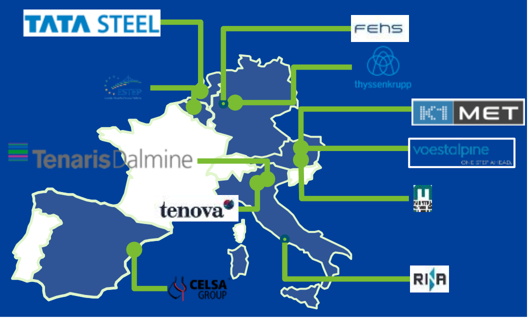
ReMFra
Recovering metals and mineral fraction from steelmaking residues

The Clean Steel Partnership



Development of a Pyrometallurgical Approach for Iron and Zinc Recovery: Design and Modeling of a Plasma Reactor within the ReMFRa Project

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ReMFra project

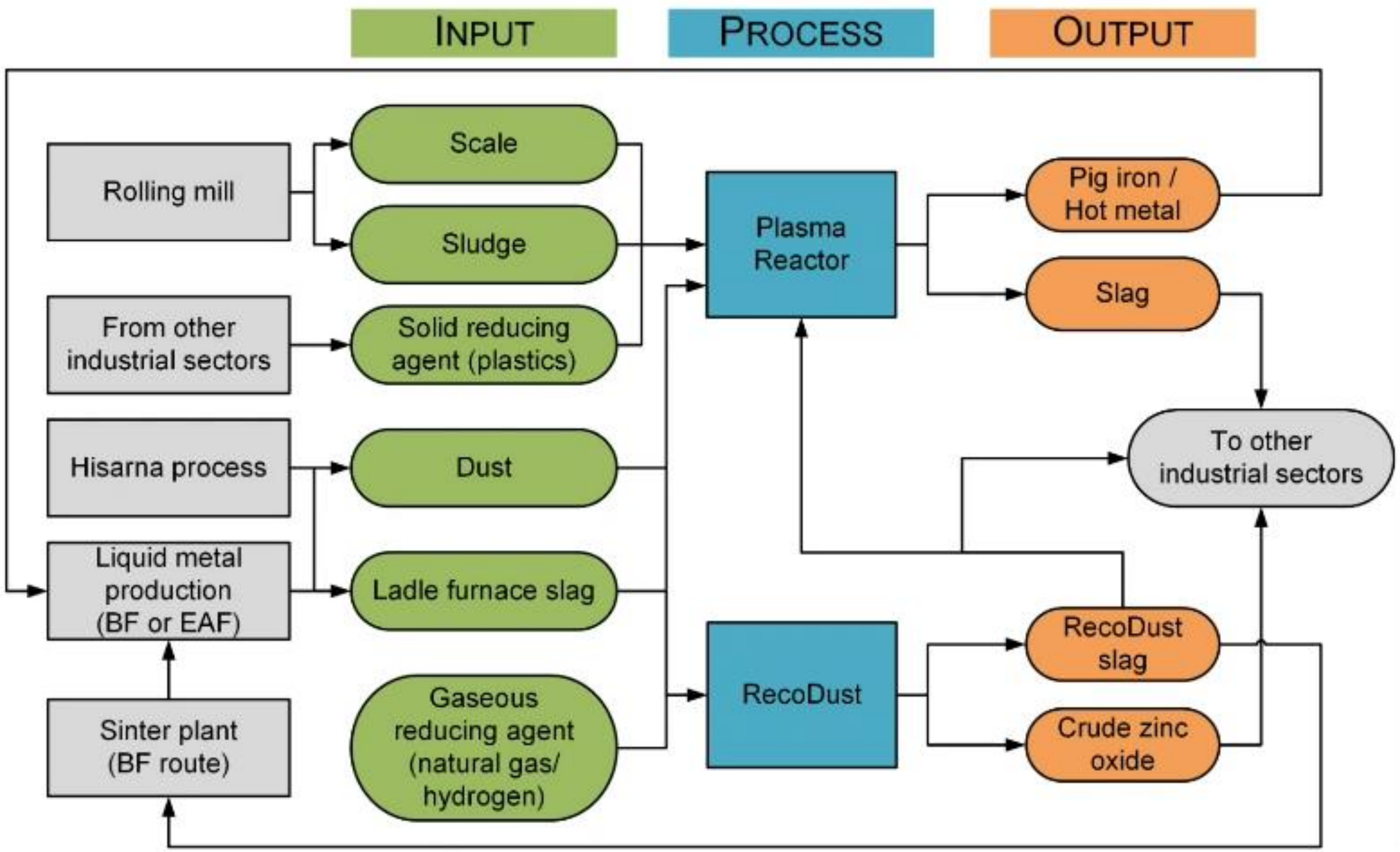
The objective of the **ReMFra** project is to demonstrate and qualify a complete system for the **recovery** and the **valorization** of the metal and mineral fractions contained **in steel making processing residues**.

Improving **metal recovery yield**, to reach the full **circularity** and to reduce the **environmental impacts** of the steel sector all over Europe.

ReMFra project

The ReMFra concept is based on 2 processes:

- ✓ Plasma Reactor for the treatment of coarse- grain residues such as scale, sludge, and secondary metallurgical slag
- ✓ RecoDust process for fine-grained residues (dust).

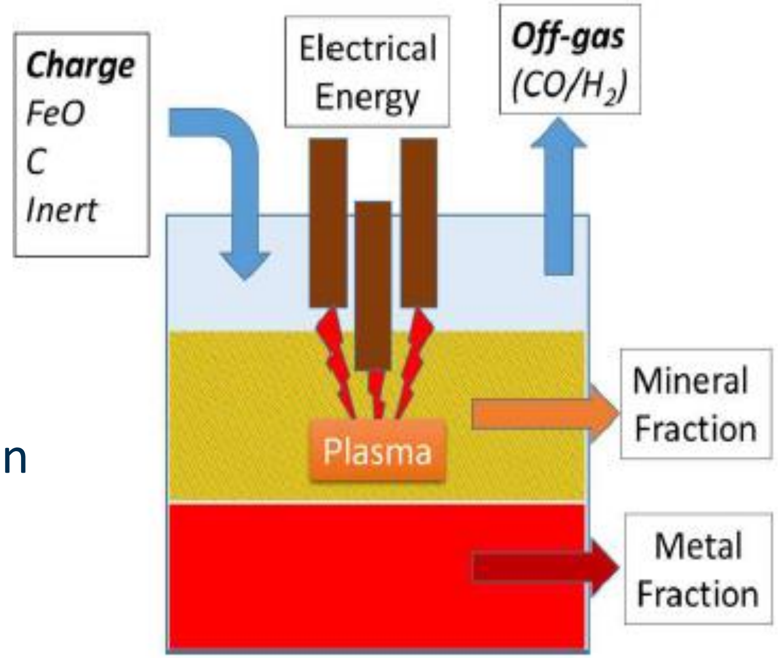


Plasma Reactor

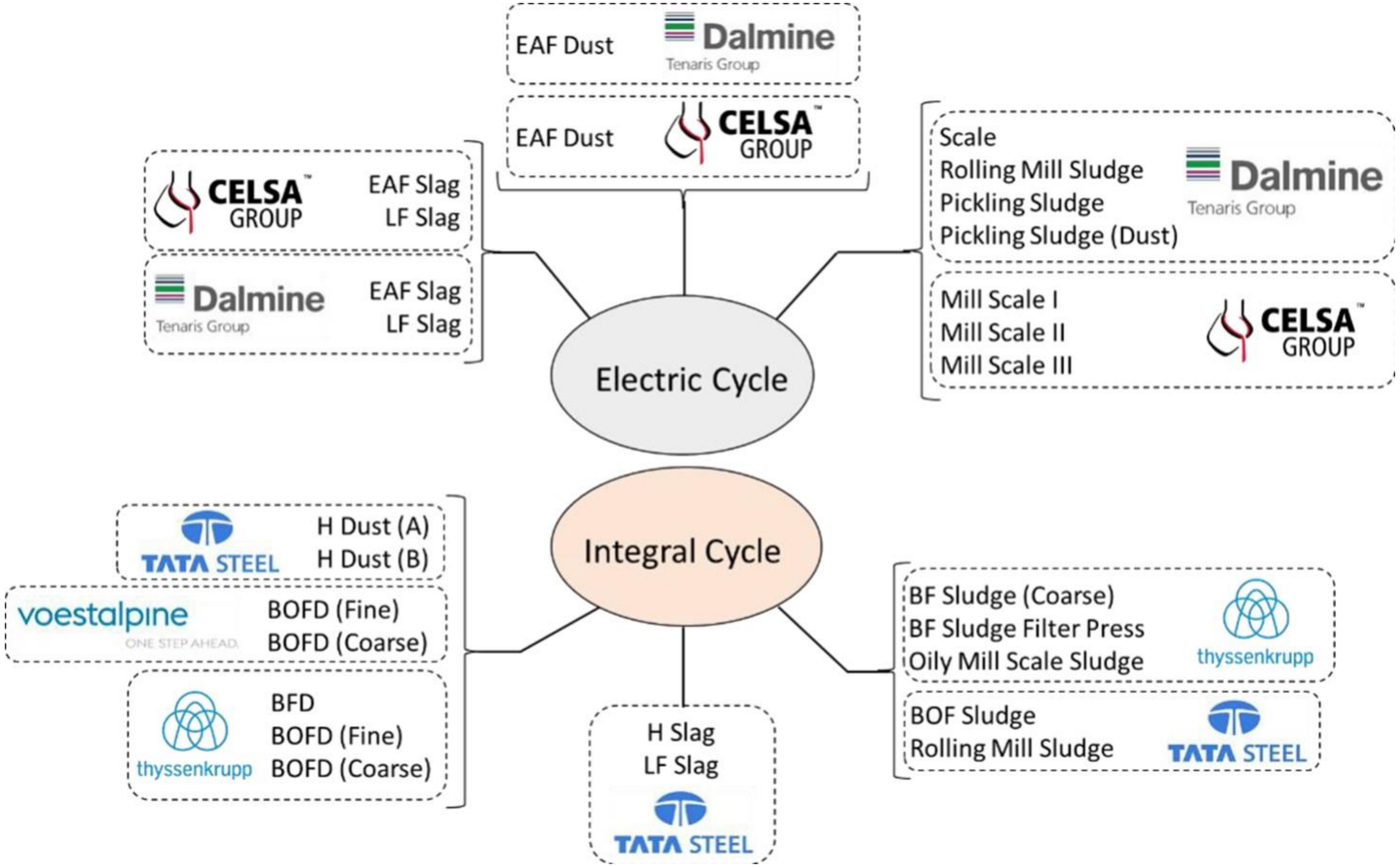
Plasma Reactor is based on plasma technology, electrical arc generated by graphite electrodes, working in **reducing atmosphere**.

This pyrometallurgical process can:

1. Work in **reducing process atmosphere** allowing metal recovery from oxides and low concentration of pollutants in off gas (NOX, SOX and dioxins)
2. Treat a ***large variety*** of waste streams containing high percentage of iron
   - ✓ **scale** from rolling mill
   - ✓ **sludge** from cooling water circuits
   - ✓ **EAF/BOF dusts** and **slags**.
3. Accept residual containing Si (ceramic, refractory and glass).
4. Generate foaming slag enhancing oxides reduction kinetic and minimizing energy losses due to electrical arc radiation to the reactor walls.
5. Use electrical energy, opening a big potential for the direct use of renewable energy (RES) and secondary carbon sources (i.e. polymers from waste plastics) to decrease the GHG emissions and improve the circularity of the process



Residue classification



Using historical database of the steel producers, grain size distribution and chemical analyses have been considered.

BF…Blast Furnace
EAF…Electric Arc Furnace
BOFD…Basic Oxygen Furnace dust
LF…Ladle Furnace
H…HIsarna

Briquettes composition definition

The overall investigation for Tenaris residues was as follows:

1. Briquettes composition has been identified starting from historical data of Tenaris Dalmine, then confirmed with the chemical analyses of materials.
2. First briquettes were obtained in laboratory step by blending the streams from DALMINE and conventional anthracite according to the recipes obtained from calculation. The best amount of binder needed to obtain briquettes with appropriate mechanical characteristics has been defined.
3. A product was provided by IBLU with 75% of scale and 25% of polymer (named extrudate), obtained by extrusion.
4. New three recipes of the briquettes were identified, obtained balancing the amount of scale in the extrudate, and were produced.
5. Mixes of extrudate and briquettes were tested in melting furnace.

Secondary carbon sources

- **BLUAIR®** by i.BLU (Recycled Raw Material, compliant with UNI 10667- 17) as a substitute for coal with the functions provided by the technical standard (e.g. reducing agent)
- **I.BLU extrudate composition** (75% scale and 25% **BLUAIR®** polymer) defined to obtain a density value (2,55 g/cm^3) permitting the passage through the slag phase during the charging.
- **Extrudate** is charged in Tenaris Plasma reactor together with the remaining scale fraction in mixed briquettes with the other materials.

iBLU Extrudate

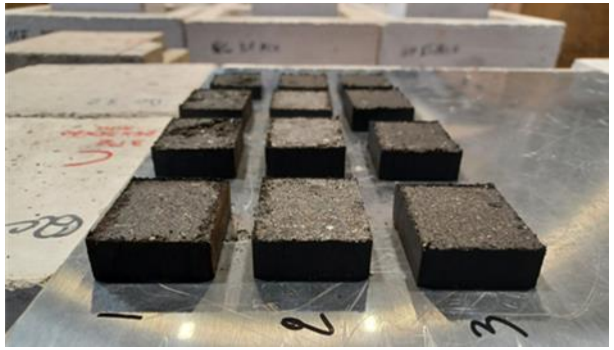
Density [g/cm3]	Moisture [%]	Ash [%]	Volatile Matter [%]	Hydrogen [%]	Total Carbon [%]	Fixed Carbon [%]
0,35	0,37	4,15	95,9	11,87	73,99	<1

BLUAIR® characteristics

Briquettes composition definition

The considered mixed (briquettes+extrudate) compositions to be charged in Plasma Furnace were as follows:

1. ***ratio 70:30 Briquettes 1 : IBLU extrudate***
2. ratio 30:70 Briquettes 2 : IBLU extrudate
3. ratio 50:50 Briquettes 3 : IBLU extrudate



%	LF Slag	Scale	Rolling Mill Sludge	EAFD	Coal	Molasses	CaO	Water
1	16,16	40,4	8,08	3,03	9,09	8,08	8,08	7,07
2	11,27	36,89	17,42	6,15	6,15	8,20	8,20	5,71
3	12,28	40,92	12,28	4,09	8,18	8,18	8,18	5,88

Briquettes composition definition

Melting tests

	Metallic yield [%]	Carbon on the reduced metal [%]
1	98.82	0.07
2	75.23	0.20
3	79.32	0.31

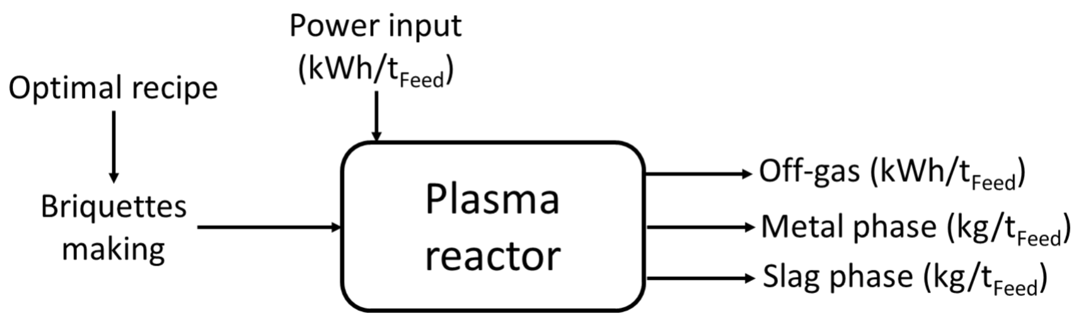
Slag composition

%	Fe	Al	Si	Ca	Mg	Mn	Ni	Cr	V
1	40	8	0.9	9.5	0.5	0.6	0.1	0.2	<0.1
2	47	5.9	0.8	5.0	0.3	0.8	0.1	0.3	<0.1
3	43	6.6	0.9	7.2	0.3	0.7	0.1	0.2	<0.1

Mass and energy balance for PLASMA REACTOR

For the mass balance

- ✓ The distribution of the different chemical species between metal bath, slag and dust has been defined on the basis of literature data and previous experimental activities and industrial tests
- ✓ The metal bath shall have the 3% of carbon content
- ✓ The coal used for reduction has 10% of ash content



For the energy balance

- ✓ It has been assumed that the temperature of melting and reduction is 1600°C. This is the reason why thermodynamic parameters have been calculated at 1600°C
- ✓ In the reduction reaction CO is generated
- ✓ The process gas has the same temperature of the process 1600°C.

In the choice of the possible charging material mix the following criteria has to be met:

- ✓ The ratio of produced amounts of ferro alloy/slag has to be not less than 1.5
- ✓ The composition of the produced slag has to have an IB2 (IB2-CaO/SiO2) between 1.2 - 1.8

Plasma reactor process

Mass and energy balance for **PLASMA REACTOR :** Model Results for Dalmine

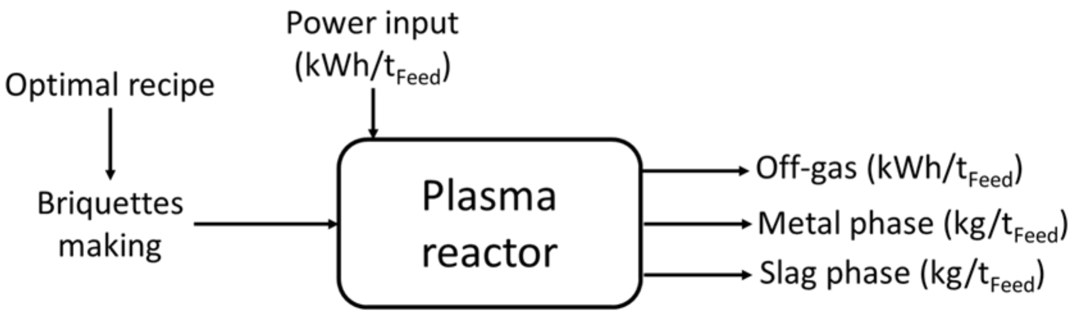
Recipe No.	*1*	*2*	*3*
Charge rate (t/h)	7.40	7.80	7.90
Charge (t/heat)	22.20	23.40	23.80
Coal (kg/t_{Feed})	161.00	154.00	139.00
Energy (kWh/t_{Feed})	1868.00	1843.90	1795.00
Off-gas flow (Nm^3/t)	227.00	218.50	252.10
Off-gas heat (kWh/t)	163.00	169.30	193.70
Height metal (m)	0.35	0.36	0.35
Max height foam (m)	1.62	1.71	1.84

Plasma reactor process

Plasma Reactor Process Design example (5 t/h)

METAL		14099	t/y
		70	t/d
		6	t/heat
	%		
Fe	97,60		
Mn	1,58		
Ni	0,17		
Cu	0,11		
Cr	0,44		
Si	0,08		
V	0,00		
Zn	0,02		
h	0,16	m	

SLAG		6263	t/y
	%		
FeO	11,55	31	t/d
MnO	0,24	3	t/heat
Cr2O3	0,13		
CaO	36,98		
Al2O3	14,05		
SiO2	23,45		
MgO	6,79		
NaO	6,73		
V2O5	0,00		
ZnO	0,08		
PbO	0,00		
IB2	1,6	IB4	1,2
h slag	0,20	m	
h foam min	0,61	m	
h foam max	1,02	m	



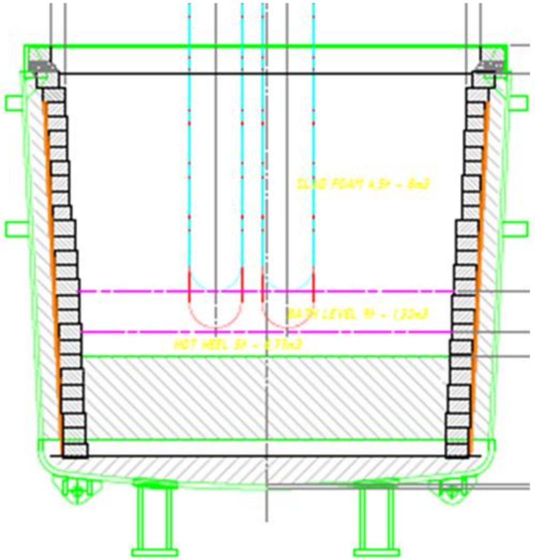
Recipe 1 (briquettes 70% + extrudate 30%) were simulated at **5 t/h and 10 t/h**

The outputs are used for the enginering phase:

- volume of metal bath
- volume of slag
- max volume of foaming slag
- off-gas flow rate
- % CO in the off-gas

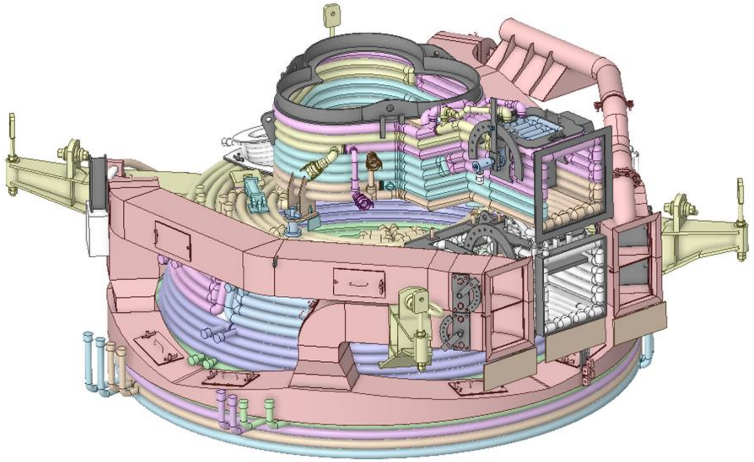
Basic Engineering: Ladle Design

Constrain:
- volume for slag foaming (diameter vs.hight)
- electrodes maximum length



Need dedicated ladle:
- nominal heat size: 9 t of metal and 4,5 t of slag
- nominal charge: 15 t/heat
- nominal flow rate charge: 7,5 t/h (from 5 to 10 t/h)

Constrain:
- adaptation of the existing hood at waste gases consisting mainly of CO before entering the fumes system



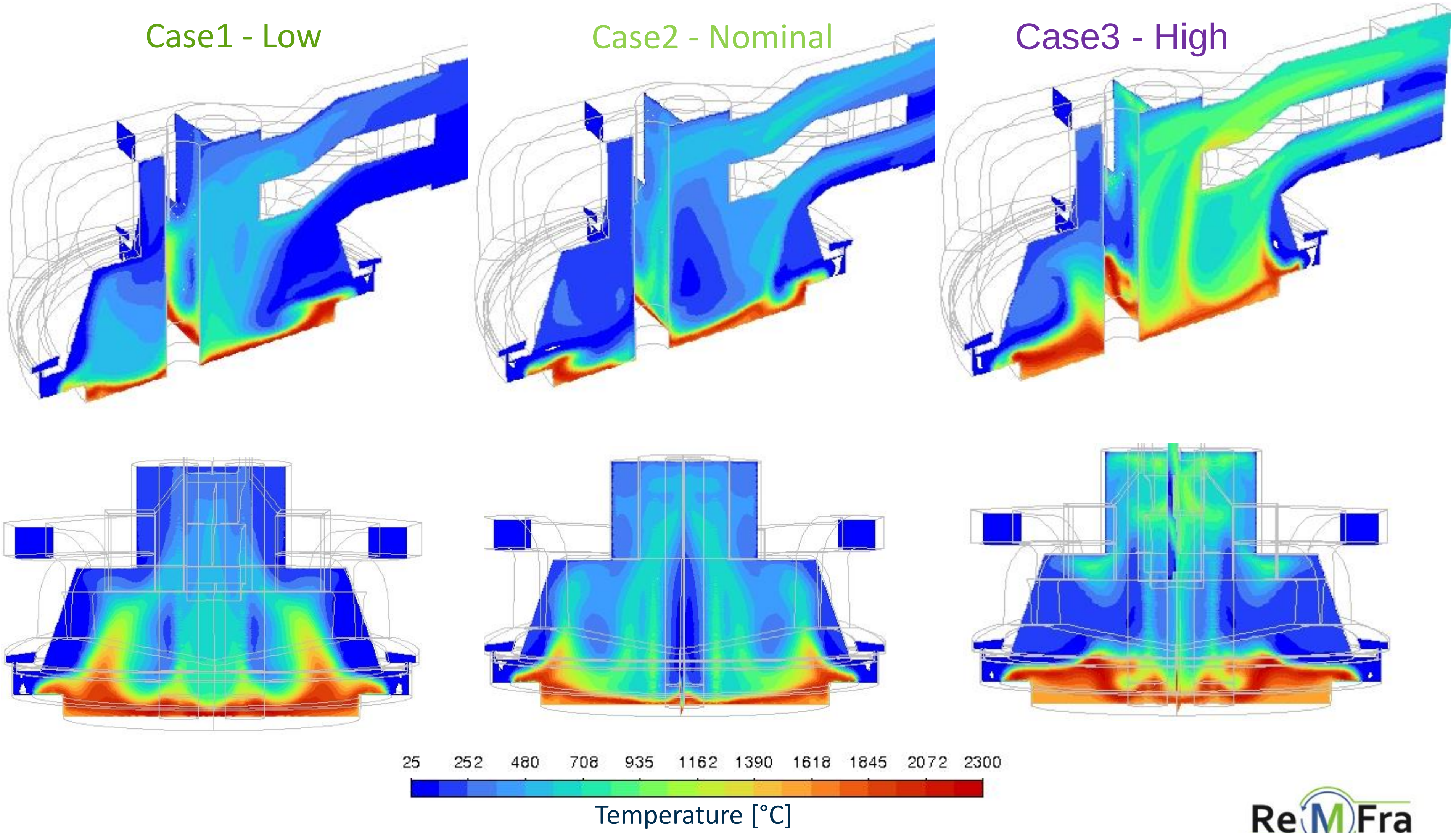
CFD simulation confirmed that the existing hood can be maintain whithout modicafication for the ReMFra process

Hood CFD modelling

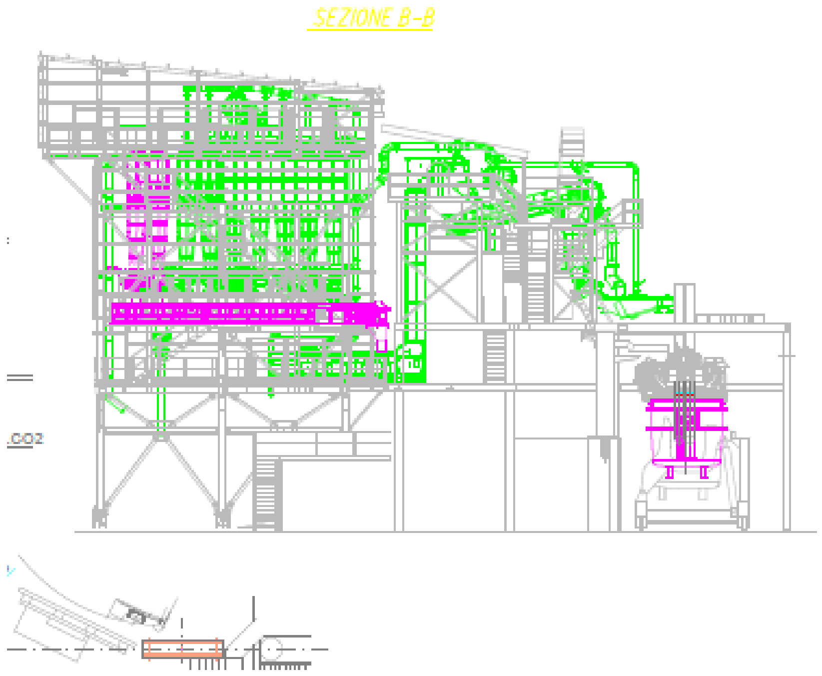
Setup and boundary conditions

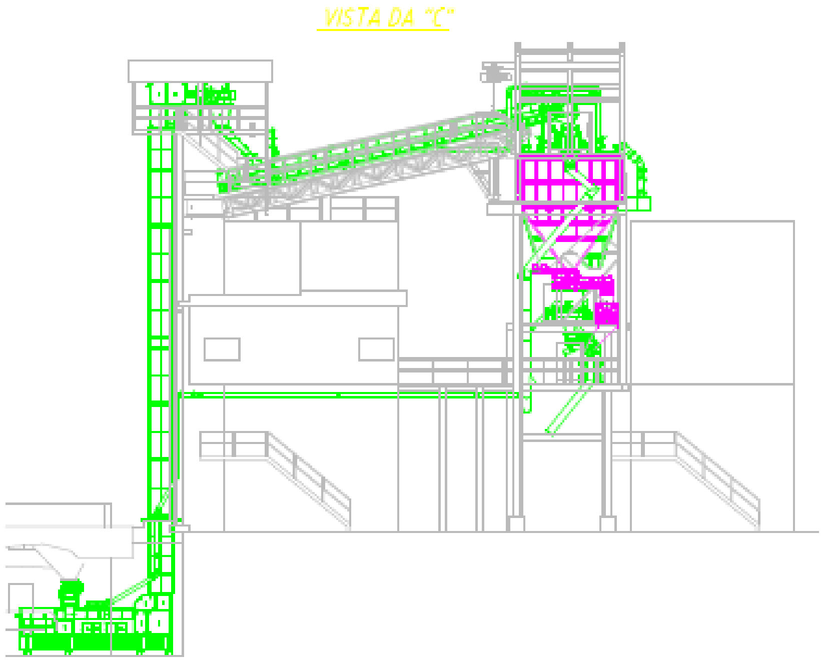
The data referred to half geometry:

		Waste Gases Mass Flow Rate	
	t briquettes/h	Nm³/h	kg/s
Case1 – Low production	5	500	0.153
Case2 - Nominal	7,5	750	0.230
Case3 – High production	10	1000	0.307



Plasma Furnace: Lay out





- ✓ 2 new silos to be added to existing MH
- ✓ capacity 10 m3/each
- ✓ briquettes density 2,15 t/m3 (1 t/m3 in pile)
- ✓ capacity of silo: approx. 10 t/each (pile density)
- ✓ from silos to new conveyor belt designed for nominal flow rate 7,5 t/h (range 5 – 10 t/h)
- ✓ to existing conveyor belt (bucket elevator conveyor belt)
- ✓ to the existing hopper on ladle roof

Next steps

- ✓ Construction Plasma Reactor (ladle furnace equipment, and its auxiliaries) will start within the end of the year in Tenaris Dalmine plant
- ✓ Briquette production for industrial trials will start in the first semester of 2025
- ✓ First industrial tests are planned by the end of 2025

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