METEC & 2ND ESTAD 2015

EUROPEAN STEEL TECHNOLOGY AND APPLICATION DAYS

NSENGI DANIELI tenova

The breakthrough ironmaking technologies combined with ENERGIRON, Blast furnace and Syngas

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Alessandro Martinis :Ironmaking DRI, Danieli & C.

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1. Introduction

Strategic alliance with Tenova, Danieli and NSENGI

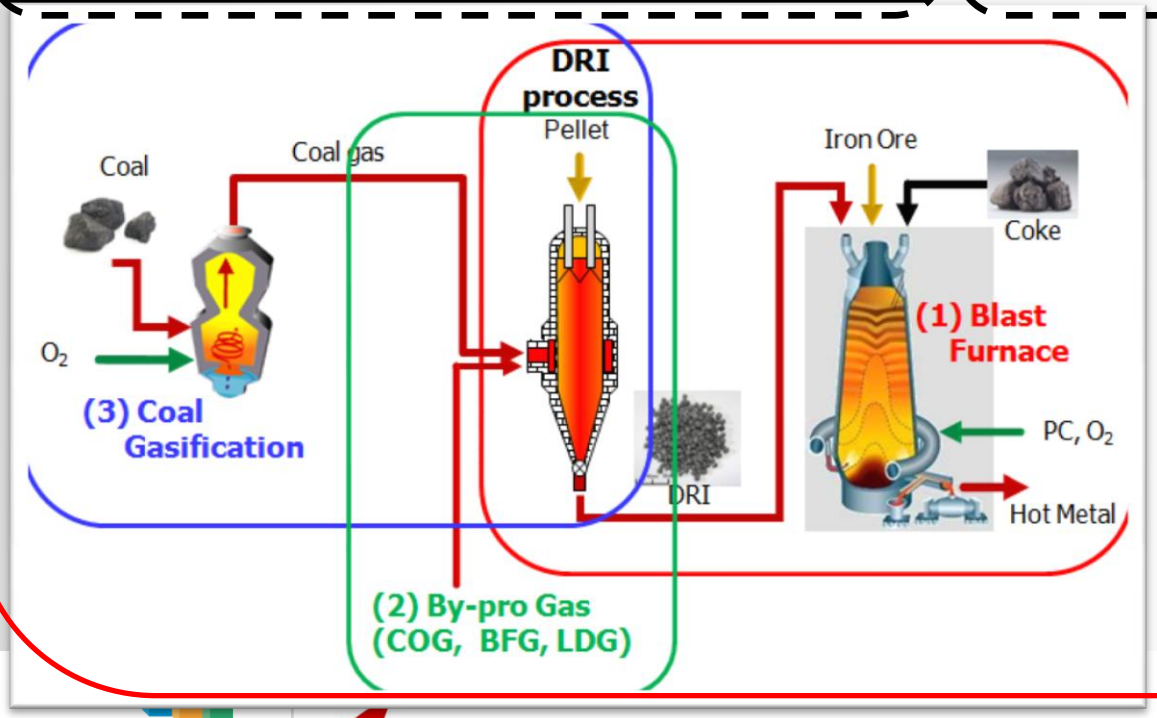
Leading with Determination
NIPPON STEEL & SUMIKIN ENGINEERING

(1) **Blast Furnace** Technology
(2) **By-pro Gas Utilizing** Technology
(3) **Coal Gasification** Technology

ENERGIRON HYL
THE INNOVATIVE DIRECT REDUCTION TECHNOLOGY

DANIELI tenova

DRI Process



This technologies can expand ENERGIRON to the integrated steel mills and in non-natural gas producing region.

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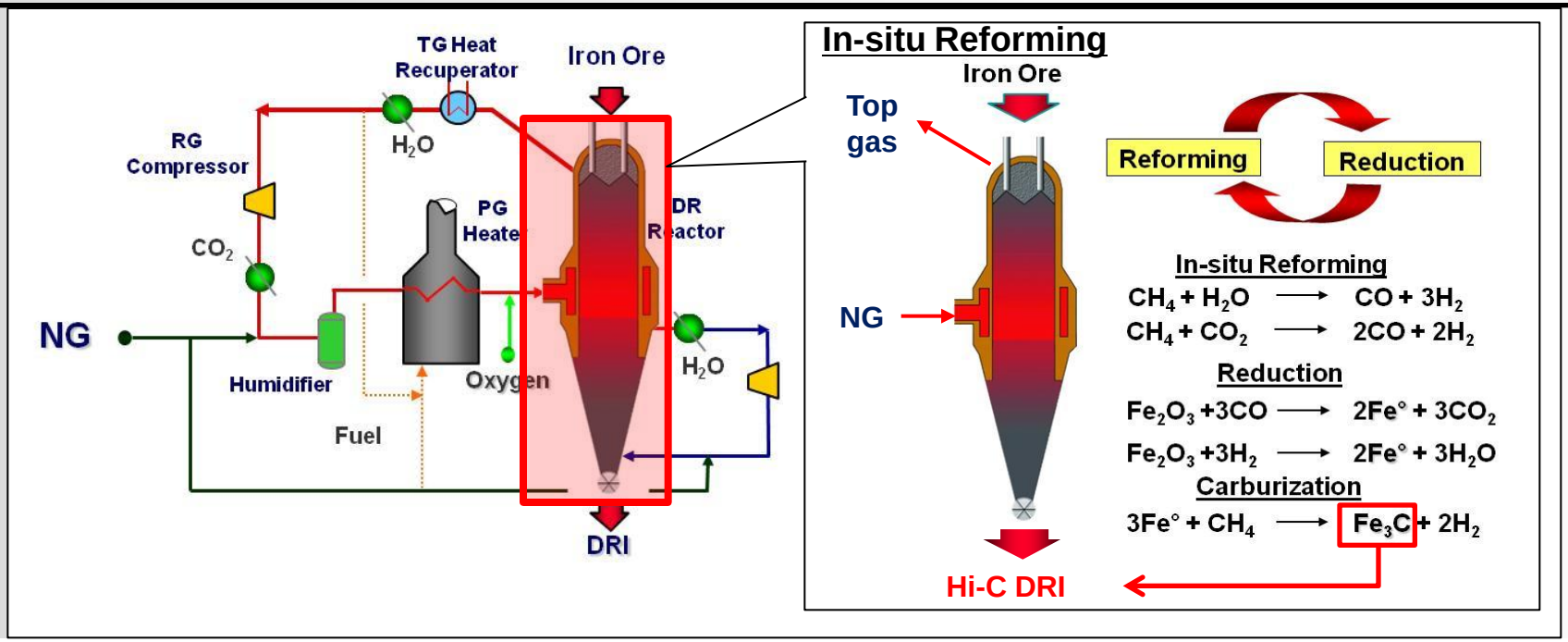
2. Features of ENERGIRON process : Hi-C DRI

ENERGIRON-ZR Process and Hi-C DRI

- ENERGIRON-ZR is the most advanced DR process due to **no external Reformer**.
- ENERGIRON-ZR can produce Hi-C DRI because of "In-situ Reforming" ,**gas reforming**, reduction and **carburization of DRI inside the reactor**.



2. Features of ENERGIRON process : Hi-C DRI

Comparison of **Hi-C DRI** and Low C HBI

- Hi-C DRI has the form of **Fe_3C** that **prevents re-oxidation**
- Hi-C DRI has **higher reduction rate** because of **carbon content** and **porosity**
- The size of Hi-C DRI is same as iron ore pellet, it makes the handling to be easy

⇒ Hi-C DRI is more suitable for DRI charging to BF

		High C DRI	Low C HBI
Picture			
Fe metallization	(%)	92 - 96	92 - 96
Carbon	(%)	2.5 - 5.0	0.8 - 2.5
Apparent Density	(g/cm3)	3.4 - 3.6	5.0 - 5.5
Porosity	(%)	50 - 54	26 - 33
Typical Size	(mm)	4 - 20 (diameter)	30 x 50 x 110
Production cost	($/t-DRI)	Base	+10 - 15

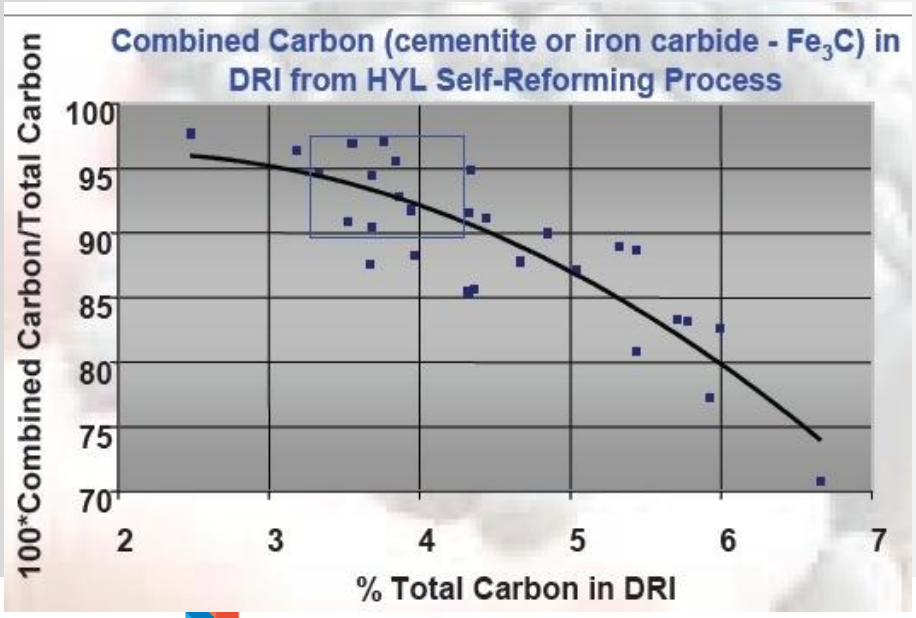
2. Features of ENERGIRON process : Hi-C DRI

Hi-C DRI with Fe_3C and its stability → **No hot briquetting**

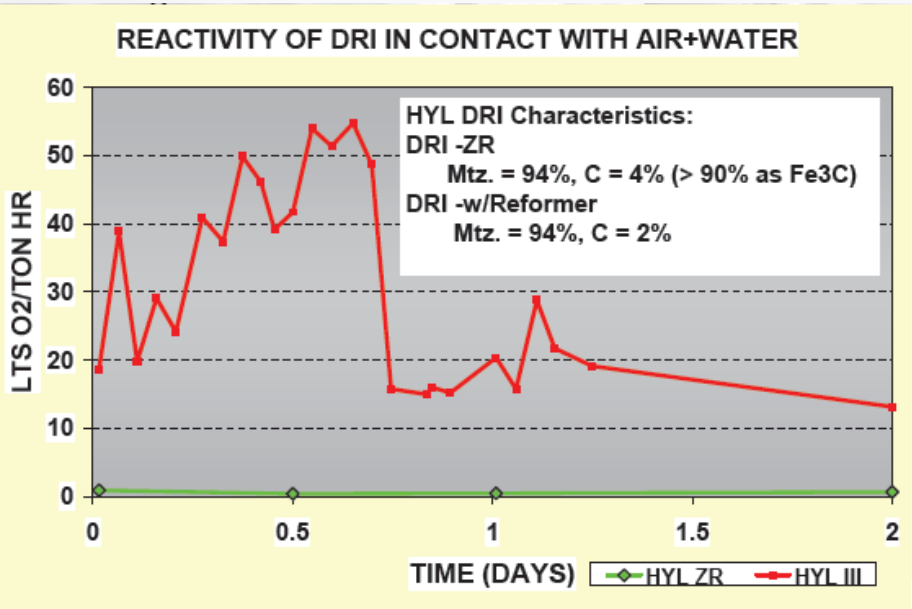
- Most of the Carbon in Hi-C DRI is **Fe_3C**. If Hi-C DRI contains 4% of total carbon, **90-95%** of the total carbon is present as **Fe_3C**.
- Hi-C DRI is very **stable against re-oxidation** because of **high Fe_3C** content.

⇒ **Easy storage and transportation without hot briquetting**

<Fe_3C in High C DRI>



<Stability of High C DRI against water & air>



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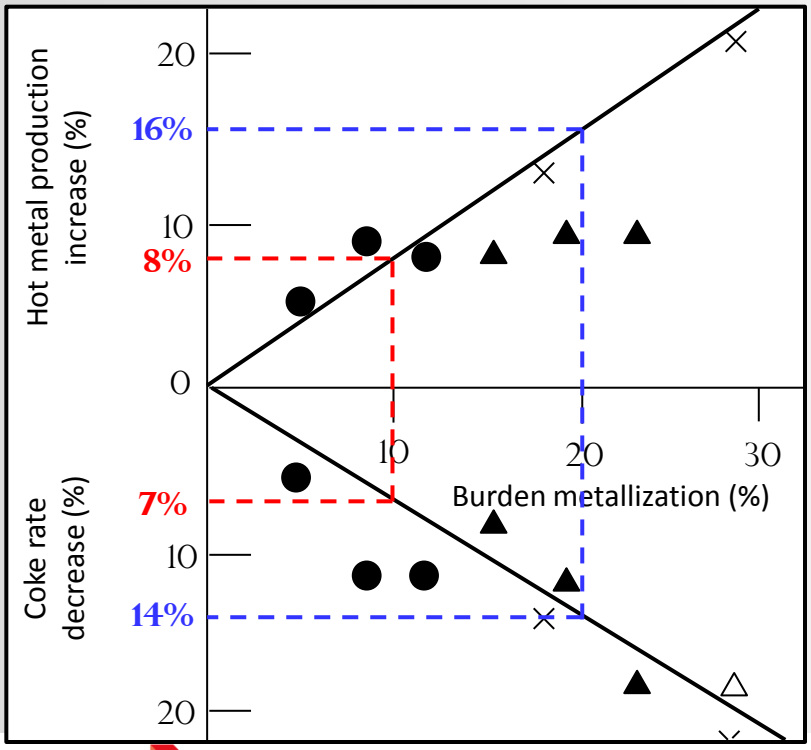
3. Charging Hi-C DRI and optimized BF operation Summary

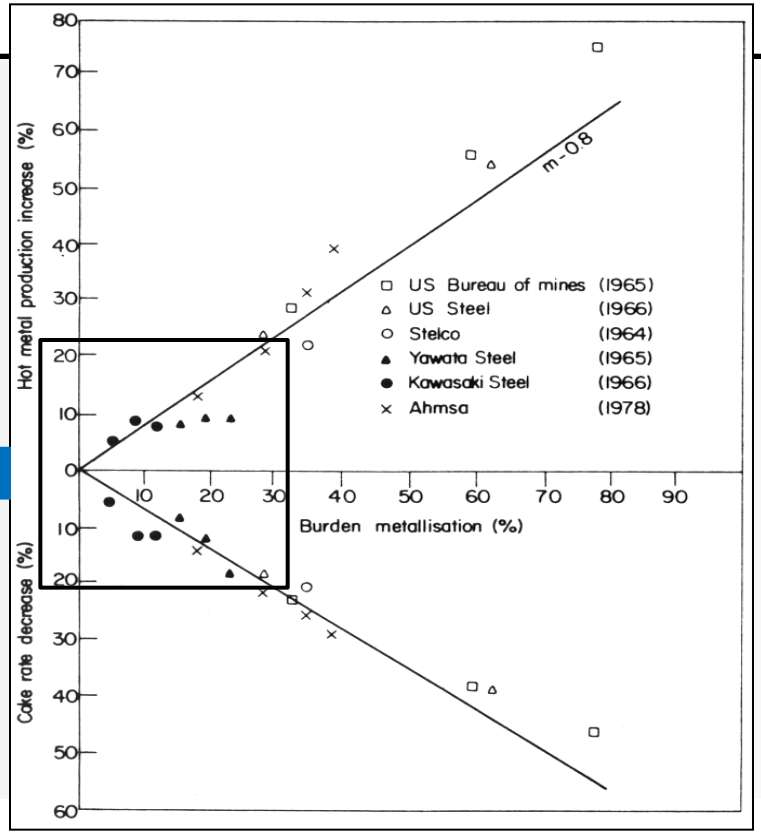
1. By Charging **Hi-C DRI** and **optimized BF hardware and operation**, Hot metal cost is decreased by **6~10** US$/t, at annual hot metal production is 9 million ton, annual merit is **54~90** million US$.

2. **CO_2 emission** decreased by **1.6** million ton annually, at annual hot metal production is 9 million ton. It is corresponded to **13** million US$ annually, based on present EU-ETS credit (8 US$/t-CO2).

Effect of Low-C HBI Charging to BF

- Many operational tests regarding **Low-C HBI** charging to BF have been executed in the past.
- Hot metal production increases by **6-8%** and coke rate decreases by **5-7%** per 100kg of metallic iron per ton of pig iron.





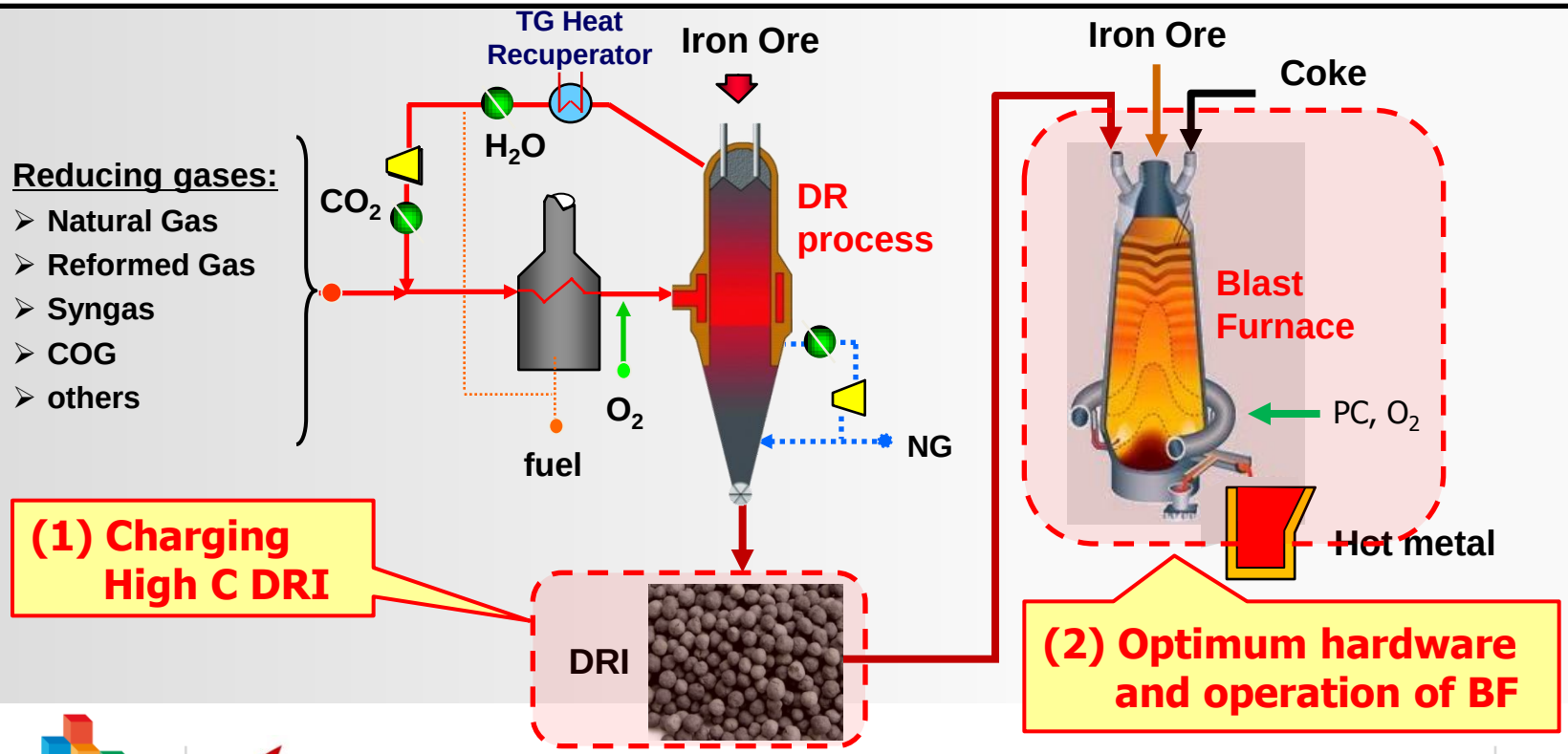
Home page of International Iron Metallics Association (IIMA)

Improvement of DRI charging operation

•In order to improve the feasibility of DR plant for BF (**coke reduction** and **production increase**), following two items are very effective.

(1) Charging Hi-C DRI to BF

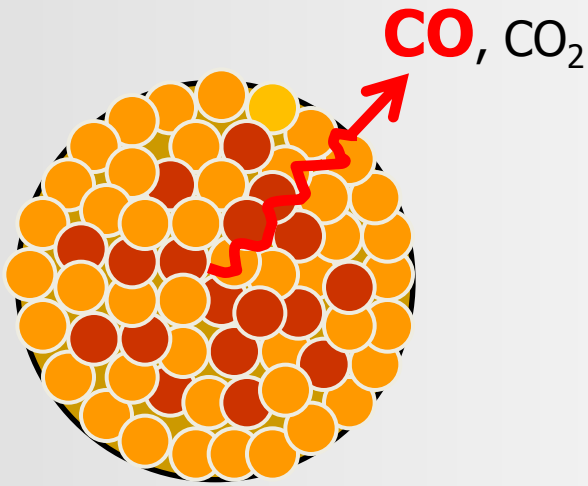
(2) Optimum hardware and operation of BF



3.1. Additional effects of Hi-C DRI

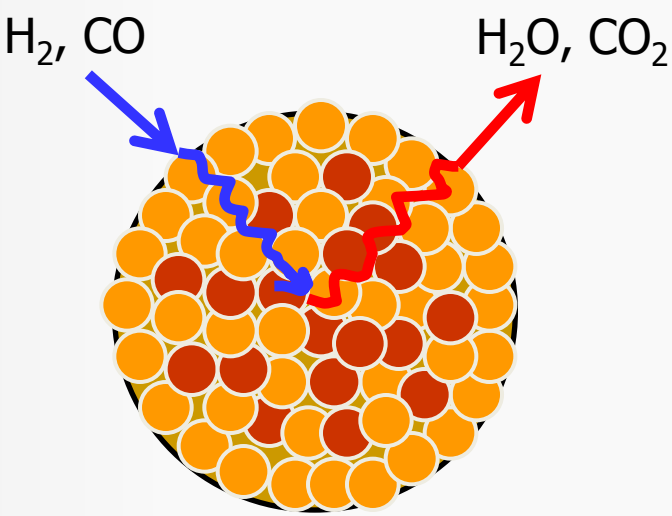
Improvement of reducing in BF by **Hi-C DRI**

Wustite (FeO) in **Hi-C DRI** can be **reduced by carbon** in Hi-C DRI **by only heated**.
Generated CO gas can advance to **reduce the iron ore** around **Hi-C DRI**, compared to low carbon HBI.



$FeO + C \rightarrow Fe + CO$
$C + CO_2 \rightarrow 2\ CO$
$FeO + CO \rightarrow Fe + CO_2$

Hi-C DRI



$FeO + H_2 \rightarrow Fe + H_2O$
$FeO + CO \rightarrow Fe + CO_2$

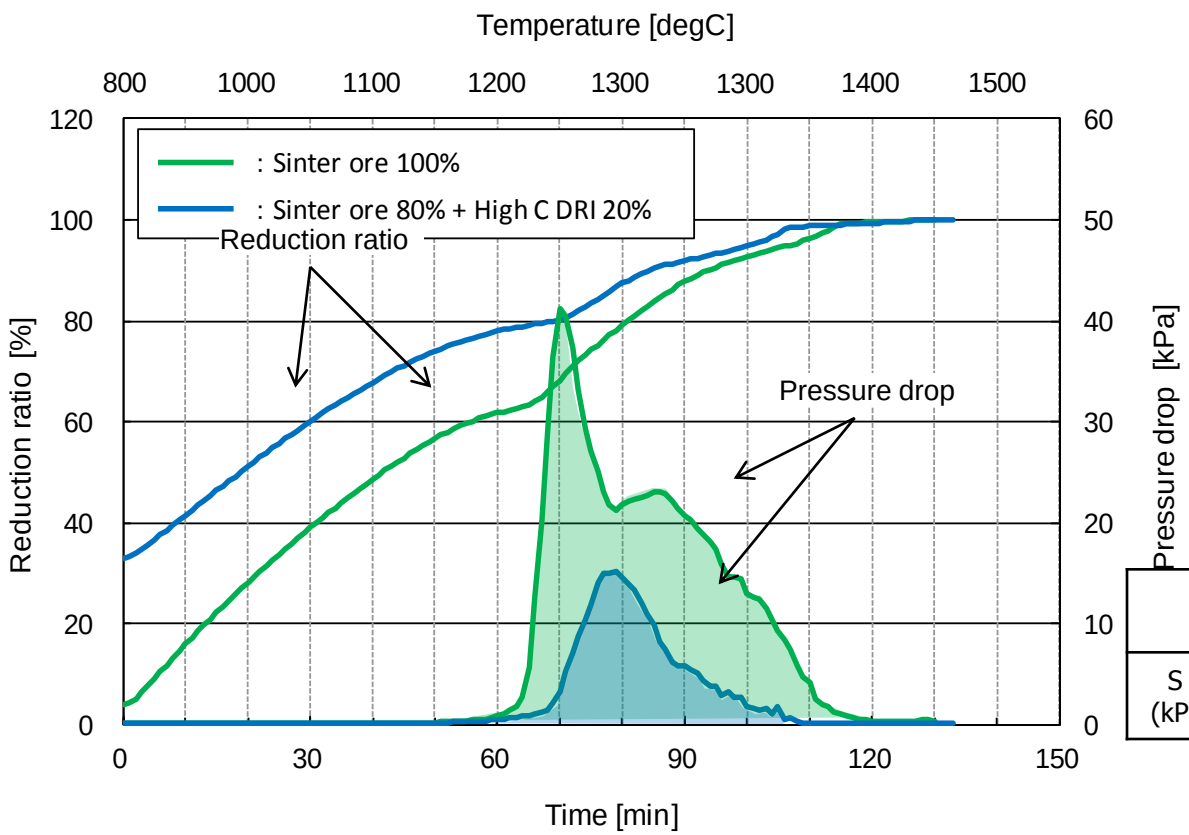
Low C HBI

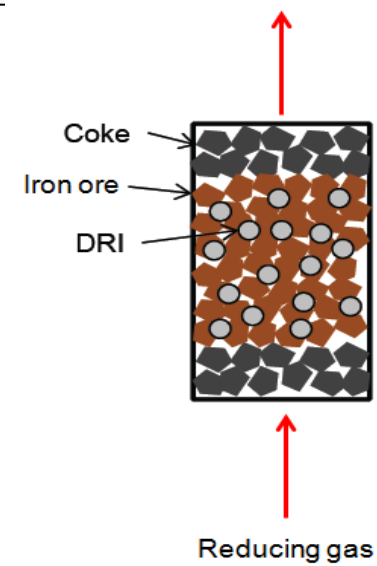
3.1. Additional effects of Hi-C DRI

Improvement of permeability in BF by **Hi-C DRI**

Hi-C DRI charging can **improve the permeability** in BF.

<Gas permeability laboratory test results>





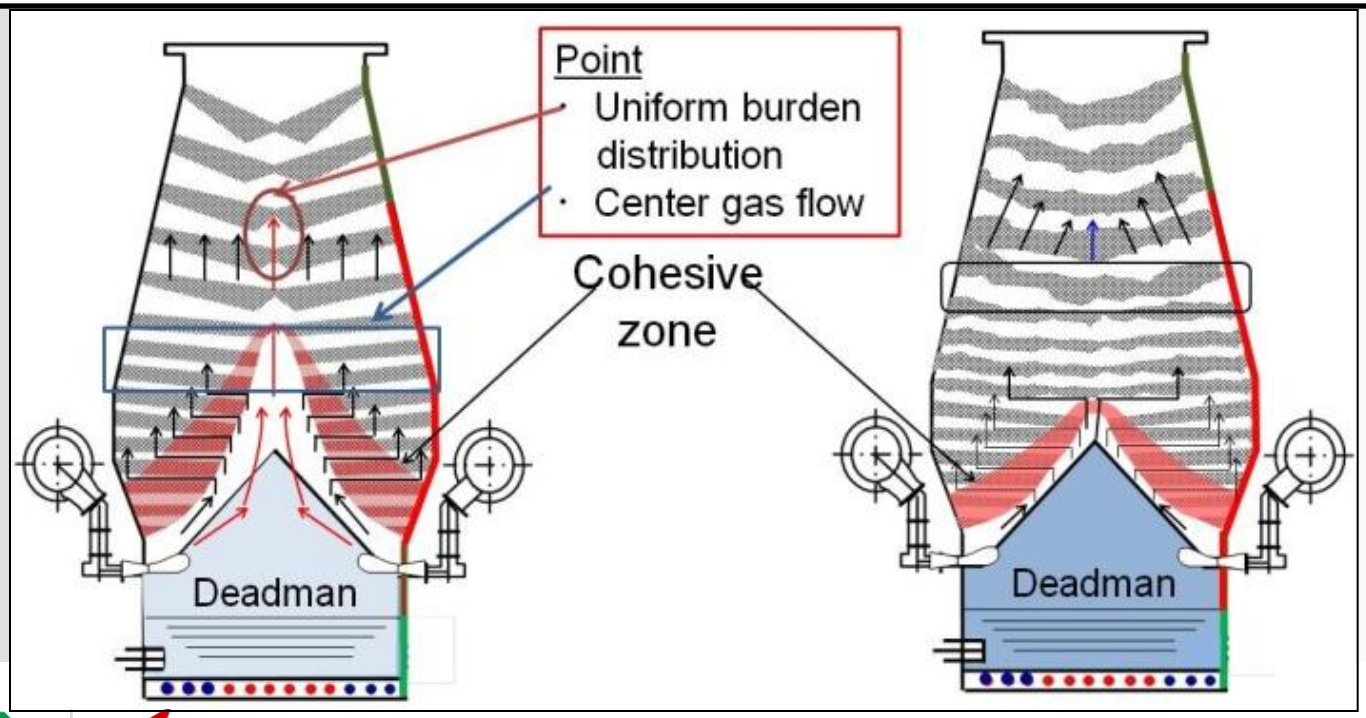
	Sinter 100%	Sinter 80% **HC-DRI 20%**
S value (kPa・min)	**827**	**191**

1/4 to 1/5

3.2. Additional effects of optimum hardware and operation of BF

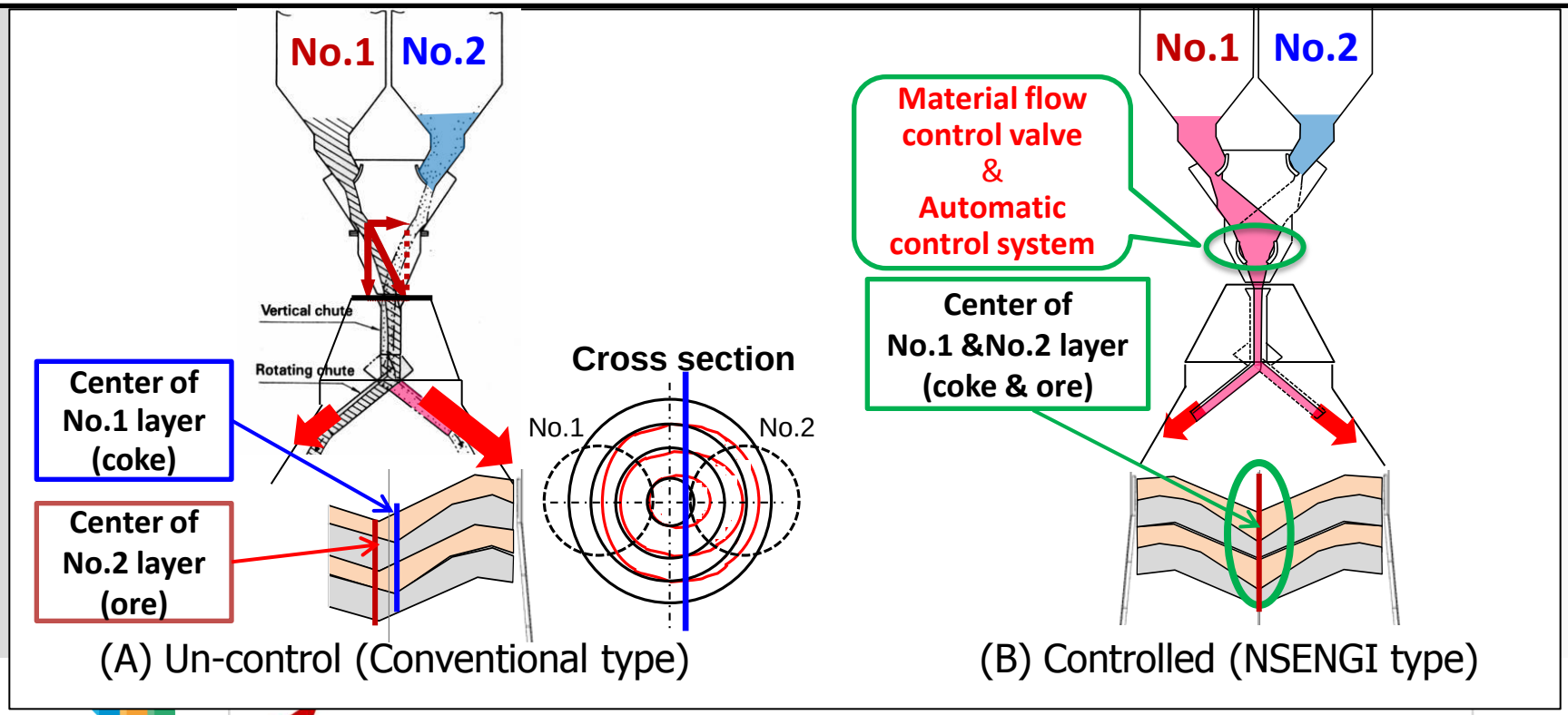
Control gas flow uniform

- The point for achieving lower coke rate and higher productivity is to **control gas flow uniform**. To make the gas flow uniform, the following two points are necessary.
  1) **Uniform burden distribution** in radius direction in BF
  2) **Proper center gas flow**



3.2. Additional effects of optimum hardware of BF
Material flow control system

- In case of **Conventional parallel hoppers** (A), materials tend to be charged into BF **non-uniform**, because of **horizontal component** of the velocity.
- **NSENGI's material flow control system** (B) can prevent inertia-caused uneven flows, so can charge materials into BF **uniformly**.



3.2. Additional effects of optimum hardware of BF Advanced top charging equipment

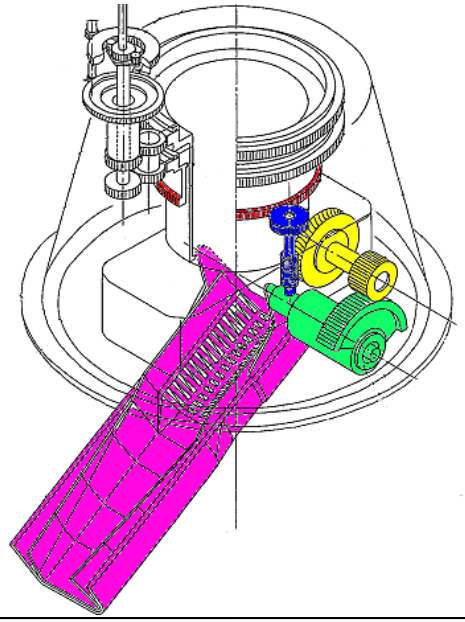
Advanced top charging equipment can support uniform gas flow and center gas flow with the following capabilities.

(1) High rotating speed : 12 rpm (**1.5 times** of conventional type)

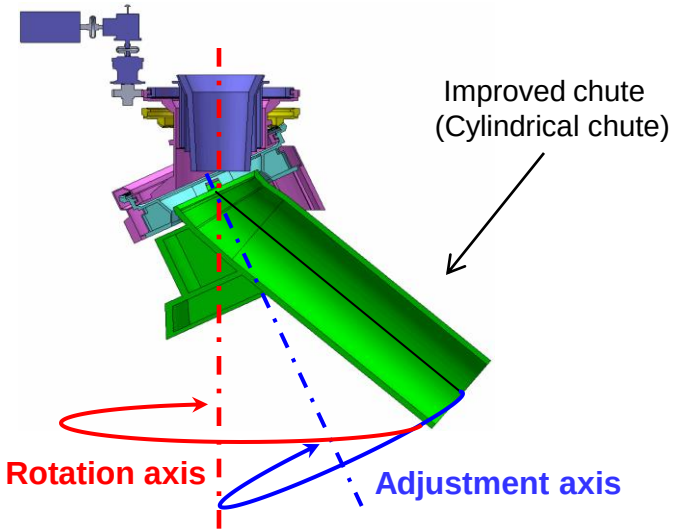
(2) High tilting speed : **3 times** of conventional type

(3) Improved chute : Avoiding material disperse and ensuring the center coke charge

Conventional Type



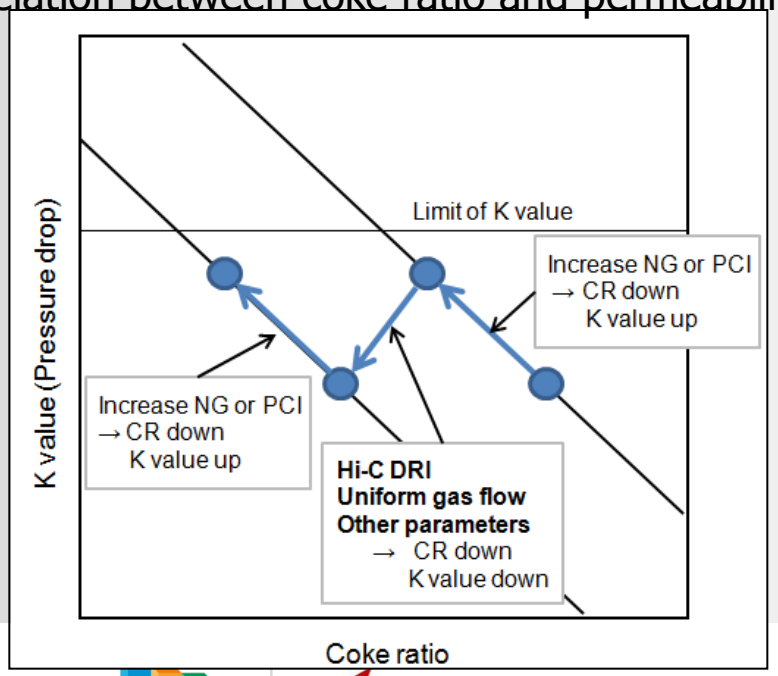
Advanced Type



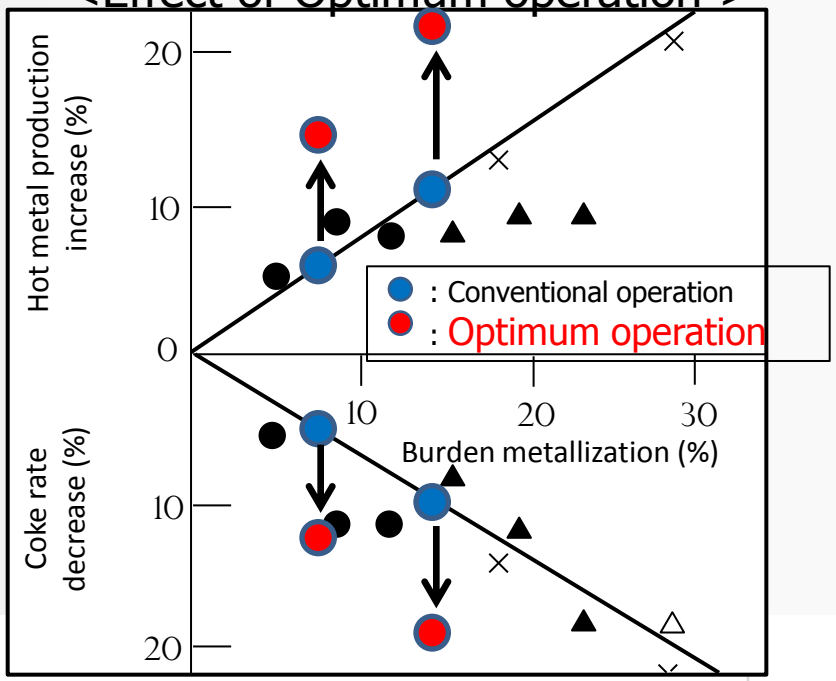
3.2. Additional effects of optimum hardware and operation of BF

- Generally, the coke ratio reduction by PCI is limited by upper limit of K value (gas permeability resistance in BF)
- Charging **Hi-C DRI** and optimum hardware and operation of BF can **improve gas permeability** of BF, and can increase PCI.
- **Double** to the conventional effects has been verified to the BF **productivity increase** and **coke ratio reduction**.

<Relation between coke ratio and permeability>



<Effect of Optimum operation >



3. Charging Hi-C DRI and optimized BF operation

- **Hi-C DRI** and **optimized BF hardware & operation** can enhance **hot metal cost merit** more than **twice** compared to Low C DRI and Conventional DRI charging.

		Conventional operation (no DRI)	Low C DRI and conventional BF hardware & operation	Hi-C DRI and optimized BF hardware & operation
DRI	kg/t-p	0	**100**	**100**
PCI		Base	Base	Increase
Material distribution		Base	Base	Optimum
Coke ratio	kg/t-p	Base	**- 7%**	**- 16%**
Productivity	t/m3/day	Base	**+ 6%**	**+ 14%**
Hot metal cost merit	$/t-p*1)	Base	**- 3 ~ -4**	**- 6~ -10**
	Million $/y*2)	Base	**-27~-36**	**-54~-90**
CO2 emission	Million t/y*2)	Base	**-1.4**	**-1.6**

*1) COG=24$/Gcal, Electricity=0.07$/kWh, O2=0.05$/Nm3, Coke=210-270$/t, PC=100$/t, Sinter=74$/t, Lump=81$/t, Pellet=117$/t *2) In case of annual production is **9** million ton.

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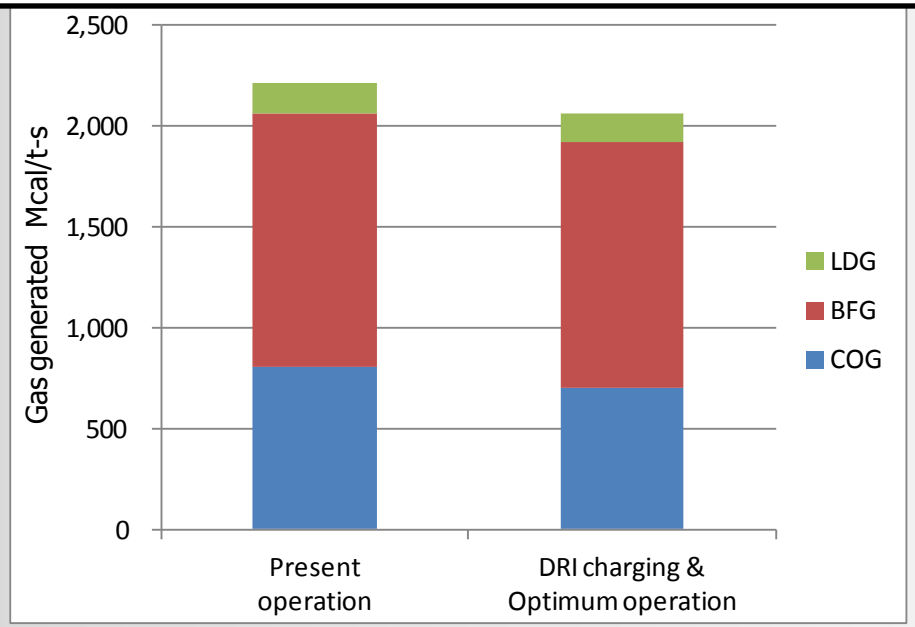
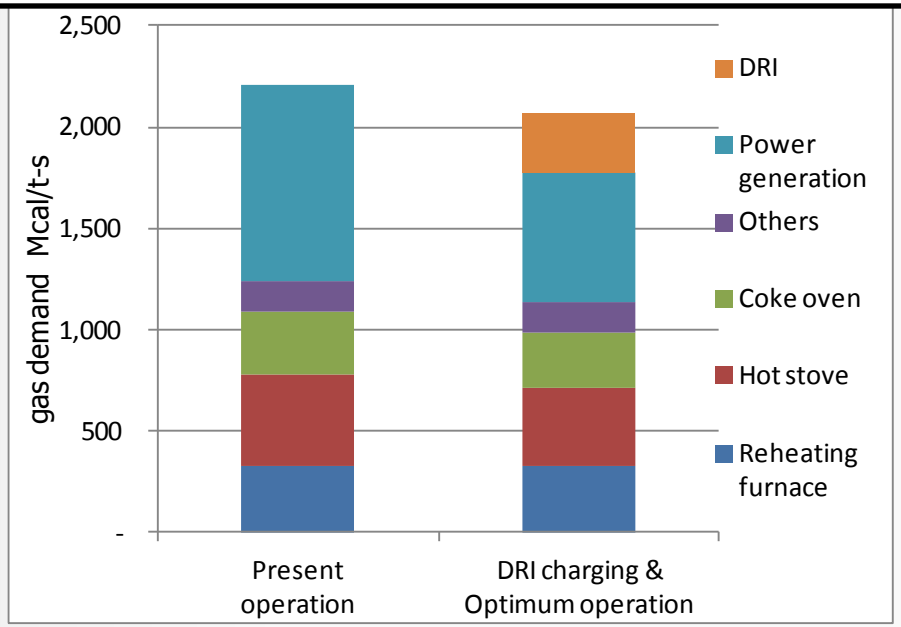
4. Beneficial using by-pro gas (COG, BFG, LDG)

4.1. Gas balance and feeding to ENERGIRON in integrated steel mill

By-pro gas is generated 2.2 Gcal/t-steel, and 40% is for power generation. **0.25** Gcal/t-s of by-pro gas, only **30%** for power generation, can produce **100**kg/t-s of DRI for charging to BF.
⇒ Beneficial using by-pro gas can utilize reduction gas to ENERGION on **low cost** in **non-natural gas producing region**.



Example of by-pro gas generation in integrated steel mill



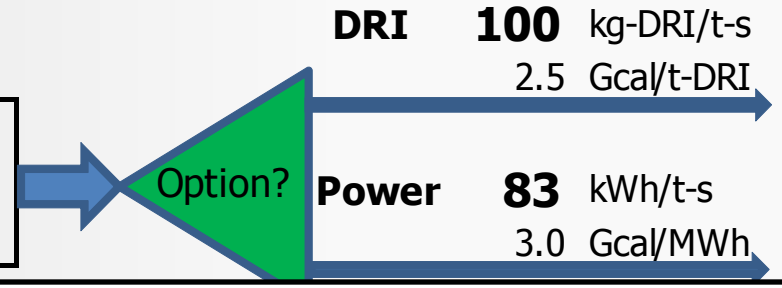
Example of by-pro gas usage in integrated steel mill

4. Beneficial using by-pro gas (COG, BFG, LDG)

4.1.Gas balance and feeding to ENERGIRON

0.25 Gcal/t-s of gas can produce **100**kg/t-s of DRI or **83** kWh/t-s.

By-pro gas	**0.25**	Gcal/t-s
COG	0.18	
BFG	0.07	



Power generation benefit is **0.8** US$/t-s, if by-pro gas cost is 20 US$/Gcal and purchased power price is 80 US$/MWh.

	unit	$/unit	unit/MWh	$/MWh	$/t-s
By-pro gas	Gcal	20	3	60	
Other cost				10	
Power cost				70	
Power price				80	
Power Benefit				**10**	**0.8**

On the other hand, benefit of DRI producing and charging to BF is **6** to **10** US$/t-s, it is **much bigger** than power generation.

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4. Combination of coal gasification and ENERGION

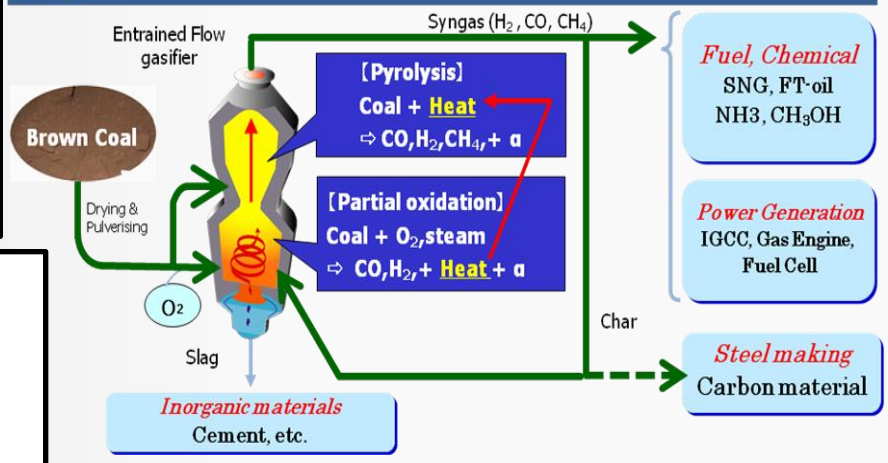
(1) Efficient Co-Production with Coal Flash Partial Hydro-pyrolysis Technology (**ECOPRO**):high efficient two-stage entrained flow gasifier

Pilot plant test has been completed from 2003 to 2009, supported by Japanese Government (METI) through Japan Coal Energy Center (JCOAL), and verified as follows,

(1) **World highest energy efficiency** of **85%**, **5 to 10% higher** than the other gasifier
(2) Applicability of the process to **low-rank coals** including **brown coal** and operating stability

By application of ECOPRO and **ENERGIRON**, total energy efficiency is increased by **5 -10%**

◆ **Pyrolysis** reaction in upper chamber **utilising the sensible heat from lower chamber.**
⇨ *High efficiency (**85% at commercial plant**) for coal to syngas conversion.*
⇨ *High **Methane content in Syngas***
⇨ *Applicable to low rank coal.*



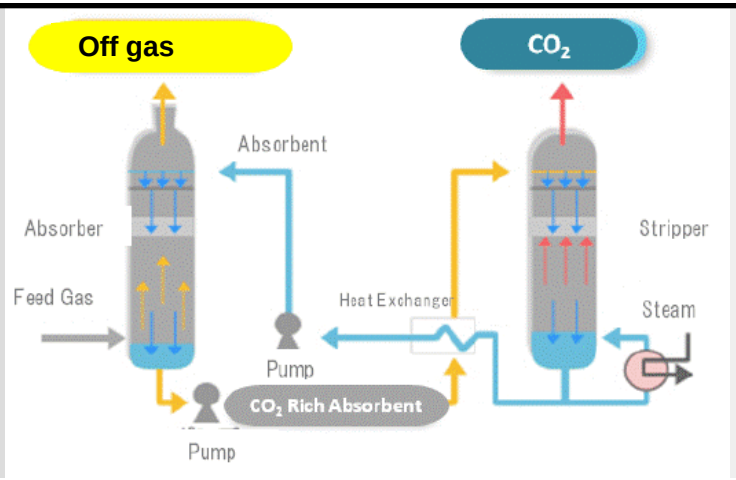
4. Combination of coal gasification and ENERGION

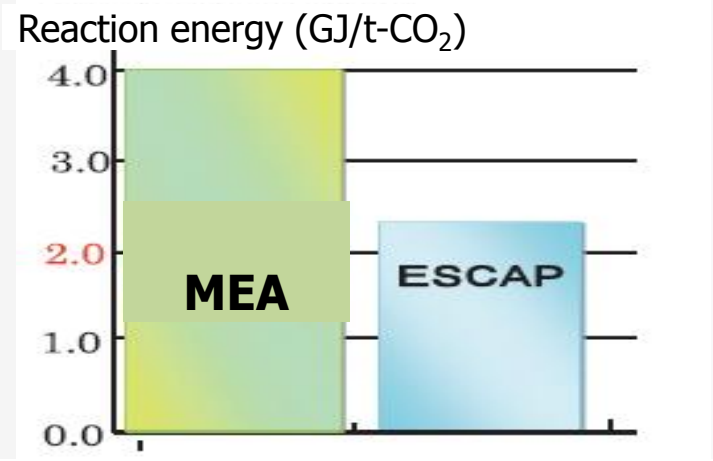
(2) Energy Saving CO2 Absorption Process (**ESCAP**)

the most efficient energy cut-off chemical absorption process for CO_2 capture

NSENGI have developed ESCAP in the project sponsored by NEDO(*1). ESCAP were **42% reduction** in reaction energy (**2.3 GJ/t-CO_2**) compared to conventional MEA (Mono Ethanol Amine).

The commercial plant of ESCAP with 120 t-CO_2/day was constructed in NSSMC(*2) in 2014, and have been **operated well on planed condition**. The recovered CO_2 from the hot stove exhaust gas of BF is used mainly dry ice and beverage.





(*1) New Energy and Industrial Technology Development Organization (*2) Nippon Steel & Sumitomo Metal

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Conclusion

(1) Charging **Hi-C DRI** and optimized BF hardware & operation can **increase productivity** and **decreased coke ratio**, because of **improving reduction**, **permeability** and **flow control** in the BF. Hot metal cost down merit is **6~10** US$/t-s, at annual production is 9 million ton, annual merit is **54~90** million US$.
The reinforcing coke oven and BF is **not necessary** for increasing steel production, because productivity is increased and coke rate is decreased.

(2) By-pro gas can be converted from power generation to producing Hi-C DRI, considering gas balance and benefit.

(3) Combination with **coal gasification** can expand market to **non-natural gas producing region**.
Total efficiency can be improved more by application of **ECOPRO** (high efficiency coal gasifier) and **ESCAP** (Energy Saving CO_2 Absorption Process).