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The Breakthrough Technology Conference

Innovative Blast Furnace Process Aimed at Reducing CO_2 Emissions by Combining Carbon Recycling Technology

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Today's Topics

1. Background

2. Concept of Carbon Recycling Blast Furnace

3. Evaluation of reduction of CO_2 emission by simulation model

4. Conclusions

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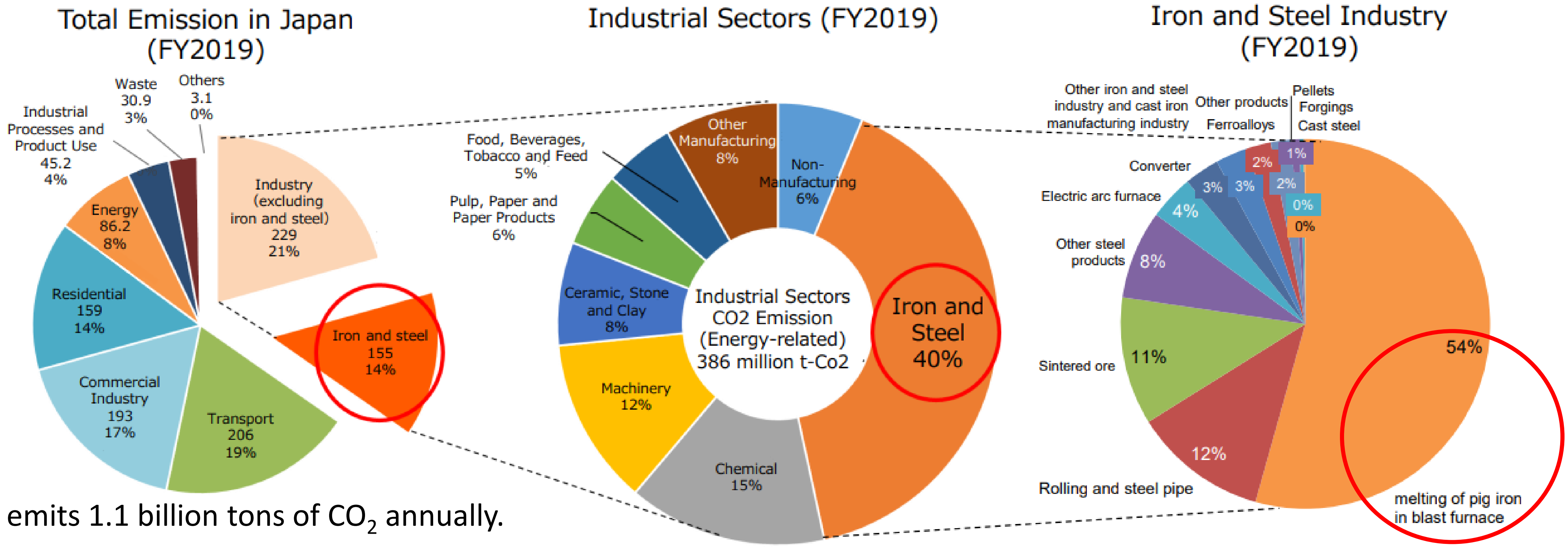
Current Status of CO_2 Emission in Japan

Reducing the amount of CO_2 emission is an urgent issue in Japanese iron and steel industry.
In particular, it is important and impactful to reduce CO_2 emissions from the blast furnace process.

<Amount of CO_2 emission> *Unit: 1 million tons of CO_2

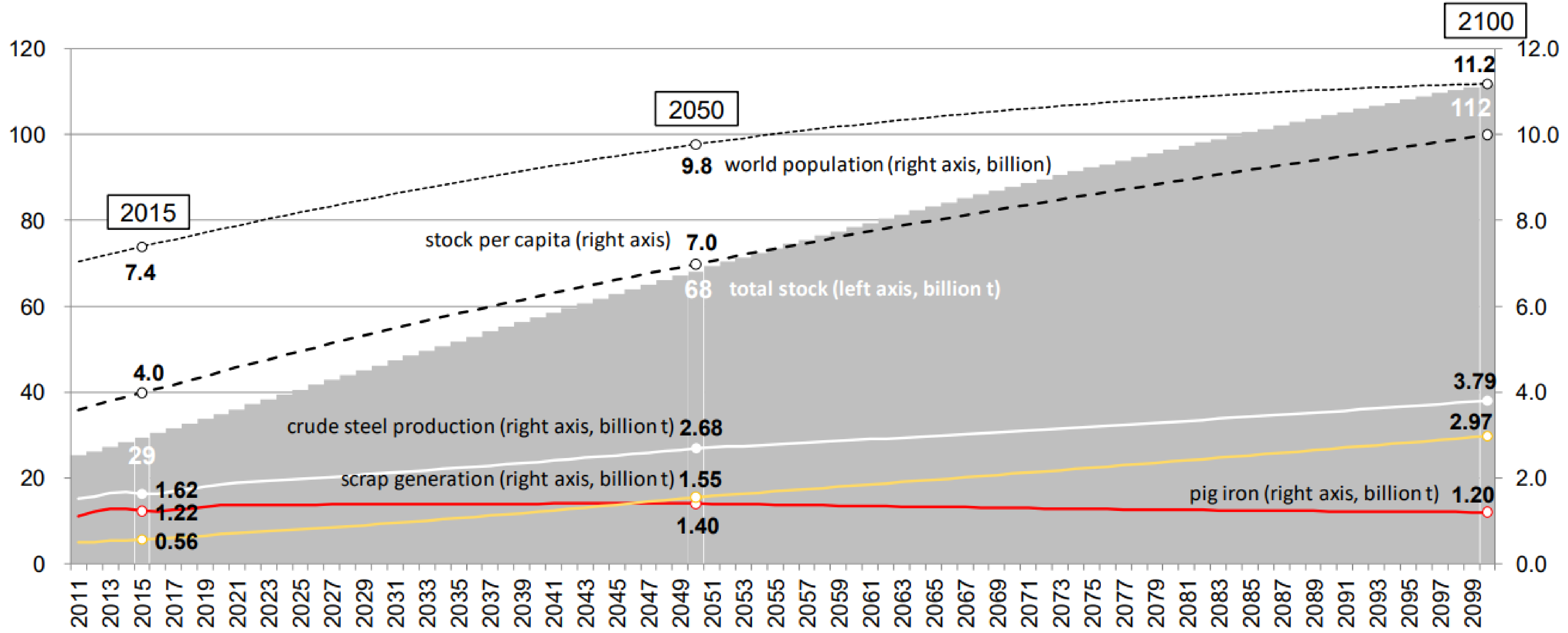


Japan emits 1.1 billion tons of CO_2 annually.

[Technology Roadmap for "Transition Finance" in Iron and Steel Sector; Ministry of Economy, Trade and Industry]
(Source) Japan's National Greenhouse Gas Emissions in Fiscal Year 2019 (Final Figures), National Institute for Environmental Studies, Comprehensive Energy Statistics; the Ministry of Economy, Trade and Industry

Why blast furnace?

Pig iron production is expected to remain at roughly current levels at the end of the century. (The Japan Iron and Steel Federation)
→ The way to utilize the blast furnace process is also investigating for utilization of existing facilities and price competitiveness.

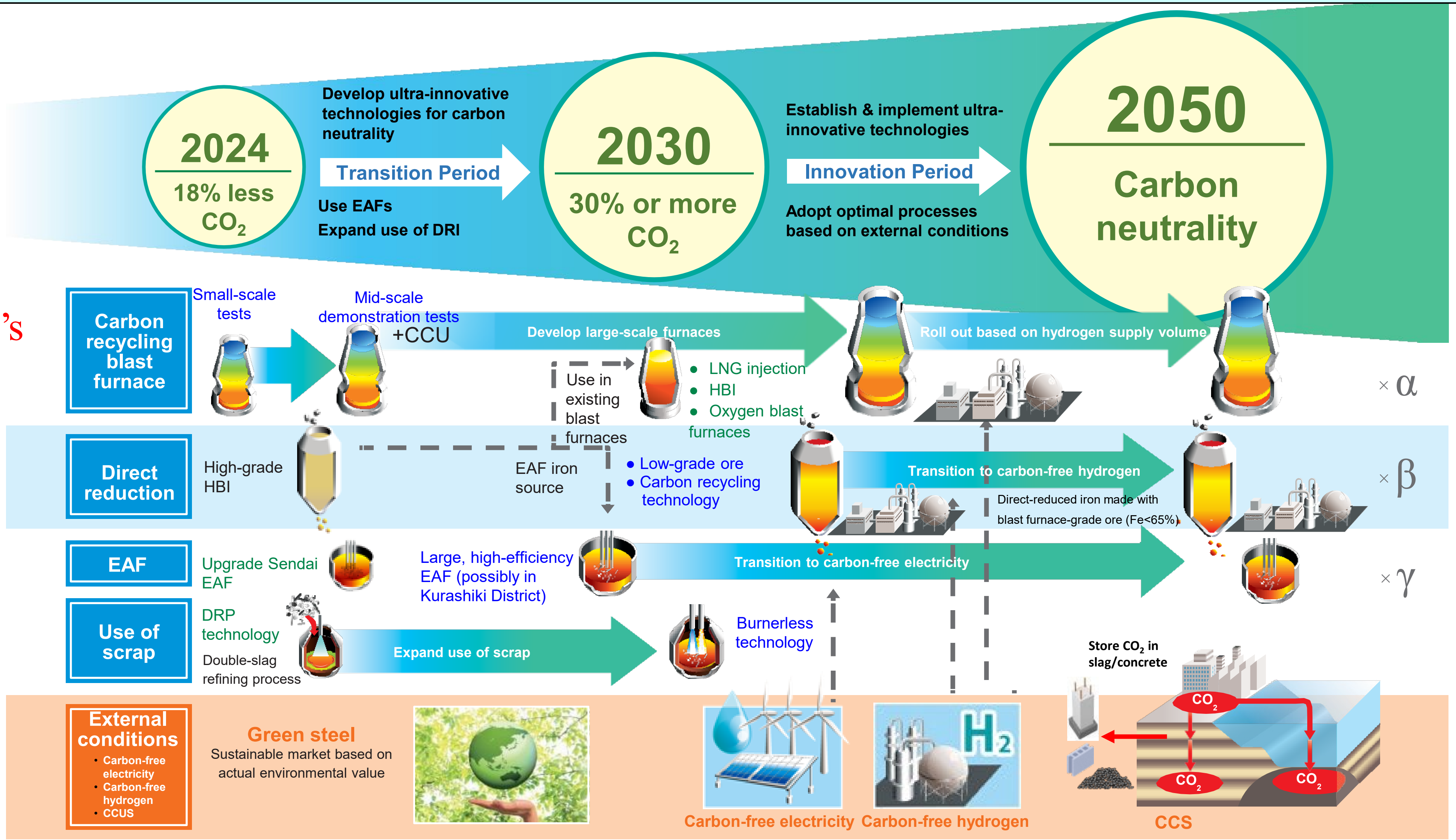


"Long-term vision for climate change mitigation: A challenge towards zero carbon steel" (JISF Long-term Vision), Nov. 2018.
https://www.jisf.or.jp/en/activity/climate/documents/JISFLong-termvisionforclimatechangemitigation.pdf

JFE Steel's Transition to Low-carbon Processes

To achieve carbon neutrality, deployment of the most optimized configuration of green steelmaking processes is investigated.

Today's topic



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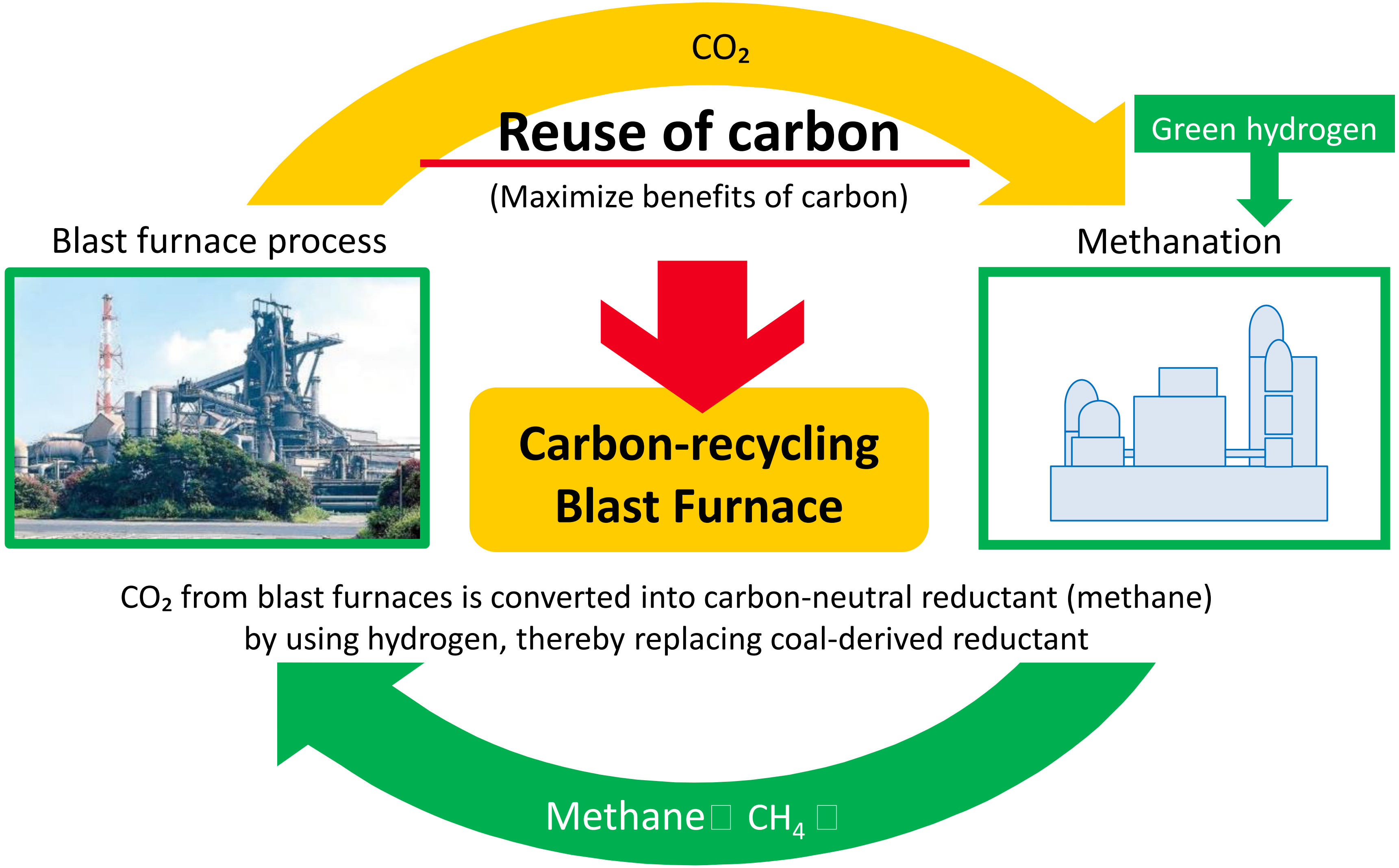
Concept of Carbon-recycling Blast Furnace

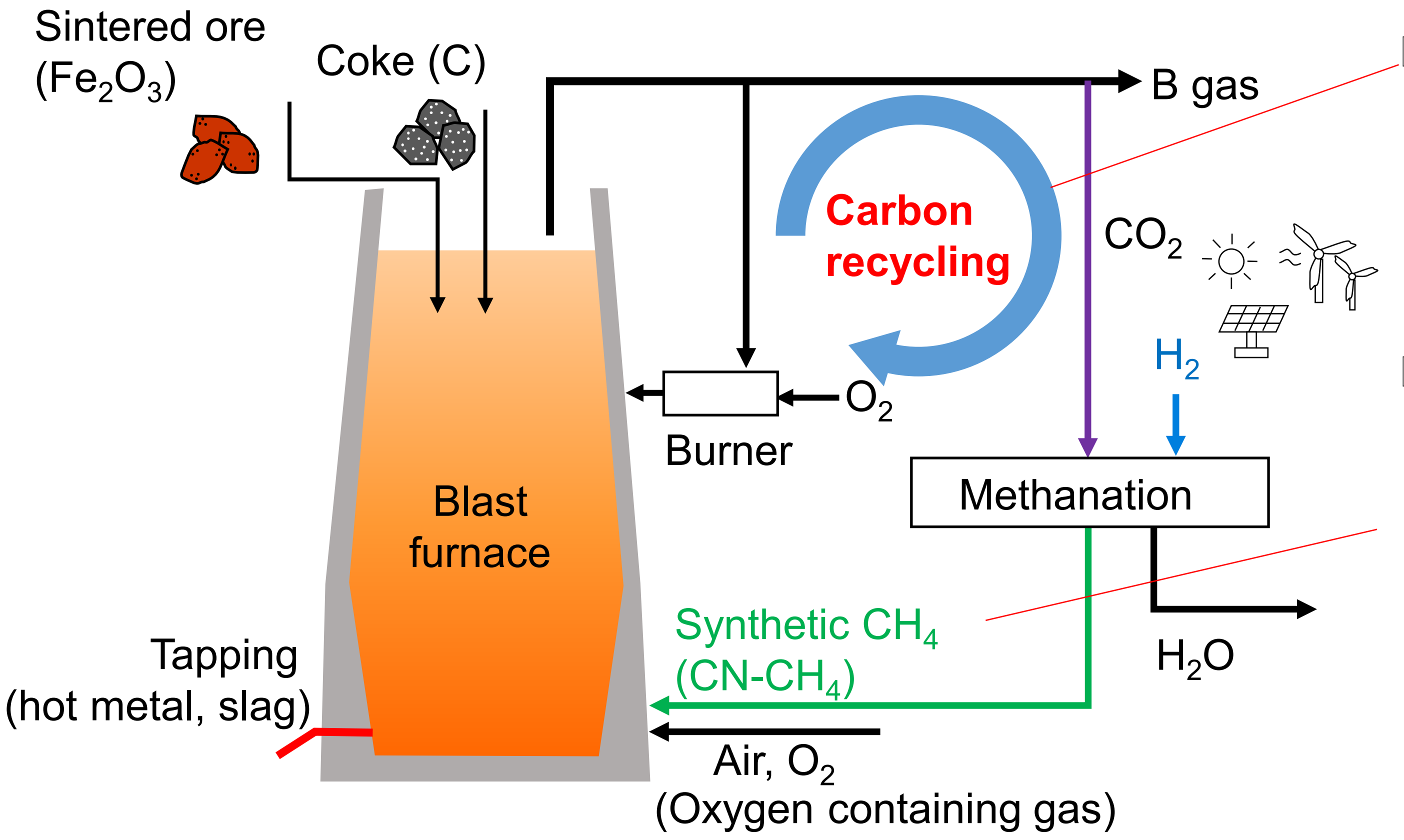
The aim of the carbon-recycling blast furnace is to achieve carbon neutrality by repeatedly reusing carbon. This is achieved by converting the CO_2 generated in the blast furnace process to methane by methanation using green hydrogen.



Concept of Carbon-recycling Blast Furnace

Carbon is recycled by using the methane synthesized from CO_2 in exhaust gas from blast furnace (B gas) and green H_2.
The aim is to enhance CO_2 reduction by converting H_2 to CN-CH_4. It is due to reacts with oxygen in front of tuyere.

□ A conceptual diagram of carbon-recycling BF□



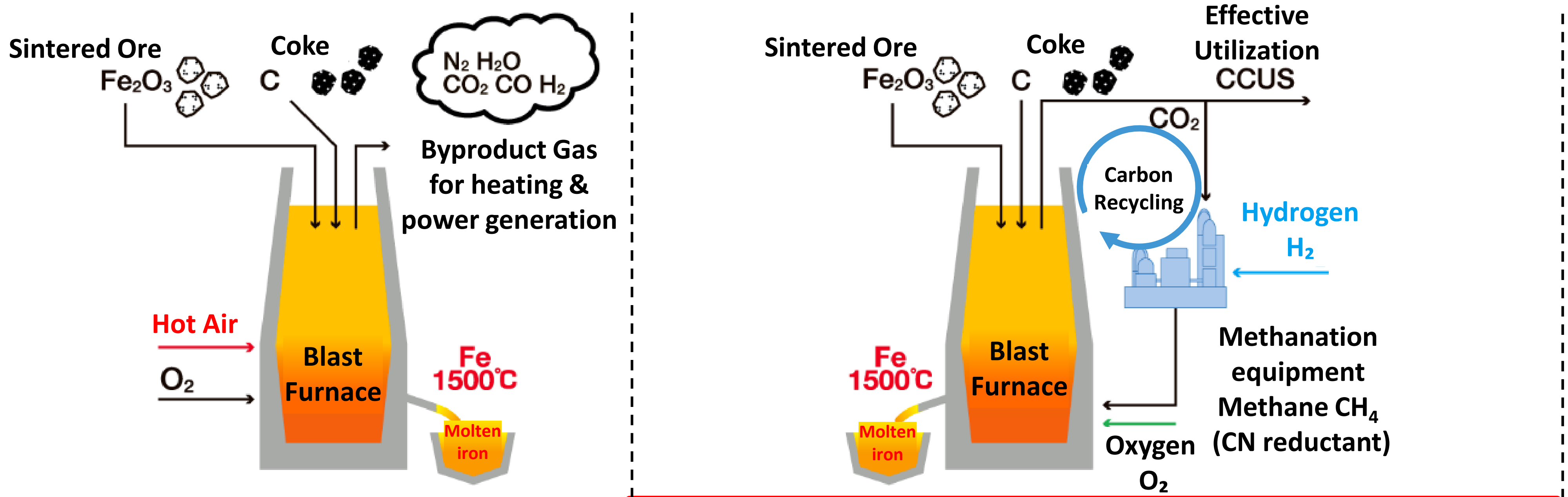
□ The **methane(CH_4)** is synthesized from CO_2 in B gas and green **H_2** and injected into BF. **Carbon is recycled**.

□ The aim is to decrease the amount of CO_2 emission by using **Carbon Neutral(CN)-CH_4** instead of **H_2**, which does not generate heat in front of the tuyere.

- H_2 → H_2 Does not generate heat
- CH_4 + (1/2)O_2 → CO + 2H_2 Generates heat

Characteristics of Carbon-recycling Blast Furnace

Combining carbon-recycling blast furnaces with carbon dioxide capture, utilization and storage (CCUS) will enable steel works to recycle CO_2 , thereby leading to net zero-carbon emissions. Carbon recycling blast furnaces can produce same scale iron and use same grade raw materials and produce same high-grade steels as conventional blast furnaces.



	Conventional blast furnace	Carbon-recycling blast furnace
Production scale	4 million tons per unit per year	4 million tons per unit per year (similar to normal blast furnace)
Reductant	Coke and pulverized coal	Coke and recycled methane
Raw materials	Low-grade raw materials possible	Low-grade raw materials possible
CO_2 emissions	Two tons of CO_2 per ton of pig iron	Targeting zero (blast furnace reductions and CCUS methods)

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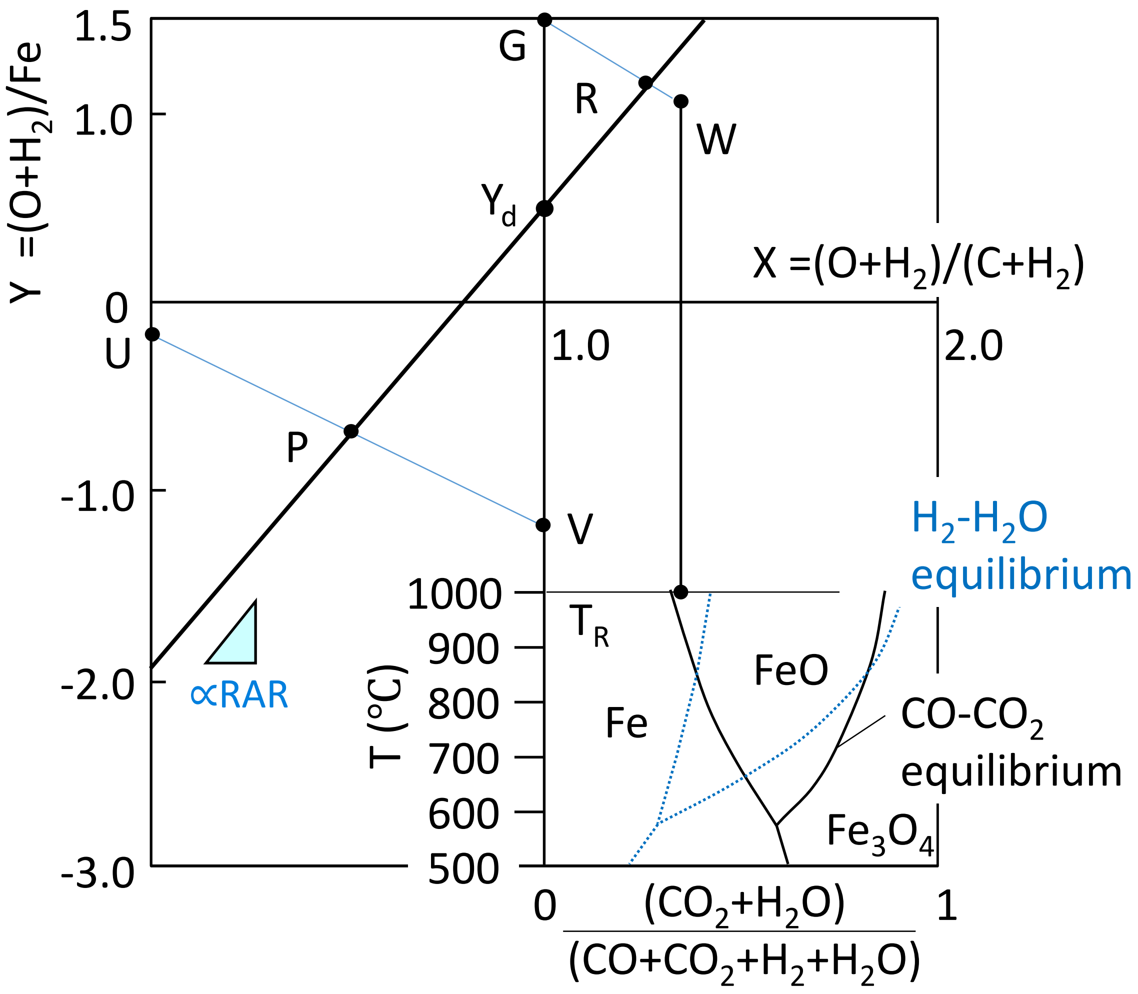
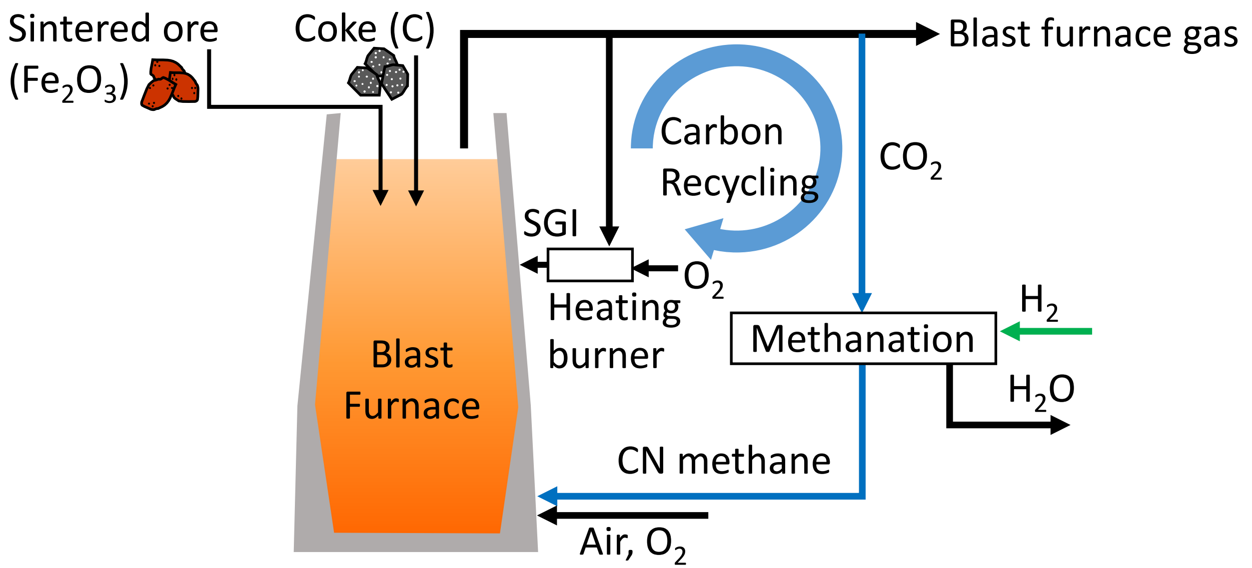
Evaluation method by simulation model (Rist diagram)

The potential amount of CO_2 emissions reduction in a blast furnace process using the carbon recycling technology was studied with a Rist diagram (Heat and mass balance simulation model of the blast furnace).



<Evaluation method and assumption>

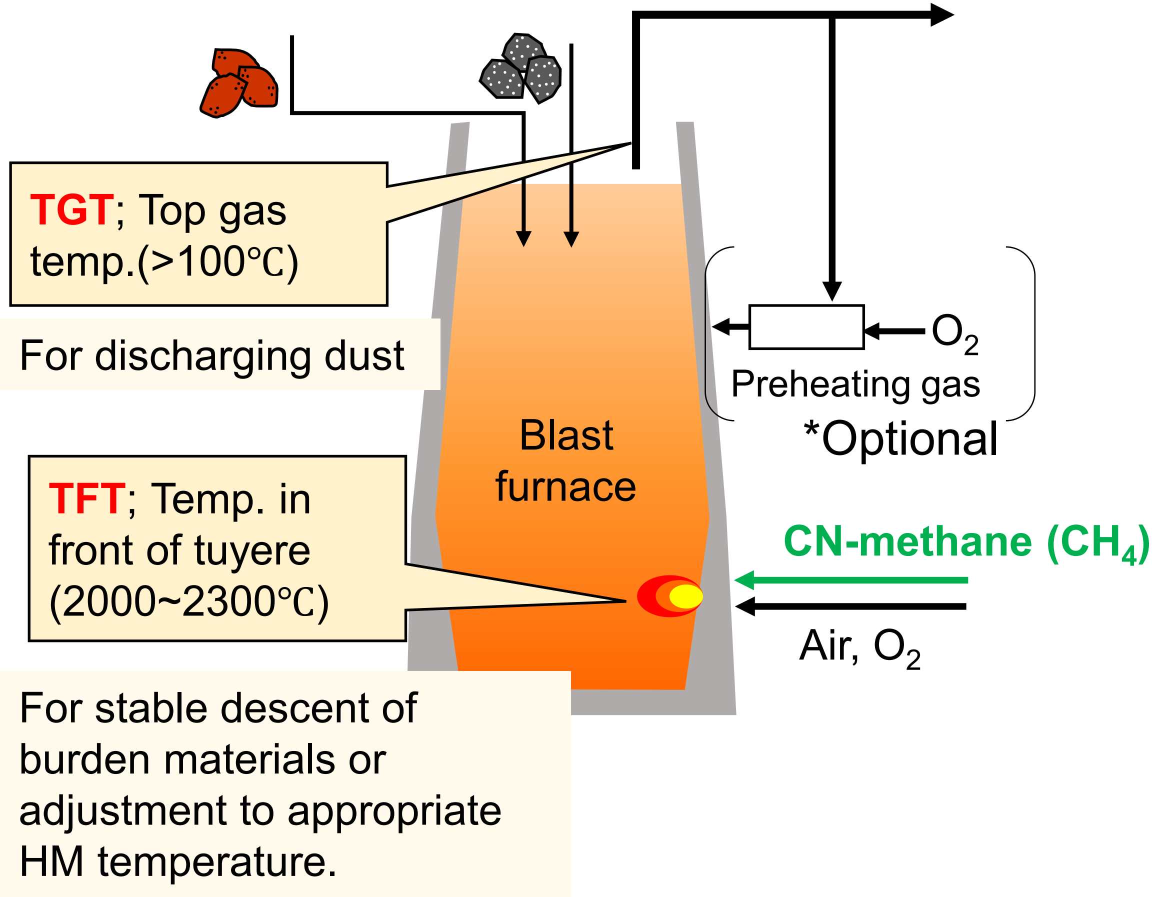
- Evaluate blast furnace operation considering operational constraints (Theoretical Flame Temperature(TFT), furnace Top Gas Temperature(TGT))
- Calculate blast temperature assuming mixing of hot air and room temperature oxygen
- Calculate CO_2 emissions from carbon consumption (slope is reducing agent ratio(RAR) = carbon consumption)
- Carbon of carbon neutral(CN) methane gas and Carbon for preheating gas injection(SGI) is not counted (Because both carbon circulate in the system)



Calculation conditions

The optimum operating mode was investigated in consideration of the operable range. (TGT, TFT)
The injection amount of CN-CH_4 and the O_2 concentration in blast are changed. Operational change is predicted.

□ **Operation constraints** on BF□



□ Input condition□

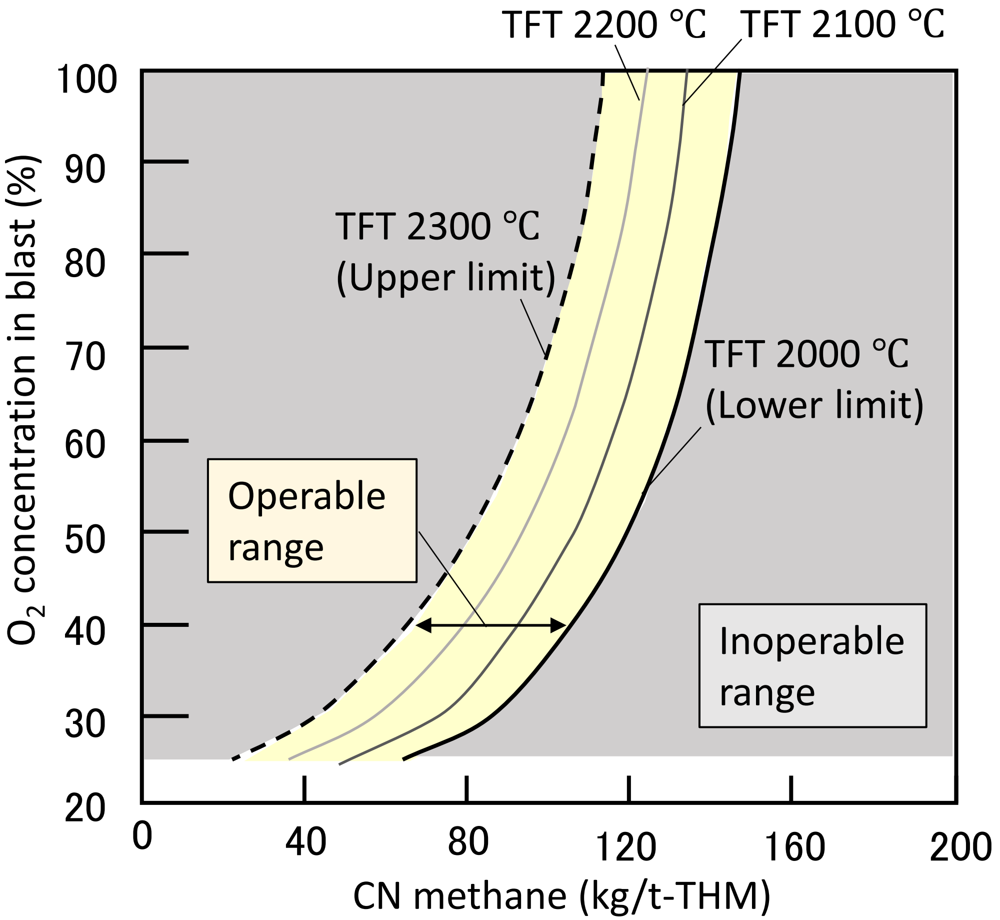
Item	Range	Note
Injection amount of CN-methane	0 ~ 200kg/t	Excluded from calc. of CO_2 emissions
O_2 concentration in blast	25 ~ 100%	The details are on the next page.
Blast temp.	1200 ~ 25℃	According to the O_2 conc. in blast

□ Output□

- □Coke ratio
- □**Amount of CO_2 emission**
- □TFT , TGT …

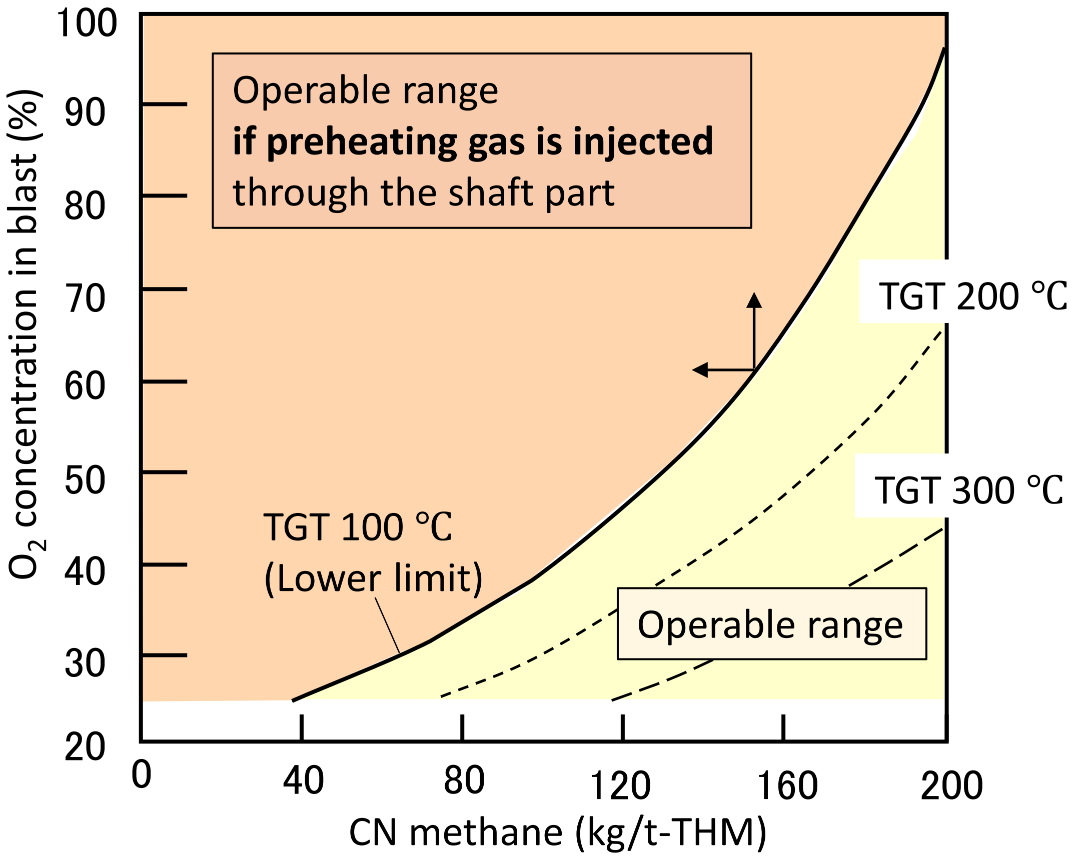
Calculation results (Theoretical Flame Temperature: TFT)

Calculate operation condition to satisfy the heat and mass balance by changing CN methane rate and O_2 concentration in blast.
TFT decreases due to increase in CN methane injection rate and TFT increases due to increase in O_2 concentration in blast.
The upper and lower limits of TFT were set at 2300˚C and 2000˚C, respectively, based on actual operation results.



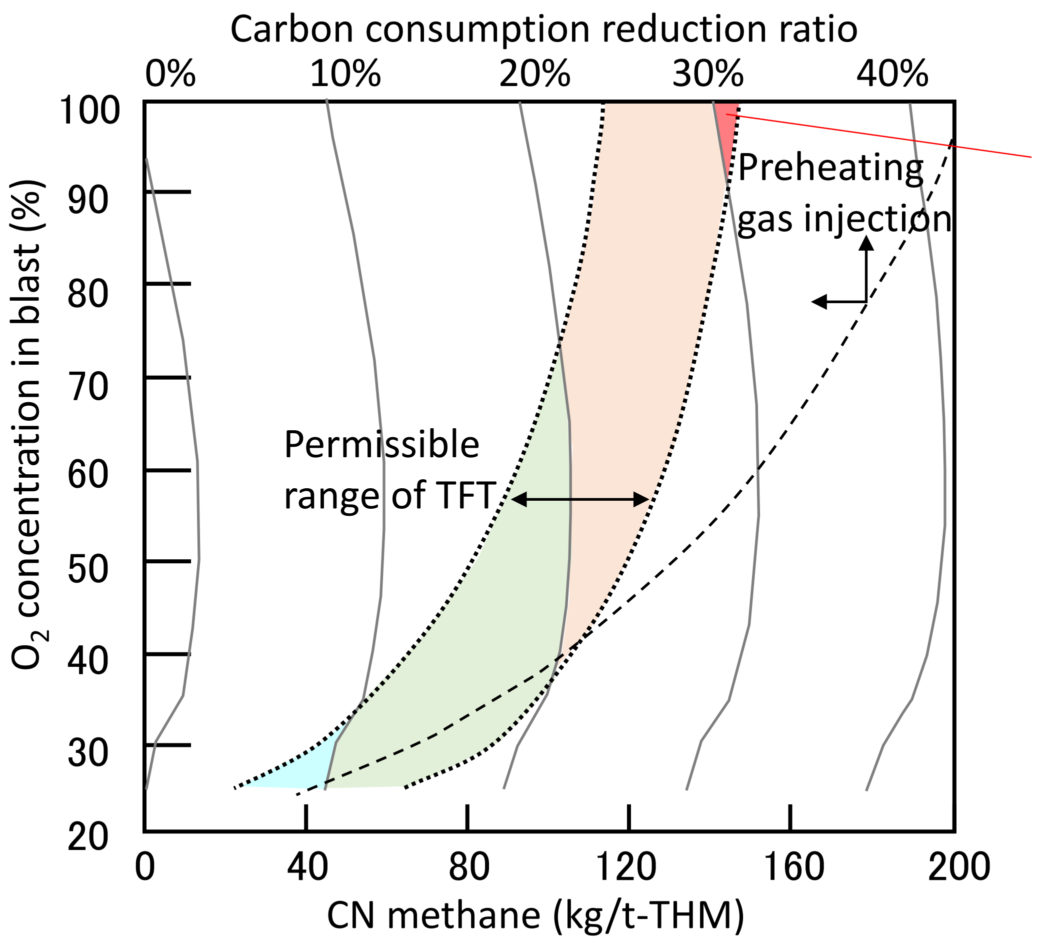
Calculation results (Top Gas Temperature : TGT)

TGT increases due to increase in CN methane injection rate because gas volume through blast furnace increases, and TGT decreases due to increase in O_2 concentration because gas volume through blast furnace decreases.
It is necessary to maintain TGT by using SGI below 100℃. → By using SGI, lower limit of TGT can be avoided.



Calculation results (CO_2 emission reduction ratio)

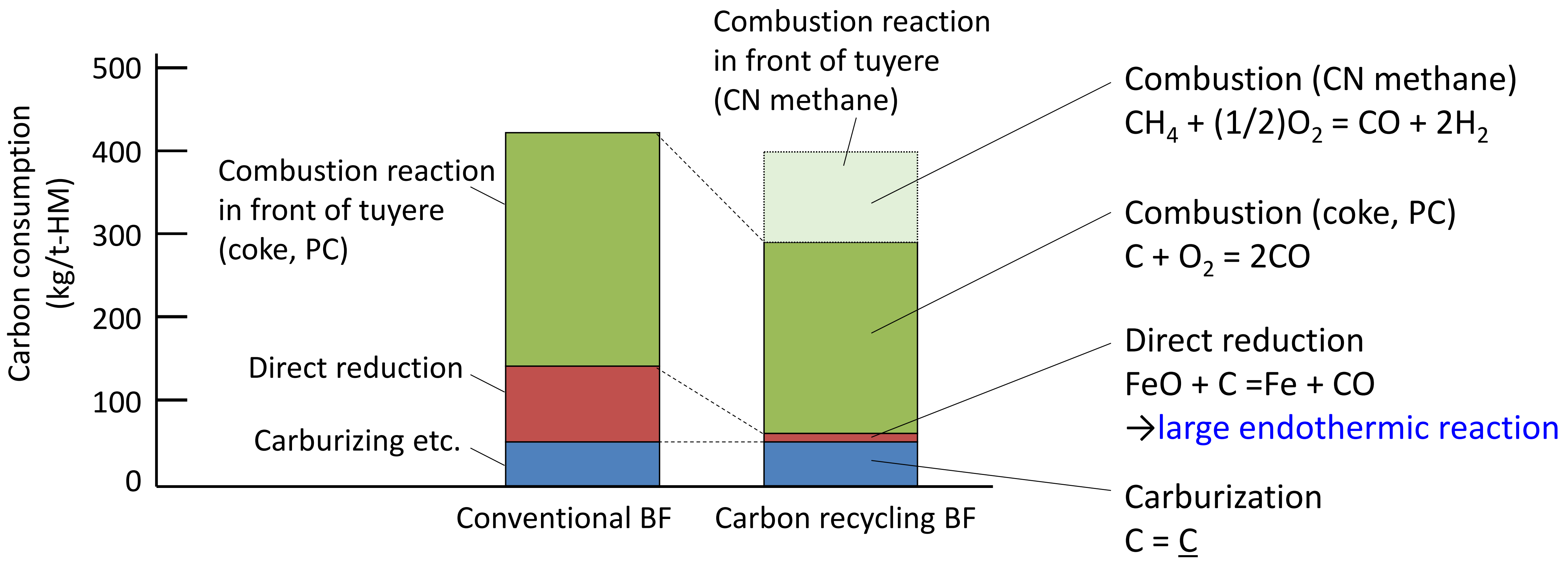
Carbon consumption reduction ratio increases due to increase in methane injection rate.
High O_2 concentration and SGI are required to increase carbon consumption reduction ratio (for maintaining TFT and TGT).
Maximum CO_2 reduction ratio was obtained under conditions of O_2 100% and increase in methane up to the TFT lower limit.



Maximun carbon consumption reduction
≒CO_2 emission reduction
(more than 30%)

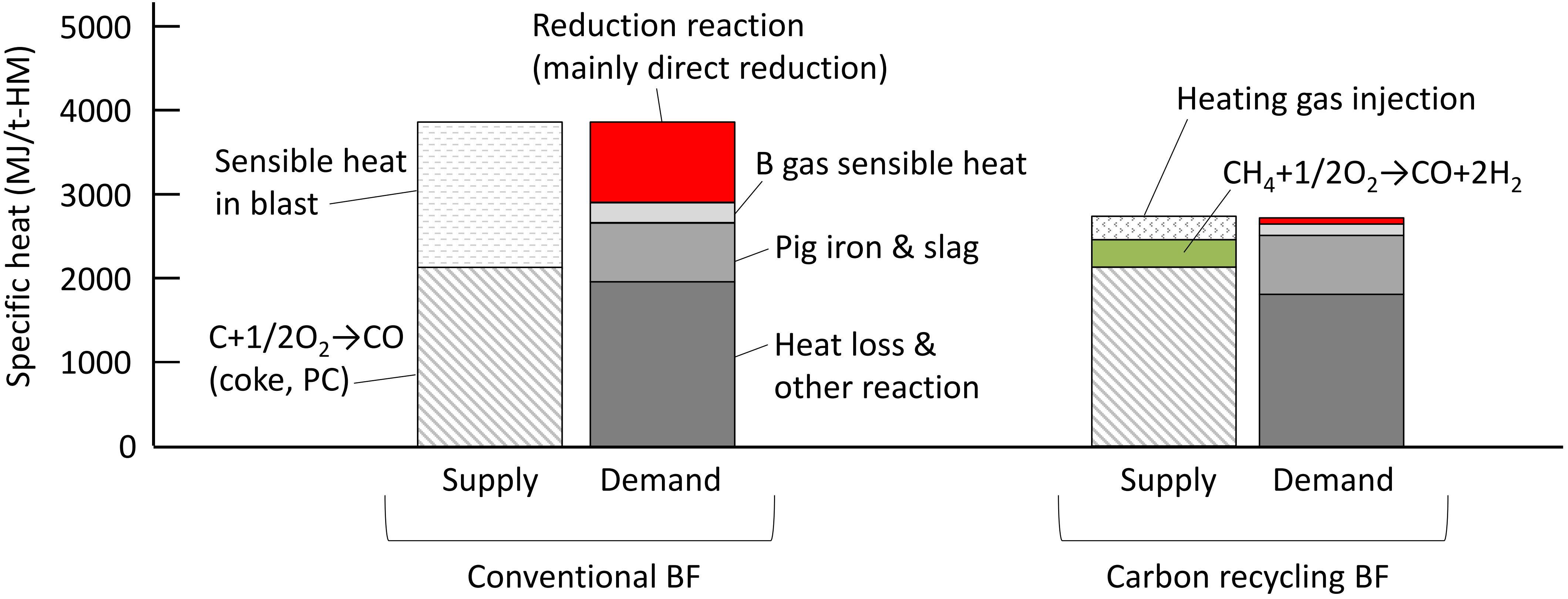
Change in carbon consumption balance

In the carbon recycling blast furnace, carbon consumption by direct reduction decreases greatly.
The amount of the combustion reaction in front of the tuyeres is high, but a part of the carbon of the combustion reaction is the CN methane carbon, so the amount of the coke consumption in front of the tuyeres is approximately same.



Change in heat balance

In the carbon recycling blast furnace, the amount of heat necessary for reduction reaction is small due to the small amount of direct reduction (large endothermic reaction). Therefore, the heat demand is reduced (approximately 1 000 MJ/t-HM). Sensible heat by hot blast is reduced, but increase in heat supply by combustion reaction of coke is supressed because a part of the heat is supplied by combustion reaction in front of the tuyeres of CN methane.



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Reduction of CO_2 emissions by the carbon recycling blast furnace was studied using the Rist diagram approach, and the following knowledge was obtained.

(1) Use of carbon neutral (CN) methane reduces the CO_2 emission of the blast furnace by the decrease in the amount of direct reduction and supply of heat by reaction with oxygen in front of the tuyeres.

(2) It is possible to reduce CO_2 emissions more than 30% at a maximum by using CN methane in the blast furnace.

(3) In maximizing CN methane injection, oxygen blowing and preheating gas injection from the upper shaft level are effective.

Thank you for your kind attention

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