



7TH ESTAD



**ASSOCIAZIONE
ITALIANA DI
METALLURGIA**

**EUROPEAN STEEL TECHNOLOGY
AND APPLICATION DAYS**

VERONA, ITALY

6-9 OCTOBER 2025

**Beyond Carbon Neutral with
Ultra-low Coke-rate Blast Furnace**

Takeshi Sekiguchi SimpLE-labo Co., Ltd.

Beyond Carbon Neutral with Ultra-low Coke-rate Blast Furnace**SimpLE: Smart iron-making process for Low Emissions****Our Aims:**

- **Introduce “SimpLE” as a two-step pathway to/beyond carbon-neutral ironmaking :**
 - *Step 1, Ultra-low coke-rate BF (verified in [2])*
 - **Step 2, Utilizes *MSW-derived RDF as a renewable reductant* ⇔ *focus of today***
 - *Step 2 surpasses others in terms of energy saving, CO₂ reduction, and cost saving.*
- **Seeking collaboration for engineering, joint-research, pilot tests, etc.**

Beyond Carbon Neutral with Ultra-low Coke-rate Blast Furnace

Input/ Output for 1 ton of hot metal on a dry basis

	Conv.BF	SimpLE BF
Input (Coal)	700 kg	95 kg (Step1+2)
Input (MSW)	0 kg	700 kg (Step2)
Surplus heat incl. BOF gas	6.9 GJ	0 GJ (Step1)

In Step 1. coke rate (CR) is reduced to 1/5 and surplus heat reduces to zero.

In Step 2, MSW (RDF) is utilized to eliminate other fossil fuels except for ultra-low coke.

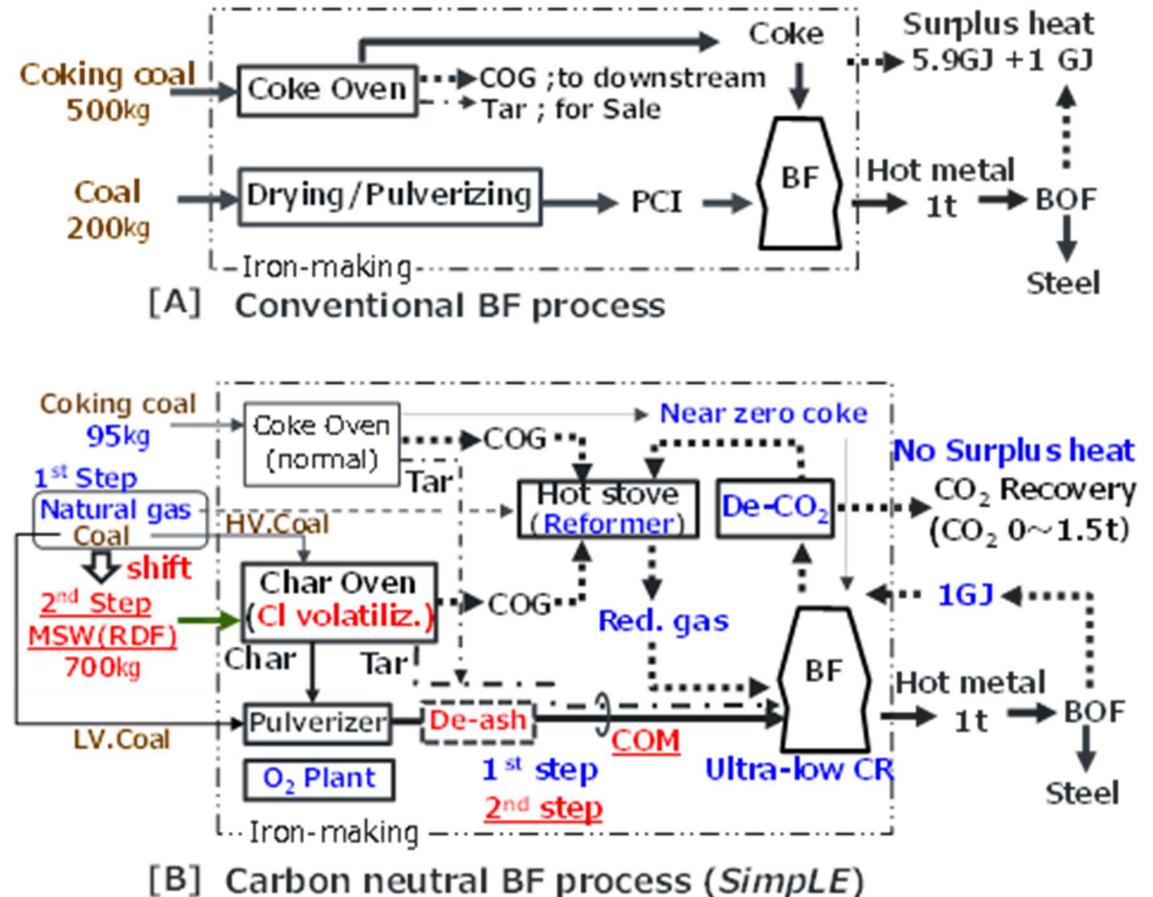
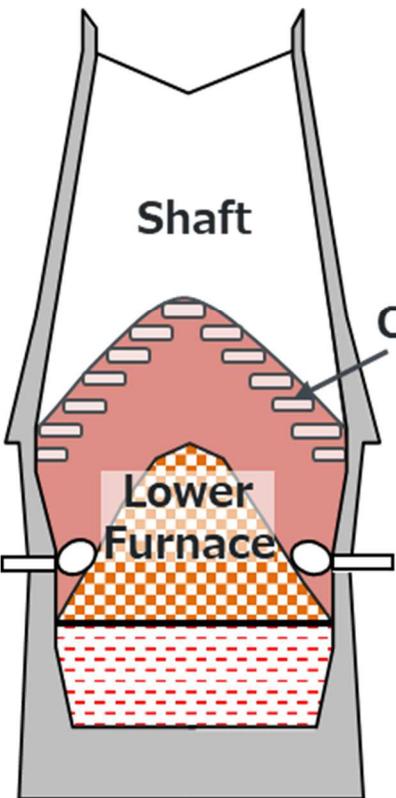


Fig.1 - Conventional BF and SimpLE BF (Step1, 2).

Beyond Carbon Neutral with Ultra-low Coke-rate Blast Furnace



critical issues to minimize coke rate

70% gas-based reduction ⇒
30% reduction by coke ①

Coke Slit

Coke slit as fire-grate ② ⇒
permeability/gas-distribution

PCI :Coke alternative ③④ ⇒
PC combustion efficiency

Carburization ⑤

Conv. BF

Key Roles of Coke :

- ① Direct reductant, ② Fire-grate, ③ Heat source, ④ Gas source, ⑤ Carburizer

Concepts to minimize CR :

- Smart reduction ⇒ 100% gas reduction ①
- Smart charging ⇒ Coke slit-less operation ②
- Smart combustion ⇒ Higher PC combustibility ③④

Beyond Carbon Neutral with Ultra-low Coke-rate Blast Furnace

Smart reduction

DRI process and Melter integrated

- O₂-BF with TGR like ULCOS-BF
- Fuel-reformer



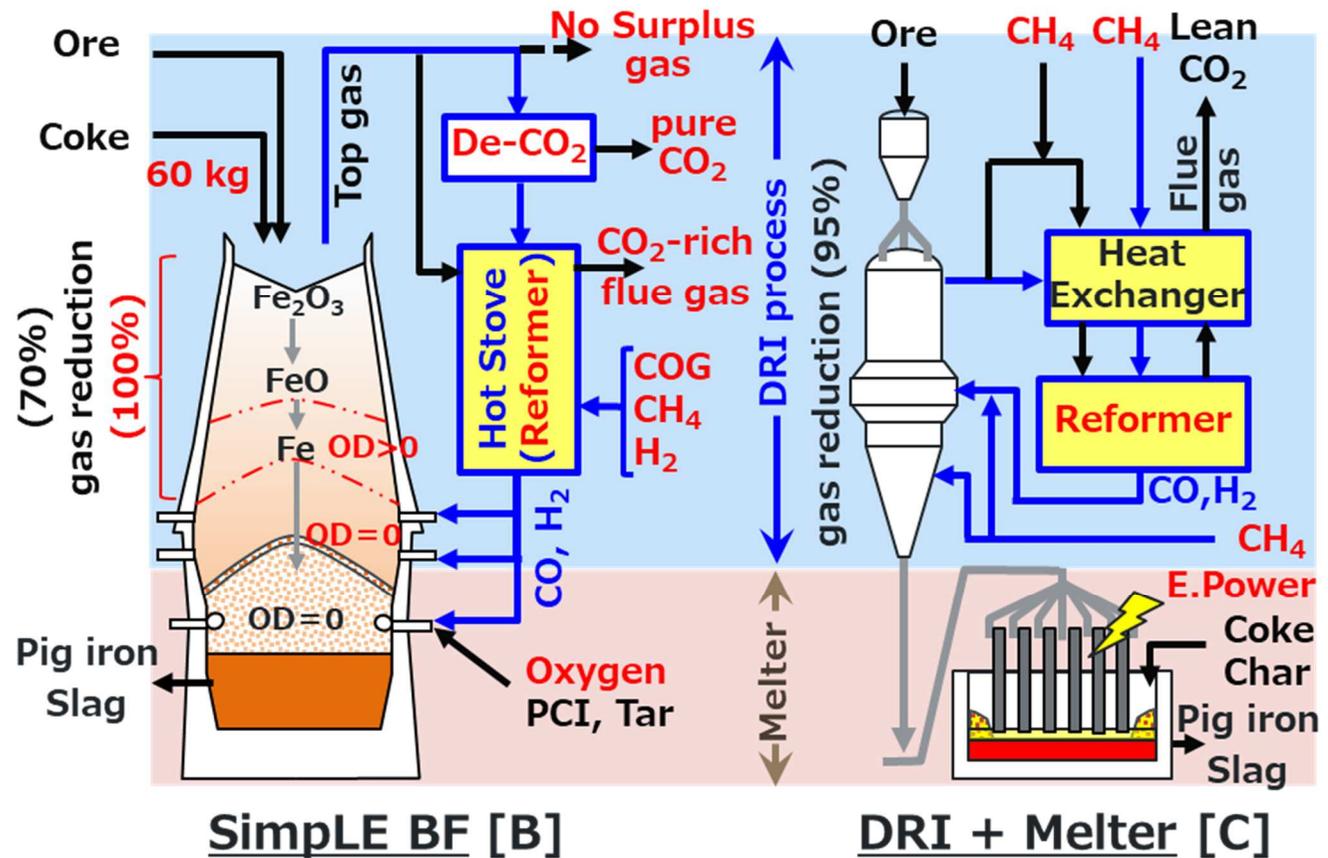
100% gas-based reduction



Reducing the lower furnace heat load



Ultra-low RAR(reducing agent rate)



Beyond Carbon Neutral with Ultra-low Coke-rate Blast Furnace

Smart reduction

3-stage tuyeres to control temperature ;
avoid sinter degradation

& coke gasification/degradation

⇒ Quality large coke to lower furnace

Ultra-low coke rate is achieved by

- Ultra-low reducing agent rate (RAR)
- Quality large coke
- **Smart Combustion** (raceway-free) [2]

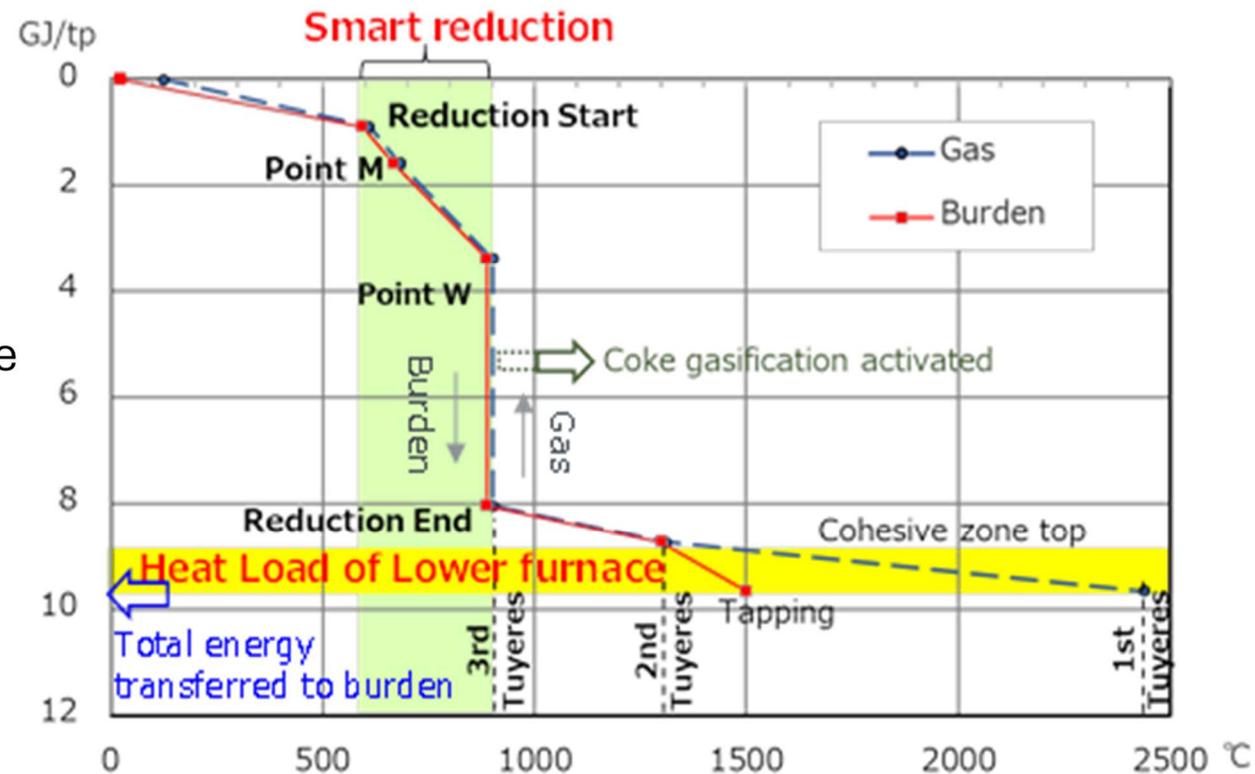


Fig.3 - Heat transfer diagram of Simple BF [2]

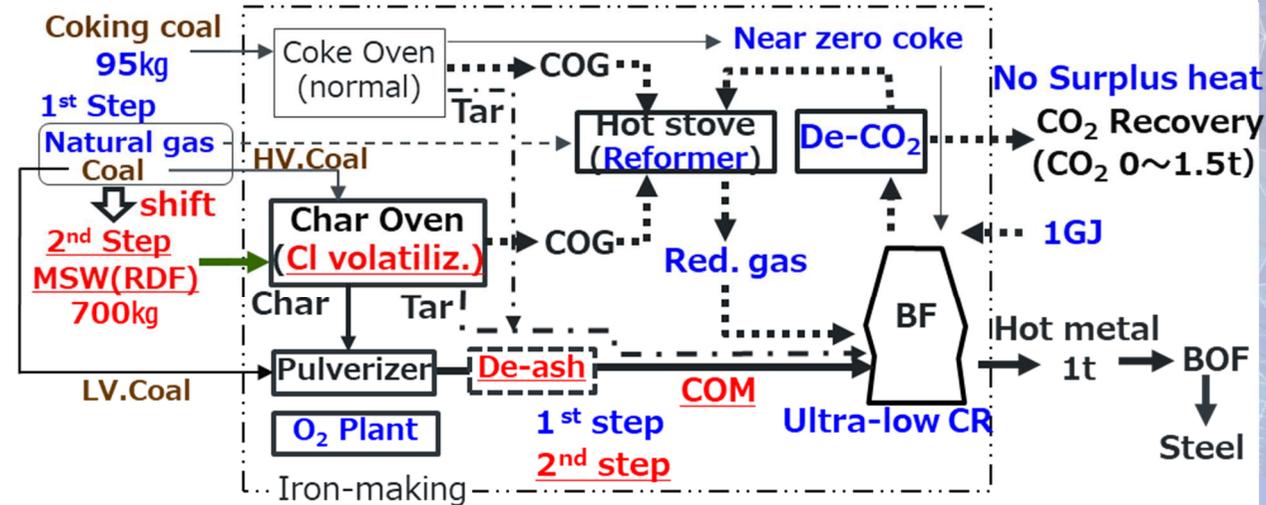
Beyond Carbon Neutral with Ultra-low Coke-rate Blast Furnace

Step 2 (Smart pre-processing) :

Converting MSW into reductants prior to its use in BFs

Advantages:

- No use of H₂ or e-fuels
⇒ **preserve green power for buildings & transport**
- use surplus coke oven capacity (due to Step1)
- **enhance energy efficiency of circular resource**



[B] Carbon neutral BF process (*Simple*)

Note) Typical MSW incineration (in Japan):
 10% at power generation [12]
 5% at output to Grid [12]
 Δ 4% for ash melting (volume red.) [23]
SUM 1% useful out put ≈ 0%

Beyond Carbon Neutral with Ultra-low Coke-rate Blast Furnace

MSW quality issues :

1. **Plenty of adsorbed water** (~50% in Japan)
⇒ cannot be any fuels & becomes heat loss
2. **High Volatile matter** ⇒ low char yield
⇒ cannot be an alternative for PCI
3. **Impurities:** chlorine, metals, alkali, etc.

Countermeasures :

1. **2-stage drying;** pre-drying ~25% at local regions
⇒ waste heat drying at steelworks
2. **High-temp. slow pyrolysis** (~1000°C) to separate into tar, char, and gas (high LHV)
3. **Chloride volatilization** to remove impurities from char, repurposing Cl as reactive agent
⇒ **pulverizing & de-ashing**

Tab.1 -Yields and LHVs of products from high-temperature slow pyrolysis of dry RDF

	Yield (wt.%)	LHV(MJ/kg)
Char	26.5 (inc.12% ash)	15
COG	43.7	18.7 (19.2MJ/Nm ³)
Tar	13.8	35
Water	16 (inc.14%water)	—

Tab.2 -Combustible Fractions in MSW (d.a.f.)

MSW Category	Fraction (wt.%)	Carbon content (wt.%)	LHV (MJ/kg)	CO ₂ emissions (tCO ₂ /t)
Fossil-derived	21.9	15.2	33.7	0.56
Non-fossil	78.1	38.2	19.1	(1.40)
Total	100.0	53.4	22.3	0.56+(1.4)

Beyond Carbon Neutral with Ultra-low Coke-rate Blast Furnace

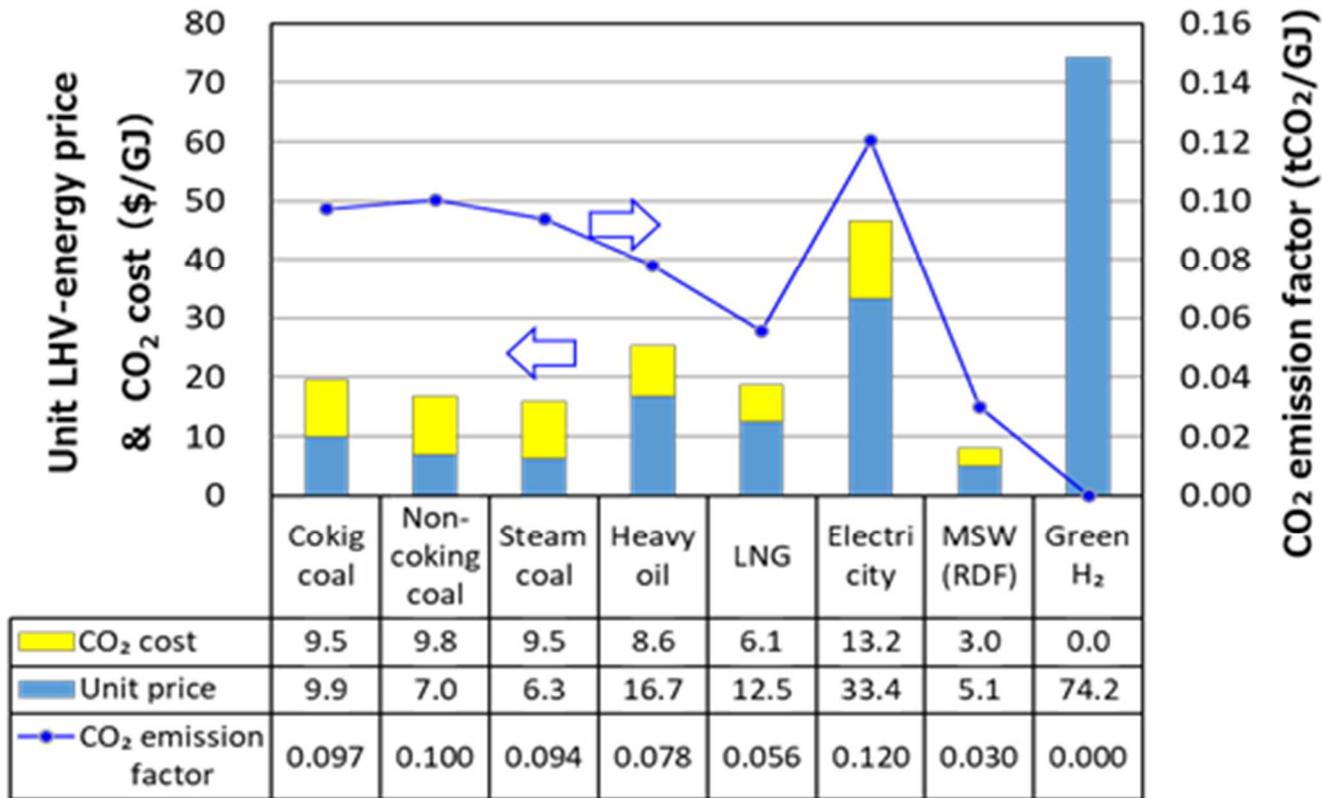
Tab.3 – Major ironmaking routes and their fuel consumptions

	UNIT(/thm)	Conv.BF	S.BF Step1 LV coal	S.BF Step1 HV coal	S.BF Step2 RDF	CH ₄ -DRI +Melter	H ₂ -DRI +Melter
Fuel consumptions							
Coking coal	kg-dry (kgC)	500(402)	95(76)	95(76)	95(76)	–	–
Non-coking Coal	kg-dry (kgC)	200(160)	283(224)	297(228)	–	105(84): char for melter	
CH ₄	Nm ³ (kgC)	–	63(34)	71(38)	–	324(174)	44(35)
H ₂	Nm ³	–	–	–	–	–	600
MSW*	kg-dry (kgC)	–	–	–	700(106)	–	–
Flux	(kgC)	(34)	(28)	(25)	(26)	(25)	
Green Electricity	kWh	25 for O ₂	80 for O ₂	77 for O ₂	78 for O ₂	800	1800
Surplus Heat	GJ	6.9	0	0	0	1	

Assumptions for cost evaluation:

- 1.Raw materials (BF grade hematite), hot metal and slag are set equal.
- 2.DRI pellets are produced at the mine site using natural gas(NG).
- 3.Unit prices reflect Japanese market. But for DRI+Melter, NG is set 1/6 and electricity is set 1/2 .

Beyond Carbon Neutral with Ultra-low Coke-rate Blast Furnace



MSW assumed to be converted to “ RDF with 25 wt.% moisture and 10 wt.% ash (dry basis) ”, at 80% unit energy price of steam coal.

Note) CO₂ cost is calculated as €100/t-CO₂ for carbon price.

Fig.5 - Unit LHV price and CO₂ cost of energies used for Comparison of ironmaking routes

Beyond Carbon Neutral with Ultra-low Coke-rate Blast Furnace

Gross heat consumptions

S.BF Step 2: due to the fuel shift,

- Increase in heat consumption at steelworks to 19 GJ/thm
- **Reduction in heat loss at incineration plant by 14 GJ/thm; MSW disposal offset**



Nationwide gross heat consumption = 5 GJ/thm

- **SimpLE Step 2 : < 1/3 of Conv. BF**



- **H₂-DRI+Melter : > 3 × Conv. BF**

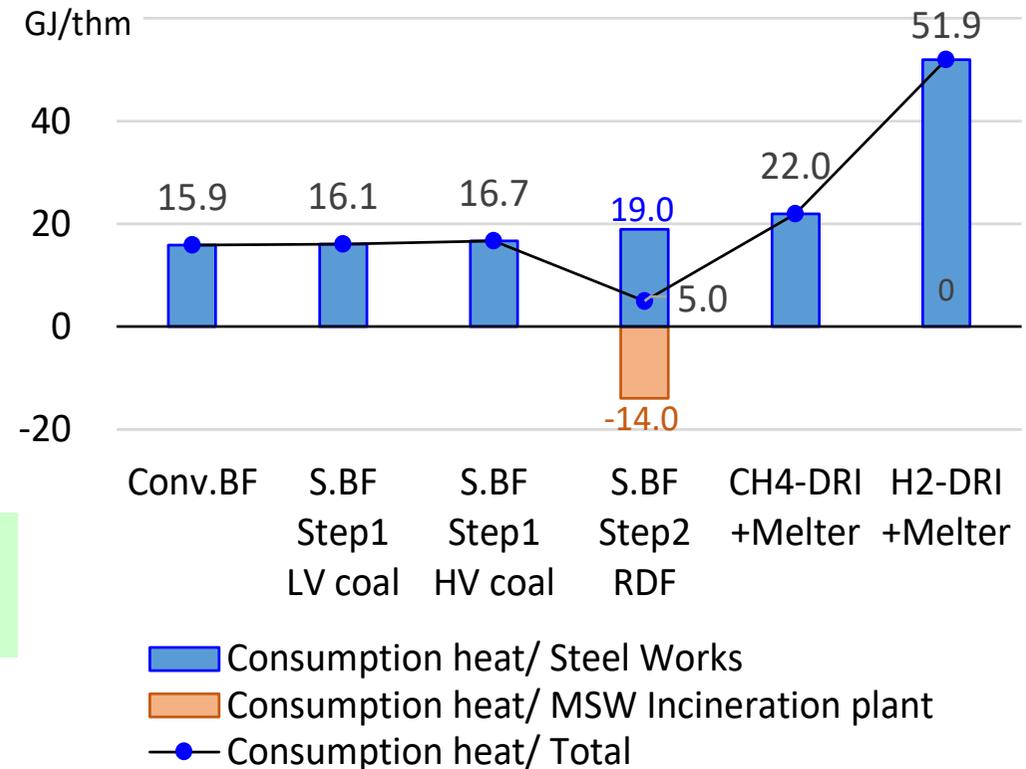


Fig.6 - Gross heat consumptions of routes

Beyond Carbon Neutral with Ultra-low Coke-rate Blast Furnace

Input C / CO₂ emissions

S.BF Step 2: due to the fuel shift,

- Input C 65% reduced from Conv.BF
- MSW disposal offset = **Input C reduction(-0.18) in its incineration plant**



Nationwide Input C reduction = 83%, regardless of the fossil carbon content in MSW.

Remaining Input C comes **only from carburization coke and additives (flux) ≈ near-zero Input C**

EUROPEAN STEEL TECHNOLOGY AND APPLICATION DAYS

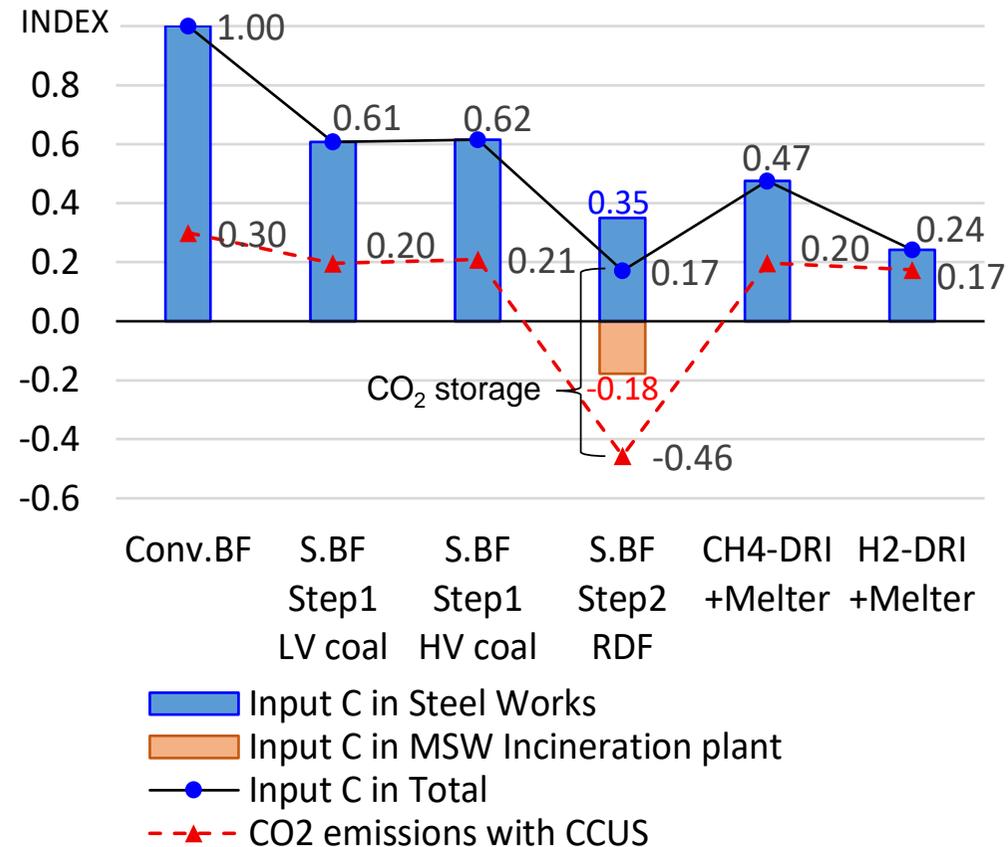


Fig.7 - Input C and CO₂ emissions of routes (including MSW offset in Simple Step 2)

Beyond Carbon Neutral with Ultra-low Coke-rate Blast Furnace

OPEX

S.BF Step 2:

- **OPEX $\approx 0.91 \times$ Conv. BF**
- **Even with C.P., still comparable to current BFs**

H₂-DRI+Melter:

- **high OPEX even with lower energy prices**
 \Rightarrow **exceed current BFs without CO₂-measures**

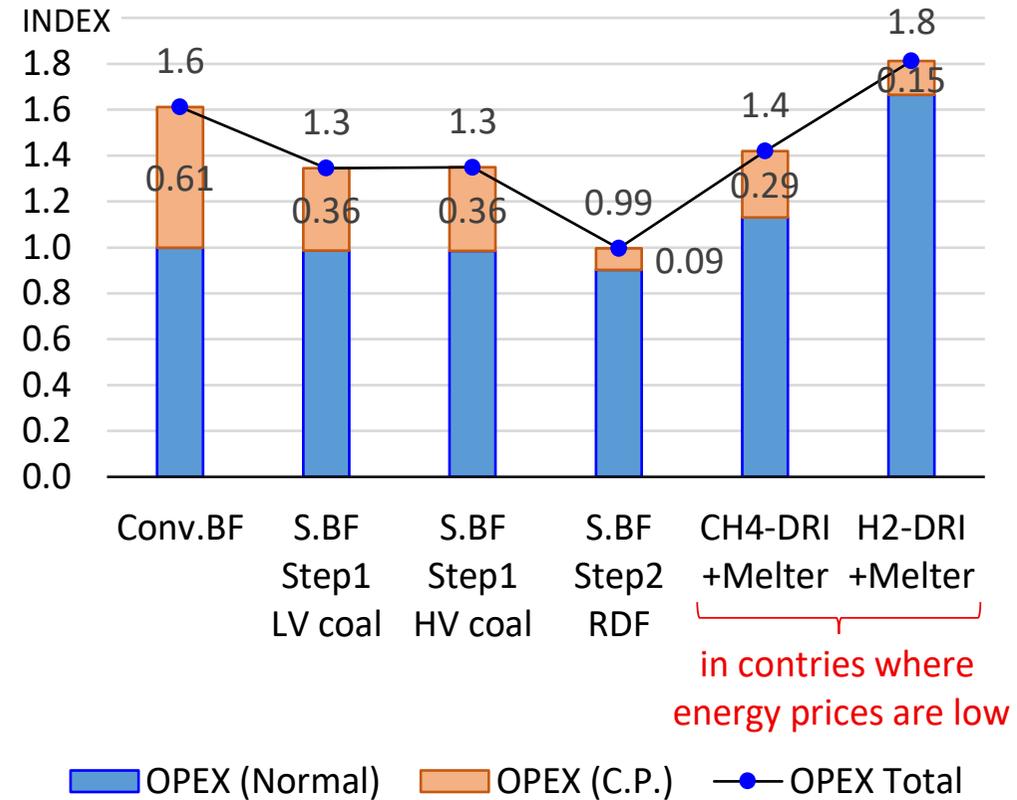


Fig.8 – OPEX of routes

Beyond Carbon Neutral with Ultra-low Coke-rate Blast Furnace

Summary: when compared with current conventional BFs,

Step 1: CR to 1/5; gross energy & OPEX maintained

Step 2: Smart Pre-processing (MSW) ;

- reduce nationwide gross energy **to less than 1/3** of current BFs
- reduce nationwide Input C **by 83%** of current BFs
- reach **46% negative emissions** by integrating CO₂ capture
- remain **competitive on OPEX even at a C.P. of €100/t-CO₂**

Conclusions:

SimpLE represents not only a pathway beyond carbon neutral, but also a societal transition framework—bridging industrial sustainability and circular resource innovation in the decarbonization era.

**Beyond Carbon Neutral with
Ultra-low Coke-rate Blast Furnace**

Thank you very much for your kind attention.

SimpLE-labo Co., Ltd.