WSA Breakthrough Technology Conference 2023
Abu Dhabi

Carbon Neutrality Initiatives in Japanese Steel Industry

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GREINS project overview

Challenge of reducing CO_2 emissions in the steel industry

Details of GREINS project development

Industry-Academia Collaboration ～Carbon Neutrality Initiatives of ISIJ～

"GREINS" = " GREen INnovation in Steelmaking"

Hydrogen Reduction Steel Making aimed at reducing CO_2 emissions.

2008, **Blast furnace hydrogen reduction technology COURSE50 project started**.

”COURSE50” : ”CO_2 Ultimate Reduction System for Cool Earth 50”

2017, **Scientific verification for the first time in the world**

Reduction of CO_2 emissions by 10% in a blast furnace using the experimental blast furnace

2021, **Hydrogen Utilization in Iron and Steelmaking Processes Project (GREINS)** in the Green Innovation Fund Project **started**.

Multi-track technical development project ;

- Blast furnace process
- Direct reduction ironmaking process
- Electric arc furnace process

https://www.greins.jp/en/message/message01/

Organization

GREINS is carried out by **the Hydrogen Steelmaking Consortium**.

Four partners: **Nippon Steel Corporation, JFE Steel Corporation, KOBELCO, and JRCM**(the Japan Research and Development Center for Metals)

Hydrogen Steelmaking Consortium

The consortium conducts joint research **with 13 research institutes.**

Joint research institutes

- HOKKAIDO University
- Central Research Institute of Electric Power Industry（CRIEPI）
- WASEDA University
- University of TOYAMA
- College of Industrial Technology
- OSAKA University
- NIPPON Institute of Technology
- TOHOKU University
- The University of TOKYO
- TOKYO Institute of Technology
- KYOTO University
- Research Institute of Innovative Technology for the Earth（RITE）
- KYUSHU University

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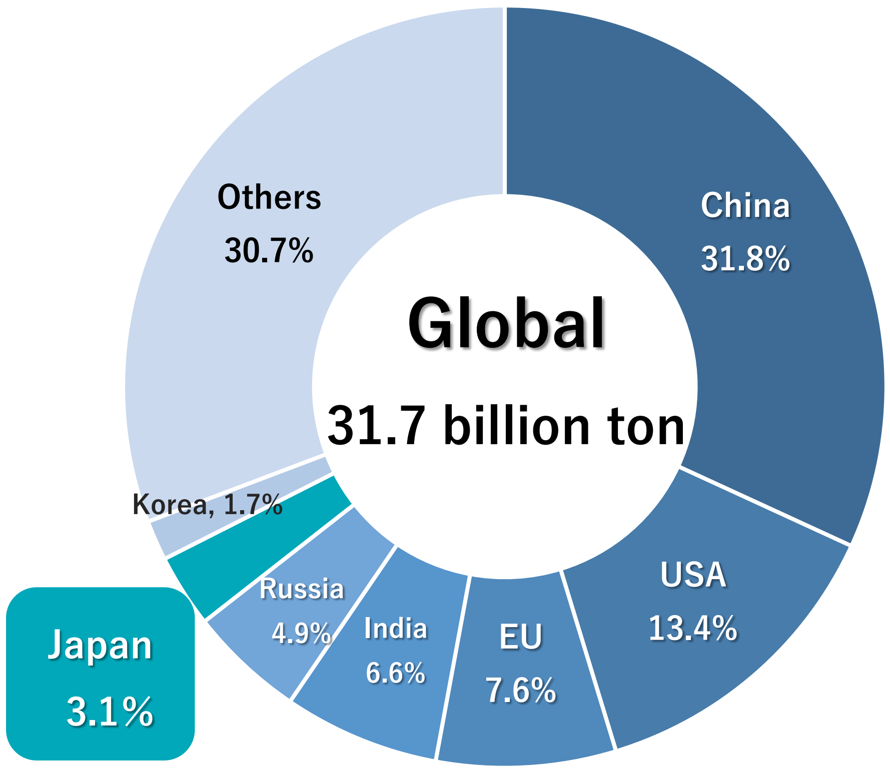
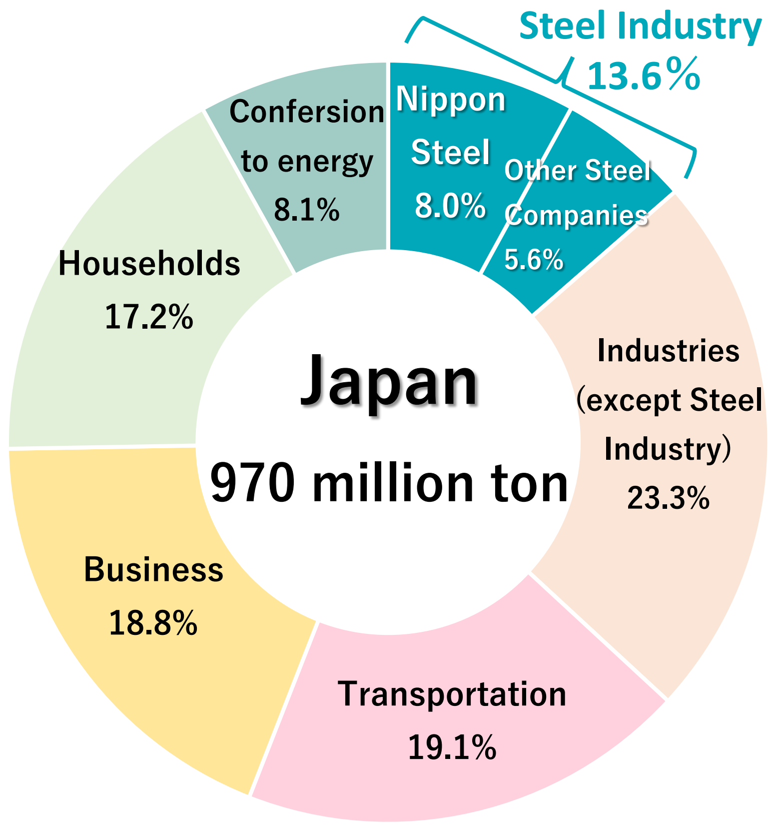
"GREINS" = " GREen INnovation in Steelmaking"

Global and Japan's CO_2 emissions from Energy (2020)



Japan's emissions is 3.1% of global emissions.

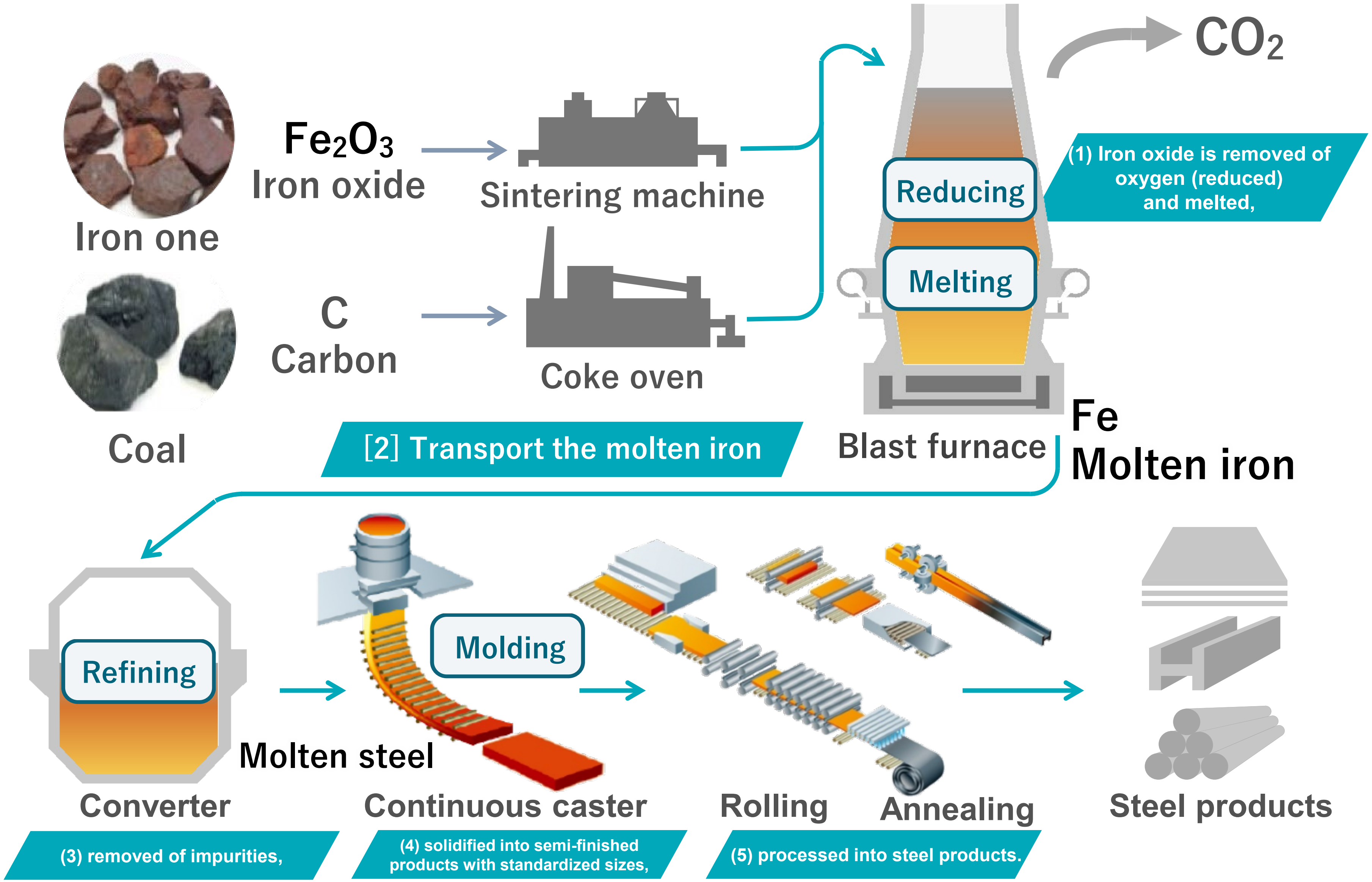
Source of reference: Ministry of Environment: (000098246 (1).pdf) "Global CO_2 emission from Energy"



Emission from the Japanese steel industry account for 13.6% of Japan's total emissions

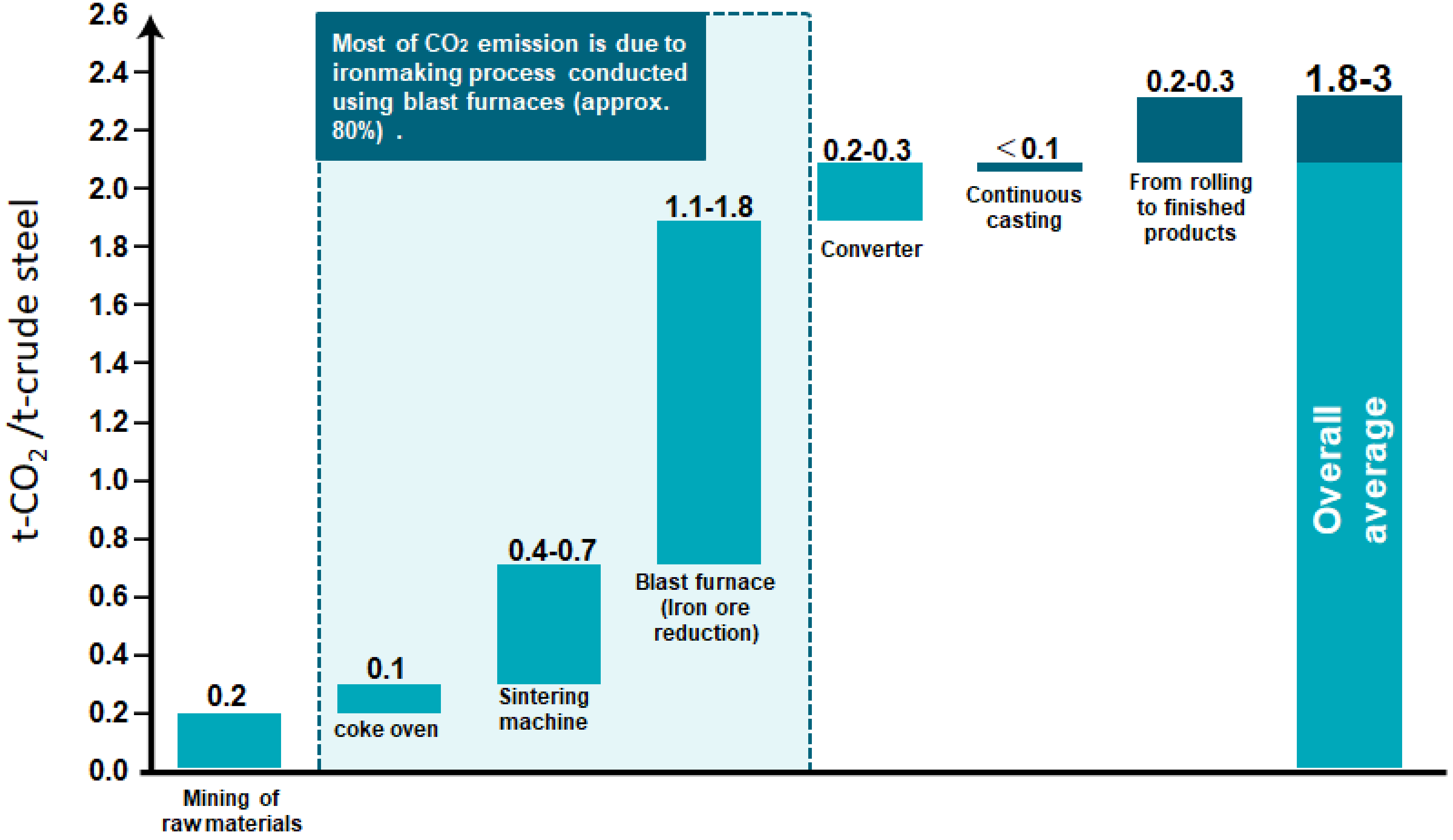
Source of reference: National Institute for Environmental Studies "The GHG Emissions Data of Japan (1990-2020)

Overview of blast furnace-converter process



Revised from Nippon Steel Carbon Neutral Vision 2050
https://www.nipponsteel.com/en/ir/library/pdf/20210330_ZC.pdf

Breakdown of CO_2 emissions during steelmaking process

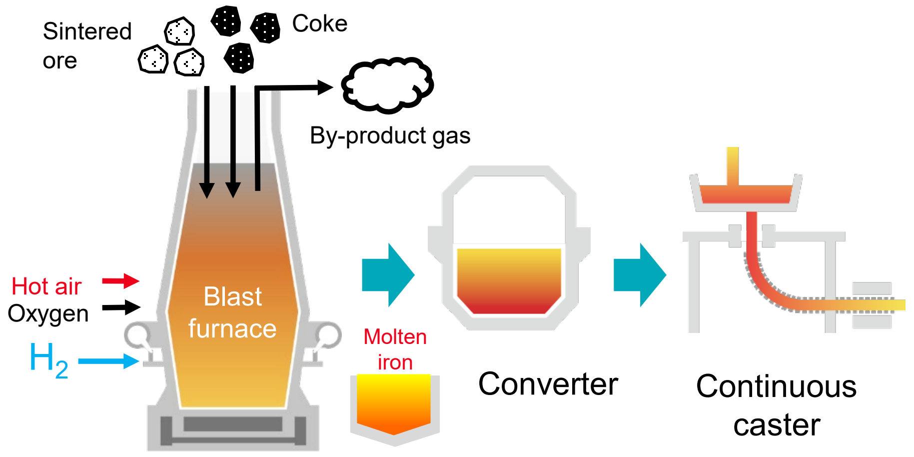


"Carbon Trust, International Carbon Flows - Steel (2011)," modified

Importance of double-track initiatives

High-grade steel production by carbon-neutral steelmaking process has not yet been established.
In the GREINS project, we are pursuing development for both the blast furnace-converter process and the direct reduction-electric arc furnace process.

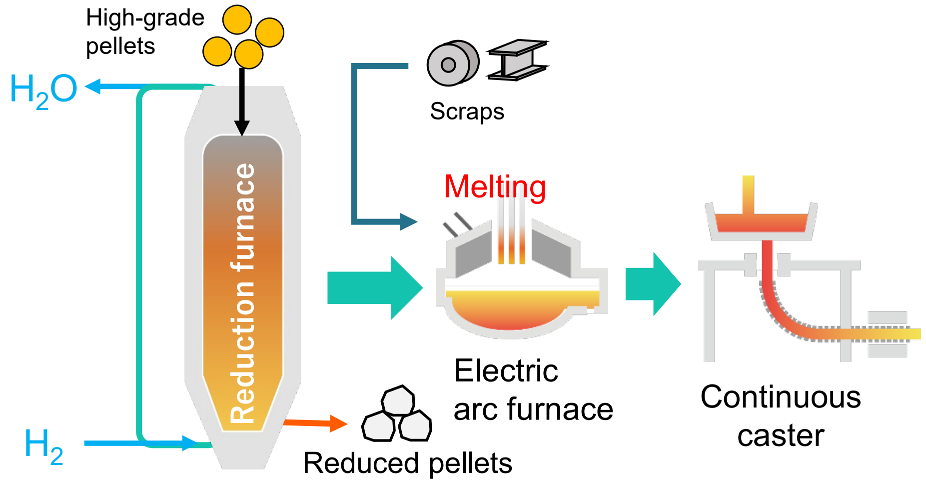
Hydrogen reduction technology in blast furnace



○Merits
- Easier to use low-grade iron ore
- Production of high-grade steel possible

○Demerits
- Utilization of CCUS indispensable in order to realize carbon neutrality

Direct hydrogen reduction technology to reduce low-grade iron ore



○Merits
- Realize carbon-neutral steelmaking process if green hydrogen/power are supplied sufficiently

○Demerits
- Uncertain whether low-grade ore can be used or not (No announcement of commercial use at this time)
- Challenges with impurities and nitrogen constraints for high-grade steel

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"GREINS" = " GREen INnovation in Steelmaking"

Research and development items of GREINS project

1. Development of hydrogen reduction technology using blast furnaces

-1) Development of hydrogen reduction technologies utilizing hydrogen from within steelworks（COURSE50）

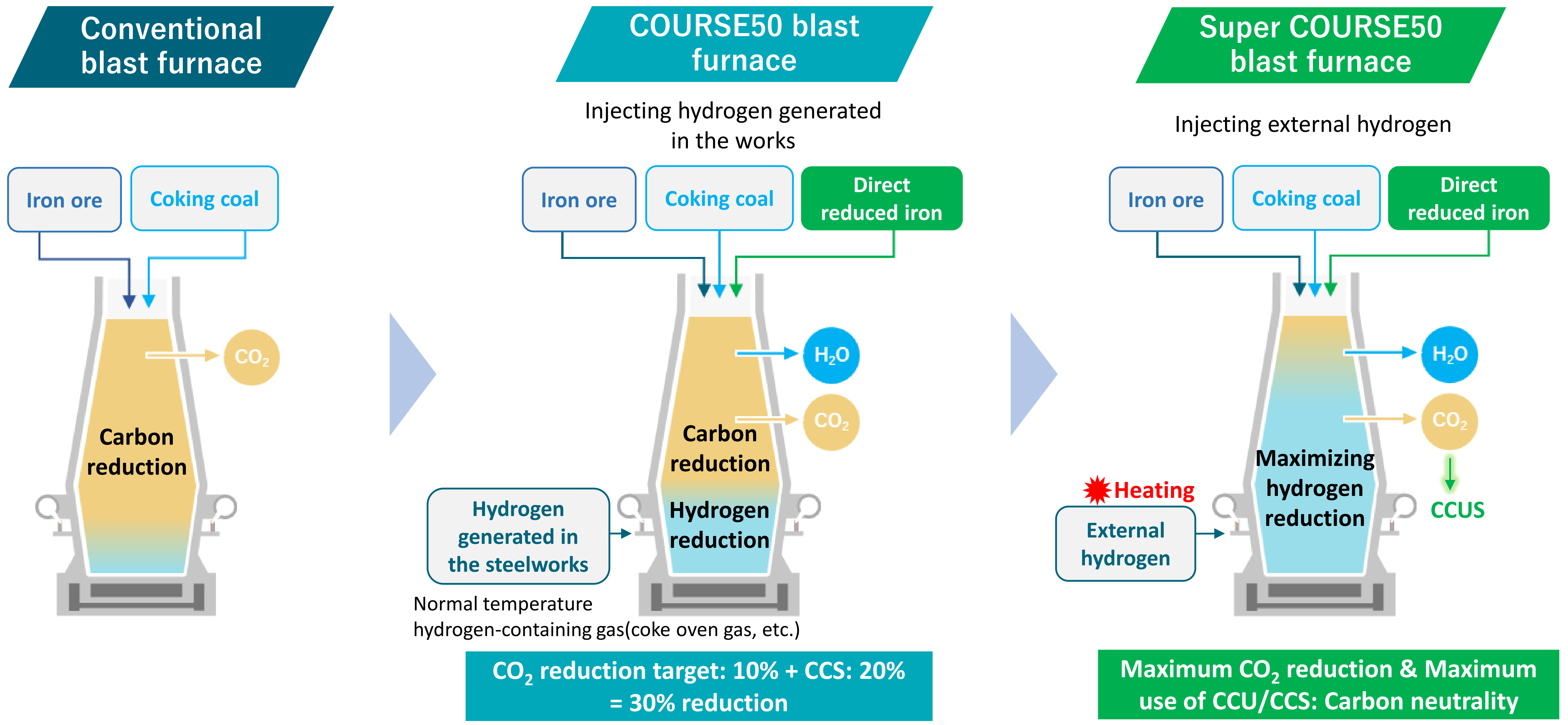
-2) Development of low-carbon technologies using external hydrogen and CO_2 contained in blast furnace exhaust gas

2. Development of direct hydrogen reduction technology to reduce low-grade iron ore using only hydrogen

-1) Development of direct hydrogen reduction technology

-2) Development of technology to remove impurities in electric furnaces using directly reduced iron

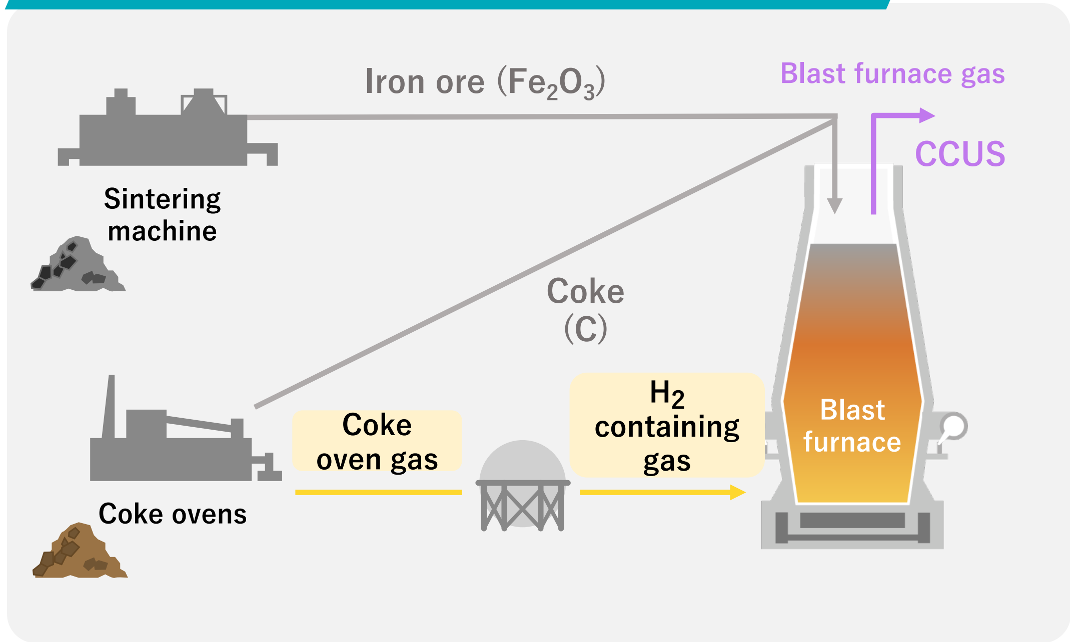
Hydrogen reduction technology in blast furnaces: Direct use of hydrogen



Demonstration of COURSE50: Mass injection test of hydrogen-containing gas in a large sized actual blast furnace

Hydrogen-containing gas injection facility will be introduced **at the Kimitsu No.2 Blast Furnace of Nippon Steel Corporation** and a **demonstration test** is scheduled to **begin in FY2025**.

Blast furnace hydrogen reduction technology (CO_2 reduction by 10%)



Demonstration test in FY2025 with Kimitsu No.2 Blast Furnace of Nippon Steel corporation

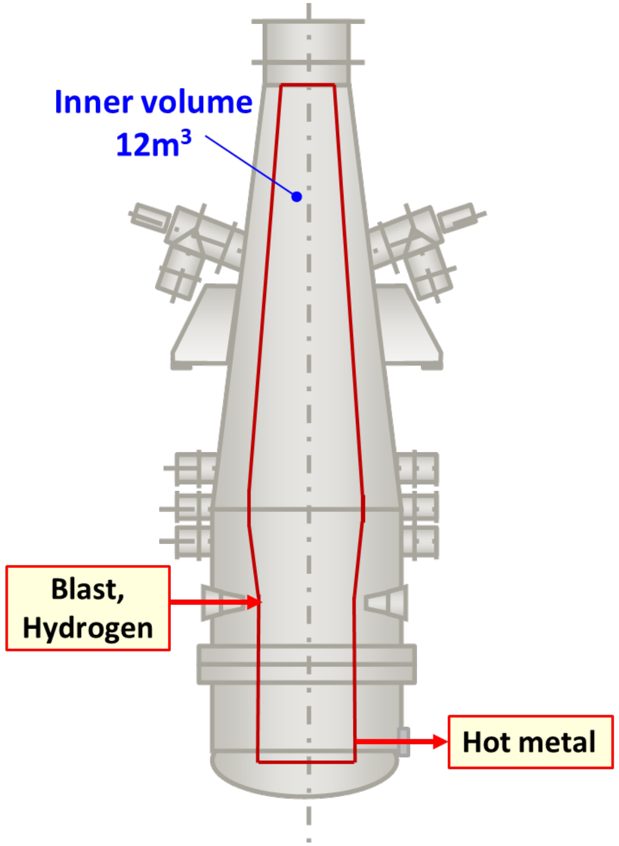
https://www.nipponsteel.com/en/news/20230209_100.html

Super COURSE50 experimental blast furnace（EBF)

Hydrogen injection operation test is **underway** in **the experimental blast furnace** at East Nippon Works Kimitsu Area of Nippon Steel Corporation.

Experimental blast furnace(EBF) facilities

Vertical cross-section of EBF



Results of Hydrogen injection test in EBF

COURSE50 EBF : Carbon consumption reduction of **16%** by injecting **room temperature hydrogen** from tuyeres

Super COURSE50 EBF : Carbon consumption reduction of **22%** by injecting **high temperature hydrogen** from tuyeres

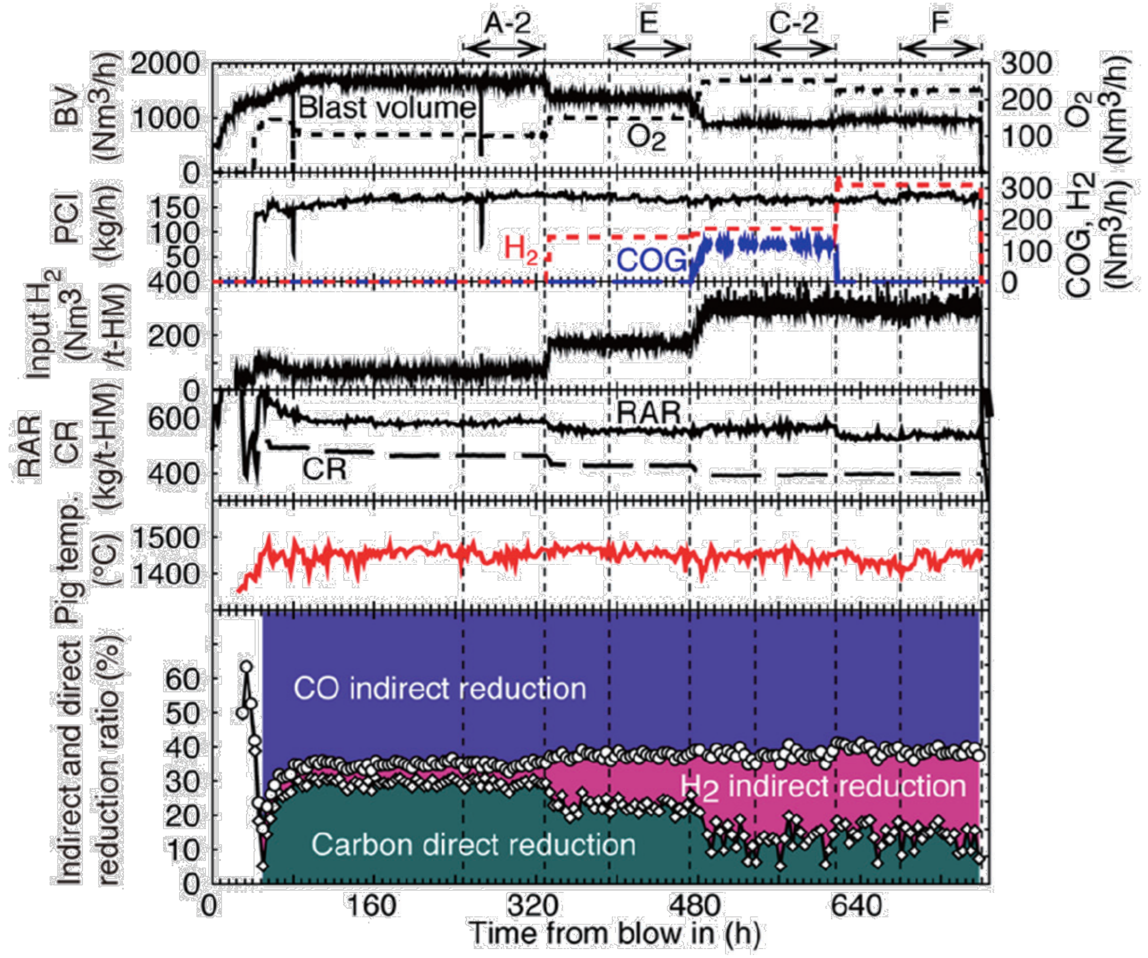


Fig. Example of operation trend of experimental blast furnace.

Revised from Kamijo et. al., ISIJ International, Vol. 62 (2022), No. 12, pp. 2433–2441

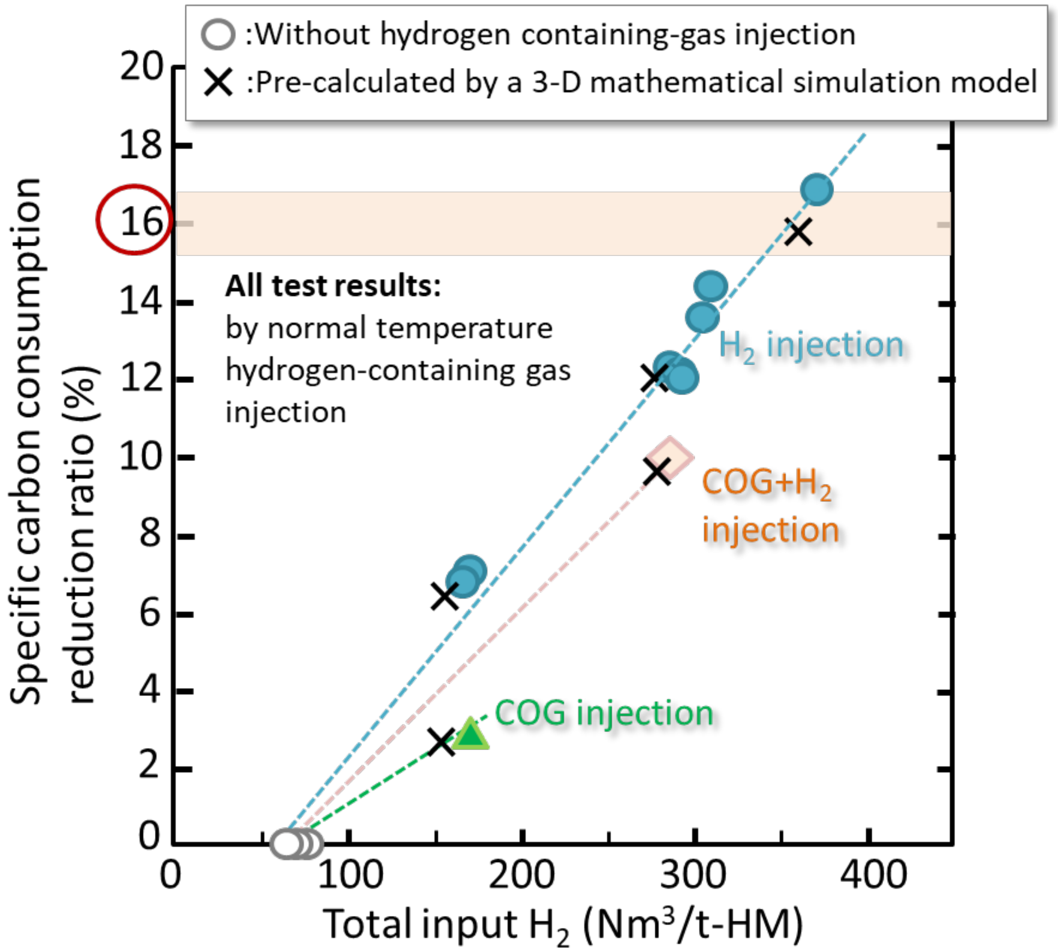
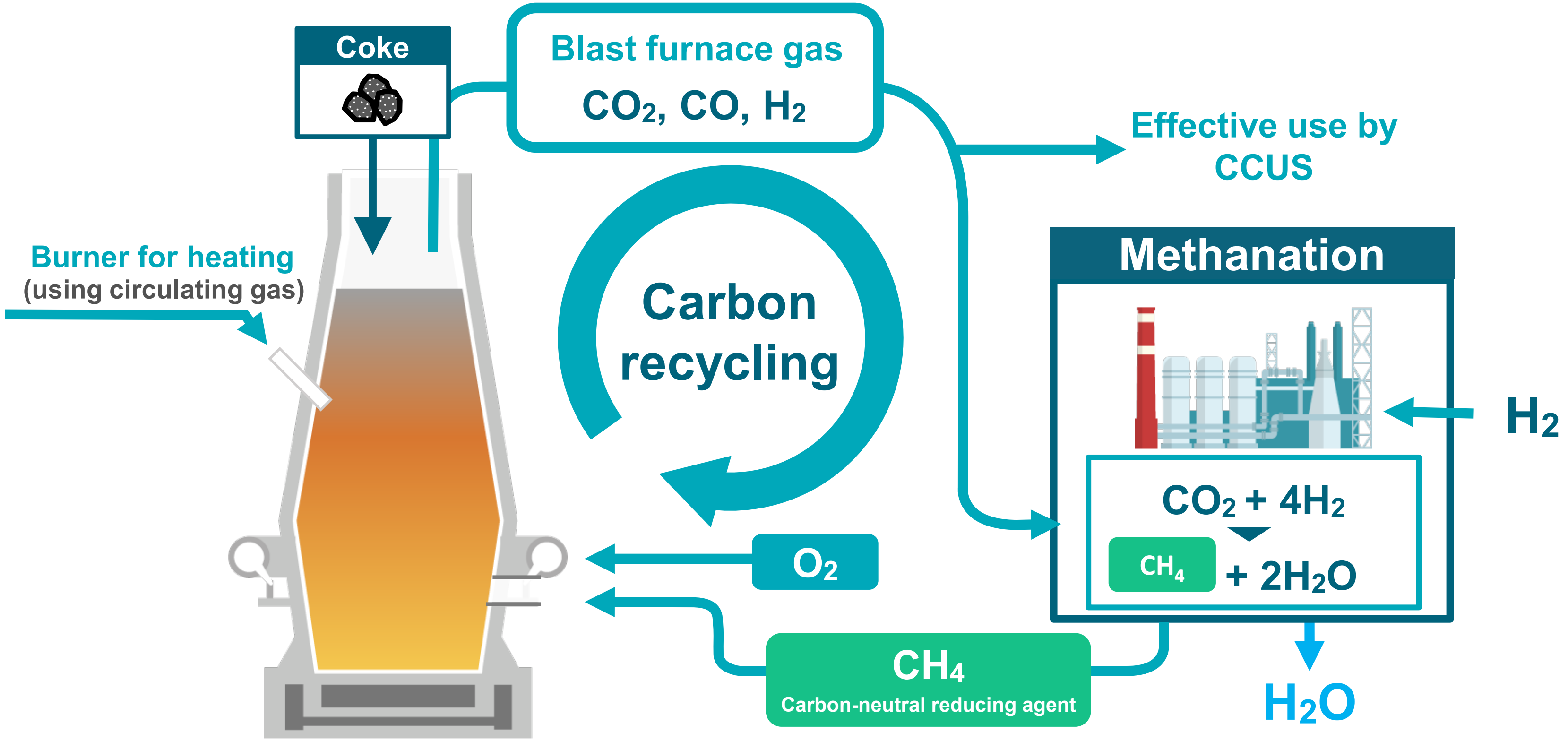


Fig. Relationship between total H_2 input and carbon consumption rate.

Hydrogen reduction technology in blast furnace: Indirect use of hydrogen

- Conversion of CO_2 generated in a blast furnace into methane and repeated use of it as a reducing agent.
- Part of the reducing agent is changed from coke to carbon-neutral methane to reduce CO_2 emissions.



- Construction of small carbon recycling BF(150m³ scale).
- Experiments will start in 2025 at JFE Steel, East Japan Chiba Works.

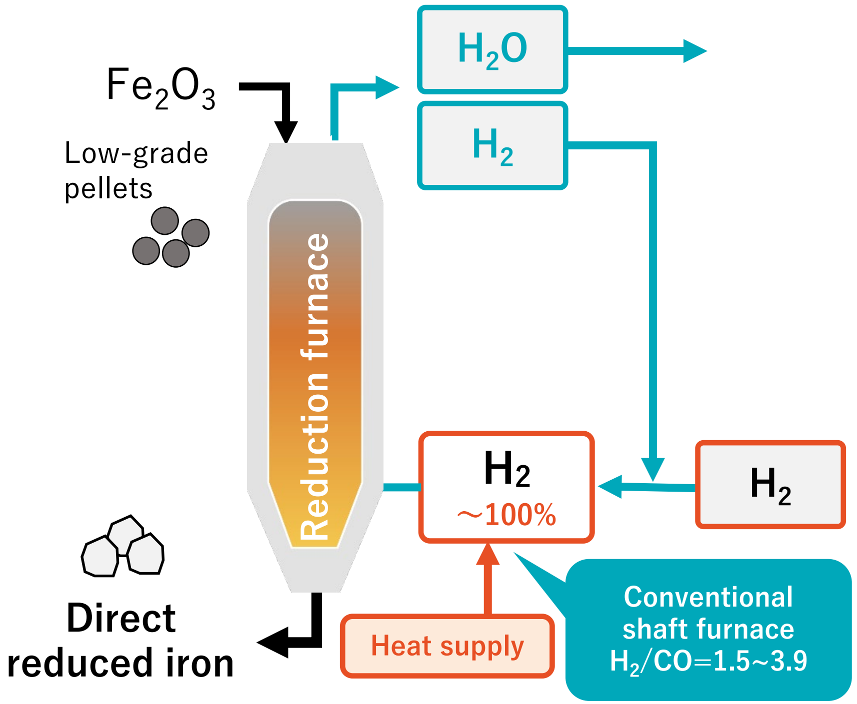
Direct hydrogen reduction technology to reduce low-grade iron ore

- Demonstrating technology that reduces CO_2 emissions by 50% or more relative to the existing blast furnace method through technology that directly reduces low-grade iron ore using hydrogen by the year 2030
- Proceeding to pursue the development of technology to enable the utilization of low-grade pellets

Comparison with existing shaft furnace processes

	Existing shaft furnaces	Hydrogen-reducing shaft furnaces
Reduction materials	Natural gas	Hydrogen
H_2 concentration	60~80%	~100%
Heat supply	natural gas/exhaust gas combustion	heating hydrogen, etc.
Raw materials	High-grade pellets	Lower-grade Pellets

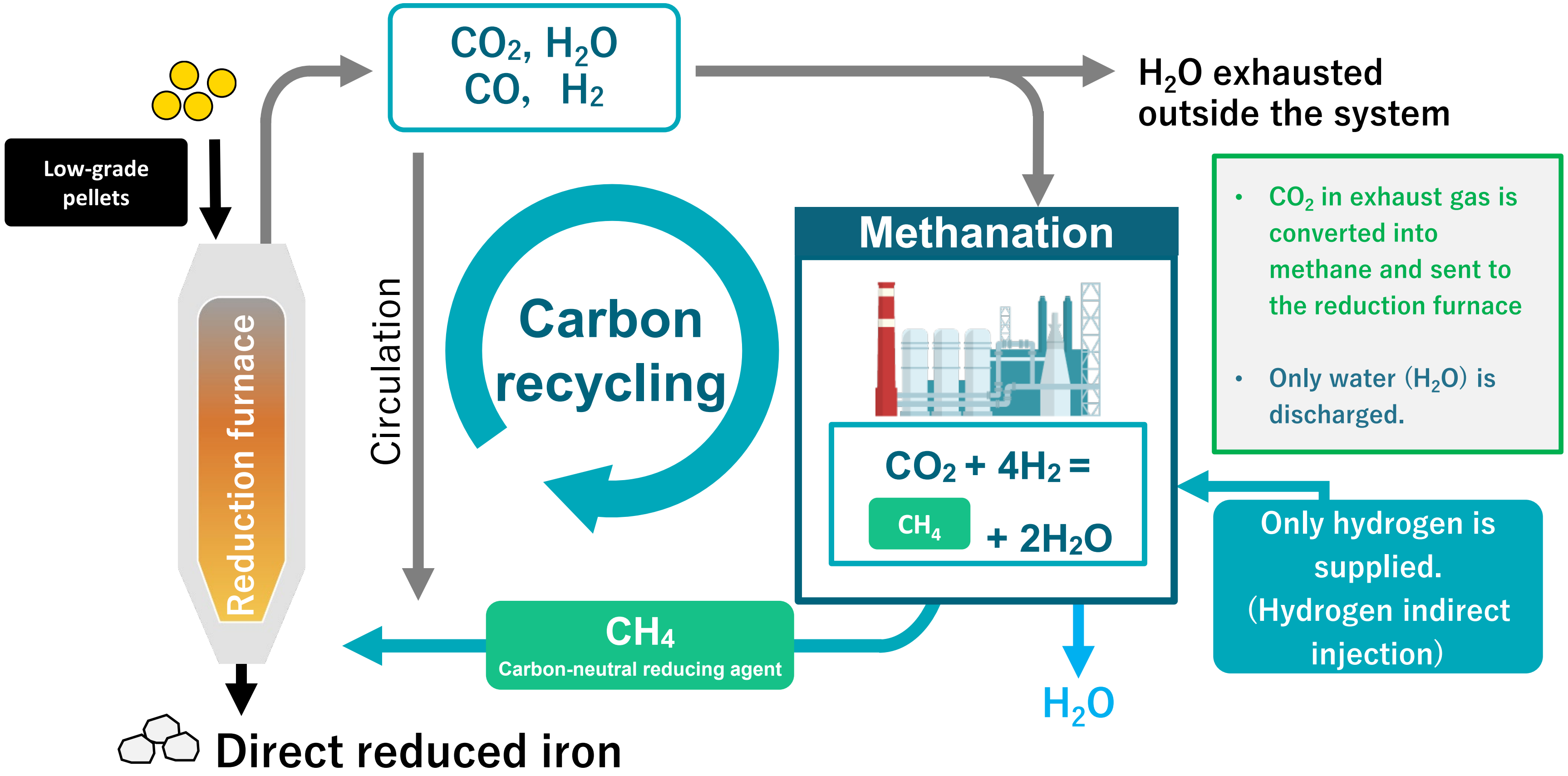
Business Strategy Vision
https://green-innovation.nedo.go.jp/pdf/utilization-hydrogen-steelmaking/item-002/vision-direct-hydrogen-reduction-nipponsteel-002.pdf



$$Fe_2O_3 + 3H_2 \rightarrow 2Fe + 3H_2O \quad -886 \text{ MJ/t-Fe}$$
$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2 \quad +222 \text{ MJ/t-Fe}$$

Development of carbon recycling direct reduction method

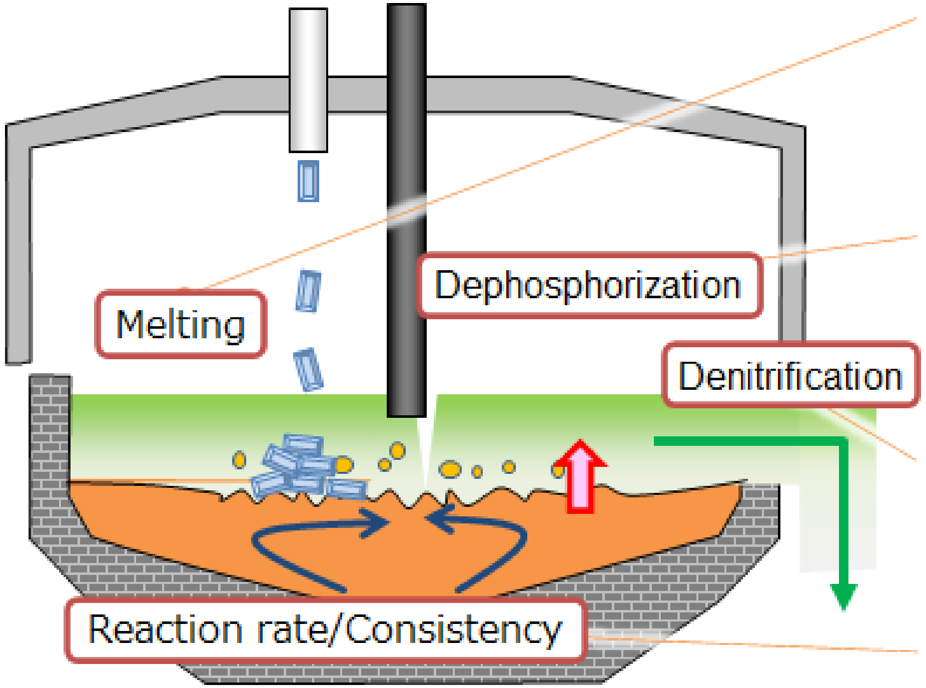
Proceeding to also develop a carbon recycling direct reduction method that uses methanation technology to capture carbon inside the system, and direct reduction is conducted using hydrogen only.



- Construction of bench-test furnace.
- Experiments will start in FY2024 at JFE Steel, East Japan Chiba Works.

Development of EAF Technology for High-grade Steelmaking

Demonstrating the technology to refine impurities to the same level as the blast furnace process (150 ppm or less of phosphorus and 40 ppm or less of nitrogen) using hydrogen direct reduced iron from low-grade iron ore in the large-scale integrated electric arc furnace process (approx. 300 tons) by 2030.



Improvement of DRI dissolution rate
Optimization of DRI specifications, feeding position and rate, and improvement of agitation

Phosphorus reduction
Promotion of dephosphorization by improving agitation and controlling slag composition, reduction of slag generation

Nitrogen reduction
Accelerated denitrification by atmosphere control, carbon addition and decarburization

Optimal stirring technology
Optimization of stirring methods such as energizing type, furnace dimension, etc.

Innovative CO_2 Capture Technology with energy-saving

ESCAP®

The basic technology was established in COURSE50 project.

- **Chemical absorbent**: Nippon Steel & RITE*
- **Chemical process** : Nippon Steel Engineering

*Research Institute of Innovative Technology for the Earth

→ **Commercialized 2 plants (120t & 143t-CO_2/day)**

ESCAP ® (Energy Saving CO_2 Absorption Process): Registered trademark of Nippon Steel Engineering Co., Ltd.

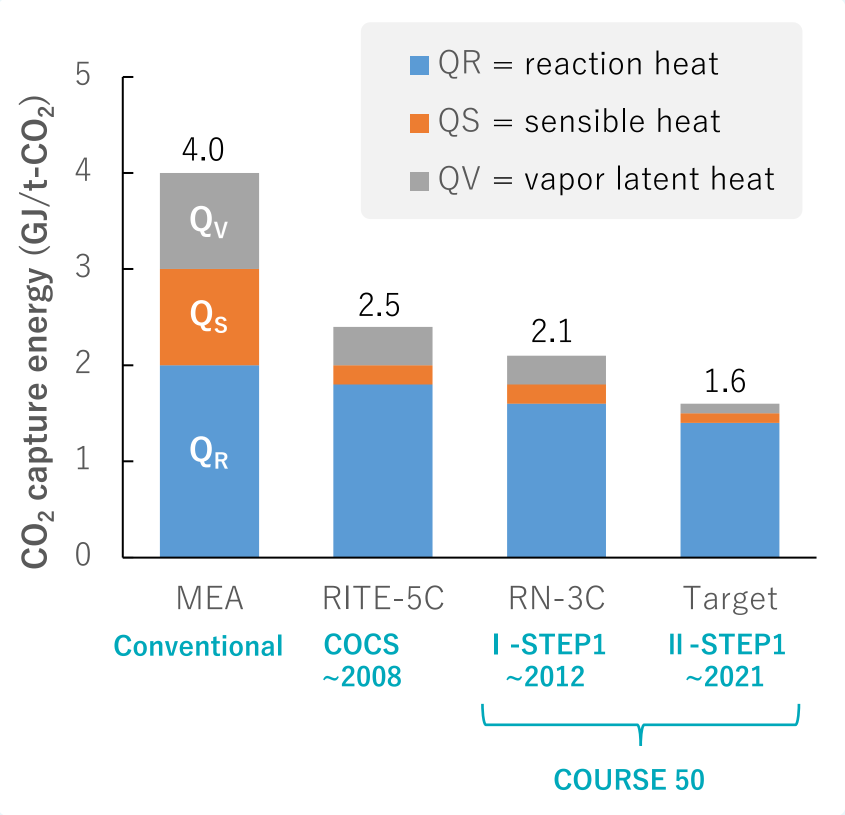


Fig. Reducing CO_2 capture energy **by developing new absorbents**.

Commercialized plant No.1
(AIR WATER CARBONIC INC.)

Commercialized plant No.2
(Sumitomo Joint Electric Power Co., Ltd)

	Plant No.1 **(from 2014)**	Plant No.2 **(from 2018)**
Specification	120 t/day	143 t/day
Emission source	Steelmaking hot-stove	Coal-fired power
CO_2 use	Generates industrial CO_2	Manufactures feed additives

Source of reference: Nippon Steel Technical Report No.127 (2022) p29.

Source: https://www.eng.nipponsteel.com/english/whatwedo/energy_solutions/escap/escap

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"GREINS" = " GREen INnovation in Steelmaking"

ISIJ committee of carbon neutral iron & steel making

was established in 2022 to unite industry and academia to promote activities that contribute to carbon neutrality in the steel industry

- ✓ Discussions on flexible strategies based on academic principles
- ✓ Complementary role to large-scale project led by steel-maker supported by national budget

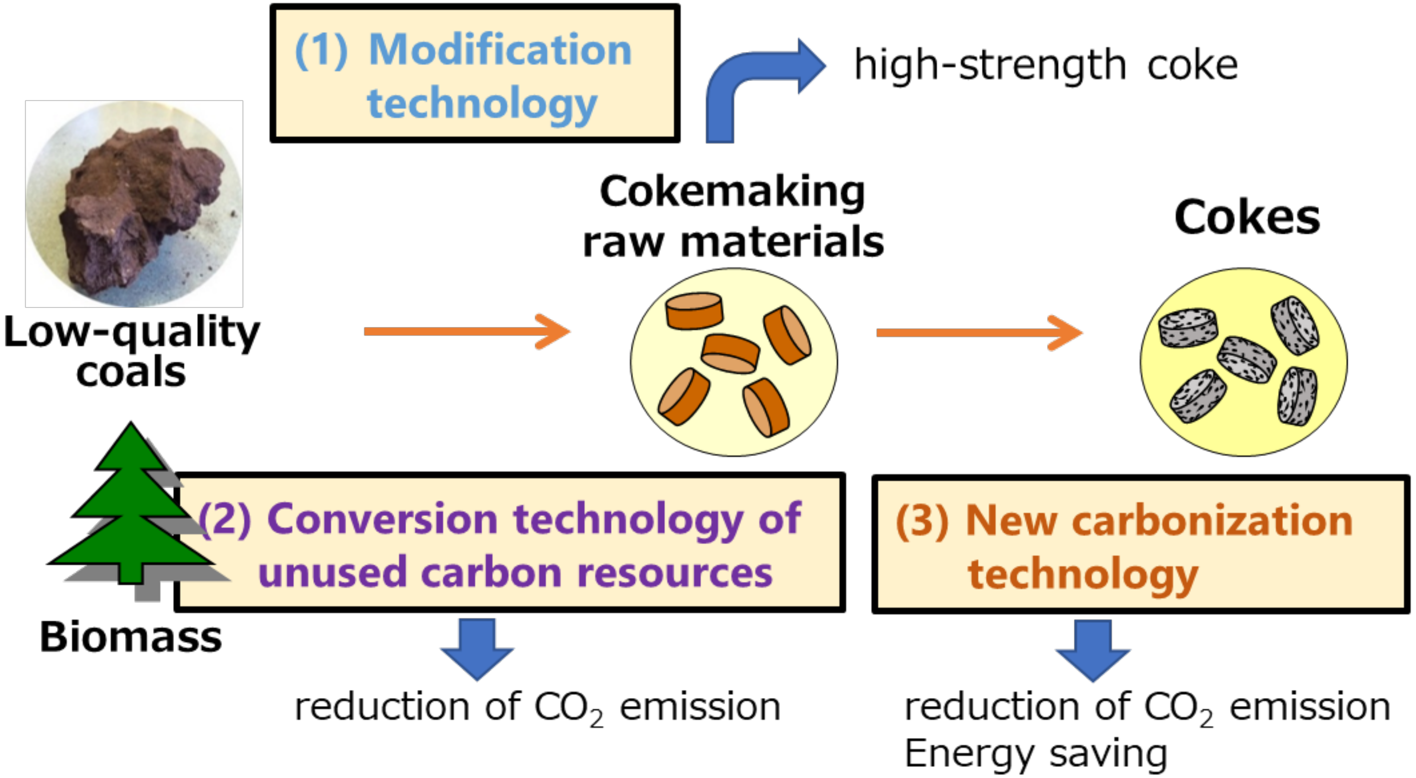
Research grant system of ISIJ

- ✓ Grants for Research **Persons** on Carbon-Neutral Iron and Steel
  - 2022 FY **24** / 92 (Number of adoptions / applications)
  - 2023 FY **23** / 89
  - 2024 FY qualifying in progress
- ✓ Grants for Promotion of Iron and Steel Research
- ✓ Grants for Research Groups; **24** projects (number in progress at the end of Dec. 2022)

“Cokemaking Technology for Low CO_2 Emission and High Quality while Extending Available Resources.”

2019～2021, Now moving on to the next stage

- ✓ Newly developed pre-treatment of cokemaking raw materials with biomass could increase coke strength.
- ✓ A new co-processing with biomass and waste plastic was proposed and found to improve carbonisation yield and coke strength.
- ✓ The clarification of the pyrolysis behaviour of tar under pressure has led to dry distillation technology under low energy consumption conditions.



(1) Modification technology

Kyoto Univ., Nagoya Univ.,
National Institute of Advanced Industrial Science and Technology,
Mitsubishi Chemical, Nippon Steel Stainless Steel

(2) Conversion technology of unused carbon resources

Nagoya Univ., Kyushu Univ., Mie Univ.,
Nippon Steel Stainless Steel,
JFE Steel, Kansai Coke and Chemicals

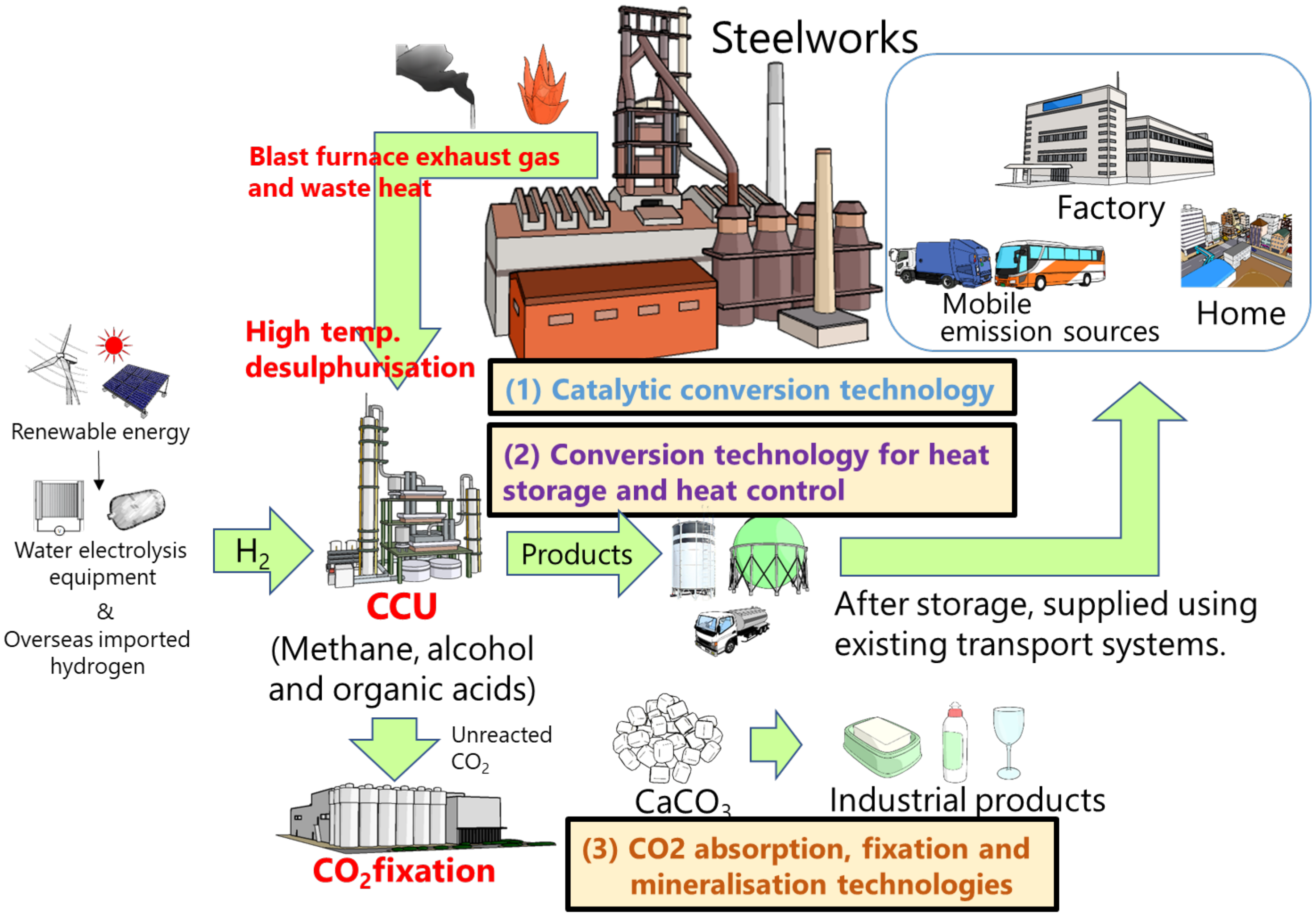
(3) New carbonization technology

Hokkaido Univ., Tohoku Univ.,
National Institute of Advanced Industrial Science and Technology,
Kobe Steel, Nippon Steel Stainless Steel,
JFE Steel

"CCU for iron and steel making"

Now in progress

Point is the development of CCU from steelmaking flue gases, including CO_2, CO and S, rather than from concentrated CO_2.



(1) Catalytic conversion technology

National Institute of Advanced Industrial Science and Technology,
Hokkaido Univ., Kyushu Univ.,
Nippon Steel, Kobe Steel

(2) Conversion technology for heat storage and heat control

Hokkaido Univ.,
JFE Steel, Kobe Steel

(3) CO2 absorption, fixation and mineralisation technologies

Tohoku Univ., Nihon Univ.,
Nippon Steel, Kobe Steel

Disseminating CN research activities

The 1st Symposium on Carbon Ultimate Utilization Technologies for the Global Environment (CUUTE-1)

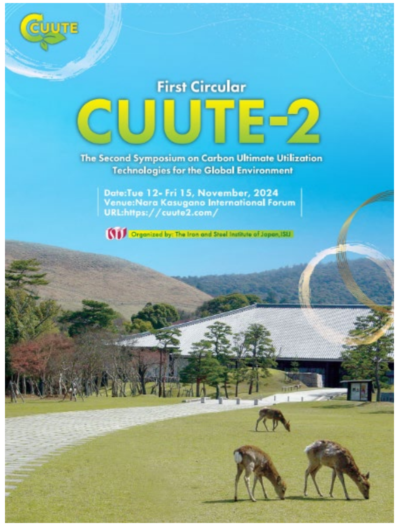
- ✓ 14th～17th, Dec, 2021 at Nara, Japan
- ✓ Contribution; **84** papers （domestic:**69**, overseas:**15**）

The 2nd Symposium on Carbon Ultimate Utilization Technologies for the Global Environment (CUUTE-2)

12th～15th, Nov, 2024 at Nara, Japan

Deadline of Abstract Submission: 29th Feb., 2024

https://cuute2.com/



Topics

1. Perspective for Low Carbon Society
- (1) Megatrends in industrial sector
- (2) Sector coupling
- (3) System modeling and analysis

2. Advanced Carbon and Energy Carrier Utilization
- (1) Iron and steelmaking industry
- (2) Chemical industry
- (3) Hydrogen and derived energy carriers
- (4) Generation and utilization of heat and power

3. CO_2 Utilization and Storage
- (1) CO_2 capture/separation technologies
- (2) CO_2 conversion processes
- (3) CO_2 utilization/sequestration technologies

ISIJ, an academic institute, provides an open platform for global researchers in the field of low-carbon ironmaking and steelmaking to present and publish their research results and discuss the scientific validity.
We welcome your participation in the activities of ISIJ.

Summary

- ✓ The Japanese steel industry has been the first in the world to engage in hydrogen reduction steelmaking from the earliest stage, through the COURSE50 project supported by NEDO.
- ✓ Based on the technologies gained in COURSE50, we launched a multitrack technical development project (GREINS) to realize a carbon neutrality in steelmaking as one of NEDO Green Innovation Fund Projects sponsored by METI.
- ✓ For the carbon neutrality, massive and stable supply of carbon-free hydrogen and electricity with rational costs as well as overcoming many technical difficulties is essential.
- ✓ Academic societies are collaborating to strengthen our multi-track approach and to promote exploratory research with an eye on the future.

This presentation is based on results obtained from a project, JPNP21019, commissioned by the New Energy and Industrial Technology Development Organization (NEDO)

شكرا لكم على اهتمامكم

Thank you for your attention