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DRI/SCRAP blending in EAF practice. Impacts on slag composition, energy consumption and furnace productivity

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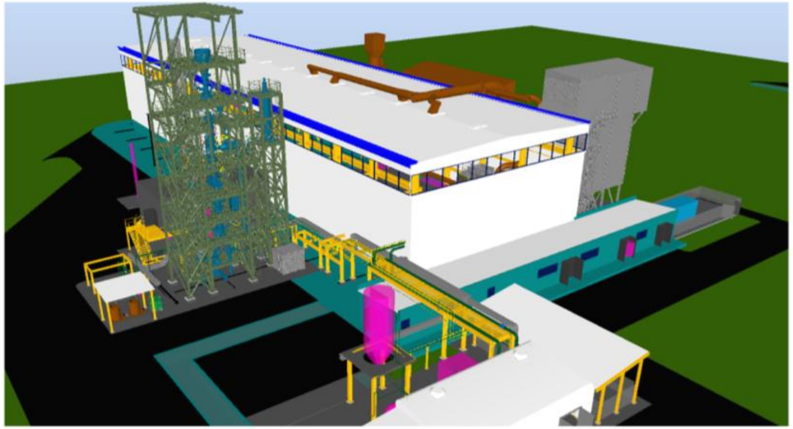

INTRODUCTION

The net zero emission target for steelmaking is pushing toward the adoption of breakthrough technologies, The process route based on Direct Reduction and Electric Arc Furnace melting is recognized as a valid alternative to the traditional BF-BOF based route [1].

The DRI-EAF process route is expected to increase its global production share, from the current 5% up to 30% in 2050 [2].

The energy demand of the EAF melting step is strongly determined by the different input materials. DRI as charge material has strong impact on EAF energy demand and slag formation.

[1]Green Steel for Europe, GA number 882151

[2] Bloomberg NEF analysis [https://about.bnef.com/insights/clean-energy/steel-industry-set-to-pivot-to-hydrogen-in-278-billion-green-push/]

INTRODUCTION

The optimization of operating practices, tailored to the different charge mix of materials, requires a deep quantitative analysis of the occurring phenomena.

The blending of DRI and scrap is a way to compensate for the increased energy demand for DRI melting. The ratio DRI/scrap is also governed by the required final steel quality, the plant productivity needs, the energy demand, and the quality of input pellets (gangues content and carbon content).

The scope of this activity is to study the EAF melting step with a combination of experimental data (form lab and pilot tests) and analysis by a purposely tuned EAF model

HYDRA project

In this general framework, HYDRA project aims at developing an industrial open platform integrating pilot plants for DRI production and melting, labs and downstream studies.

Realised under the IPCEI funding scheme (Important Projects of Common European Interest): approved by European Union and financially supported by Italian Minister

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HYDRA project: the pilot plants

DRP tower of about 30 m height

100 kg/h DRI produced (about 2,4 t per day)

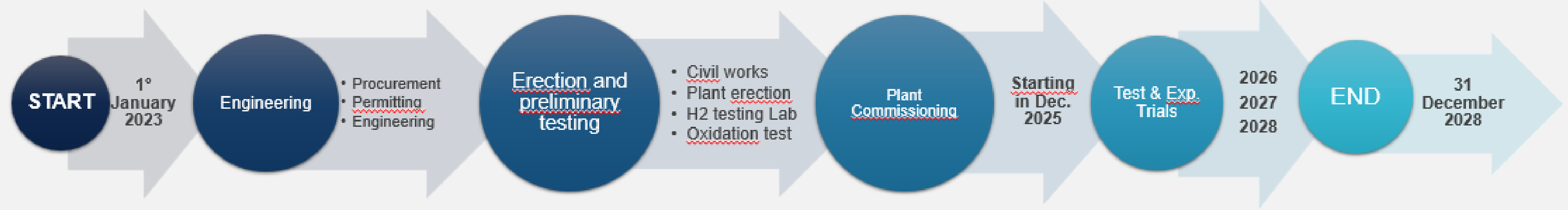
Gas input by wagon tank to work with hydrogen and gas blends

Gas treament line equipped with CO_2 capture

7 t capacity, with 4 m3 internal volume
AC three electrodes
Scrap and DRI charge
Continuous charging of DRI
Injection of solid materials (additive, coal, alternative carbonaceous materials)
KT lance working as Hydrogen burner or Oxygen injector
Furnace shell refractory insulated

HYDRA project

- Project officially started on the 1° January 2023 and will last six years
- DRP based on ENERGIRON technology
- DRP and EAF provided by Tenova, Gas line and installation by Danieli, gas system by Sapio
- All the facilities almost completed
- The first heat with pilot EAF carried out in December 2025
- Commissioning of DRP ongoing
- Full operativity of the whole experimental platform July/September 2026



EXPERIMENTAL ACTIVITY

Test in VIM furnace

Test 1: DRI melting

Test 2: DRI + slag melting

Test 3: scrap + slag melting

Energy consumption and system temperature recorded continuously.

Scope of test 1: evaluate the resulting slag formed from DRI melting

Scope of tests 2 and 3. evaluate first energy consumption for model application

Test in pilot 7t furnace

heat 1: 7 t scrap melting + slag

heat 2/3/4: 5 t scrap melting + slag

Scope of the test is to collect energy consumption data for model tuning and utilization to simulate DRI utilization

Steel and slag samples collected

Provide info to design subsequent tests with DRI (and HBI)

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Test in VIM furnace

C	0.002
Si	<0.005
Mn	0.06
Cr	0.03
Al	<0.001
S	0.007

Scrap

Fetot	84,4
Fe met	80,6
Al2O3	1
CaO	1,2
MgO	0,7
SiO2	4,8
FeO	4,9
C	3,4
S	0,01
Met. degree	95,5

DRI

- Test 1: 8 kg of DRI (no slag)
- Test 2: 8 kg of DRI + 0,5 kg slag
- Test 3: 8 kg of scrap + 0,5 kg slag

Temperature: 1650°C

Slag analysis

CaO (%)	50
MgO (%)	13
Al_2O_3 (%)	31
SiO_2 (%)	6
FeO (%)	0

- Slag with high Al2O3 content to reduce pollution from Al2O3 crucible
- Low melting point
- Viscosity comparable with current EAF slags
- Satured in MgO

Test in VIM furnace

starting gangue and iron oxide content		formed slag after melting
Al_2O_3 (%)	7,9	12,9
CaO (%)	9,5	14,1
MgO (%)	5,6	8,2
SiO_2 (%)	38,1	55,2
FeO (%)	**38,9**	**10,3**

During melting there a partial reduction of iron oxide, confirmed by bubbles evolution (by visual inspection)

The reactivity of the system and impact on slag analysis provide information for model input data

Test 2 and Test 3 aimed at first evaluation of energy consumption reported only qualitative results:

- The test with DRI recorded as expected higher energy consumptios values respect scrap
- Recorded values (for both DRI and scrap) are significantly higher respect EAF average values (about ten times higher). These results provide qualitative info but not suitable for model calibration

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Test in pilot EAF

C	0.002	Scrap 
Si	<0.005	
Mn	0.06	
Cr	0.03	
Al	<0.001	
S	0.007	

CaO (%)	50
MgO (%)	13
Al_2O_3 (%)	31
SiO_2 (%)	6
FeO (%)	0

- Four heats carried out (first heat with 7 tons scrap, heats 2-3-4 with 5 tons scrap
- About 200kg of slag used in each heat
- No oxygen injection and no foaming practice
- 5 kg of coal addition at the beginning of the heat

Average specific energy, tapping temperature and slag analysis used for model calibration

Model specification

- Static model based on mass and energy balance
- Oxygen injection can be used as input or calculated from target values
- FeO in the slag used as input data (from slag analysis)
- Oxygen reacts with molten bath following the order of thermodynamic affinity
- In case of reaction with C, only CO formation is considered
- The specific heat is variable with temperature (literature values used)
- Bath temperature is an imput data
- The dependency of specific heat as function of different steel grades of scrap is under implementation

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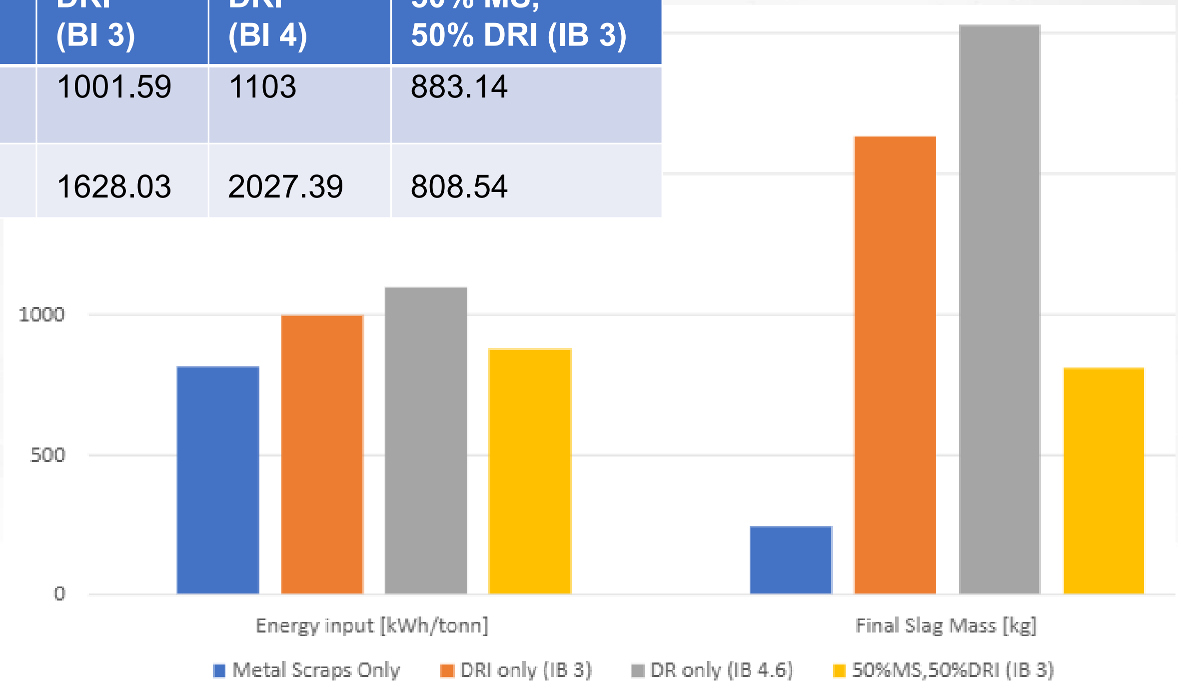
Model results: Energy and mass slag as a function of different input charge materials

	scrap	DRI (BI 3)	DRI (BI 4)	50% MS, 50% DRI (IB 3)
Energy [kWh/t]	810	1001.59	1103	883.14
slag [kg]	241.76	1628.03	2027.39	808.54



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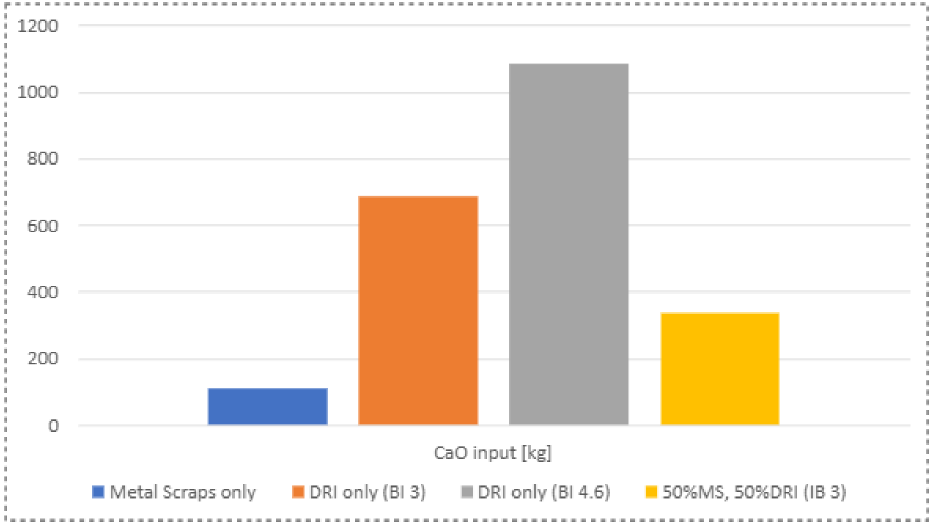
Model results CaO slag input as function of EAF charge mix

	Metal Scraps Only	DRI only (BI 3)	DRI only (BI 4.6)	50% MS, 50% DRI (IB 3)
CaO input [kg]	110	686.4	1085.76	344.03



Conclusions (1)

- HYDRA IPCEI project started the operative phase, with plants commissioning and first tests.
- An activity aimed at studing mechanisms of DRI and mixed charged melting started, with support of static model for process operation optimization.
- Lab and pilot tests used for first calibration of model.
- Scrap used in pilot heats and low grade DRI for model analysis of melting process.

Conclusions (2)

- The use of a feedstock composed entirely of DRI, as expected, leads to a significant increase in energy demand.
- The impact of slag basicity (slag practice) on energy demand is significant: 20% for BI = 3 and up to 30% for BI = 4.6 compared with conventional EAF operation.
- DRI-based operation promotes higher slag generation due to the larger gangue content and the increased flux additions. These additions may create operational constraints related to slag volume and furnace capacity
- Scrap blending possible countermeasure to be adopted.

These findings further highlight the technological and operational challenges associated with the transition toward DRI EAF steelmaking.

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Thank you for your attention

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