COACH

COld-bonded **A**gglomerates for blast furnace ironmaking with **CH**emically engineered binders

Frédéric VAN LOO – CRM Group

30th of October 2024

ESTEP
European Steel Technology Platform
20 years together

H2 FOR GREEN STEEL
3rd INTERNATIONAL CONFERENCE
meets
A CIRCULAR ECONOMY DRIVEN BY THE EUROPEAN STEEL

voestalpine ONE STEP AHEAD.
PRIMETALS TECHNOLOGIES

COACH – EU funded RFCS

RFCS-2019 - **899318**

Project objective

Demonstrating the use of cold-bonded agglomerates in Blast Furnaces

- ✓ cement-free
- ✓ from waste material
- ✓ self-reducing

Final prospect

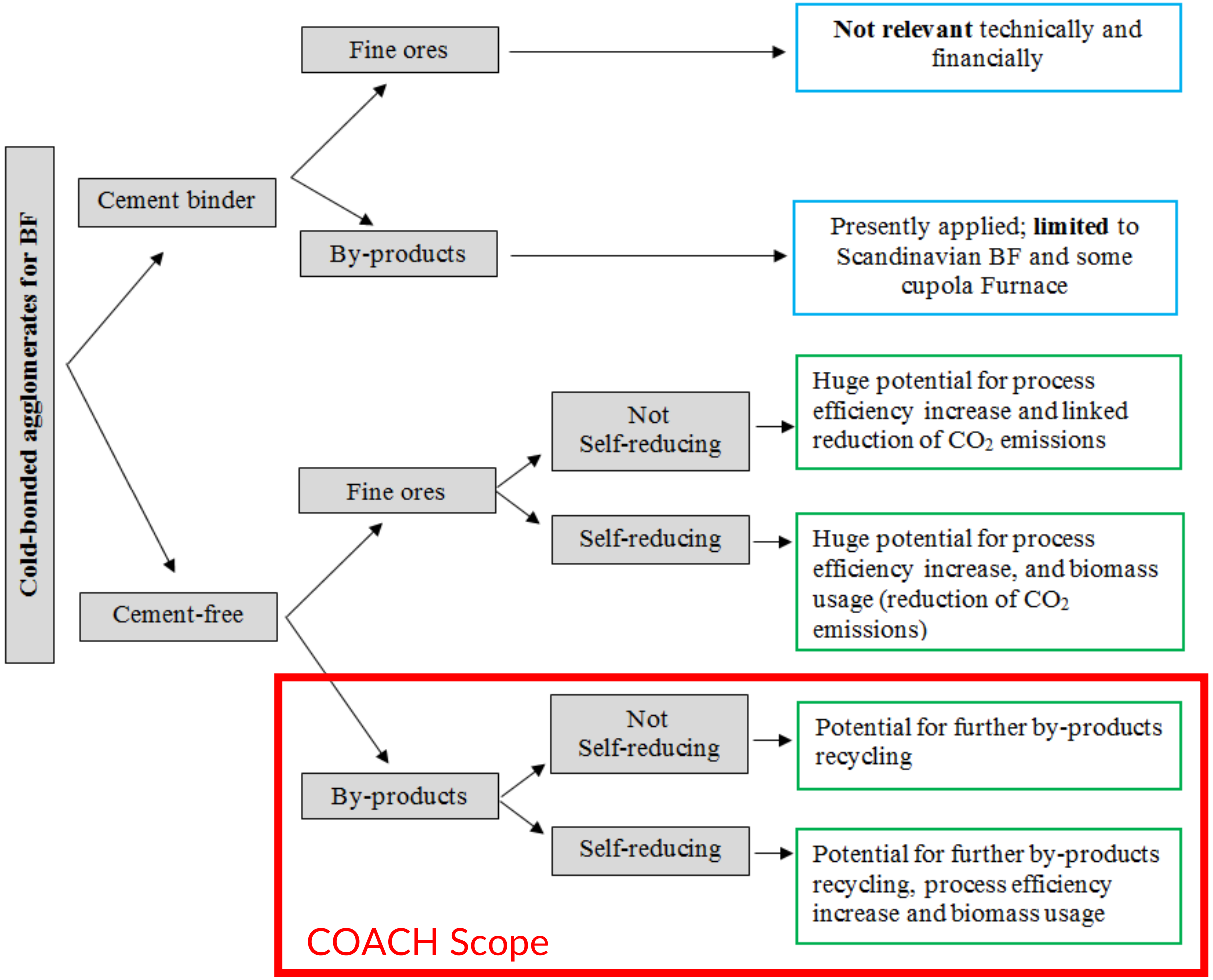
Improve internal wastes recycling at BF

= Increased recycling rate through BF route

↔ sinter plants closure due to transition BF → DR

Reduce energy use and CO_2 emissions :

- Cold agglomeration is more energy efficient and generates less CO_2 than sintering
- Reduced BF coke consumption
  - ⇔ %C briquets (Recipe 3)
  - ⇔ % Fe_metal briquets (Recipes 1 & 2)



COACH - Project Structure

ArcelorMittal TATA STEEL BASF We create chemistry CRM GROUP

Overview

Investigation on binding mechanisms
→ **Binders development**

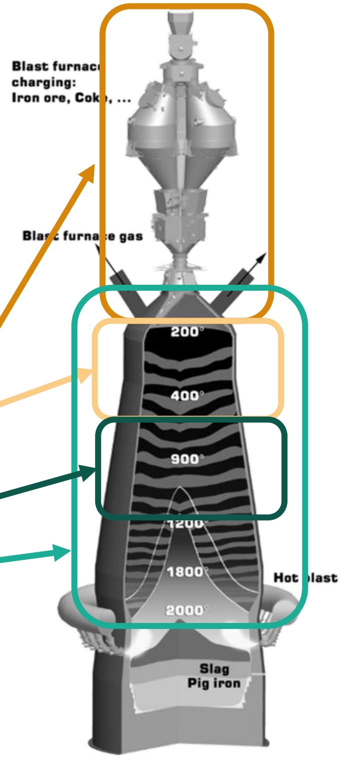
By-Products

- Selection
- Briquette-ability at small lab scale

Up-scaling

Lab agglomeration trials
Roll-press Briquetting
Vacuum Extrusion

- Step 1 : Screening based on behavior in upper shaft
- Step 2 : Behviour in lower shaft
- Step 3 : Assessment of behavior considering whole BF process



Life Cycle Analysis

Up-scaling

Pilot production tests
&
Industrial trials

- Pilot briquetting/ Extrusion trials
- Industrial trial at Tata Steel

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By-products

wt%	Moisture	Dry sample composition								
		C	S	Fetot	Fe_{metal}	Al2O3	CaO	SiO2	MnO	ZnO
BOF Coarse Sludges	9,20	2,8	0,24	82,5	69,9	0,39	8,0	0,4	0,16	0,88
Oily mill scales (DDS scales)	3,94	0,3	0,10	74,0	0,3	0,11	0,1	0,1	0,55	0,10
BF sludge low Zn	32,50	33,6	0,30	36,7	0,7	2,08	2,3	4,5	0,22	0,62
Fine BF flue	7,45	55,1	0,07			1,36	5,2	3,0		0,41
waste carbon fines	10,7	34,6	0,06			2,11	4,1	9,0		0,02

Selection

3 recipes defined :
→ 2 x Fe based
→ 1 x high %C

Materials briquette-ability

- Mini roll-press briquetting device

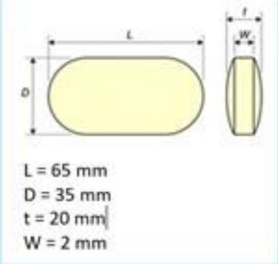
➢ Cement alone X
➢ Polymeric binders : OK with selected ones (0,5 to 1%)
➢ Cement (5%) + Polymeric binder (0,5%) → OK
   - Cement : ↑ mechanical strength + faster curing time
   - Polymeric binder : plasticity for agglomeration

→ Selection of trial conditions to be tested at bigger scale :
Roll-press briquetting & Stiff vacuum extrusion

Lab agglomeration trials

Wastes from integrated steel plants
→ 3 recipes identified

Fe based	Recipe 1	100% BOF coarse sludge	Fe Fe_met ZnO C	82 % 70 % 0.9 % 3%
	Recipe 2	60 % BOF Coarse sludge 40 % OM Scales	Fe Fe_met ZnO C	79 % 42 % 0.6 % 2 %
High %C	Recipe 3	47.5% Fine BF Flue dust 47.5% BF Sludge low Zn 5% waste carbon fines	Fe Fe_met ZnO C	25 % 0 % 0.5 % 44 %



Roll-press Briquetting

1. Eirich intensive mixer of 40 liters
2. **KOMAREK B220 Roll press**

Lab & pilot scale :
114-450 kg/h

Stiff Vacuum Extrusion

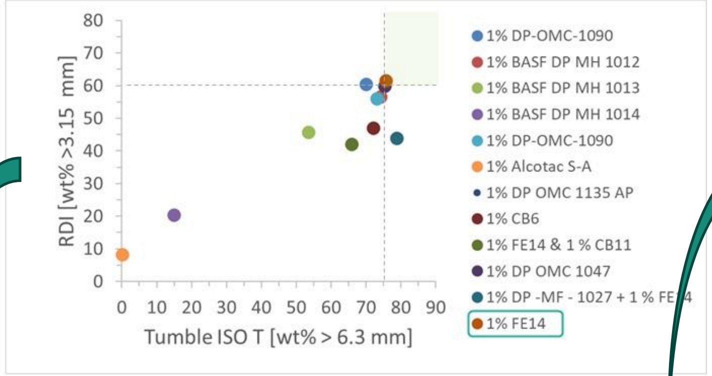
1. Eirich mixer of 5 liters
2. **Extruder Handle PZVM8e**

50 kg/h

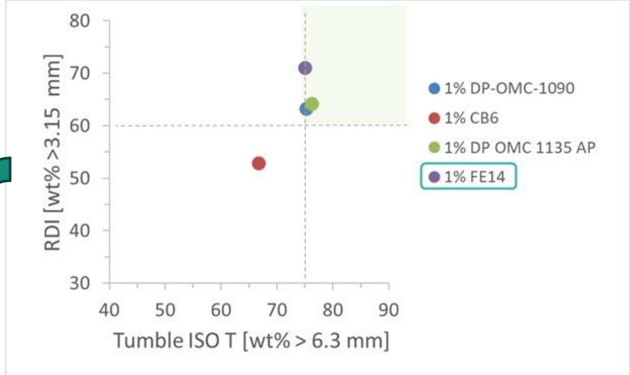
Lab agglomeration trials

Optimisation trials – Some results ...

EXTRUSION WITH VARIOUS **POLYMERIC BINDERS** (by BASF)

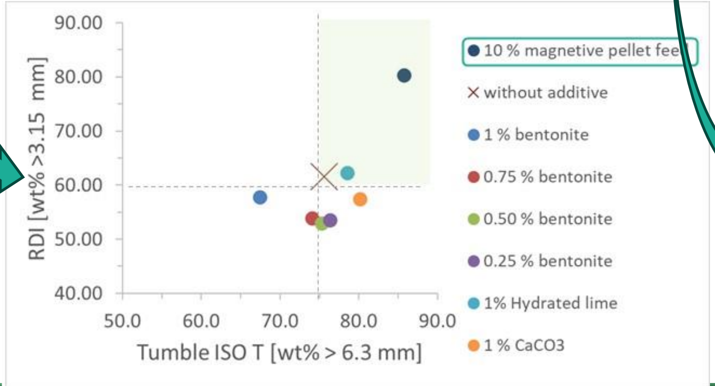


R1 - 100 % BOF Sludge



R2 - 60 % BOF Sludge – 40 % DDS Scales

EXTRUSION WITH POLYMERIC BINDER **FE14** **& ADDITIVES**



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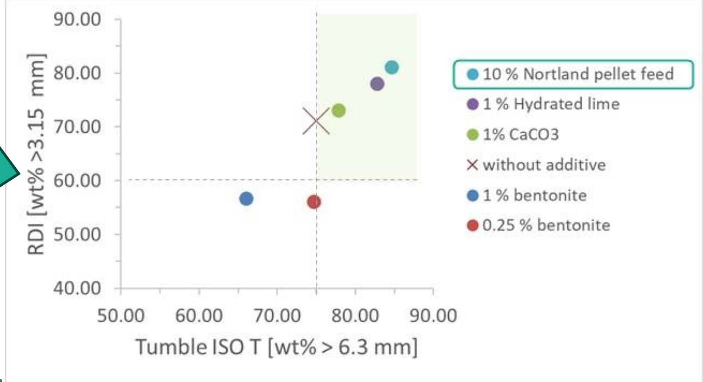
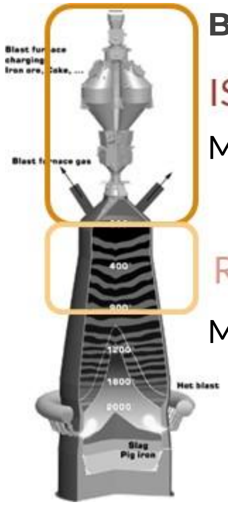


R2 - 60 % BOF Sludge – 40 % DDS Scales



Behaviour in upper shaft

ISO T

Min 75 % >6,3 mm

RDI

Min 60 % >3,15 mm

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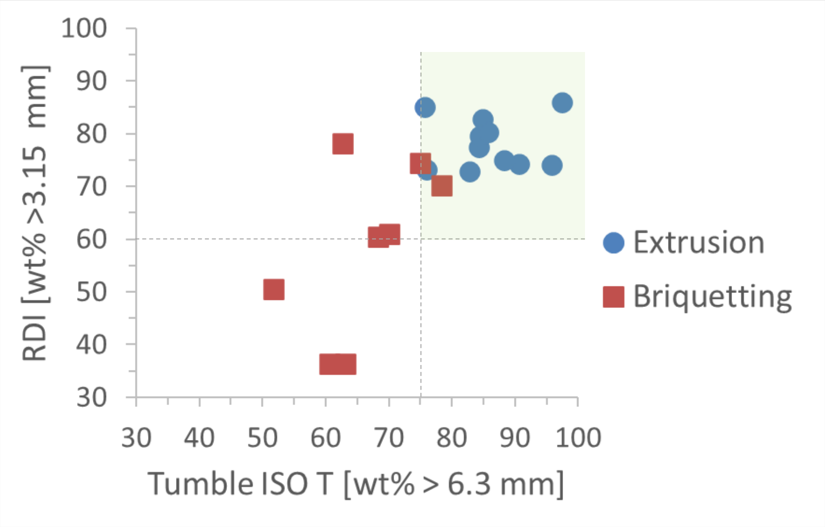
ArcelorMittal

COMPARISON BETWEEN BRIQUETTING vs EXTRUSION



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Lab agglomeration trials

Summary

D50
BOF sludge = 230 µm
OMS = 458 µm
Pellet feed = 21 µm

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ArcelorMittal

Development steps

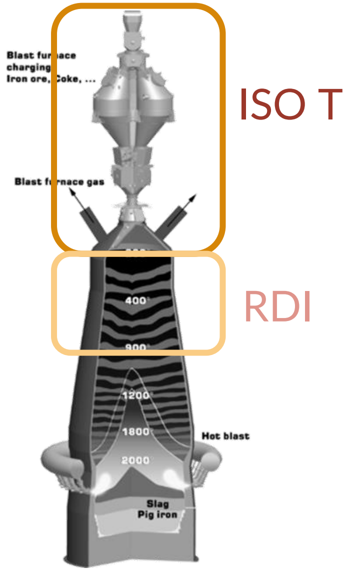
Technology selection
→ Extrusion
(same additive and briquets size)
+ Working points Optimisation

Binder selection
→ Polymeric
(Alcotac®FE14 or CB6)
= polyacrylamide based

Relevant additives selection
→ Pellet feed for R1 and R2
⇔ Optimised PSD

Best achieved quality ↔ Step 1 = Behaviour in upper shaft

	Recipe	Binder	ISO T wt% > 6.3 mm	RDI wt% < 3.15 mm
BRI	R1 + 10% PF	1 % FE14	70,1	39,0
EXT			85,7	19,7
BRI	R2 + 10% PF		78,3	29,8
EXT			84,8	17,2
BRI	R3	2% CB6	74,9	25,5
EXT			97,5	14,1
		Target	min 75%	Max 40%



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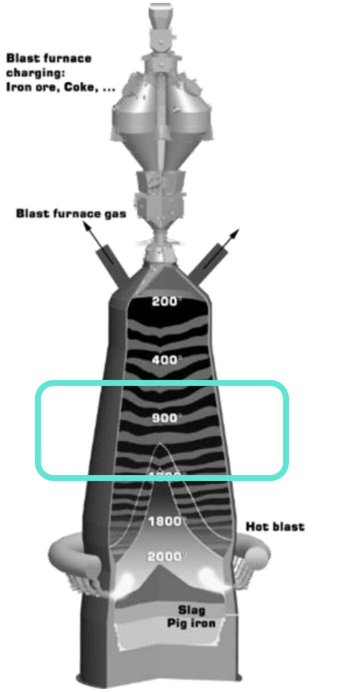
Lab agglomeration trials

Step2 = Behaviour in Lower shaft : Will briquettes keep their integrity until cohesive zone ?

Best agglomerates (Extrusion) were tested at higher temperature (1000°C)
under reducing atmosphere (40%CO)

+ submitted to tumble degradation

	Recipe	Binder	Weight loss %	Tumble degradation % > 3,15 mm	Tumble degradation % <0,5 mm
BRI	R1 + 10% PF	1 % FE14	9	69	26
EXT			10	77	20
BRI	R2 + 10% PF		9	90	7
EXT			10	87	10
BRI	R3	2% CB6	24	0	95
EXT			56	1	84



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Lab agglomeration trials

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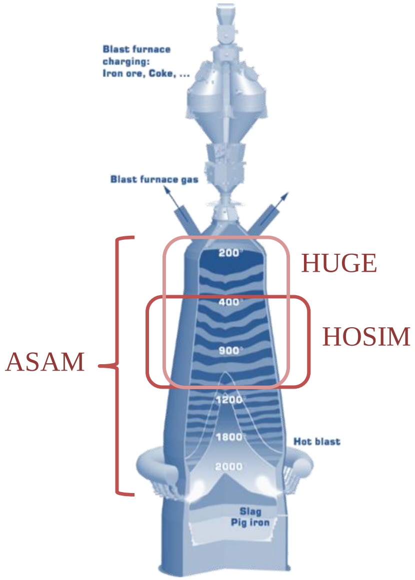
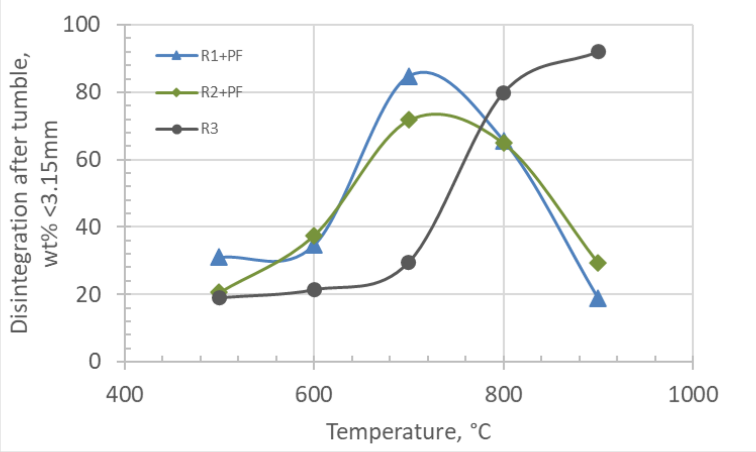
Step 3 = Behaviour in the overall BF (Extruded briquets)

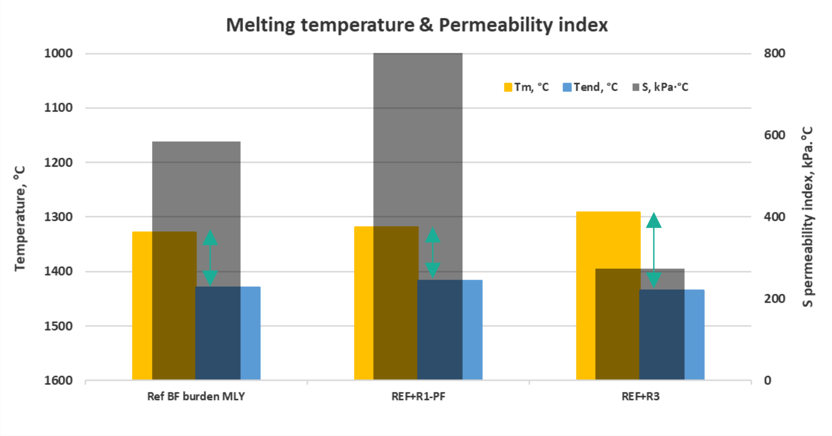


- Interrupted HOSIM → upper Shaft (400-910°C)
  - 600-700 °C : polymer degradation → %dust ↑
  - > 800 °C :
    - R1/2 + PF : strength recovery ↔ 'sintering'
    - R3 : ++ degradation



- ASAM (advanced Softening and melting) Cohesive Zone (→ 1600°C)

  Ref. Ferrous burden
  - + 10% [R1+PF] → slightly ↓ permeability | minor impact on CZ
  - + 10% R3 → ↑ permeability | CZ downwards to >T°C



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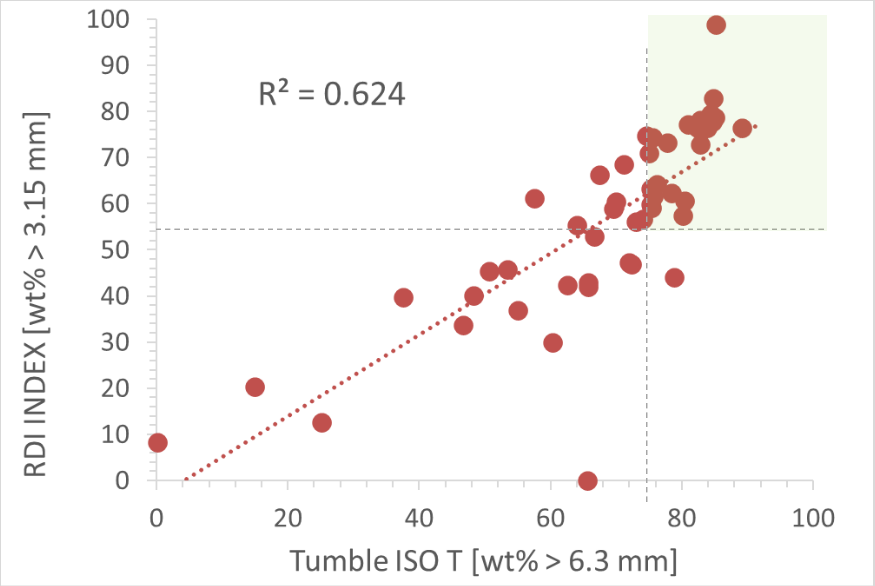
Lab agglomeration trials

On the binding mechanisms

<u>Fundamental question</u> : the polymer is expected to degrade at high temperature, yet FE14/CB6 improves the RDI index …

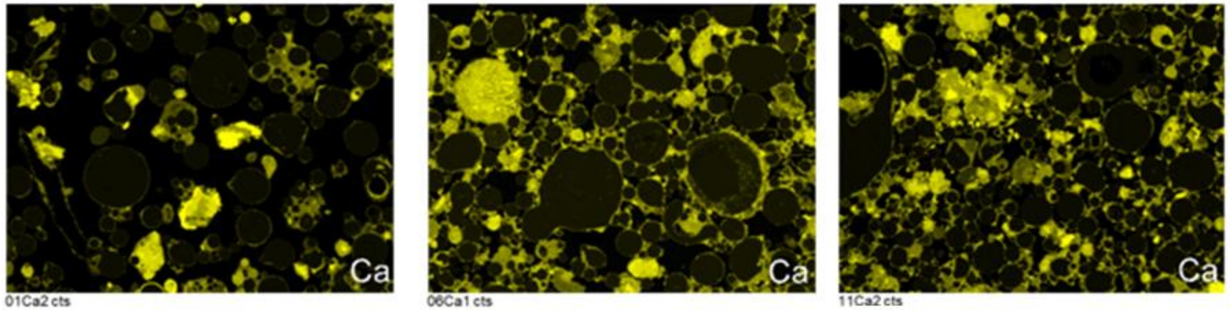
Correlation of resistances



Bonding effect is non-reversible

Polymeric binders

→ **Calcium dispersion** (observed with SEM-BSE)



Binderless | With FE14 | With FE14 after RDI

Hypothesis : Interstitial Ca promotes adhesion at high

The calcium redistribution is explained by the affinity of the polymer binder with cations such as Ca2+ "

Pilot and industrial trials

Pilot trials

Stiff-Vacuum Extrusion

MAGMA 475 vacuum group –7–26 m^3/h ~ **28 – 104 t/h**

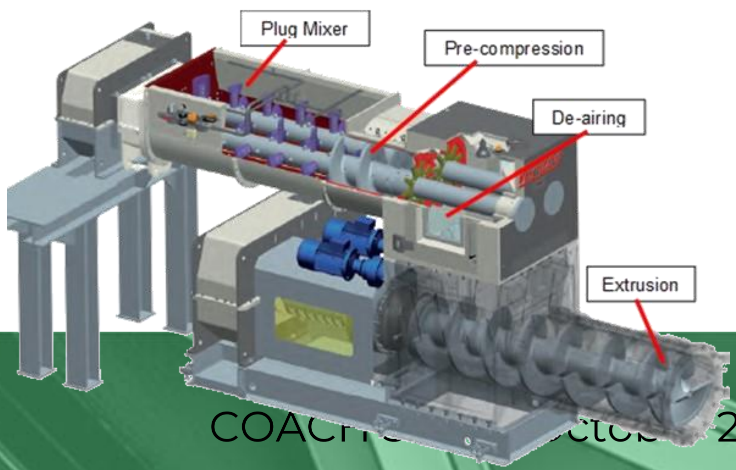
Successful production of 2,2 tons of R1 :

- (R1+) BOF coarse sludge, 10% magnetite pellet feed + 1% Fe14
- 2 batches (7,89 - 7,69 % moisture content)

But un-optimal processing conditions :

- Recently produced briquets → tends to stick each other.
- Quite soft
- Part compacted by the weight of the pile of material → amorphous mass

Critical parameter = **moisture control**



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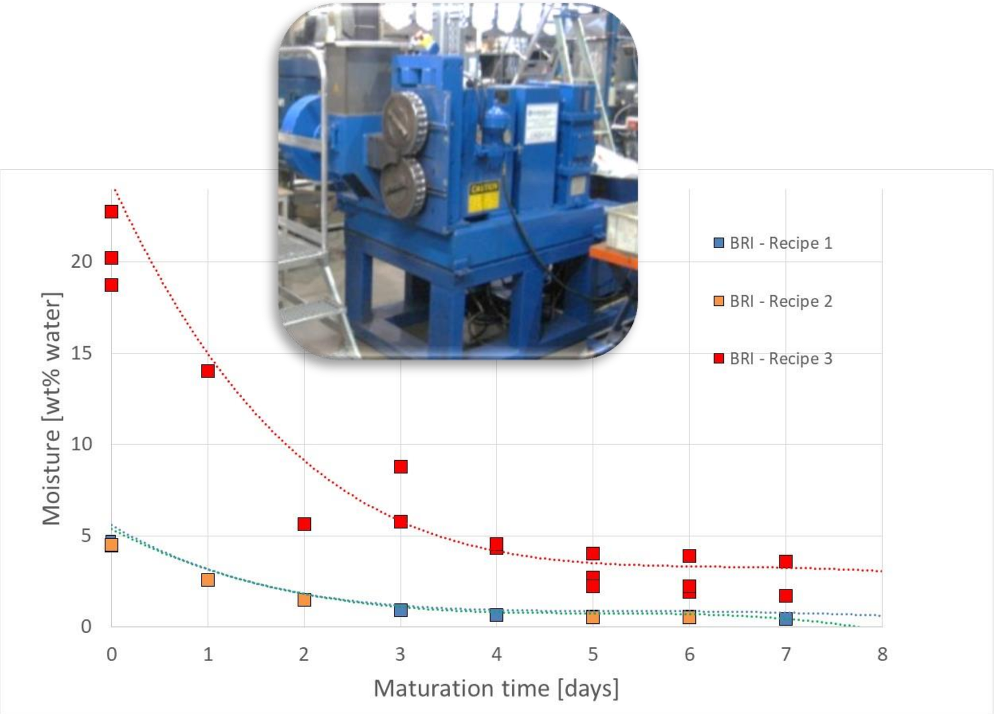
   114-450 kg/h



Pilot and industrial trials

Industrial trial at Tata Steel IJmuiden

DEX 300 Extruder Productivity 3t/hr

- Q1 2024 : adaptation of the extruder of the HISARNA pilot plant for continuous production

  + small volume production & quality tests
  ⇔ Optimum recipe

  + Lab scale trials at CRM

- May : commissioning and shifts training
- June : Production of extrudates = **150-160 tons**

  + 20 days curing

  → Briquettes charged into BF

Recipe =

BOF sludge

+ 20% BF bunker dust ⇔ reduce %moisture + improve PSD

binder =

1% Alcotac®FE14

+ 1% waterglass ⇔ rainy weather during curing time

Optimal moisture content = 8 – 8,5%

Curing under rainy weather

Pilot and industrial trials

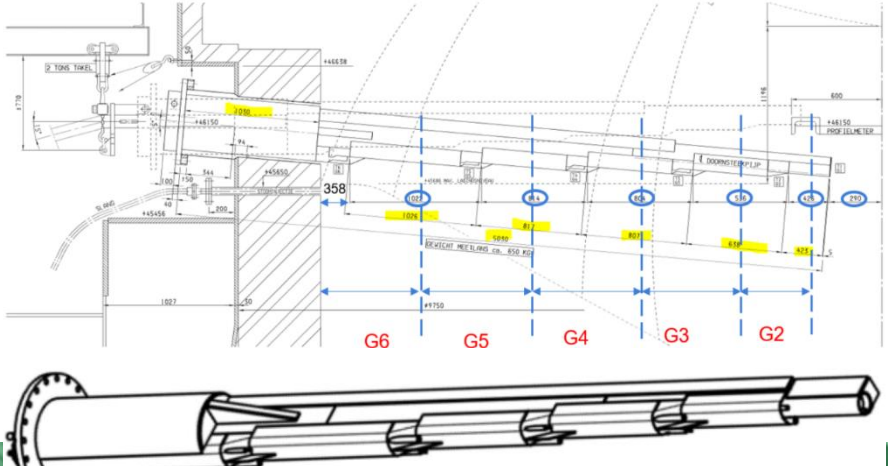
Industrial trial at Tata Steel IJmuiden

➔Briquets charging in BF6 (2,6 Mt/y) in 18hours

⬄ **2%** of the ferrous burden (locally > 3%)

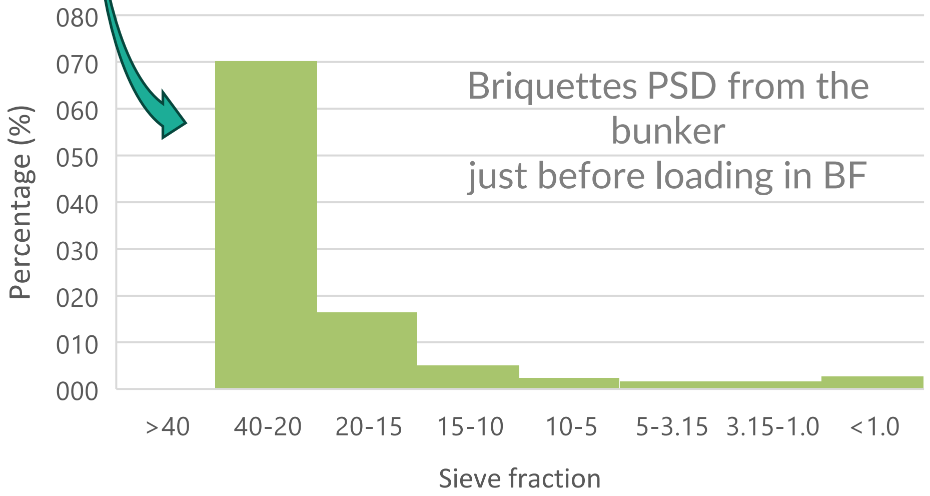
➔Results :

- BF process stability : no impact
- Dust : lower dust emission



Above burden sampling probe

Briquettes just after production : average size 8-10 cm



COACH – Process impact evaluation

MMBF ArcelorMittal model

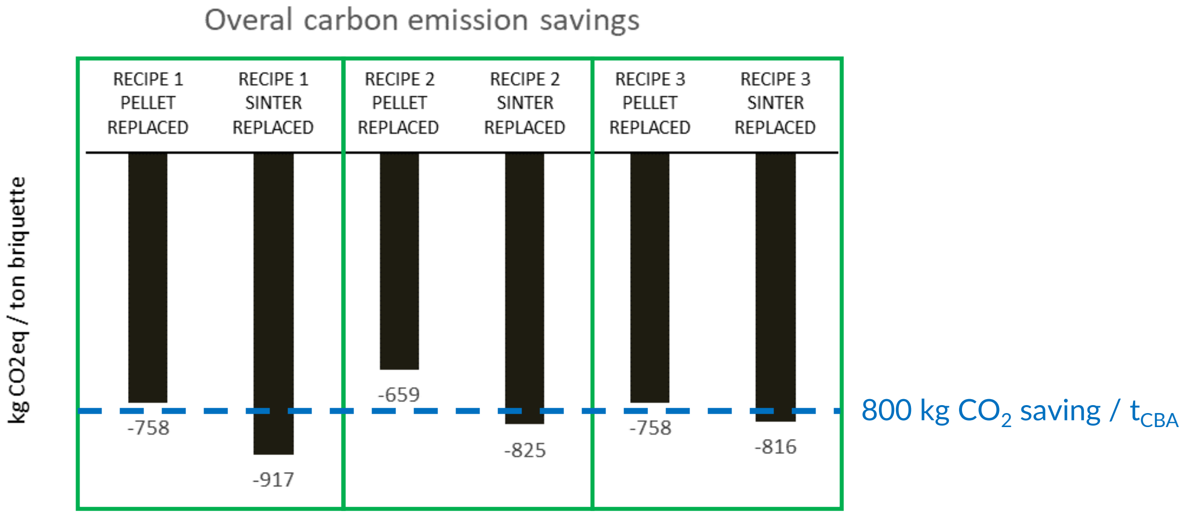
➔ benefit calculation

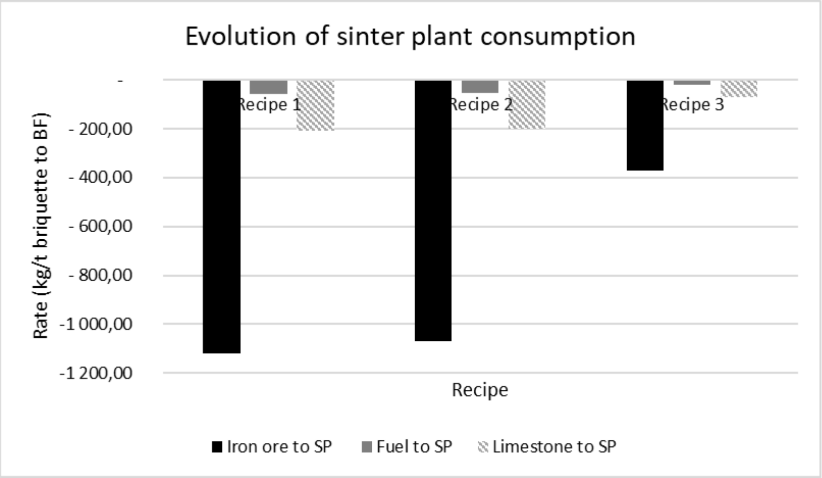
↳ Integrated in an overall plant balance calculation

↳ LCA (WSA, LCI Methodology Report 2017 – ISO standards)

If CBA replace sinter at BF		R1	R2	R3
Coke savings	Coke/t_{CBA}	227	148	**501**
	kg_{coke}/t_{HM} *	36	23,7	80
Sinter replacement	kg_{Sinter}/t_{CBA}	**1417**	**1353**	203

* Hypothesis : Briquets = 10% of the ferrous burden = 160 kg_{CBA}/t_{HM}





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