Green Tomorrow, With POSCO

Progress in low carbon BF-BOF bridge technology In POSCO

December 5-7, 2023

Low-Carbon Iron and Steel Making R&D Center
PosLAB, POSCO

Dongjo Lee

POSCO's Carbon Neutrality by 2050

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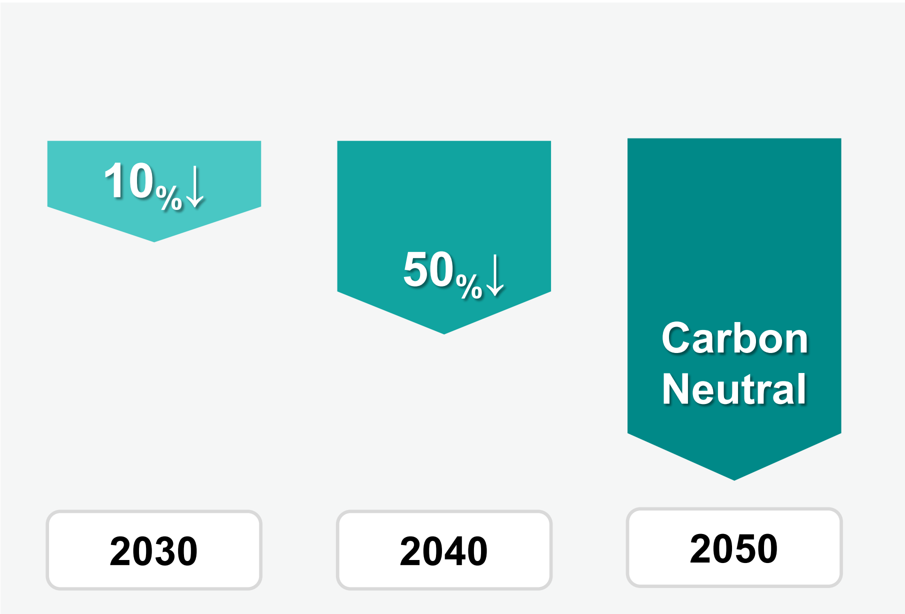
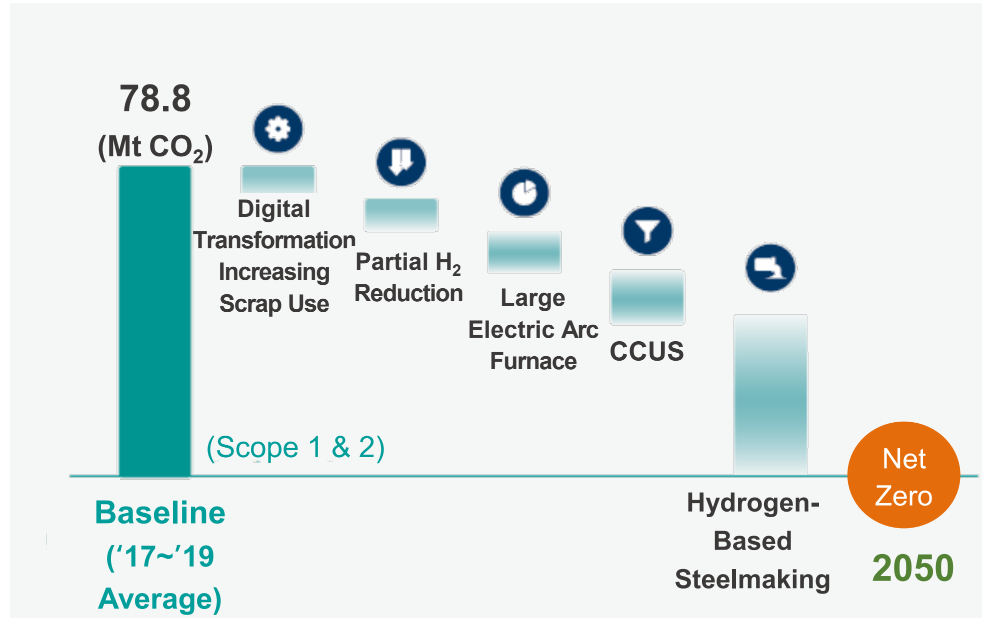
Commitment to reduce CO_2 emissions



Pathway to achieving carbon neutrality



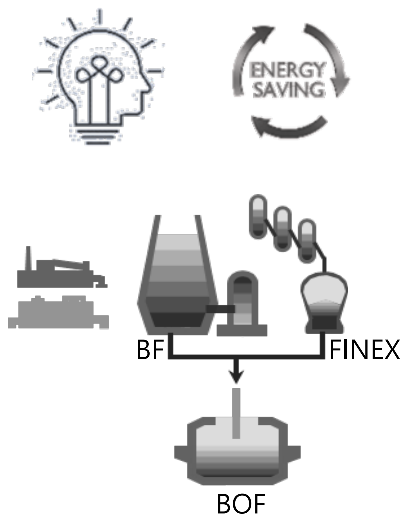
POSCO is the first steelmaker in Asia to commit to carbon neutrality by 2050

- Keeping domestic crude steel production by 38Mton in 2050
- CO_2 reduction by 2030 with optimization & improvement of the existing facilities
- Development and adoption of bridge technologies
- Development of hydrogen steelmaking by 2030 and stepwise transition from mid 2030s

Essential Technologies for Carbon Neutral Transition

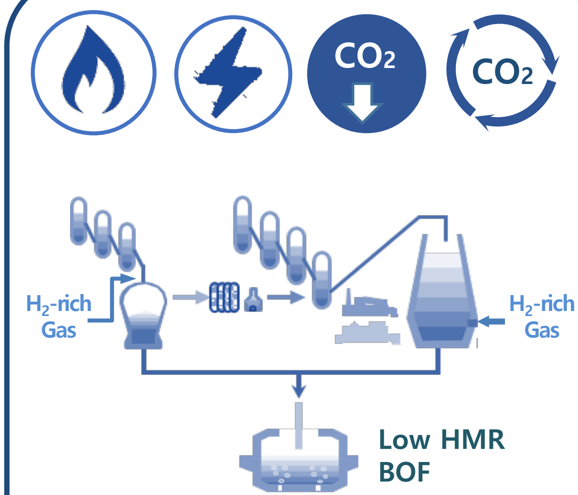
Carbon → Carbon Neutral

Near-Term



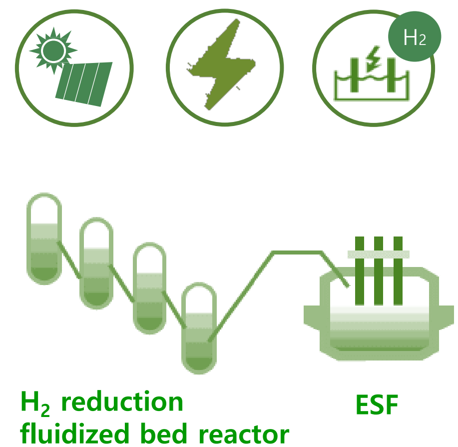
- Smartization
- Increase efficiency
- Energy Saving

Mid-Term(~2030)



- Partial Hydrogen reduction (Hybrid BF+FINEX)
- Low HMR* BOF
- FINEX with CCUS

Long-Term(~2050)



- Utilizing green electricity and H_2
  ➡ Carbon-Neutral Steelmaking

*HMR : Hot Metal Ratio

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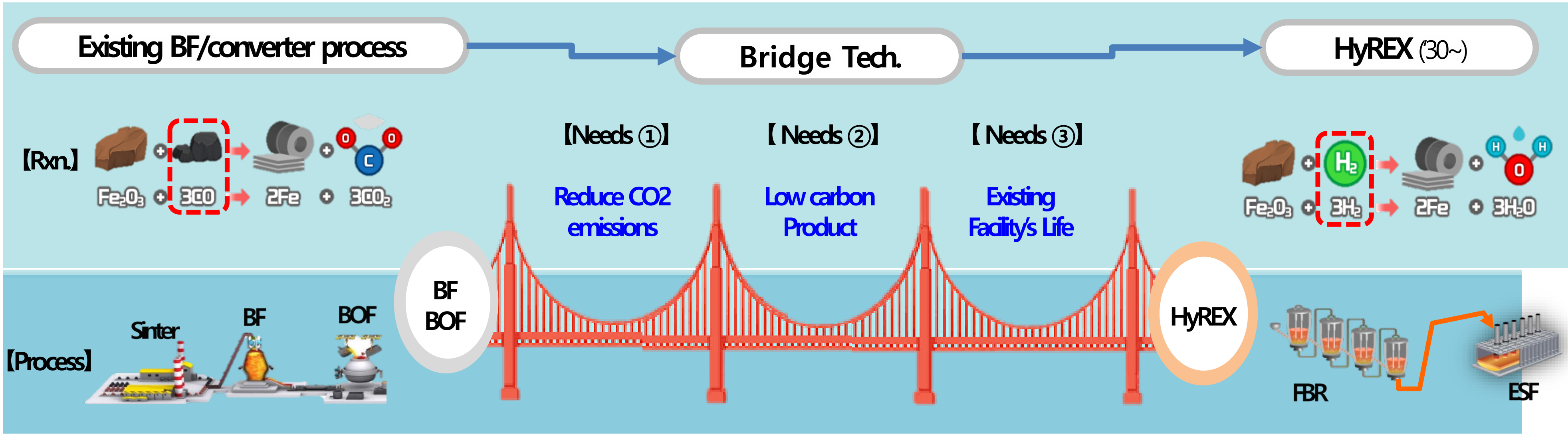
Decarbonization technology that utilizes existing processes prior to commercialization of hydrogen reduced steelmaking (HyREX)

Production of low CO2 emissions products based on blast furnace/converter prior commercialization of HyREX



Low carbon Bridge technology (National Project)

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○ COOLSTAR Overview

※ **COOLSTAR: CO_2 L**ow emission technology of **St**eelmaking **A**nd hydrogen **R**eduction

Ministry of Trade, Industry and Energy

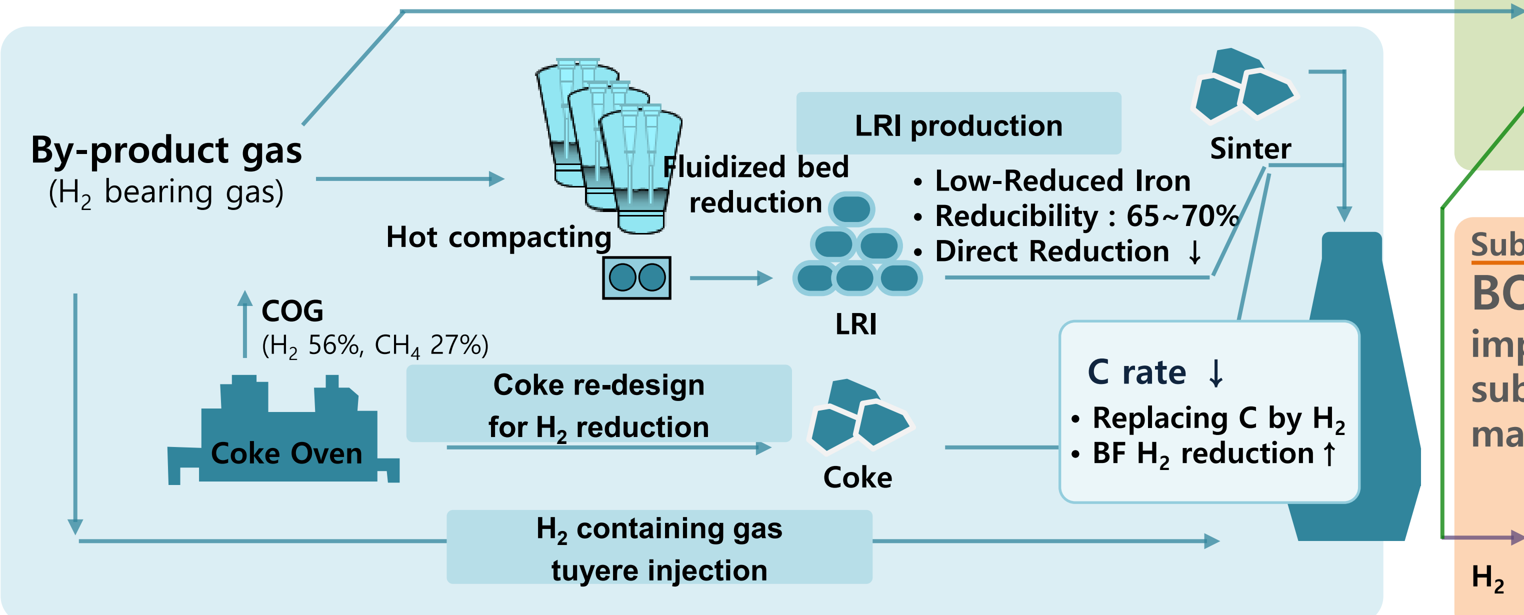
Ministry of Trade, Industry and Energy → Government-led Project →

- Companies : POSCO, HYUNDAI Steel,..
- Universities, Research Institutes

○ Target : Develop technologies to reduce CO_2 emissions(direct/indirect) by 15% in steelworks

Sub 1

Hybrid ironmaking technology based on BF
- H_2 enriched gas injection
- Application of low reduced iron

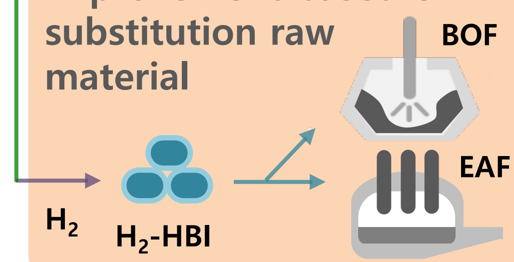


Sub 2

H_2 amplification based on by-product gas

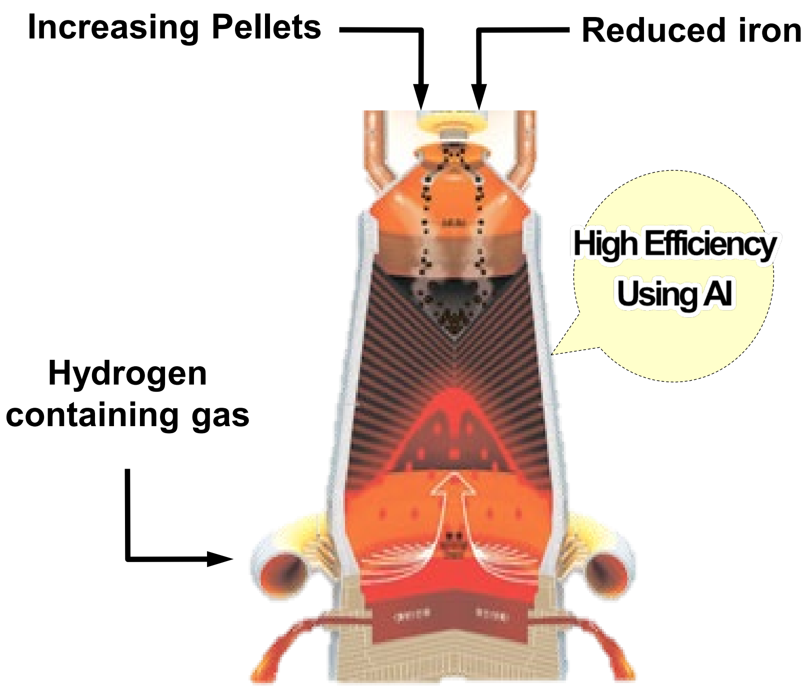
Sub 3

BOF/EAF improvement based on substitution raw material



Bridge Technology - Blast Furnace

Technology is required to produce less carbon, but high efficiency



Efficiency

AI-based operation process
(Data-based operation prediction and automatic control, etc.)

※ selected as Lighthouse factory(2019)

Pellet

High Reducibility, Low Gangue compared to other ores
(Basic Pellets, Semi-basic Pellets, etc)

Reduced Iron

Energy saving for iron ore reduction in BF
(HBI, DRI, LRI, Scrap, etc)

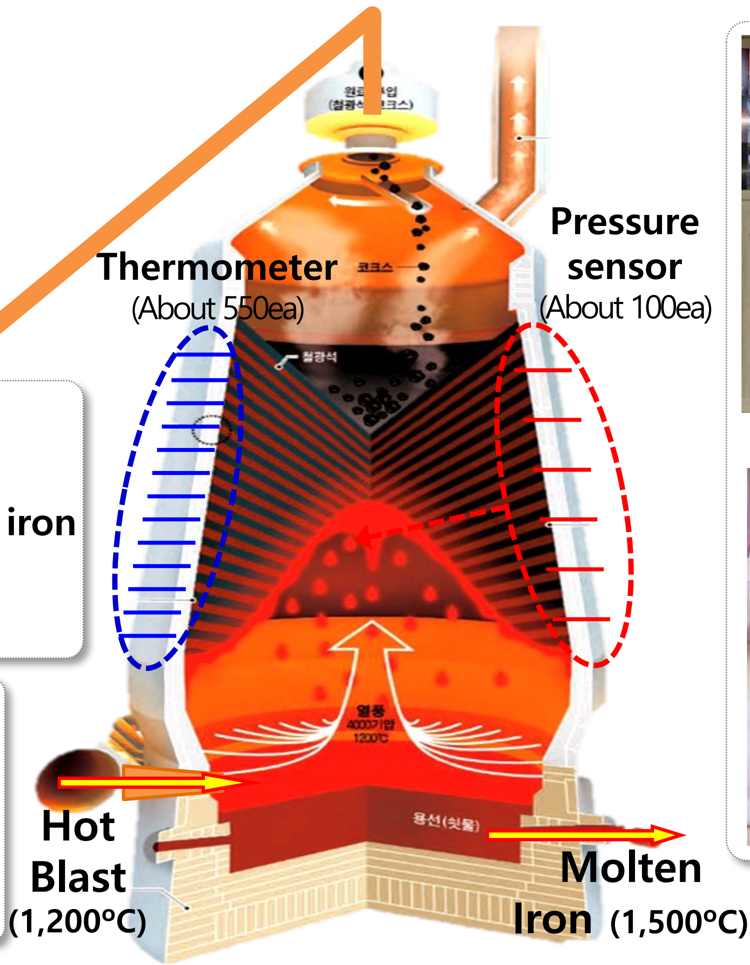
H_2 Reduction

Replacement of reduction agent from C to H_2
(LNG, COG, H_2, etc)

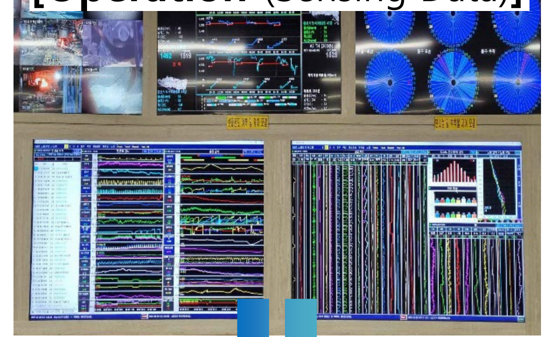
Total optimization with AI will maximize productivity and reduce coal usage

Bridge Technology - What is Blast Furnace?

Status of the furnace is estimated through the surface detected data



[Operation (Sensing Data)]



[Oriental Doctor pulse]

[Function of the Furnace]

① **Physical & Melting**
- Solid Iron Ore → **Liquid molten iron**

② **Chemical & Reduction**
- $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

○ **Real-time Gas composition analysis** (CO, CO_2, N_2, H_2)

○ **Thermometer & Pressure sensor by direction/height**

Similar to oriental doctor's diagnostic methods, experience plays a very important role

Bridge Technology - Smart Blast Furnace

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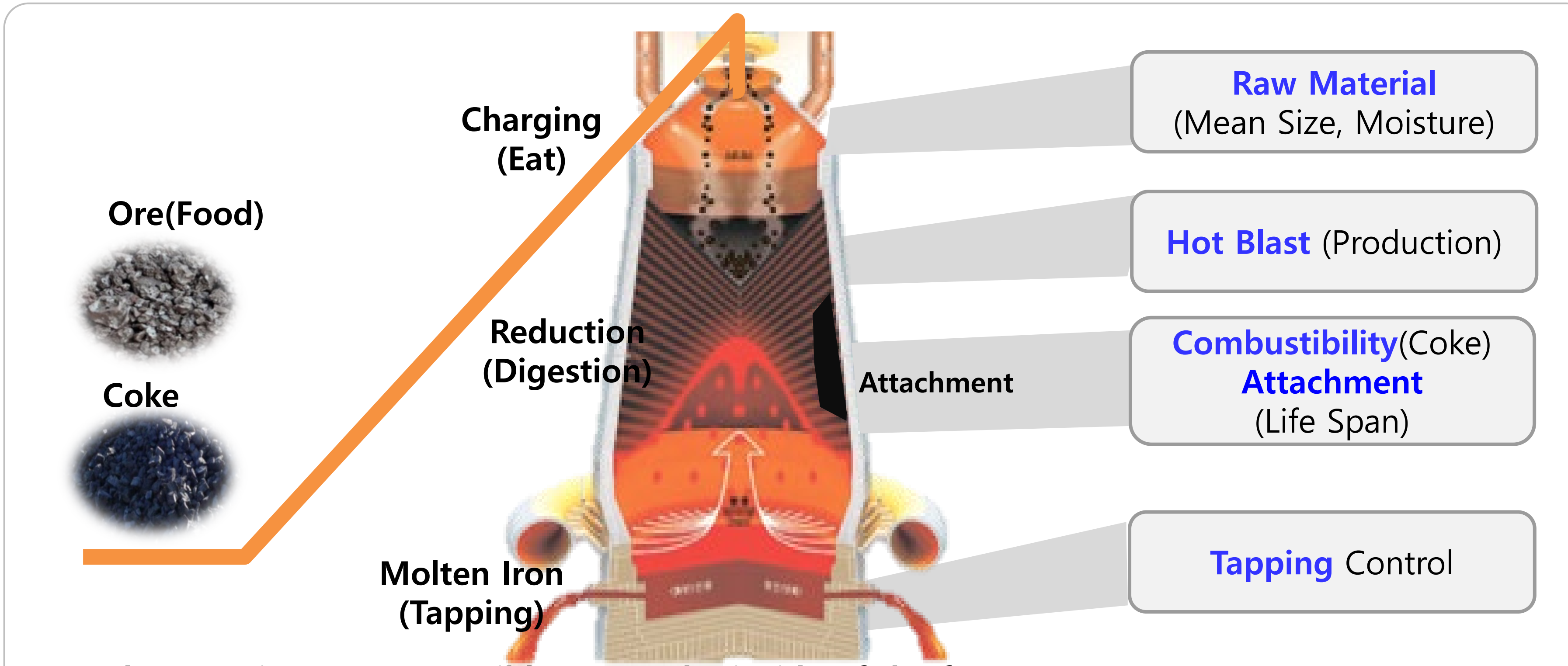
Smart Blast Furnace : Furnace that automatically controls using AI

Human	Food	Digestion, Absorption	Discharge	"Human Condition"
Furnace	Ore / Coke	Reduction, Melt	Tapping	"Blast Furnace Condition"



※ In the past, it was not possible to see the inside of the furnace, so manual operation depended on the experience and intuition of the operator

Bridge Technology - Smart Blast Furnace

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Raw material & Blast Model

【 Before 】

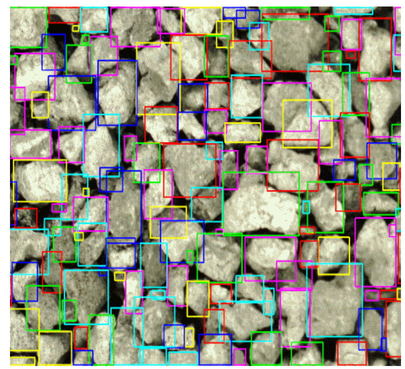
- Manual measurement (Size, Moisture) (40kg/time, 3times/day)

※ Visual Judgement in field

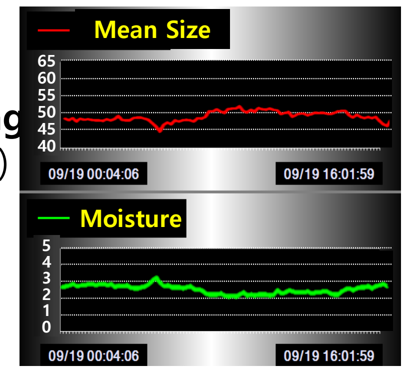
- Manual control based on experience

【 After 】

- Real-time data conversion using high-definition video and AI



Deep Learning (*CNN)



- Blast Prediction & Auto Control using AI

[Input Data]

Operator experience regularization

+

Operation data

Deep Learning Algorithm →

[Blast Control]

Blast Prediction & Auto Control

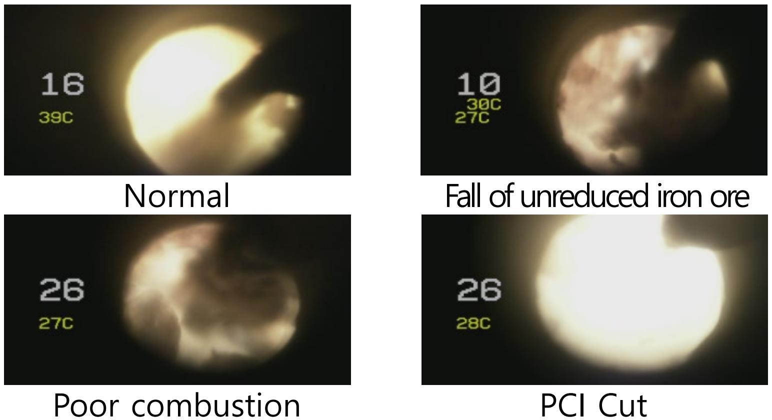
*CNN : **C**onvolutional **N**eural **N**etwork

Bridge Technology - Smart Blast Furnace

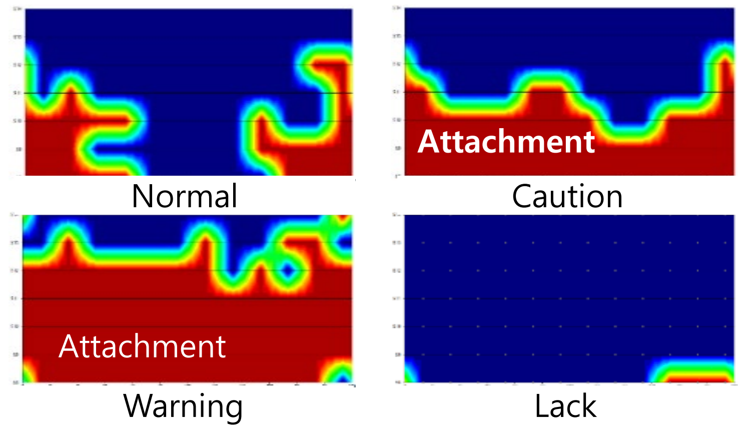
Combustibility & Attachment Model

- Image classification and data conversion by learning with AI

[Combustibility Data (5,600 sheets)]



[Attachment Data (60,000 sheets)]



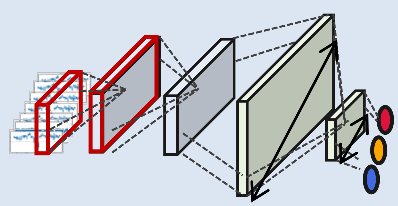
※ Before : Visual judgement through the hole

※ Before : Judgement of Attachment based on experience

- Combustibility & Attachment Prediction and Auto Control using Deep Learning

[Input Data]

[Deep Learning Algorithm]



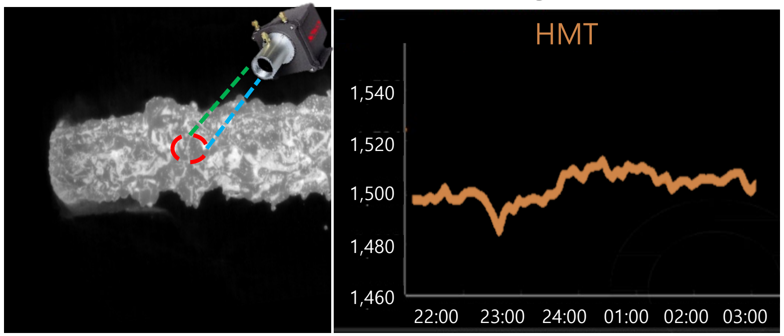
[Auto Control]

Combustibility,
Attachment Control
(Solving chronic problems)

Molten Iron Temperature Prediction & Auto Control Model

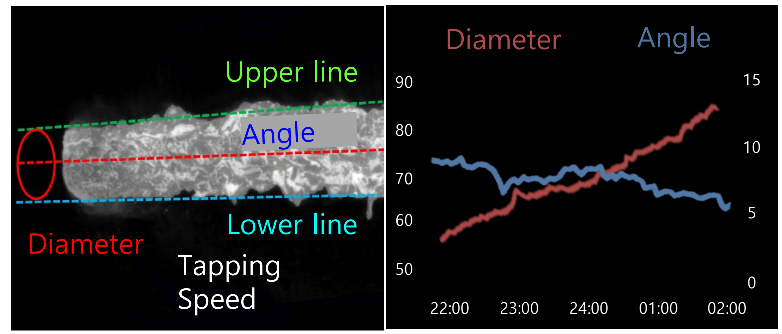
- Real-time temperature and molten iron discharge data using Smart Sensor

[Real-time HMT measurement using IOT sensor]



※ Before : Manual measurement (1time/2hours)

[Real-time molten iron discharge status data]



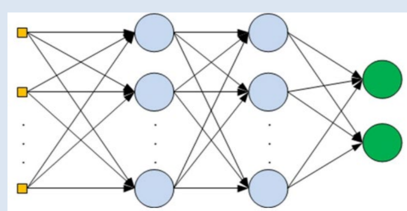
※ Before: Visual Judgement in field

- Prediction and automatic control of HMT after 1hour using Deep Learning

[Input Data]

Operator Know-how Into Data
+
Data standardization (Video)

[Deep Learning Algorithm]



[HMT Prediction, Control]

HMT Prediction, Control (After 1hour)

Bridge Technology - Pellet usage in BF

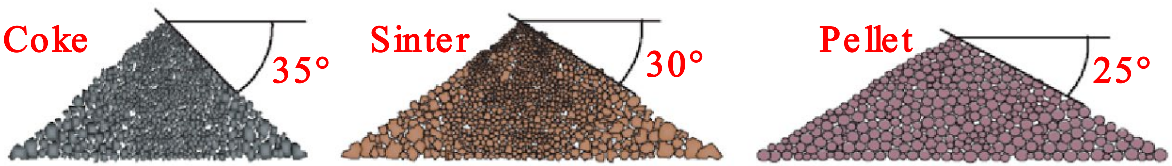
Characteristics of Pellet in BF

- Pellets reduce Coke & Coal rate with high reducibility and low slag ratio.
- Highest tendency to center segregation due to their high rolling properties.

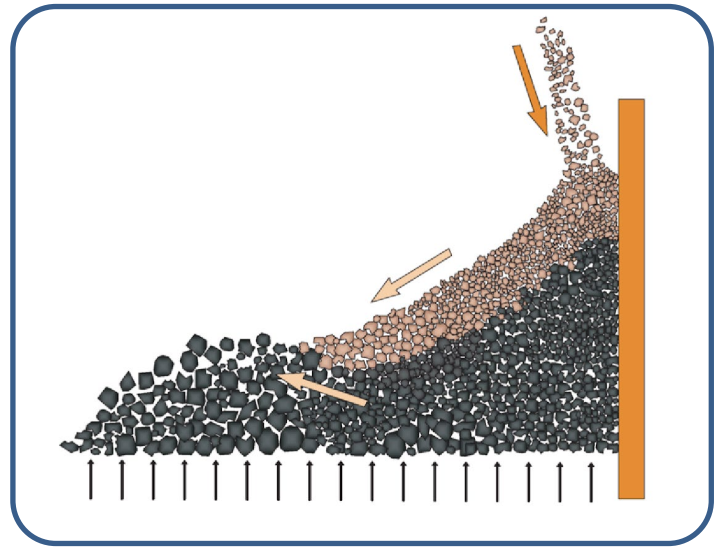
Sinter

< Reducibility
Rolling <
> Disintegration
> Slag ratio
Price <

Pellet



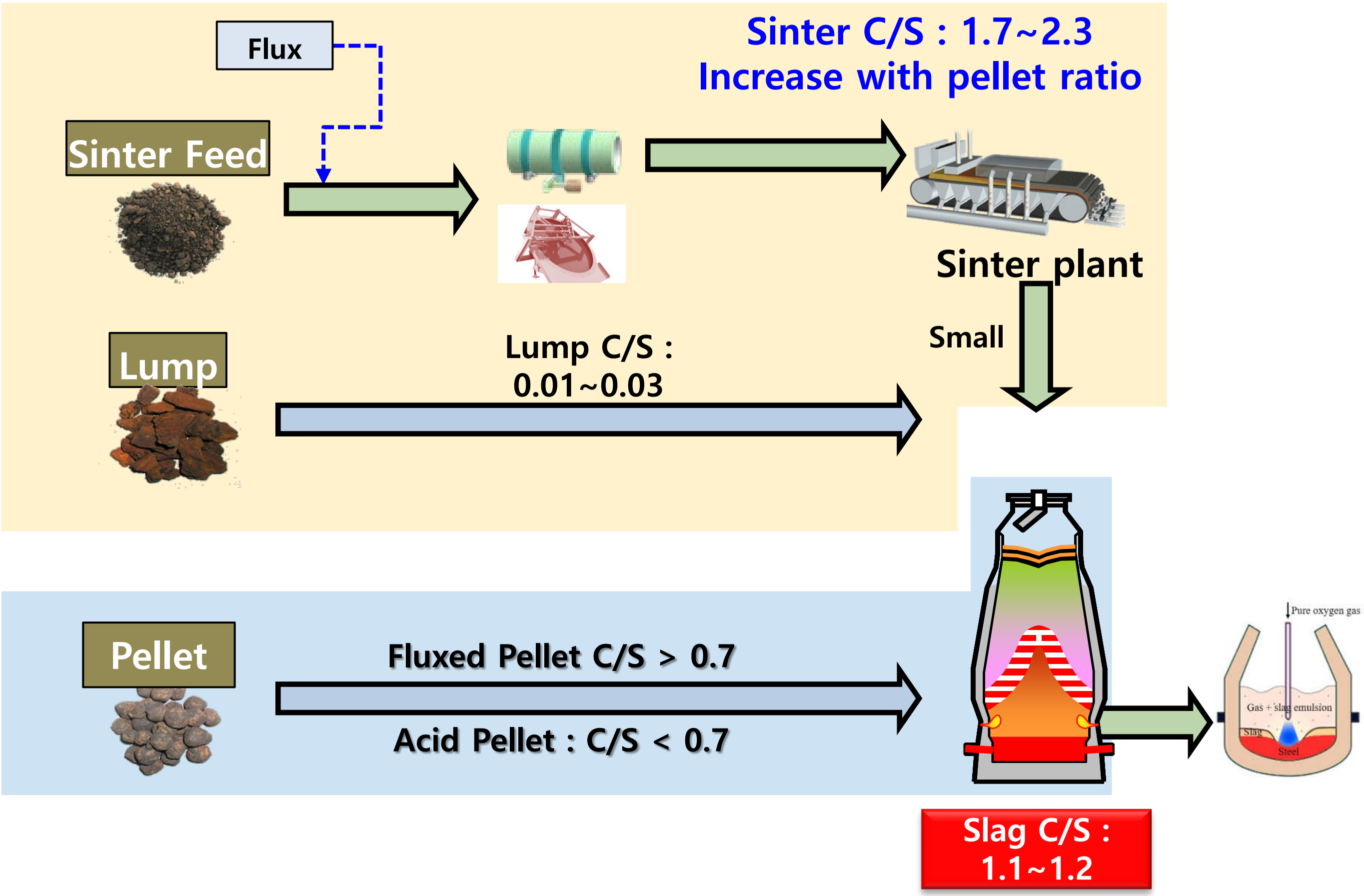
Ref) Modern Blast Furnace Ironmaking An Introduction, 2015



Bridge Technology - Pellet usage in BF

Effect of pellet usage ratio on sintered ore basicity

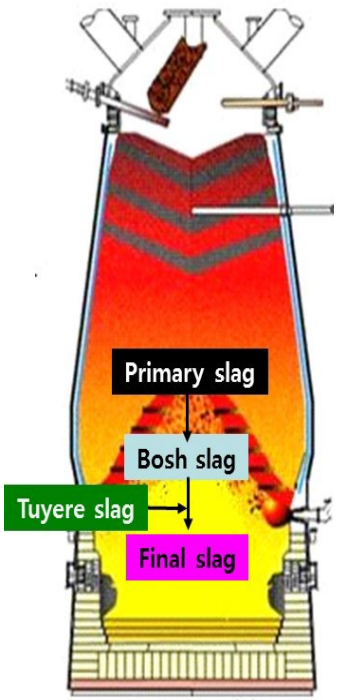
- To maintain the basicity of tapping slag, the basicity of sintered ore needs to be increased.
- The difference in basicity between sintered ore and pellets gradually increases.

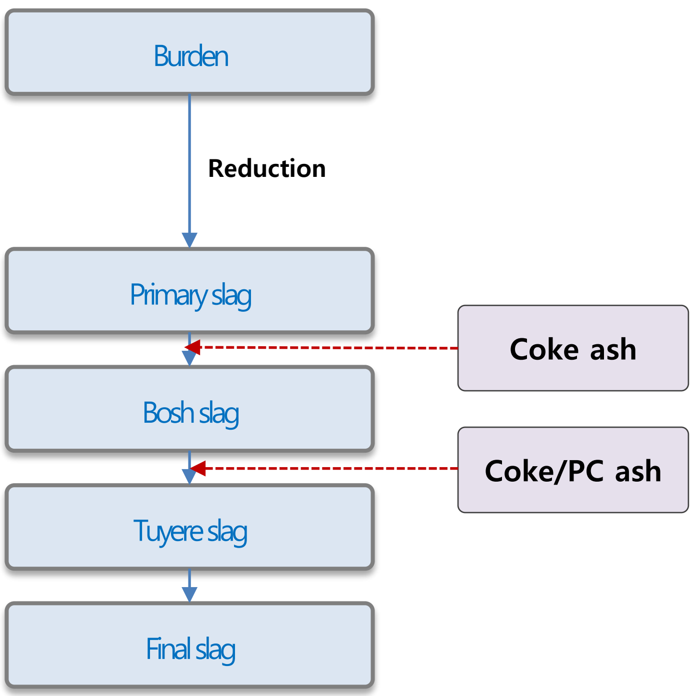


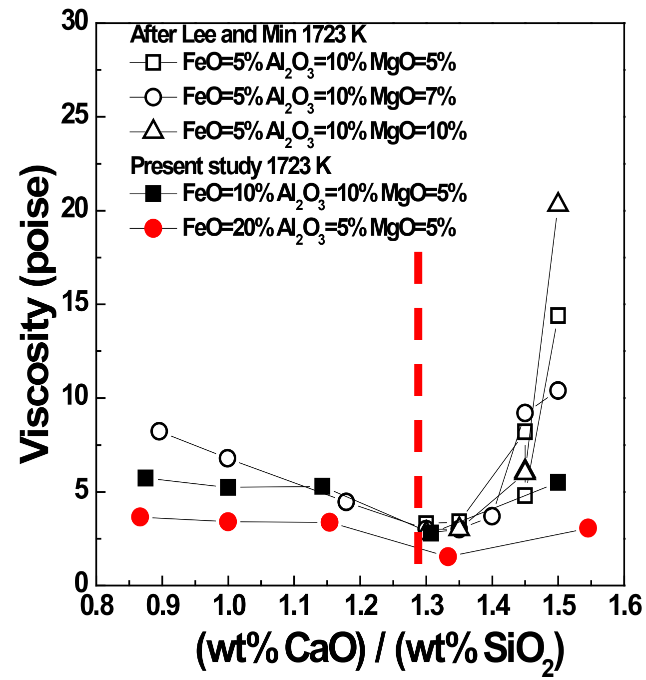
Bridge Technology - Pellet usage in BF

Necessity of development of pellet charging technology

- Segregation of pellets/sintered ore causes imbalance in slag basicity in the furnace
- Deviation in fluidity and gas permeability, adhesion and tapping problem can occur







Fluidity Permeability Adhesion Tapping

Bridge Technology – Reduced Iron usage in BF

Characteristics of Reduced iron in BF

- Reduced irons reduce Coke & Coal rate with saving energy for reduction in BF
- Scrap among reduced iron requires shape control to prevent problems with charging equipment.

Sinter/Pellet

< Pre-reduction

> Disintegration

> Gangue

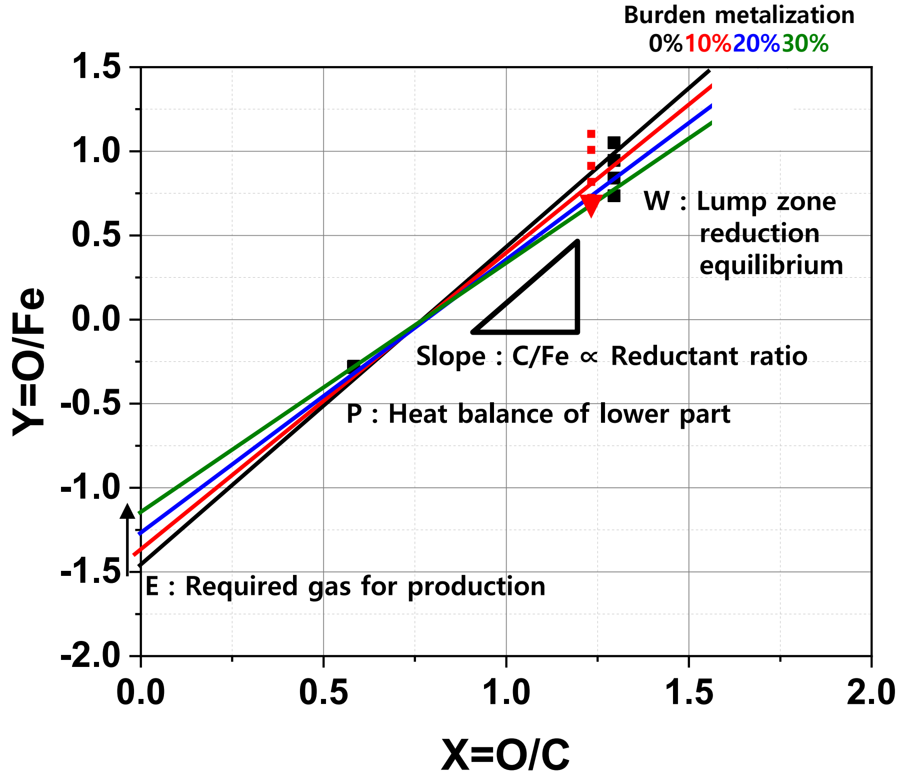
Price <

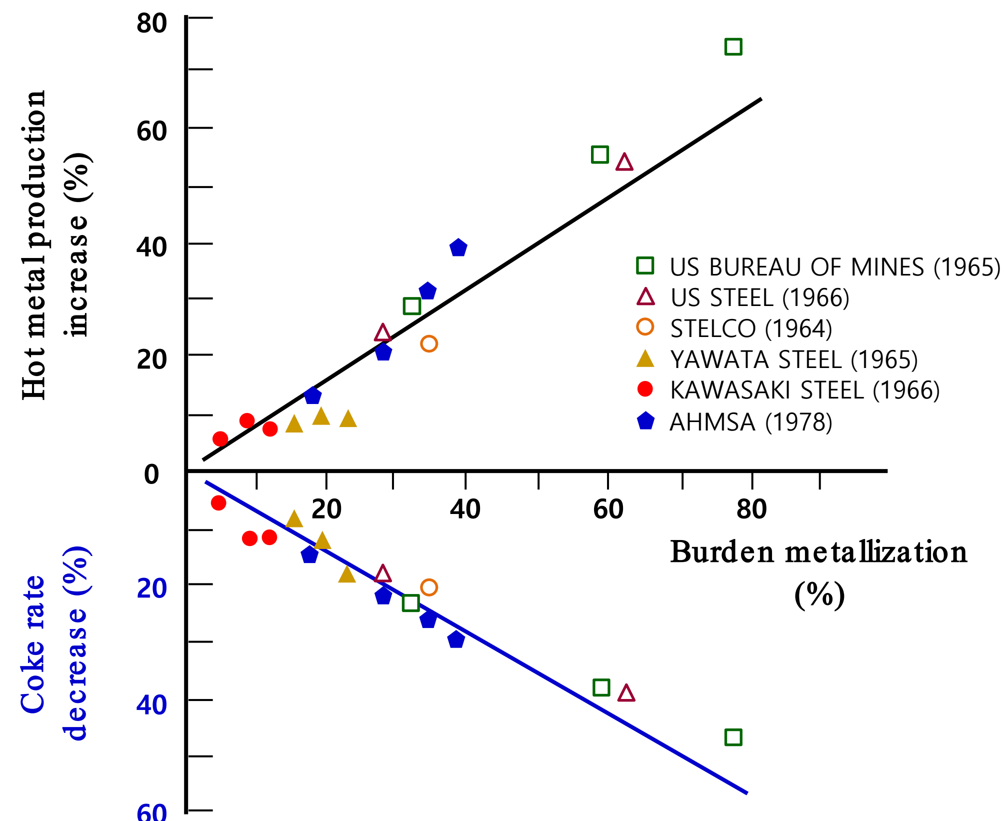
Shape >

Reduced iron

Reduced iron usage in BF for low carbon

- Reducing agent ratio decreases and productivity increases depending on metalization of burden determined by type and amount of reduced iron

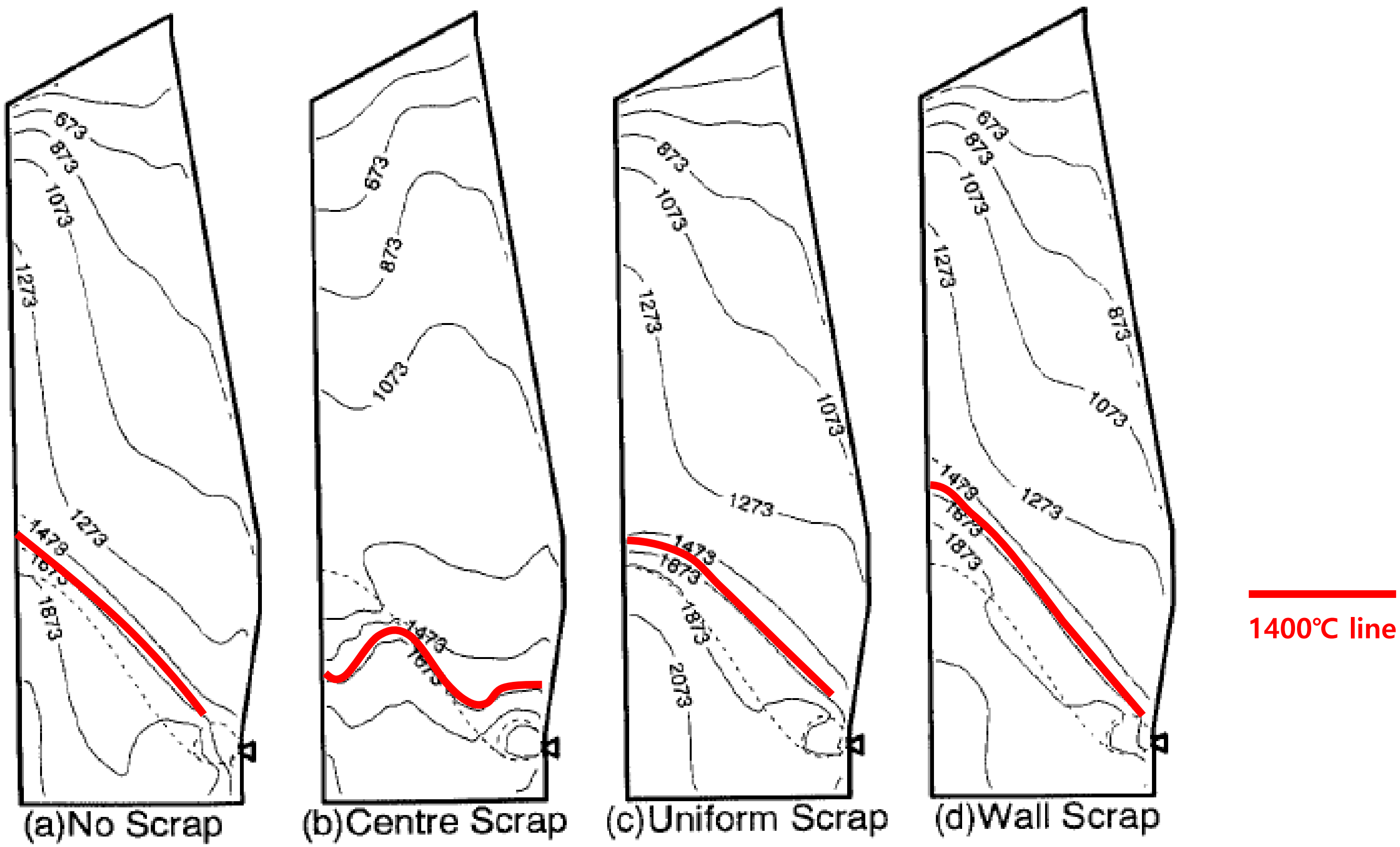




Ref. : International Iron Metallics Association (IIMA)

Necessity of development of reduced iron charging technology

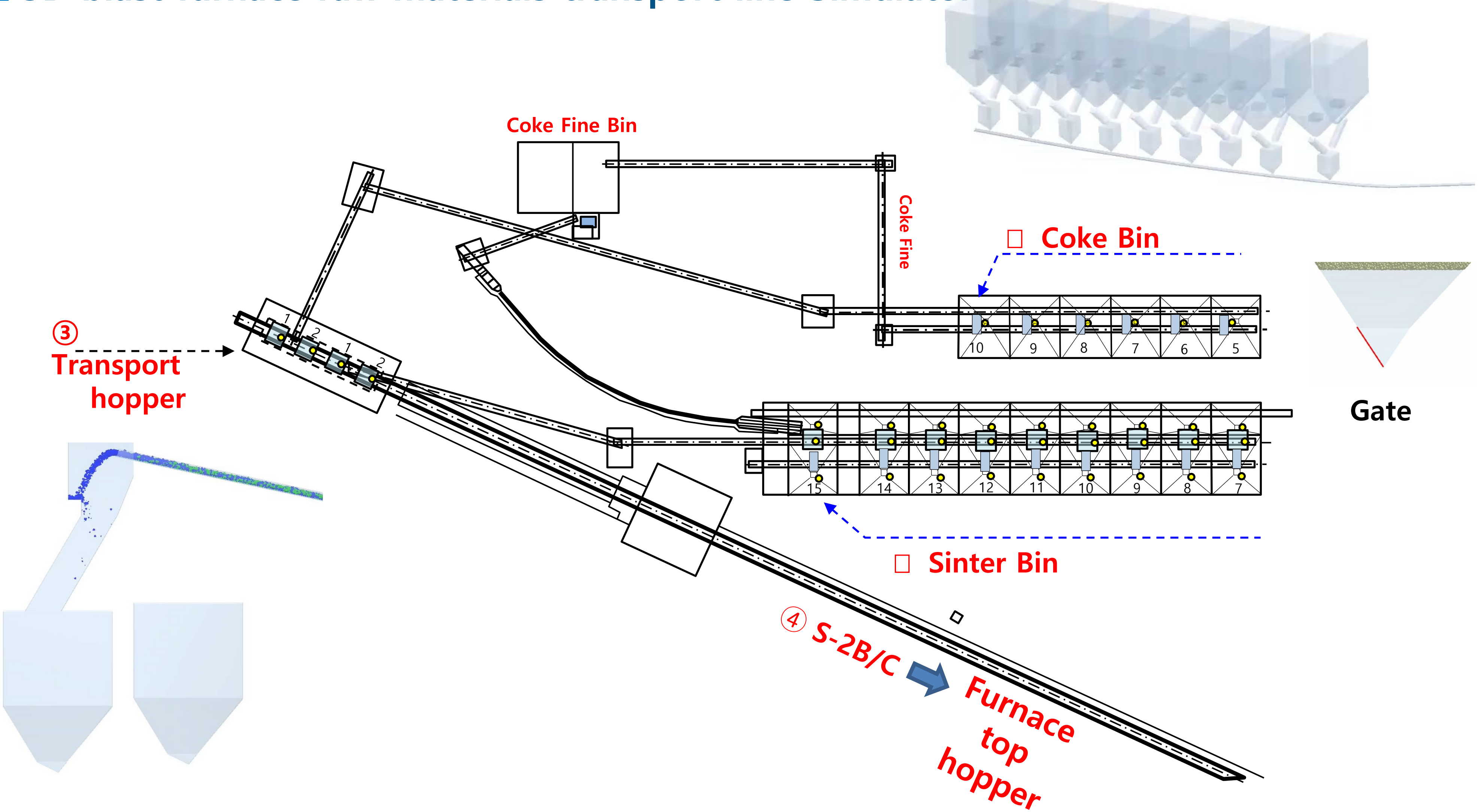
- Segregation of reduced iron causes imbalance in temperature in furnace



Ref. : Austin et al., ISIJ int. 1998

Bridge Technology - Material Charging Digital Twin

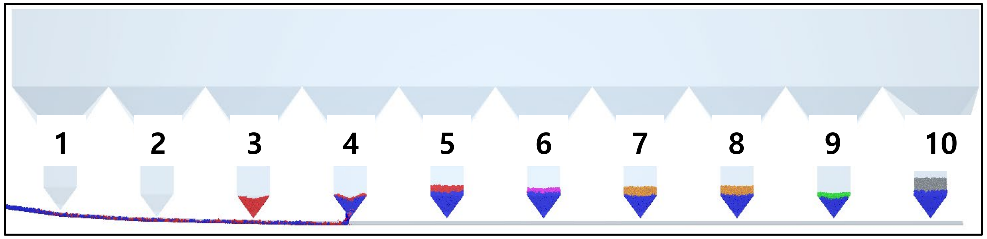
3D blast furnace raw materials transport line Simulator

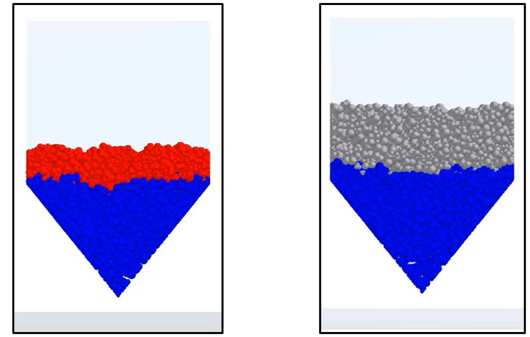


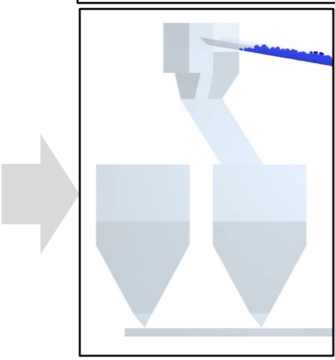
Bridge Technology - Material Charging Digital Twin

POSCO

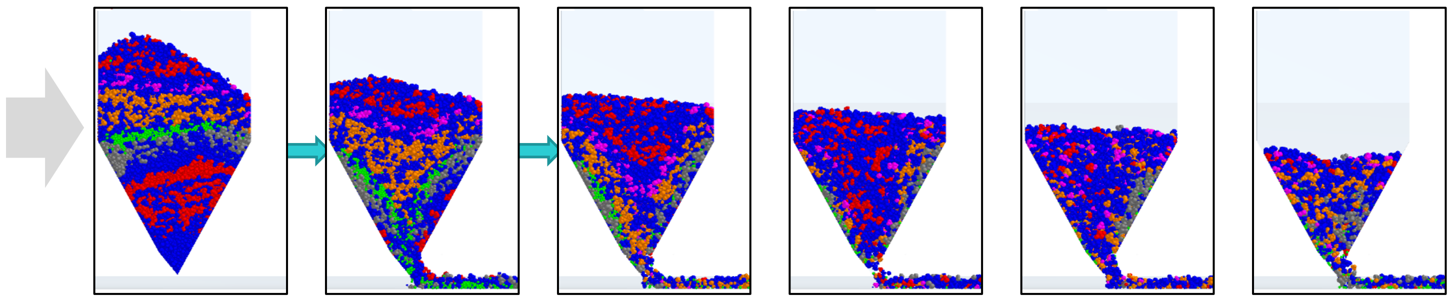
Details of Digital Twin model



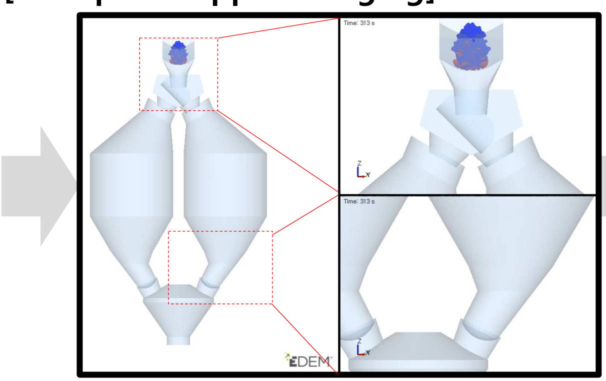




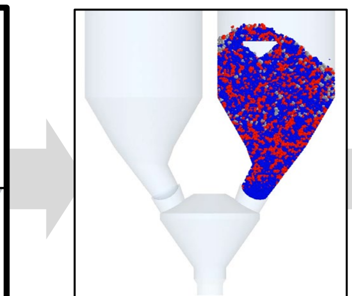
[Transport hopper charging]



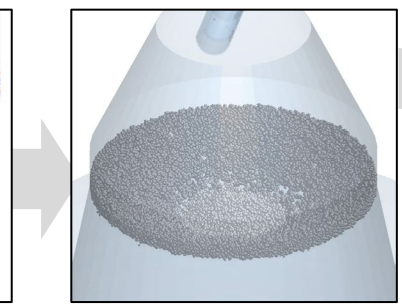
[Transport hopper discharging]



[Furnace top hopper charging]



[Furnace top hopper discharging]



[Furnace charging]

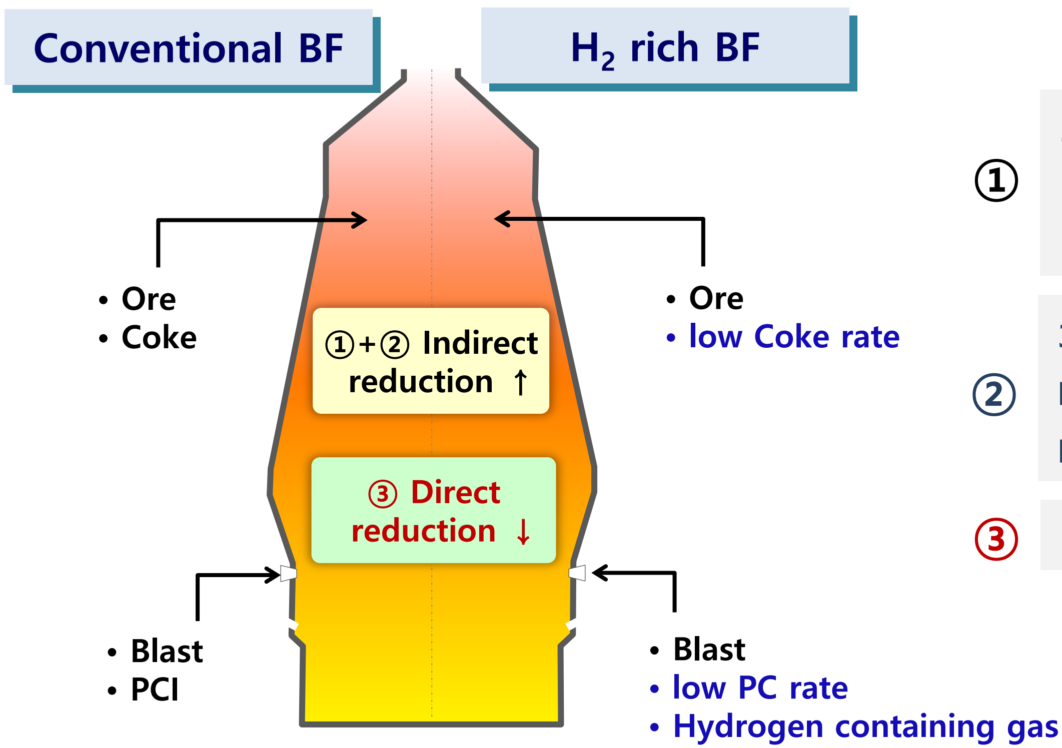
① Burden structure
② Distribution of burden

Find charging method for high efficient pellet/reduced iron uses

Bridge Technology - Hydrogen Containing Gas Usage in BF

Hydrogen containing gas usage in BF for low carbon

- Hydrogen containing gas includes NG, COG, H2 generated with green power
- Reduce coal rate by suppressing direct reduction with increasing indirect reduction by H2

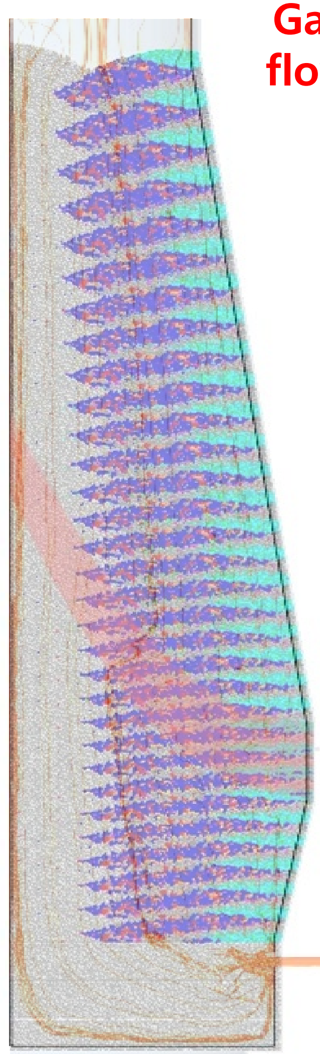


① $3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$ + 10,330 cal/mol (Exothermic)
$Fe_3O_4 + CO \rightarrow 3FeO + CO_2$ - 8,750 cal/mol (Endothermic)
$FeO + CO \rightarrow Fe + CO_2$ + 3,990 cal/mol (Exothermic)

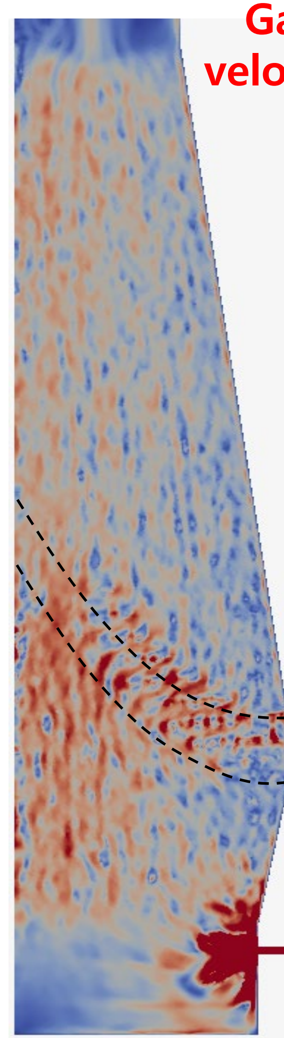
② $3Fe_2O_3 + H_2 \rightarrow 2Fe_3O_4 + H_2O$ + 650 cal/mol (Exothermic)
$Fe_3O_4 + H_2 \rightarrow 3FeO + H_2O$ - 18,430 cal/mol (Endothermic)
$FeO + H_2 \rightarrow Fe + H_2O$ - 5,690 cal/mol (Endothermic)

③ $FeO + C \rightarrow Fe + CO$ - 37,220 cal/mol (Endothermic)

Gas flow Digital Twin linked to Charging D/T



Gas flow



Gas velocity

Bridge Technology - Gas Flow Digital Twin for H2 BF

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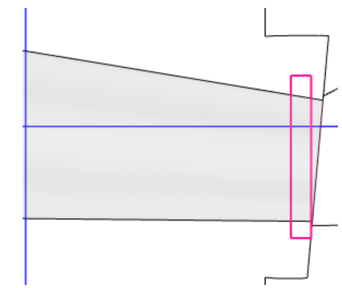
Gas flo Temperatu

- PC
  Single Inje

- PC and N
  Dual Inje

- PC Particle Tracking In tuyere

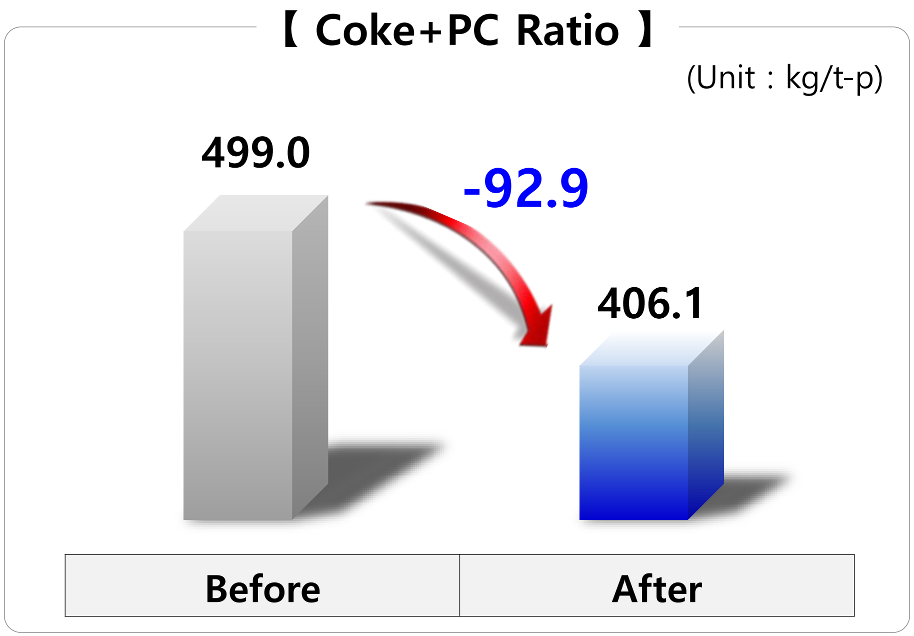


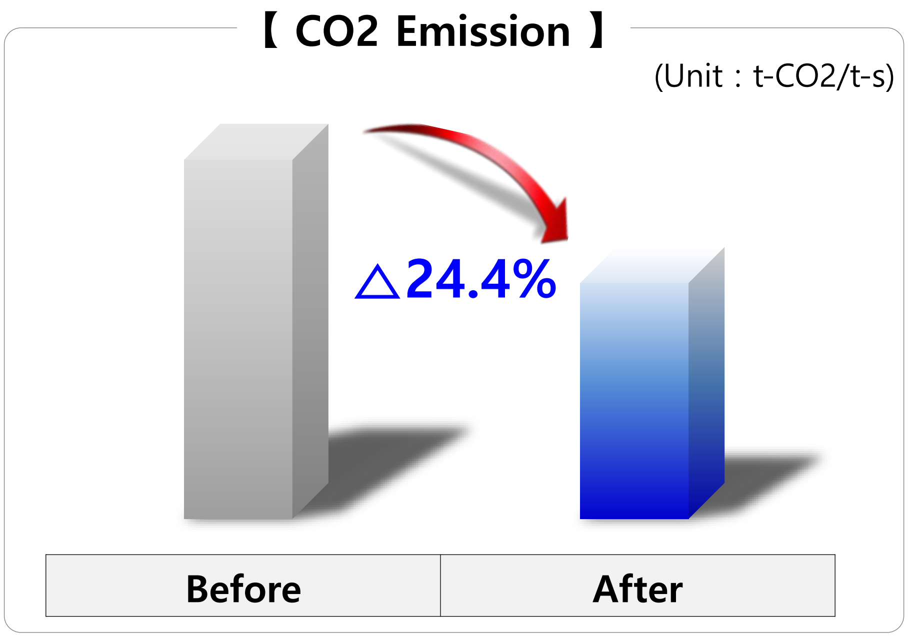
- PC Particle Tracking Surface

Operating test results

- HBI+Pellet+NG co-usage* test with improved smart BF & D/T technology at P2BF in 2023

* HBI 10% + Pellet 50% + NG 30kg/t-p

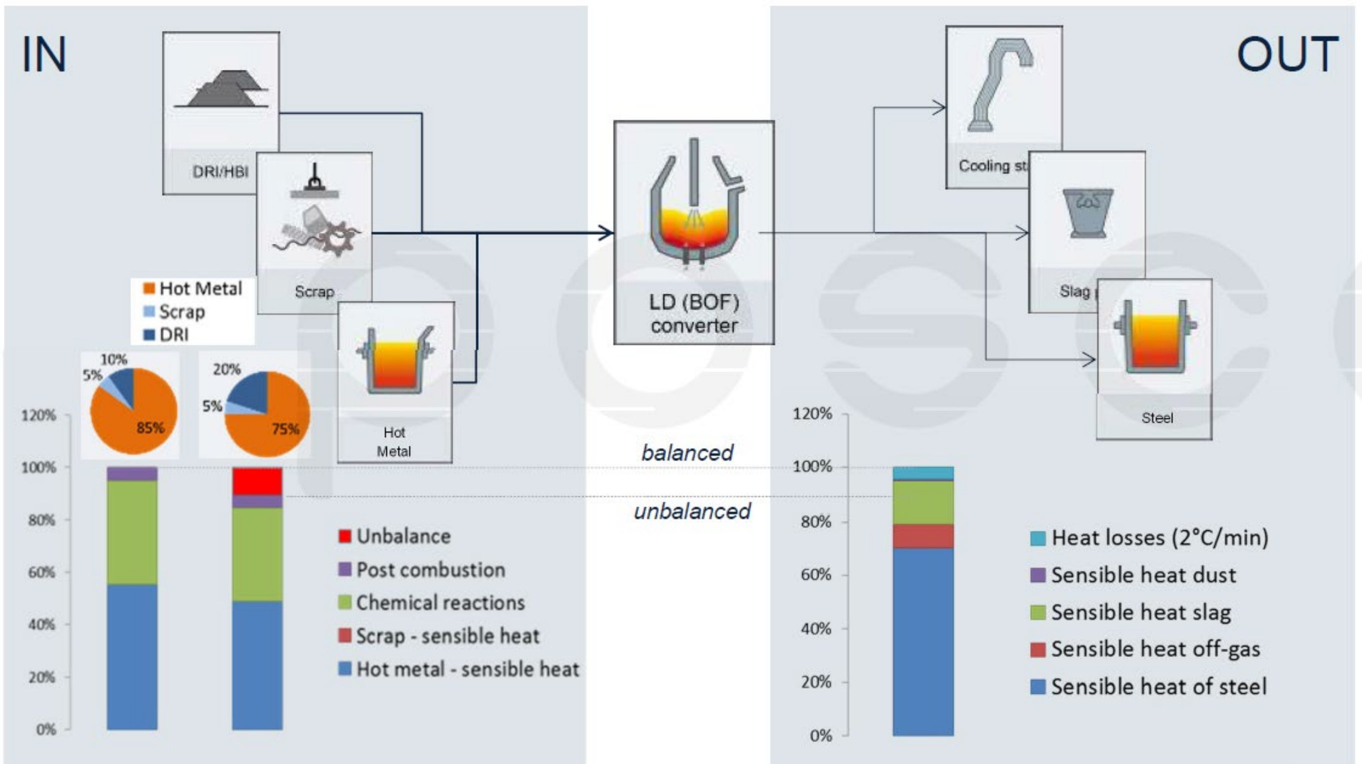




Bridge Technology – Pos-OBM

Heat balance in BOF

- Process well balanced for 85% HMR – for lower HMR energy not blanced, not enough energy to melt down all cold inputs (Scrap, DRI) and reach target tapping conditions

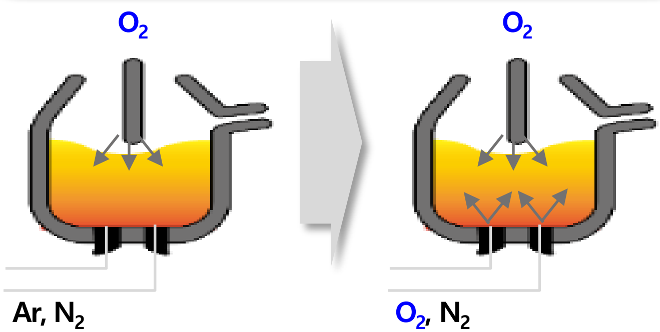


Bridge Technology – Pos-OBM

POS-OBM(Oxygen top and Bottom blowing Maxhuette)

- POS-OBM is very good for Post combustion control in vessel
  - → Bottom O2 for De-C, Top O2 for Post combustion and De-C
  - → Change of lance heights freely for control of post combustion ratio

Top and Bottom Blowing Converter



	Top blowing converter	Top and bottom blowing converter
Oxygen blowing location	Top	Top, Bottom
Post combustion ratio(%)	5~10	25~30

* [Primary combustion] [C] + ½ O_2 → CO : + 2,200 kcal/kg_C
  [Post combustion] CO + ½ O_2 → CO_2 : + 5,630 kcal/kg_C

[Comparison between Top Blowing Converter and Top & Bottom Blowing Converter]

Supplying oxygen to top and bottom parts simultaneously, a converter easily generates the heat required to increase the scrap ratio

Bridge Technology - Biomass

POSCO

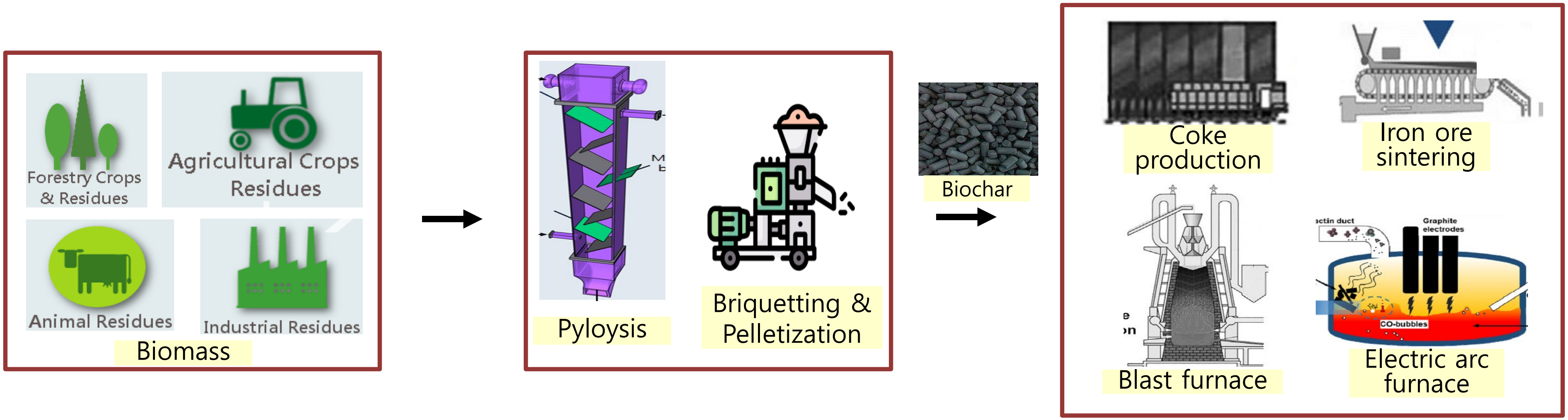
○ Utilization of biomass in steelmaking process

Ministry of Trade, Industry and Energy

Ministry of Trade, Industry and Energy → Government-led Project →

- Companies : POSCO, HYUNDAI Steel,..
- Research Institutes : KIER..

○ Target : Utilization of Biomass in steelmaking process for coal replacement



Biomass Feedstock

- Survey the biomass feedstock
- Policy, Global R&D Collaboration

Biomass Upgrade

- Pyrolysis, Torrefaction
- Densification Technology (Briquetting & Pelltization)

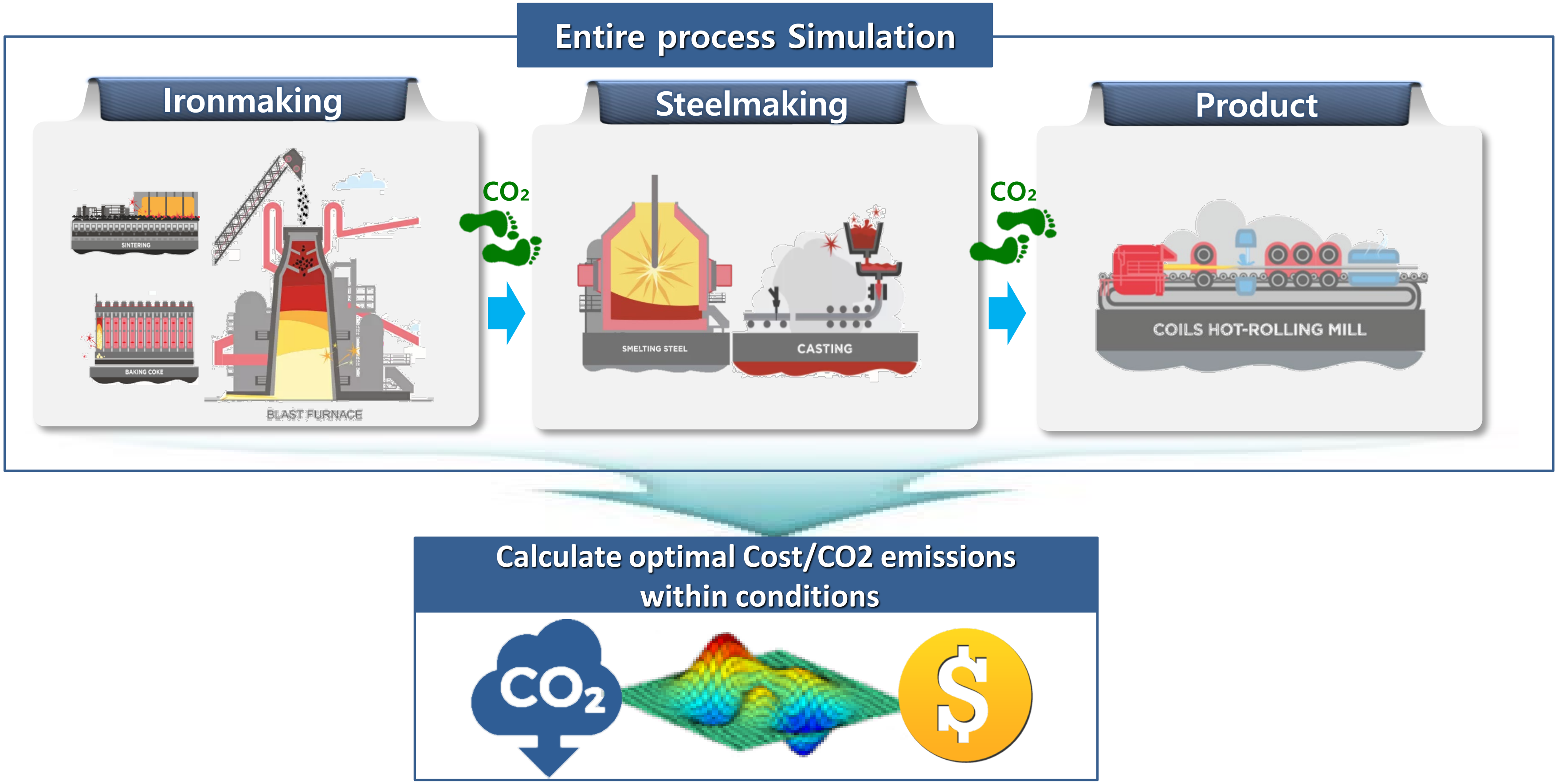
Utilization in Steel industry

- Coal replacement in BF, FINEX (Coke/BQ 2%, Sinter 3%, PCI 5%)
- Bio-Carbon for ESF, EAF

Bridge Technology - POSPLOT

Process based Lowest-cost-oriented Optimization Technology

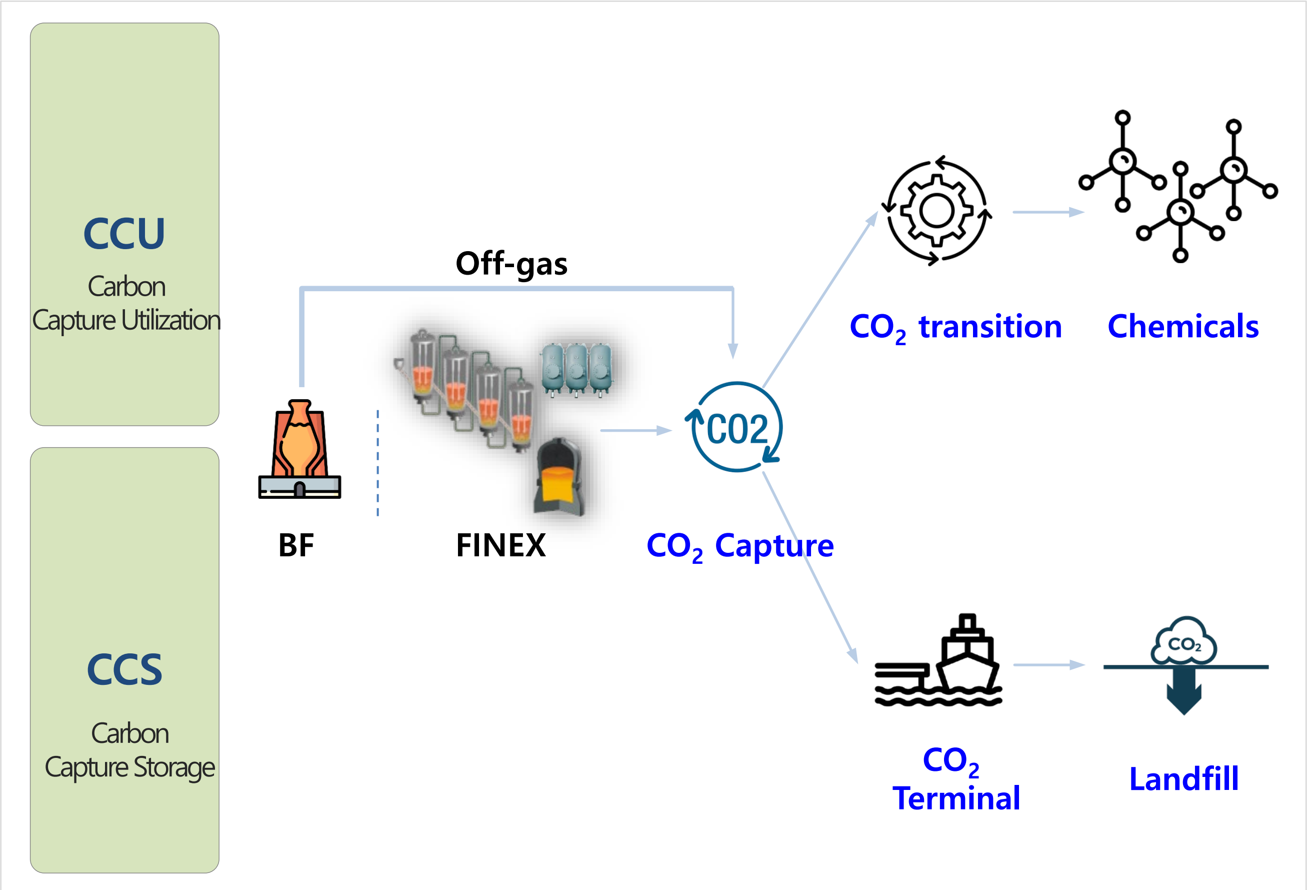
- Cost & CO2 decision making through intelligent virtual steel mill implementation
- Digital transformation that combines data processing, operation theory model, and analysis



Bridge Technology - CCUS

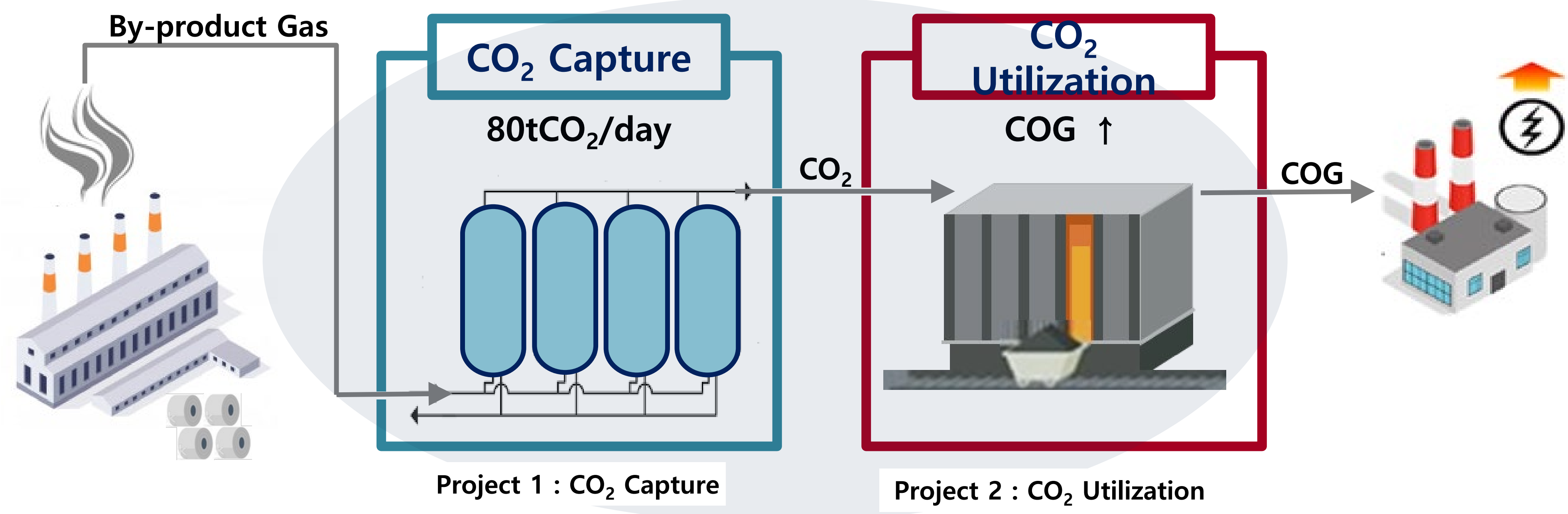
POSCO's CCUS approaches

- Establishment of system to capture or store carbon dioxide generated from blast furnace/FINEX

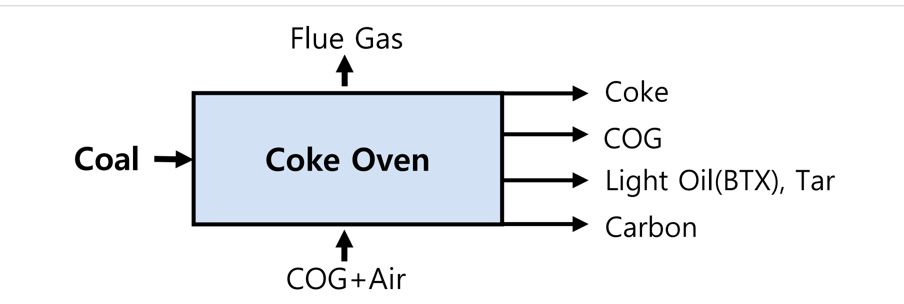


Bridge Technology - CCUS

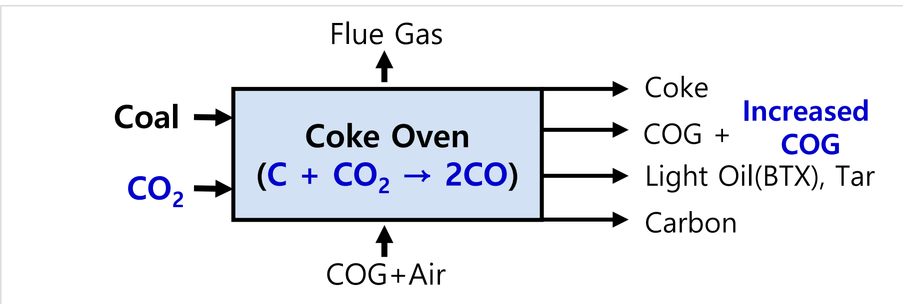
Details of CO_2 capture and utilization Government-led Project



Existing Coke Oven



Coke Oven + CO_2 Injection




Thank you for your kind attention !