# DME production from Oxygen blast furnace gas

Yotaro Ohno

RenFuD Corporation

(E-mail: ohno@renfud.com, http://www.renfud.com/)

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# Coal consumption by sector

- Iron and Steel industries consume plenty of coal next to the power generation, having a large handling capacity of coal, they have a high potential of energy supply to surrounding area.

Annual coal consumption by sector 2012 (million ton)

| | China | India | Japan | Korea |
|---|---|---|---|---|
| Iron and Steel | 663 | 96 | 72 | 36 |
| Electricity | 1,988 | 559 | 92 | 86 |
| Residential | 85 | 8 | 0 | 0 |
| Others | 678 | 112 | 13 | 6 |
| Total | 3,414 | 775 | 177 | 127 |

Ref: IEA Energy statistics of OECD & Non-OECD countries,2014

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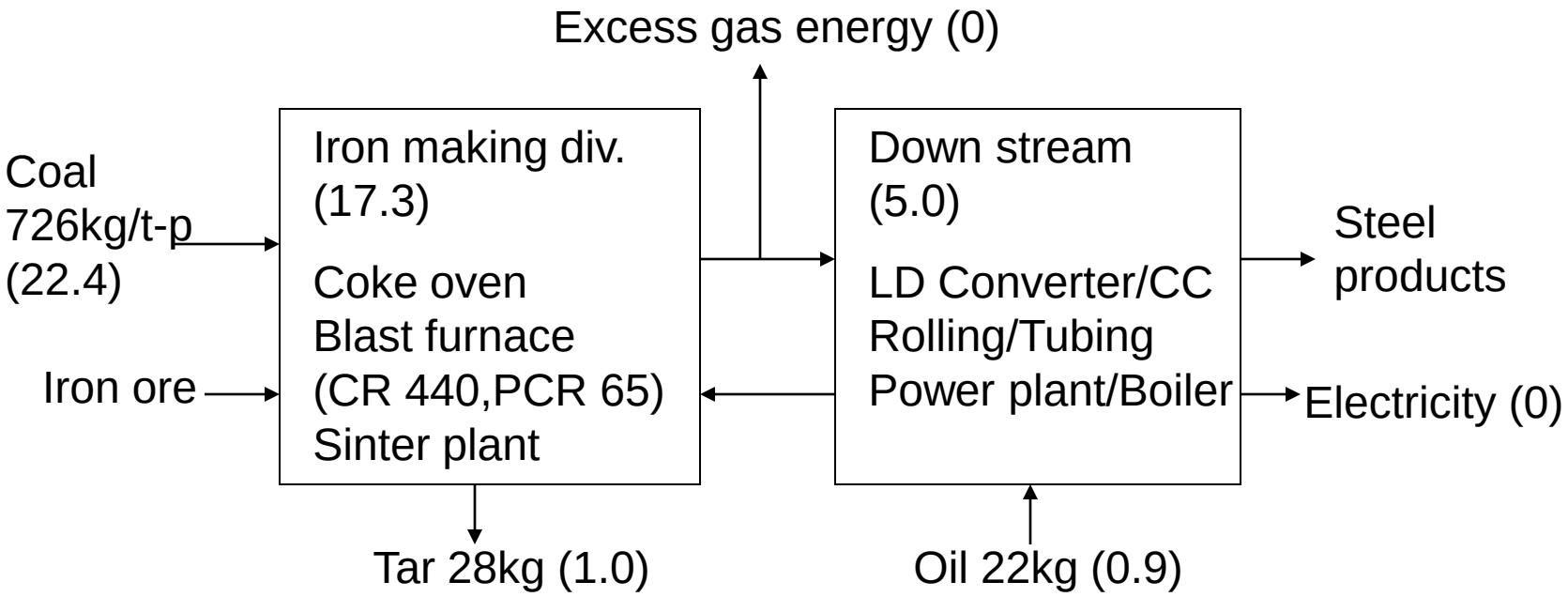
# Energy balance of model integrated steelworks

• Energy demand of integrated steelworks is practically covered by coal. By-produced gas from Coke oven, Blast furnace and LD Converter are utilized entirely as fuel in steelworks. Iron making division consumes about 80 % of Total energy.




CR: Coke rate (kg/t-p), (t-p): 1 ton of pig iron, ( ): Energy (GJ/t-p),
PCR: Pulverized Coal injection rate into Blast furnace (kg/t-p)

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Total Energy consumption =17.3+5.0=22.3 GJ/t-p

# Composition, generation and consumption amount of by-product gas in steelworks

- Nitrogen content in BFG (Blast furnace gas) is as high as 55%. Almost of Nitrogen comes from hot blast air.
- Generation amount of BFG and COG (Coke oven gas) change with Reducing agent ratio (RAR = CR+PCR).
- For synthesis gas feed, BFG is disadvantageous because $N_2$ content is large. Hydrocarbons such as $CH_4$ in COG is necessary to be reformed.

| Composition(%) | | | | | | Generation (GJ/t-p) | Consumption (GJ/t-p) | |
|---|---|---|---|---|---|---|---|---|
| | CO | $CO_2$ | $H_2$ | $CH_4$ $C_2H_x$ | $N_2$ | | Ironmaking div. | Down stream |
| BFG | 21.6 | 20.4 | 2.7 | 0 | 55.3 | 4.6 | 2.9 | 1.7 |
| COG | 7.4 | 2.6 | 51.0 | 34.4 | 4.6 | 3.9 | 2.8 | 1.1 |
| LDG | 73.4 | 13.3 | 1.2 | 0 | 12.1 | 0.9 | 0.2 | 0.7 |

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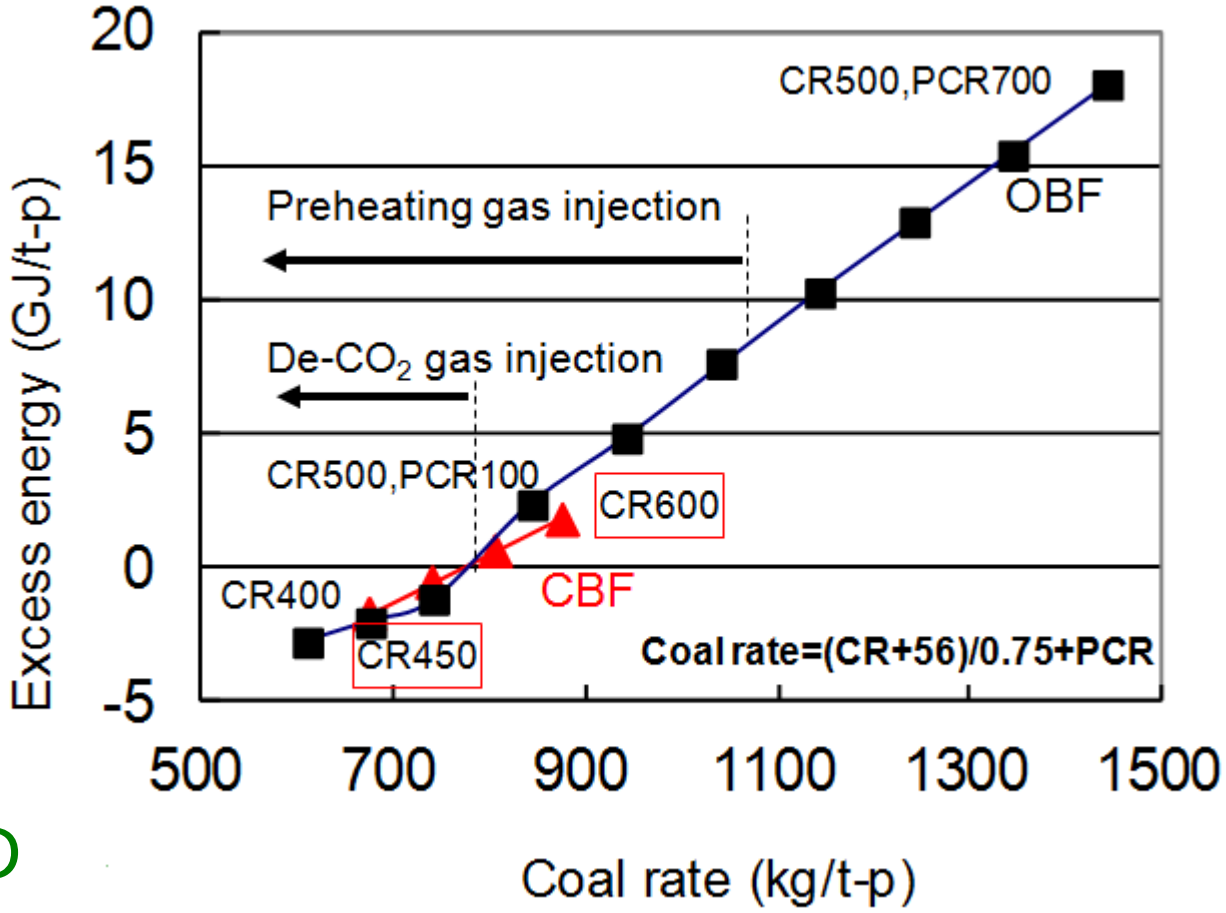
# Coal rate and Excess energy in Integrated steelworks

- Operable range of RAR of blast furnace process is determined by the upper limit of furnace top temperature and the lower limit of hot metal temperature.
- Operable range of RAR of Conventional blast furnace (CBF) is of about 450 ~ 600kg / t-p and Generation capacity of excess gas energy is small.

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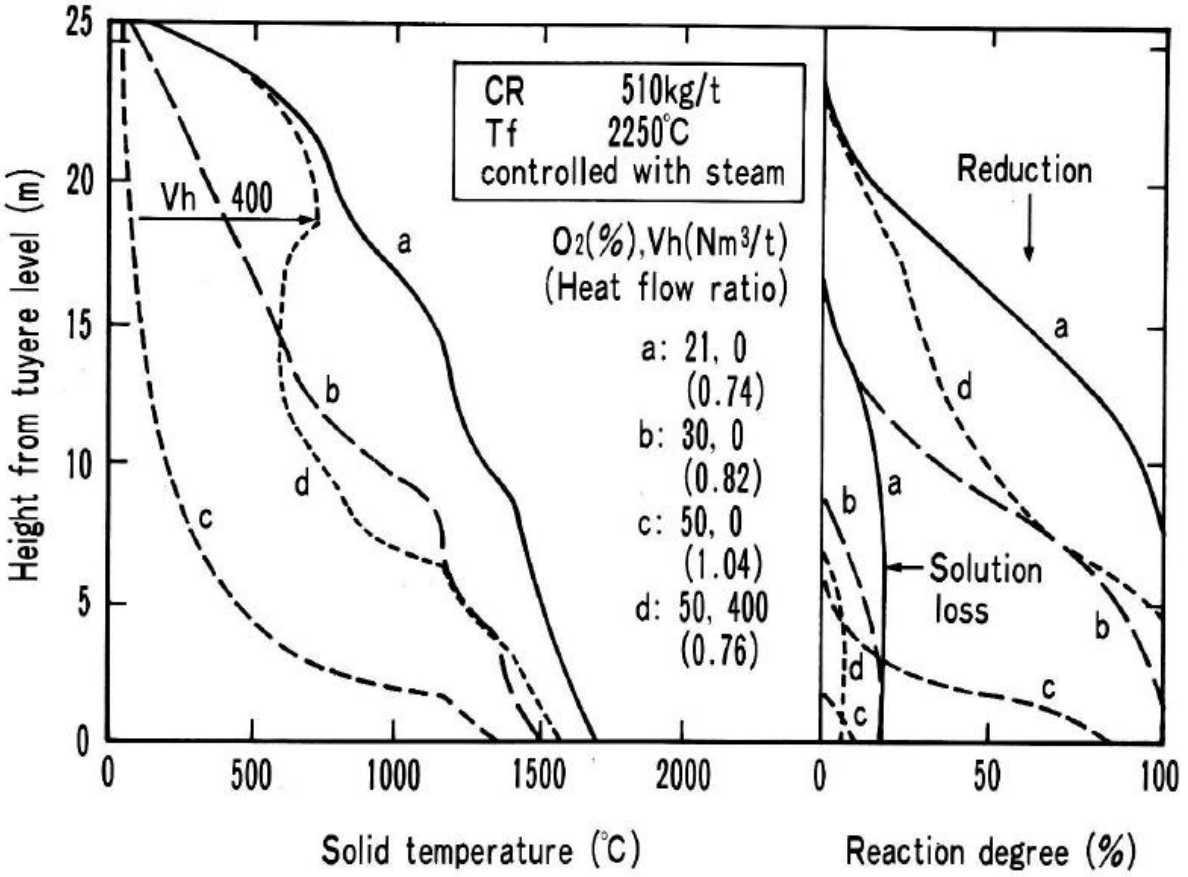
# Change of Temperature distribution with $O_2$ concentration in blast

• As Oxygen concentration increases (Case a→b→c), Heating-up and reduction of solid descending from the top are retarded and the furnace operation becomes impossible.

It results from shortage of the heat capacity of gas rising from the furnace bottom and increase of the heat flow ratio (ratio of heat capacity of solid and gas) .

• As a countermeasure for this heating and reduction stagnation of solid, a preheating gas is injected in the furnace shaft and the proper temperature distribution is realized (Case d).

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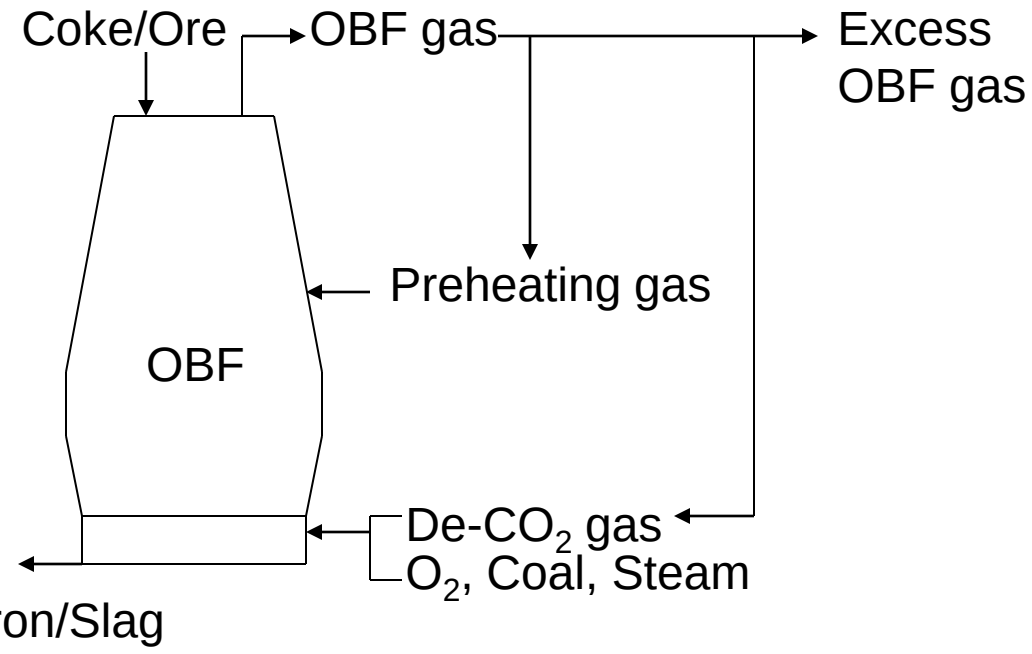
# Concept of Oxygen blast furnace process

- A preheating gas is obtained by partial oxidation of the furnace top gas and injected in the furnace shaft.
- The flame temperature in front of tuyere is controlled by adding the top gas, steam and/or coal to oxygen in order to properly maintain the furnace temperature distribution and to stably operate the blast furnace.

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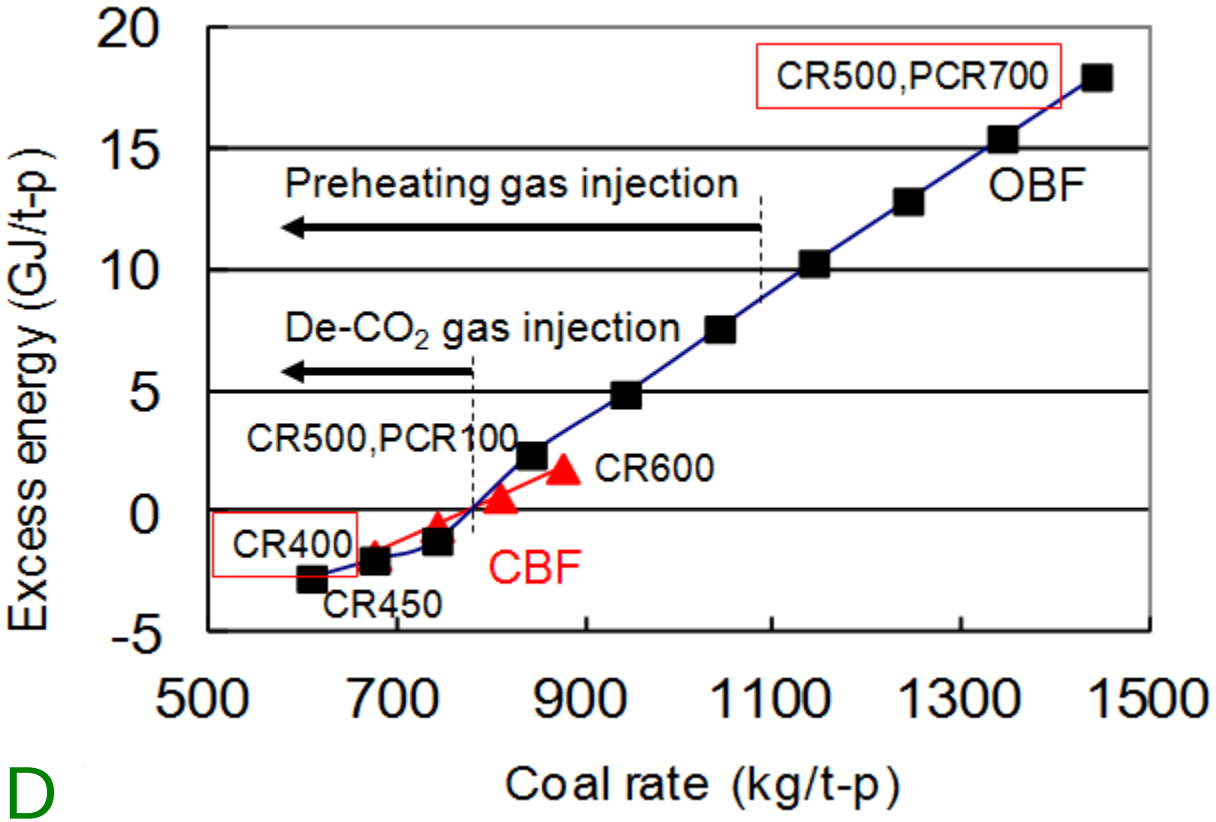
# Coal rate and Excess energy in Integrated steelworks

- OBF has a larger operable range of RAR and a larger generation capacity of excess gas energy compared to CBF.
- When the furnace top gas is blown in through tuyere after removing $CO_2$, RAR of OBF can be reduced.

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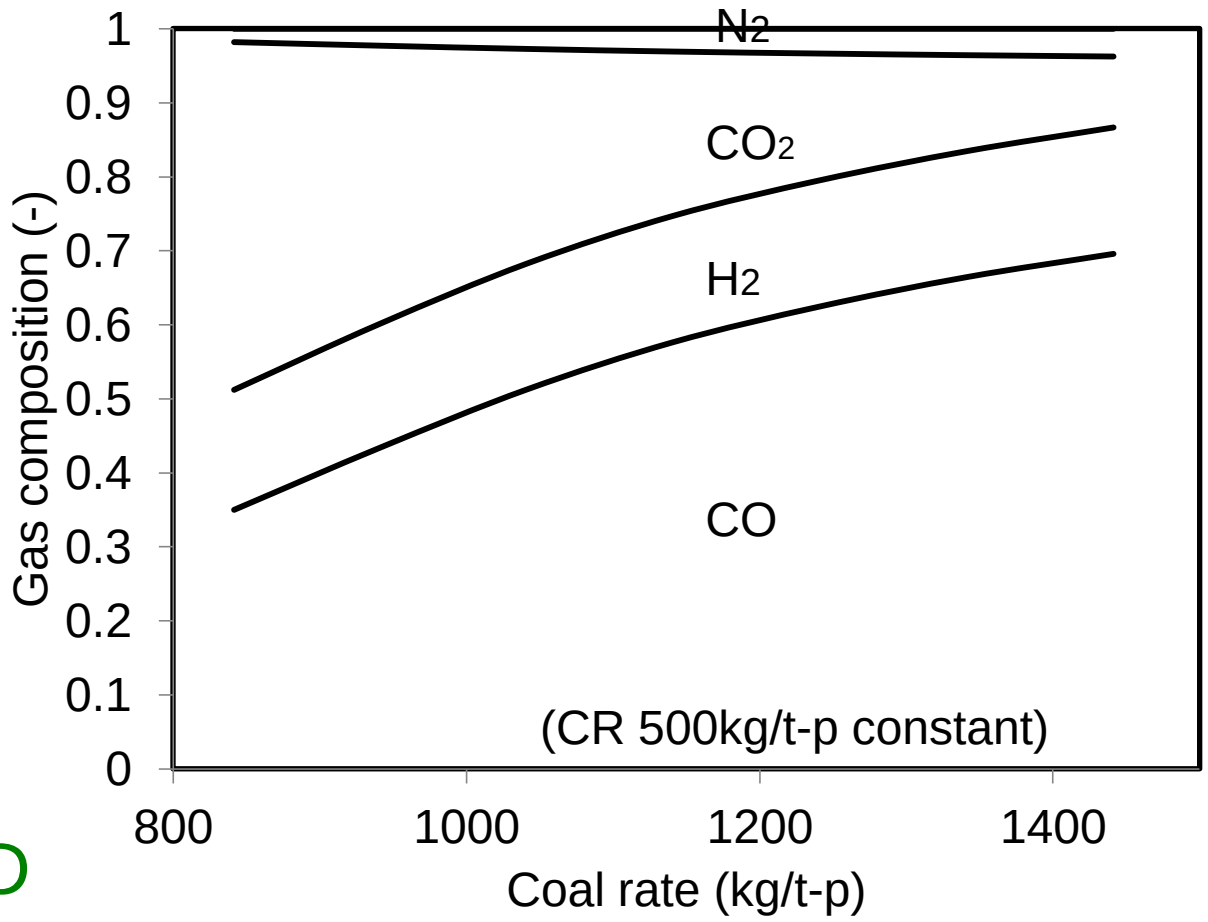
# Composition of Oxygen blast furnace gas vs. Coal rate

• With increase of Coal rate, CO concentration increases, $CO_2$ concentration decreases. $H_2$ concentration is almost constant. A little $N_2$ comes from coke and coal.

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# Impurities in Oxygen blast furnace gas

- As injected coal is gasified at high temperature in blast furnace, neither tar nor methane remains in blast furnace gas.
- As almost of sulfur is fixed in liquid slag in blast furnace, its concentration in blast furnace gas is little.
- Nitrogen compound content in OBF gas is less than in CBF gas.

| | $H_2S$+COS | $NH_3$+HCN |
|---|---|---|
| CBF* | 15ppm | 18ppm |
| OBF* | 14ppm | 8ppm |
| Coal gasifier** | 12000ppm | 2400ppm |

* measured in experimental blast furnace operation

** Example, EPRI AP3109

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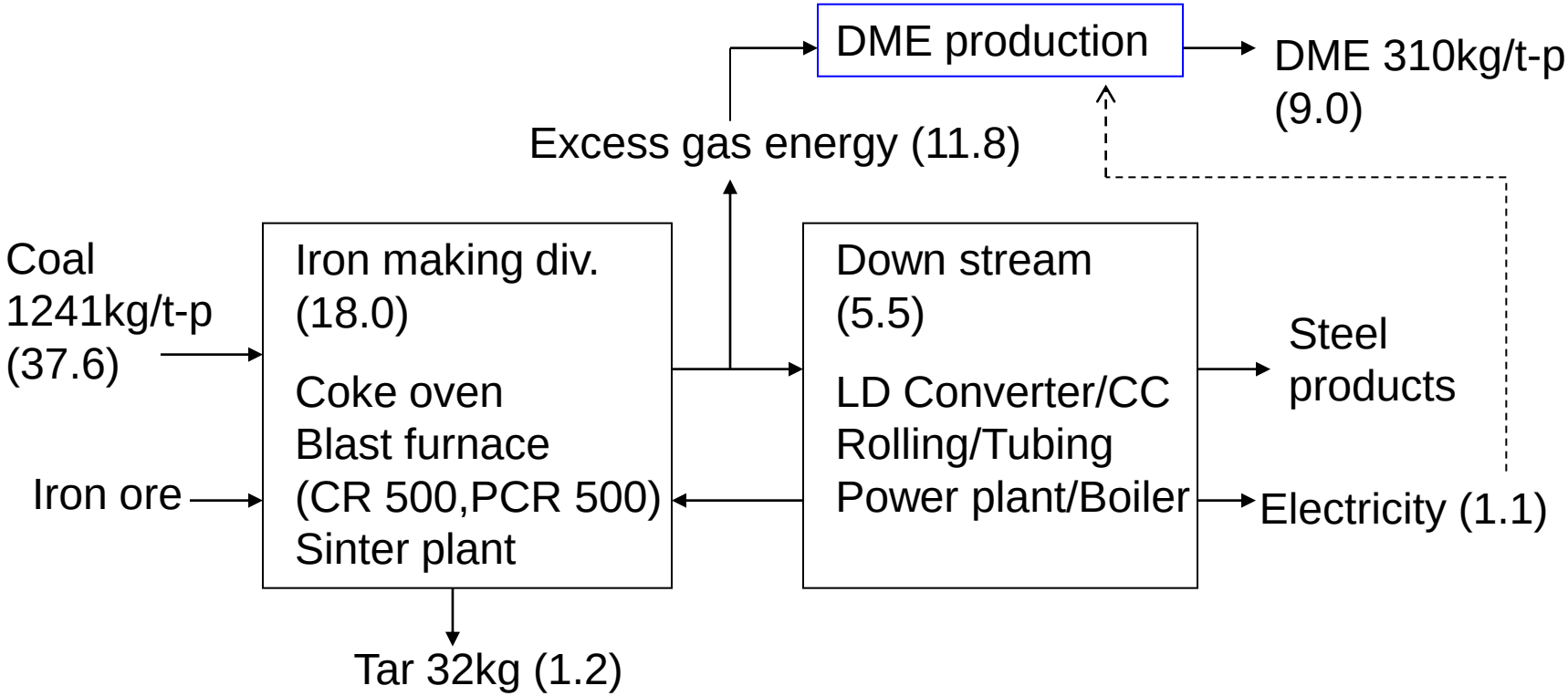
# Example of Energy balance of steelworks in case that DME is produced from Excess gas of Oxygen blast furnace

- It is simulated that 3,100ton/day of DME can be produced from Excess gas coming out of Oxygen blast furnace which is operated at 10,000ton/day of pig iron production with (CR 500+PCR 500kg/t-p).




Excess =37.6-1.2-18.0-5.5=12.9 GJ/t-p ( ): Energy (GJ/t-p)

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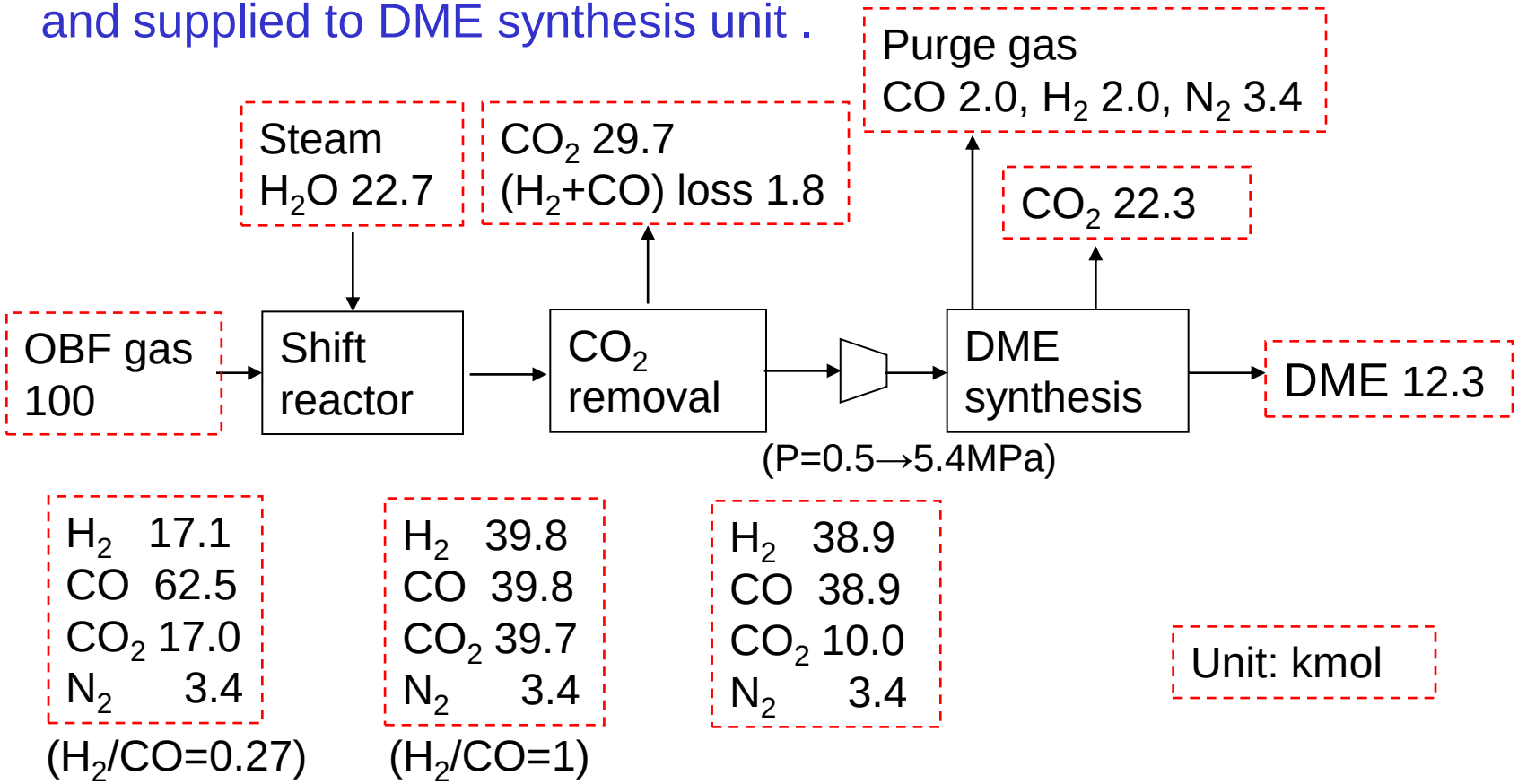
# Process flow of DME production from OBF gas

- $H_2$/CO of OBF gas is adjusted to $H_2$/CO=1 by Shift reaction and $CO_2$ and Sulfur compounds are removed to adequate level. A little $H_2$ and CO is lost in $CO_2$ removal unit. The treated gas is compressed and supplied to DME synthesis unit .

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# Coal gasification performance of Oxygen blast furnace

- Cold gas efficiency of Coal gasification of OBF can be estimated from difference of two cases in the table below,

  10.52 (GJ / t-p) / (400 (kg / t-p) x 28.7 (MJ / kg)) = 91.6%

- Oxygen unit consumption 188 ($Nm^3$/t-p)/0.4(t-coal/t-p)=470$Nm^3$/t-coal

Electricity required for Oxygen production is supplied internally by power plant in steelworks.

In addition to the oxygen in blast, about half of the oxygen removed from iron ore contributes to gasification of carbon in the blast furnace.

| | CR | PCR | $O_2$ | Excess gas | Excess energy |
|---|---|---|---|---|---|
| | (kg/t-p) | (kg/t-p) | ($Nm^3$/t-p) | ($Nm^3$/t-p) | (GJ/t-p) |
| CaseA | 500 | 500 | 523 | 1340 | 12.85 |
| CaseB | 500 | 100 | 335 | 384 | 2.33 |
| Difference | 0 | 400 | 188 | 956 | 10.52 |

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# Comparison of Coal to DME systems

| | Coal gasifier /DME production * | Oxygen blast furnace /DME production |
|---|---|---|
| Coal gasification | Pressure 3MPa,Dry coal feed<br>Cold gas efficiency 81.5%<br>Oxygen consumption 540$Nm^3$/t-coal<br>Flux required for coal of high ash melting temperature | Pressure 0.5MPa,Dry coal feed<br>Cold gas efficiency 91.6%<br>Oxygen consumption 470$Nm^3$/t-coal<br>Not required |
| Shift reaction | $H_2/CO$ 0.43 → 1 | $H_2/CO$ 0.27 → 1 |
| Desulfurization | 12,000ppm → 0.1ppm | 15ppm → 0.1ppm |
| De-$CO_2$ | 17 → 11% | 32 → 11% |
| Gas compression | Pressure (3.0→5.4MPa) | Pressure (0.5→5.4MPa) |
| Coal to DME | Cold gas efficiency 63.2%<br>Total efficiency 57.4%** | Cold gas efficiency 70.1%<br>Total efficiency 64.1% |

*Ref: DME Handbook Supplement, p.12 (2011)
**include Electricity consumption for Oxygen production

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# Conclusion

- Steelworks consume plenty of coal next to power plants, having a large handling capacity of coal. Blast furnace produces pig iron and by-produces blast furnace gas to be used as fuel in the steelworks.
- Oxygen blast furnace has a large capacity of generating excess gas, of which the amount can be controlled by Reducing agent rate(RAR). Oxygen blast furnace gas is suitable for synthesis because nitrogen content is little.
- Co-production of pig iron and DME is studied by process simulation. DME production from oxygen blast furnace gas has higher thermal efficiency and lower unit oxygen consumption in comparison with DME production from conventional coal gasifier gas.
- As the blast furnace itself has a gasification function, there is no need to install an expensive coal gasifier. Facilities required for coal gasification is an expansion of oxygen plant and pulverized coal facility, and a syngas compressor.

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