transitioning towards non-fossil fuels and regularly report their progress.

Steel-specific remarks

JISF and major Japanese steelmakers have expressed concerns that the implementation of additional carbon pricing instruments in the steel industry, where alternative low-emission options are not yet established, could lower competitiveness and hinder innovation by reducing capital for investment.

The basic concept of the GX League has been endorsed by major steelmakers, including Nippon Steel, JFE Steel and Kobe Steel.

The Green Innovation Fund includes a project dedicated to low-emission steelmaking technologies, funding up to $1.5 billion (JPY 0.2 trillion).

For the top five energy-consuming sectors, including steel and chemicals, the government suggests targets for the transition towards non-fossil energy.

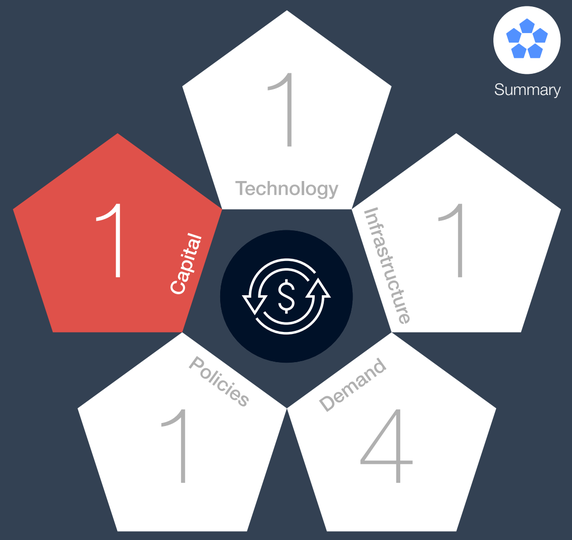
Notes: 1. Refers to the Tax for Climate Change Mitigation; **2.** The World Bank defines indirect carbon pricing as "instruments that change the price of products associated with carbon emissions in ways that are not directly proportional to those emissions", such as fuel and commodity taxes, as well as fuel subsidies affecting energy consumers; **3.** The GX League is a forum established by METI to promote cooperation between a group of companies and the government, universities and academic institutions to meet GHG reduction targets and increase industrial competitiveness. As of January 2023, the basic concept of the GX League has been endorsed by 679 companies.

Sources: *OECD, Net Effective Carbon Rates,* n.d., https://stats.oecd.org/Index.aspx?DataSetCode=ECRS; METI, *Study Group on Economic Measures for Achieving Carbon Neutrality Worldwide: Interim Report,* August 2021, https://www.meti.go.jp/shingikai/energy_environment/carbon_neutral_jitsugen/pdf/20210825_2.pdf (in Japanese); METI, *GX League,* n.d., https://gx-league.go.jp/aboutgxleague/document/GX_League_Overview.pdf; Cabinet Secretariat, *Basic Policies towards the Realization of GX,* February 2023, https://www.cas.go.jp/jp/seisaku/gx_jikkou_kaigi/pdf/kihon.pdf (in Japanese); JISF, *Carbon Pricing for Supporting Economic Growth,* 1 March 2021, https://www.meti.go.jp/shingikai/energy_environment/carbon_neutral_jitsugen/pdf/002_06_00.pdf (in Japanese); METI, *Green Innovation Fund: R&D and Social Implementation Plan for the "Hydrogen Utilization in the Steelmaking Process" Project,* 14 September 2021, https://www.meti.go.jp/policy/energy_environment/global_warming/gifund/pdf/gif_05_randd.pdf (in Japanese); World Bank, *State and Trends of Carbon Pricing 2022*, May 2022, http://hdl.handle.net/10986/37455

Steel

Capital required to transform Japan's steel asset base

$77 billion (JPY 10 trillion) is necessary to transform the Japanese steel industry asset base. The industry needs to attract more investments in low-emission steel assets.



Assets and investments

Transformation investment required — $77 billion (JPY 10 trillion)

Industry net property, plant and equipment (PPE) — $51 billion (JPY 6.6 trillion)

= **1.5** Investment to PPE multiple

Green/transition finance

Japanese steelmakers recently started using green and transition financing, such as:

1 JFE Steel
Total $231 million (JPY 30 billion) transition bonds issued in 2022

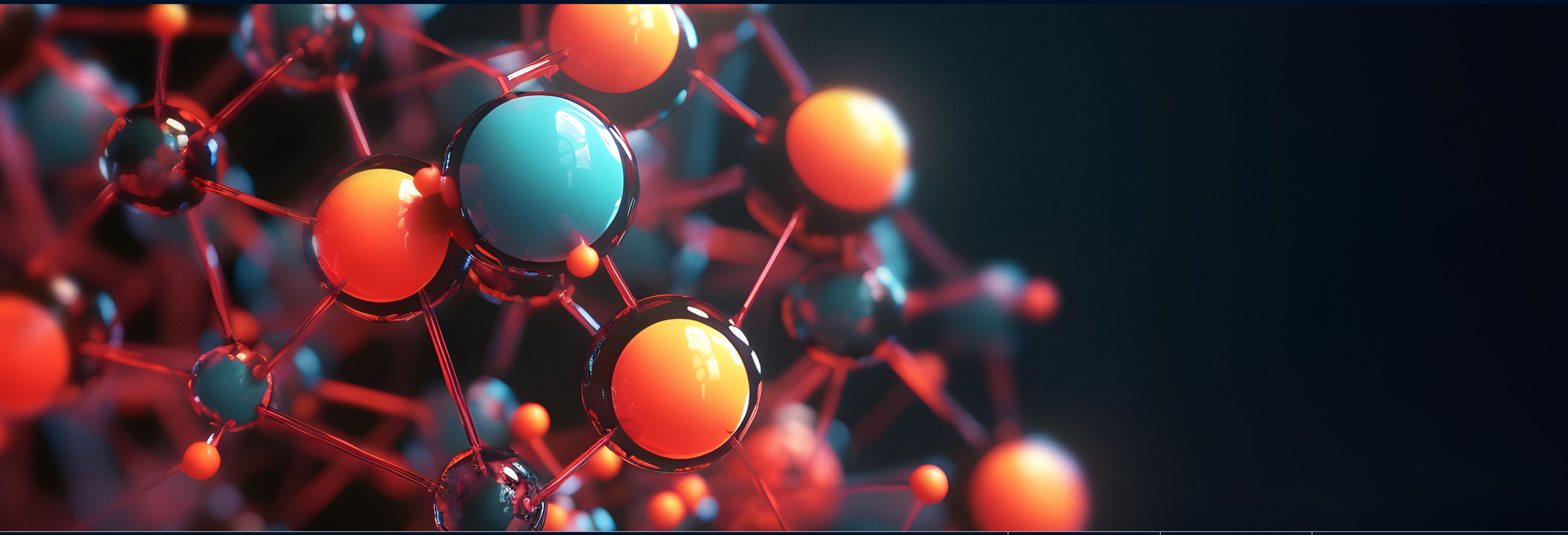
2 Daido Steel
Total $77 million (JPY 10 billion) transition bonds issued in 2022

3 Nippon Steel
Total $385 million (JPY 50 billion) green bonds issued in 2023

However, government subsidies are still often seen as a prerequisite when making an investment decision to transform the industry asset base, so the business case needs to improve significantly to attract more private funds.

Sources: JISF, *Efforts towards Carbon Neutrality*, 21 February 2022, https://www.meti.go.jp/shingikai/sankoshin/seizo_sangyo/pdf/011_03_02.pdf (in Japanese); MOF Policy Research Institute, *Financial and Monetary Statistics Monthly Report No. 835*, November 2021, https://www.mof.go.jp/pri/publication/zaikin_geppo/hyou/g835/835.html (in Japanese); JFE Steel, *Notice Regarding Determination of Conditions for Issuing Transition Bonds*, 3 June 2022, https://www.jfe-holdings.co.jp/release/2022/06/220603.pdf (in Japanese); Daido Steel, *Notice Regarding Determination of Conditions for Issuing Transition Bonds*, 26 August 2022, https://www.daido.co.jp/info/2022/220826_transitionbond.html (in Japanese); Nippon Steel, *Nippon Steel Corporation Issues Green Bond*, 3 March 2023, https://www.nipponsteel.com/en/news/20230303_100.html; expert interview

Chemical industry
Industrial decarbonization in Japan



Chemicals

Key takeaways

The outcomes of the chemical in-depth industry analysis can be summarized in five key takeaways:

1	Japan's chemical industry has **steadily improved the efficiency of its process energy consumption** over the past few decades. However, a significant amount of CO_2 is still emitted from the use of **off-gas (methane) as a heat source** in naphtha crackers and **fossil-based captive power plants.** To further reduce emissions from process energy, the sector aims to switch those fuels to low-emission options such as hydrogen and ammonia.
2	Although the use of **fossil energy as chemical feedstock** does not directly contribute to GHG emissions, **70% of plastic waste is currently incinerated** (including energy recovery) in Japan, resulting in significant indirect CO_2 emissions. To avoid these emissions, the development of **chemical recycling** technologies, as well as the use of **biomass** and **captured CO_2** as chemical feedstock (i.e. **CCU**), is underway.
3	**Hydrogen** will be used not only as a fuel, but also as a feedstock for many CCU solutions. In the chemical sector, there is a potential demand for **6.3–7.3 MTPA** of hydrogen by 2050, which requires investments of **$40–84 billion[1] (JPY 5–11 trillion).** However, **CCU solutions that do not require hydrogen,** as well as **artificial photosynthesis** to produce hydrogen, are also being developed, and may play a strategic role given the uncertainty in hydrogen supply.
4	**Total investments required to transform Japan's chemical industry asset base by 2050,** including R&D, are estimated at **$57–75 billion (JPY 7.4–9.7 trillion).** To finance the capital requirements, the business case needs to be **more attractive for private investors/financiers,** and the sector is taking action to **communicate the value of green chemicals to consumers,** such as **branding** and increasing clarity on **carbon footprint.**
5	The government has been supporting the sector's transition through various measures, including providing **$1 billion (JPY 0.1 trillion) for the development of low-emission chemical technologies** (as part of the $15 billion (JPY 2 trillion) **Green Innovation Fund**). To further accelerate the transition, more extensive policies could be considered, e.g. setting a standard for CO_2-fed chemicals, promoting a more reliable waste management system, etc.

Note: 1. Assumes the required CapEx to be $6.5–11.5 billion (JPY 0.8–1.5 trillion)/MTPA.

Chemicals

Performance of Japan's chemical sector: towards net zero

The chemical sector is responsible for 14% of Japan's industrial emissions. While the energy efficiency of processes in the sector has improved, more robust action is needed to decarbonize the sources of major emissions, such as naphtha steam crackers and captive power generation, as well as further promoting recycling.

What is produced

HVCs account for 97% of Japan's primary chemical production, with 3% ammonia and no methanol.

Japan is ranked seventh in ethylene production capacity today; its production was 5.9 Mt in 2020, expected to decrease by 8% by 2050.

How it is produced

All HVCs are made by naphtha steam cracking in Japan.

In 2020, 24% of plastic waste was sent for recycling,[1] with the majority of the remainder being thermally treated with or without energy recovery.

What it contributes to

GHG emissions by the chemical sector were 57 Mt for Scope 1, and 1 Mt for Scope 2 (2020).

The chemical industry is responsible for 5% of Japan's GHG emissions – 14% of industrial emissions – the second-biggest emissions for a single sector.

In addition to Scope 1 and 2 emissions, 10 Mt CO_2e is emitted from plastic and rubber production, and 16 Mt CO_2e is emitted from the incineration of plastic waste at end of use.

What energy is used

~90% of energy consumption comes from fossil fuels.

Process energy today accounts for 36% of total energy consumption, and has been decreasing over the past few decades, indicating improvement in process energy efficiency.

~40% of electricity demand is generated by the sector's captive power plants. Fossil fuels account for ~70% of the energy used for power generation, including ~30% for coal.

Note: 1. Includes only mechanical recycling and chemical recycling.

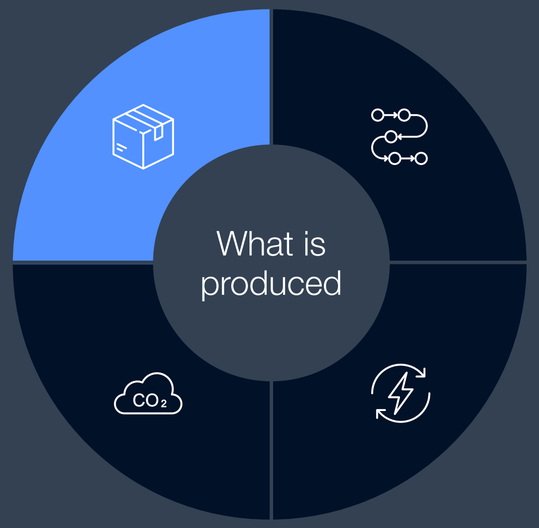
Sources: METI, *Yearbook of Current Production Statistics: Chemical Industry Statistics (2020)*, n.d., https://www.meti.go.jp/statistics/tyo/seidou/result/ichiran/nenpo_2007-2020.html#menu5 (in Japanese); JPCA, *The Current State of the Petrochemical Industry in 2022*, November 2022 (available only as a physical publication); NIES, *An Analysis of Scenarios for Achieving a Decarbonized Society by 2050*, 30 June 2021, https://www-iam.nies.go.jp/aim/projects_activities/prov/2021_2050Japan/20210630_NIES.pdf (in Japanese); PWMI, *An Introduction to Plastic Recycling,* June 2022, https://www.pwmi.or.jp/ei/plastic_recycling_2022.pdf; METI, *Technology Roadmap for "Transition Finance" in Chemical Sector*, December 2021, https://www.meti.go.jp/policy/energy_environment/global_warming/transition/transition_finance_technology_roadmap_chemistry_eng.pdf; METI, *Comprehensive Energy Statistics (Fiscal Year 1990-2020)*, n.d., https://www.enecho.meti.go.jp/statistics/total_energy/results.html (in Japanese)

Chemicals

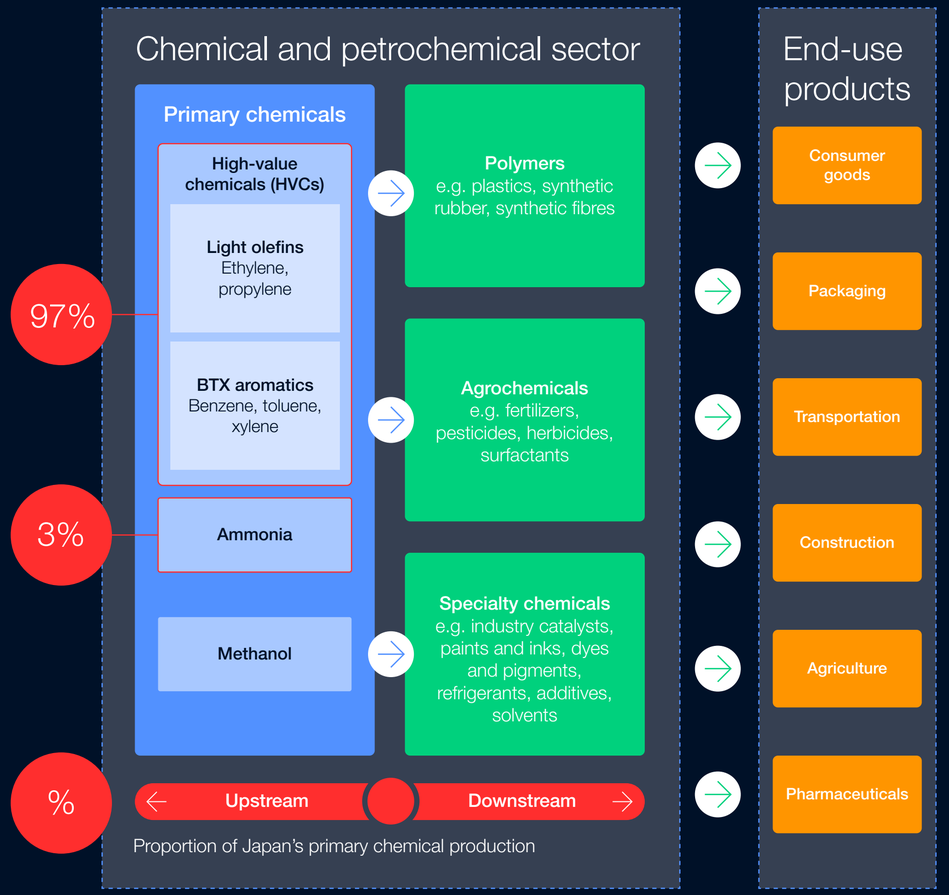
Petrochemicals – primary chemical[1] products mix

Among Japan's primary chemical production, HVCs (high-value chemicals)[2] account for 97%, with ammonia representing the remaining 3%. This report focuses on the decarbonization of HVC production.

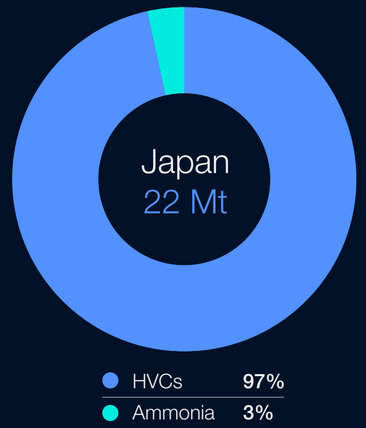
Click on an icon
below to find out more.



Primary chemicals in context

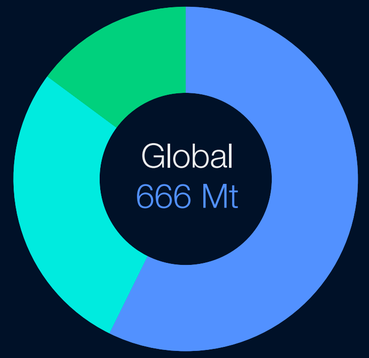


Primary chemical[1] production in 2020



The mix of primary chemicals produced in Japan is predominantly composed of HVCs.

Ammonia holds only a 3% share of primary chemicals produced, and methanol is not produced domestically.



In contrast, the portfolio of primary chemicals produced globally is more diversified, with ammonia and methanol accounting for 28% and 15% respectively.

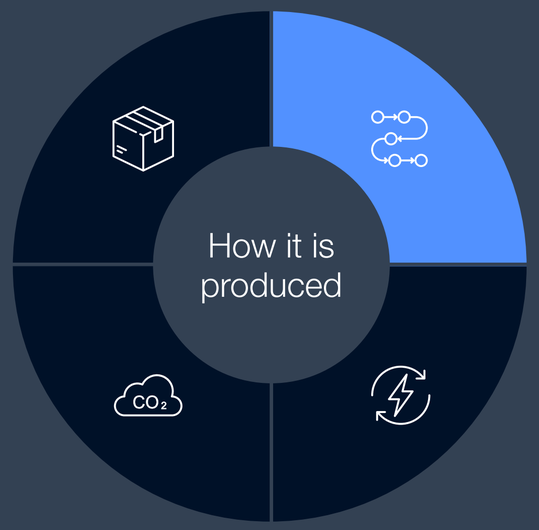
Notes: 1. Primary chemicals include HVCs, ammonia and methanol; **2.** High-value chemicals (HVCs) include light olefins (ethylene and propylene) and BTX aromatics (benzene, toluene and mixed xylenes).

Sources: IEA, *The Future of Petrochemicals*, October 2018, https://www.iea.org/reports/the-future-of-petrochemicals; IEA, *Expansion in Primary Chemical Production in the Net Zero Scenario, 2000-2030*, October 2022, https://www.iea.org/data-and-statistics/charts/expansion-in-primary-chemical-production-in-the-net-zero-scenario-2000-2030; METI, *Future Supply and Demand Trends of Petrochemical Products Worldwide*, October 2019, https://warp.da.ndl.go.jp/info:ndljp/pid/12685722/www.meti.go.jp/policy/mono_info_service/mono/chemistry/sekaijukyuudoukou201910.html (in Japanese); METI, *Yearbook of Current Production Statistics: Chemical Industry Statistics (2020)*, n.d., https://www.meti.go.jp/statistics/tyo/seidou/result/ichiran/nenpo_2007-2020.html#menu5 (in Japanese); IFA, *Nitrogen Products*, n.d., https://www.ifastat.org/supply/Nitrogen%20Products/Ammonia; Mitsui & NRI, *Feasibility Study for CO_2 to Chemical Conversion Project in Saudi Arabia*, August 2021, https://www.meti.go.jp/meti_lib/report/2020FY/000475.pdf (in Japanese)

Chemicals

Petrochemicals – production processes

The availability and cost of feedstocks are directly reflected in the selection of production processes. The ethane- and coal-based routes are increasingly adopted in the US and China, respectively, but naphtha steam cracking is the sole production method used in Japan's HVC production.



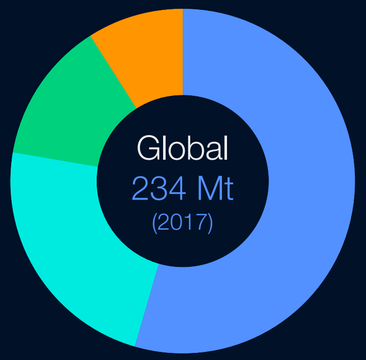
Major multi-product processes for HVC production

Production route	Description	Pros	Cons
Naphtha steam cracking	– Produces olefins and BTX aromatics from naphtha in a steam cracker – Predominantly used in Asia-Pacific and Europe	– Delivers a more balanced portfolio of olefins and BTX aromatics, compared to other routes	– Ageing steam cracking assets provide risks of additional necessary maintenance and repairs
Ethane steam cracking	– Produces light olefins (ethylene and propylene) from ethane in a steam cracker – Major process in the US since the shale revolution	– Cost-competitive, provided there is access to cheap and abundant ethane (often produced from shale gas) – Suitable for mass production of plastic materials	– HVCs other than light olefins, such as butadiene, isoprene and BTX aromatics, cannot be obtained, resulting in a shortage of rubber materials
CTO (coal to olefin)	– Produces methanol from coal and subsequently produces olefins – Seen only in China	– Cost-competitive, provided there is access to cheap and abundant coal – MTO (methanol to olefin) is being developed	– Emission intensity is five times larger than that of naphtha steam cracking – Expensive synthetic methanol

HVC by production route

Naphtha steam cracking 100%

In Japan, HVCs are produced only by naphtha steam cracking. The emissions intensity for light olefins (ethylene and propylene) is 1.15 tCO_2e/t[1] today.



Naphtha steam cracking	55%
Ethane steam cracking	23%
LPG steam cracking	13%
Others[2]	9%

Globally, not only naphtha but also light fuels (e.g. ethane, LPG) account for sizable proportion.

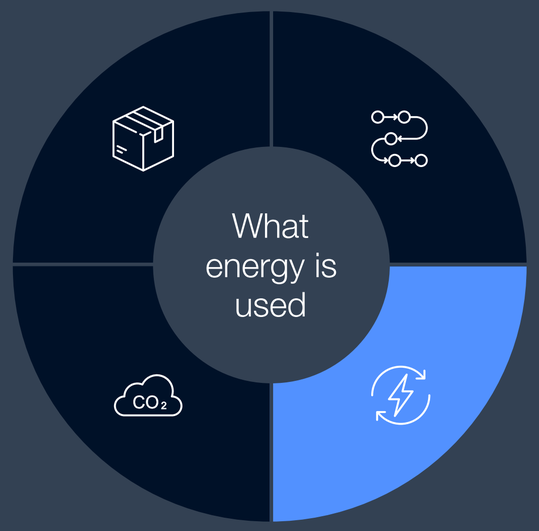
Notes: 1. Excludes emissions from the oil-refining process; **2.** Others include gas oil steam cracking, propane dehydrogenation (PDH), ethanol dehydration, and methanol to olefins/aromatics (MTO/MTA).

Sources: IEA, *The Future of Petrochemicals*, October 2018, https://www.iea.org/reports/the-future-of-petrochemicals; METI, *Green Innovation Fund: R&D and Social Implementation Plan for the "Development of Plastic Raw Material Manufacturing Technology Using CO_2 and Other Substances" Project*, 15 October 2021, https://www.meti.go.jp/policy/energy_environment/global_warming/gifund/pdf/gif_07_randd.pdf (in Japanese); METI, *Technology Roadmap for "Transition Finance" in Chemical Sector*, December 2021, https://www.meti.go.jp/policy/energy_environment/global_warming/transition/transition_finance_technology_roadmap_chemistry_eng.pdf

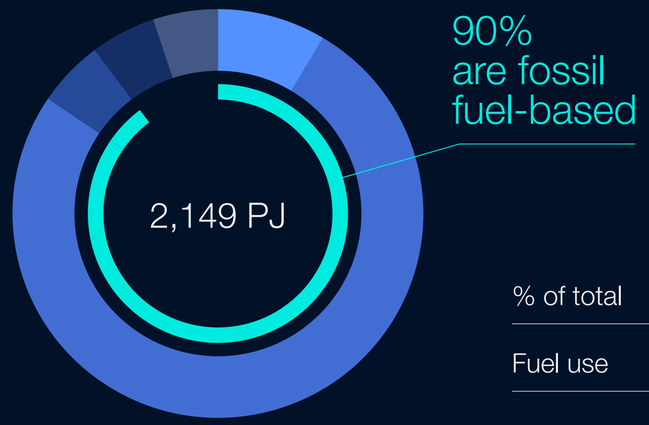
Chemicals

Fuel use in Japan's chemical industry

In the past 30 years, while the fuels consumed as feedstock have increased as production has grown, process energy consumption has decreased, indicating that the energy efficiency of processes has improved in Japan's chemical industry. Nevertheless, 90% of its energy consumption came from fossil fuels in 2020.

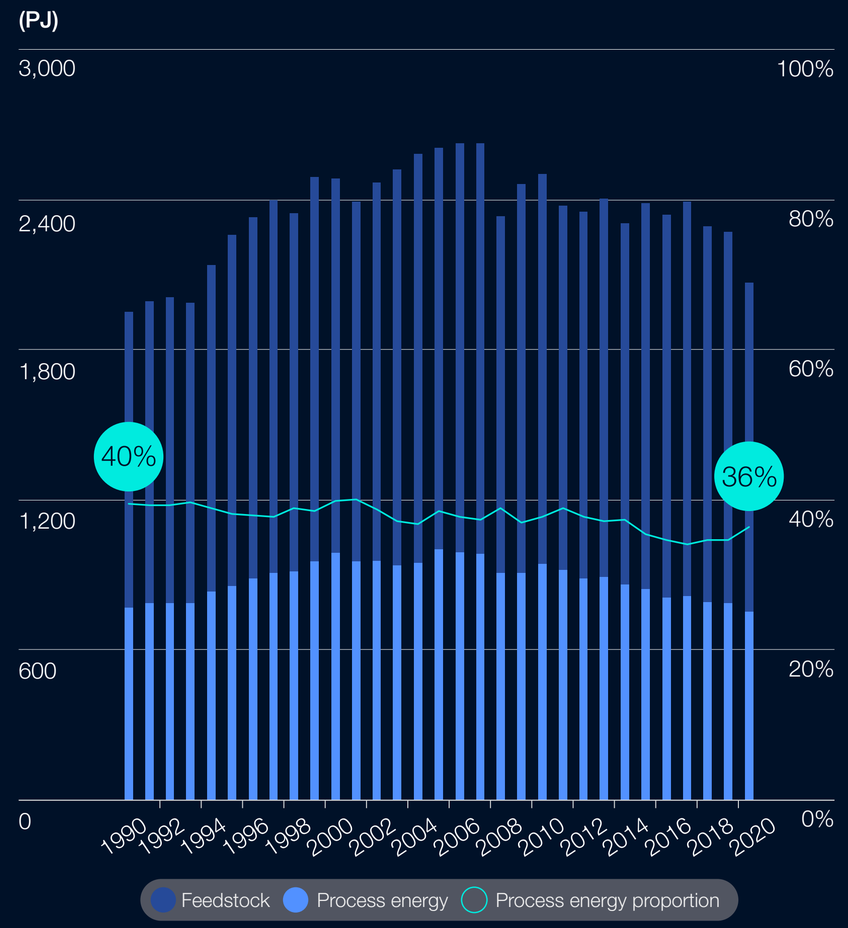


Energy input in 2020[1]



	Fuel use	% of total
Coal	184 PJ	9%
Oil (including naphtha)	1,632 PJ	76%
Gas	113 PJ	5%
Purchased electricity	110 PJ	5%
Other[2]	110 PJ	5%

Feedstock and process energy consumption (1990–2020)[3]



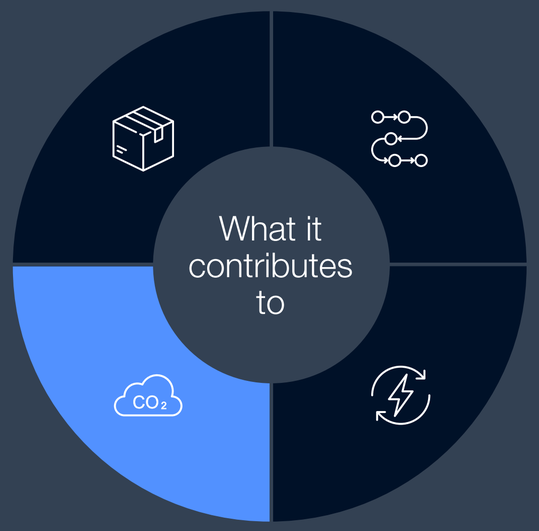
Notes: 1. Includes the energy input for captive generation of power and heat; **2.** Other energy sources include energy recovery and renewables; **3.** Final energy consumption of the chemical sector, excluding the production of petroleum and coal products.

Source: METI, *Comprehensive Energy Statistics (Fiscal Year 1990-2020)*, n.d., https://www.enecho.meti.go.jp/statistics/total_energy/results.html (in Japanese)

Chemicals

Japan's GHG emissions

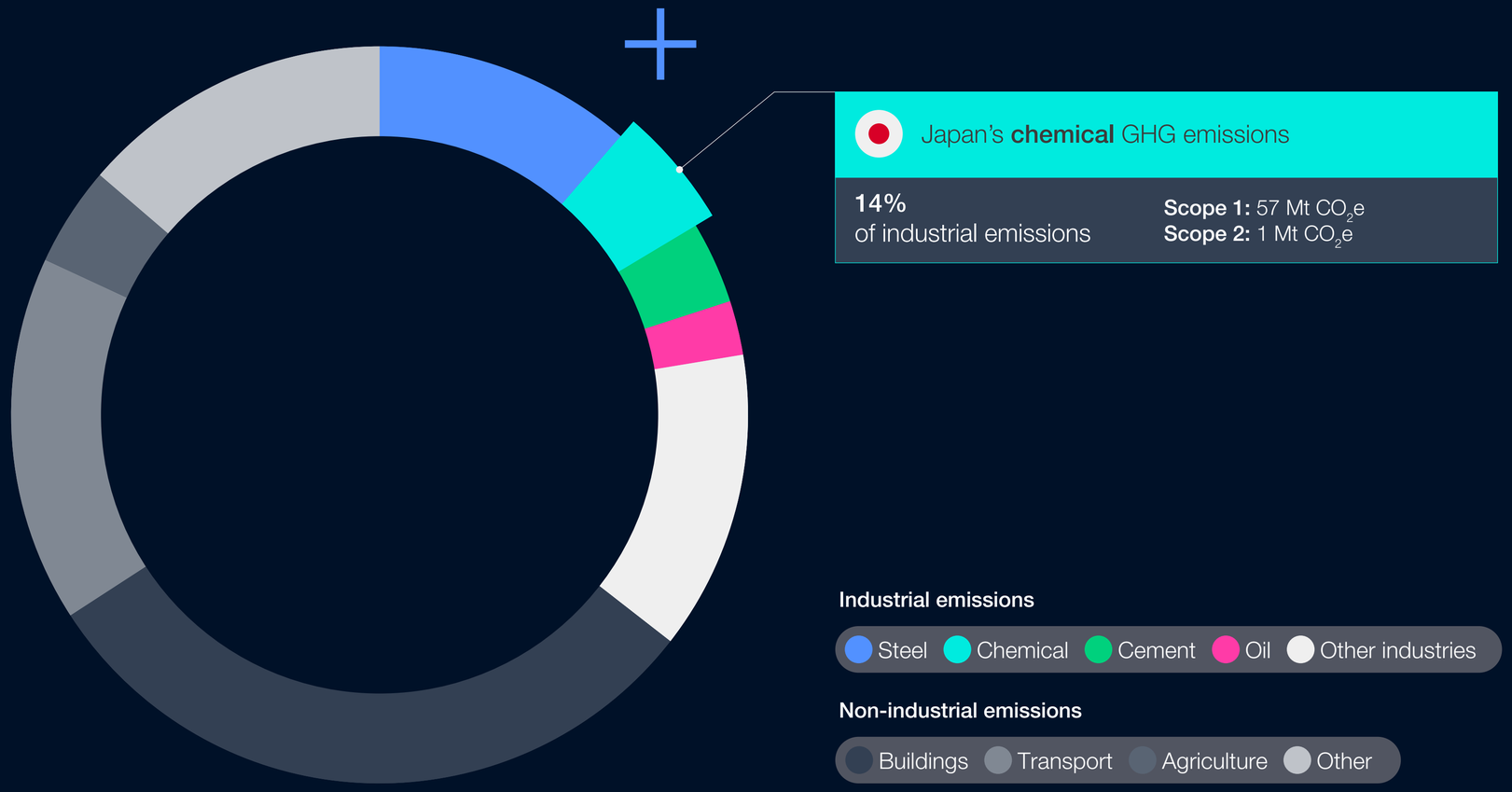
GHG emissions from Japan's chemical sector amounted to 58 Mt CO_2e (Scope 1 and 2) in 2020, accounting for 14% of industrial emissions, or 5% of the nation's total emissions. A significant amount of GHGs are generated downstream (e.g. in the production of final plastic and rubber products, in end-of-use incineration).



Major Scope 3 emissions (non-exhaustive)

10 Mt CO_2e from the production of final plastic and rubber products

16 Mt CO_2e from thermal treatment of plastic waste (with or without energy recovery)



Sources: NIES, *The GHG Emissions Data of Japan (1990-2020)*, 19 April 2022, https://www.nies.go.jp/gio/en/archive/ghgdata/index.html; METI, *Technology Roadmap for "Transition Finance" in Chemical Sector*, December 2021, https://www.meti.go.jp/policy/energy_environment/global_warming/transition/transition_finance_technology_roadmap_chemistry_eng.pdf

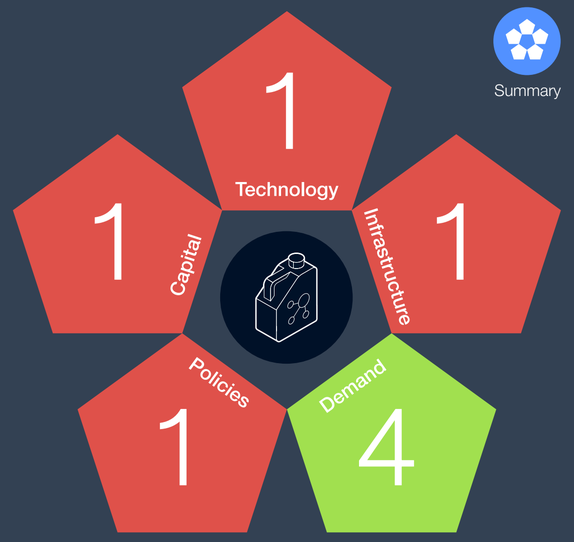
Chemicals Summary

The chemical industry benefits from the minimal cost impact on end consumers, but it requires more investments in innovative production technologies and hydrogen infrastructure, as well as improvements in supporting policies.

Readiness stage, on a scale 1 (low) – 5 (high)[1,2]

1 2 3 4 5

Click on the enablers below to find out more.



Readiness of Japan's chemical industry to achieve net zero

Technology

1 Readiness Stage

The low-emission production technologies are **largely at concept or early prototype stage.**

Key metrics

2027

Expected year of commercial readiness of first key technology.

Infrastructure

1 Readiness Stage

The necessary infrastructure required by the low-emission industry **needs to be developed almost entirely.**

Key metrics

$31 billion (JPY 4 trillion)

Investments required in low-emission power generation.

$40–84 billion (JPY 5–11 trillion)

Investments required in low-emission hydrogen production.

Data not available

Investments required in CO_2 transport and storage

Demand

4 Readiness Stage

Most of the market can pay the required green premium.

Key metrics

The impact on end consumers is expected to be limited

as +100% green premium of basic chemicals would lead to +0.7–1.0% cost increase for end consumers of cars, soft drinks or food.

Policies

1 Readiness Stage

Very limited policies complement current environment (technology, infrastructure, demand, capital), to support the growth of the low-emission industry.

Key metrics

$2 (JPY 249)/$tCO_2e$

direct carbon price in Japan.

Capital

1 Readiness Stage

Low-emission investments generate sufficient return for **barely any** CapEx to flow towards low-emission production assets.

Key metrics

$57–75 billion (JPY 7.4–9.7 trillion)

Cumulative CapEx required to transform the industry asset base by 2050, or **~$1.9–2.5 billion (JPY 0.2–0.3 trillion)/year.**

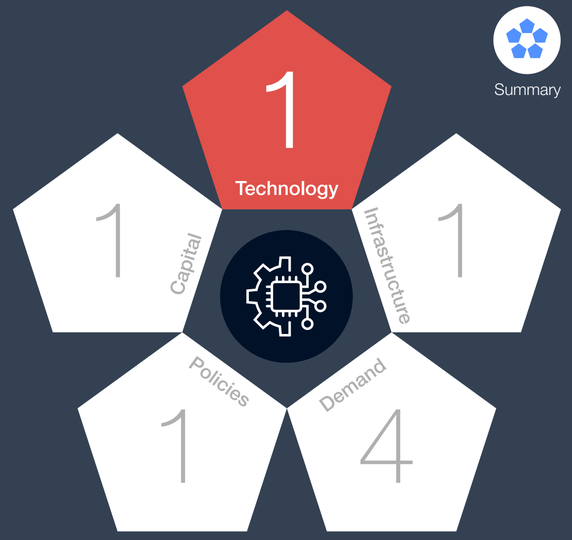
Notes: 1. As defined in World Economic Forum *Net Zero Industry Tracker*. For the definition of all stages, see "Scope of work and research approach" section of this report; **2.** This assessment is an absolute evaluation of the readiness of Japan's chemical industry towards achieving net zero, rather than a relative comparison with other countries.

Source: World Economic Forum, *The Net-Zero Industry Tracker*, 28 July 2022, https://www.weforum.org/reports/the-net-zero-industry-tracker/

Chemicals

Key technologies for achieving net-zero chemicals in Japan

Japan's chemical industry is developing various low-emission technologies, which can be categorized into three strategies: (1) fuel switch; (2) feedstock switch; and (3) feedstock circulation.



Emission reduction levers	Key technologies		Expected year of commercial readiness[1]	Emission reduction limit (absolute value per produced good)	Emission reduction limit (%)
Fuel switch	H_2/NH_3-fuelled naphtha steam crackers		2035 (2040)[2]	0.8 tCO_2e/t of olefin	70%
	H_2/NH_3-fuelled captive power generation		2027	*Data not available*	
Feedstock switch	Biomass-fed chemicals	Biomass-fed primary chemical production	Available	*Data not available*	
		Biomass-fed polymer production	2028	*Data not available*	
		Biomass-fed primary chemicals with CCUS	2027	*Data not available*	
	CO_2-fed chemicals	Artificial photosynthesis	2040	8.9 tCO_2e/t of H_2	100%
		H_2 and CO_2 (syngas)-fed methanol production	2028	*Data not available*	
		MTO/ETO (methanol or ethanol to olefin)	2028	1.6 tCO_2e/t of olefin	100%
		CO_2-fed olefin production	2030	*Data not available*	
		CO_2-fed fine chemical production	2029	1.3 tCO_2e/t of DRC, 0.8 tCO_2e/t of MDI	150%
		CO_2-fed methane production	2030	Data not available	
Feedstock circulation	Chemical recycling	Chemical recycling of plastic waste	2030	0.8 tCO_2e/t of olefin (3.3 tCO_2e/t of olefin)[3]	50%
		Chemical recycling of rubber waste	2035	0.9 tCO_2e/t of olefin (3.3 tCO_2e/t of olefin)[3]	43%

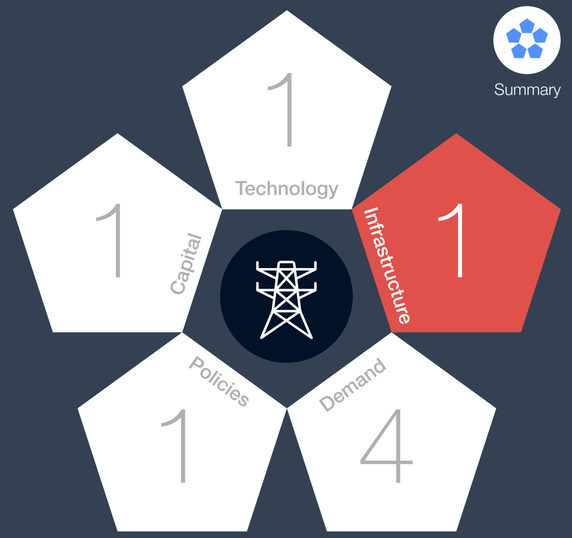
Notes: 1. Refers to the year of commercialization in METI's *Technology Roadmap for "Transition Finance" in Chemical Sector*; **2.** 2040 refers to the commercial readiness of the utilization of off-gas as chemical feedstock, which is a prerequisite for scaling up H_2/NH_3-fuelled crackers; **3.** 3.3 tCO_2e includes the avoided emissions from the incineration of plastics or rubber waste.

Sources: METI, *Technology Roadmap for "Transition Finance" in Chemical Sector*, December 2021, https://www.meti.go.jp/policy/energy_environment/global_warming/transition/transition_finance_technology_roadmap_chemistry_eng.pdf; METI, *Direction of R&D and Social Implementation of Carbon Recycling Projects (Chemical Field)*, July 2021, https://www.meti.go.jp/shingikai/sankoshin/green_innovation/energy_structure/pdf/004_04_00.pdf (in Japanese)

Chemicals

Required infrastructure for a net-zero chemical industry

More than $70 billion (JPY 9 trillion) will need to be invested in low-emission hydrogen and electricity infrastructure to enable a net-zero chemical industry.



Net-zero strategy	Low-emission technologies		Estimated infrastructure needs by 2050					
			Low-emission power generation[1]		Low-emission hydrogen production[4]		CO_2 transport and storage	
			Capacity required	CapEx/unit	Capacity required	CapEx/unit	Capacity required	CapEx/unit
Fuel switch	H_2/NH_3-fuelled naphtha steam crackers				1.1–1.4 MTPA[5]	$6.5–11.5 billion/MTPA[8]	*Data not available, but the CCS for residual CO_2 will be necessary to realize net-zero emissions*	
	Other fuel-switch technologies (including H_2/NH_3-fuelled power generation)		11.9 GW[2]	$2.6 billion/GW[3]	2.4–3.1 MTPA[6]			
Feedstock switch	Biomass-fed chemicals							
	CO_2-fed chemicals	H_2 required			2.8 MTPA[7]			
		H_2 not required						
Feedstock circulation	Chemical recycling							
	Total investment		$31 billion (JPY 4 trillion)		$40–84 billion (JPY 5–11 trillion)		*Data not available*	

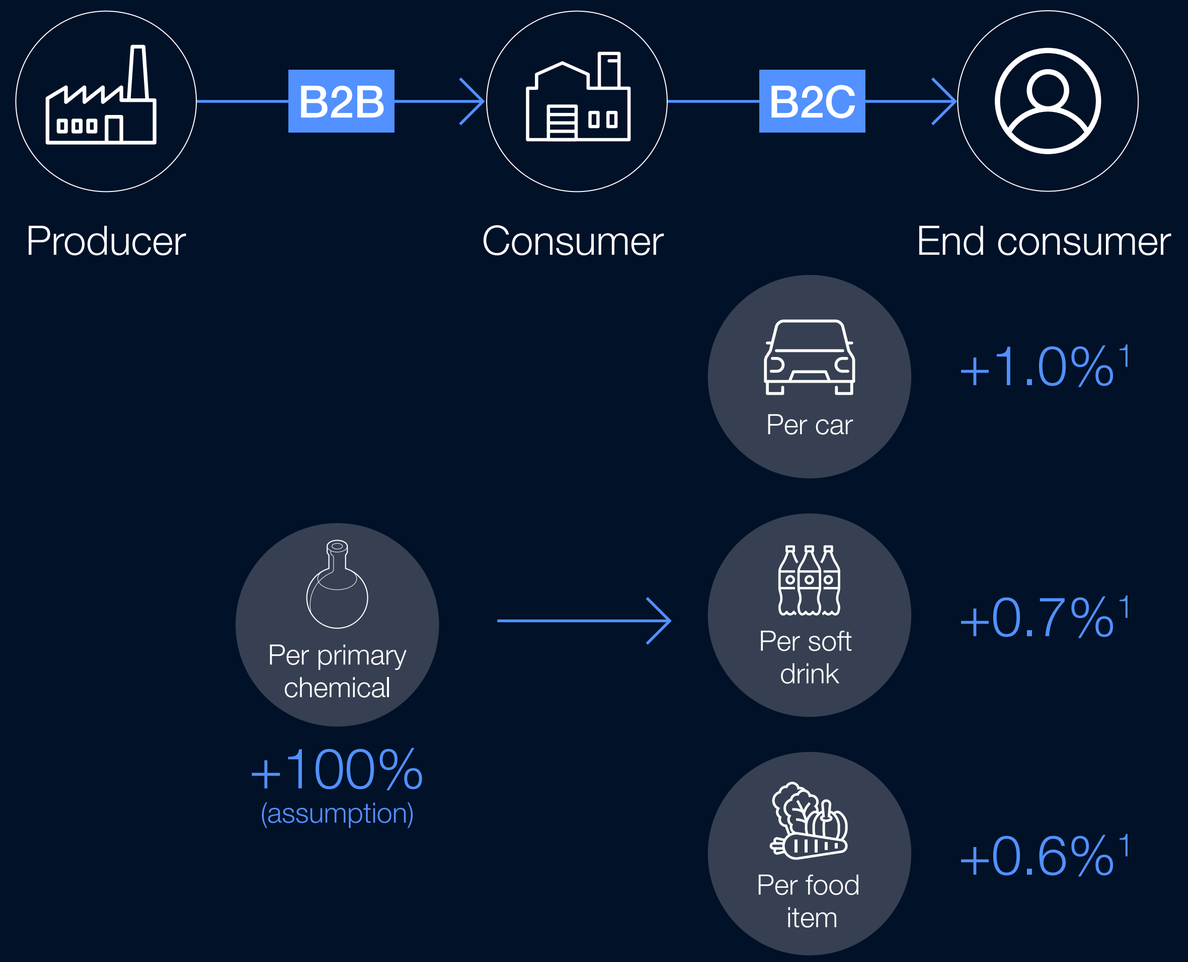
Notes: 1. Assumes a capacity factor of 30%; **2.** Assumes that today's demand for purchased electricity in Japan's chemical sector will remain and that all of the purchased electricity will be generated from low-emission sources; **3.** Weighted average of today's installed costs of renewable and nuclear power generation (as estimated by METI's Power Generation Cost Verification Working Group), based on the IEEJ's power generation mix in 2050 (the 60-year nuclear power plant lifetime scenario); **4.** Includes ammonia, expressed in H_2-equivalent tonnes; **5.** Assumes all of the fuels consumed in the crackers today will be replaced by hydrogen/ammonia; **6.** Assumes all of the energy consumption, except for naphtha steam cracking and purchased electricity, will be replaced by hydrogen/ammonia; **7.** Assumes 25% of all primary chemicals will be produced as CO_2-fed chemicals with hydrogen; **8.** Includes CapEx only for renewable electricity generation and electrolysers.

Sources: IEEJ, *Model Calculation for Decarbonization by 2030 and 2050*, 28 September 2022, https://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/2022/050/050_005.pdf (in Japanese); METI, *Power Generation Cost Verification Working Group*, September 2021, https://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/#cost_wg (in Japanese); JCIA, *Efforts of the Chemical Industry towards Carbon Neutrality and Utilization of Hydrogen and Ammonia*, 16 November 2022, https://www.meti.go.jp/shingikai/enecho/shoene_shinene/suiso_seisaku/pdf/006_01_00.pdf (in Japanese); JH2A, *Hydrogen Roadmap*, 19 August 2022, https://jh2a.sharepoint.com/sites/corporate_information/_layouts/15/guestaccess.aspx?docid=0a784813144d14566855bc8e6261a15b4&authkey=AcgCCdTd-7ju2s27zI76cSE&e=5ZS6B7 (in Japanese); Accenture analysis

Chemicals

Green premiums

While low-emission technologies could result in a significant cost increase for chemicals, even a 100% increase in the cost of primary chemicals would have only a modest impact on end consumers of 0.6–1.0%.[1]



Note: 1. Systemiq analysis using Leontief's inverse matrix, based on Japan's 2015 data.

Source: Systemiq, *Planet Positive Chemicals: Pathways for the Chemical Industry to Enable a Sustainable Global Economy*, September 2022, https://www.systemiq.earth/wp-content/uploads/2022/10/Main-report-v1.22.pdf

Chemicals

Supporting policies for a net-zero chemical industry

The Japanese government has already implemented a wide range of policies in the path to net zero, but further robust policy measures can help to create a more economically viable market for low-emission chemicals.

General policies (non-exhaustive) red bold indicates new policies under consideration

Carbon pricing:

- Japan's **direct carbon price** is **$2 (JPY 249)/t$CO_2$,**[1] among the lowest in the advanced economies. However, fuel excise taxes are imposed on all types of fossil fuels. Adding up these **indirect carbon prices,**[2] the **effective carbon price** in Japan reaches **~$28 (JPY 3,659)/t$CO_2$.**
- The METI's carbon pricing study group suggested in 2021 that the government should carefully consider the impacts on **total energy costs** for the industry and consumers in planning additional carbon pricing instrument. The study group also suggested that the government should **clearly communicate to the international community** details of the financial burdens borne by its energy consumers as they are not necessarily proportional to the emissions.
- **GX-ETS:** Under the Green Transformation (GX) League,[3] an **emissions trading system,** which uses a **baseline-and-credit system,** will be introduced. Companies participating in the GX League will set **voluntary targets,** report the actual emissions data, trade earned emission credits and disclose the information in a mutual database called the "GX Dashboard". After the trial phase starting in 2023, the system will enter the full-operation phase in 2026, with measures to improve the fairness and effectiveness of the mechanism. Furthermore, electricity companies with large emissions will need to purchase the emission allowance through auction from 2033.
- **Carbon surcharge:** From 2028 onwards, importers of fossil fuels will be charged a new surcharge, with a gradually increasing rate of burden.

Technology support:

- **Green Innovation Fund:** This public fund, worth $15 billion (JPY 2 trillion), will provide consistent support over the next 10 years to businesses that undertake ambitious innovations in various areas, including renewables, hydrogen and industrial decarbonization.

Regulations:

- **2022 Revised Energy Conservation Act:** Large energy consumers are mandated to submit their mid- to long-term plans about transitioning towards non-fossil fuels and regularly report their progress.

Chemical-specific remarks

JCIA has expressed concerns that the implementation of additional carbon pricing instruments in the chemical sector could result in a lack of resources for R&D and capital investment. On the other hand, many chemical companies have introduced internal carbon pricing, which is used for investment decisions.

The basic concept of the GX League has been endorsed by major chemical companies, including Mitsubishi Chemical, Mitsui Chemicals, Sumitomo Chemical and Asahi Kasei.

The Green Innovation Fund includes a project dedicated to low-emission chemical production technologies, with funding of up to $1 billion (JPY 0.1 trillion).

For the top five energy-consuming sectors, including steel and chemicals, the government suggests targets for the transition towards non-fossil energy.

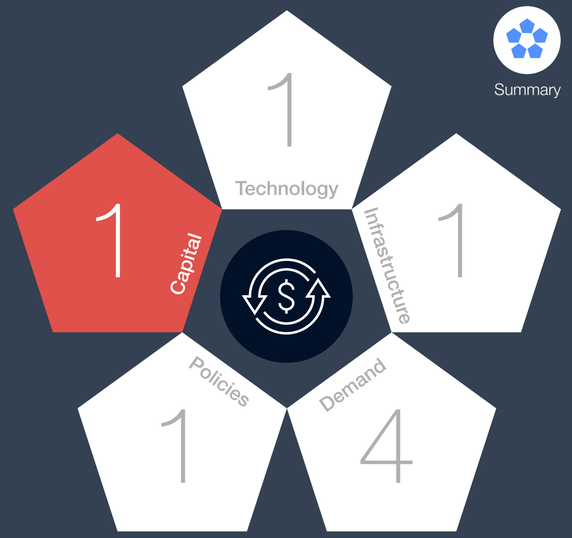
Notes: 1. Refers to the Tax for Climate Change Mitigation; **2.** The World Bank defines indirect carbon pricing as "instruments that change the price of products associated with carbon emissions in ways that are not directly proportional to those emissions", such as fuel and commodity taxes, as well as fuel subsidies affecting energy consumers; **3.** The GX League is a forum established by METI to promote cooperation among a group of companies and the government, universities and academic institutions to meet GHG reduction targets and increase industrial competitiveness. As of January 2023, the basic concept of the GX League has been endorsed by 679 companies.

Sources: OECD, *Net Effective Carbon Rates,* n.d., https://stats.oecd.org/Index.aspx?DataSetCode=ECRS; METI, *Study Group on Economic Measures for Achieving Carbon Neutrality Worldwide: Interim Report,* August 2021, https://www.meti.go.jp/shingikai/energy_environment/carbon_neutral_jitsugen/pdf/20210825_2.pdf (in Japanese); METI, *GX League*, n.d., https://gx-league.go.jp/aboutgxleague/document/GX_League_Overview.pdf; Cabinet Secretariat, *Basic Policies towards the Realization of GX,* February 2023, https://www.cas.go.jp/jp/seisaku/gx_jikkou_kaigi/pdf/kihon.pdf (in Japanese); JCIA, *Sustainable Growth and Carbon Pricing,* 1 March 2021, https://www.meti.go.jp/shingikai/energy_environment/carbon_neutral_jitsugen/pdf/002_04_00.pdf (in Japanese); METI, *Green Innovation Fund: R&D and Social Implementation Plan for the "Development of Plastic Raw Material Manufacturing Technology Using CO_2 and Other Substances" Project*, 15 October 2021, https://www.meti.go.jp/policy/energy_environment/global_warming/gifund/pdf/gif_07_randd.pdf (in Japanese); World Bank, *State and Trends of Carbon Pricing 2022,* May 2022, http://hdl.handle.net/10986/37455

Chemicals

Capital needed to transform the chemical industry asset base

$57–75 billion (JPY 7.4–9.7 trillion) is required to transform the Japanese chemical industry asset base. The industry needs to attract more investments in low-emission chemical assets.



Assets and investments

Transformation investment required — $57–75 billion (JPY 7.4–9.7 trillion)

Industry net property, plant and equipment (PPE) — $103 billion (JPY 13.4 trillion)

=

0.6
Investment to PPE multiple

Green/transition finance

Japanese chemical companies recently started using green and transition financing, such as:

1 Sumitomo Chemical

Total $138 million (JPY 18 billion) transition loans arranged in 2022 to finance the construction of new LNG-fired power-generation facilities

2 Mitsubishi Chemical

Total $231 million (JPY 30 billion) DBJ Sustainability Linked Loan with Engagement Dialogue (DBJ-SLL)[1] arranged in 2020, with the company's quantitative targets relating to chemical recycling projects set as SPTs[1]

However, it is challenging for chemical companies to take the decision to actively use green or transition finance due to the limited foreseeability of investment recovery. Therefore, government subsidies play a much more critical role for the industry today.

Note: 1. DBJ (Development Bank of Japan) Sustainability Linked Loans with Engagement Dialogue (DBJ-SLLs) encourage corporate activity aimed at achieving the borrower's targets by linking the degree of achievement of a borrower's ESG-related targets (sustainability performance targets or SPTs) with the borrowing terms.

Sources: JCIA, *Efforts of the Chemical Industry towards Carbon Neutrality and Utilization of Hydrogen and Ammonia,* 16 November 2022, https://www.meti.go.jp/shingikai/enecho/shoene_shinene/suiso_seisaku/pdf/006_01_00.pdf (in Japanese); MOF Policy Research Institute, *Financial and Monetary Statistics Monthly Report No. 835,* November 2021, https://www.mof.go.jp/pri/publication/zaikin_geppo/hyou/g835/835.html (in Japanese); Sumitomo Chemical, *Sumitomo Chemical's Transition Loans for Reducing GHG Emissions Selected as First METI Climate Transition Finance Model Project in the Chemical Sector,* 7 February 2022, https://www.sumitomo-chem.co.jp/english/news/detail/20220207e.html; Mitsubishi Chemical, *Mitsubishi Chemical Holdings Concludes Agreement with DBJ on Sustainability Linked Loan with Engagement Dialogue,* 2 December 2022, https://www.mcgc.com/english/news_release/pdf/01008/01146.pdf; expert interview

4

Net-zero industrial clusters

Why focus on industrial clusters?

With industry responsible for 30% of total global CO_2 emissions, industrial clusters will be a critical player in accelerating the path to net zero.

Industrial CO_2 emissions are considered some of the most difficult to abate on the path to a net-zero future. There are many existing initiatives and papers dedicated to reducing industry emissions, focusing on specific technologies or sectors. While these efforts are important and welcome, what is lacking is an emphasis on an integrated approach across sectors.

Industrial Clusters, geographic areas where industries are co-located, provide opportunities for scale, sharing of risk and resources, aggregation and optimization of demand.

Accenture in collaboration with the World Economic Forum, *Achieving Net-Zero Future with Industrial Clusters*

Industrial cluster foundational characteristics

Industry composition

Characteristics specific to each industry within a cluster will influence the feasibility or economics of potential solutions.

Geography

Some clusters will be able to take advantage of their surroundings to pursue specific solutions such as CCS and water cooling.

Existing infrastructure

The presence and quality of existing infrastructure and assets can enable or block solution viability for clusters.

Energy costs and policy

The cost profile and policy related to fossil energy and electricity can significantly influence decision-making.

Source: Accenture, *Achieving Net-Zero Future with Industrial Clusters*, 1 March 2021, https://www.accenture.com/us-en/insights/utilities/industrial-clusters-net-zero-future

Maximizing system value at industrial clusters

Industrial clusters need to select solutions that maximize system value beyond GHG emissions, pursuing collaborative actions that improve outcomes across the economy, the environment, society and the energy system.

Jobs and economic impact

Offshore wind projects emerging in various locations, with the potential to create up to 5K incremental jobs through to 2030. Hydrogen and CCUS will also create more jobs in the future.

Air quality and health

Decreased coal and natural gas combustion in clusters will improve air quality of nearby communities.

Energy productivity and systemic efficiency

Waste heat usage and direct electrification (e.g. industrial heat pumps) can increase energy productivity and systemic efficiency.

Foreign direct investment

Net-zero clusters can attract foreign companies and investment to benefit from the cluster's integrated partnership approach.

Smart flexibility

Industrial clusters can provide demand optimization capabilities for the larger energy system through hydrogen production and storage.

GHG emissions

Japan has the potential to cut industrial emissions by pursuing systemic efficiency, direct electrification and renewable heat, hydrogen and CCUS.

Resiliency and security

Increased domestic energy use (electricity, hydrogen production) decreases reliance on foreign fossil fuel resources, reducing supply risks.

Cost and investment competitiveness

An integrated approach to lowering emissions in industrial clusters reduces overall energy needs and cost.

System upgrade

Green hydrogen production can smooth wind and solar variability by diverting generation and integrating/optimizing the electricity and gas infrastructures.

Note: 1. The hexagons represent desired outcomes; the specific applicability and importance of each element may vary by market and timeframe of analysis. For more detail on the system value framework, see also the World Economic Forum, *System Value*, n.d.

Sources: Accenture, *Achieving Net-Zero Future with Industrial Clusters*, 1 March 2021, https://www.accenture.com/us-en/insights/utilities/industrial-clusters-net-zero-future; World Economic Forum, *System Value*, n.d., https://www.weforum.org/projects/system-value

Japan's industrial complexes, or *kombinat*

In Japan, industrial complexes, or *kombinat*, play a critical role in decarbonizing industries, with the combined annual CO_2 emissions from the nine major complexes reaching 126 Mt.

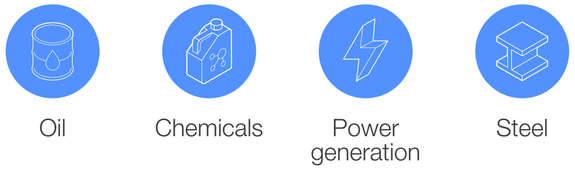
Overview

In discussing the decarbonization of industrial clusters in Japan's context, this report focuses on the areas that have been traditionally developed as industrial complexes, or kombinat, where an oil refinery and a petrochemical plant are at the core, often co-located with other energy-intensive sectors such as steelmaking and thermal power generation.

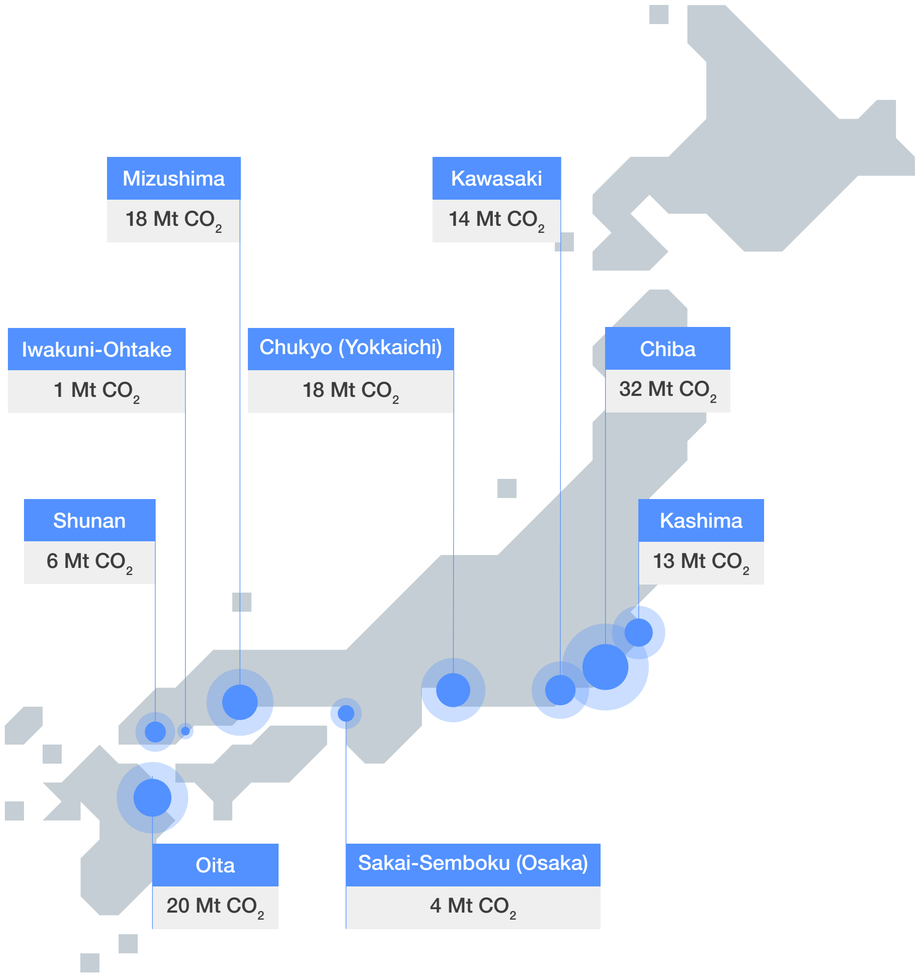
There are nine major industrial complexes today, most of which were established in the late 1950s and 1960s amid Japan's rapid economic growth. While these industrial complexes formed the basis for the nation's industrial development, they now face harsh international competition from newly established industrial clusters with scaled, more efficient facilities.

Japan's industrial complexes are in the coastal areas, especially along the Pacific Ocean and the Seto Inland Sea. This is partly due to the direct access to imported resources, as Japan gets most of its natural resources (e.g. coal, oil, gas, iron ore) from overseas.

Key sectors in Japan's industrial complexes:
(Not all complexes have all of these sectors)



Major industrial complexes in Japan and annual CO_2 emissions (2020)[1]



Note: 1. The size of circle indicates the proportional CO_2 emissions among the industrial complexes.

Source: NRI, *Report on the Results of Investigations and Studies for the Fiscal Year 2021 Energy Supply and Demand Structure Improvement Measures (Study Project towards Achieving Carbon-Neutral Industrial Complexes)*, 31 March 2022, https://www.meti.go.jp/meti_lib/report/2021FY/000364.pdf (in Japanese)

Enabling technologies to achieve net-zero industrial complexes in Japan

The table analyses the general foundational characteristics of industrial complexes in Japan and how they influence the applicability of each enabling technology.

	Industry composition	Geography	Existing infrastructure	Energy costs and policy
Systemic efficiency and circularity	Co-location of different sectors (mostly heavy industry) with different energy and material needs highlights a **potential for cross-sectoral integration** to share energy and material streams	N/a	N/a	**High energy costs** in Japan **make energy efficiency especially valuable** **Government funding and regulatory support** for energy efficiency and circularity (e.g. recycling of plastics)
Direct electrification and renewable heat	Japan's industrial complexes are mostly heavy industry with **high temperature processes**, which are **difficult to electrify today**	N/a	N/a	N/a
Carbon capture, utilization and storage (CCUS)	**Capturing CO_2** from the emissions at thermal power plants and industries such as steel mills is **more efficient** than other sectors, due to the high CO_2 density	**CO_2 captured at industrial complexes may be used onsite** by industries such as chemicals **or directly shipped to nearshore/offshore CO_2 storage sites**	N/a	**Government funding for R&D and demonstration** of various CCUS projects
Hydrogen	Hydrogen as a **viable solution for decarbonizing high temperature processes** in heavy industry and thermal power generation Low-emission steelmaking processes (except for scrap-based EAF) requires **significant amounts of hydrogen**	As an island nation with limited renewable sources, **Japan needs to import most of its hydrogen supply by sea**, at least in the short term Industrial complexes as **potential "hydrogen hubs"**, leveraging the easy access to ports and clustered hydrogen demands	**Existing pipelines and tanks** for oil, gas and chemicals **may be repurposed**, as well as **adjacent port facilities** (depending on H_2 carriers) Industries such as oil refining already use **grey hydrogen**, which may be **replaced by clean hydrogen with little change to their assets**	**Government funding for R&D and demonstration** of hydrogen supply chains and applications **Government funding for shared infrastructure** at potential hydrogen hubs (expected) **A CfD subsidy scheme to support hydrogen suppliers** (expected)

Opportunities or effectiveness of applying the technology to Japan's industrial complexes Challenges or inapplicability

Source: Accenture analysis based on various sources

Outcome

Hydrogen should be positioned as the most critical enabling technology for decarbonizing industrial complexes in Japan, followed by CCUS, systemic efficiency and circularity.

To overcome the geographical constraints on domestic hydrogen production capacity, **international hydrogen supply chains need to be built at scale and speed.**

Key considerations in designing solutions for net-zero industrial complexes in Japan

Based on public information and expert interviews with government offices and companies, three key considerations/ requirements are emphasized in designing solutions for net-zero industrial complexes in Japan.

1

Accelerate the development of hydrogen and ammonia supply chains by supporting first movers intensively

Clean hydrogen and ammonia are expected to play a critical role in decarbonizing Japanese industrial clusters, but **Japan needs to rely heavily on imports** due to the relatively lower deployment rate and higher cost of renewable power. This requires **additional investment in hydrogen transportation** (e.g. dedicated ships, port facilities, liquification and regasification facilities), compared to other countries where hydrogen can be produced and consumed locally or can be transported from neighbouring countries through pipelines. Under such circumstances, **strong government support targeted at first movers is extremely important** to attract investment into hydrogen/ ammonia supply chains in Japan.

2

Strengthen the competitiveness of industrial clusters by promoting cross-sectoral and extensive collaboration

While companies, especially oil and chemical companies, at Japanese industrial complexes have been working together on energy efficiency, there are as yet **few cases of collaboration in the context of decarbonization.**

Coordinating conflicting interests among companies will be a challenge, especially at a cluster, where a number of companies in various sectors operate businesses.

In general, there is a considerable gap between large energy-intensive companies and small and medium enterprises (SMEs) in terms of engagement in decarbonization. In order to realize the decarbonization of an industrial cluster as a whole, **SMEs should also be involved in the community.**

3

Transform the value recognition of decarbonized goods and services throughout an entire value chain

To realize a sustainable transition towards a net-zero industry, it is important that stakeholders across an entire value chain, not only the primary buyers but also the end consumers, **recognize the environmental value of decarbonized goods and services and are willing to pay for it.**

In Japan, ongoing efforts have been made by the supply side, such as branding of green steel and chemicals, but **it is not yet clear to what extent the buyers will change their purchasing behaviours.**

The **government can also play a role** in creating a society in which all stakeholders share the cost of decarbonization through various policies **such as carbon pricing and setting a standard for green products.**

Key actions for realizing net-zero industrial complexes in Japan

For each of the four strategic approach areas stipulated in the Accelerating industrial clusters playbook, developed by the World Economic Forum's *Transitioning Industrial Clusters towards Net Zero* initiative, the key actions for Japan's policy-makers and companies are summarized, with the current status in Japan.

Strategic approach area	Key actions	Current status in Japan
Partnership	Convene local stakeholder meetings to discuss a single-focus vision for the cluster's future	In progress
	Embed mechanisms to incentivize collaboration among companies on subsidy/grant programmes	New
	Clarify and/or ease the laws and regulations that could hinder collaborative activities, such as joint R&D and procurement	New
	Use connections between local governments/financial institutions and local SMEs to expand the community	In progress
Policy	Design a long-term roadmap for each of the key technologies and make a commitment to adopt policies based on the roadmap	Completed
	Develop and implement subsidies/grants programmes for R&D and the commercialization of new energy and materials	In progress
	Develop and implement mechanisms (e.g. carbon pricing) to level the playing field for decarbonized products/services	New
Financing	Explore a range of creative financing mechanisms to target specific challenges and stack them at the most effective moments	In progress
	Engage local financial institutions in the decarbonization of industrial clusters	New
	Establish a market where decarbonization efforts are fairly evaluated by investors	New
Technology	Create or update standards and regulations about safety and operators' responsibility upon handling hydrogen, CCS, etc.	In progress
	Create standards regarding the environmental value of hydrogen (including its derivatives) and low-emission industrial products (e.g. steel, chemicals)	In progress
	Apply digital technologies to ensure the industrial cluster stays at the front of decarbonization performance and cost-effectiveness	In progress

New · In progress · Completed

Source: World Economic Forum, *Transitioning Industrial Clusters towards Net Zero*, 19 January 2023, https://www.weforum.org/reports/transitioning-industrial-clusters-towards-net-zero

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