Breakthrough Technology Conference 2025 @Singapore

Development of Carbon Recycling Direct Reduction Process using Methanation Process

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JFE Steel Corporation

Steel Research Laboratory

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Contents

- Background
- Technical challenge for carbon neutrality
- Methanation test planning
- Current status of reduction tests using shaft furnace

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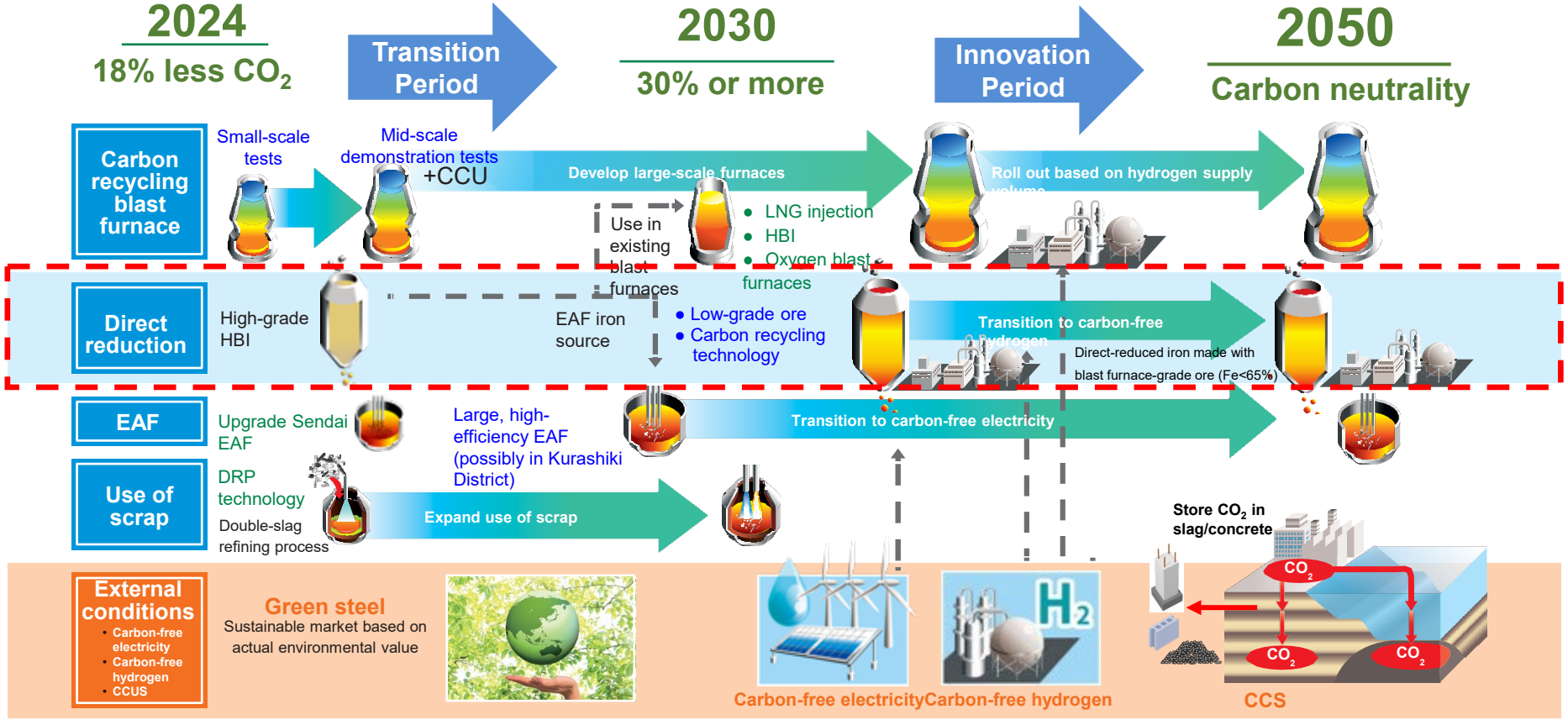
JFE Steel's Transition to Low-carbon Processes

Transition period (～2030) : Promoting low-carbon steelmaking processes (- 30%).
- Utilization of HBI in BF, introduction of highly efficient EAF

Innovation period (～2050) : Aiming to achieve carbon neutrality by innovative technology.
- Carbon Recycling Blast Furnace / H_2 utilization in direct reduction process

Today's Topic



https://www.jfe-steel.co.jp/en/company/pdf/carbon-neutral-strategy_220901_1.pdf

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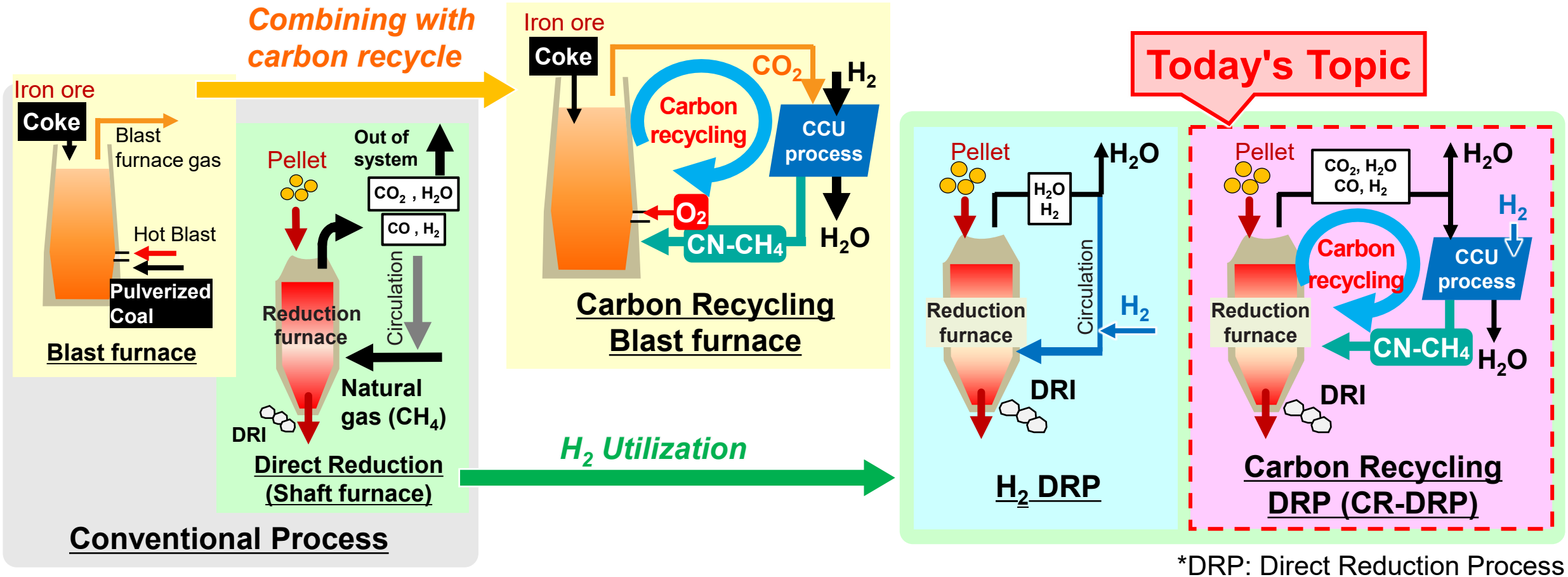
Technology Development to Achieve Carbon Neutrality in Ironmaking

Promote the realization of carbon neutrality by developing technology that combines the conventional blast furnace method and direct reduction method and carbon recycling.



*DRP: Direct Reduction Process

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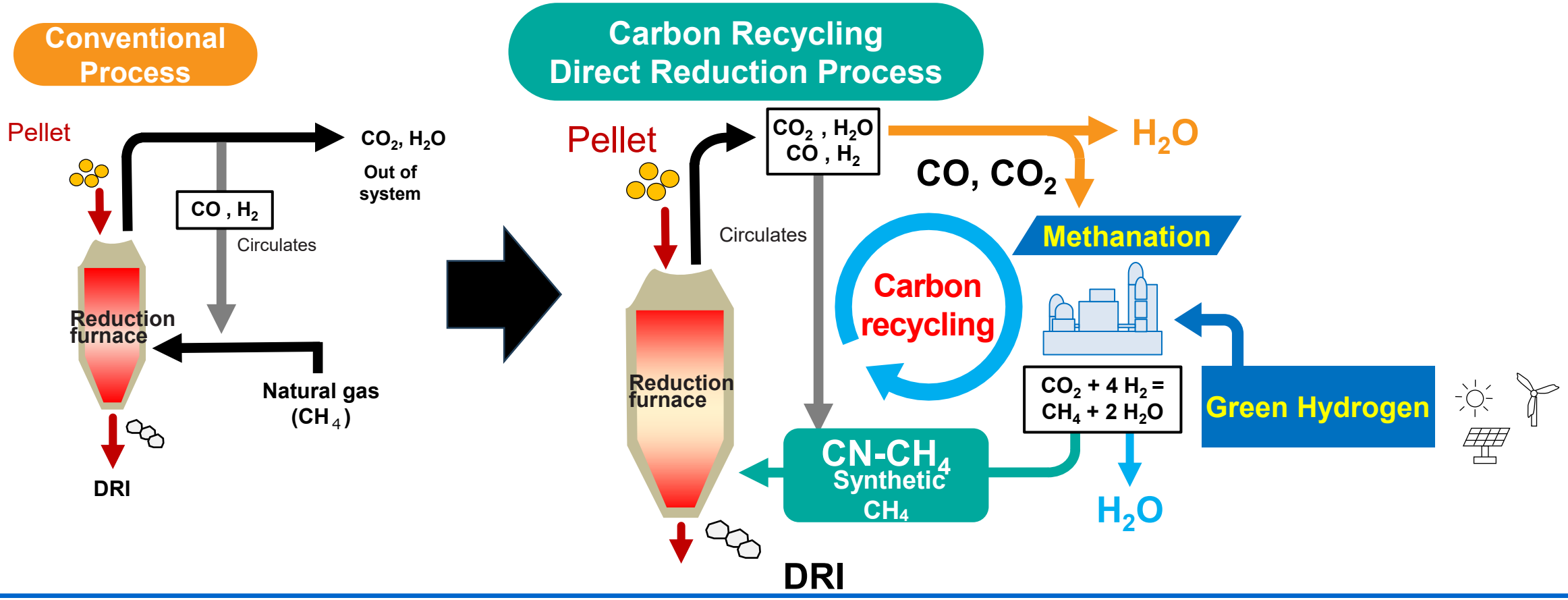
Overview of Carbon Recycling (CR) Shaft Furnace

- JFE Steel plans to develop CR direct reduction steelmaking.
- The features of this process are 1) indirect use of hydrogen through methanation, 2) circulation of carbon within the process, and 3) overcoming the endothermic effects of hydrogen reduction.



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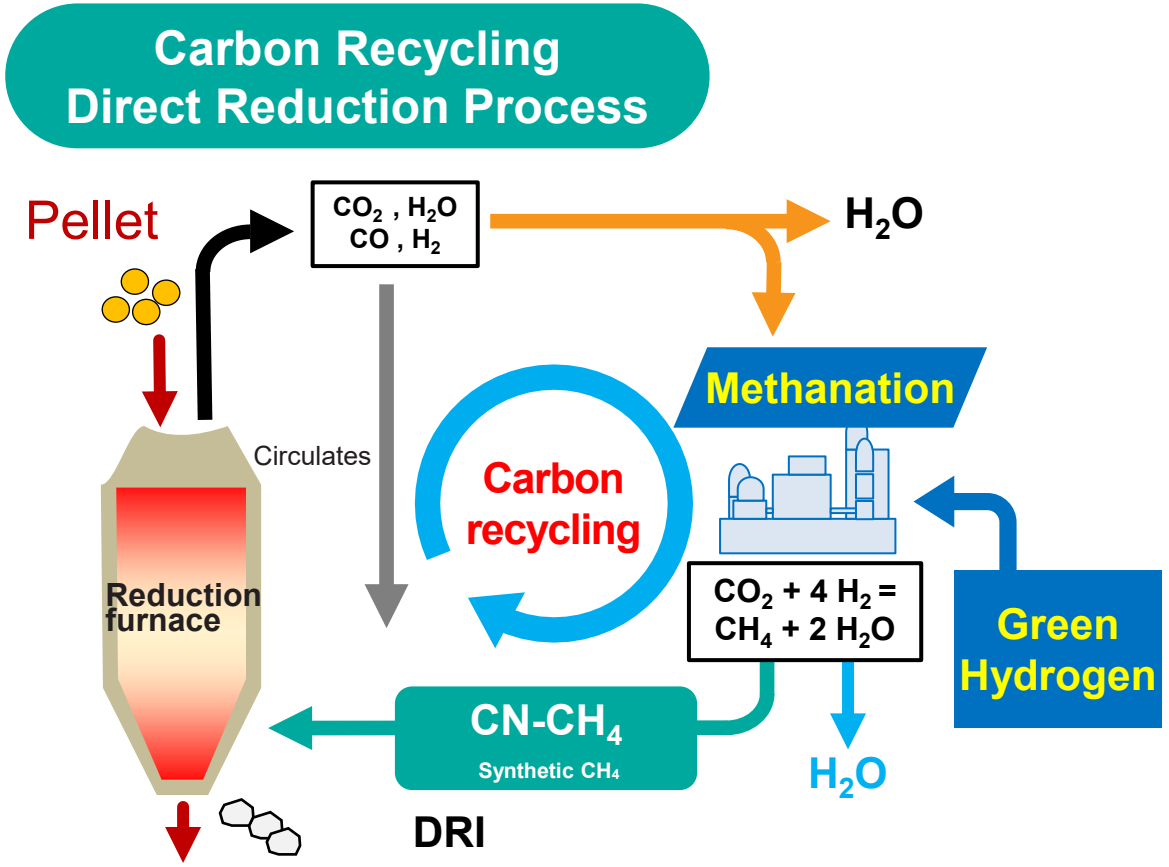
Technical development items related to CR shaft furnace



・Reduction with hydrogen is a highly endothermic reaction.

・By synthesizing methane from CO_2 through a methanation reaction, it is possible to avoid CO_2 emissions from the system and heat absorption in the shaft furnace.

・The mechanism of reduction degradation of pellets will also be examined.

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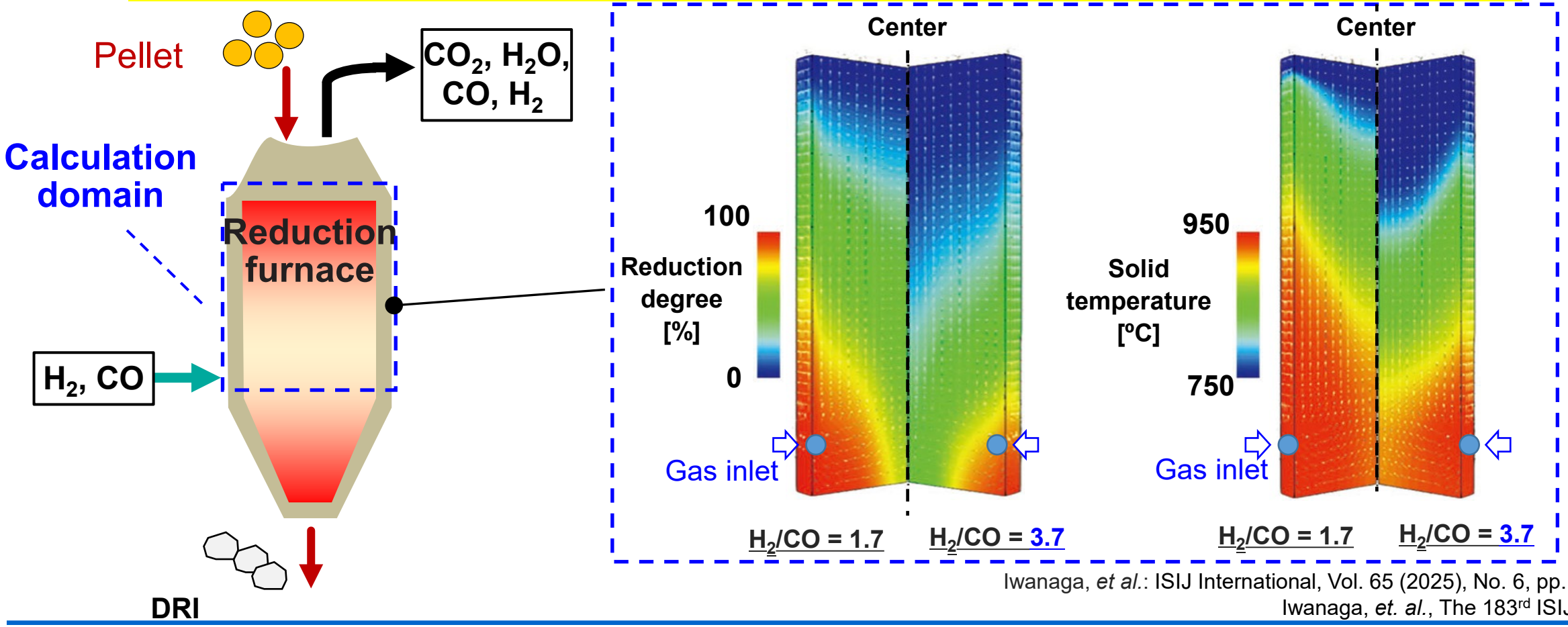
Impact evaluation of large amount of hydrogen injection

When the amount of hydrogen in the reducing gas increases, in the middle to upper part of the furnace:
- The furnace temperature decreases.
- The reduction rate decreases.



Iwanaga, *et al.*: ISIJ International, Vol. 65 (2025), No. 6, pp. 874–883
Iwanaga, *et. al.*, The 183rd ISIJ Meeting

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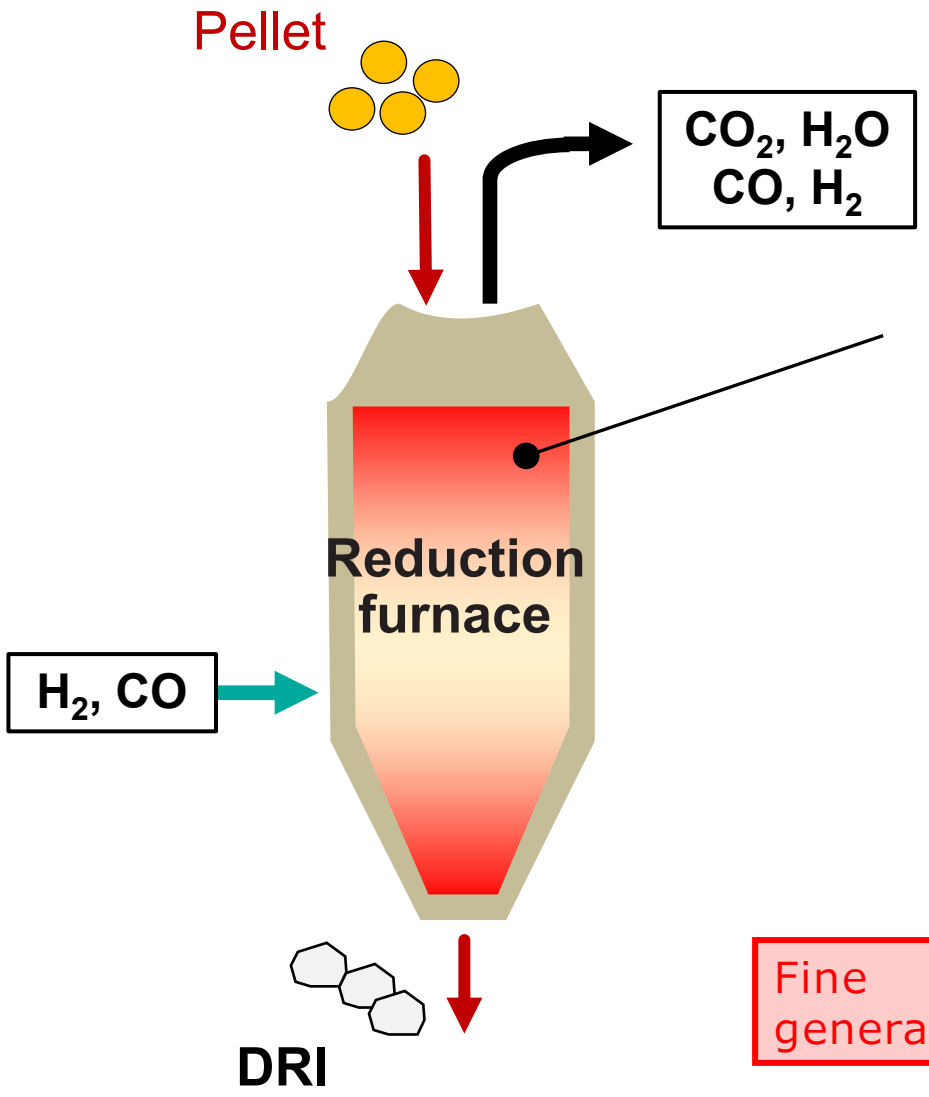
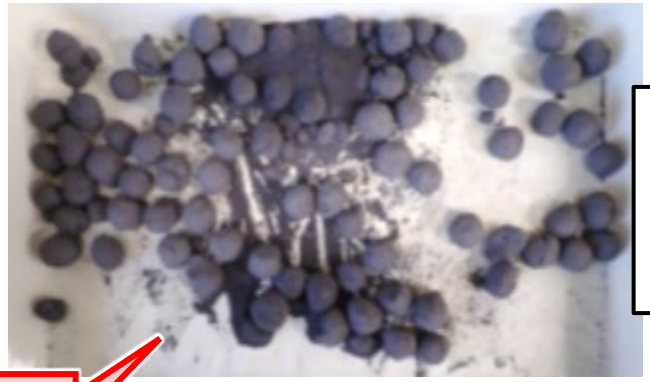
Issues with endothermic reaction



・The endothermic reaction may lead to a decrease in productivity due to a decrease in reaction rate.

・Lowering the reaction temperature may cause the reduction degradation of pellet.



General Exp. Condition
- Reduction temp.: 900ºC
- After measuring tumbling strength
- H2/CO = 4.0

Degradation behavior of pellet

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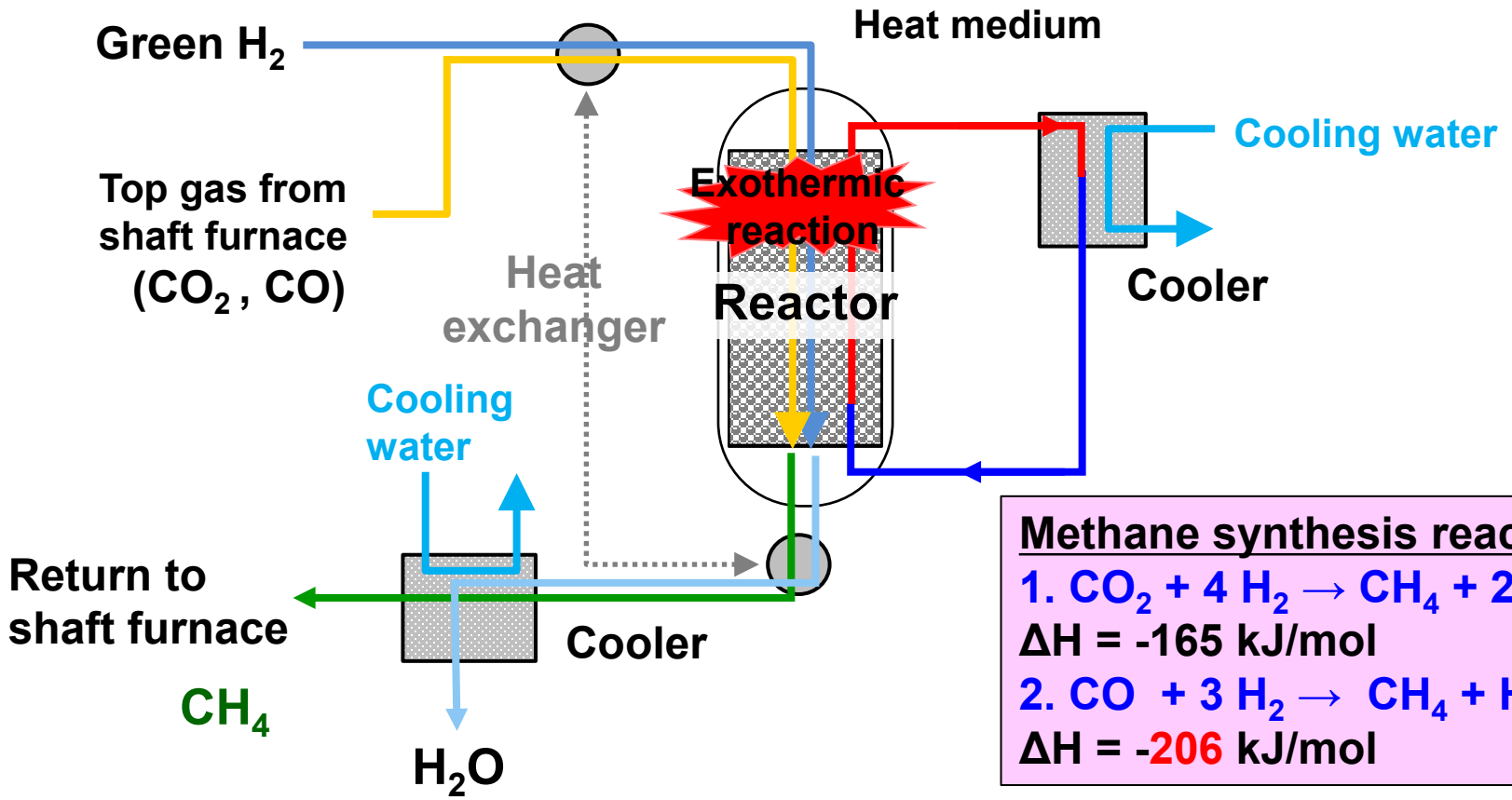
Overview of methanation

Methanation

- A process in which we can converts CO_2 and CO into CH_4 by using H_2.
- One of the promising CCU processes needed to realize a carbon-neutral society.



Methane synthesis reactions

1. $CO_2 + 4\ H_2 \rightarrow CH_4 + 2\ H_2O$
   $\Delta H = -165$ kJ/mol
2. $CO + 3\ H_2 \rightarrow CH_4 + H_2O$
   $\Delta H = -206$ kJ/mol

Exothermic reaction

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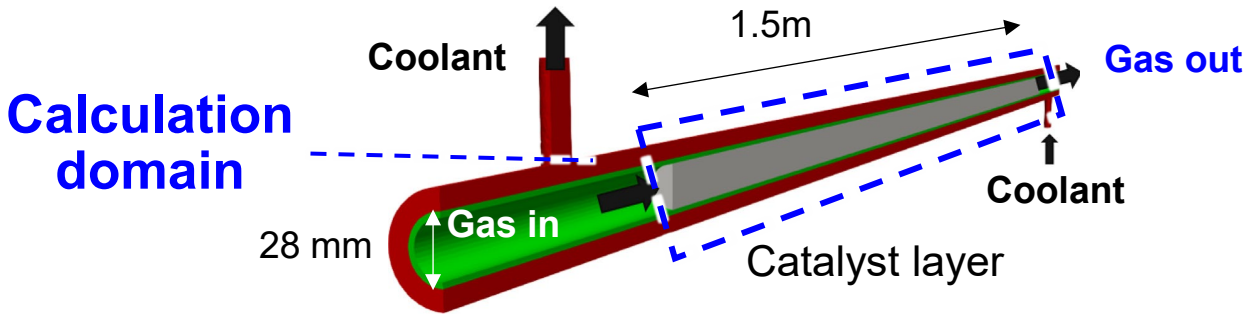
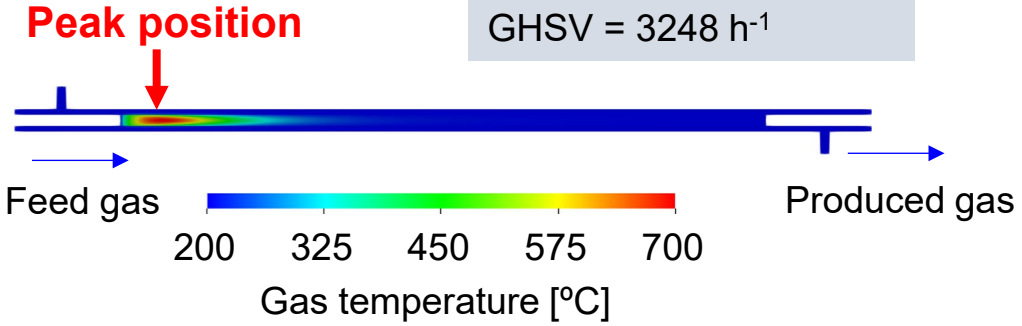
Investigation of methanation efficiency under various conditions

Concerns regarding methanation with a CO/CO_2 mixed gas:
Methanation with CO alone generates more heat.
Temperature control within the reactor may be difficult.
→ We are currently investigating the effects of CO through simulations.



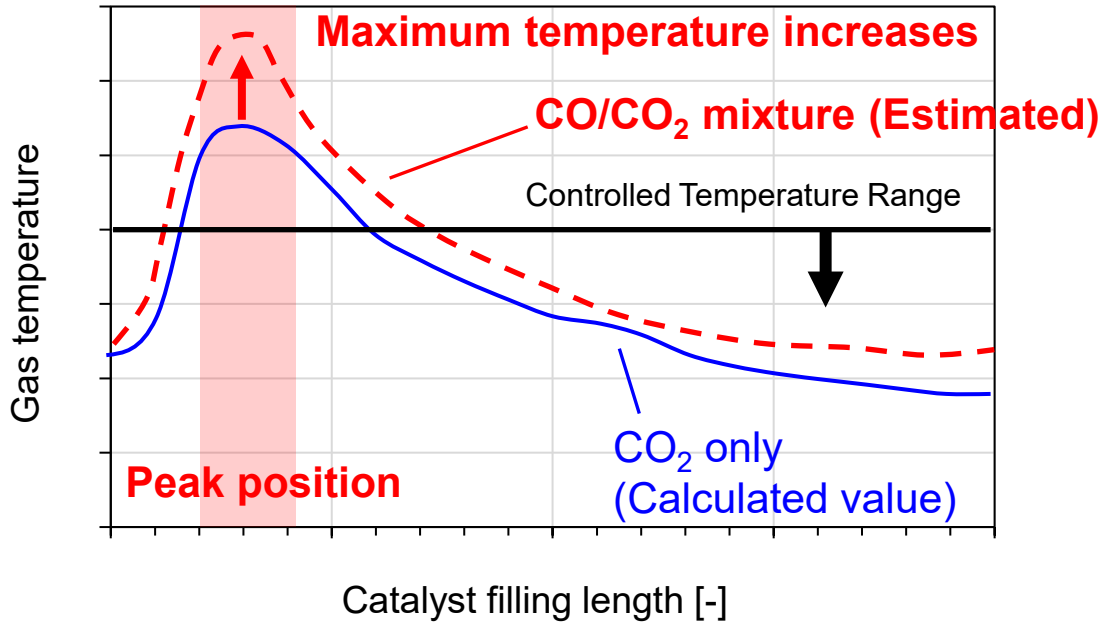
Calculation assumptions
H_2/CO_2 = 4
P = 0.5 MPaG
GHSV = 3248 h^{-1}

Calculation result



GHSV = (Catalyst bed volume [NL])/(Gas flow rate [NL/h])

Zhang , Norinaga ：*Chemical Engineering Science*, **211** (2020), 115276.



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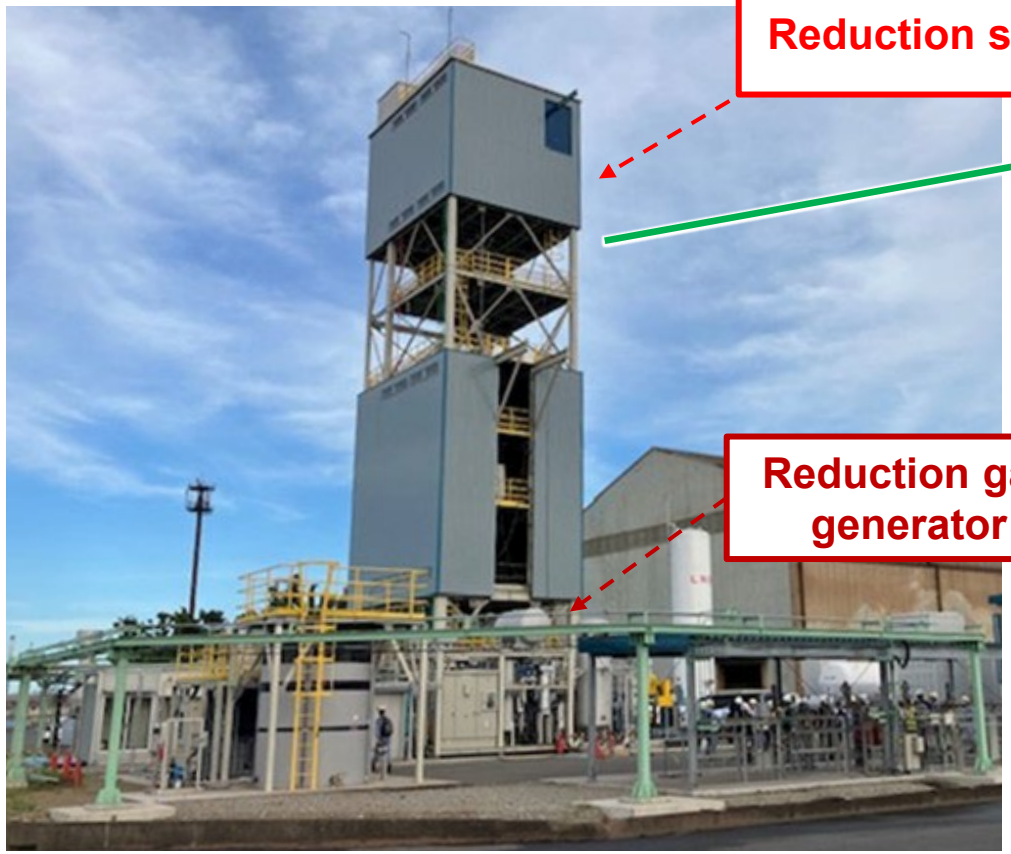
Current status of reduction tests using shaft furnace

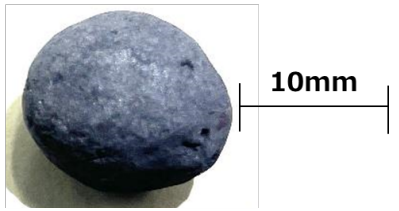
- Experimental operations have just begun at the end of 2024.
- Scheduled as 1-week operation in each month, through 2026.

★ External view (as of March, 2025)



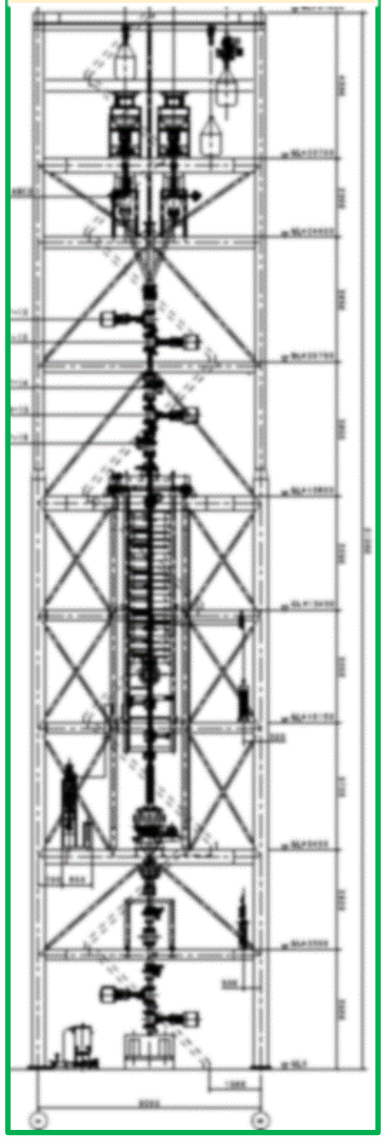
Direct Reduction bench furnace Overview
- **Site:** approx. 50 m × approx. 50 m
- **Height:** approx. 30 m
- **Test volume:** 15 kg/h

Raw material pellets
Reduction rate: 0%
Brown color



Reduced pellets
Reduction rate: >90%
Gray color with metallic luster

Exp. shaft furnace



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Summary

・JFE Steel plans to develop carbon recycling direct reduction process.

・In order to establish the CR-shaft furnace process, we plan to investigate the effects of gas composition (CO_2/CO ratio) and H_2O addition amount on methanation reaction efficiency.

・We have been conducting experiments using the shaft furnace since the end of 2024.

・This project has received funding from the New Energy and Industrial Technology Development Organization (NEDO) Green Innovation program under agreement No. JPNP21019.

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