High-Carbon DRI: the feeding material to improve performances and decrease CO2 emissions in both BF and EAF

ENERGIRON HYL
DRI TECHNOLOGY BY TENOVA AND DANIELI

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Danieli Centro Metallics
12-14 Sept, Linz, Austria

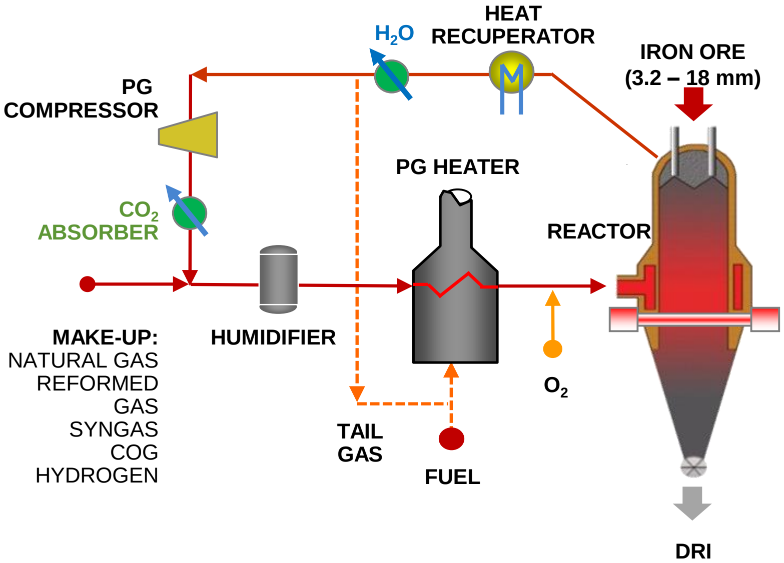
ENERGIRON HYL

- Is the innovative HYL Direct Reduction Technology developed jointly by Tenova and Danieli
- The most competitive and environmentally clean solution for lowering the liquid steel production cost

tenova HYL

DANIELI

TECHNOLOGY: ENERGIRON ZR



> **HIGH TEMP**
1050 ºC

> **OPERATING PRESSURE**
6-8 BAR

FLEVIBILITY

> Same scheme for ANY energy source

ENVIRONMENTAL:

> lowest NOx emissions: 0.030 kg_{NOX} / t_{DRI}

> Selective removal of iron ore reduction's by-products: H_2O & CO_2

ENERGIRON

PLANT EMISSIONS ARE IN ACCORDANCE WITH THE MOST STRINGENT ENVIRONMENTAL REGULATIONS WORLDWIDE

> No need to preheat the combustion air to high temperature, due to the high energy efficiency of the process itself results in eliminating high NOx generation;

> NOx emissions additionally reduced with ultra-low NOx burners and/or SCR;

> Low dust emission from heater thanks to low tail gas purged from reducing circuit to burners

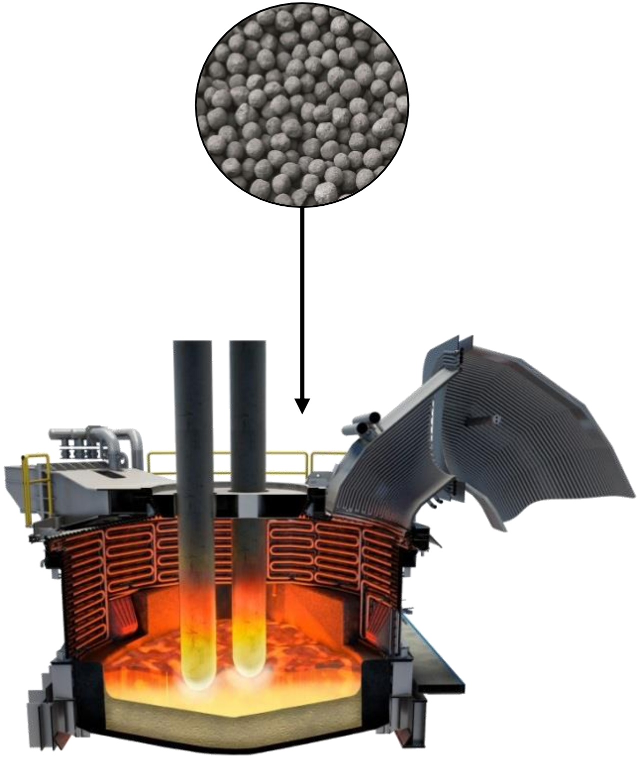
NOx with Ultra Low NOx burners	**30-80**	**[mg/Nm^3]**
NOx with Selective Catalytic Removal	**10-50**	**[mg/Nm^3]**
SO_2 (w/o and with sulphur removal)	**250-negligible**	**[mg/Nm^3]**
CO	**20-100**	**[mg/Nm^3]**
Dust from heater stack	**1-5**	**[mg/Nm^3]**
Dust from material handling dedusting	**5-20**	**[mg/Nm^3]**

HIGH CARBON DRI: USE IN EAF

DRI IS USED IN EAFS TO COMPLETELY OR PARTIALLY REPLACE SCRAP:

1. Higher Volumetric Weight
2. Uniformity of Chemical Analysis
3. Freedom from Undesirable Elements
4. Continuous Charging
5. Less Flicker
6. Less noise level
7. Better Bath Steering
8. Lower Nitrogen Content
9. Foamy Slag Practice

DRI WITH HIGH CONTENT OF IRON CARBIDE PROVIDES FURTHER ADVANTAGES...

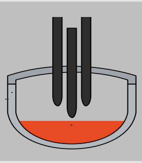


HIGH CARBON DRI: USE IN EAF

CARBON IN EAF IS REQUIRED TO REDUCE RESIDUAL FEO IN THE DRI

TRADITIONAL DRI
C ≈ 1.5 ÷ 2%
30÷40% C in GRAPHITE form

LOW-C DRI
GRAPHITE/COAL
OXYGEN
E.E.

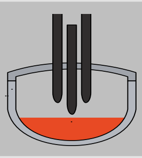


YIELD Injected carbon < < 100%

>Particles blowoff
>Ash/impurities

ENERGIRON DRI
C ≈ 1.5 ÷ 4.5%
C mostly in CEMENTITE form

HIGH-C DRI
OXYGEN
E.E.



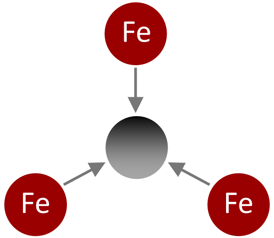
YIELD carbon bond to DRI ≈ 100%

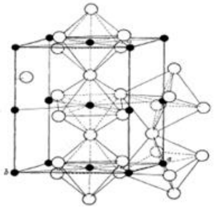
>~ 33 kWh / tLS saved
>~ 10 Nm3 O2 / 1% C

CARBURIZATION IN ENERGIRON PROCESS

$$3Fe^0 + CH_4 \longrightarrow Fe_3C + 2H_2$$

T > 1050 °C
P ≈ 6 ÷ 8 barg
CH_4 > 20%
H_2 / CO ≈ 5





CEMENTITE IS SOURCE OF ENERGY IN EAF

$$Fe_3C \longrightarrow 3Fe + C + Heat$$

$$2C + O_2 \longrightarrow CO + Heat$$

~ 8 kWh / t_{LS} saved depending on post-combustion factor

HIGH CARBON DRI: USE IN EAF

OPTIMUM CARBON CONTENT IN DRI DEPENDS ON EACH SPECIFIC APPLICATION AND STEEL GRADE:

> ENERGIRON plants are not designed to produce DRI with a specific C content, it can be easily adjusted by setting few operating parameters

> Feeding DRI with correct C content allows to reduce the residual FeO without graphite injection into EAF, that has lower efficiency

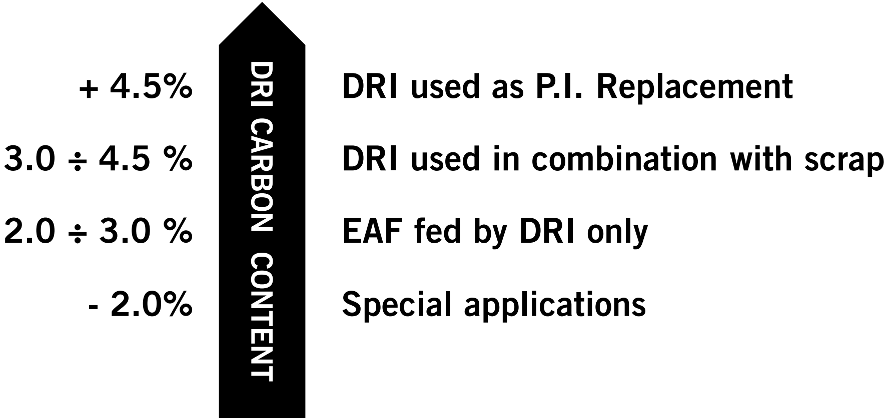
> Feeding to EAF C in cementite form, provides thermal energy (from Fe_3C dissociation) to the EAF

> C in DRI reacts with O_2 injected into EAF, providing thermal energy, better stirring, foamy slag

> Higher C content in DRI provides longer electrode's life

> Higher C content in DRI provides longer EAF refractory's life

> Feeding DRI with correct C content allows to reduce the tap-to-tap time, anyhow excessive C content in DRI can cause longer tap-to-tap time (refining time to get rid of C)



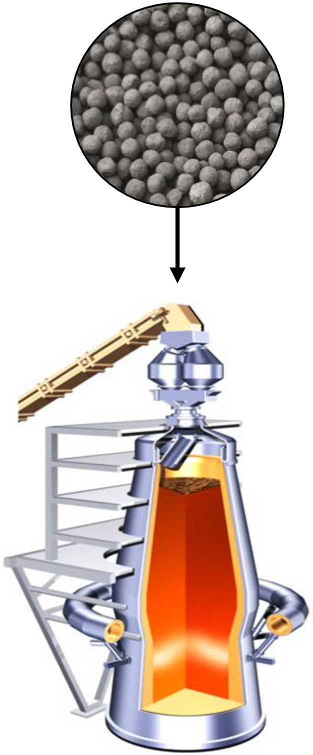
+ 4.5%	**DRI used as P.I. Replacement**
3.0 ÷ 4.5 %	**DRI used in combination with scrap**
2.0 ÷ 3.0 %	**EAF fed by DRI only**
- 2.0%	**Special applications**

HIGH CARBON DRI: USE in BF/BOF

HIGH-C DRI CAN BE FED TO BF:

1. **TO KEEP SAME LIQUID STEEL PRODUCTION RATE.** In this case the main target is reduction of environmental impact due to a decrease of specific coal consumption and CO_2 emissions by lowering PCI consumption

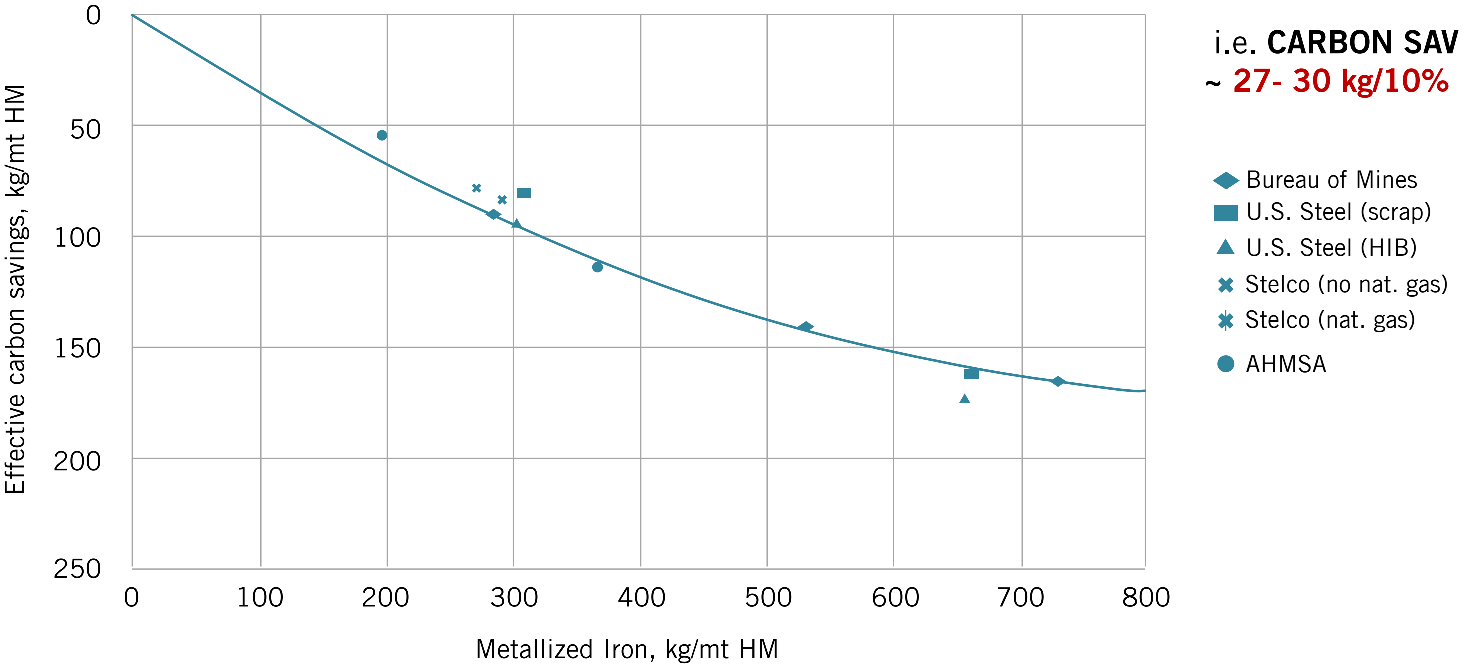
2. **TO INCREASE HM PRODUCTIVITY IN THE BF**, decreasing not only specific consumption figures and CO_2 emissions but also achieving savings in production costs.



EFFECT OF DRI IN THE BF BURDEN ON CARBON SAVINGS

Example: Standarized graph as per Flint operating factors

Based on Fe°/FeT ~ 32% metallised charge, the expected Carbon rate savings are expected to be 85 – 90 kg;



i.e. **CARBON SAVINGS**

~ 27- 30 kg/10% Mtz

HIGH CARBON DRI: USE in BF/BOF

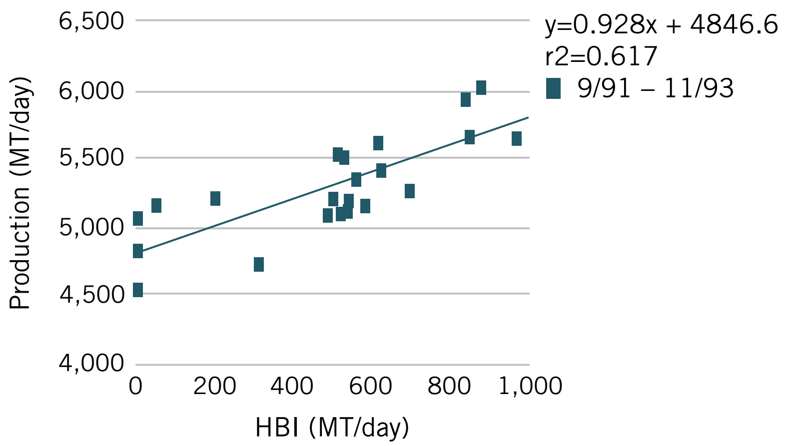
EFFECT OF DRI IN THE BF BURDEN ON PRODUCTIVITY

Hot Metal (HM) production increase;
about 6-7% per each 10% of burden metallisation.
Based on Fe° / FeT ~ 32% metallised charge, the expected Productivity increase is expected to be 19-23%.

However; the estimate of productivity increase depends on multiple factors; i.e.

- Size and quality of raw materials
- Operating practices
- Oxygen injection, PCI
- Permeability
- Charge distribution

Reference	% Productivity increase 10% Mtz	Comments
IRSID	6,6	Theoretical calculation
STELCO	6,5	5,15% NG injection
AHMSA	7,9	BF operating at low productivity
USIMINAS	7,9	Tests up to 15% Mtz
AK Steel has achieved 19% increase for production ~5.500 ton/d with 181 kg HBI/t HM		Optimising operating practices related to oxygen, NG injection, etc

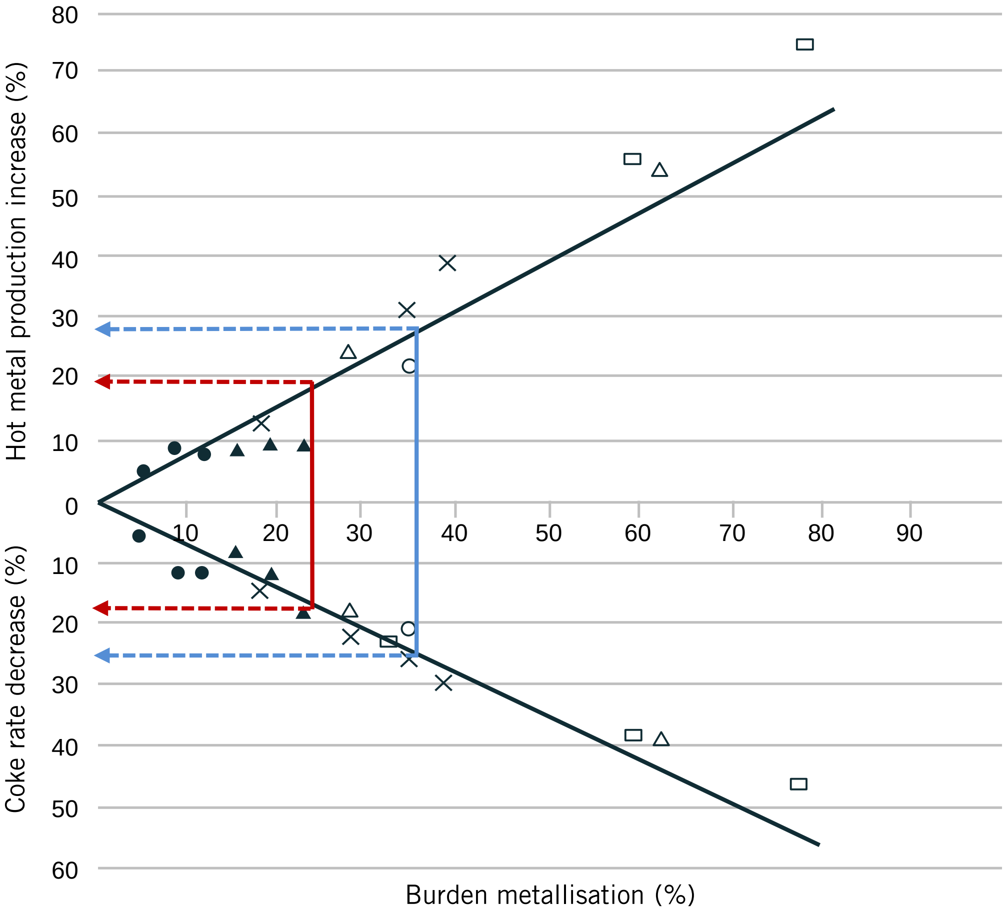


HIGH CARBON DRI: USE in BF/BOF

Hot Metal (HM) production increase; about 7-8% per each 10% of burden metallisation.

Lower coke rate; about 7% per each 10% of burden metallisation.

□ US Bureau of mines	(1965)
△ US Steel	(1966)
○ Stelco	(1964)
▲ Yawata Steel	(1965)
● Kawasaki Steel	(1966)
× Ahmsa	(1978)



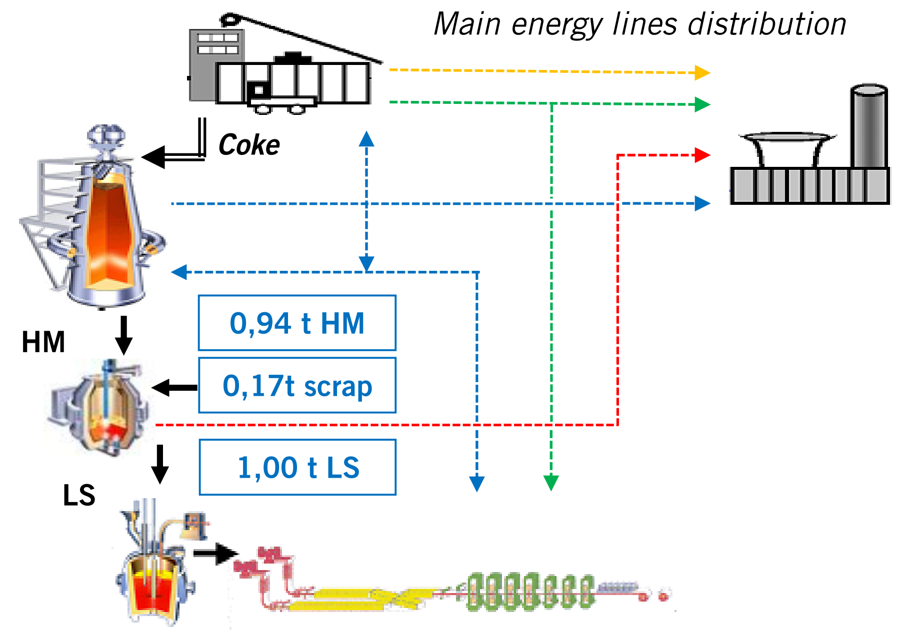
ENERGIRON DRP INTEGRATED WITH BF

BASE CASE: TYPICAL INTEGRATED MILL BF-BOF

Coking Coal
455 kg/t_{LS}

PCI
161 kg/tLS

Burden
1520 kg/tLS



CO2 Emissions
1,80 t/tLS

Export Power
324 kWh/tLS

Note: Power credit included in CO_2 Emissions
Ref: 0.5kg CO_2/kWh

Net CO2 Emissions
1,60 t/tLS

CASE 1: REPLACEMENT OF BF-BOF by DRP-EAF (a) w/o & (b) w CO2 off-taking

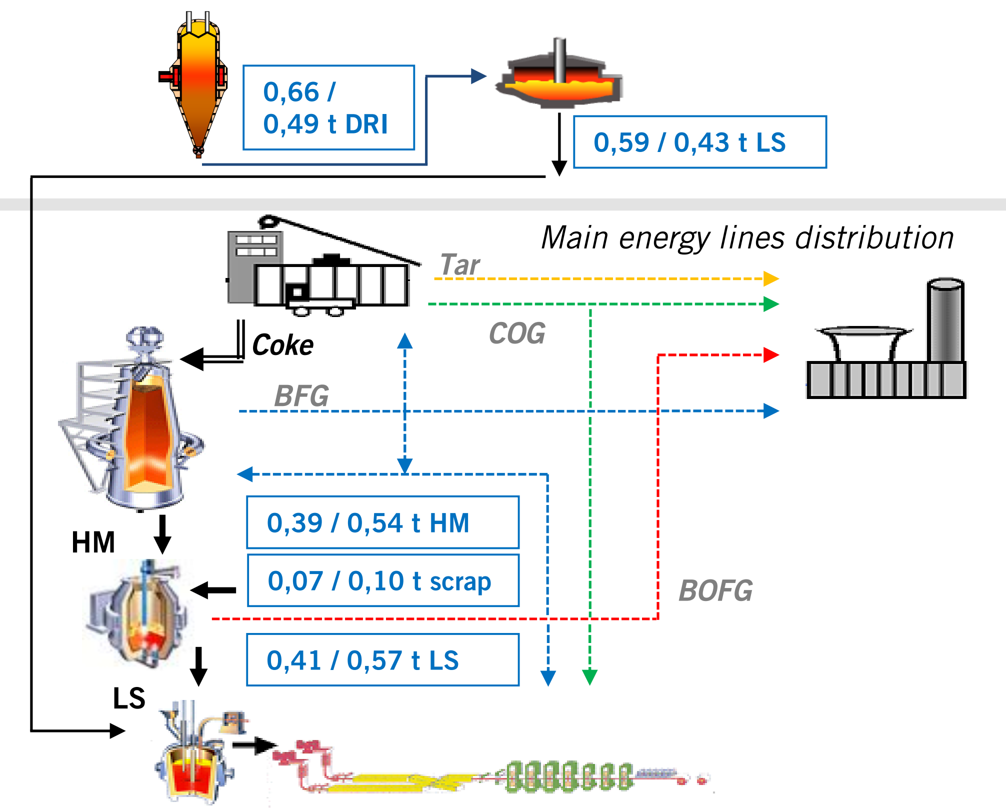
Natural Gas
190 / 140 Nm^3/t_{LS}

DR IO pellets
930 / 690 kg/t_{LS}

Coking Coal
190 / 260 kg/t_{LS}

PCI
66 / 92 kg/t_{LS}

Burden
620 / 870 kg/t_{LS}



0,66 / 0,49 t DRI

0,59 / 0,43 t LS

Main energy lines distribution

0,39 / 0,54 t HM

0,07 / 0,10 t scrap

0,41 / 0,57 t LS

CO_2 Emissions
1,20 / 1,08 t/t_{LS}

Non-selective

CO_2 Emissions
0 / 0,12 t/t_{LS}

Selective

Import Power
150 / 25 kWh/t_{LS}

Note: Power Consumption included in CO_2 Emissions
Ref: 0.5kg CO_2/kWh

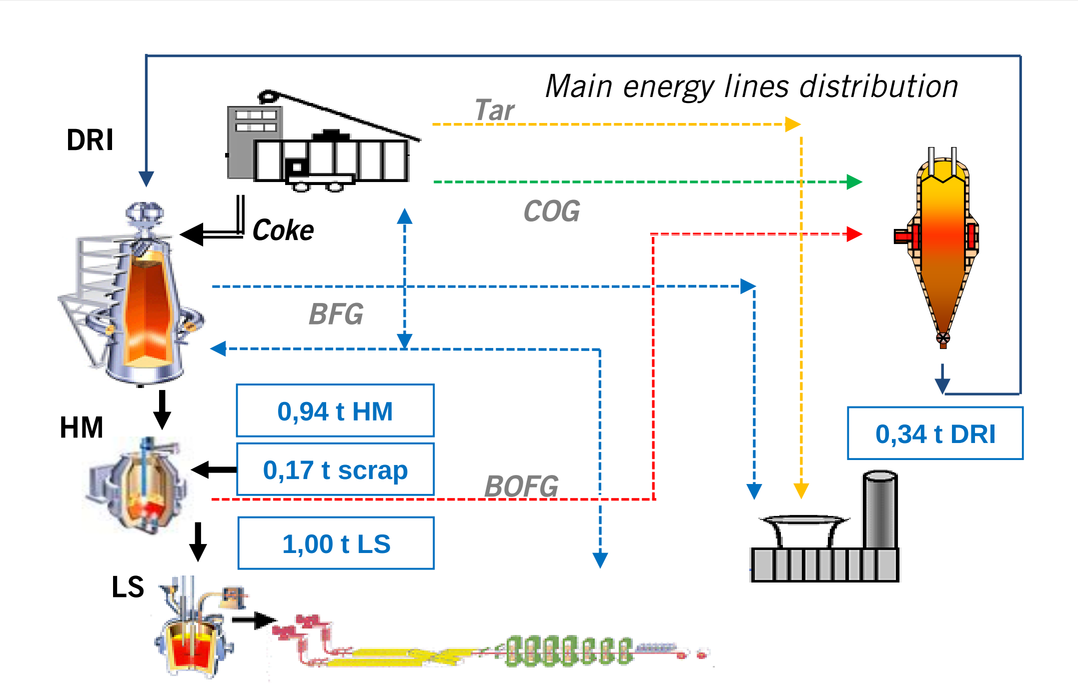
CASE 2: INTEGRATION OF DRP-EAF IN BF-BOF with CO_2 off-taking

DR IO Pellets
480 kg/t_{LS}

Coking Coal
455 kg/t_{LS}

PCI
43 kg/t_{LS}

Burden
1140 kg/t_{LS}



CO_2 Emissions
1,36 t/tLS

Non-selective

CO_2 Emissions
0 / 0,5 t/t_{LS}

Selective

Import Power
155 kWh/t_{LS}

Note: Power credit included in CO_2 Emissions
Ref: 0.5kg CO_2/kWh

Limitations:
> Total COG availability for DRP > max. % metallic burden (DRI) to BF

CASE 3: EXTERNAL DRI TO BF (a) w / (b) w/o CO_2 off-taking

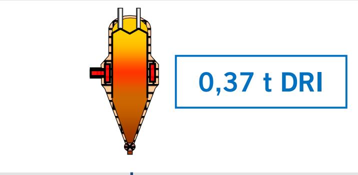
Natural Gas
104 Nm^3/t_{LS}

DR IO pellets
520 kg/t_{LS}

Coking Coal
455 kg/t_{LS}

PCI
43 kg/t_{LS}

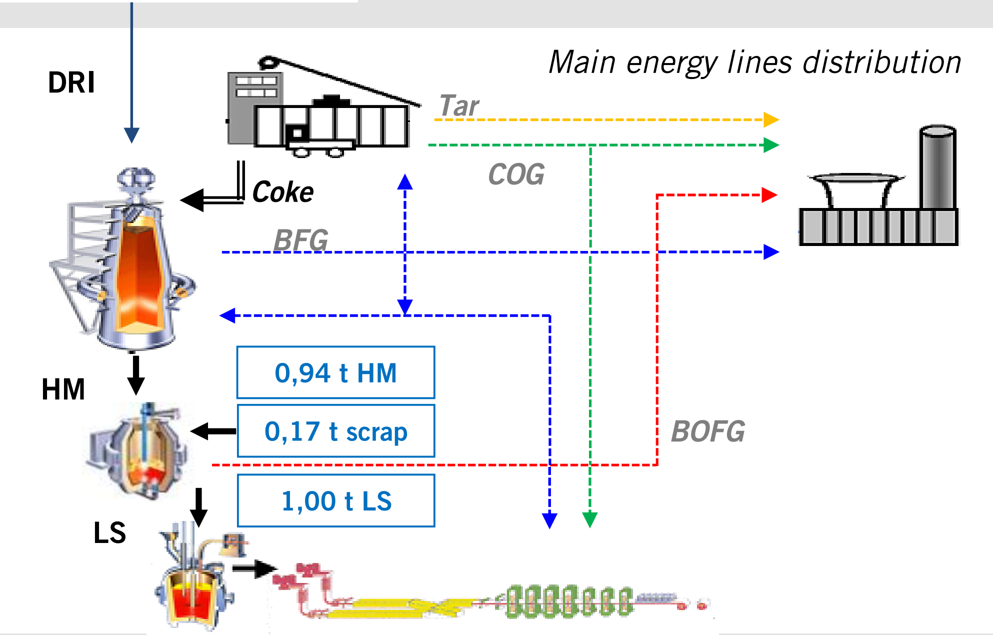
Burden
1140 kg/t_{LS}



CO_2 Emissions
0,06 t/t_{LS}
Selective (+4%)

CO_2 Emissions
0,09 t/t_{LS}
Non-selective (+5%)

Limitations:
- max. % metallic burden (DRI) to BF

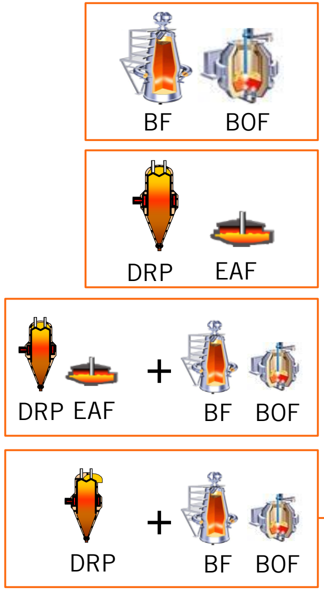


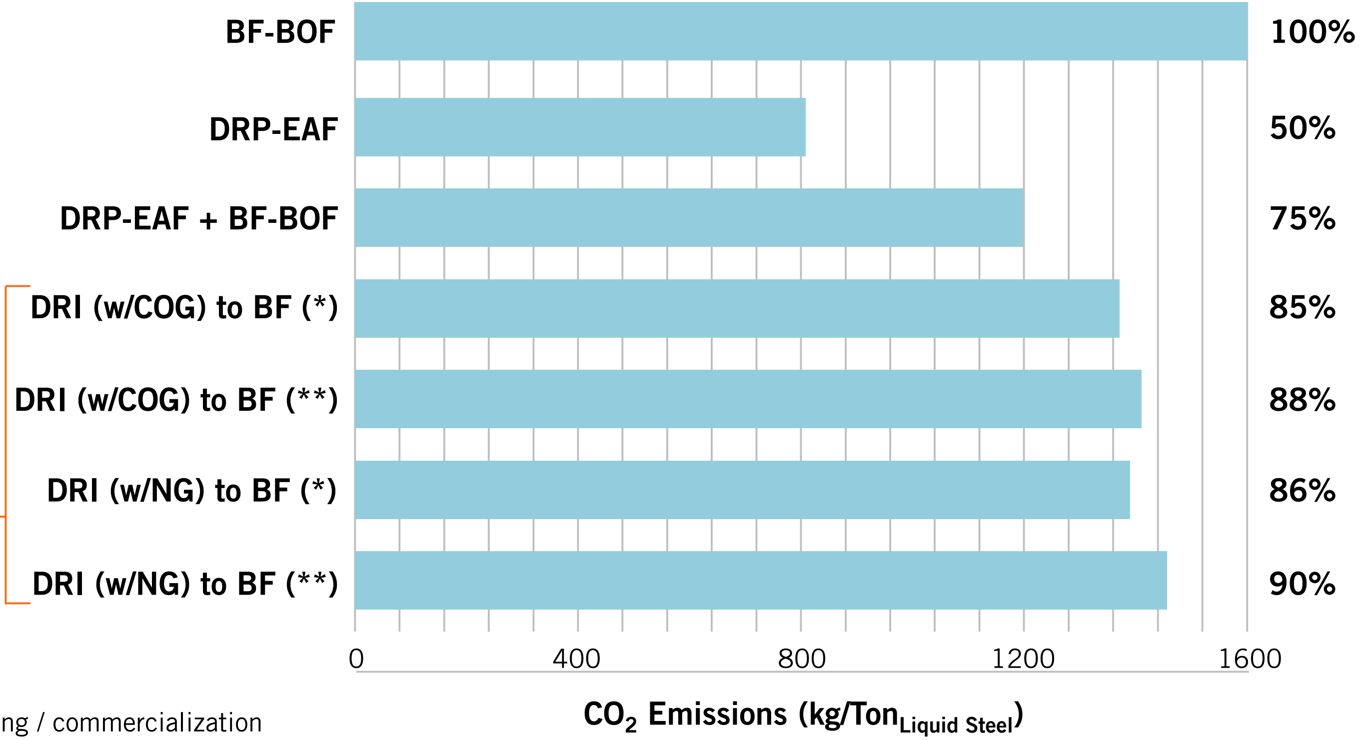
CO_2 Emissions
1,30 t/t_{LS}
Non-selective (-19%)

Exit Power
300 kWh/t_{LS}

Note: Power credit included in CO_2 Emissions
Ref: 0.5kg CO_2/kWh

CO_2 EMISSIONS – STEELMAKING ROUTES





Notes:
(*) With CO_2 off-taking / commercialization
(**) Without CO_2 off-taking / commercialization

ENERGIRON DRP INTEGRATED WITH BF

The ZR patented scheme for using COG has been tested under the following scenarios:

- > **Pilot plant tests; 1978-1982, 1997**
- > **Campaigns during 1997: With CO_2 absorption and oxygen injection (ZR)**
- > **Laboratory tests at AHMSA to prove destruction of BTX with hot DRI; 1980's**
- > **2008; Tests at Zdz, Poland in a joint effort between ArcelorMittal and Tenova HYL to confirm the above**

EFFICIENCY - No need of external combustion chamber or additional reactor

Now in analysis with JSW to implement this scheme in the existing HYL plant in India

PP Test No.	COG (Nm^3/t DRI)	OXYGEN (Nm^3/t DRI)	MTZ (%)	CARBON (%)
1	557	15	93.1	3.2
2	555	20	94.2	2.8
3	570	15	93.8	3.8
4	590	20	94.1	4.1

REFERENCES

REFERENCES

EMIRATES STEEL

Two modules:

2.0 MTPY each
Carbon 1.5% - 2.5%
Met 94% - 96%
Hot DRI feed to EAF

Start-up
2009/2011

SUEZ STEEL

One module:

2.0 MTPY
Carbon 3.0% - 4.0%
Met 94% - 96%
Hot DRI feed to EAF

Start-up
2013

NUCOR

One module:

2.5 MTPY
Carbon 3.0% - 4.5%
Met 94% - 96.5%
Cold DRI

Start-up
2013

EZZ STEEL

One module:

1.95 MTPY
Carbon 1.5% - 2.5%
Met 94% - 96%
Cold DRI

Start-up
2015

UNMATCHED EXPERIENCE IN HIGH CAPACITY MODULES

Energiron power

- > Energiron is the only proven Direct Reduction Technology available on the market with a productivity rate up to 2,5 Mtpy in a single module, able to compete with BF-BOF route
- > Controlled carbon content value in DRI affect positively EAF operation in terms of OPEX, and only Energiron can produce it
- > HyTemp system gives unmatched results in liquid steel productivity and efficiency
- > Energiron has designed and supplied facilities that are successfully operating under some of the strictest environmental standards in the world

Packing Energy and Iron - Feeding power to EAF

THE FIRST INDUSTRIAL GAS BASED REDUCTION TECHNOLOGY IN 1957

THE FIRST TO BE READY FOR THE IRONMAKING OF THE FUTURE