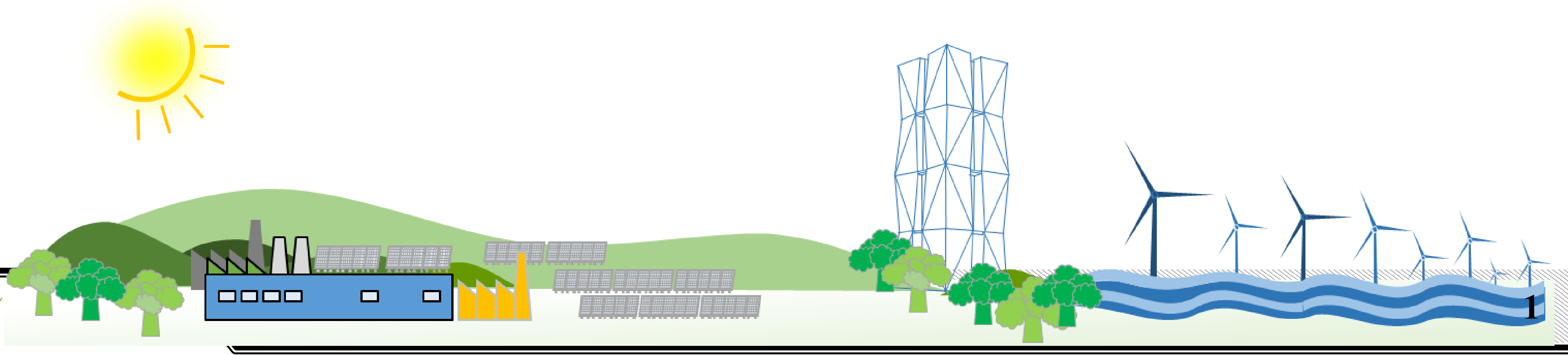
Progress of Low Carbon Blast Furnace Initiatives at CSC

- Brief Introduction of CSC
- Countermeasures for Carbon Reduction
- Efforts toward a Low-Carbon BF
  - Reduced Iron Charging
  - Hydrogen-Rich Gas injection Test
- Summary

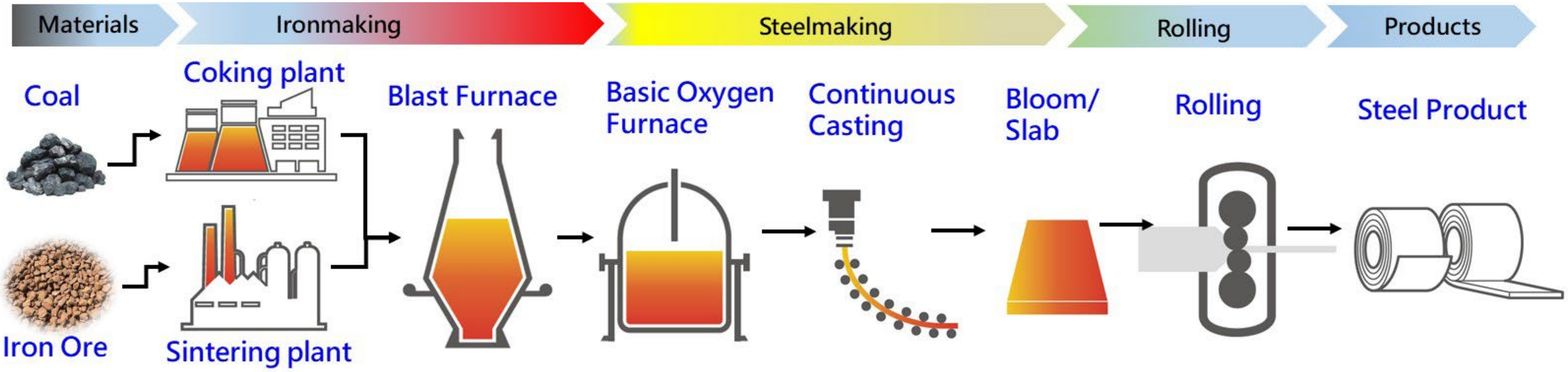
Speaker : Huang Tsung-Yen
Iron Making Process Development Section, R&D Dept., China Steel Corporation (Taiwan)

Date: Dec. 2-3, 2025

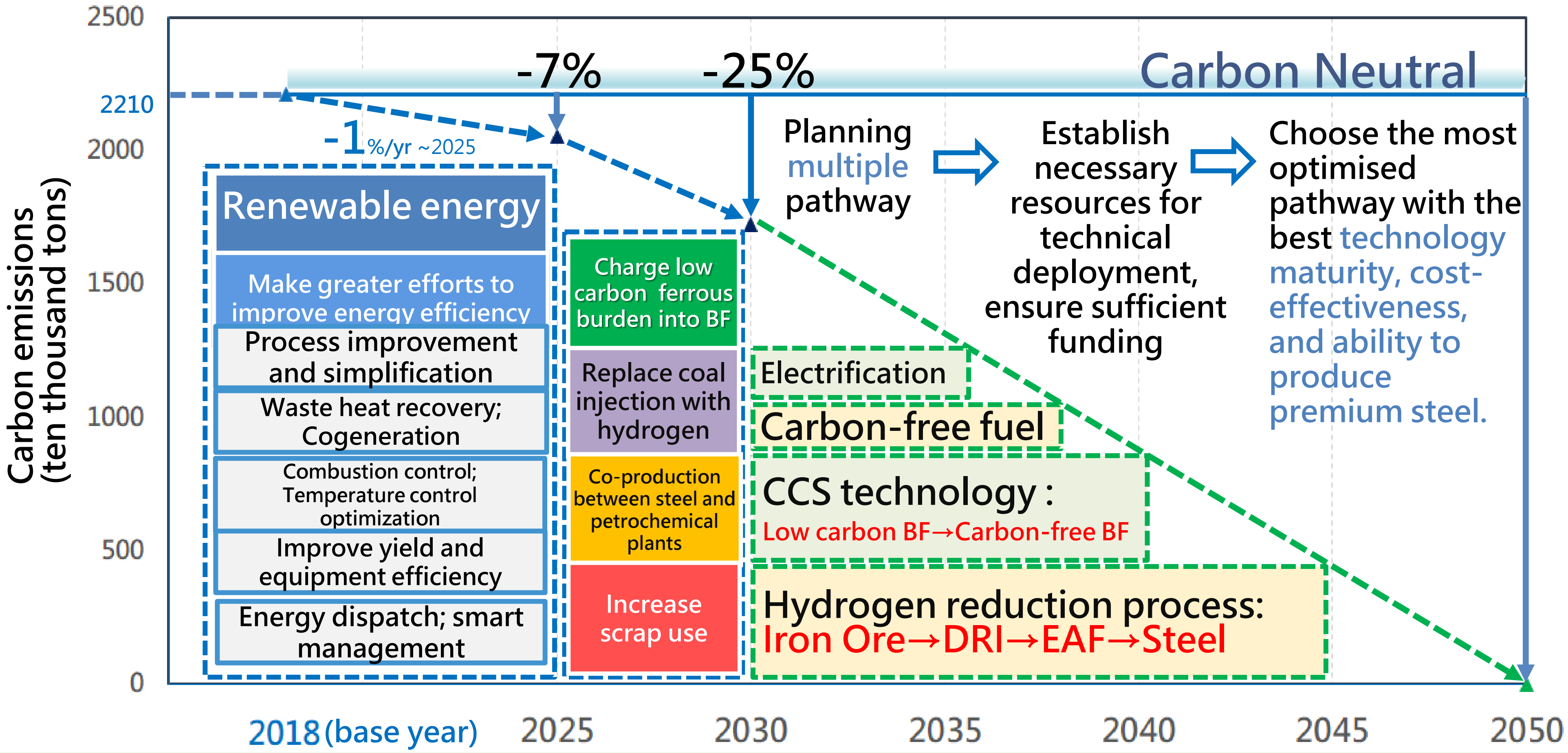


Brief Introduction of CSC

- CSC Group is the only integrated and largest steel mill in Taiwan, with a designed annual hot metal output of 15 million metric tones by 6 BFs and 1 EAF.
- The production processes include BF Ironmaking, BOF Steelmaking, Continuous Casting, and Hot/ Cold Rolling.
- Generally, an integrated steel mill generates a large amount of CO_2 since its blast furnace ironmaking is coal-based process, which consumes around 75% energy of the mill.



Pathways for CSC to achieve Carbon Neutrality in 2050

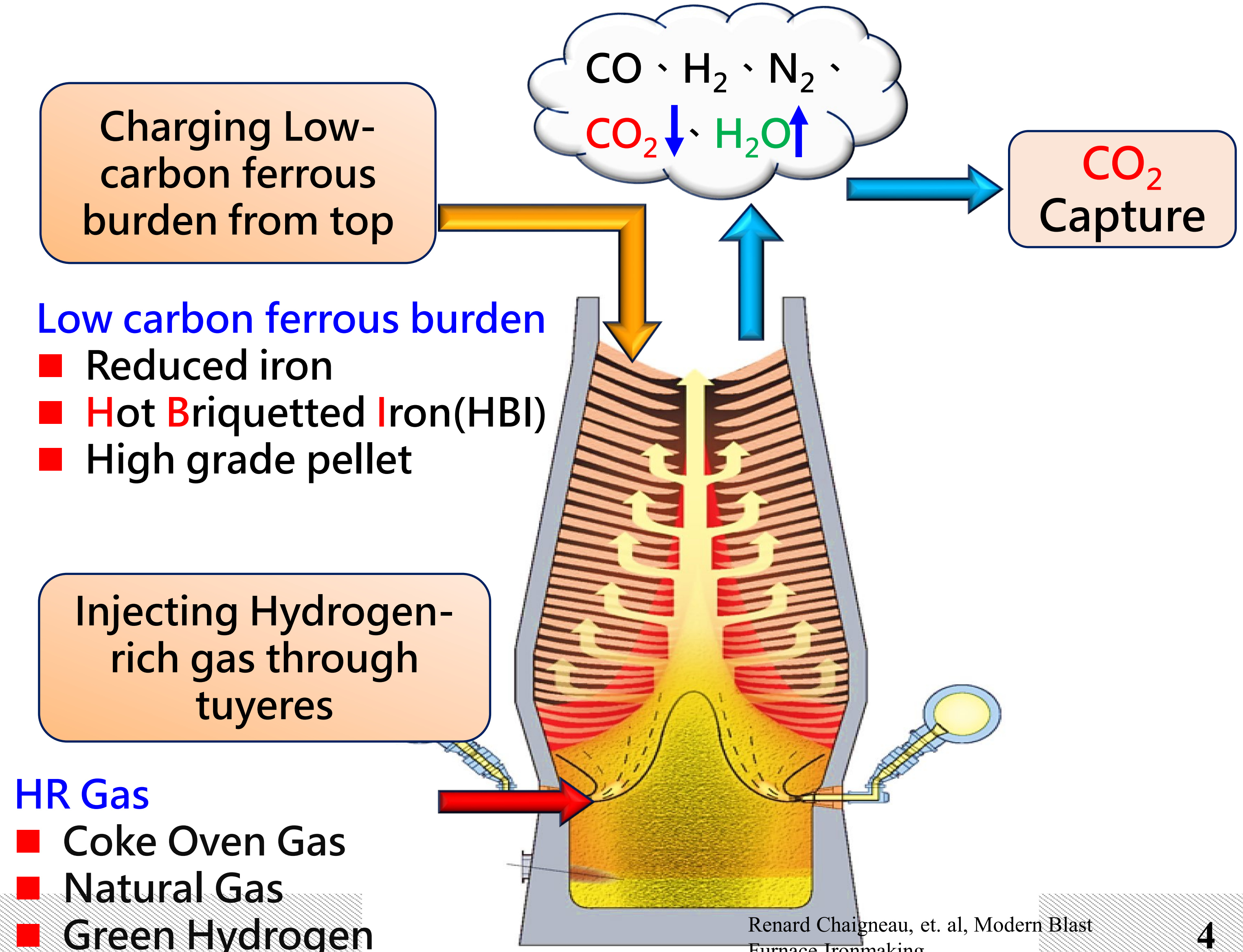


- To optimize the energy efficiency and to use the renewable energy have been practiced before 2025.
- Countermeasures on Low Carbon BF, CCU (carbon to chemicals) and increase of scrap addition in BOF will be tested and validated. The countermeasures which are economically feasible will be taken into operation.
- When green hydrogen with reasonable price becomes available, the production of liquid steel by DRI-EAF route and the use of carbon free fuel can be realized.

Routes towards Low Carbon Blast Furnace

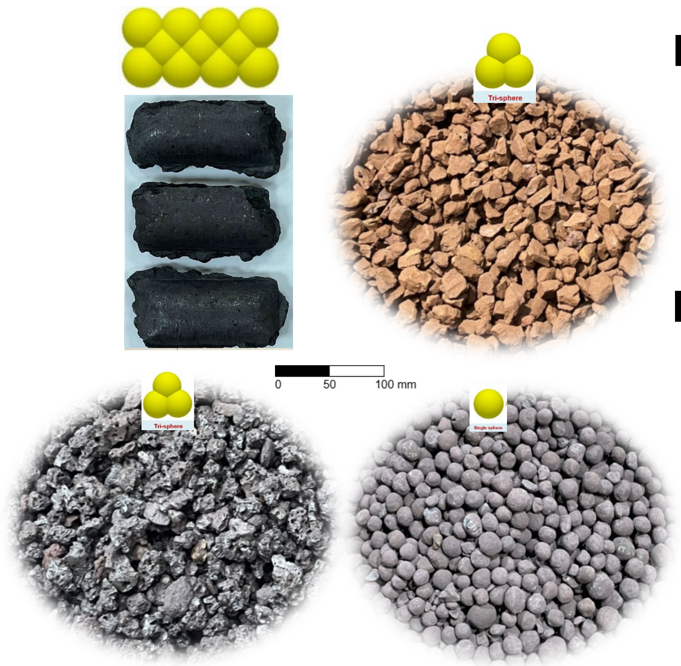
- CSC is actively working on the development of low carbon BF ironmaking process by collaborating with academics, research institutes, and industries for achieving carbon neutrality by 2050 in Taiwan.

- Charging low carbon ferrous burden, injecting hydrogen rich gas and carbon capture are the effective ways to abate CO_2 emissions of BF .



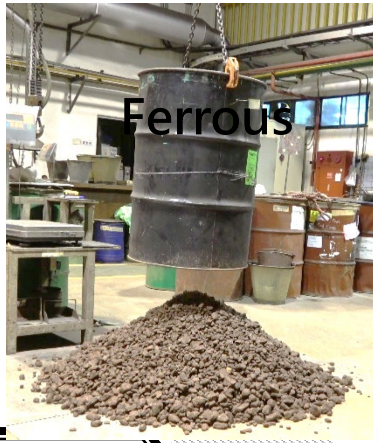
Renard Chaigneau, et. al, Modern Blast Furnace Ironmaking

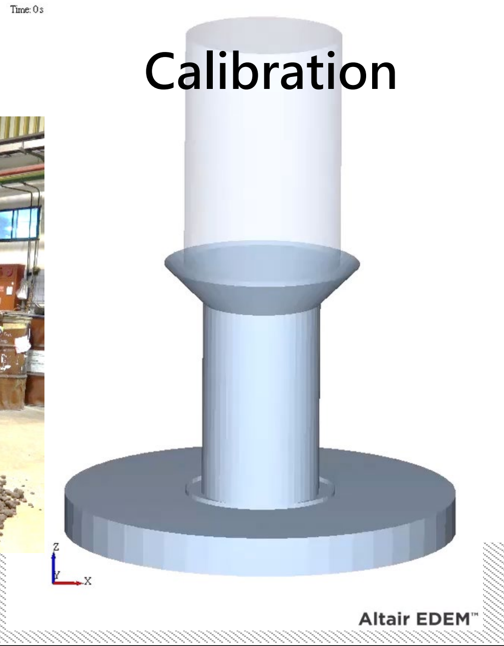
Burden flow simulation in Real-Scale Particle

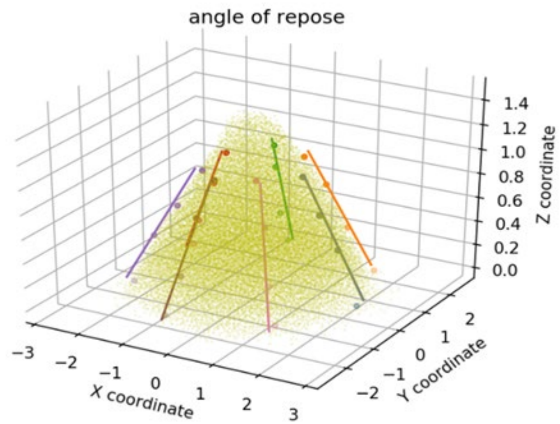


- To ensure that HBI and all burden materials can be safely and precisely distributed to the furnace top, a real-scale particle flow and movement simulation was conducted.
- Physical properties of burden materials, such as repose angle, static friction coefficient, and coefficient of restitution were measured to calibrate digital particle model.

Cylinder Diameter
Particle MS*25

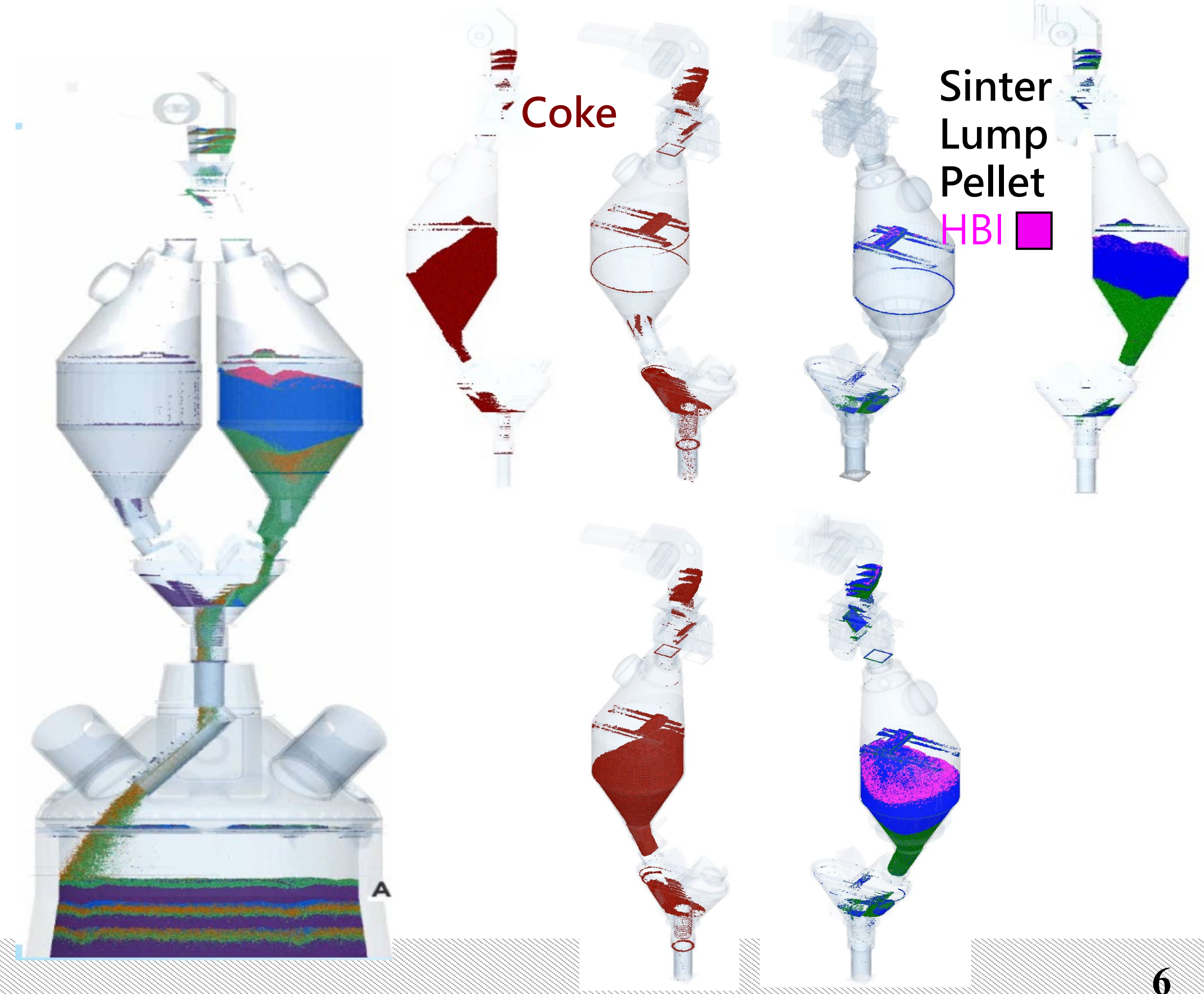






Burden transportation, charging, distribution Simulation

- Simulate the flow form conveyor, filling, discharging, to distribution in real geometry of belt, silo, and BF.
- Original size of HBI was delivered by conveyor belt to top silo.
- 150kg-HBI/tHM replaces sintered ore
- Computing by NVIDIA DGX A100-GPU*4, total particle number over 60 million.
- Simulation results were validated not only by top furnace profile meter, but also a 1/12-scale experimental top furnace model.

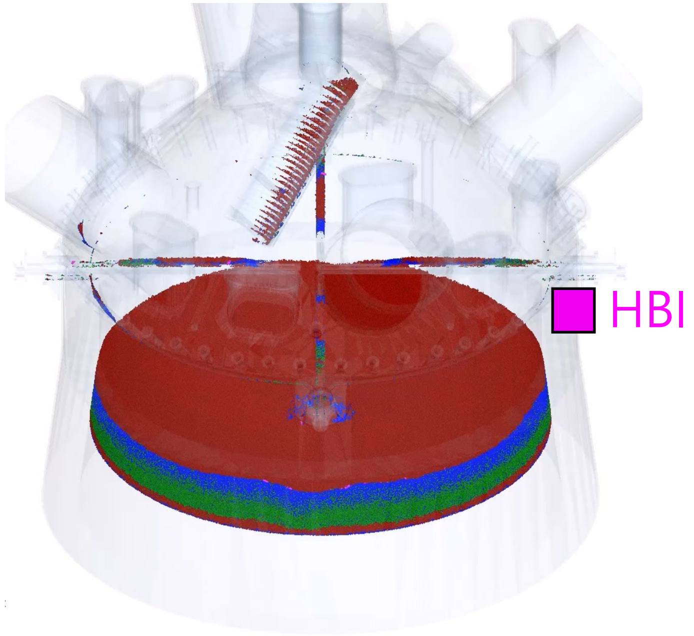


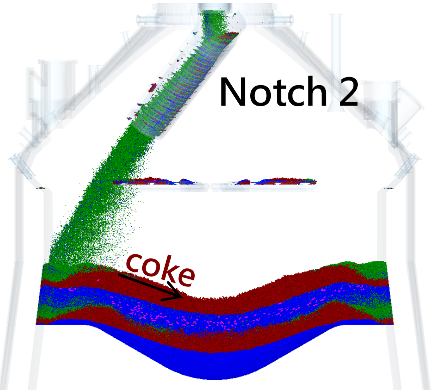
Analysis and Design of Burden Characteristics

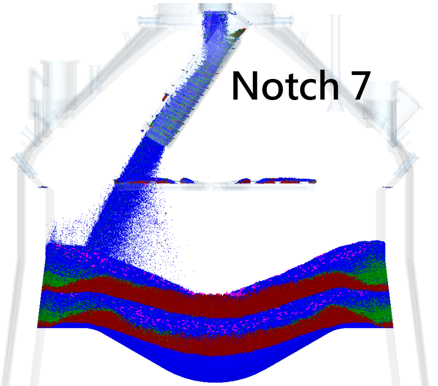
- 4 or 6 layers burden distributing
- Coke was pushed to the center during ferrous charging.
- Divide the furnace into 10 equal rings to analyze the material distribution on the top two layers.

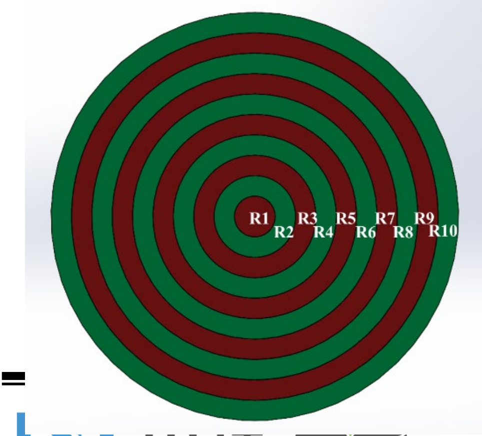
- The HBI disperses uniformly from wall area to the center. Propose HBI in center is beneficial to melting because of the stronger gas flow intensity there.

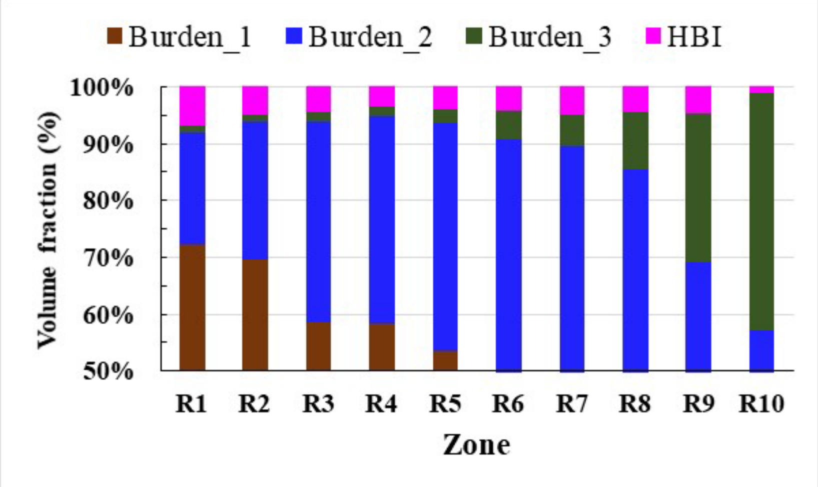
- Ore/Coke ratio in wall area is high; porosity at center is the highest and near the wall area is also good. Our production engineer is happy for this distribution.

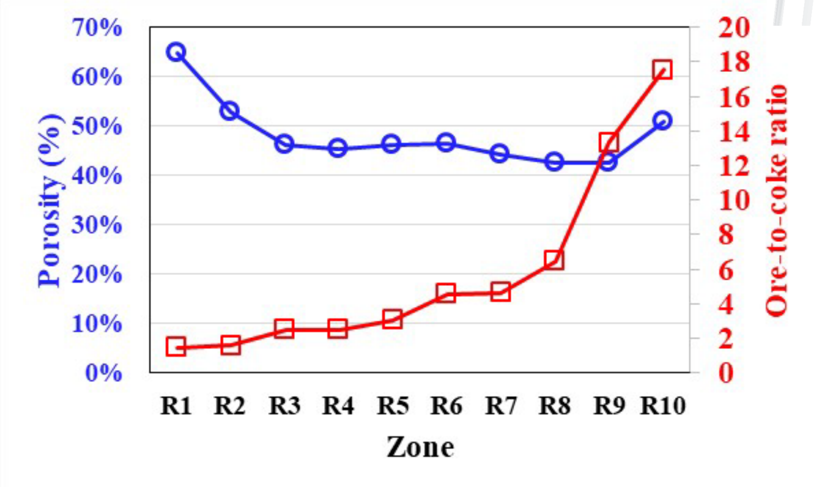


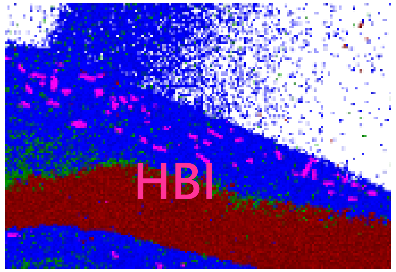




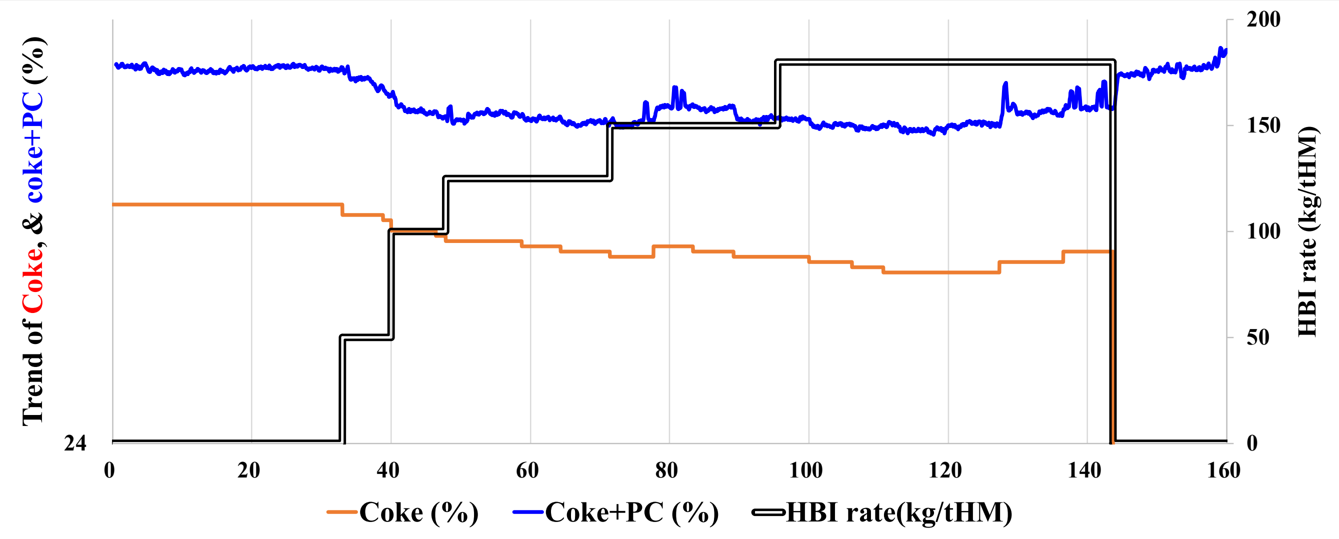


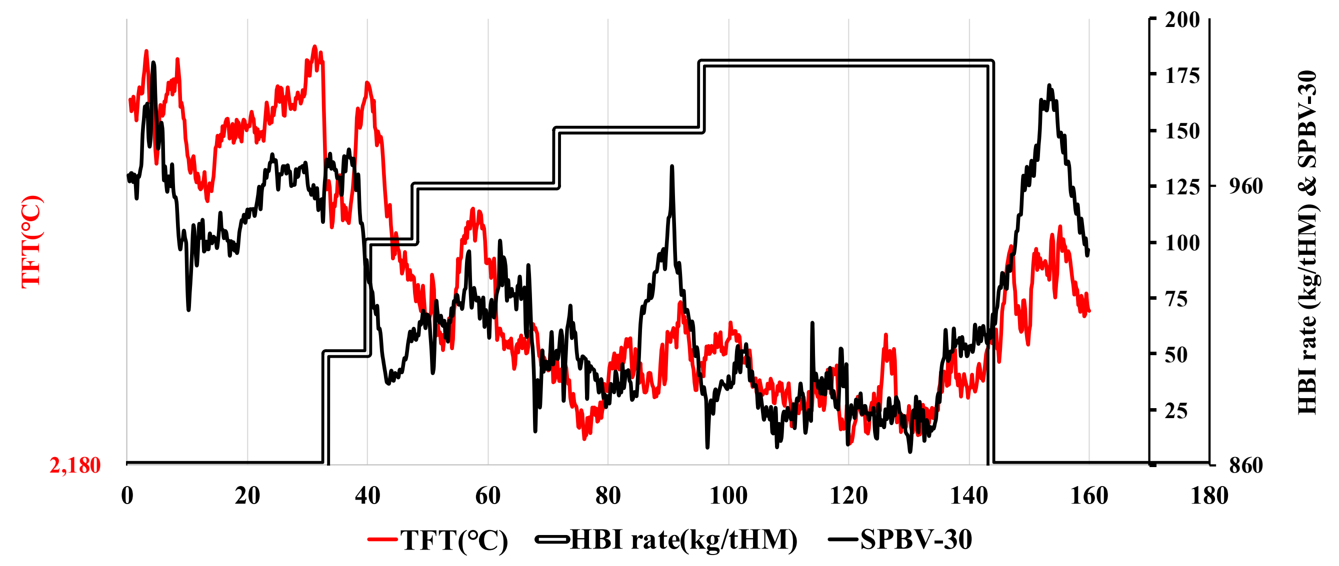






Production Trial of HBI Addition in the BF

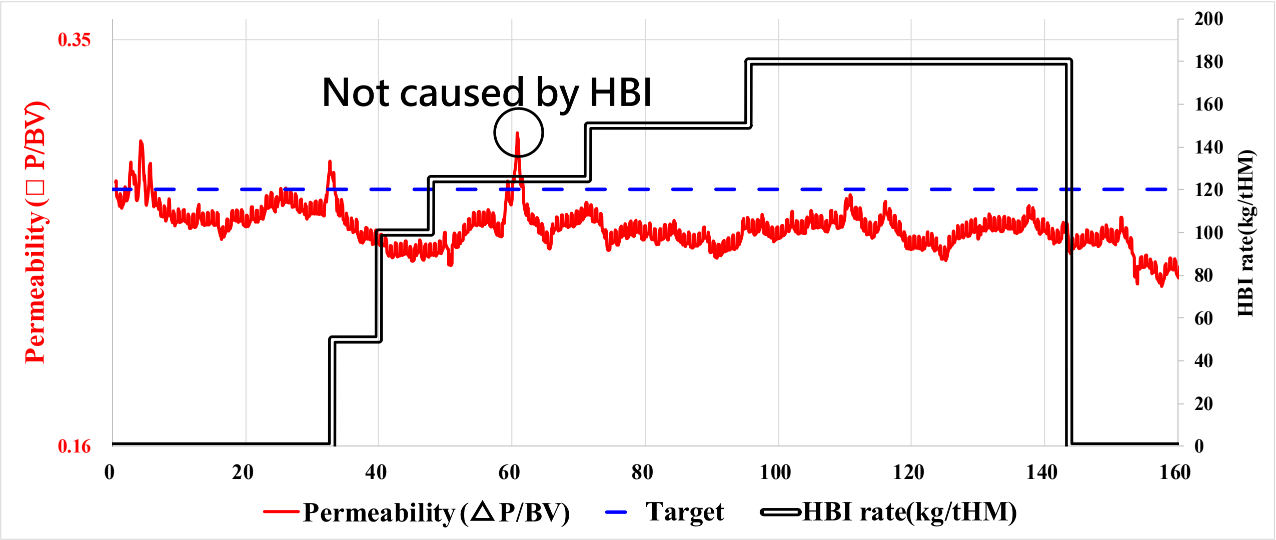


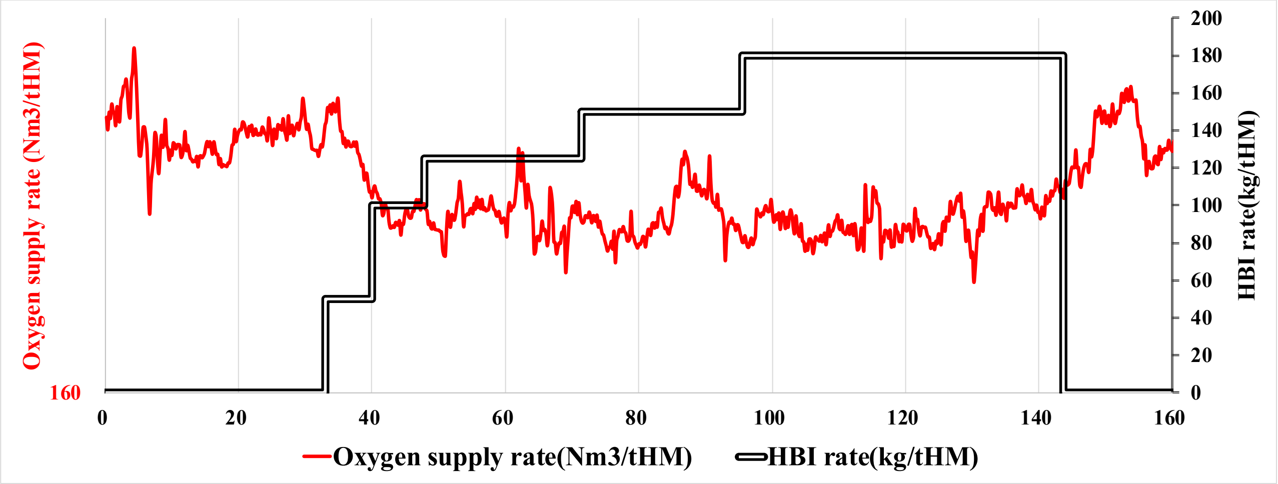


- HBI charging test was conducted at CSC BF.
- HBI addition rates 50、100、125、150、180kg/tHM
- During 150kg-HBI/tHM, a short time HM temp. dropped, so increase the reductant rate.
- The lowest coke rate was 280kg/tHM at 180kg-HBI/tHM.
- During HBI, operated TFT at low level; SPBV (Specific Productivity per Blast volume) also went down. It is to keep hot metal production the same as in the base case

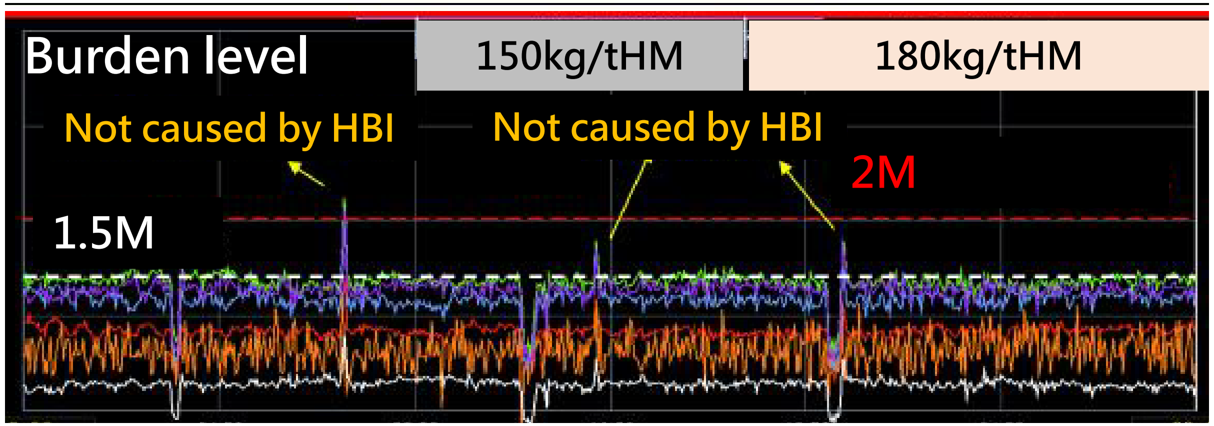
中鋼 50

Production Trial of HBI Addition in the BF

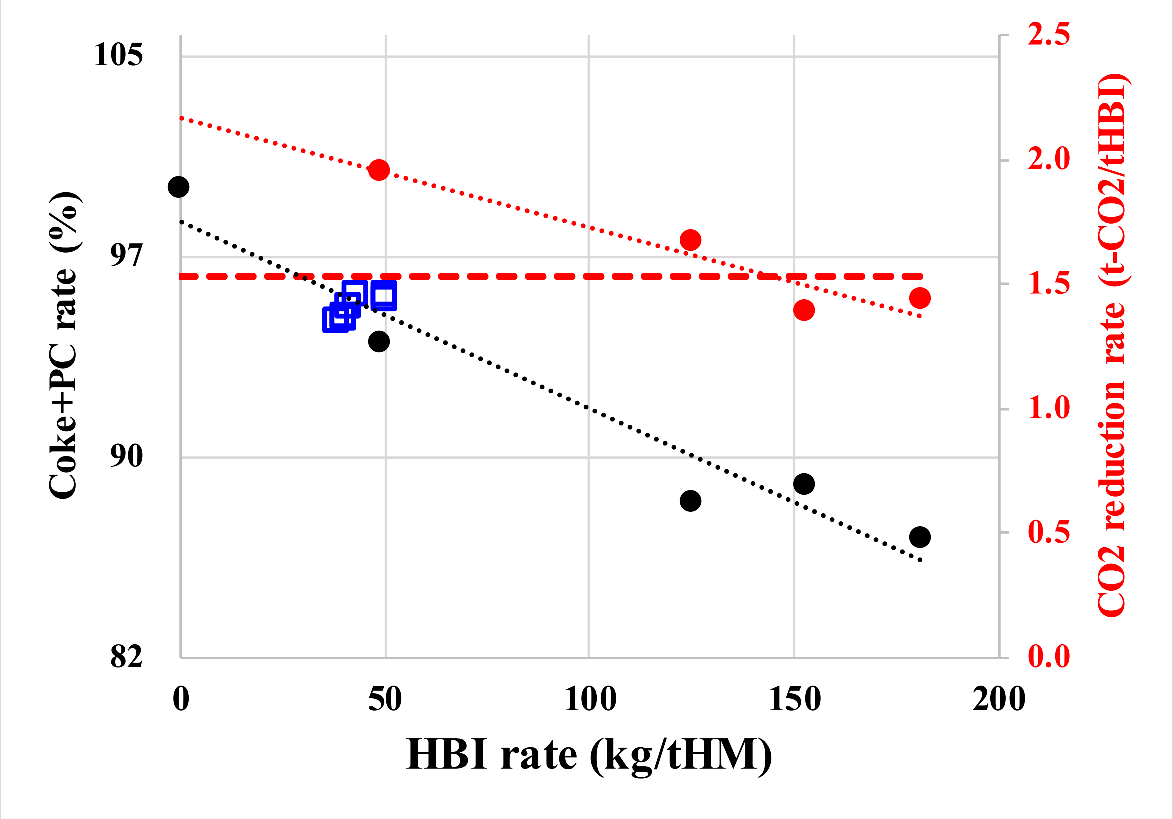




- BF Permeability performed quite good throughout the entire HBI period.
- Since HBI consists mostly of metallic iron and requires less reduction, the total oxygen demand decreased from 230 to 205Nm^3/tHM.
- During entire HBI period, burden descent was very stable, no slip, no drop occurred.



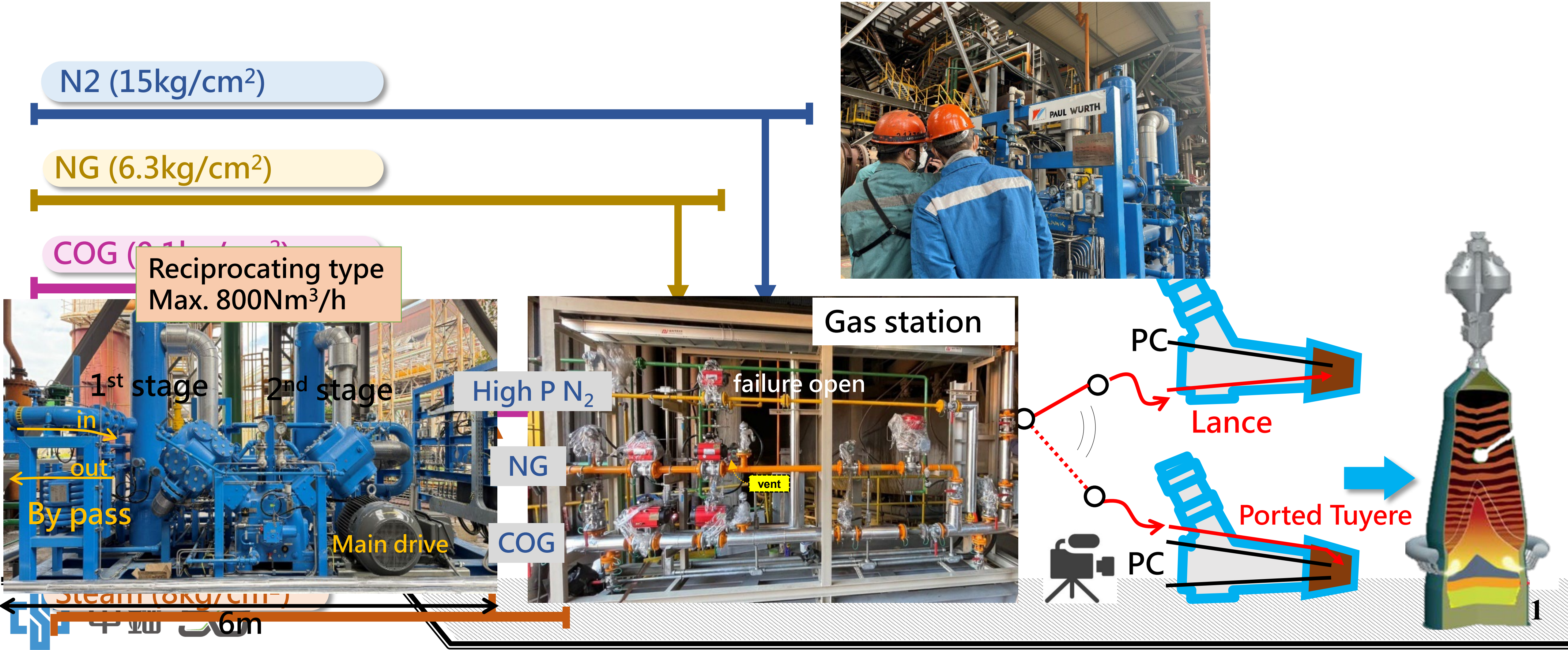
Performance of HBI for decarbonization



- The lowest coke+PC was 419kg/tHM at 180kg-HBI/tHM
- With increasing HBI rate, the CO_2 reduction rate decreases.
- After considering the in-plant energy balance (top gas heat, utility usage), average reduction rate is 1.53t-CO_2/t-HBI.

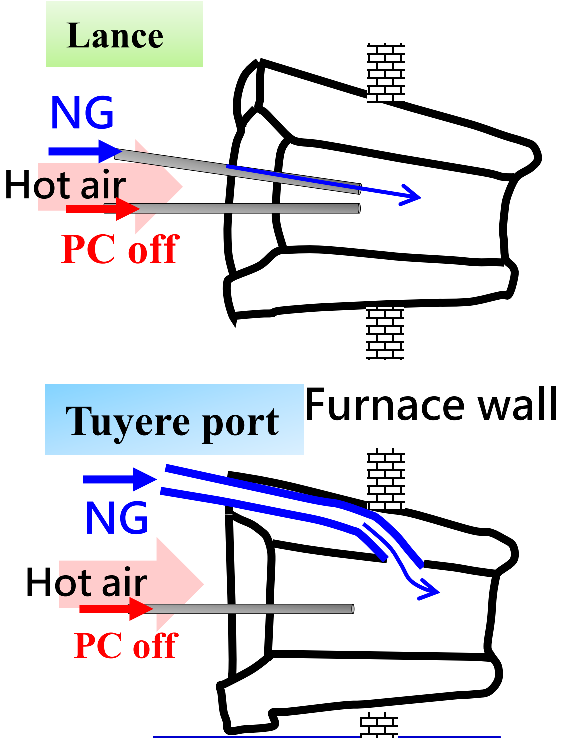
One tuyere NG/COG injection test at CSC BF1

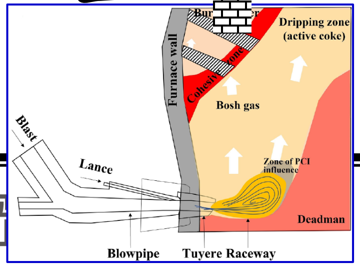
- All CSC blast furnaces currently operate with PC injection and have no prior experience with gas injection. To firmly develop hydrogen-rich gas injection operation technology, one-tuyere gas injection system has been constructed.
- The objective is to define the safety control sequence for gas injection and further to evaluate the combustion characteristics of NG and COG.

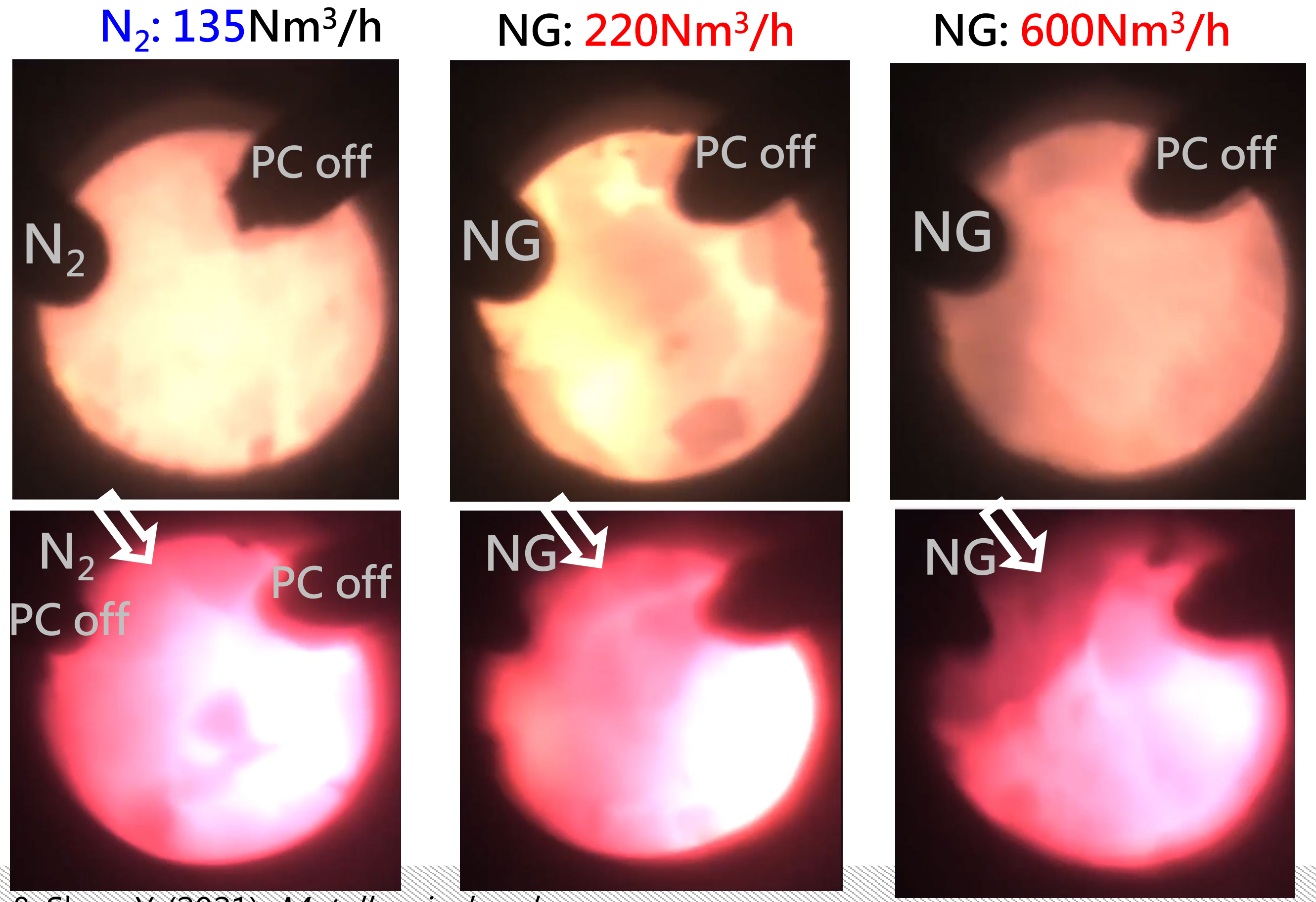


Comparison of raceway dynamics between lance and tuyere port injection

- With increasing NG flow rate from 220 to 600Nm³/h, the combusted luminous intensity fade gradually.
- Lance injection shows a significant reduction in luminous intensity, whereas tuyere port injection does not. Suggests tuyere port injection offers better combustion performance.





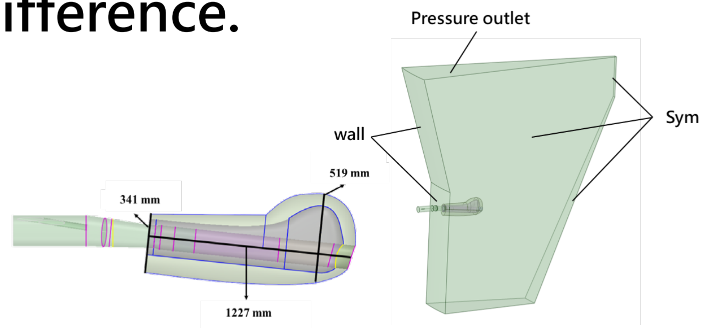


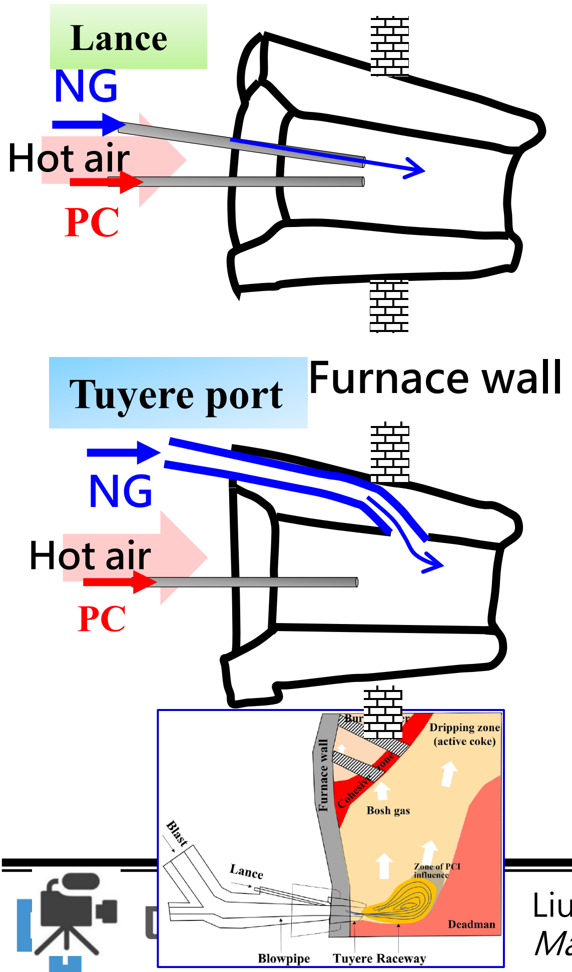
Liu, Y., Hu, Z., & Shen, Y. (2021), *Metallurgical and Materials Transactions B*, *52*(5), 2971-2991.

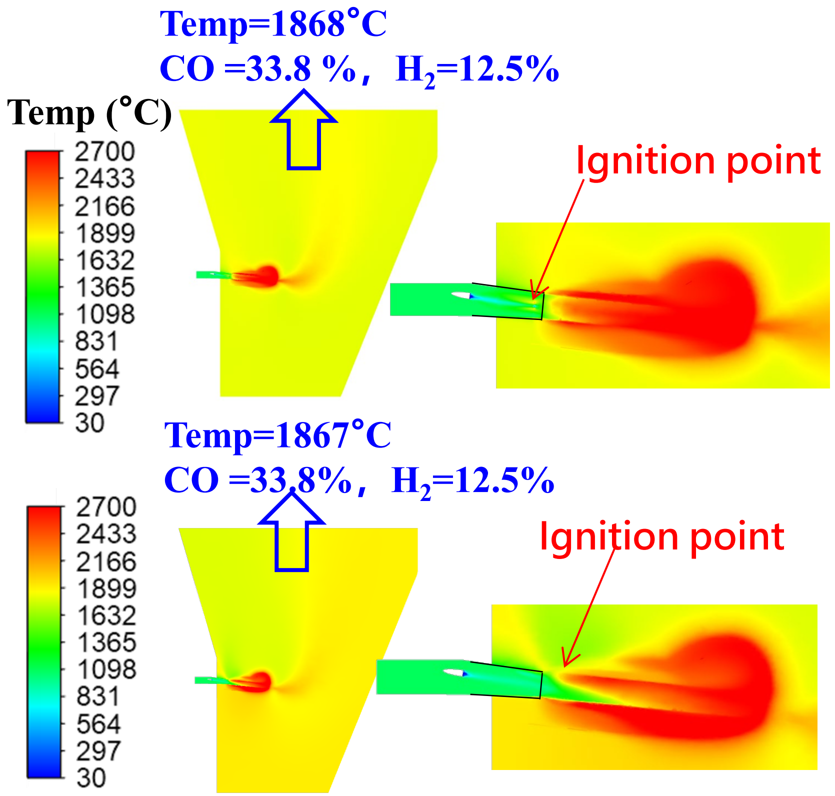
Comparison of CFD result of Lance and tuyere port

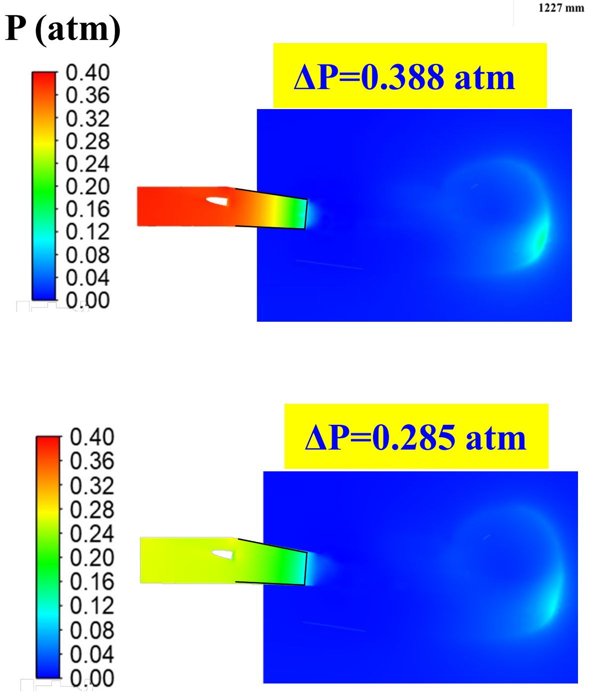
(1) Tuyere port: NG outlet is more toward the raceway, ignition point is at the raceway, pressure loss not significant.

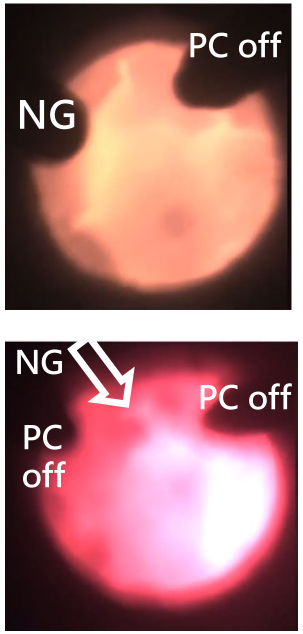
(2) Bosh gas temperature and gas composition are similar, no big difference.







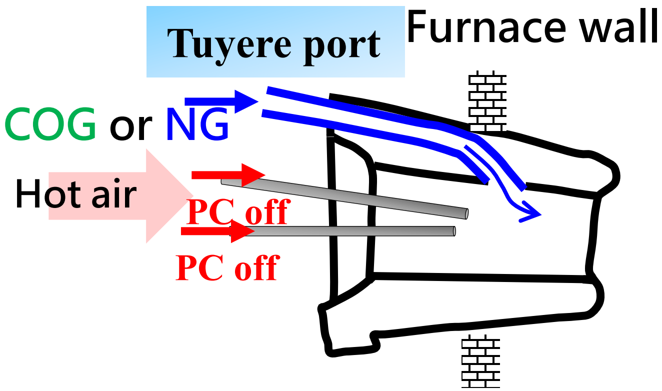


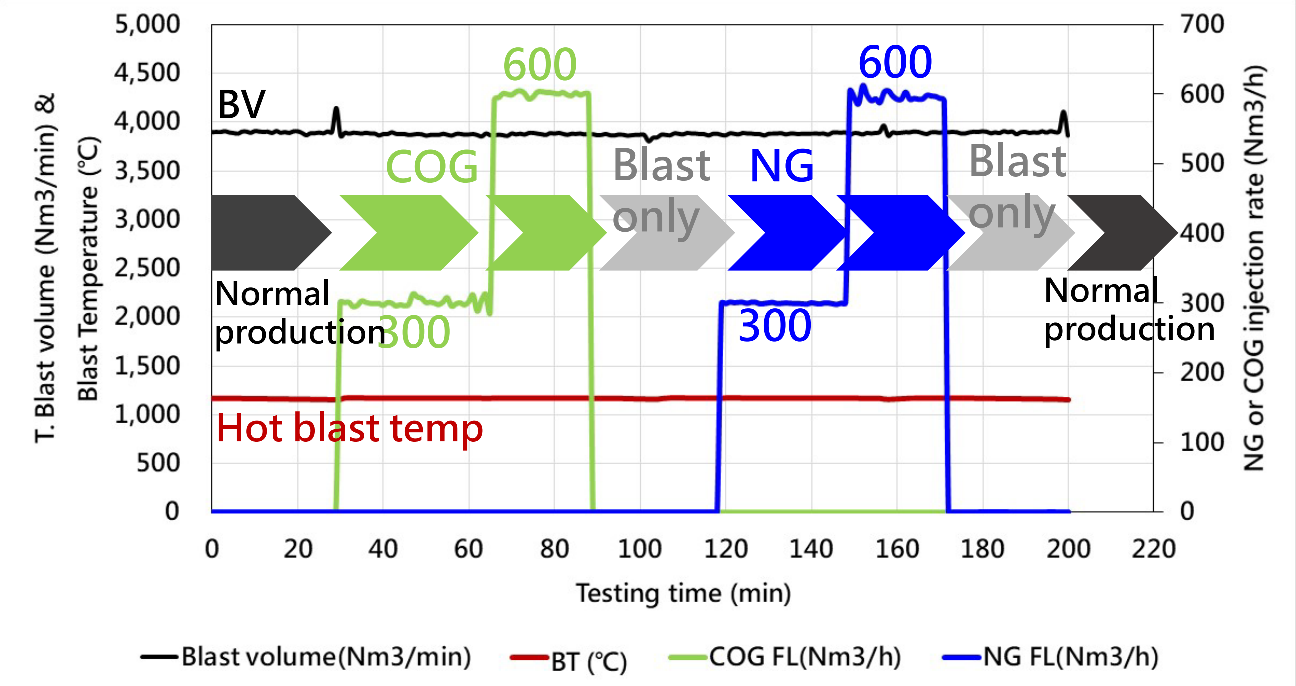


Liu, Y., Hu, Z., & Shen, Y. (2021), *Metallurgical and Materials Transactions B*, *52*(5), 2971-2991.

Comparison of raceway behavior between NG and COG injection

- To study the raceway behavior between COG and NG injection, same flow rate 300、600Nm³/h are injected into BF. PC are off.
- Expt. Procedure: (1) normal operation with PC ; (2) COG-300 only ; (3) COG-600 only ; (4) Blast only ; (5)NG-300 only ; (6) NG-600 only ; (7) Blast only ; (8) Back normal operation.





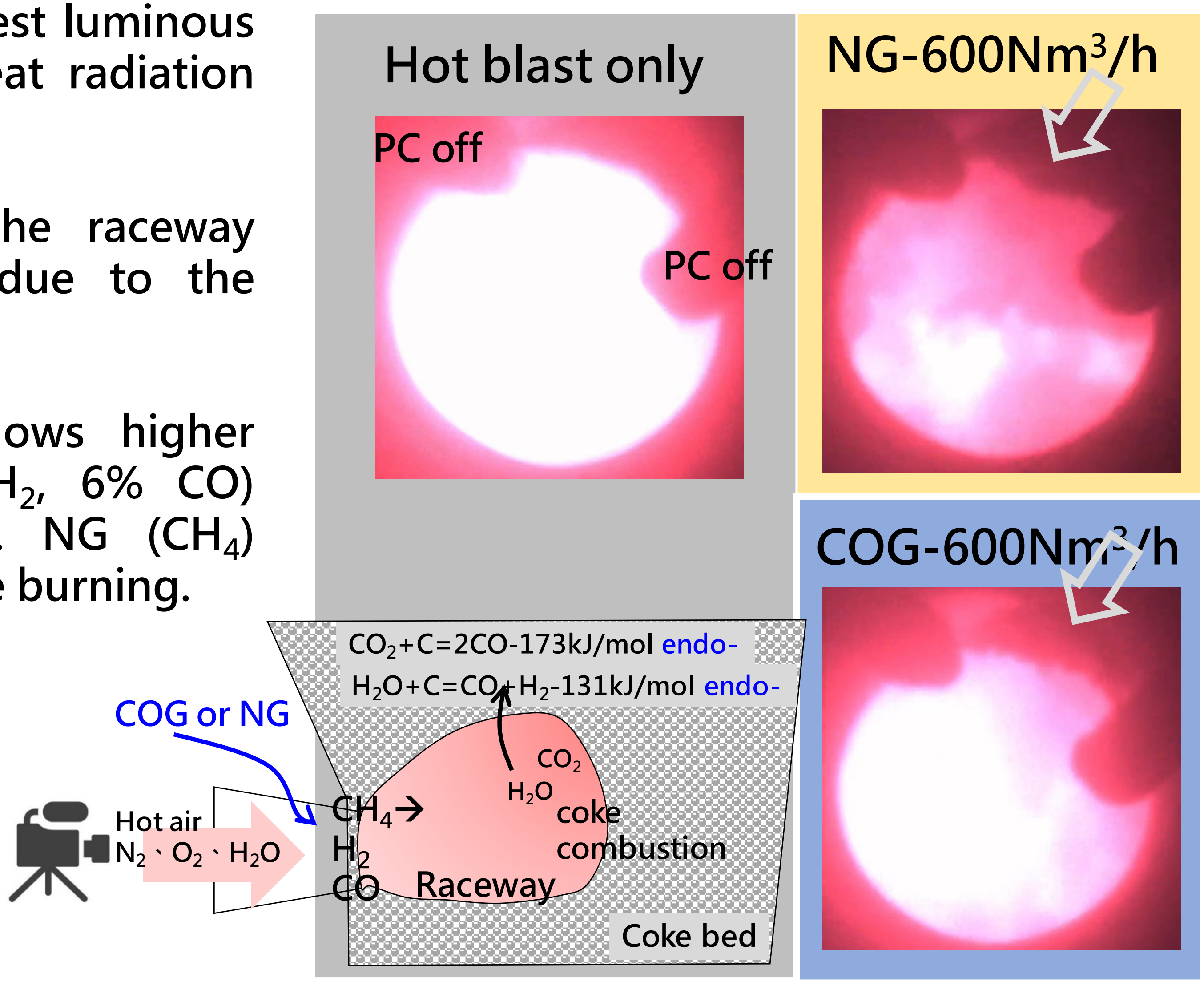
1 mole COG	
H_2	0.556
O_2	0.002
N_2	0.084
CH_4	0.245
CO	0.062
CO_2	0.022
C_2H_4	0.028

1 mole NG	
CH_4	0.922
N_2	0.024
O_2	0.054

Comparison of NG & COG injection at raceway

- Only the hot blast exhibits the highest luminous intensity, as it is caused by the heat radiation from coke combustion (TFT 2,437°C).
- As the injection rate increases, the raceway gradually becomes darker, likely due to the cooling effect of the injectant.
- At equal injection rates, COG shows higher brightness than NG. COG (56% H_2, 6% CO) combusts directly with hot blast. NG (CH_4) requires endothermic cracking before burning.

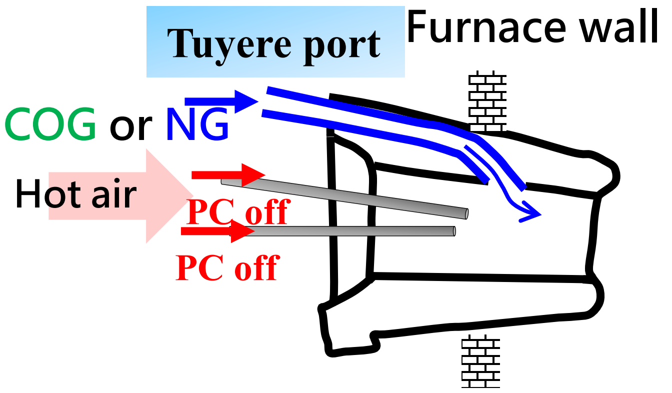
Condition	TFT(℃)
Blast only	2,437
NG-600	1,987
COG-600	2,209

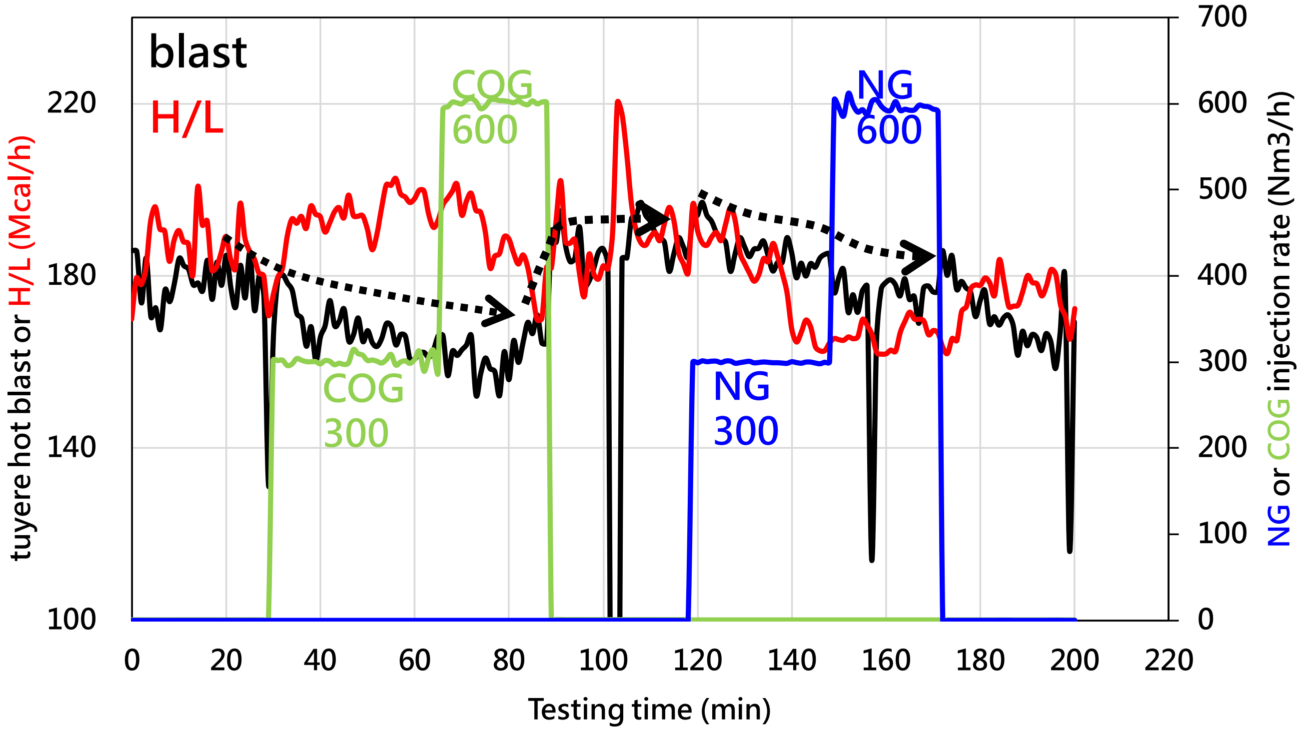


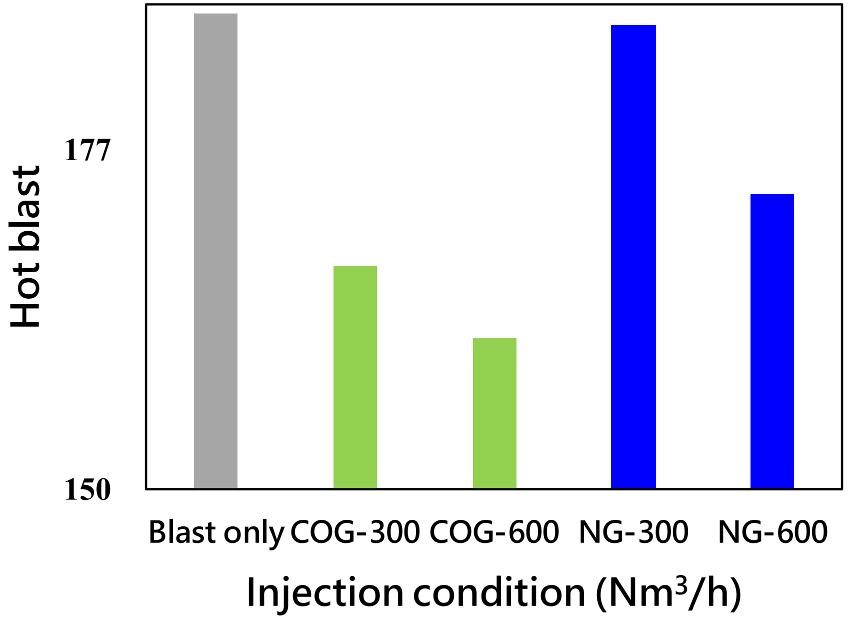
Comparison of NG & COG injection at raceway

■ Blast rate

After COG injection, blast drops, then back to normal as COG stopped. Then during NG injection, blast keeps decreasing. This behavior suggests that the injection gas combusts very soon inside tuyere. The combustion gas volume expands sharply, creating additional flow resistance at the tuyere outlet and reducing the hot-blast rate. COG injection has lower blast rate than NG injection. Proposed H2 & CO contained COG provide good combustibility and generates larger combustion gas volume.



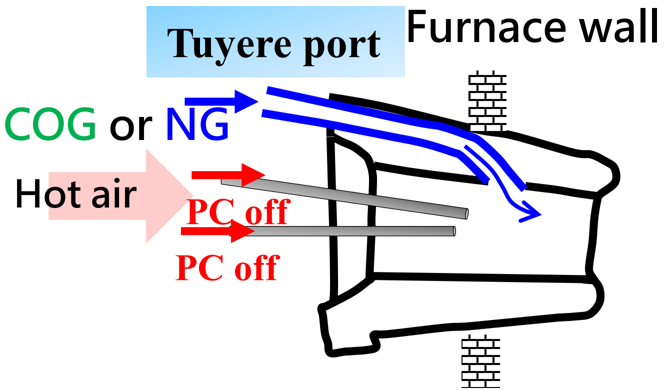


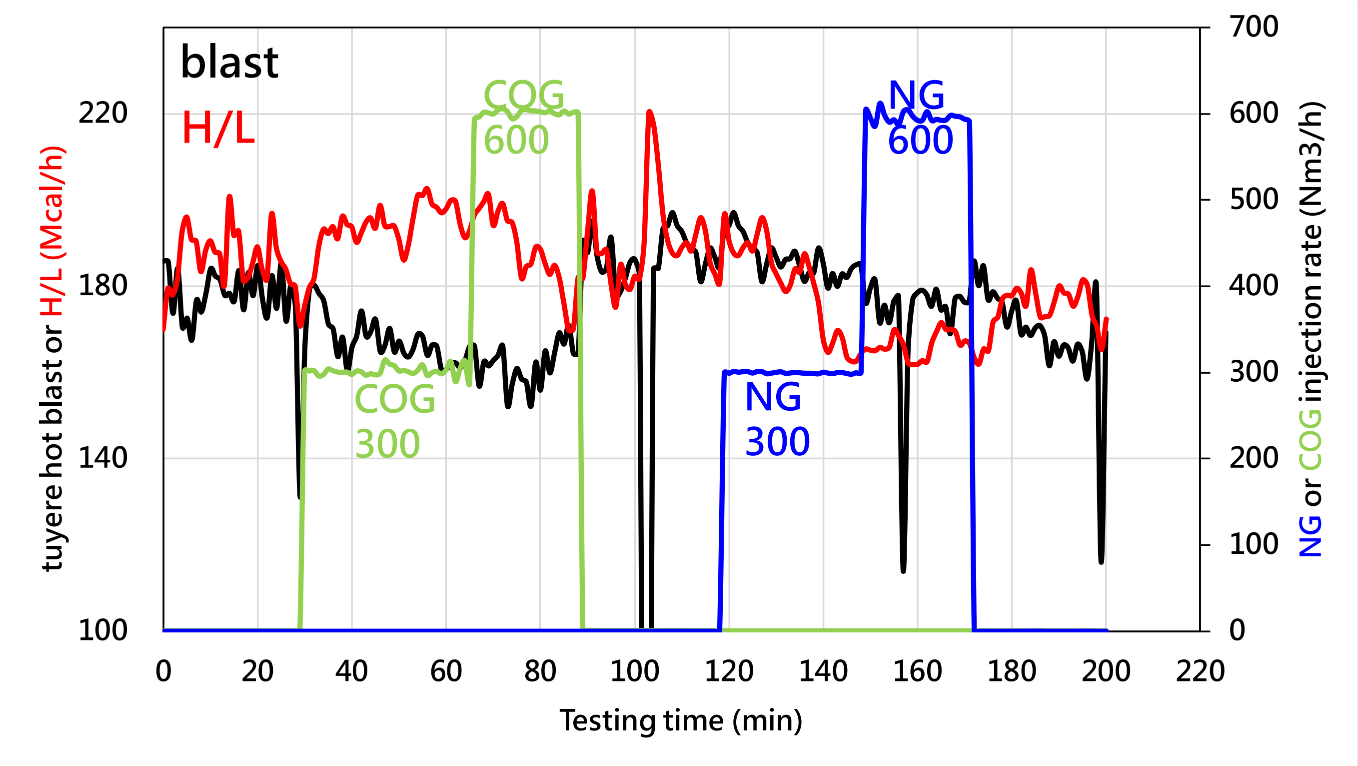


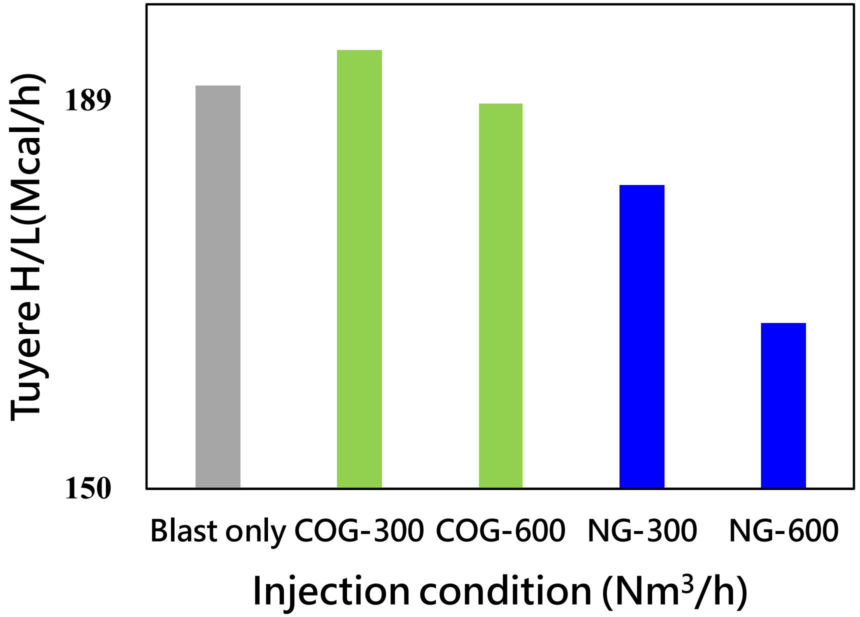
Comparison of NG & COG injection at raceway

- **Tuyere heat loss(H/L)**

  With COG injection, no significantly changes； With NG injection, H/L goes down.
  This suggests that NG does not combust effectively and instead cools the surrounding hot blast.







Summary

- Under the decarbon pressure, CSC has planned the strategies to cut the emissions in the medium term and to reach carbon neutrality in the future.

- CSC has developed the technology for **charging low-carbon raw materials (HBI, reduced iron, and pellets)** and achieved **comparable operational results to the reference**. In addition, a one-tuyere NG/COG injection test was conducted to validate the safety control sequence.

- CSC will **erect a demonstration plant for all tuyere NG/COG injection** to validate how effective it is at reducing CO_2.

- When we decide whether to implement the decarbon measures at CSC, we need to consider **not only just how effective** they are, **but also** how much they **might raise our operating costs**.