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Challenges and Strategies for Decarbonizing Japan's Steel Industry aligned with the 1.5°C Target

1. Japan's Steel Industry—Further Contribution Needed for 1.5°C

Japan's current emission reduction target for 2030 (NDC) is not aligned with the 1.5°C target. Further emission reductions are needed.

- Japan's 2030 emission reduction target is only a -35% reduction from FY 2019 levels
- This is far short of the 48% reduction level required by the IPCC AR6's 1.5 Scenario
- The IPCC scenario requires 65% reduction by 2035, and further reductions are needed

Emissions from the steel industry are about 1/2 of the industrial sector

- Energy-derived CO_2 emissions from the steel industry account for 13% of Japan's total direct emissions

G7 Commitment, May 2022

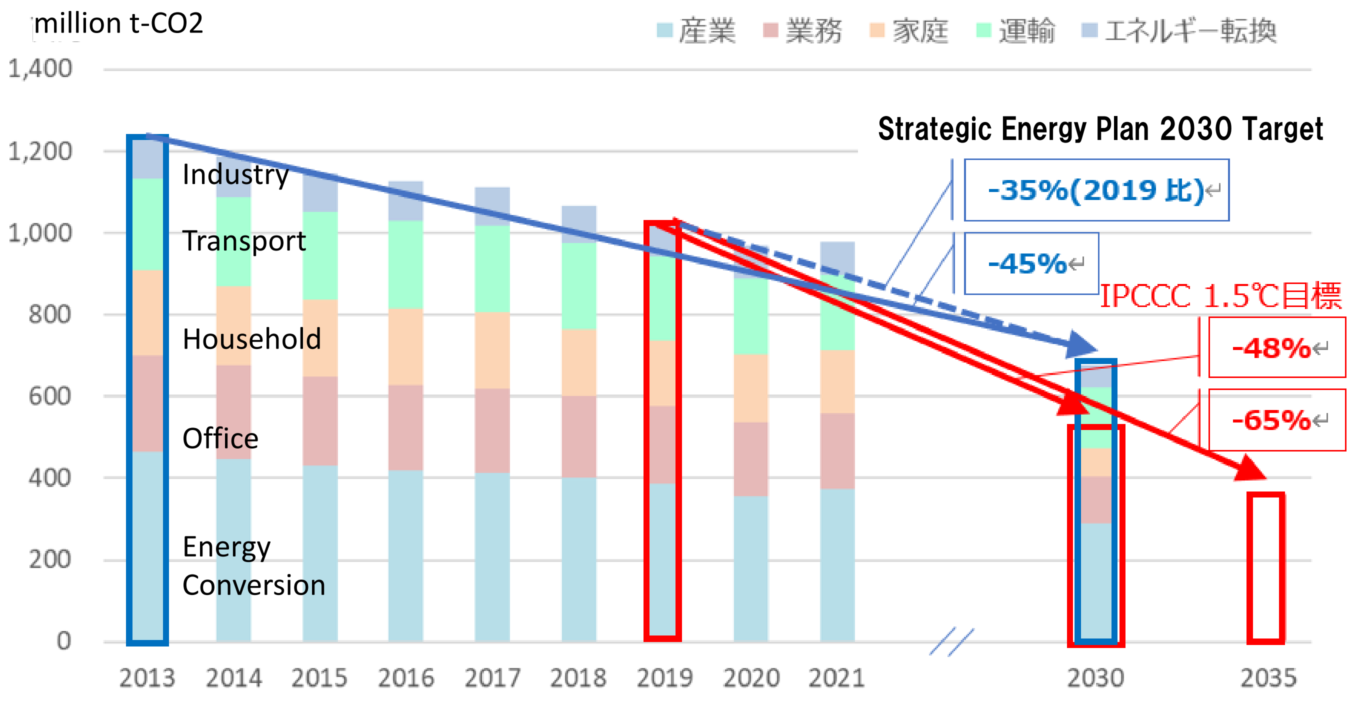
- Pointed out to limit temperature-rise to 1.5° C decarbonization of key industrial sectors is critical and committed to accelerate decarbonization of heavy industry

➤2030 timeline is critical

Current 2030 targets of major steelmakers (all compared to 2013)

- Japan Iron and Steel Federation, Nippon Steel Corporation, JFE Steel: 30% reduction
- Kobe Steel: 30-40% reduction

Japan's NDC and the level of commitment required for 1.5°C



(Source) Renewable Energy Institute based on the Agency for Natural Resources and Energy's "Comprehensive Energy Statistics Time Series Table" and "Outlook for Energy Supply and Demand in FY2030 (related data).

1. Japan's Steel Industry - Near Zero Emission Steelmaking Needed to Meet 1.5°C

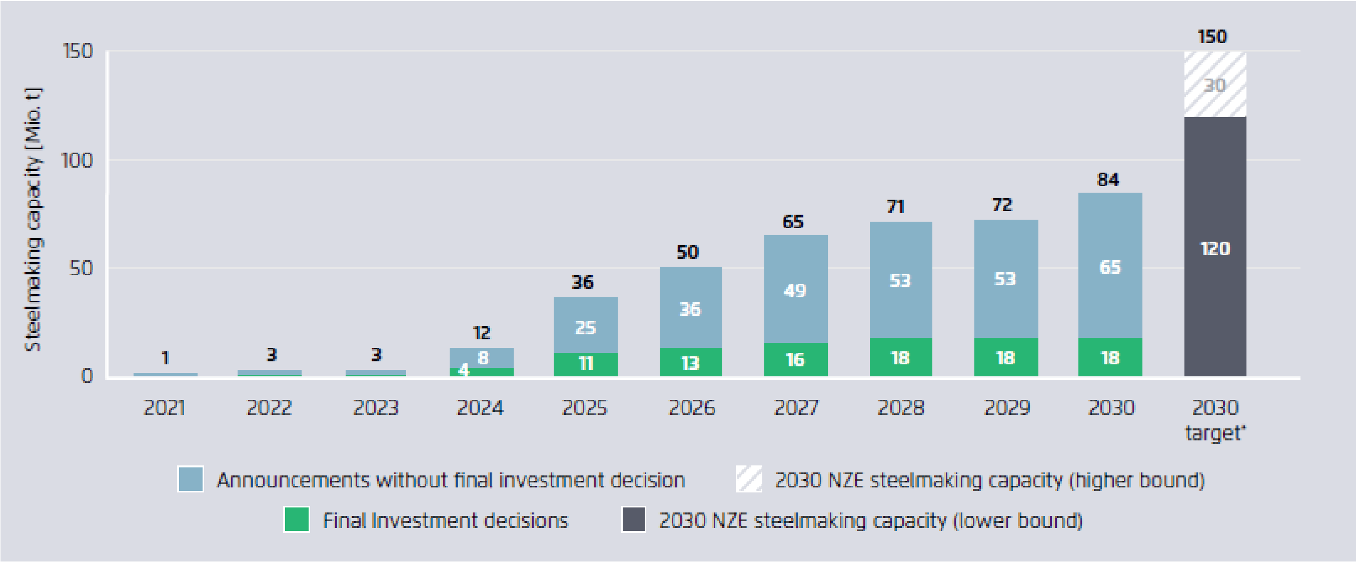
Near Zero Emission Steel Production Needed to Meet 1.5°C Target
100 million tons per year of “near-zero emission steel (NZS)” production is needed worldwide by 2030 = 120-150 million tons in installed capacity

In Japan 15 million tons production capacity required -G7 milestone of NZS production 14% (IEA)

VS. Japanese government target set at
10 million tons at GX basic policy

VS. 40 million tons planned for EU
plus 20 million tones (scrap EAF)

2030 pipeline: near-zero emissions primary steelmaking capacity announcements and final investment decisions



Agora Industry (2023), Global Steel Transformation Tracker (2023). Note: All announced projects can be H_2-ready DRI plants, in principle. However, to date only around 25% of the project pipeline is designed at outset to accommodate switch to renewable H_2. All other DRI plants will run on natural gas or a mix of natural gas and H_2 with the stated intention of most companies to switch to 100% low-carbon H_2 eventually, once it becomes available (see Agora Industry, Global Steel Transformation Tracker). *The 2030 targets refer to the near-zero emissions primary steelmaking capacity that would be needed to be on a 1.5°C compatible pathway based on IEA, IRENA, UN 2022 and authors' scenarios.

（Source）Agora Industry and Wuppertal Institute (2023): 15 insights on the global steel transformation

(Reference) What is Near Zero Emission (NZE) steelmaking capacity ?

Near Zero Emission steelmaking capacity is currently based on the following methods

Method	Content	Technical Maturity	Plan
H_2DR	Direct hydrogen reduction method	In demonstration phase	Most of the NZEs planned in the world today are H2DRI-based
	Need to remove impurities from the produced reduced iron in the electric furnace/converter process	Commercialization by 2030	In many cases, natural gas will be used initially, with plans to convert to hydrogen in the future
	Decarbonized hydrogen use is a prerequisite		
BF-BOF+CCS ➤In effect, it is difficult to make NZE	Capture and storage almost all emissions from blast furnaces and converter furnaces	Difficult to capture almost all emissions from the process with CCS	Only one is currently planned in the world
	In some cases, hydrogen is injected into the blast furnace to reduce emissions (CCS volume reduction)		Japan's COURSE50/Super COUSE50 targets up to 50% emission reductions and is not a NZE
	Decarbonizing hydrogen is a prerequisite.	Reduction by hydrogen injection is in pilot stage, but reduction is 20+%.	
EAF	Scrap iron use or direct hydrogen reduction iron use	Mature (High-grade steel production in a large electric furnace is in the pilot stage))	There are plans for new electric furnaces around the world
	Assumption of decarbonized electricity use		In Japan, there are plans to introduce electric furnaces in place of blast furnaces

NZE steel facilities currently planned in Japan are only Electric Furnaces

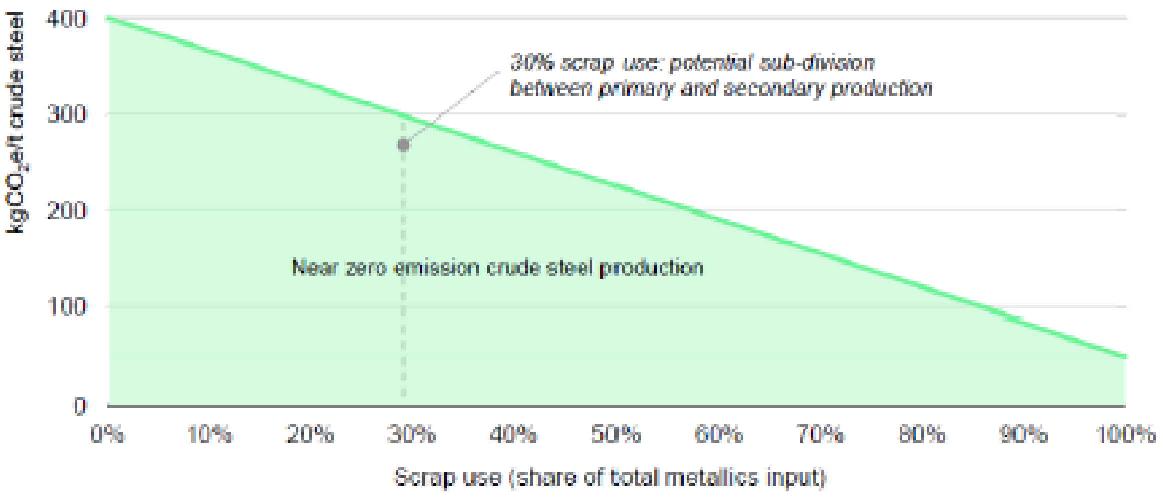
Requirements for 2030

- Secure scrap iron or direct hydrogen-reduced iron
- Secure decarbonized power sources

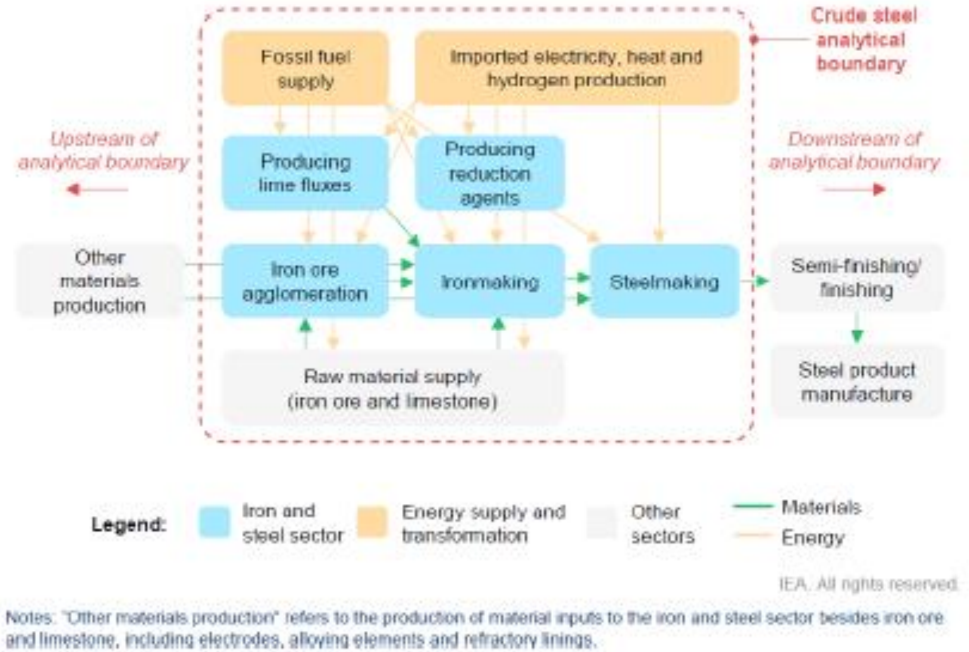
(Reference) What is the definition of near zero emission steel?

IEA definition of near-zero emission steel (G7 Report 2022)
Reduction of 85% or more in total direct and indirect emissions compared to conventional blast furnace steelmaking;
CO2 emissions per ton of crude steel: 400 kg-CO2e or less
In case of using scrap, the definition is based on the scrap ratio, with 50 kg-CO2e/ton in the case of 100% scrap (see figure).

Near Zero Emission Crude Production Threshold as a Function of Scrap Use



Analytical Boundary for Defining Near Zero Emission Steel Production



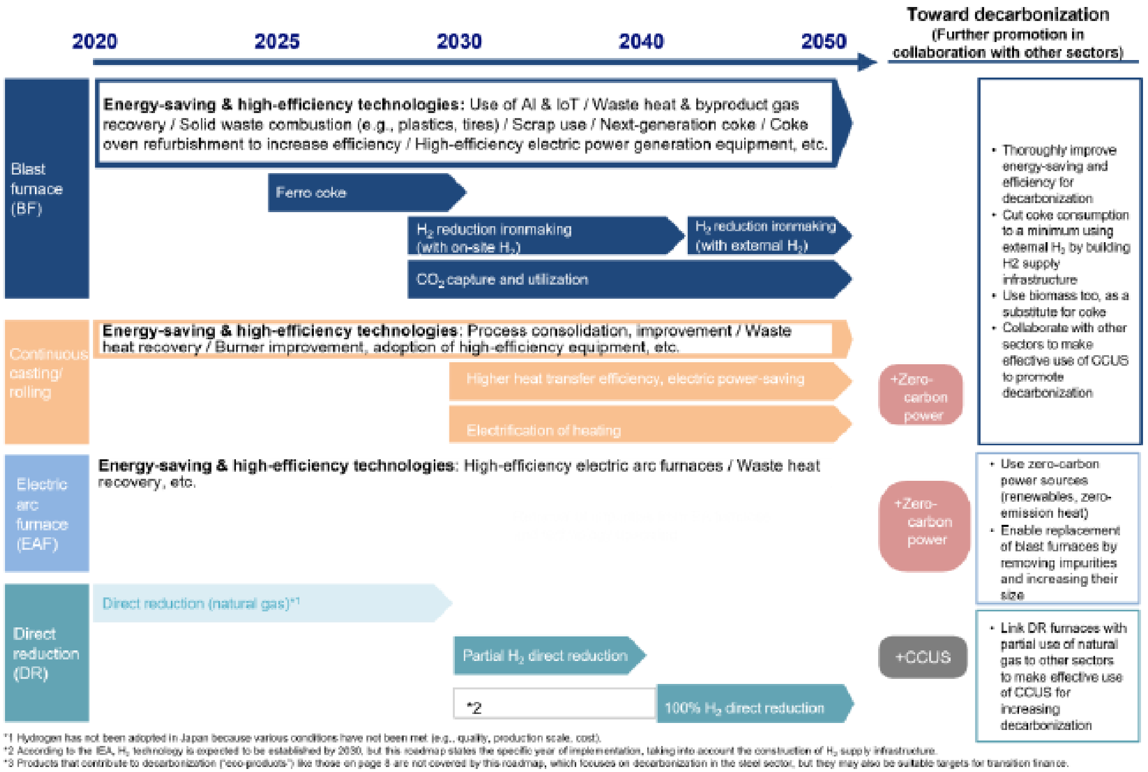
(Source) IEA "Achieving Net Zero Heavy Industry Sectors in G7 Members" (May 2022)

(Reference) Japan's Steel Industry - Current Decarbonization Plan

Decarbonization plan of primary steelmaking (blast furnace) in Japan: All implementations after 2030

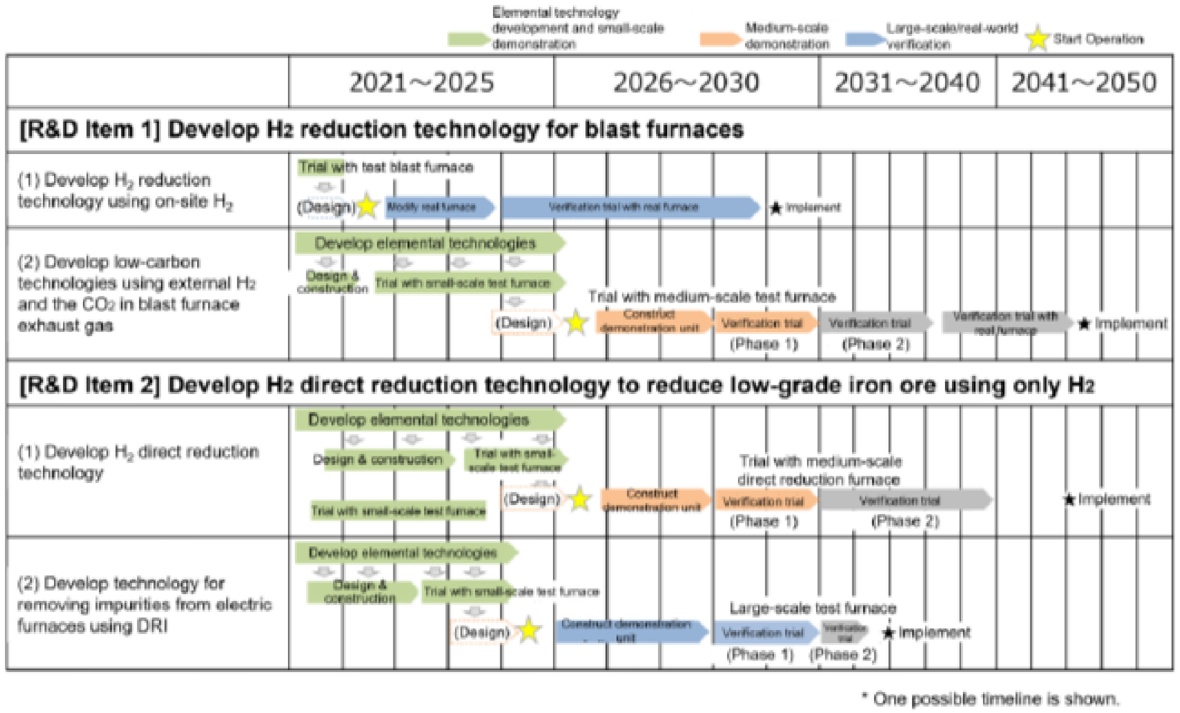
1) Partial hydrogen reduction in blast furnaces + CO2 capture and storage (BF-BOF + CCS) ➤COURSE50 (Implementation 2030), SuperCOURSE50 (Implementation 2043)
2) 100% direct hydrogen reduction (Implementation 2043)
3) Introduction of large electric furnace (Demonstration 2032)

Steel Industry Roadmap for Transition Finance



(Source) Ministry of Economy, Trade and Industry, “Technology Roadmap Formulated for Transition Finance Toward Decarbonization in the Iron and Steel Sector” (October 2021)

R&D and Implementation Plan



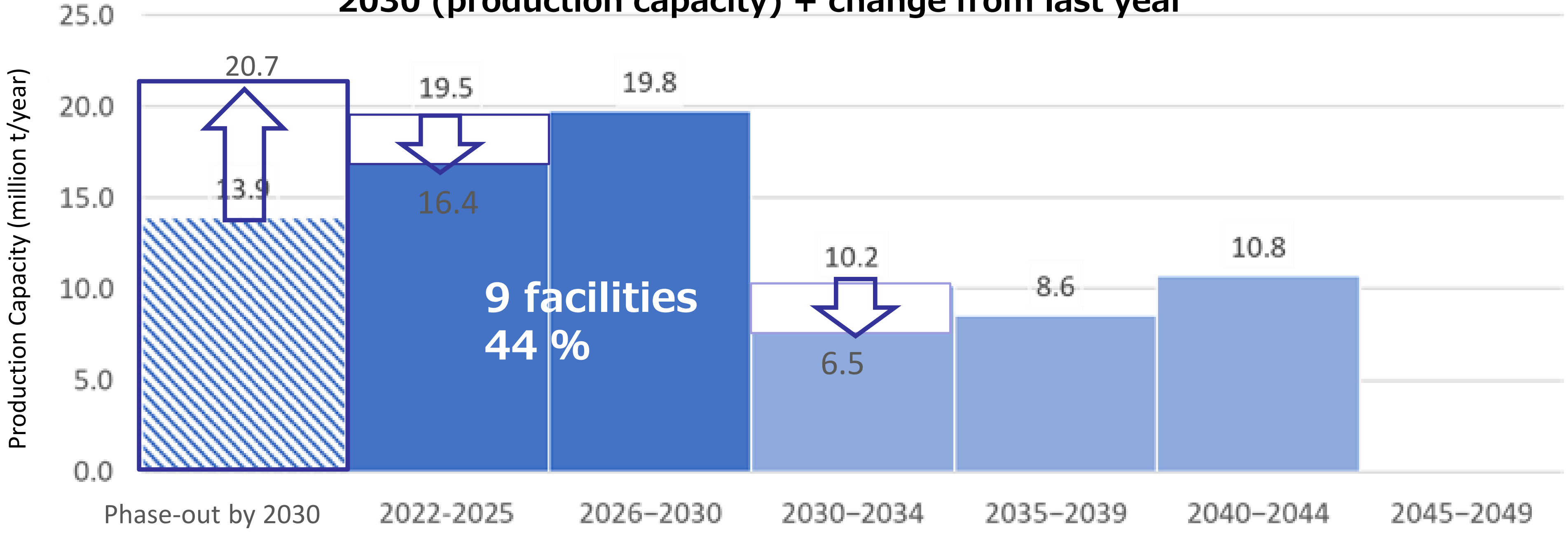
(Source) METI, “An R&D and Social Implementation Plan for ’Hydrogen Utilization in Iron and Steelmaking Processes’” (September 2021)

1. Japan's Steel Industry: Accelerated Action Needed Toward 1.5°C

Investment Cycle - Need to Start Transformation Now

- Blast furnaces need to be relined every 20-25 years, while refurbishment costs are rising in Japan
- The level and timing of refurbishment need to be determined based on the assumption of a blast furnace phase-out plan to prevent stranded assets
- Last year and this year, a plan to shift from blast furnaces to electric furnaces has been announced

Blast furnaces that will reach the end of their facility life by 2030 (production capacity) + change from last year



(Source) Compiled by Japan Renewable Energy Foundation from various sources

2. Bottleneck 1) Impracticality of active use of CCS

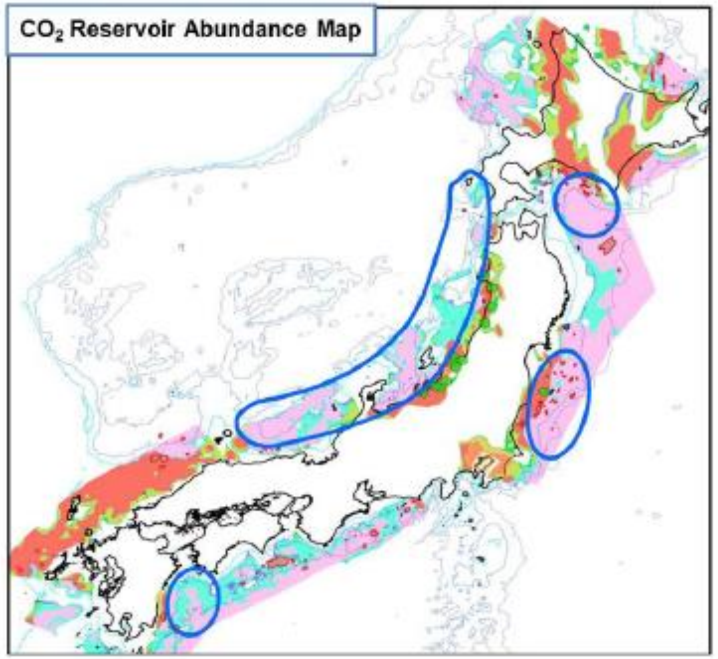
Absence of geographical conditions suitable for CCS in Japan

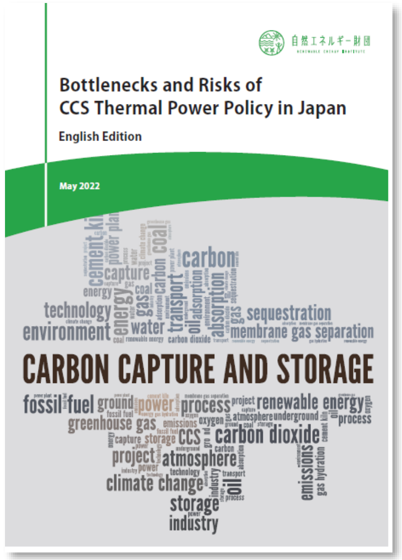
(1) Few existing depleted oil and gas fields exists that are suitable for CO2 storage
(2) There are few suitable sites for CO2 storage on land
(3) Offshore storage is not well known and is expensive. Suitable sites for social-scale storage have not been identified.
(4) In Japan, no risk assessment of seismic risk and other risks posed by CO2 sequestration has been conducted

National Policy for CO2 Export and Storage to Southeast Asia

Ministry of Economy Trade and Industry Subcommittee Feb 15, 2021 “Overseas, especially in neighboring Southeast Asian countries, there are large potential for inexpensive storage sites”
→Already some local criticism

CCU? Even if it is possible to utilize a part of CO2 emission, it is not possible to recycle it permanently.





(Ref) Renewable Energy Institute

Source: Excerpt from "Future Issues for Commercialization of CCS" (January 28, 2022), Agency for Natural Resources and Energy

➤➤ **Toward a decarbonization pathway not heavily dependent on CCS**

2. Bottleneck 2) De-carbonized hydrogen

Securing decarbonized hydrogen

Basic Hydrogen Strategy" with no plans to supply hydrogen to the steel industry

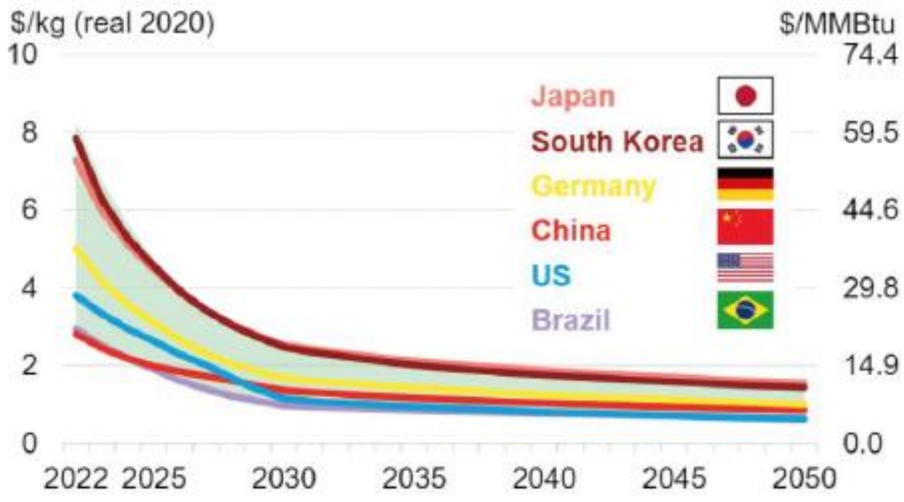
- **2030 Hydrogen supply target** 30 yen/Nm3 (2030) 3 million tonnes
- Hydrogen emission standards to be introduced after 2030 (gray hydrogen allowed)

Imported hydrogen will remain relatively expensive compared to the global market in the future

- Long-distance shipping, and transportation costs are expected to be nearly double the production price

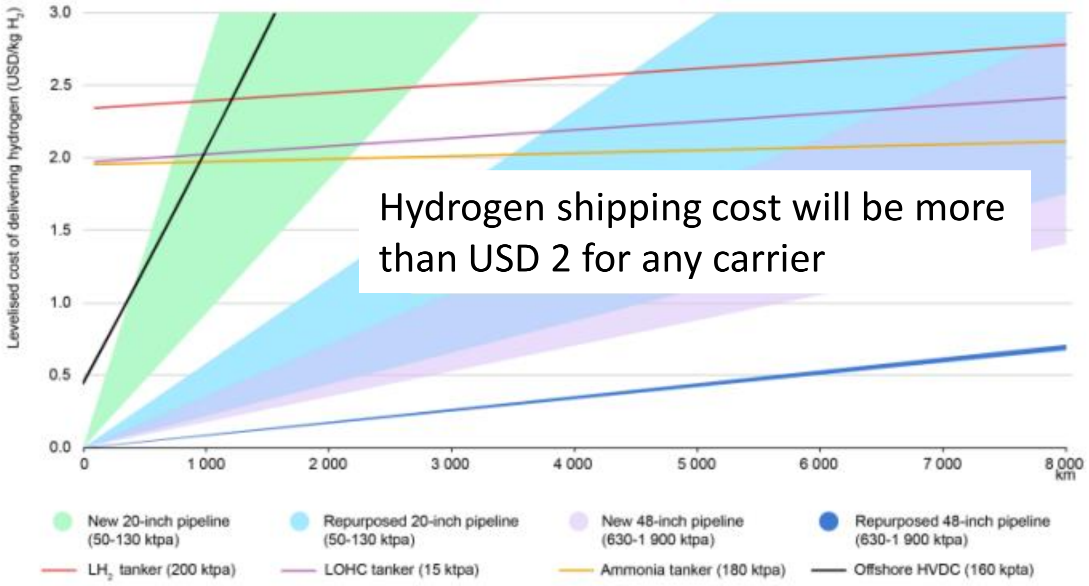
➤➤Direct hydrogen reduction overseas (green iron trade) and pursue domestic hydrogen supply

Levelized Cost of Hydrogen Production from Renewable Electricity, 2022-2050



(Source) BloombergNEF, "1H 2022 Hydrogen Levelized Cost Update" (June 2022)

Transport Cost by Hydrogen Carrier (2030)



(Source) IEA "Global Hydrogen Review 2022" (September 2022)

2. Bottleneck 3) Decarbonizing Power Sources

Securing decarbonized power for electric furnace utilization and decarbonized hydrogen production

Need to secure a large amount of decarbonized power sources

- Shift to electric furnaces requires a large amount of decarbonized power sources: Electric furnaces currently produce about 1 ton of crude steel per ton of production
- Hydrogen production requires securing an even larger amount of decarbonized power sources

Need to further decarbonize power sources

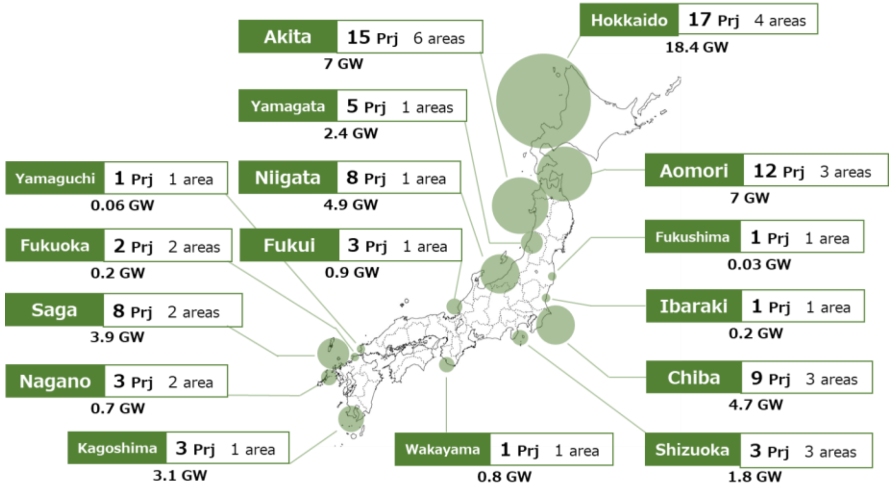
The current 2030 emission factor in the Strategic Energy Plan is not sufficient

Based on NZE Steel definition, CO_2 50 kg/ton of crude steel for 100% scrap steel vs. current situation in Japan is about 500 kg/ton

Nuclear power is unreliable in Japan - the outlook is bleak

➤➤Renewable energy, especially offshore wind needs to be developed

Offshore Wind Power Development Plan



Source: Renewable Energy Institute based on "Environmental Assessment Case Study Information" by the Ministry of the Environment

Percentage of Renewable Electricity in Electricity2030 Target and Actual

Country/ Region	2030	2021
EU	69%*	–
Germany	80%	43%
France	40%	26%
UK	Decarbonize by 2035	39%
US	Decarbonize by 2035	21%
Japan	36~38%	22%

*Share of renewables in electricity when the share of renewables in final energy consumption is 45% (results of scenario analysis by the European Commission)

Source: REI based on government data

2. Bottleneck 4) Scrap iron

NZE by the electric furnace requires scrap iron

(1) Securing scrap iron supply

If blast furnace is shifted to electric furnaces and scrap iron is used, even if the current exports (8.3 million tons) are shifted to domestic consumption, there is still a shortage of scrap iron

(2) Ensuring the quality of scrap iron

Old scrap iron, the quality of which is difficult to control, accounts for 45% of the total

Need to improve quality to make products not covered by conventional recycled steelmaking

Table 1 Iron Source Consumption and Crude Steel Production by Process (FY2019) (thousand tonne)

Production process	Crude steel production (by production process)	Iron consumption source	
		Scrap iron consumption	Pig iron consumption
Blast Furnace-Basic Oxygen Furnace (BF-BOF)	74,900 (76%)	8,891	71,006
Electric Arc Furnace (EAF)	23,526 (24%)	23,674	95

(Note) FY 2019 data is referenced here, due to the substantial drop in production in 2020 due to the caused by the COVID-19 pandemic.
(Source) Japan Metal Daily, "Steel Yearbook 2021" (2021)

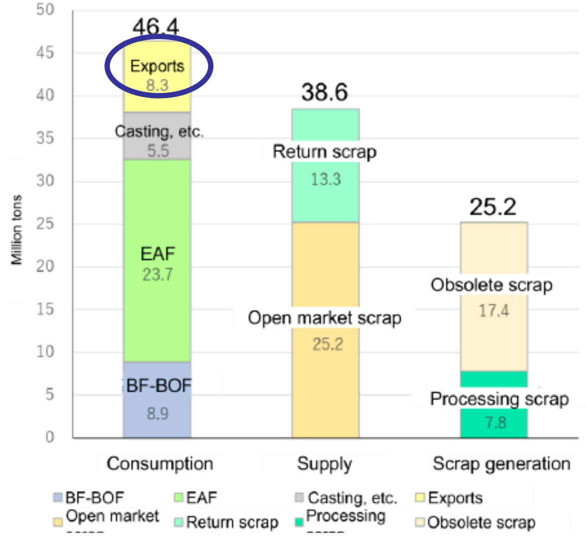
➤➤Promote reduction of domestic demand and maximum utilization of scrap by shifting to a circular economy

Types of Scrap, Their Properties and Future Directions (FY2019)

Type of scrap	Qty. (ktonnes)	%	Description/quality	Remarks
(1) Return scrap	13,320	35%	Scrap from iron and steel production processes; of high quality	Linked to steel production, so availability will not significantly increase. Availability tends to be decreasing as production becomes less wasteful.
(2) Process scrap	7,808	20%	Commercially available scrap generated from steel processing; of relatively high quality	Linked to the quantity of steel consumption, so availability will not significantly increase. Availability tends to be decreasing as processing becomes less wasteful.
(3) Obsolete scrap	17,384	45%	Scrap iron and steel recovered from obsolete products, structures, etc.; of variable quality	Linked to past consumption and demand for various products and structures. Even if quantity does not increase, it can be exhaustively utilized by increasing quality.
Total	38,512	100%		
(4) Exports	8,286		Scrap exported abroad. Supplements the domestic supply-demand balance.	Decreasing in accordance with domestic demand increases

(Source) Created by Renewable Energy Institute based on Japan Ferrous Raw Materials Association, "Annual Report of Iron Sources No. 31" (2020)

Steel Scrap Consumption (FY2019)



(Source) Japan Ferrous Raw Materials Association, "Annual Report of Iron Sources No. 31" (2020)

3. Steel Industry Decarbonization Strategy for Japan

Strategy 1: "EF Phase-in and BF Phase-out Plan" to develop the local economy

- The need for a fair transition plan that takes into account local jobs and economy
- Blast furnace phase-out in line with the investment cycle
- Flexible power system created by demand response of electric furnaces and local renewables, storage batteries

Strategy 2 Lead in international H2-DRI market and supply chain - create win-win

- Contribute to suitable international locations for RE and hydrogen production and lead the way in H2-DRI trade
- Reduced investment in large scale hydrogen import infrastructure along with lower costs

Strategy 3: Select optimal sites for domestic H2 DRI in combination with offshore wind development

- Especially in locations suitable for offshore wind power development - Hokkaido, Tohoku, and other
- Incentives for renewable energy development and hydrogen production, and the need to develop and concentrate investment in transmission and hydrogen infrastructure

Strategy 4 Reduce domestic demand and maximise the use of scrap steel by shifting to a circular economy

- Pursuit of longer life and lighter weight products and streamlining of steel demand
- Incentive policies to increase demand for scrap utilization
- Promotion and enforcement of design suitable for recycling (design guidelines)
- Form a closed-loop system
- Support for advanced intermediate treatment

Strategy 5 Development of policies to increase demand for green steel

- Clarification of NZE steel demand and supply targets (including clarification of definitions)
- Promotion of public procurement and incentives for private procurement
- Establish mechanism to reduce embodied carbon

3. Comprehensive policies and stakeholder collaboration are essential

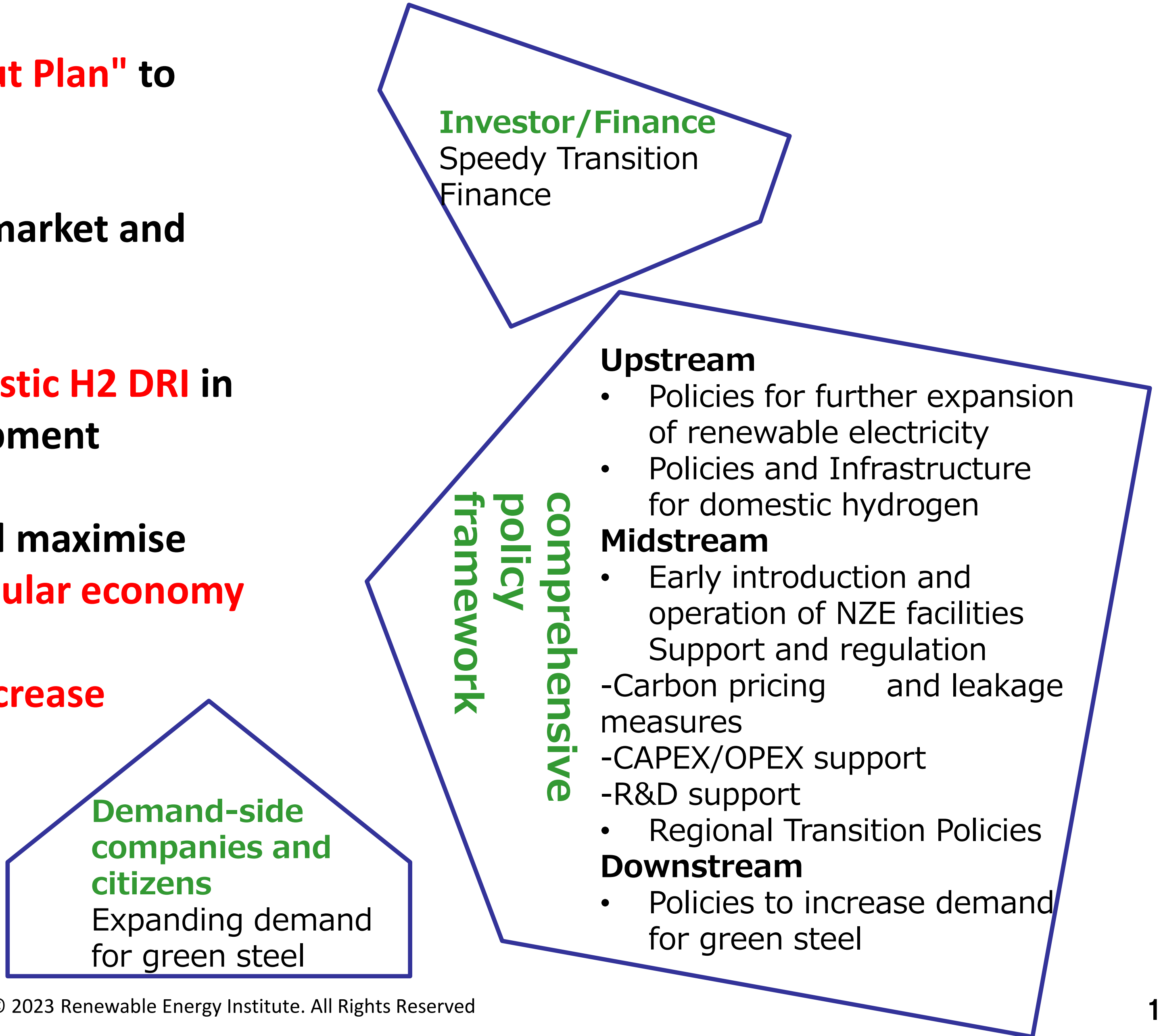
Strategy 1: "EF Phase-in and BF Phase-out Plan" to develop the local economy

Strategy 2 Lead in international H2-DRI market and supply chain

Strategy 3: Select optimal sites for domestic H2 DRI in combination with offshore wind development

Strategy 4 Reduce domestic demand and maximise the use of scrap steel by shifting to a circular economy

Strategy 5 Development of policies to increase demand for green steel



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