WSA Breakthrough Technology Conference

Investigation of Carbon Neutralization of Direct Reduction Process by Applying Carbon Recycling

05/12/2023

JFE Steel Corporation

Steel Research Laboratory

Carbon Neutral Process Research Department

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- Background
- Technical challenge for carbon neutrality
- Methanation test planning
- Construction plan for experimental shaft furnace

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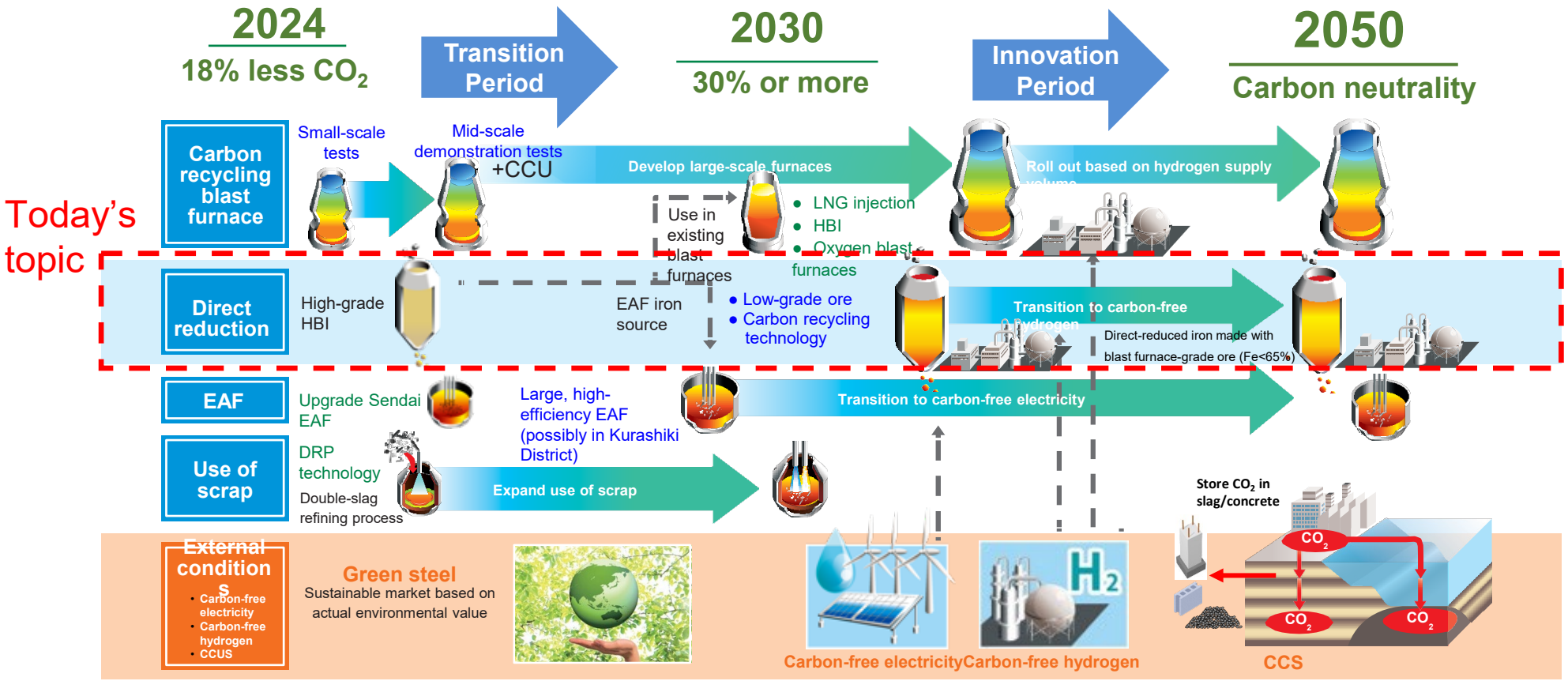
JFE Steel's transition to low-carbon processes

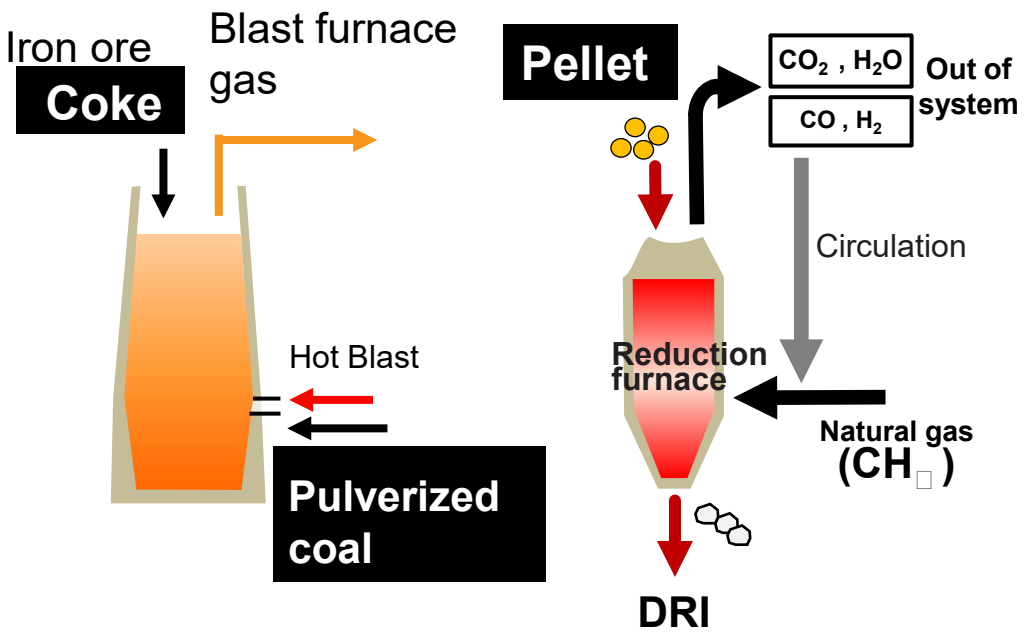
- **JFE Steel consider the period up to 2030 to be a transition period and will promote the transition to low-carbon steel processes.**
- **The period from 2030 to 2050 is defined as the innovation period.**
- **We aim to achieve carbon neutrality by establishing and implementing innovative technology.**



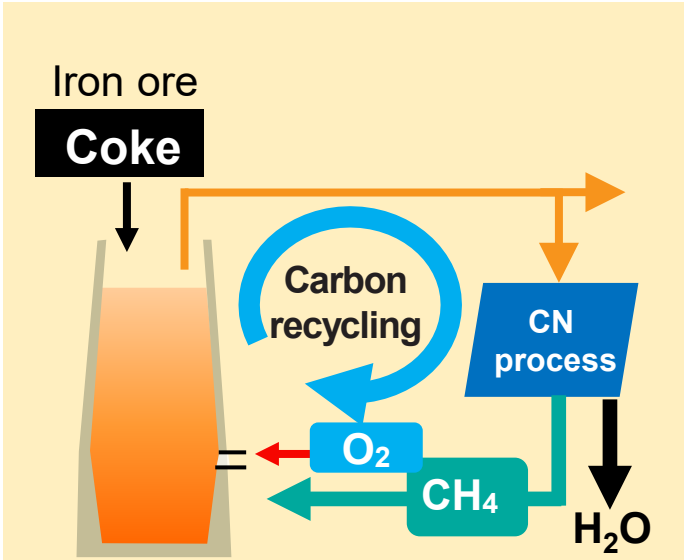
https://www.jfe-steel.co.jp/en/company/pdf/carbon-neutral-strategy_220901_1.pdf

Technology development to achieve carbon neutrality in ironmaking

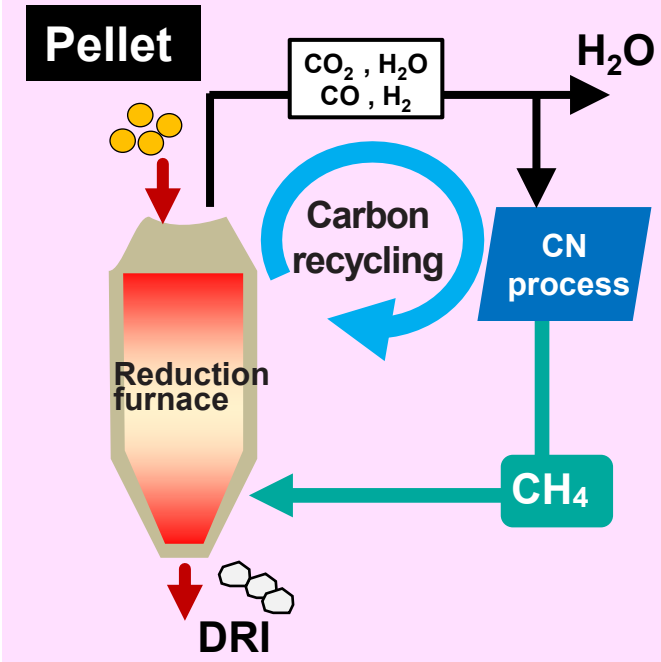
Promote the realization of carbon neutrality by developing technology that combines the conventional blast furnace method and direct reduction method and carbon recycling.



Blast furnace　　Shaft furnace



Carbon recycling
Blast furnace



Carbon Recycling
Shaft Furnace

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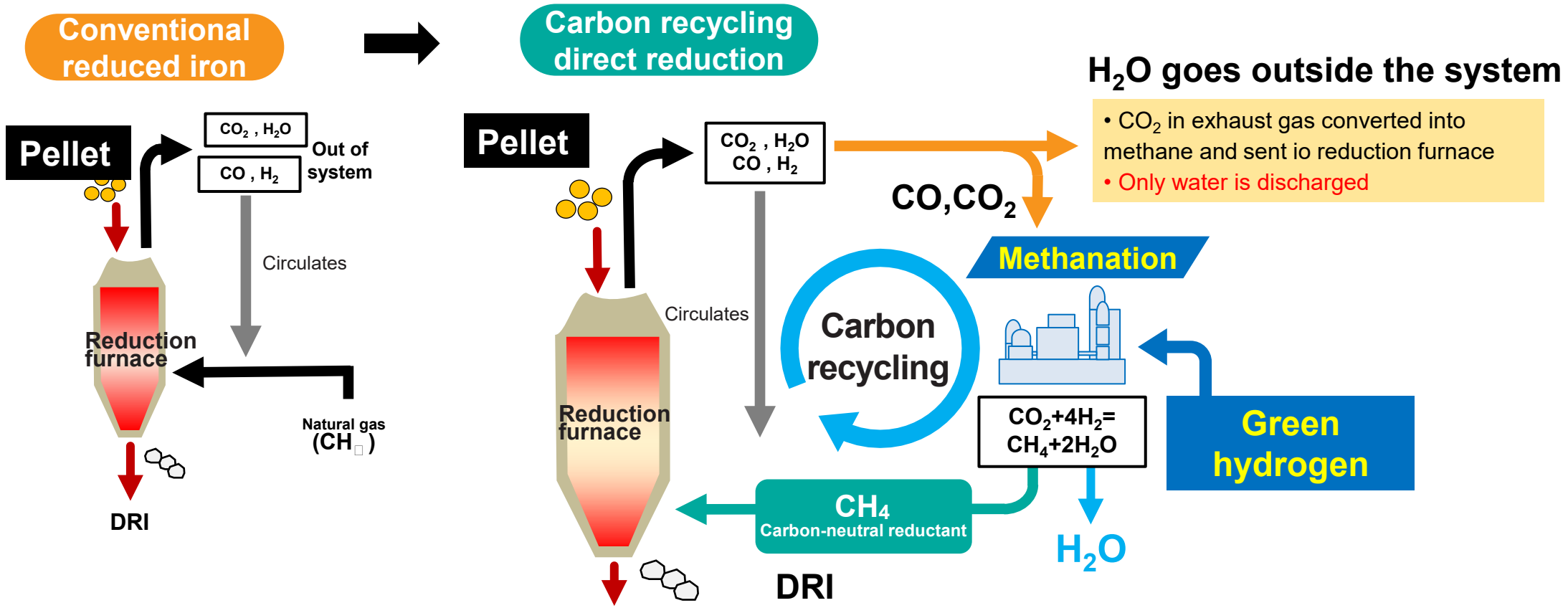
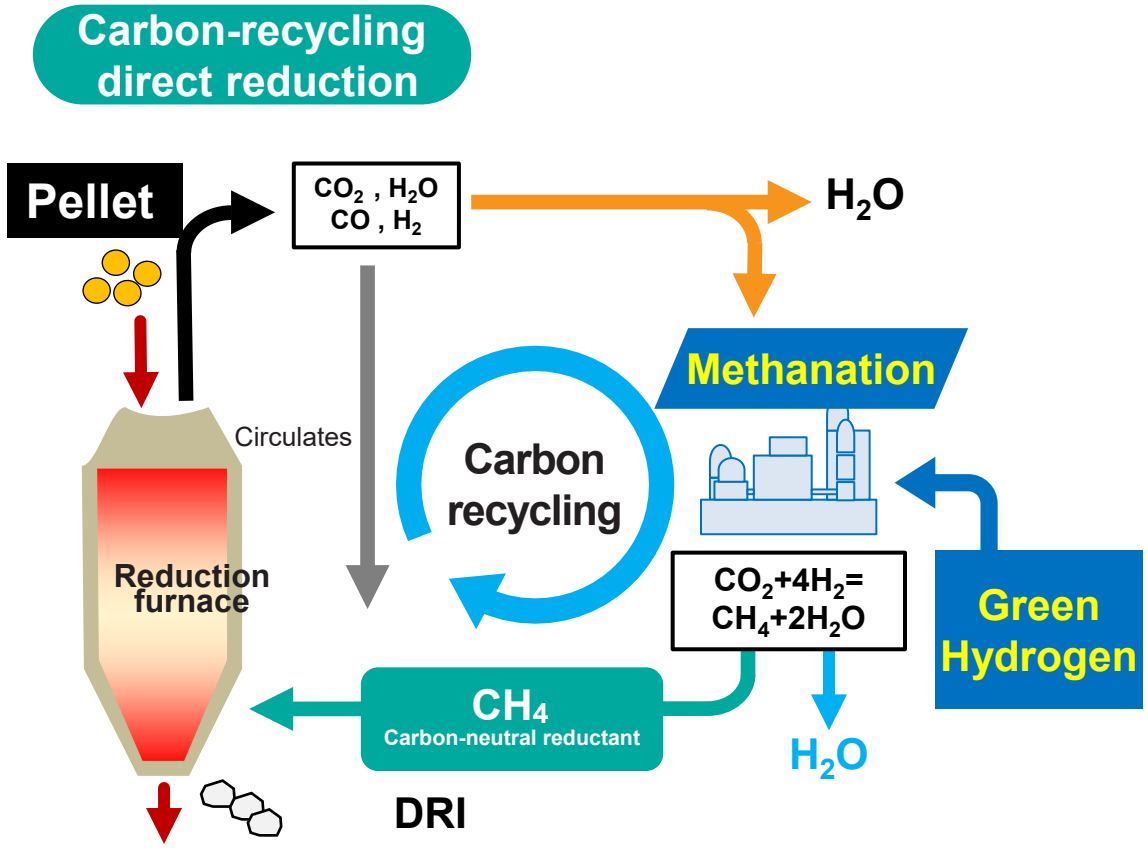
Overview of carbon recycling (CR) shaft furnace

- **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**



Technical development items related to CR shaft furnace

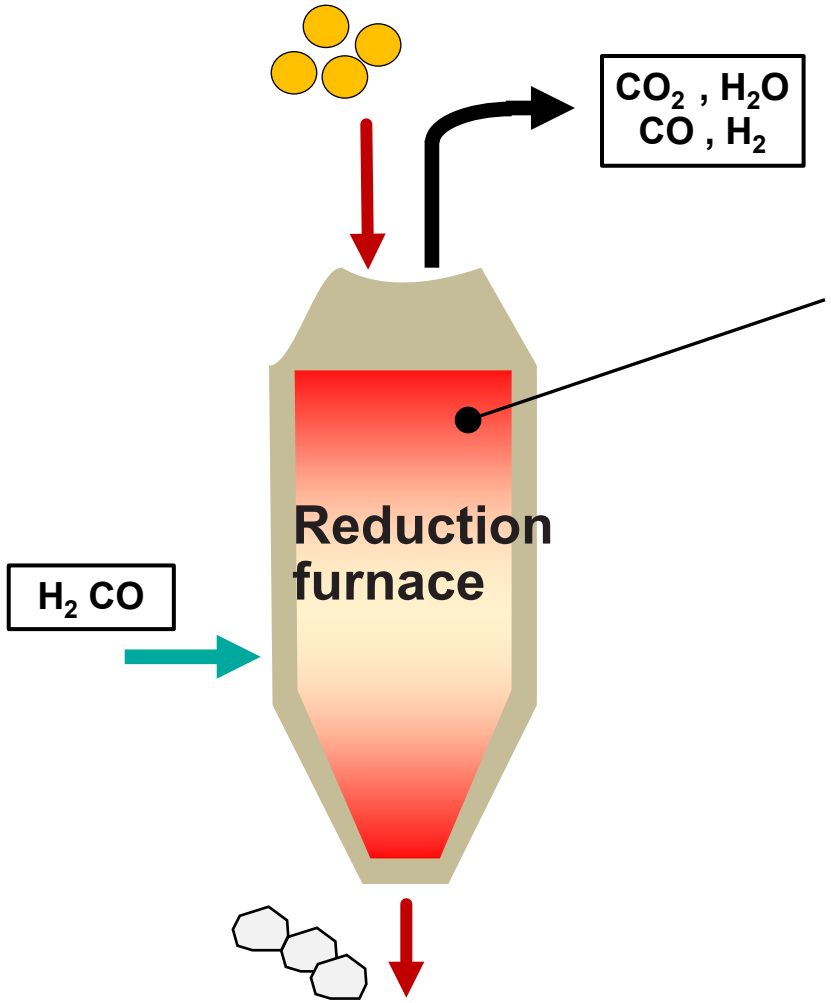


・Reduction with hydrogen is a highly endothermic reaction.

・Avoids CO_2 emissions outside the system and heat absorption in the shaft furnace, by using CR.

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

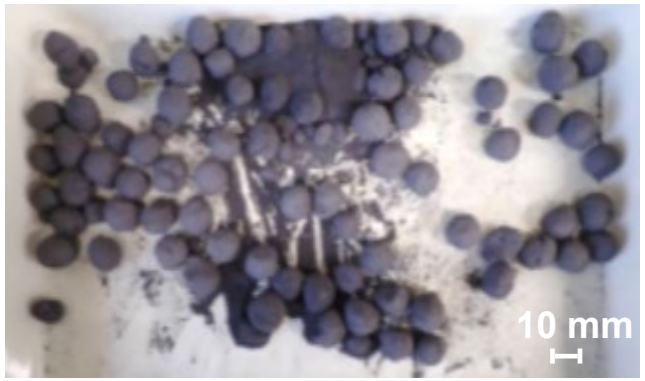
Issues with endothermic reaction



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

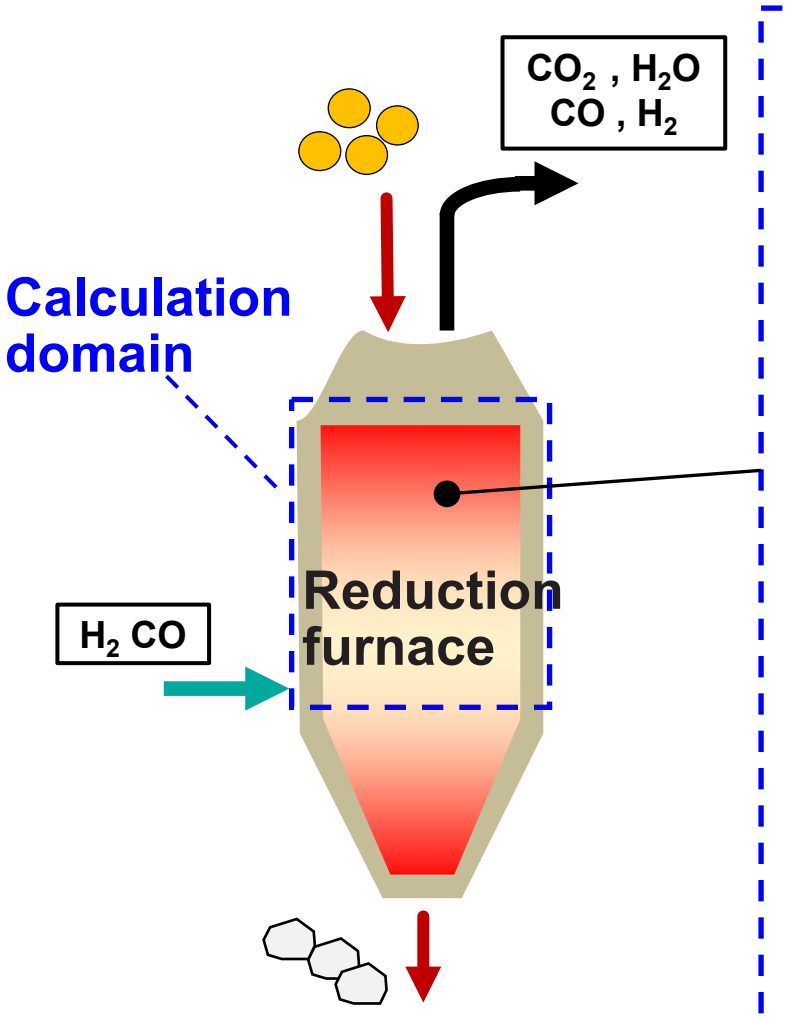
・Lowering the reaction temperature may cause the reduction degradation of pellet.

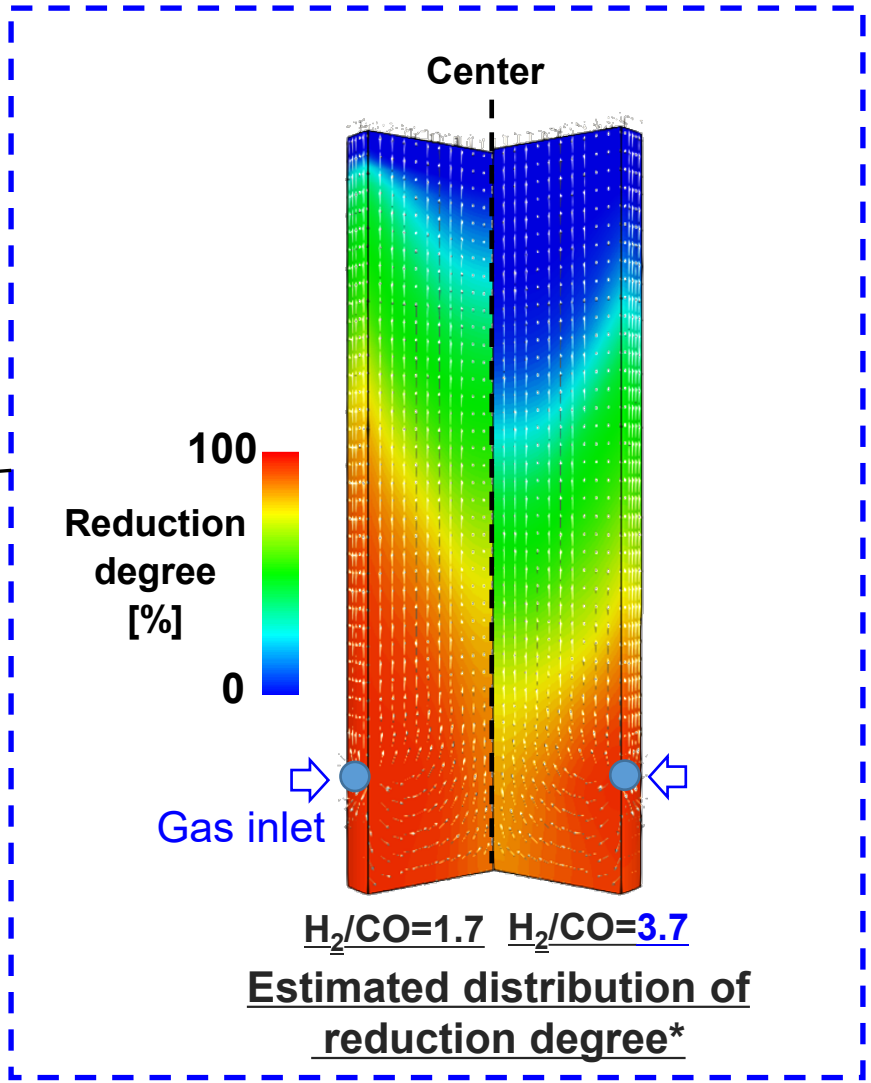
・H_2/CO = 4.0
・After tumbling test



Degradation of pellet

Impact evaluation of large amount of hydrogen injection





Estimated distribution of reduction degree*

- By increasing the hydrogen ratio in the reducing gas, the low reduction area inside the furnace is expanded.
- There is a possibility that the reduction degradation that occurs in the low reduction rate region will be significant.

*) Iwanaga, *et al*: The 183rd ISIJ Meeting

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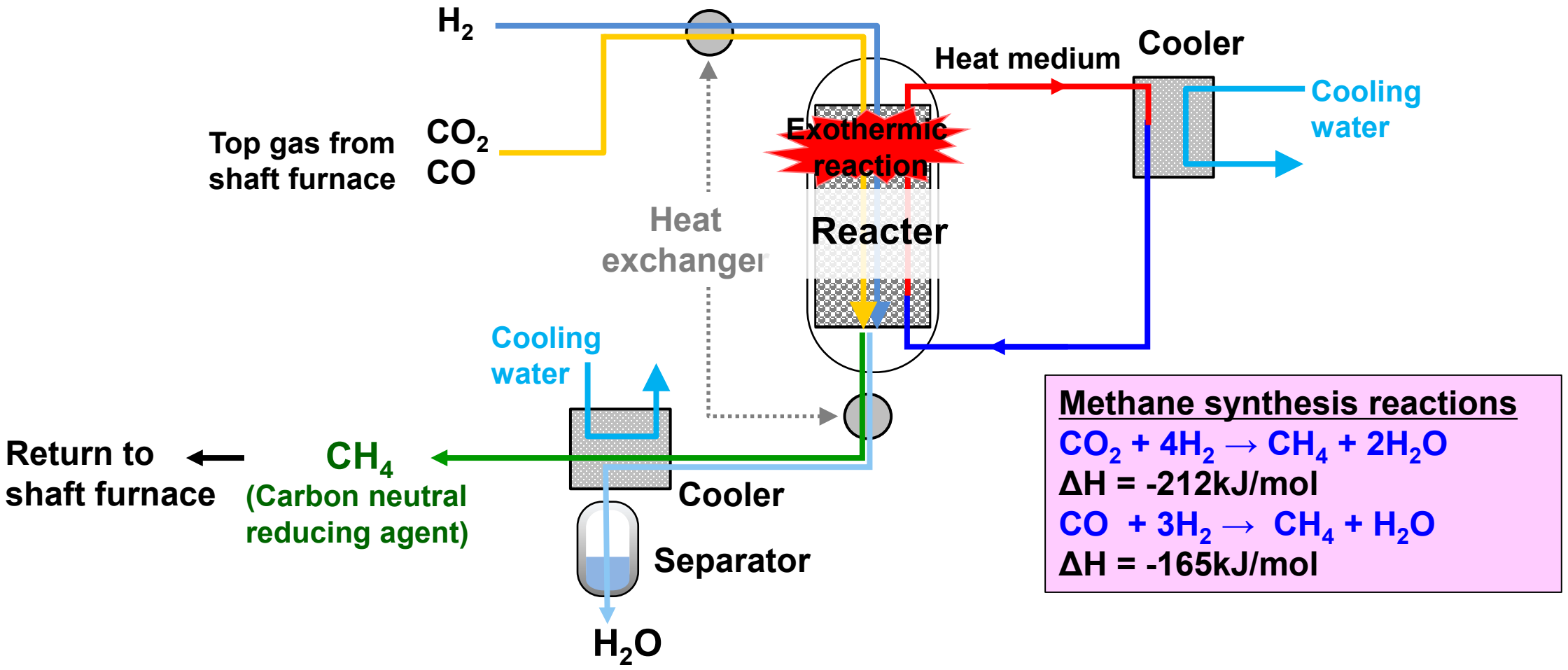
Overview of methanation

Methanation technology

- A technology converts CO_2 and CO into methane (carbon neutral reducing material) using green hydrogen.
- One of the promising CCU technologies needed to realize a carbon-neutral society.



Methane synthesis reactions

$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

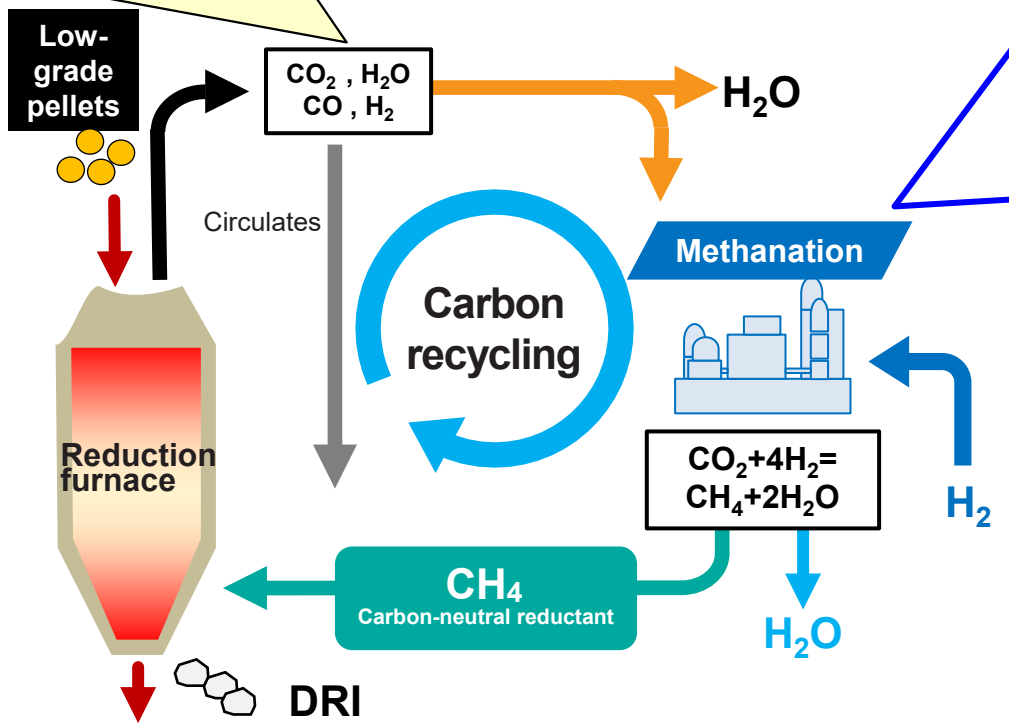
$\Delta H = -212kJ/mol$

$CO + 3H_2 \rightarrow CH_4 + H_2O$

$\Delta H = -165kJ/mol$

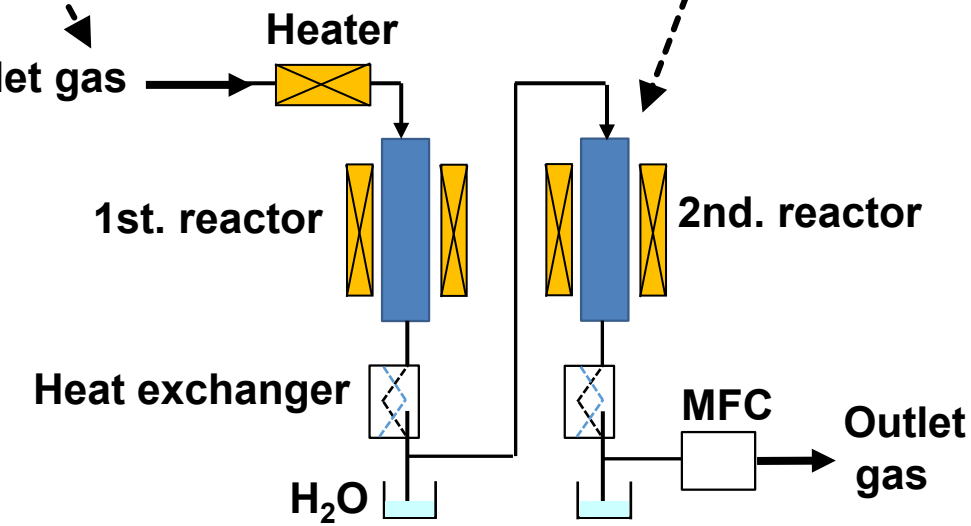
Investigation of methanation efficiency under various conditions

Top gas composition varies depending on the raw material quality and operating conditions.
Appropriate distribution of circulating gas is necessary.



Experimental conditions
- $CO_2/(CO_2+CO)=0.1$
- Gas composition
CO, CO2, H2, H2O
- Experiment time:4hr

Reactor
- Catalysis: Ni-based
- Temperature: 230°C
- Pressure: 0.7MPaG



Experimental apparatus

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.

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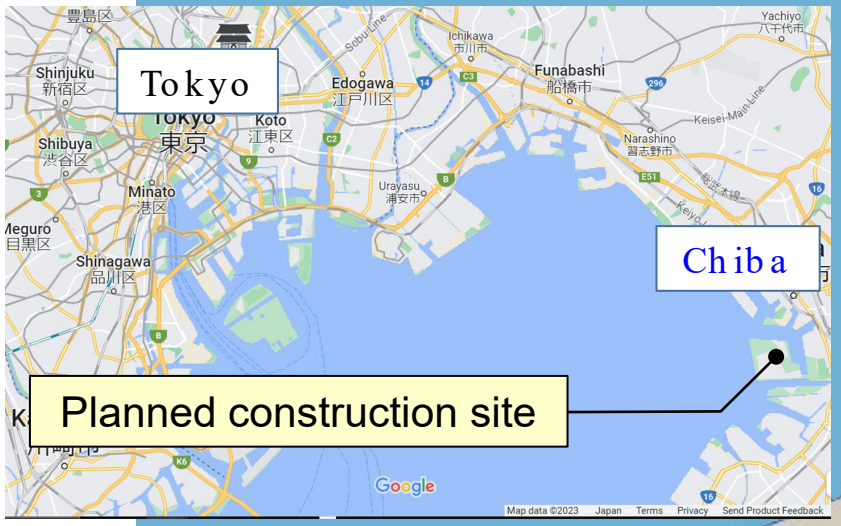

Test furnace will be built at JFE Steel's East Japan Works, and testing is scheduled to begin in 2024.

Summary

・JFE Steel plans to develop carbon recycling (CR) direct reduction steelmaking.

・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.

・Bench-scale test furnace will be built at JFE Steel's East Japan Works, and testing is scheduled to begin in 2024.

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