INSTITUT FÜR BAUSTOFF FORSCHUNG

ESTEP European Steel Technology Platform

FEhS

5 & 6 MARCH 2025

ESTEP Focus Group
Circular Economy & FEhS

are pleased to announce

2 days workshop

The role of slags and other by-products within circular economy in the steel industry

& RFCS InSGeP project workshop

Wyndham Duisburger Hof, Opernplatz 2, 47051 Duisburg, Germany

PROGRAMME

PROGRAMME

DAY 1
5 March

09:00 – 09:45 Registration
09:45 Welcome Thomas Reiche (FEhS)

09:50 - 11:15 1st session: Situation of slags in different regions – *Thomas Reiche*

09:50 Ferrous slags in France: a short overview on figures, main uses and existing regulatory framework over last decade - *Jérémie Domas (CTPL)*
10:05 Ferrous slags in Germany: Regulatory Framework and Its Impact on Utilization - *Anna Sokol (FEhS)*
10:20 Ferrous slags in Poland - *Przemysław Korczak (TMS International)*
10:35 EAF and SMS slag in Italy - *Alfredo Schweiger (Federacciai)*
10:50 Current status of slag recycling and activities related to environmental regulation in South Korea - *Rick Lim (POSCO)*
11:05 Questions

11:15 – 11:30 Coffee break

11:30 - 13:00 InSGeP workshop – *Agnieszka Morillon*
11:30 Introduction to the InSGeP project – *David Algermissen (FEhS)*
11:40 Simulation of effects on slag and process of DRI or HBI charge in electric arc furnace – *Valentina Colla (SSSA)*
11:55 Collection and laboratory development of slag samples using DRI and HBI in industrial and pilot scales – *Mattia de Colle (ArcelorMittal Maizieres Research)*
12:10 Valorization of EAF slags from DRI melting with dry granulation process – *Marta Guzzon (Tenova) and Loredana Di Sante (RINA-CSM)*
12:25 Market analysis and stakeholder consultation – *Parinaz Seifollahzadeh (K1-MET)*
12:40 Questions and discussions

13:00 – 14:00 Lunch buffet

14:00 – 15:40 2nd session: Valorisation of industrial by-products: dust, sludge… – *Enrico Malfa*
14:00 Welcome – *Klaus Peters (ESTEP)*
14:05 Focus Group Circular Economy – *Enrico Malfa (Tenova)*
14:20 Circular valorization of steelmaking by-products: the Italian case study in the HEPHAESTUS project – *Vincenzo Pepe (RINA-CSM)*
14:40 Current results on upgrading iron- and steelmaking by-products: the TransZeroWaste project – *Gerald Stubbe (BFI)*
15:00 Treatment for valorization of Zn containing residues in dust and sludge: Hydrocyclone treatment – *Damiano Capobianco (RINA-CSM)*
15:20 ZHyRON project: Valorization of iron-rich & Zinc-containing steelmaking by-products via hydrogen-based reduction – *Benoit Mignon (CRM)*

15:20 – 16:00 Coffee break

16:00 – 19:00 **Visit of FEhS** (in 2 groups)
At the same time 30 min presentation of steel history of North Rhine-Westphalia for the participants waiting for the FEhS visit by Andreas Ehrenberg (FEhS)

19:00 Dinner at the Wyndham hotel

PROGRAMME

DAY 2
6 March

08:45 – 09:00 Registration

09:00 - 10:40 3rd session: Valorization of industrial by-products: slag – *Marta Guzzon*

09:00 Steel slags utilization as multipurpose and low-cost catalysts – *Giuseppe Guglielmo (Acciaierie d'Italia)*

09:20 Investigating the high-temperature properties in oxidic slags through a combined molecular dynamics: experimental approach – *Inge Bellemans (Ghent University)*

09:40 Sequestration potential of EAF C and ladle slags – *Mojca Loncnar (SIJ Acroi)*

10:00 Carbon footprint calculation for slag from a reducing electric furnace – *Julian Suer (tkSE)*

10:20 Harmonisation of GHG accounting methodologies to assist in the decarbonisation of the steel industry – a focus on by-products – *Clare Broadbent (WorldSteel)*

10:40 – 11:00 Coffee break

11:00 – 12:50 4th session: Industrial Symbiosis – *Valentina Colla*

11:00 Assessing the progress of the impact of Industrial Symbiosis on the steel sector in recent initiatives based on the Symbio-Steel project: workshop – *Valentina Colla (SSSA) & Teresa A. Branca (SSSA)*

11:30 Upcycling methods of Electric Arc Furnace steelmaking slags: phosphorus removal from wastewater and fillers for polymers – *Giulia Bragaggia (University of Padova)*

11:50 Pittini Group experience in valorisation and recovery of waste from the production process as new products: the Zero Waste Initiative – *Matteo Chini (Pittini)*

12:10 In the age of decarbonization: smelter-slag as a substitute for granulated blast furnace slag – *Falco Lischke (tkSE)*

12:30 Investigation of electric arc furnace slag for sustainable wheat and lettuce production – Rifat Buğra Bĭldĭrĭ (Gebze Technical University)

12:50 Closing – David Algermissen (FEhS)

13:00 Lunch buffet/networking – end of workshop

POSTERS

Metakaolin – Blast furnace slag geopolymers as support for catalytic process in water remediation - *Stefano Savino (Università degli Studi di Bari "Aldo Moro")*

ESTEP MEMBERS ONLY

13:30 – 17: 00 ESTEP Steering Committee meeting

15:00 Coffee break

The role of slags and other by-products within circular economy in the steel industry

- Introduction to the InSGeP project
- David Algermissen

5.–6. MARCH 2025

ESTEP Focus Group Circular Economy & FEhS-Institute

European Steel Technology Platform

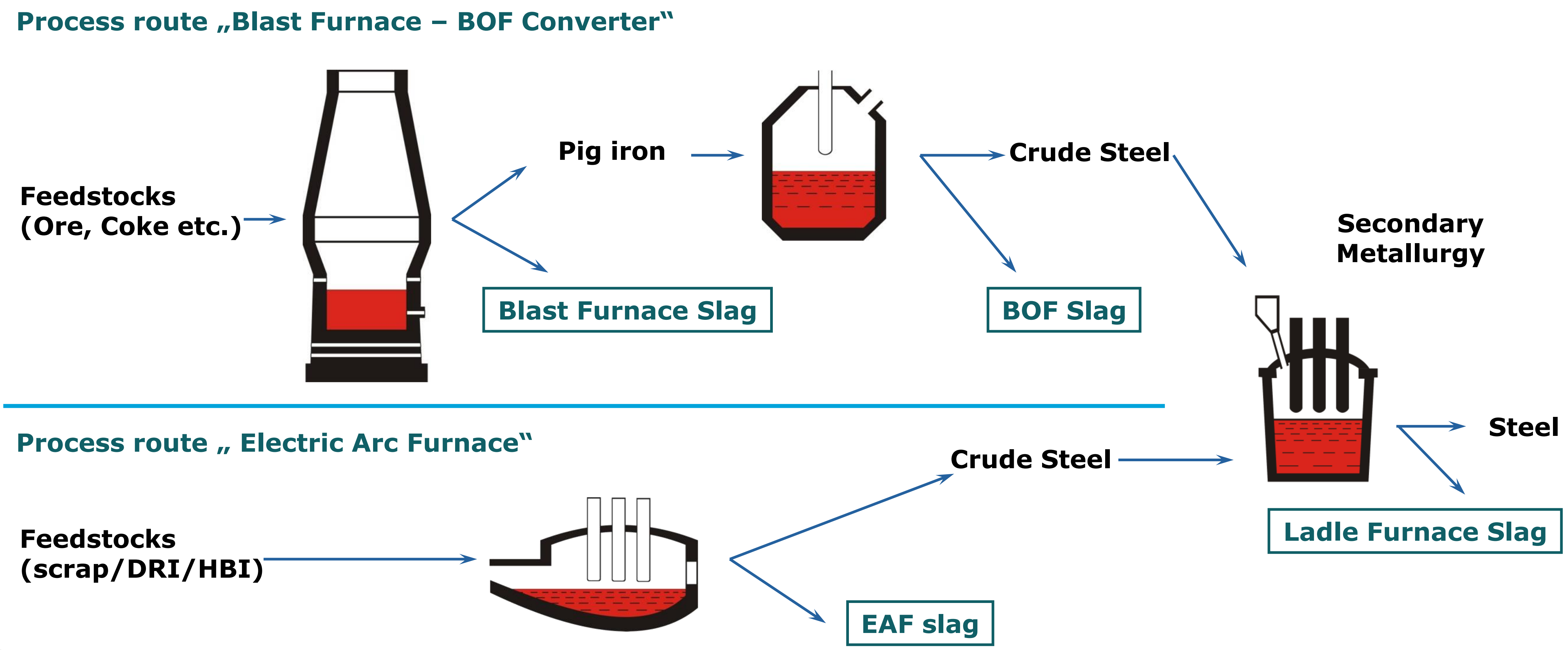
INSTITUT FÜR BAUSTOFF FORSCHUNG

European Commission

The research leading to these results has received funding from the European Union's Research Fund for Coal and Steel research programme under grant agreement number: 101112665

InSGeP
Investigations of Slags from Next Generation Steel Making Processes

Iron and Steel Slags



Iron and Steel Slags

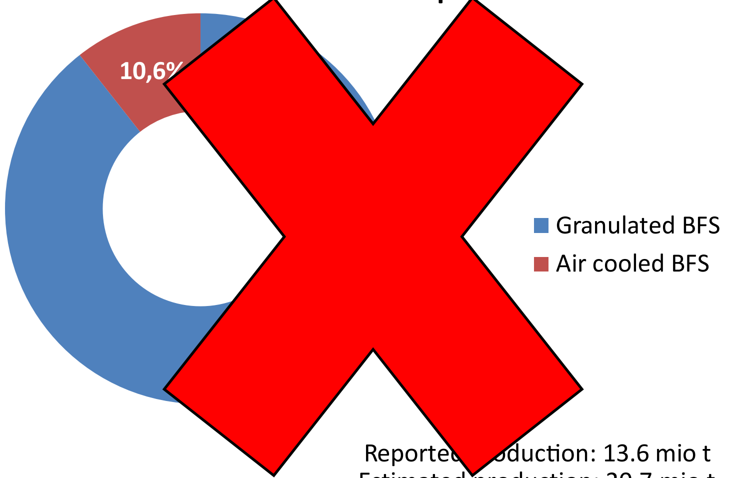
- Blast Furnace Slag
  - Granulated Blast Furnace Slag
  - Air cooled Blast Furnace Slag
- Steel Slags
  - BOF Slag
  - EAF(-C) Slag
  - Ladle Furnace Slag
  - EAF-S Slag
  - + Special Procedures

Non-ferrous Slags

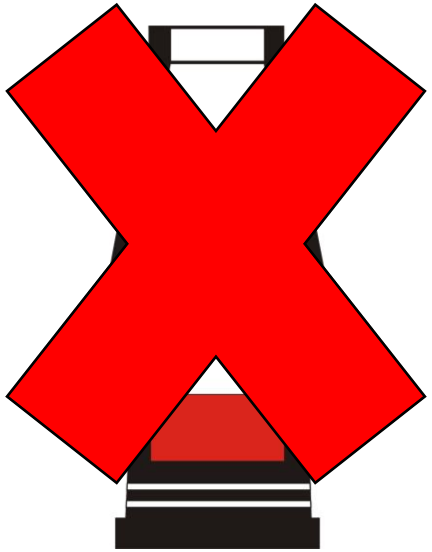
- Lead smelter Slag
- Ferrochrome Slag
- Copper Smelter Slag
- Waelz Kiln Slag
- + Other

Production and Use of Iron and Steel Slags in Europe (EU27+UK)

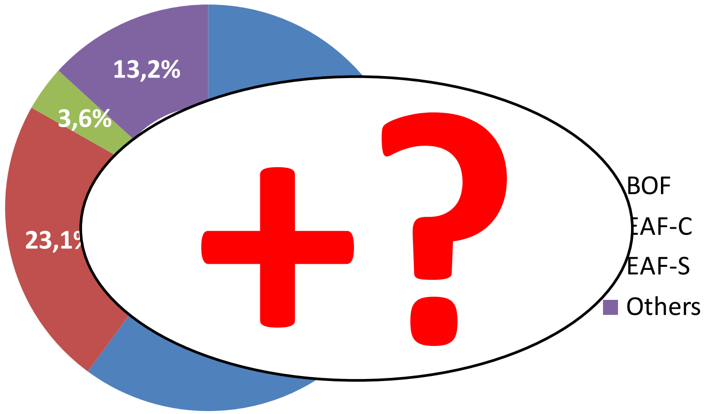
Production of BFS in Europe 2023



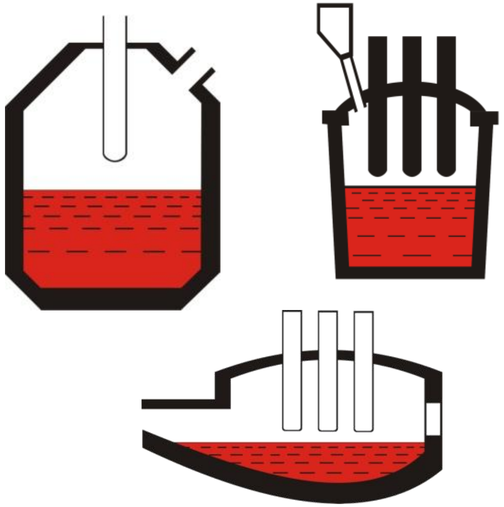
Reported production: 13.6 mio t
Estimated production: 20.7 mio t



Production of SFS in Europe 2023



Reported production: 8.5 mio t
Estimated production: 16.9 mio t

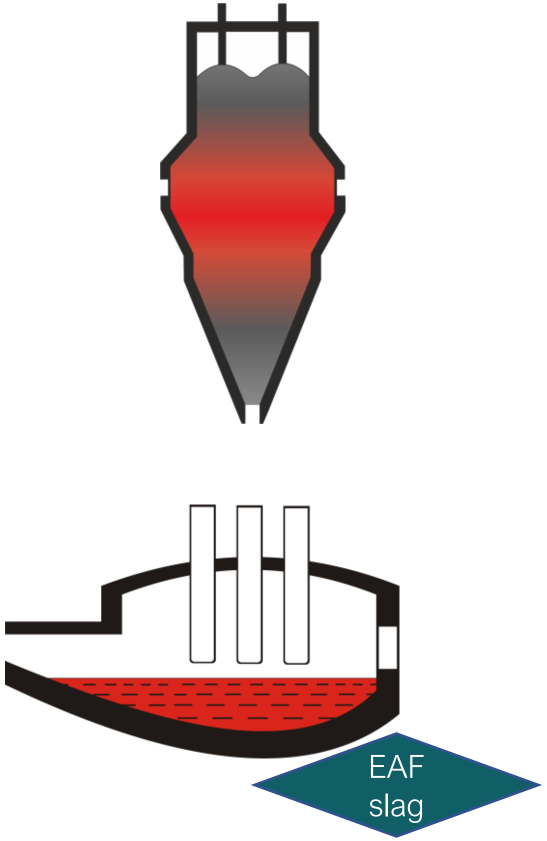


Effect on usage?

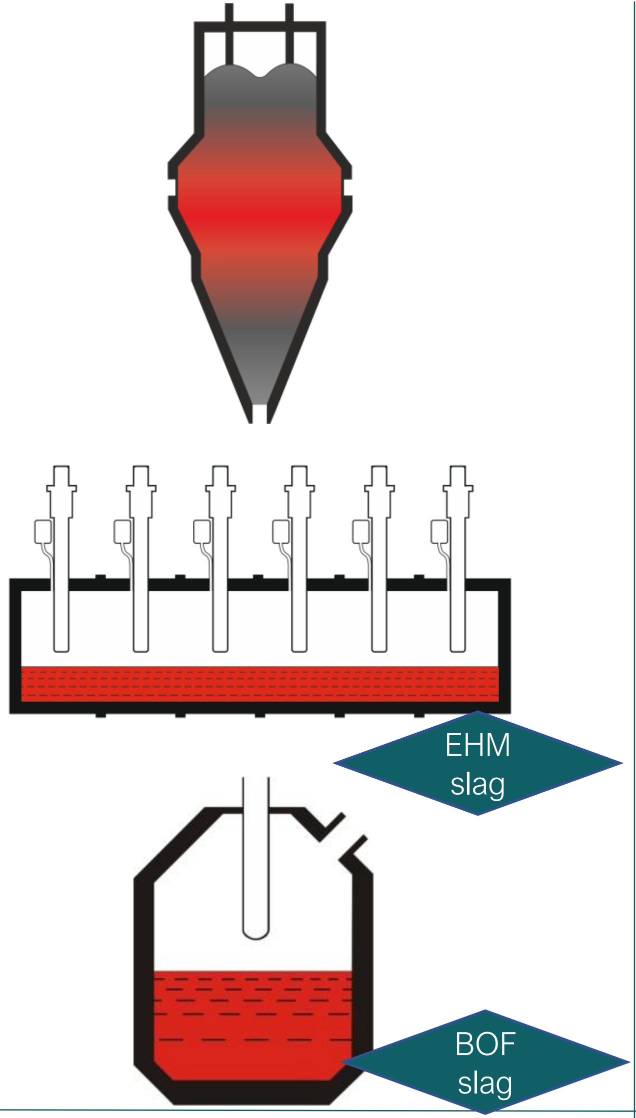
Ref.: EUROSLAG, 2024

InSGeP

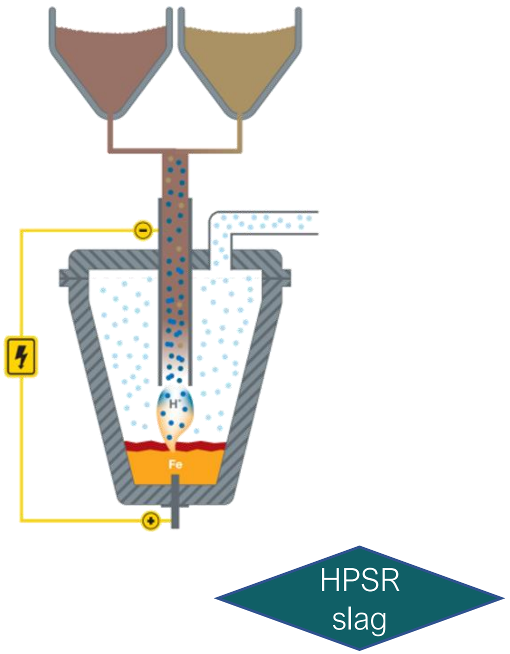
New production routes in Europe – New type of by-products



DR-EAF



DR-Smelter-BOF



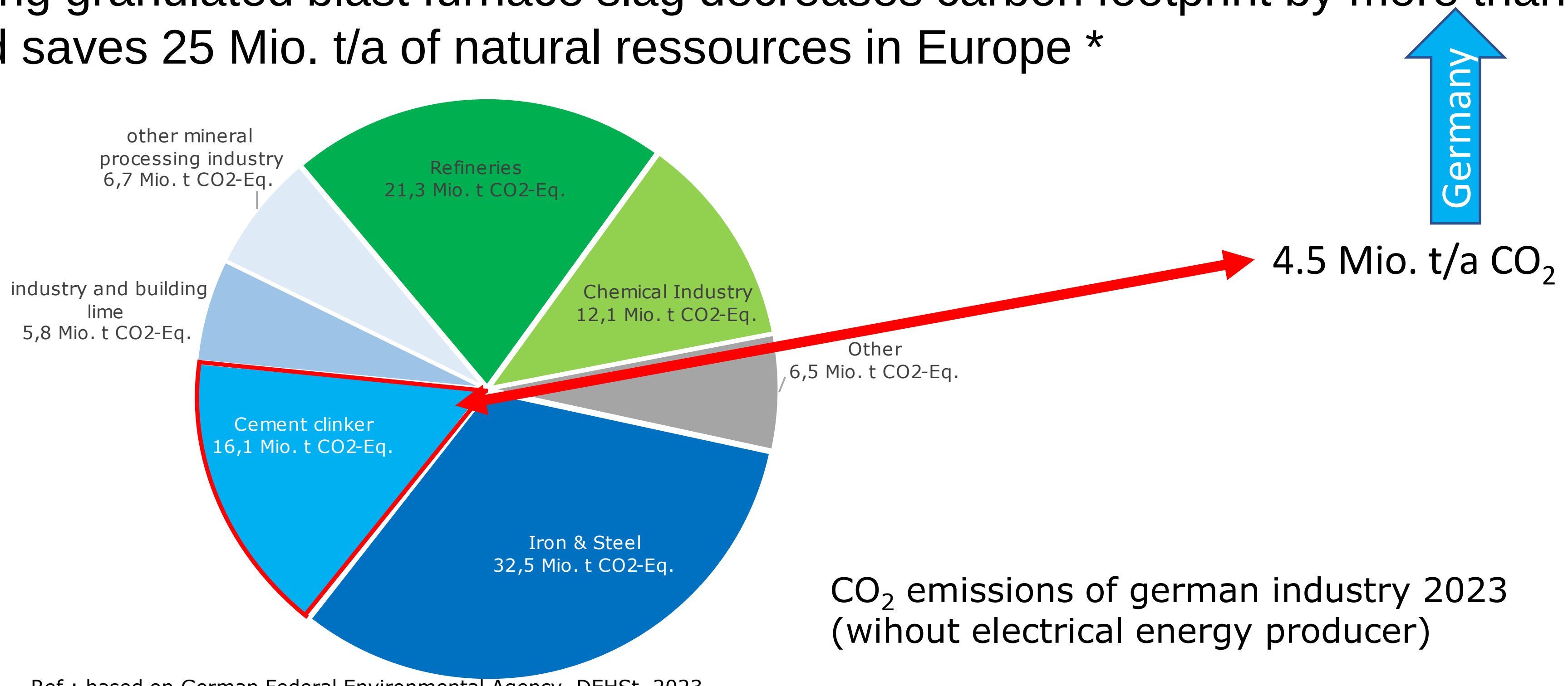
HPSR

InSGeP

Granulated Slag – A beneficary material for cement industry

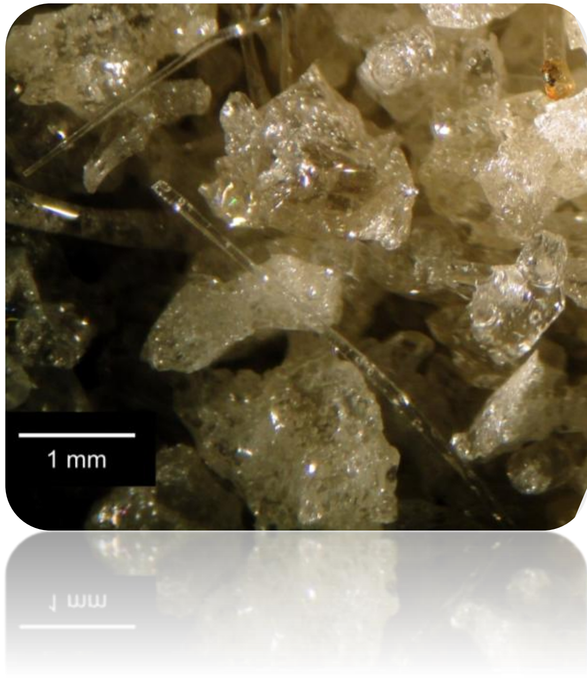
Emmitting approx. 800 kg CO_2 per ton of clinker (60 % of this is due to raw materials)

Using granulated blast furnace slag decreases carbon footprint by more than 10 Mio. t/a and saves 25 Mio. t/a of natural ressources in Europe *



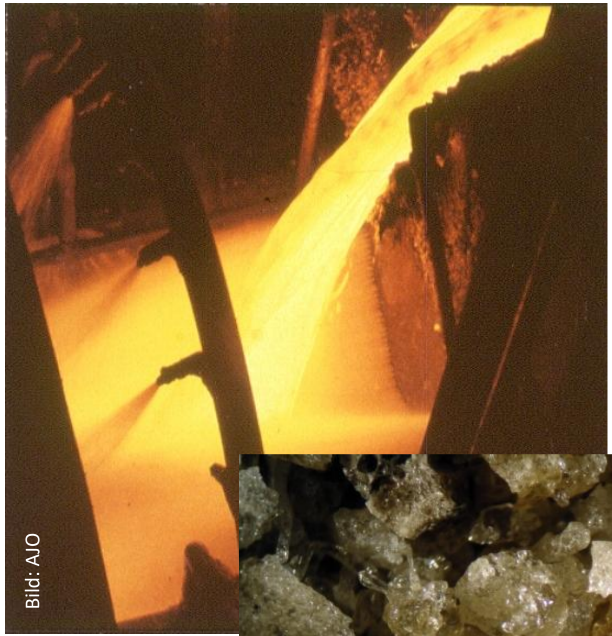
CO_2 emissions of german industry 2023 (wihout electrical energy producer)

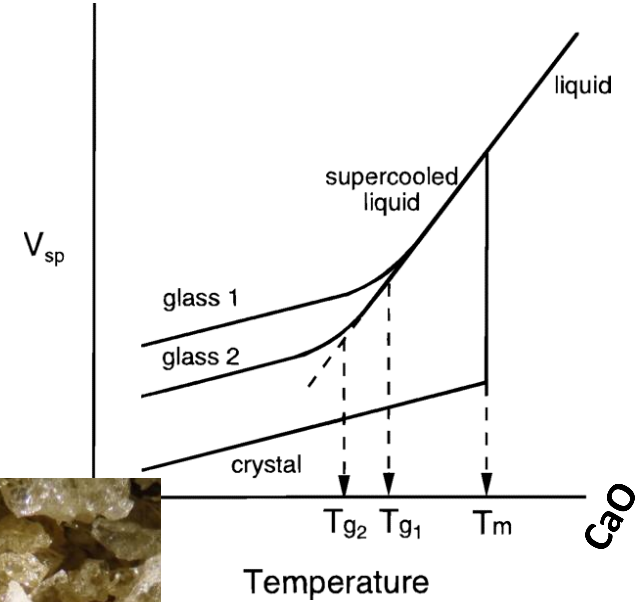
Ref.: based on German Federal Environmental Agency, DEHSt, 2023



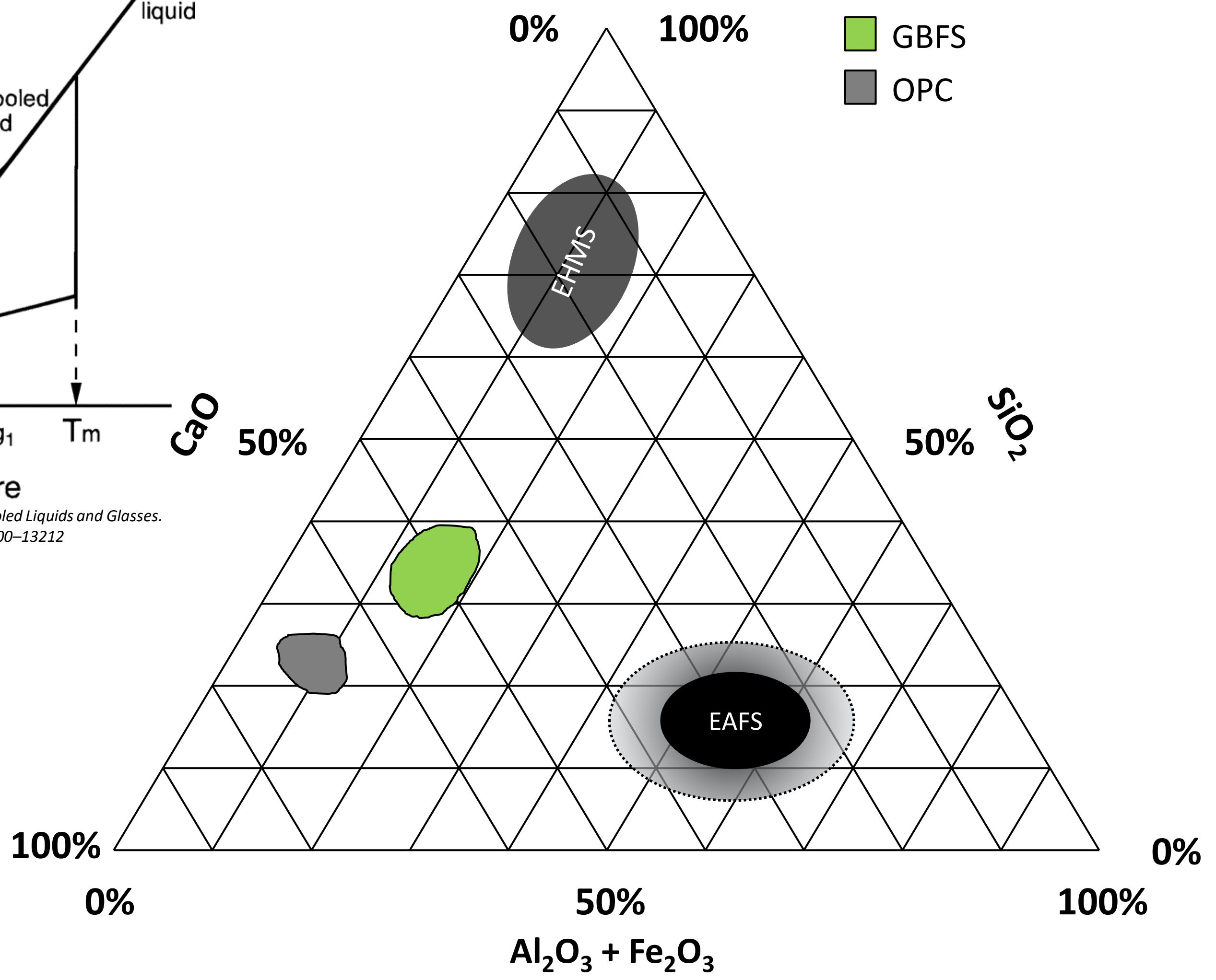
* estimated, based on German data and EUROSLAG statistic

Requirements to produce a material for the cement industry

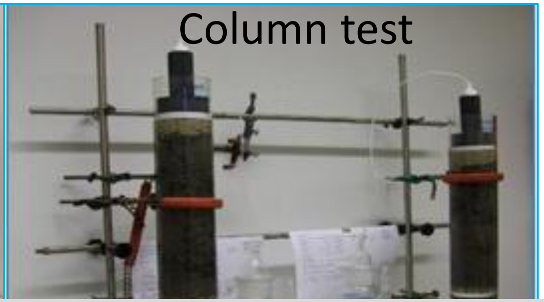


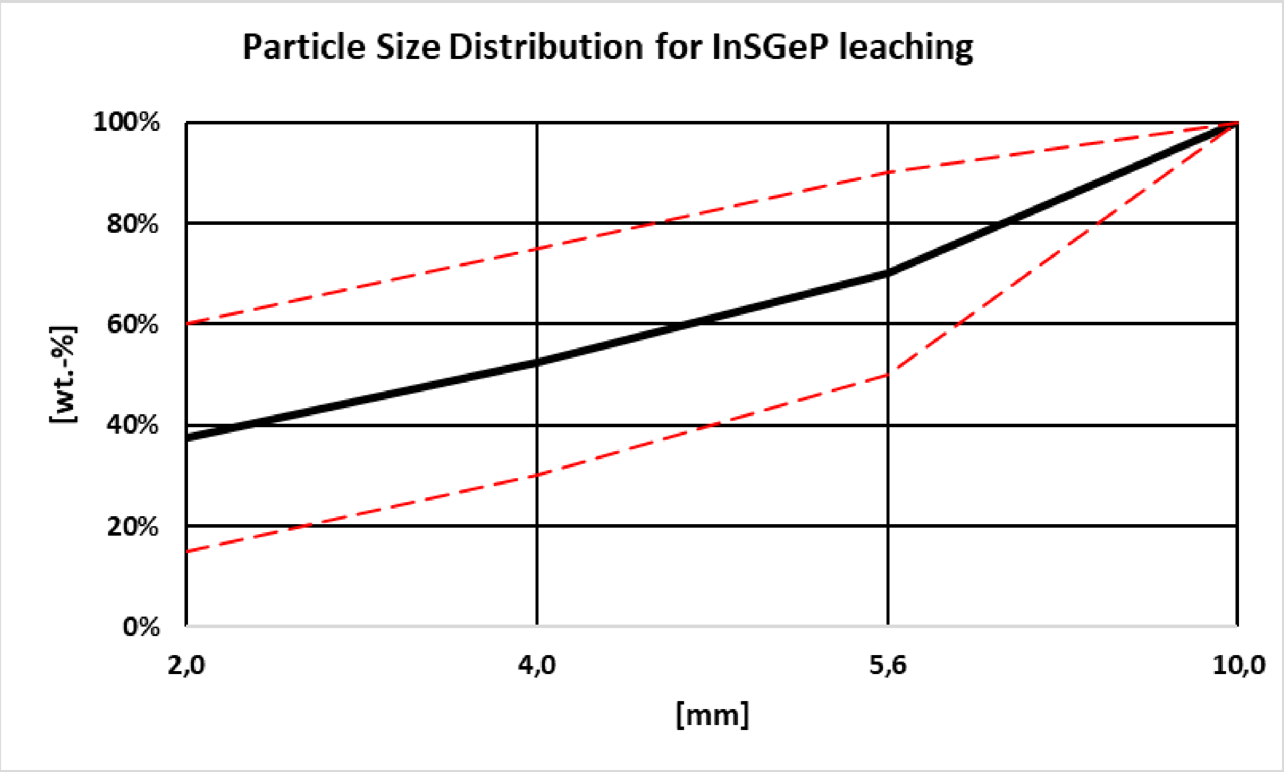


Ref.: M.D. Edinger et al.: Supercooled Liquids and Glasses. J. Phys. Chem. 1996, 100, 31, 13200–13212



Road construction – limiting values for leaching

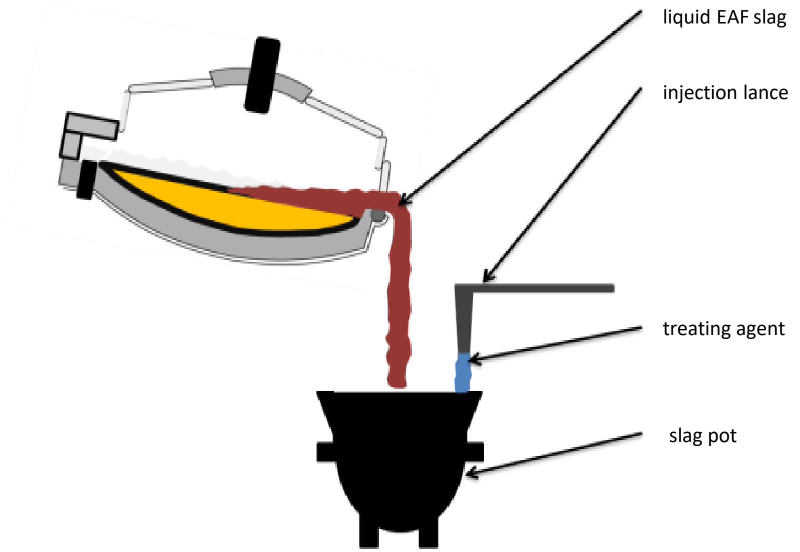




Exa
Low
Dep
(e.g.
Dem
→ m
→ L
→ Ir

France	Germany	Italy	Basque (Spain)
As	pH	pH	As
Ba	EC	COD	Ba
Cd	$Cr_{(total)}$	As	Cd
$Cr_{(total)}$	Mo	Ba	Cr
Cr (VI)	V	Be	Cr (VI)
Cu	F^-	Cd	Cu
Hg		Co	Hg
Mo		$Cr_{(total)}$	Mo
Ni		Cu	Ni
Pb		Hg	Pb
Sb		Mo	Sb
Se		Ni	Se
Zn		Pb	V
Cl^-		Sb	Zn
F^-		Se	Cl^-
SO_4^{-2}		V	F^-
		Zn	SO_4^{-2}
		Cl^-	
		CN^-	
		F^-	
		NO^{3-}	
		SO_4^{-2}	

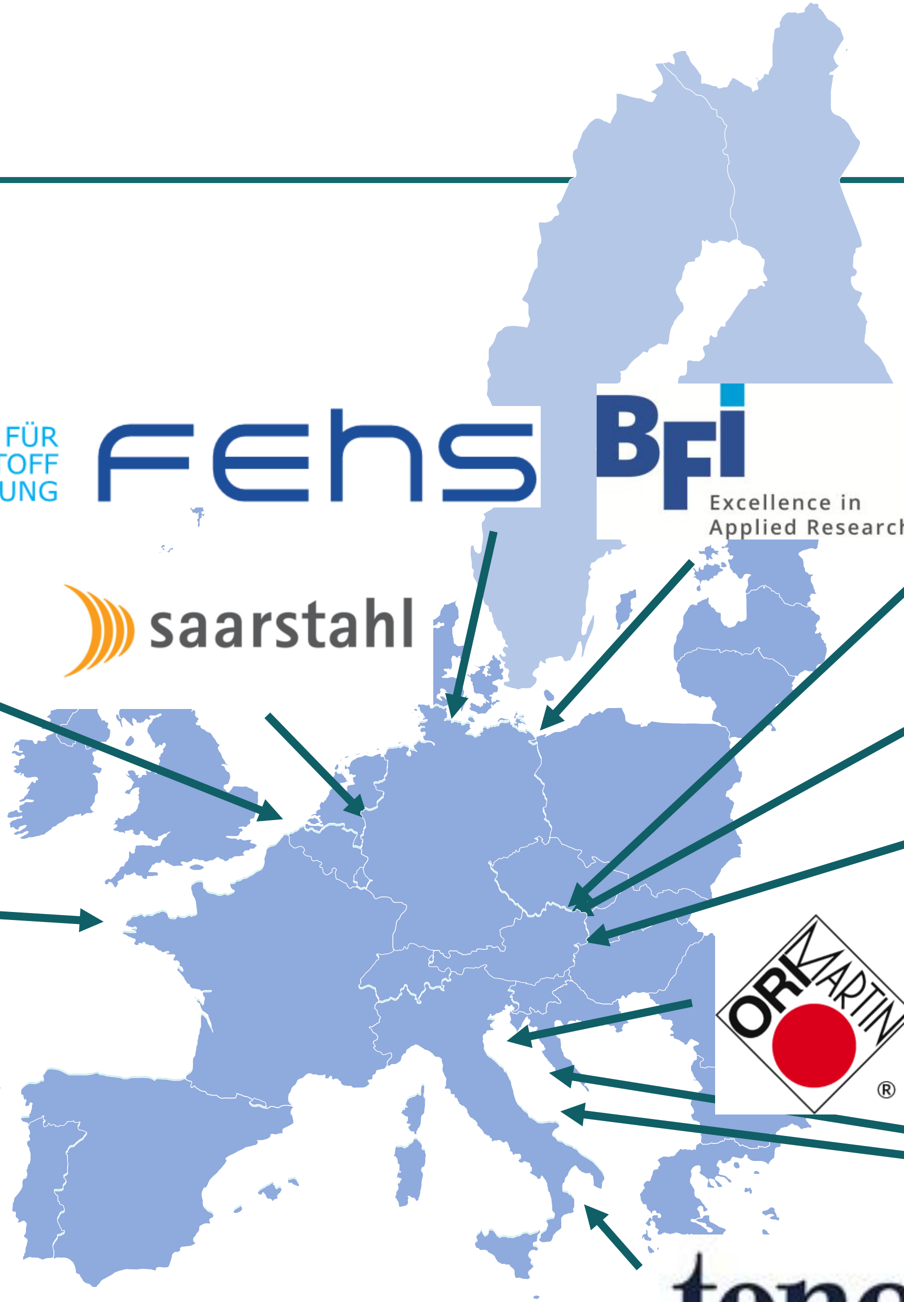
Slag treatment necessary? Take care about boundary conditions!



Treating
during tapping

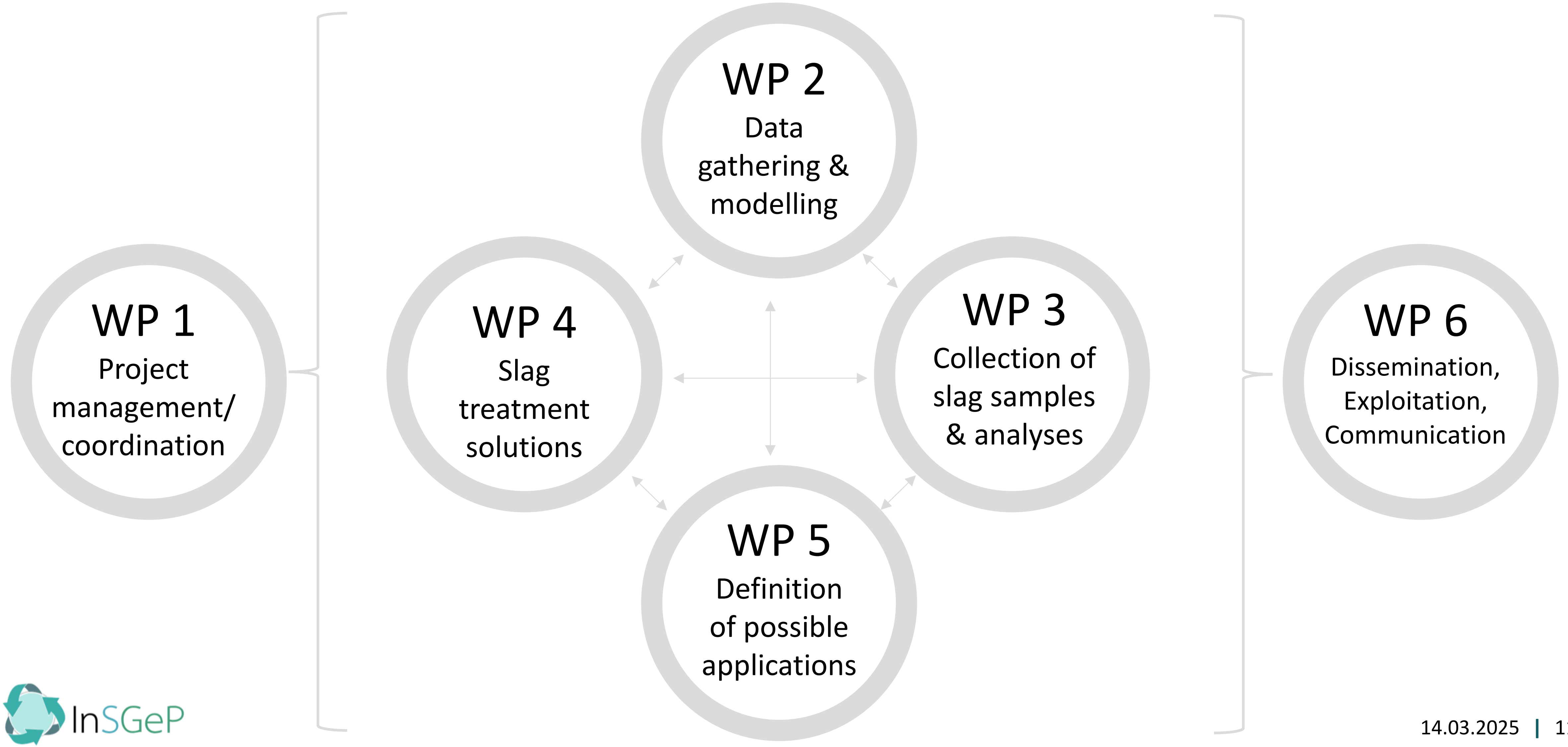
InSGeP Partners

5 RTO
5 steel works
2 plant manufacturers
+ ESTEP



InSGeP

InSGeP Workplan (07/2023 – 06/2027)



InSGeP

- Simulation of effects on slag and process of DRI or HBI charge in electric arc furnace
- Collection and laboratory development of slag samples using DRI and HBI in industrial and pilot scales
- Valorization of EAF slags from DRI melting with dry granulation process
- Market analysis and stakeholder consultation

David Algermissen

European Commission

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InSGeP

Simulation of effects on slag and process of DRI or HBI charge in electric arc furnace

Valentina Colla, Ismael Matino, Teresa Annunziata Branca, Marta Guzzon, Raquel Arias Perez

TELECOMMUNICATIONS, COMPUTER ENGINEERING, AND PHOTONICS INSTITUTE

Sant'Anna School of Advanced Studies – Pisa

tenova sidenor

05.03.2025

1st InSGeP workshop - Investigations of Slags from Next Generation Steel Making Processes

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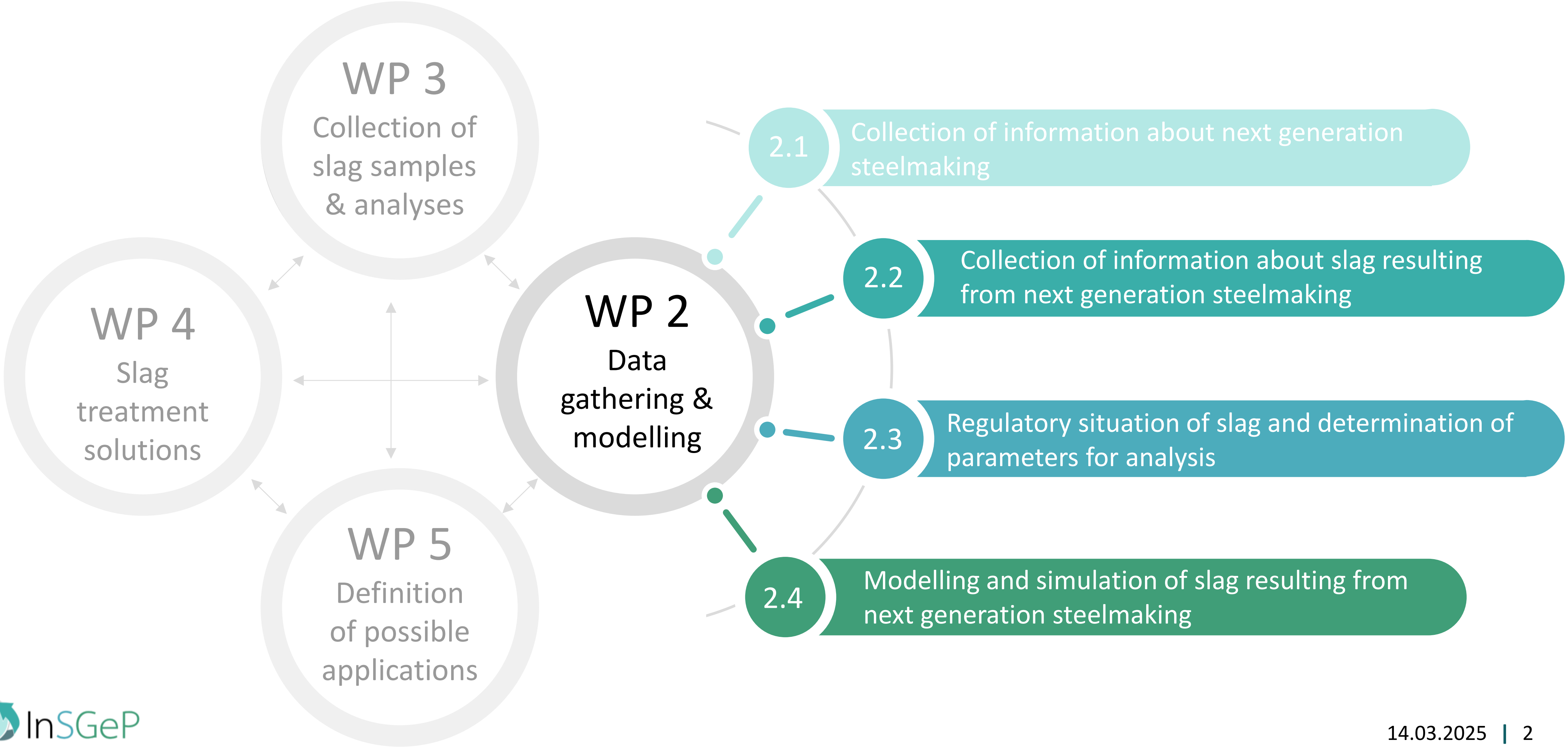
Project Structure

WP2 Data gathering about slag produced from next generation steelmaking



InSGeP

Modelling and Simulation Role

- Among the different activities foreseen in the InSGeP project, **modelling and simulations activities** are the basis of a dedicated Work Package

- **Simulations can allow making several scenario analyses for investigating a huge number of possibilities and related effects of DRI or HBI use in electric arc furnace focusing on slags but also on process and steel**

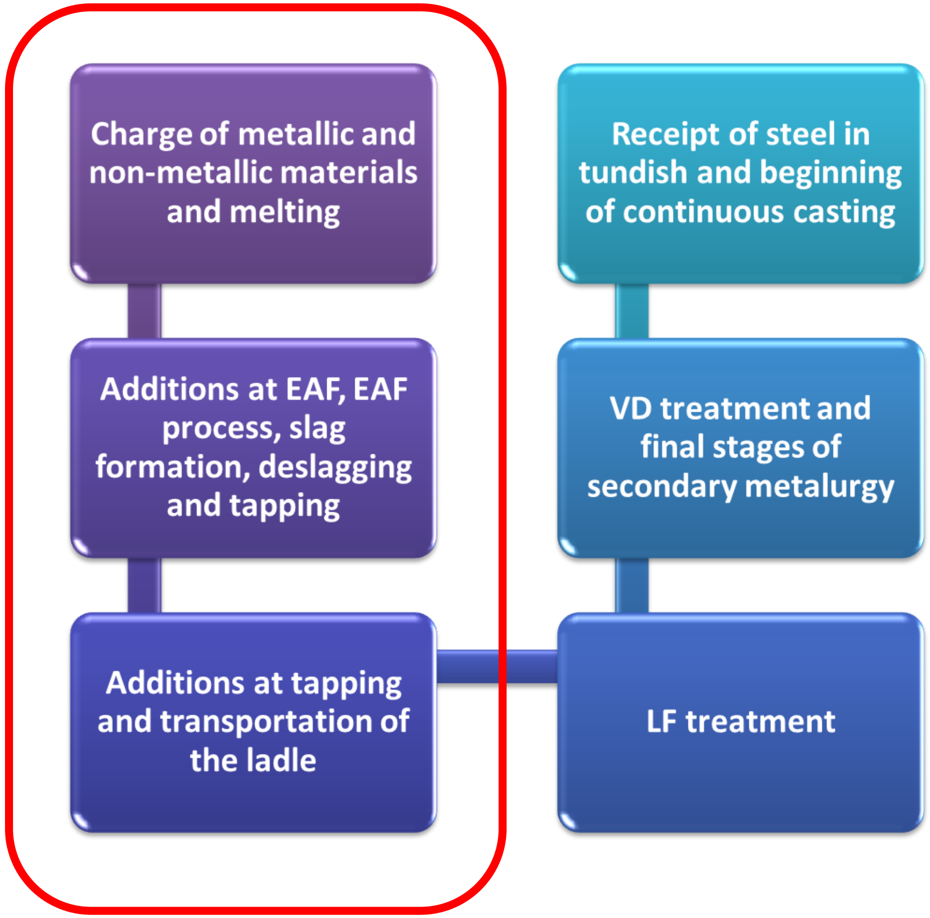
- **Solutions for counteracting negative effects can be analysed**

- Everything for obtaining low cost, low impact and safety indications for real tests/implementations

Flowsheet model of EAF-based steelmaking route

Overview

- One of the exploited model is a **flowsheet model of EAF-based steelmaking process** developed in Aspen Plus®
  - It was developed and improved in several years and projects
  - **It allows simulating EAF steelmaking route until start of continuous casting**, **and the effects of changing operating conditions and feeds** by combining several unit blocks and customized calculators
  - **Among others it allows computing and monitoring the evolution of main process parameters during the different process steps: temperatures, liquid steel and slag amount and composition, energy exploitation, CO_2 emissions, efficiencies**
  - Only the primary steelmaking part is used in InSGeP

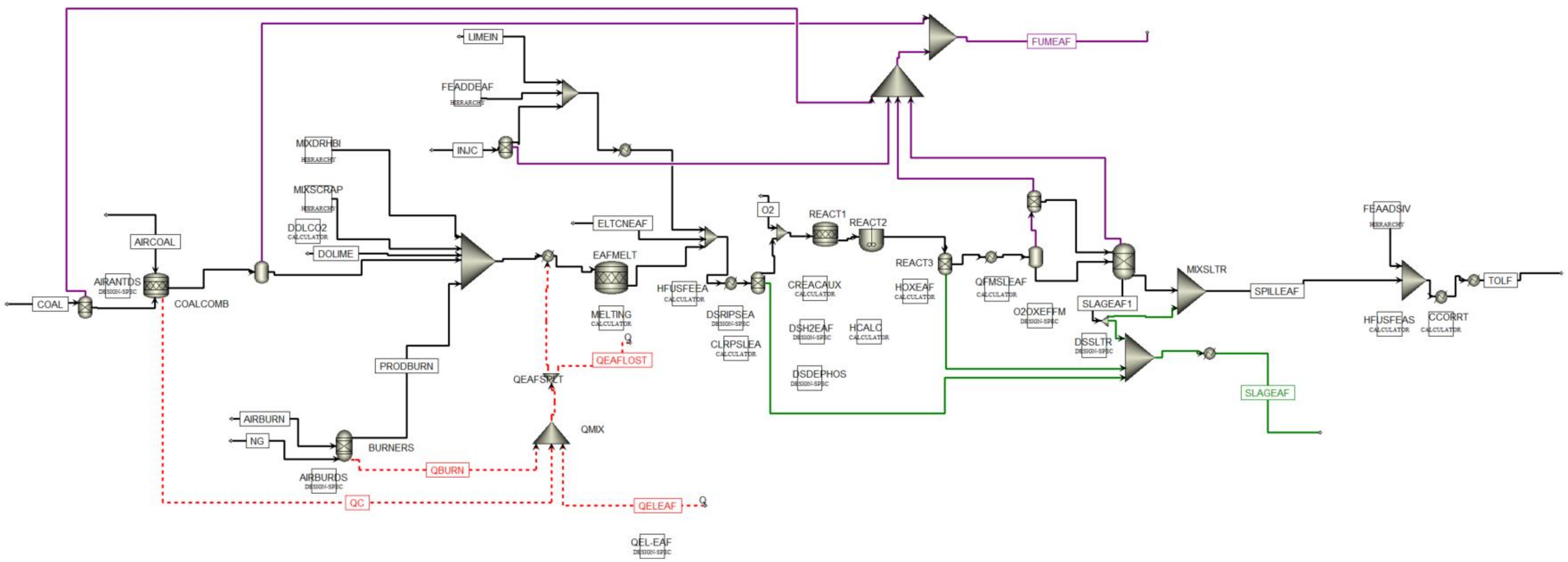


InSGeP

Flowsheet model of EAF-based steelmaking route

Adapted model

- **The flowsheet model of EAF-based steelmaking process** developed in Aspen Plus®
  - **was adapted, tuned and validated for allowing simulations considering the use of DRI/HBI in EAF**
  - Industrial and Technology Provider data were used for the scope



Flowsheet model of EAF-based steelmaking route

Adapted model

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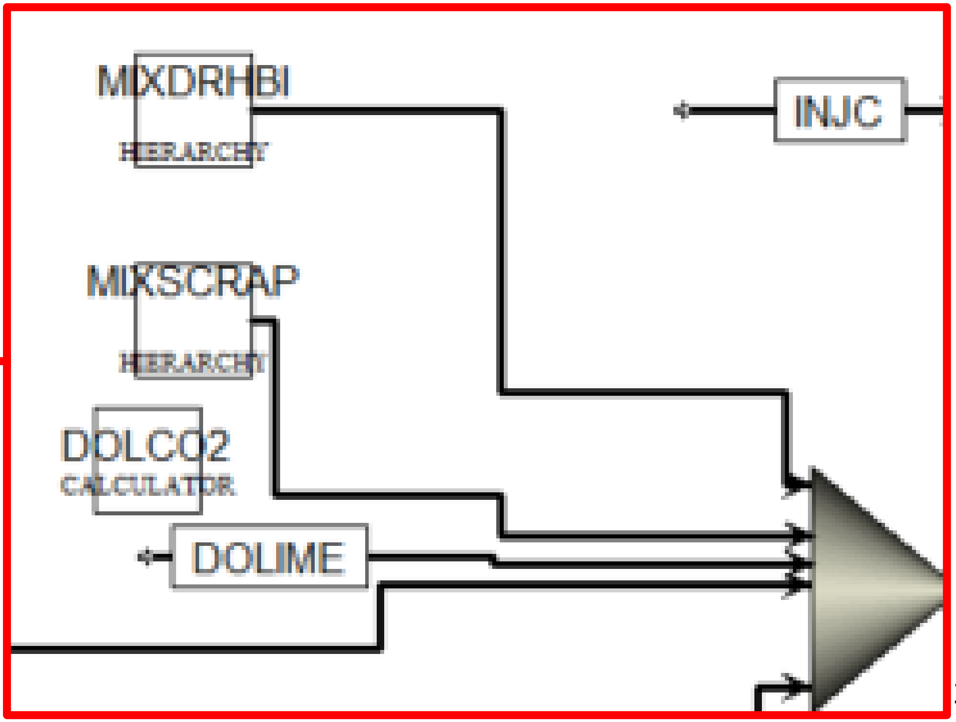
  - **was adapted, tuned and validated for allowing simulations considering the use of DRI/HBI in EAF**
  - Industrial and Technology Provider data were used for the scope

Added hierarchycal block Including streams of HBI and DRIs of different qualities and temperatures:

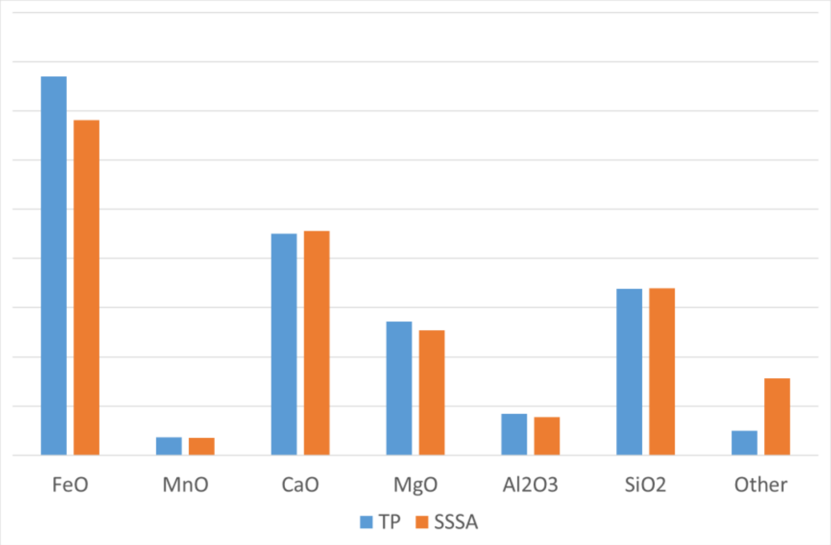
- BF quality
- DR quality
- Produced with a natural gas-based reducing gas
- Produced with a hydrogen-based reducing gas
- Cold
- Hot



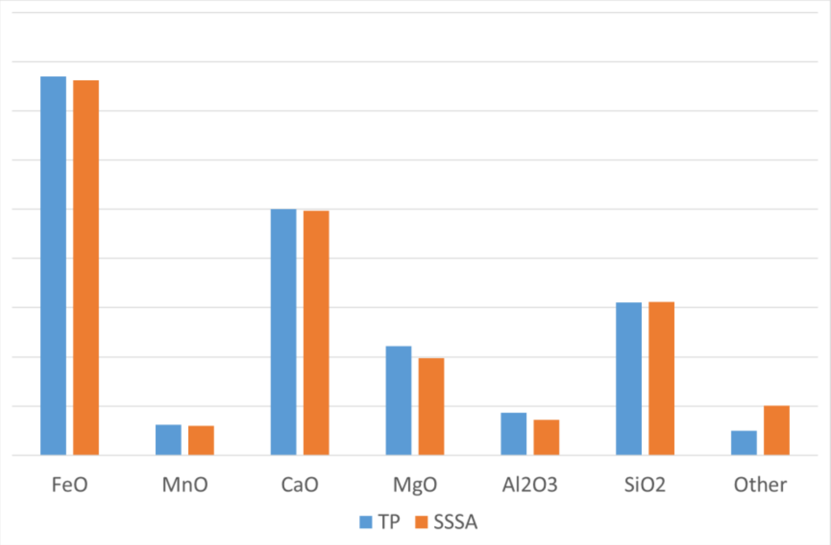
Flowsheet model of EAF-based steelmaking route

Validation

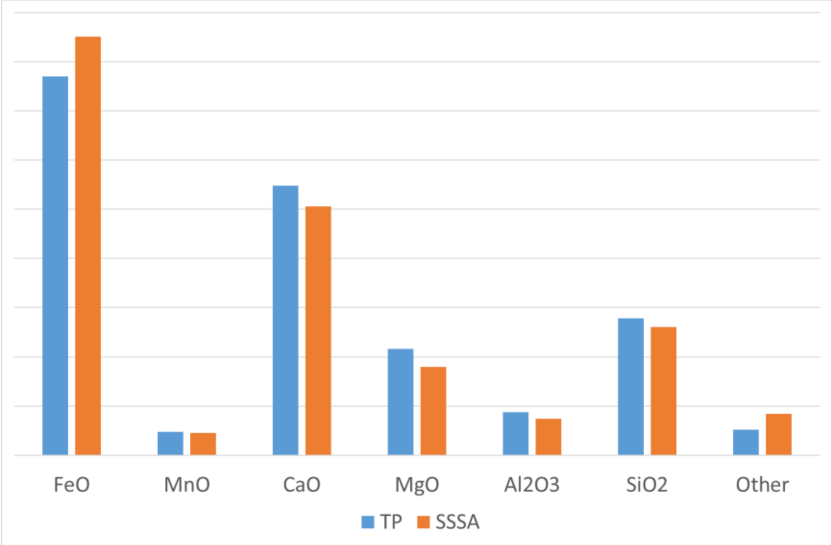
- **Example of validation results** comparing slag compositions of Technology Provider Data and flowsheet model (values are not reported for confidentiality reasons) → **model has a good accuracy**



EAF charged with 30% scrap and 70% Hot DRI (mix of different qualities)



EAF charged with 60% scrap and 40% Hot DRI (mix of different qualities)



EAF charged with 30% scrap and 70% HBI

InSGeP

- **Also for steel composition the accuracy is good**
- Improvements are ongoing to better fit model results with electric energy related to TP data because of different furnace of the original model; good fit with industrial data also on this aspect

Flowsheet model of EAF-based steelmaking route

Scenario analyses - Overview

- **The current version of the model is being used for simulations to analyse the effects of feeding different DRI and HBI ratios and qualities in EAF**

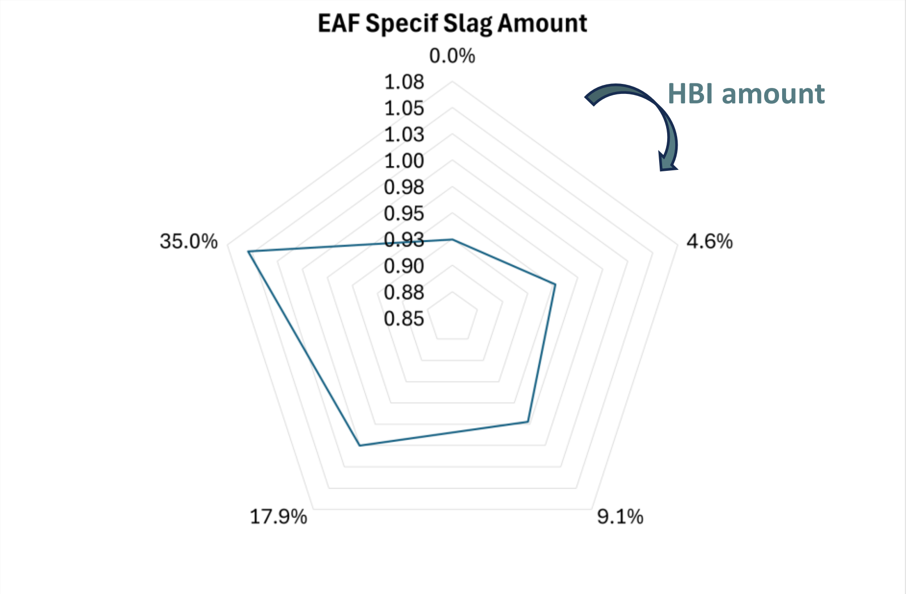
- Besides the composition and the amount of EAF slags, depending on the scenario, the following further parameters are monitored:
  - Tapped steel composition (especially in terms of tramp element, e.g. P)
  - EAF electricity
  - Resource consumptions

Flowsheet model of EAF-based steelmaking route

Scenario analyses – First results – Case A

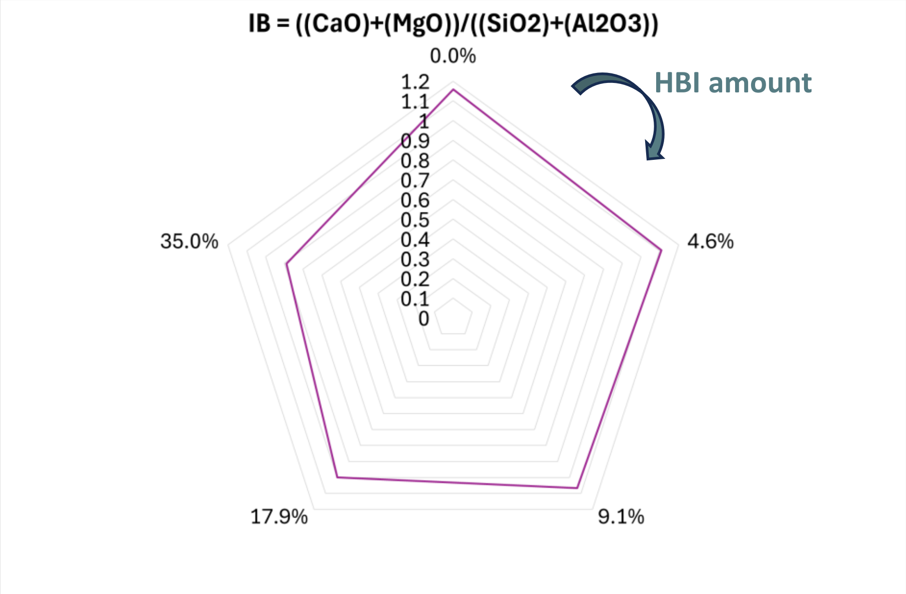
A. Simulation of steel production with different ratios of scrap/HBI considering as reference the heat produced using an HBI amount of 17.9% (results are normalized with respect to this reference heat for confidentiality reasons)

- **By ensuring the same amount of fed iron**
- **Keeping fixed all the other inputs (e.g. non-metallic charge materials and additions)**



Effects on EAF slag
Increasing HBI:

- **more slag is produced**
- **Slag basicity decreases** mainly due to observed
  - SiO_2 content increase
- **FeO content increases** in slag because of incomplete metallization of HBI

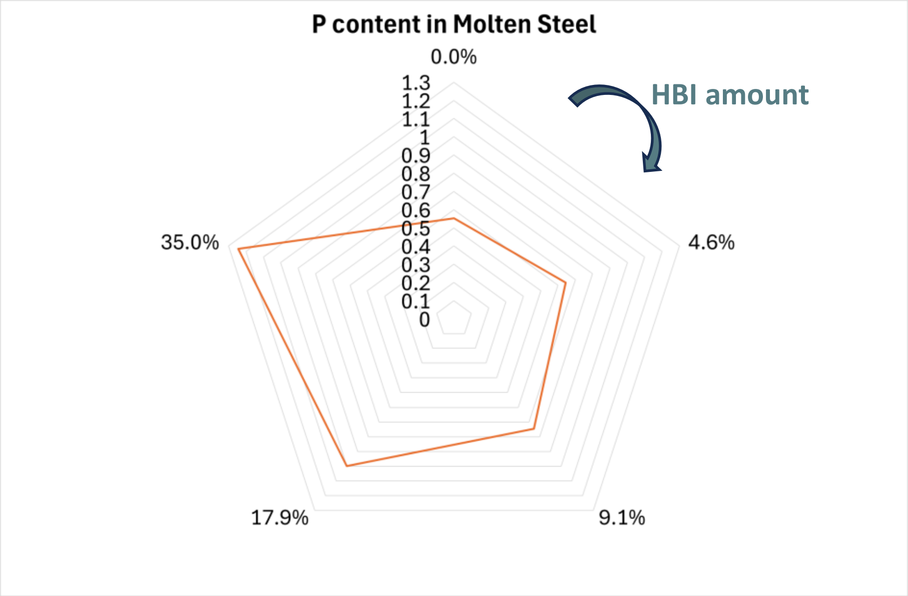


Flowsheet model of EAF-based steelmaking route

Scenario analyses – First results – Case A

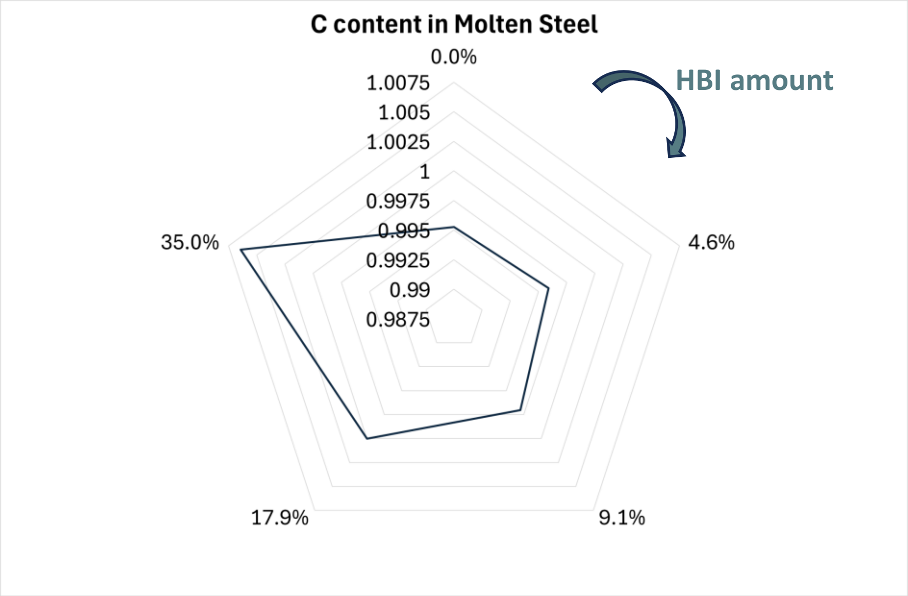
A. **Simulation of steel production with different ratios of scrap/HBI** considering as reference the heat produced using an HBI amount of 17.9% (results are normalized with respect to this reference heat for confidentiality reasons)

- **By ensuring the same amount of fed iron**
- **Keeping fixed all the other inputs (e.g. non-metallic charge materials and additions)**



Effects on molten steel
Increasing HBI:

- **P content increases** because of more acidic slag
- **C content is almost stable** (reported variation is small)
- **S content slightly increases** because of IB decrease and FeO increase in slag

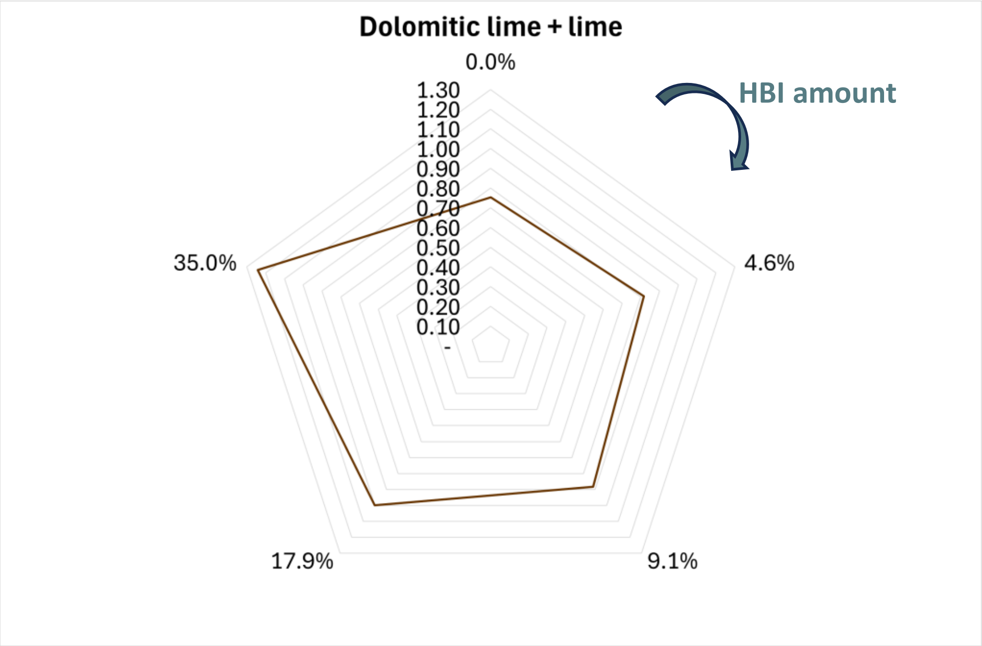


Flowsheet model of EAF-based steelmaking route

Scenario analyses – First results – Case B

B. Simulation of same steel production of A case with different ratios of scrap/HBI considering as reference the heat produced using an HBI amount of 17.9% (results are normalized with respect to this reference heat for confidentiality reasons)

- **By ensuring fixed content of P in molten steel**
- **Modifying IB of EAF slags by changing the amount of fed dolomitic lime**



Effects on fluxes
Increasing HBI:

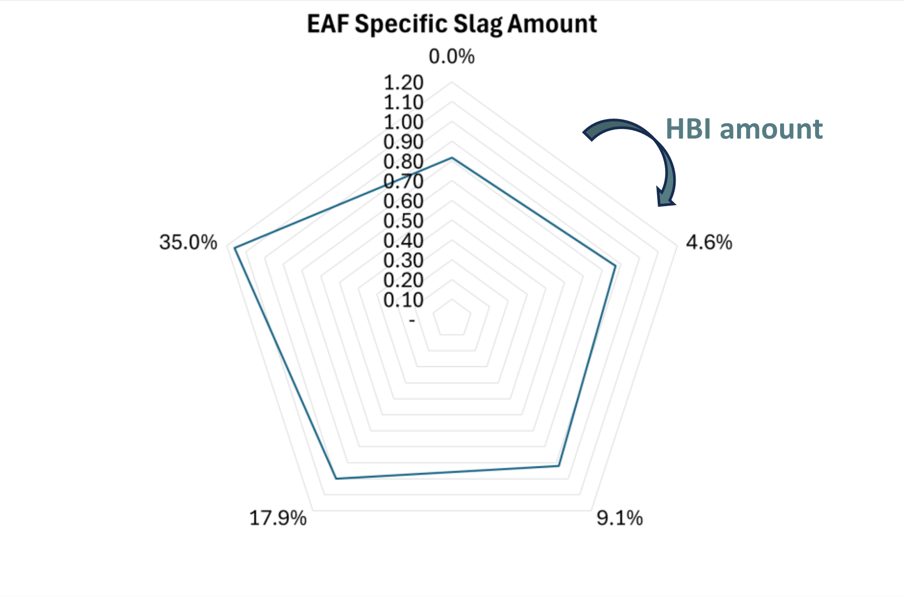
- **Increases the amount of required fluxes**

Flowsheet model of EAF-based steelmaking route

Scenario analyses – First results – Case B

B. Simulation of same steel production of A case with different ratios of scrap/HBI considering as reference the heat produced using an HBI amount of 17.9% (results are normalized with respect to this reference heat for confidentiality reasons)

- **By ensuring fixed content of P in molten steel**
- **Modifying IB of EAF slags by changing the amount of fed dolomitic lime**

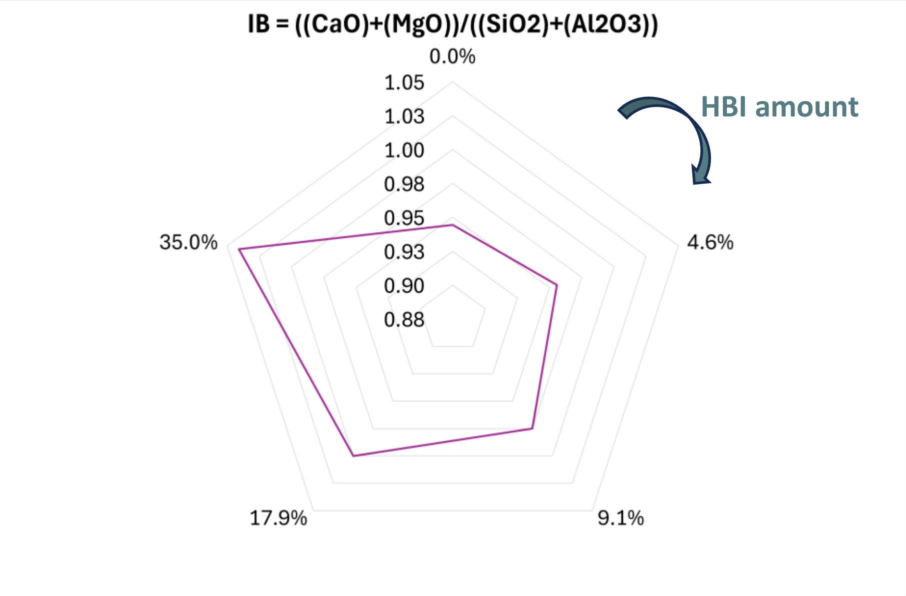


Effects on EAF slag
Increasing HBI:

- **more slag is produced**
- **Slag basicity slightly increases** for ensuring the fixed content of P in molten steel (used HBI has higher P content than the scrap mix)

Effects on the process:

- **Increase of required electric energy**

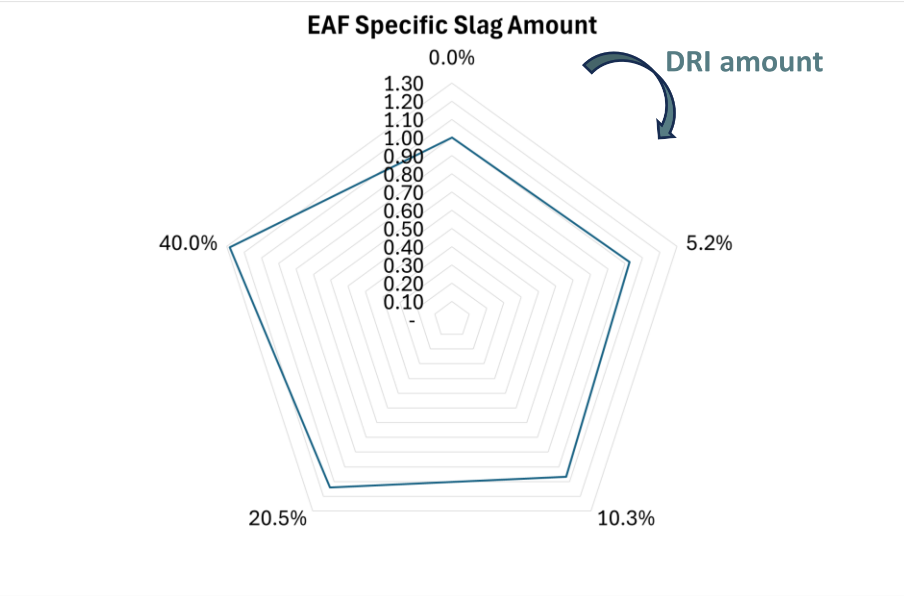


Flowsheet model of EAF-based steelmaking route

Scenario analyses – First results – Case C

C. **Simulation of steel production (different steel grade and scrap mix with respect the previous simulations) with different ratios of scrap/DRI (BF-/DR-grade ratio of about 2:1)** considering as reference the heat produced using only scraps (results are normalized with respect to this reference heat for confidentiality reasons)

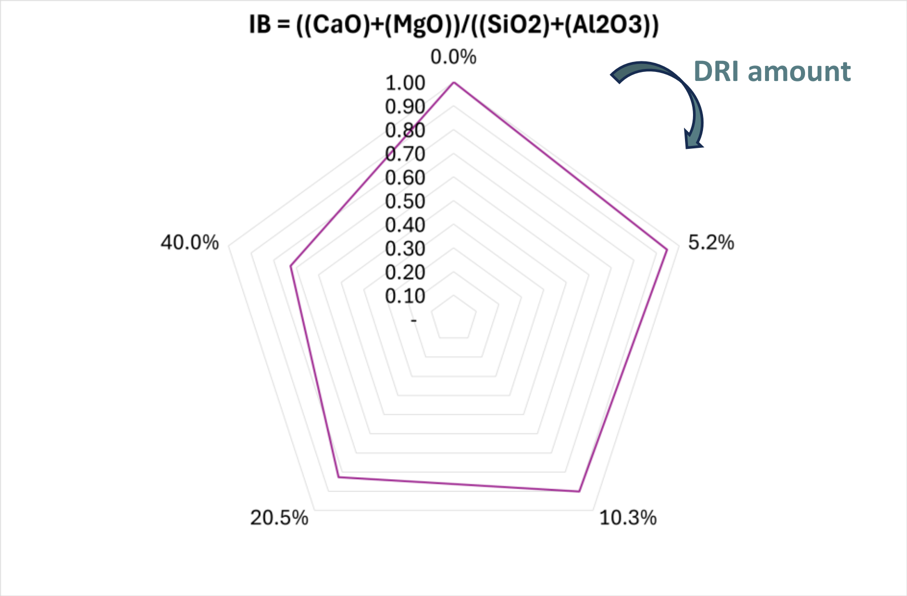
- **By ensuring the same amount of fed iron**
- **Keeping fixed all the other inputs (e.g. non-metallic charge materials and additions)**



Effects on EAF slag

Increasing DRI:

- **more slag is produced**
- **Slag basicity decreases** mainly due to observed
  - SiO_2 and Al_2O_3 content increase
- **FeO content increases in slag** because of incomplete metallization of DRI

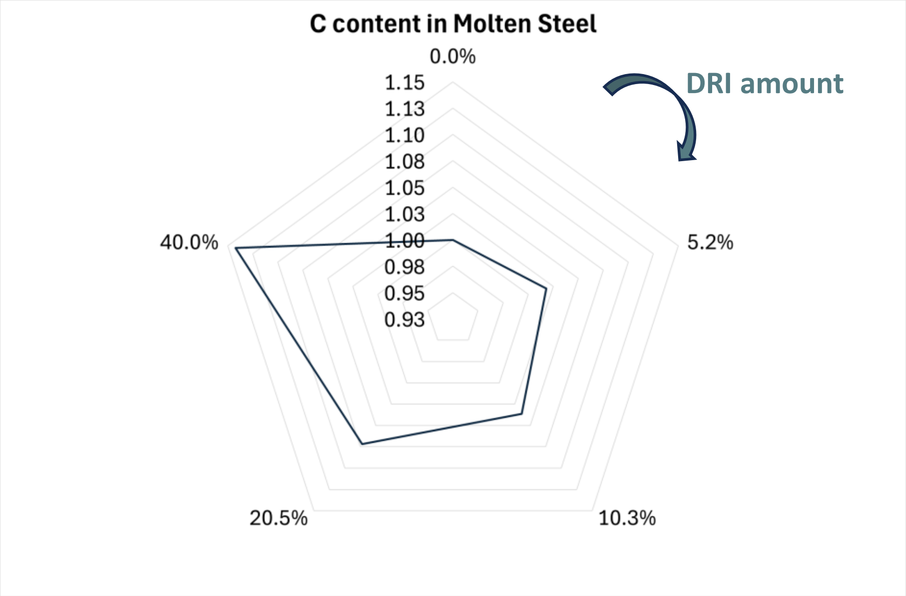


Flowsheet model of EAF-based steelmaking route

Scenario analyses – First results – Case C

C. **Simulation of steel production (different steel grade and scrap mix with respect the previous simulations) with different ratios of scrap/DRI (BF-/DR-grade ratio of about 2:1)** considering as reference the heat produced using only scraps (results are normalized with respect to this reference heat for confidentiality reasons)

- **By ensuring the same amount of fed iron**
- **Keeping fixed all the other inputs (e.g. non-metallic charge materials and additions)**



Effects on molten steel
Increasing DRI:

- **C content increases**
- **Low variations are observed on P content** because DRI mix holds a lower P content than used scrap mix and compensate the IB decrease
- **Negligible variations on S content**

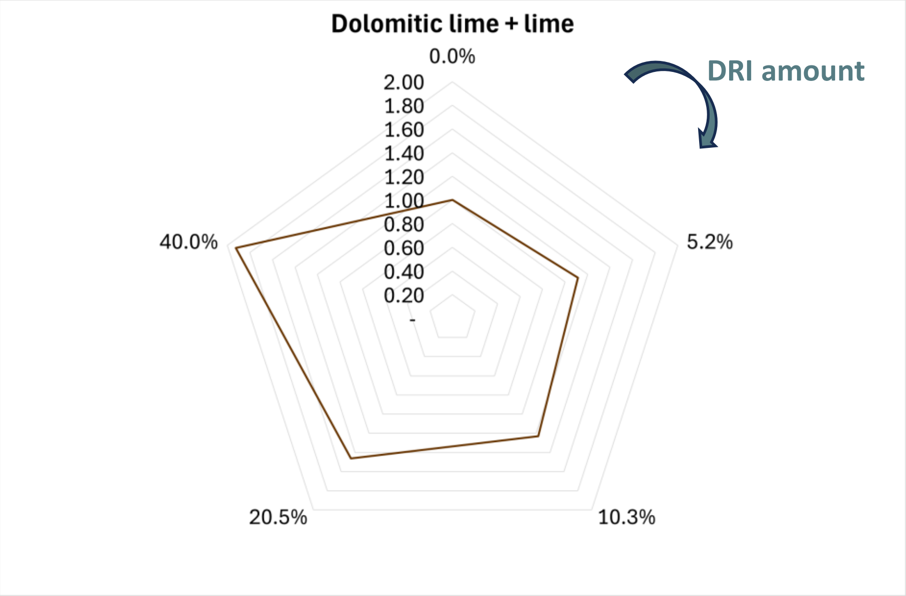
InSGeP

Flowsheet model of EAF-based steelmaking route

Scenario analyses – First results – Case D

D. **Simulation of same steel production of case C with different ratios of scrap/DRI (BF-/DR-grade ratio of about 2:1)** considering as reference the heat produced using only scraps (results are normalized with respect to this reference heat for confidentiality reasons)

- **By ensuring fixed IB**
- **Changing the amount of fed dolomitic lime**



Effects on fluxes

Increasing DRI:

- **Increases the amount of required fluxes**

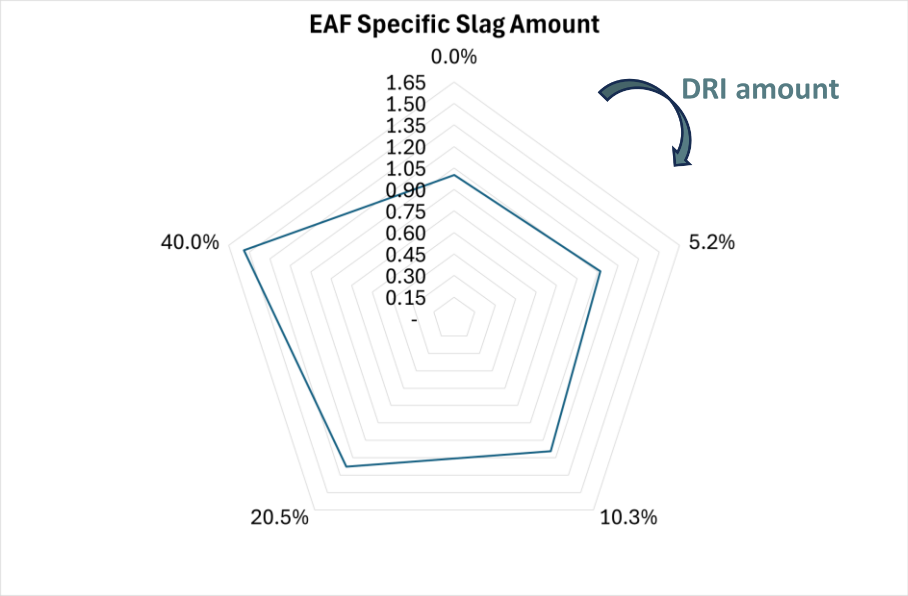
Effects on EAF slag

Increasing DRI:

- **more slag is produced**

Effects on the process:

- **Increase of required electric energy**



Conclusions & Ongoing Work

- Models and related simulations can help for studying the changes in slags related to EAF process changes related to the use of high DRI/HBI ratios
- A flowsheet model was presented and is being used for scenario analyses
- First results show how high ratio of HBI/DRI affect mainly amount and IB of the slags with consequent counteractions for contrasting IB changes that affect content of undesired compounds in steel (e.g. P) and slag features (e.g. viscosity)
  - Significant amount of lime-based fluxes are required in case of high HBI/DRI ratios
- Further simulations are ongoing for studying the effects of different DRI qualities in different mixes
- Smelter modelling is ongoing for making similar simulations

InSGeP

Simulation of effects on slag and process of DRI or HBI charge in electric arc furnace

Valentina Colla, Scuola Superiore Sant'Anna, valentina.colla@santannapisa.it

European Commission

The research leading to these results has received funding from the European Union's Research Fund for Coal and Steel research programme under grant agreement number: 101112665

InSGeP

Collection and laboratory development of slag samples using DRI and HBI in industrial and pilot scale

Mattia De Colle, ArcelorMittal Maizières Research

10 March 2025

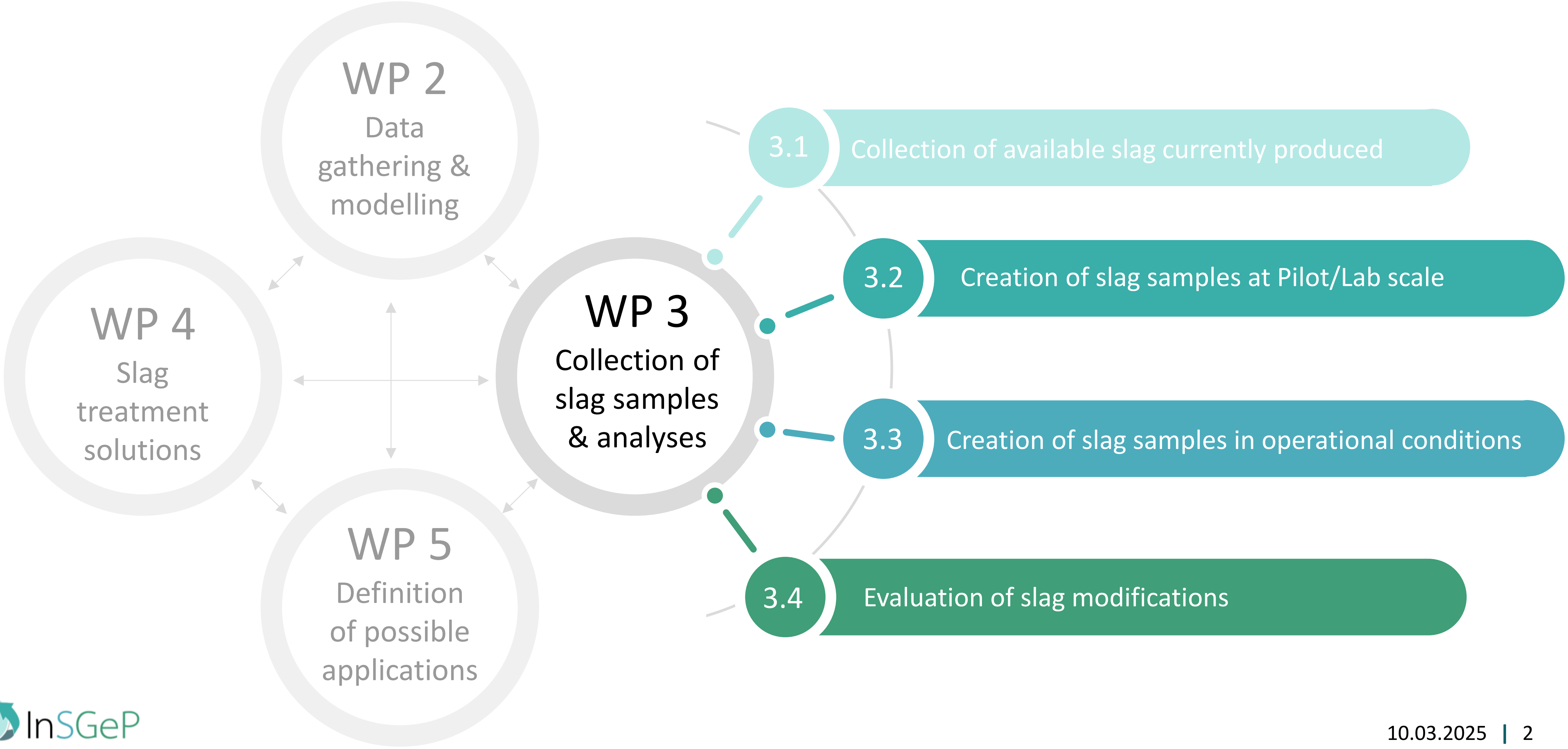
The role of slags and other by-products within circular economy in the steel industry

European Commission

The research leading to these results has received funding from the European Union's Research Fund for Coal and Steel research programme under grant agreement number: 101112665

Project Structure

WP3 – Collection of slag samples and laboratory analyses



InSGeP

Samples amount per task & geographical location

3.1 Collection of available slag currently produced:

- Partner “K”: 3 samples, 30 kg
- Partner “G”: 6 samples, 120 kg
- Partner “N”: 2 samples, 30 kg
- Partner “Y”: 4 samples, 200 kg

3.2 Creation of slag samples at Pilot/Lab scale:

- Partner “U”: 2 samples
- Partner “N”: 4 samples, 800 kg
- Partner “Z”: 1 sample, 1.7g

3.3 Creation of slag samples in operational conditions:

- Partner “J”: 11 samples, 993 kg
- Partner “Q”: 4 samples, 1200 kg

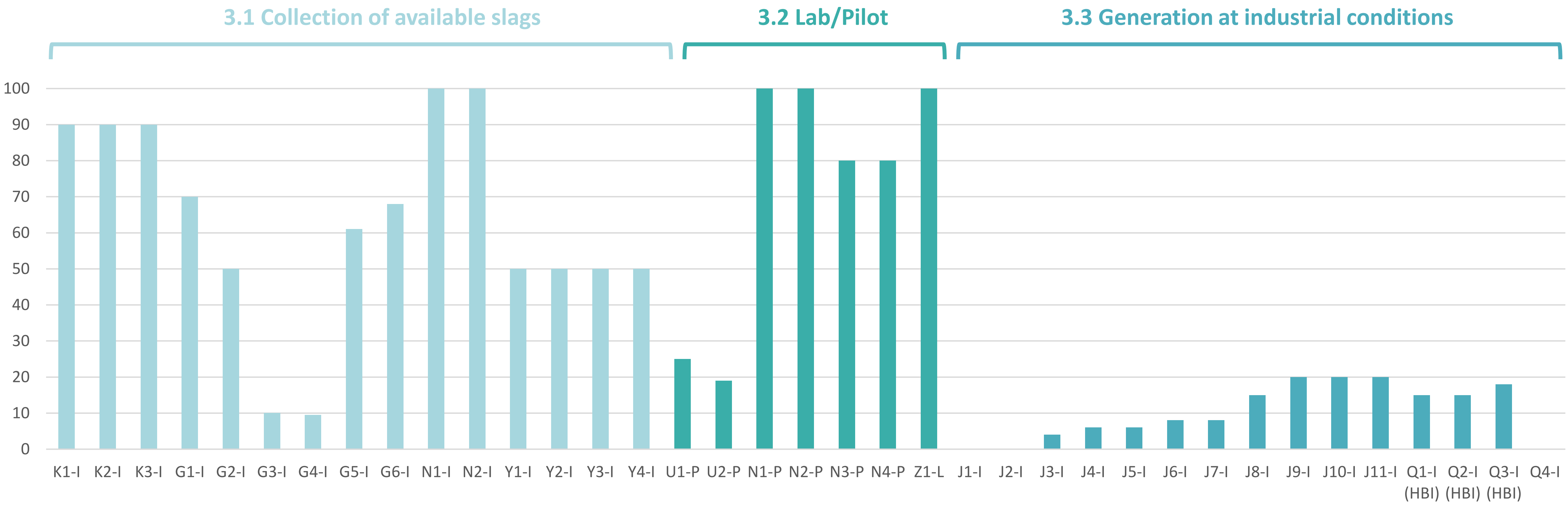
Samples were collected in:

Some of the DRI/HBI was also produced in:

InSGeP

WP 3 - Collection of slag samples and laboratory analyses

DRI% in samples across different tasks



Legend: Partner initial (randomized letter) + number of the sample – "I" if industrial, "P" if pilot, "L" if lab

InSGeP

Showcase: Industrial sampling from DRI-EAF plants

Sampling of already sorted material (G3) ↑

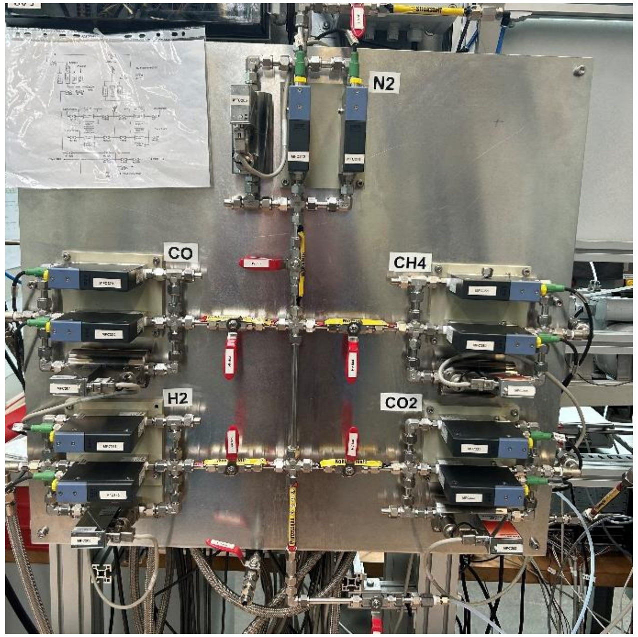
Isolation of specific heats to be sampled (G4 & G5) →

Task 3.2

Showcase: Smelting of DRI and gangue evaluation in lab scale

Pellet comp.	wt%
Fe (met.)	91.2
FeO	4.7
MgO	0.51

Z1-L	wt%
MgO	28.36
Al2O3	11.51
SiO2	32.19
CaO	21.63
MnO	0.19
Fe2O3	0.70



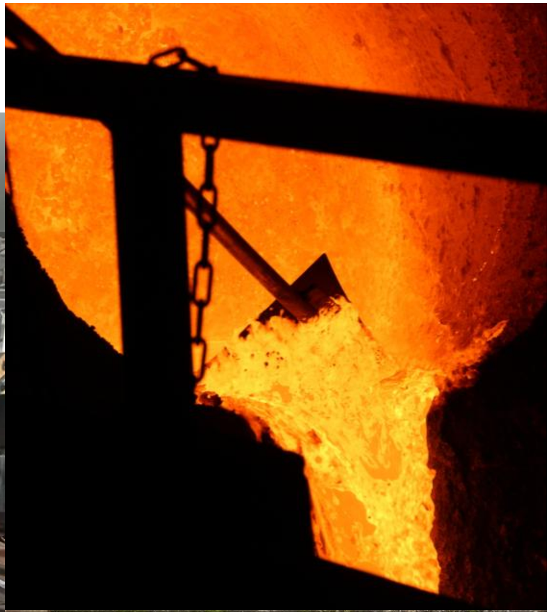
Next trials will focus on direct reduction trials with H_2 and H_2/CO combination

Task 3.2

Showcase: Creation of smelter slag in pilot scale

- 4 test trials to reproduce smelter slag
- 1 ton electric furnace (≈EAF/SAF)
- Reducing agents like biochar and anthracite were used

Heat	CaO	SiO_2	Al_2O_3	MgO	Fe_2O_3	Fe_{met}	B2
N1-P	36,5	31,0	14,5	14,0	< 0,1	0,27	1,17
N2-P	25,8	22,6	11,4	9,3	1,8	18,6	1,14
N3-P	37,5	37,3	9,9	7,2	1,2	1,37	1,01
N4-P	19,8	15,2 %	9,6	15,5	3,9	19,3	1,29



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Task 3.3

Showcase: Creation of slag samples in operational conditions

HBI composition

SiO_2	Al_2O_3	CaO	MgO	MnO	P	Fe total	Fe met	S	C
2,41	0,60	1,18	<0,10	0,16	0,041	88,8	78,2	<0,005	0,99±0,02

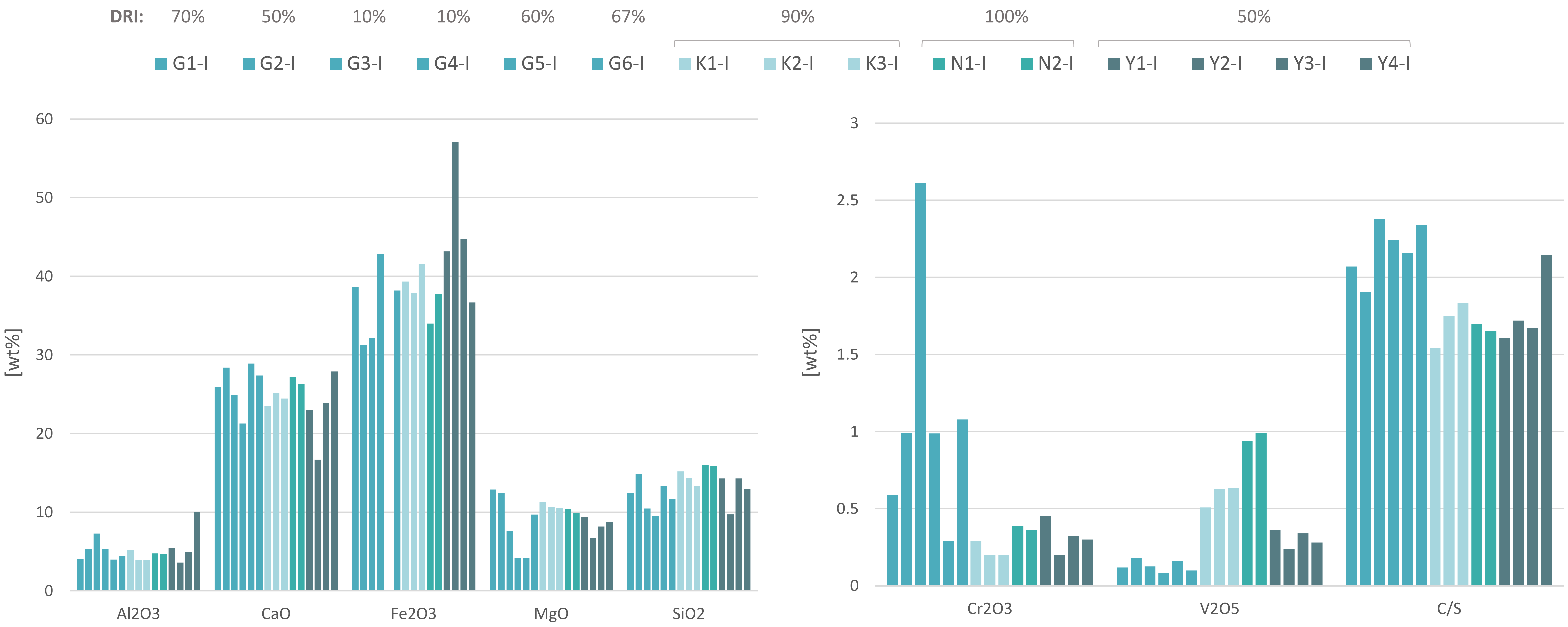
Q1-I: 15% HBI, High quality scrap
Q2-I: 15% HBI, Low quality scrap
Q3-I 18% HBI, High quality scrap
Q4-I 100% Scrap (reference case)

- Each sample is made by cumulating 3 heats
- After 3 heats all the slag was excavated and put into a pot for the final cooling

InSGeP

Task 3.1

Chemical analyses



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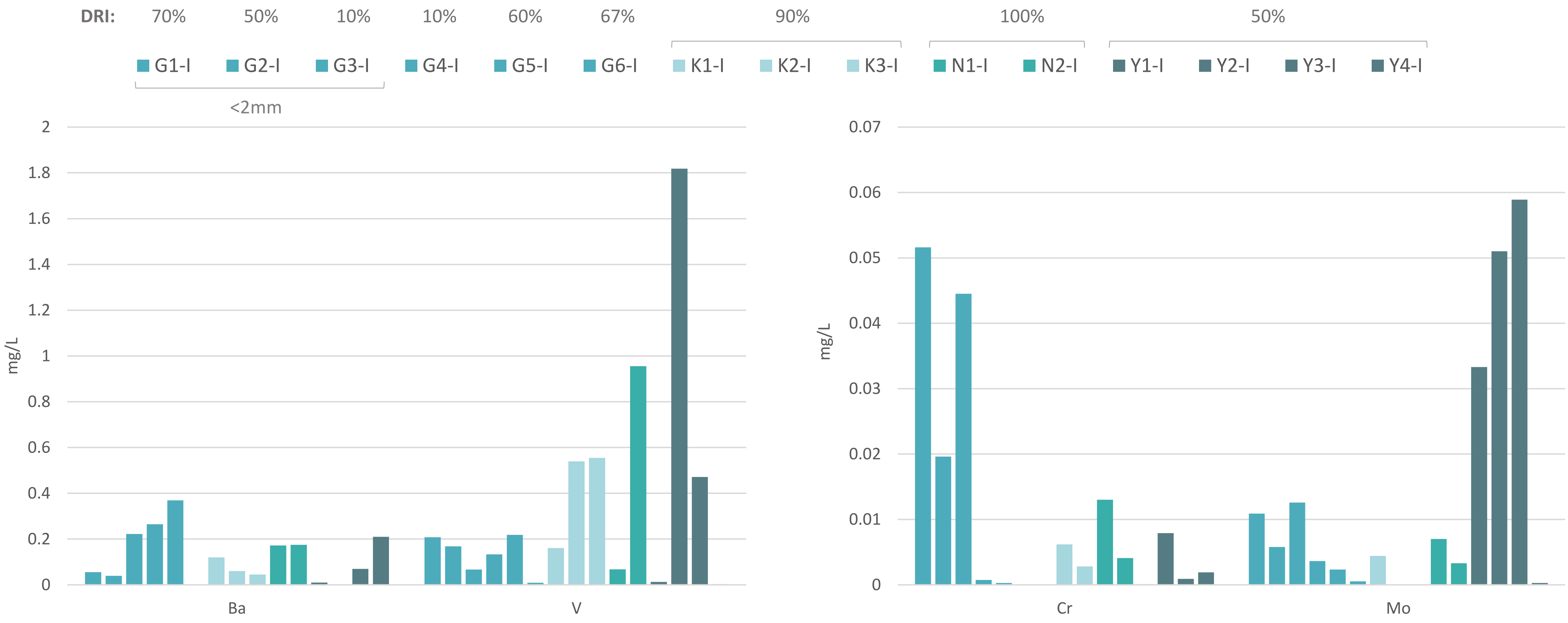
Task 3.1

10:1 Leaching <10mm



WP 3 - Collection of slag samples and laboratory analyses

Next steps

WP 3
Collection of slag samples & analyses

Task	Description	Status
3.1	Collection of available slag currently produced	Completed ☑
3.2	Creation of slag samples at Pilot/Lab scale	More trials undergoing
3.3	Creation of slag samples in operational conditions	More trials undergoing
3.4	Evaluation of slag modifications	The results of tasks 3.2 and 3.3 will be used for the design of the experiments

InSGeP

InSGeP

Collection and laboratory development of slag samples using DRI and HBI in industrial and pilot scale

Mattia De Colle, ArcelorMittal Maizières Research

European Commission

The research leading to these results has received funding from the European Union's Research Fund for Coal and Steel research programme under grant agreement number: 101112665

InSGeP

Valorization of EAF slags from DRI melting with dry granulation process

Marta Guzzon - Tenova

05/03/2025

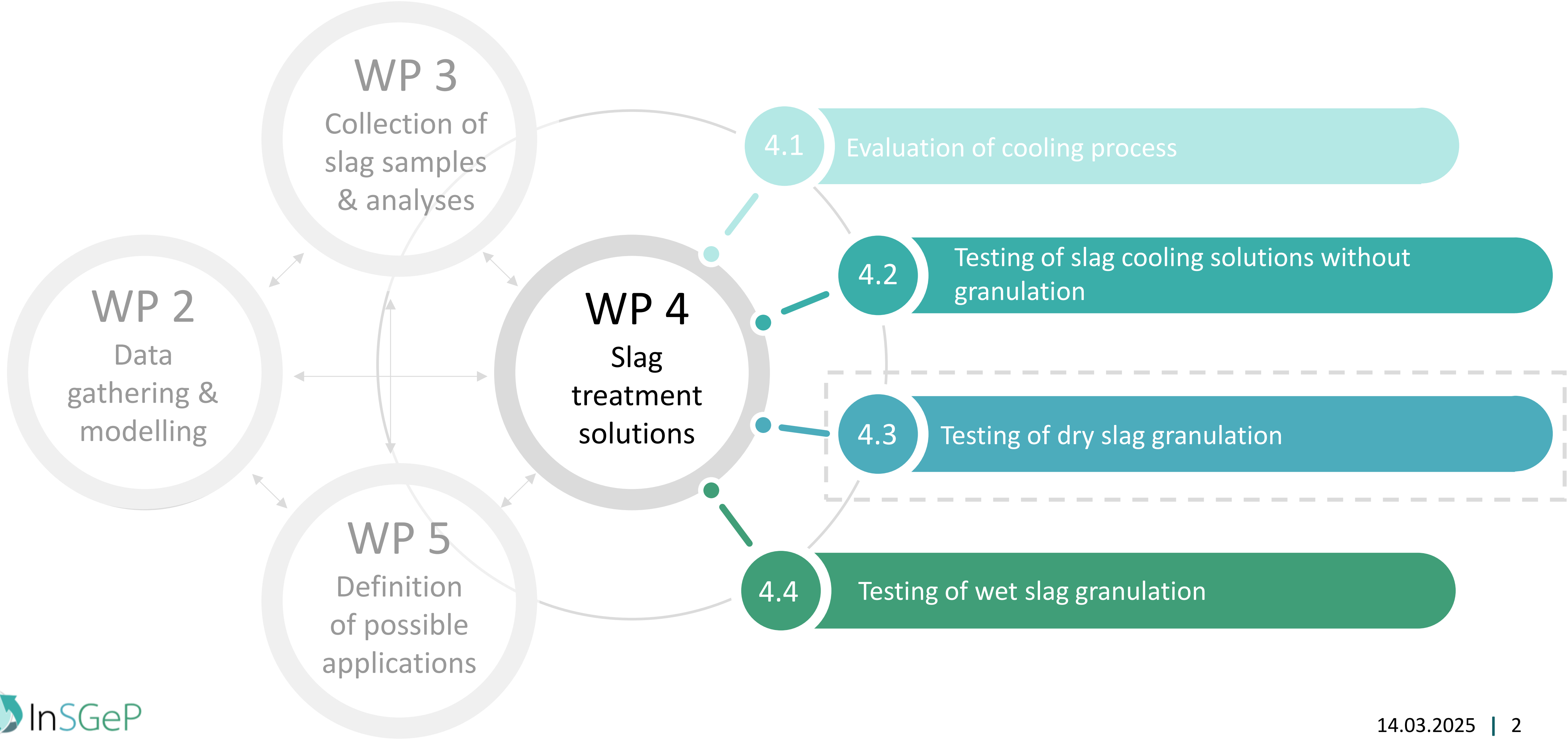
Event title

European Commission

The research leading to these results has received funding from the European Union's Research Fund for Coal and Steel research programme under grant agreement number: 101112665

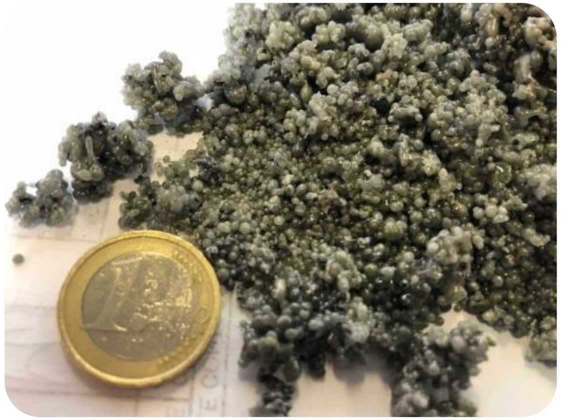
Project Structure

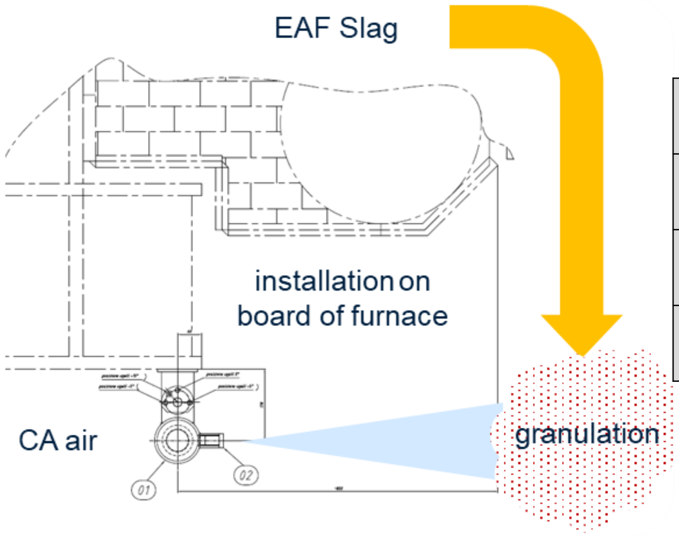
WP4 – Slag Treatment Solutions



Tenova Dry Slag Granulation

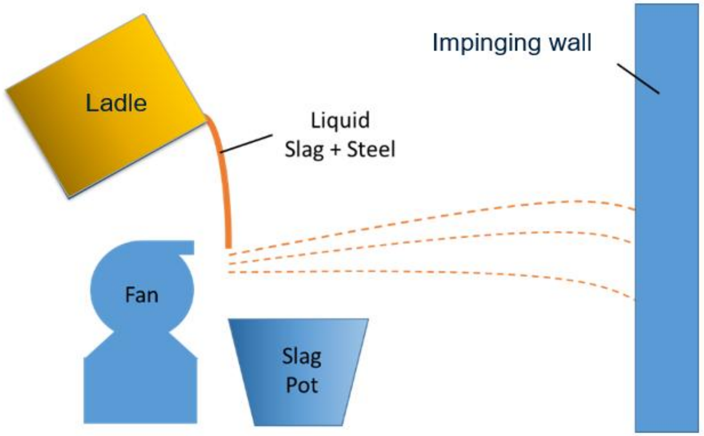
On Line: EAF slag directly in the pit





Type	Industrial
Application	On Line
Slag	EAF Slag
Slag Flow Rate	variable

Off-Line: EAF slag in slag pot and LF slag in ladle



Type	Pilot
Application	Off line
Slag	LF Slag + steel*
Slag Flow rate	Controlled (costant)

Tenova Dry Slag Granulation Modelling

6- Restart with semi-empirical correlation or using CFD

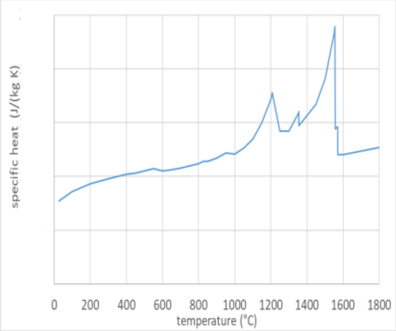
1- Definition of the chemical and physical properties of the slag

2- Design of the fan size and the definition of the working points

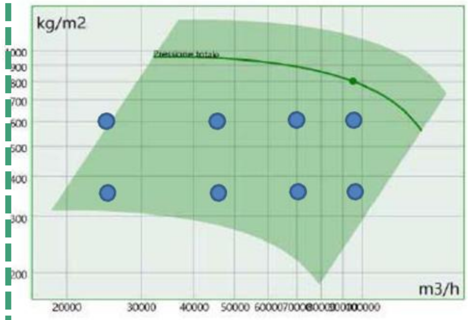
3- Granulometry Simulation (semi-empirical / CFD)

4- Computation Fluid Dynamic Modelling

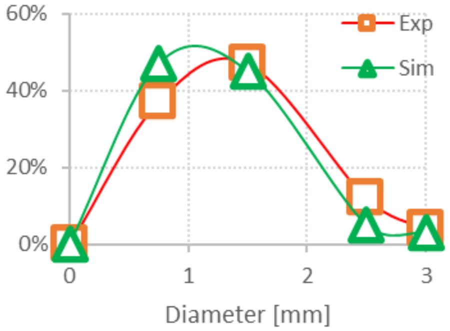
5- Pilot test



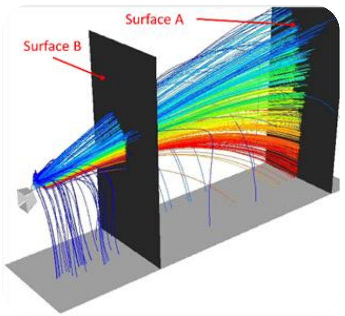
Rina-CSM
Slag Properties Models



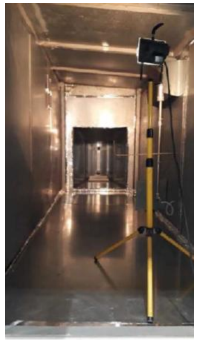
Tenova
Process Definition



Tenova
Granulometry Definition



Tenova
CFD
Particle Trajectory/ Cooling



Rina-CSM
Validation

InSGeP

Slag properties

Slag properties given by CSM:

100% DRI FEED		SLAG COMPOSITION	
Chemical compound	% WEIGHT	Species	% WEIGHT
Fetot.	84.4	SiO_2	18.7
Al_2O_3	1	TiO_2	1.3
CaO	1.2	CaO	37.1
MgO	0.7	MgO	6.9
SiO_2	4.7	FeO	24.1
ZnO	0.03	MnO	1.6
S	0.01	Al_2O_3	9.4
C	3.3	Na_2O	0.5
Metallization	95.5	K_2O	0.2

100% DRI

Temperature	1550	°C
Density @T	3081	Kg/m3
Surface tension @T	0.539	N/m
Viscosity @T	0.0261	Pa*s
Thermal conductivity @T	0.08	W/m/K
Specific heat @T	1401	J/kg/K

InsGeP – task 4.3

Tenova Dry Slag Granulation Modelling

tenova

6- Restart with semi-empirical correlation or using CFD

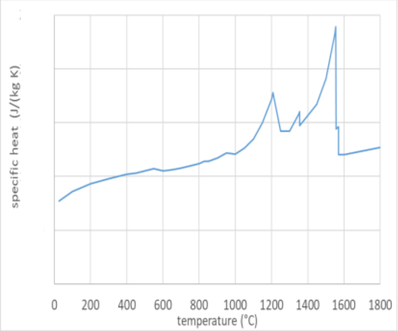
1- Definition of the chemical and physical properties of the slag

2- Design of the fan size and the definition of the working points

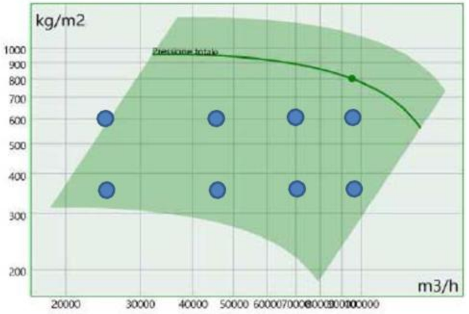
3- Granulometry Simulation (semi-empirical / CFD)

4- Computation Fluid Dynamic Modelling

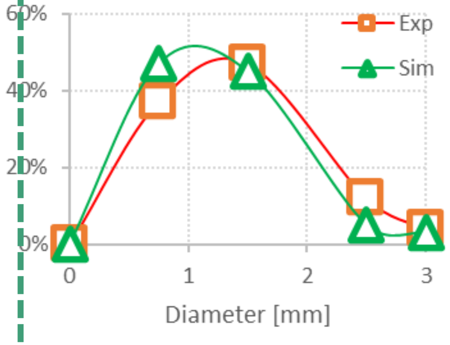
5- Pilot test



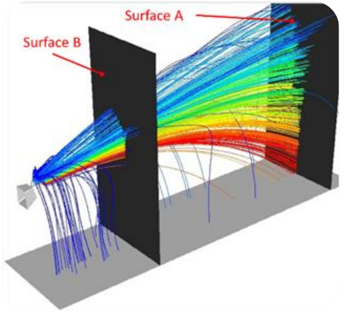
Rina-CSM
Slag Properties Models



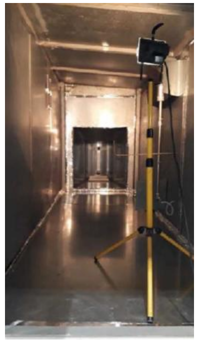
Tenova
Process Definition



Tenova
Granulometry Definition



Tenova
CFD
Particle Trajectory/ Cooling



Rina-CSM
Validation

InSGeP

tenova

Model setup

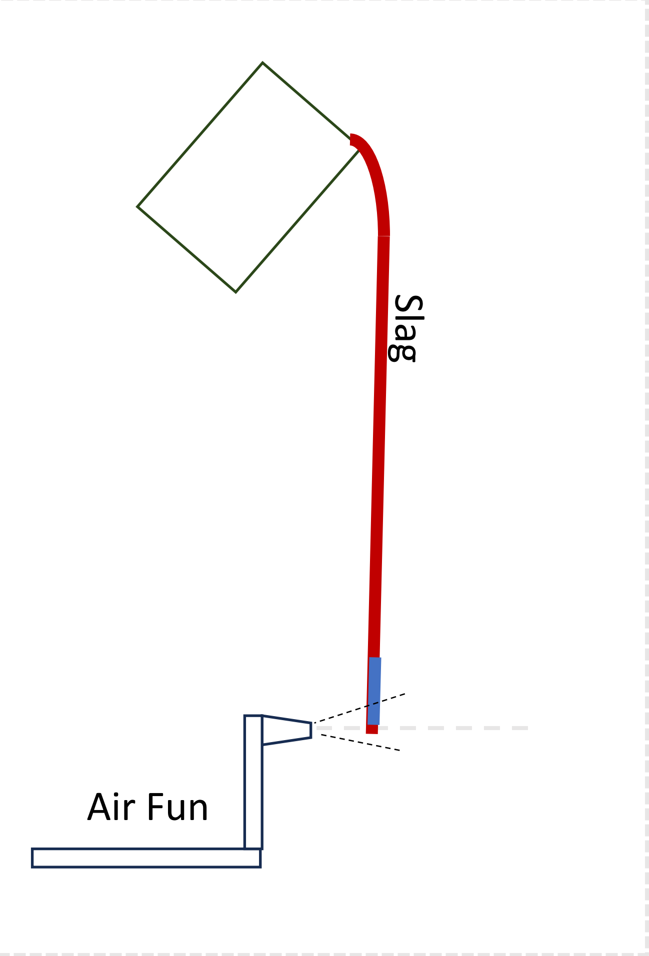
The system is described in a transient way by means of a multiphase model called VOF-to-DPM. The energy is enabled and the turbulence model used is the κ-ω SST.

VOF (Volume Of Fluid) – to – DPM (Discrete Phase Model)

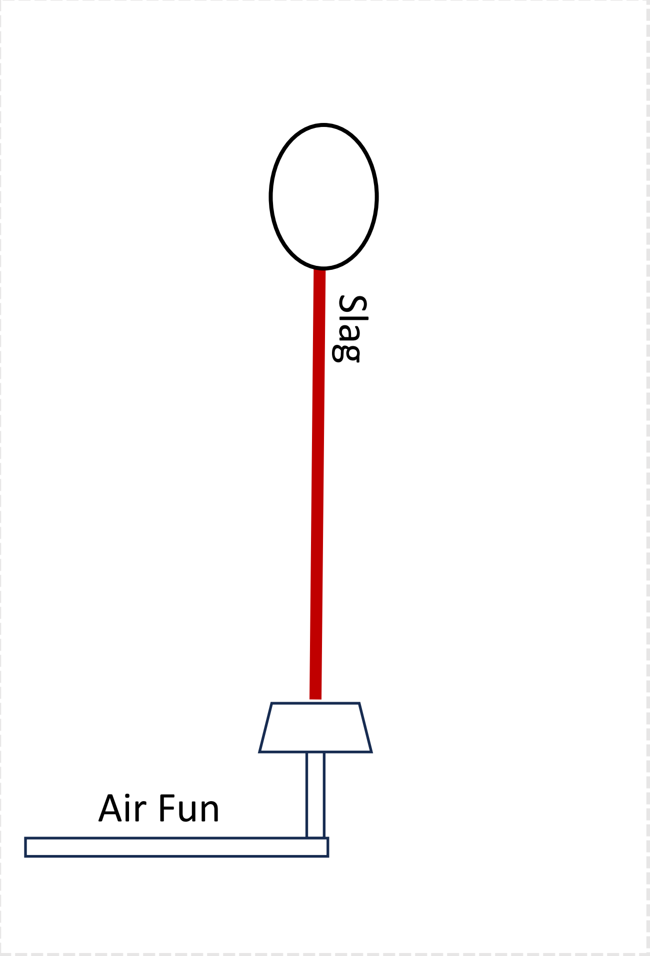
- ✓ Jet initial description (tracking liquid-gas interface)
- ✓ Capture instabilities and large structures formation (**primary breakup**)
- ✓ Explicit spray description from atomization to dispersion with a computationally intensive approach (*long* computation time)
- ✓ The **inputs are based on the process conditions** (such as the slag mass flow rate)
- ✓ The dispersion phase **(DPM) consists in the spherical droplets** formed during primary breakup
- ✓ **The output is the granulometry**, temperature and properties of the individual particles

Granulation Process – Geometry

*Side view**



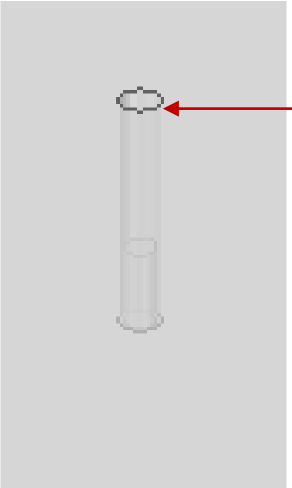
Front view



Plant view

*draw made by CSM

Boundary Condition

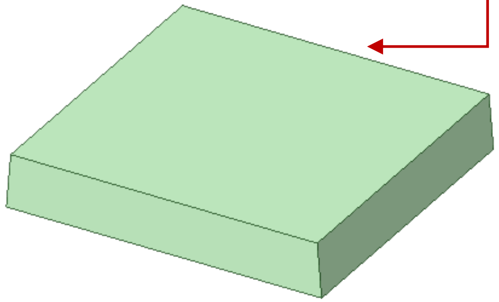


Inlet Slag

Mass Flow Inlet

m

T **1550** °C

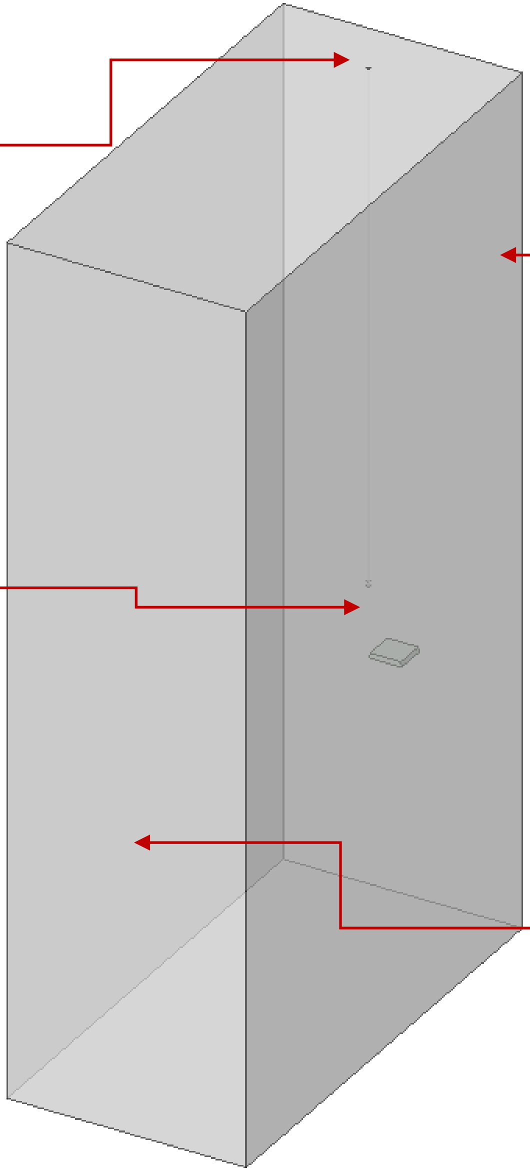


Inlet Air

Velocity Inlet

v

T **25** °C



Wall

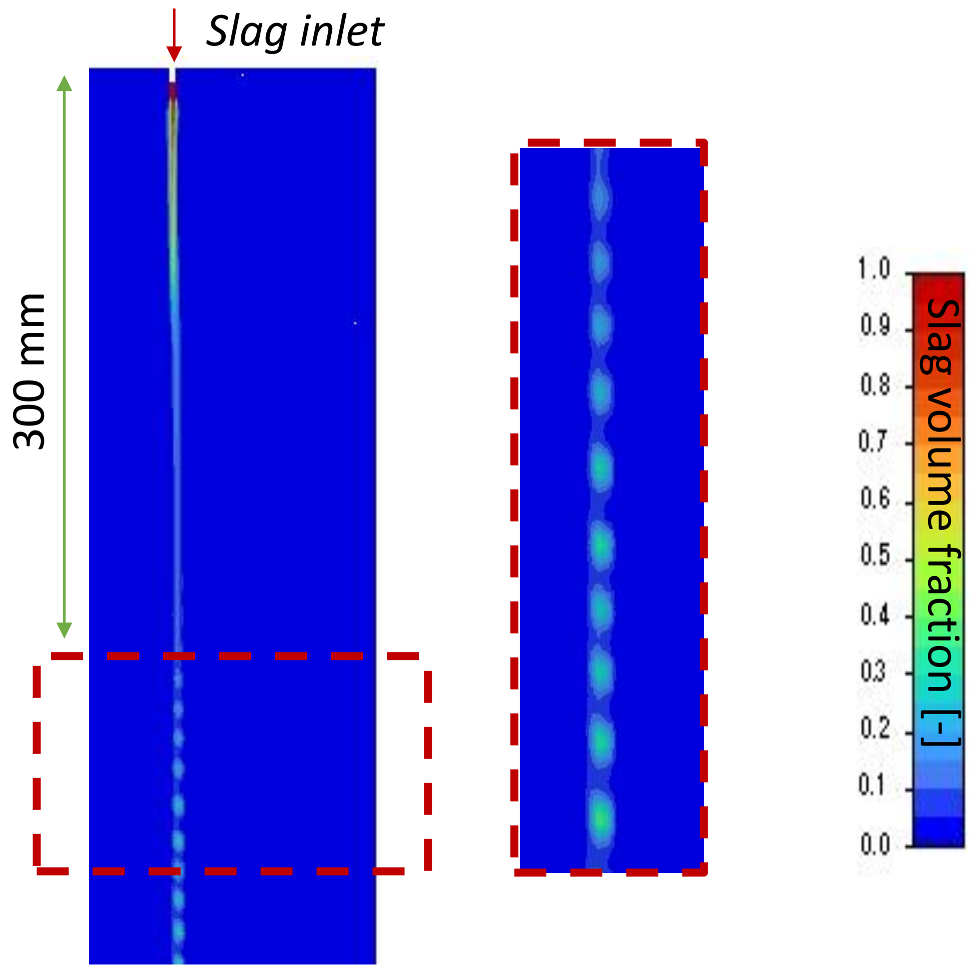
Outlet (Back)

Pressure Outlet

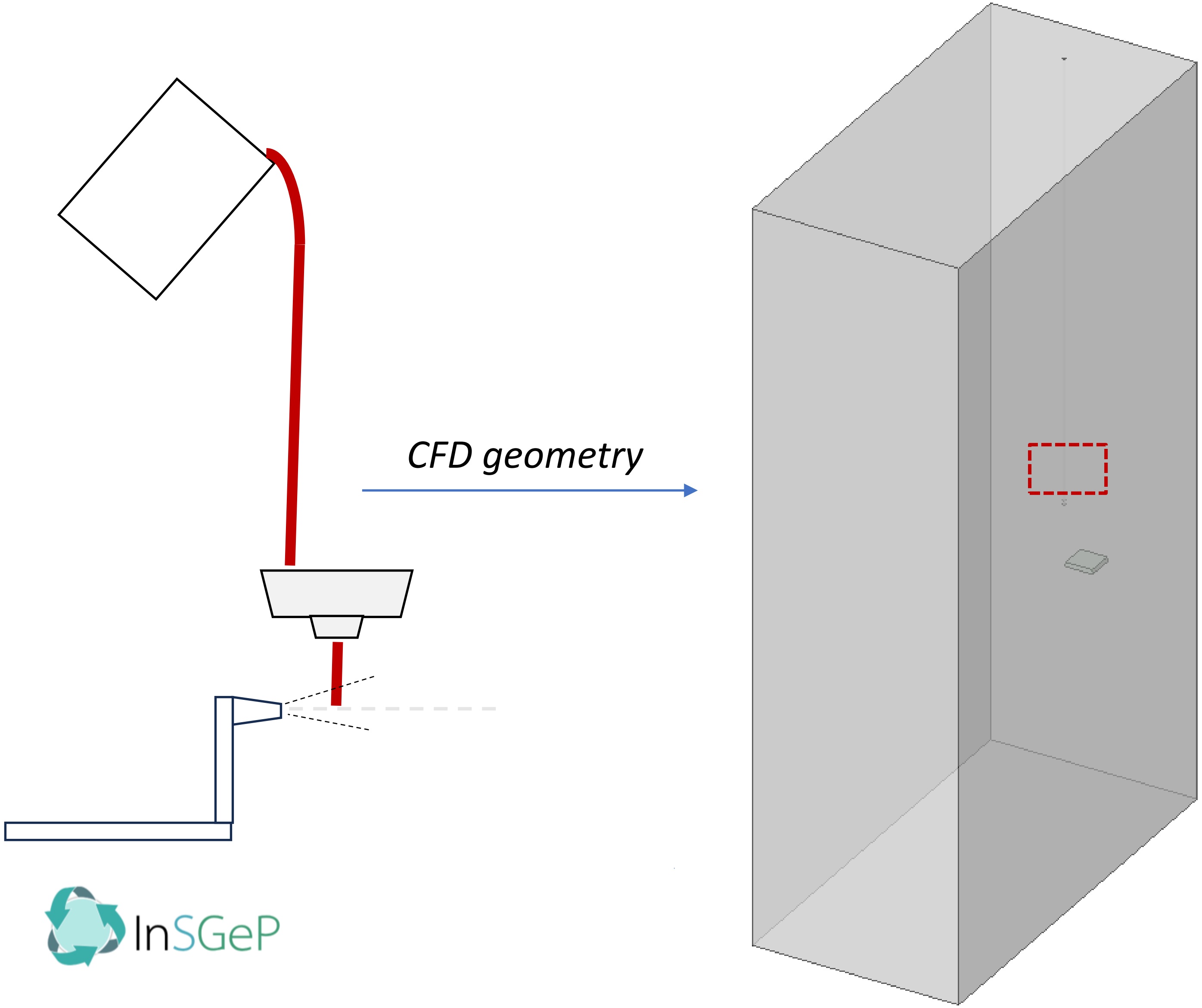
Simulation of the actual configuration

The CFD simulation with the CSM's geometry gives:

- a jet with a strong ***instability*** due to the distance between the point of slag release and the air nozzle
- The work conditions are ***unusual*** compared to the well know plant conditions



Simulation of New Configuration



In order to be closer to the standard granulation conditions and to achieve a stable jet, a new plant configuration was proposed by CSM.

The main difference is the introduction of a ‘***slag tundish***’ that allows to obtain a more stable jet with a higher diameter.

The CFD geometry is different by means:

- Position of the slag inlet
- Diameter of the slag inlet

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Tenova Dry Slag Granulation Modelling

6- Restart with semi-empirical correlation or using CFD

1- Definition of the chemical and physical properties of the slag

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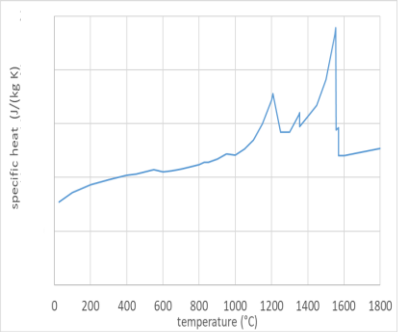
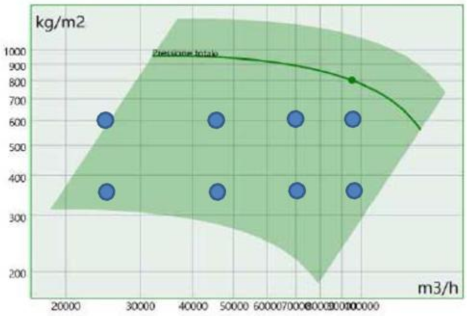
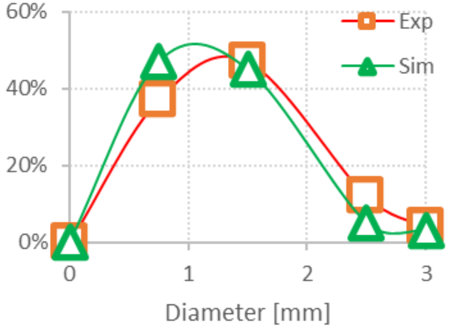
5- Pilot test



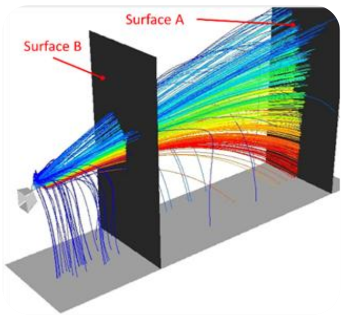
Rina-CSM
Slag Properties Models



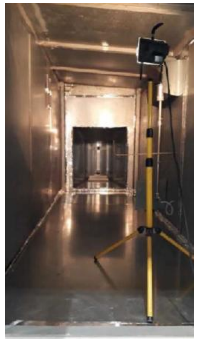
Tenova
Process Definition



Tenova
Granulometry Definition



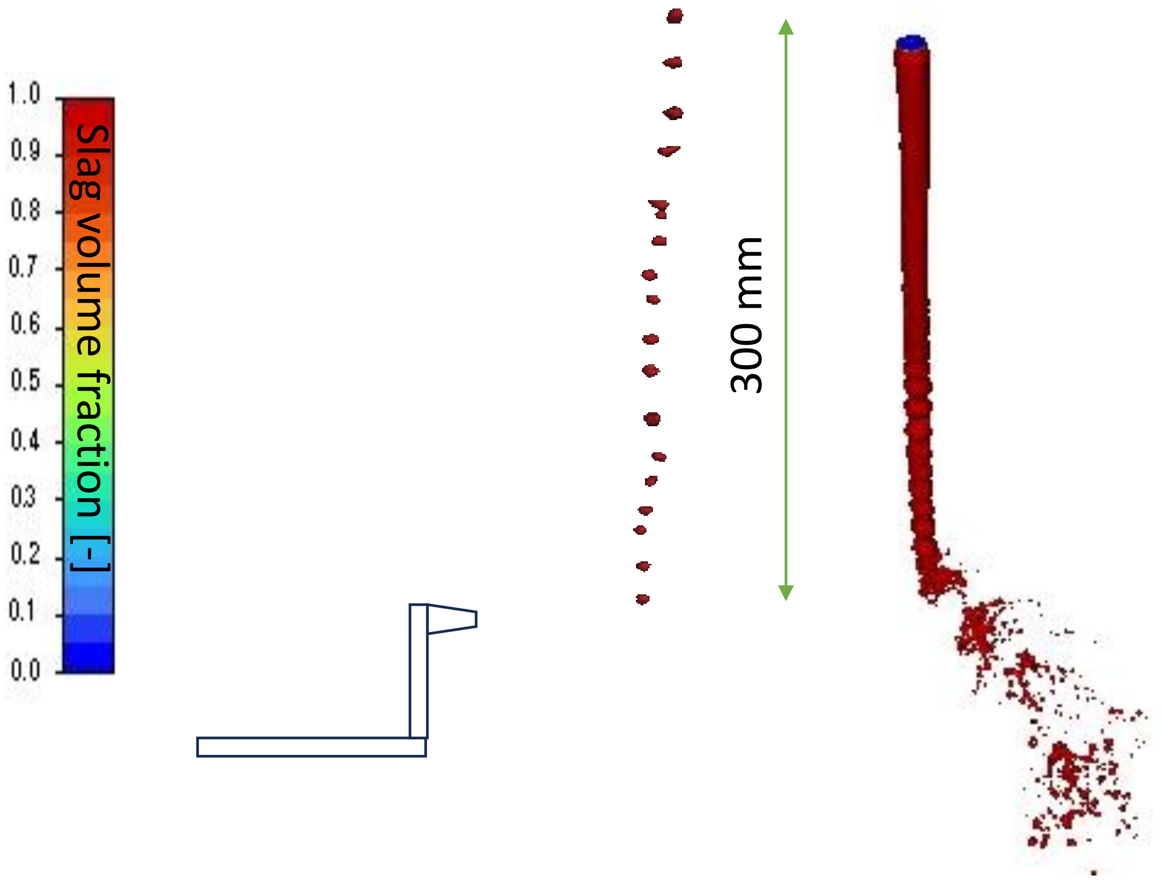
Tenova
CFD
Particle Trajectory/ Cooling



Rina-CSM
Validation

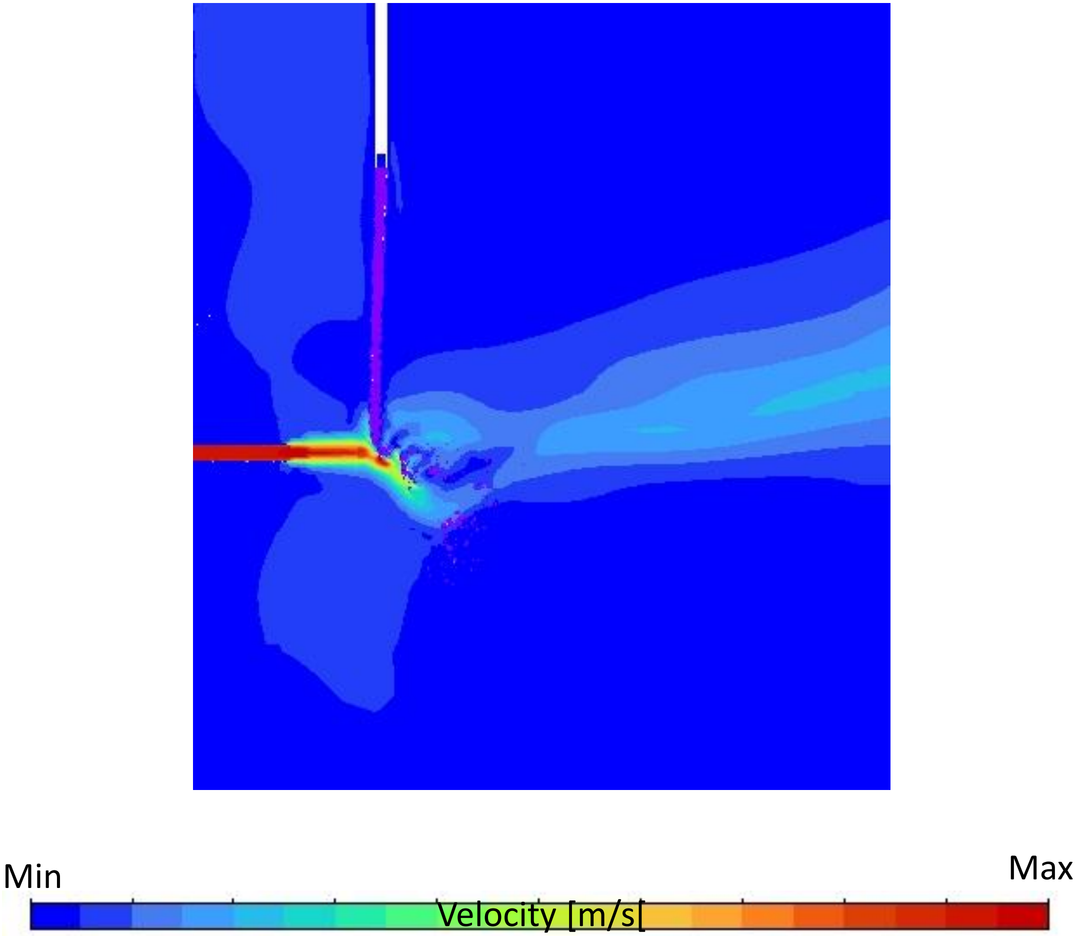
Simulation of New Configuration

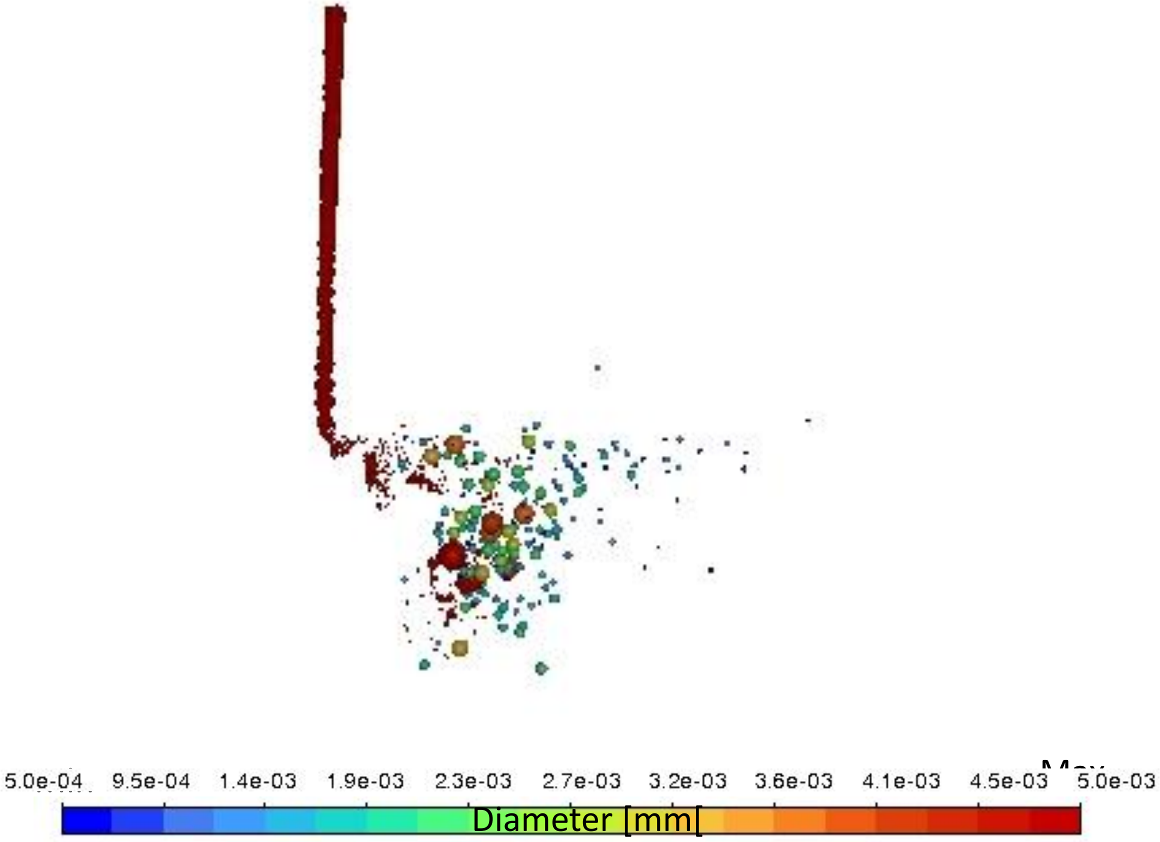
Old configuration **New configuration**



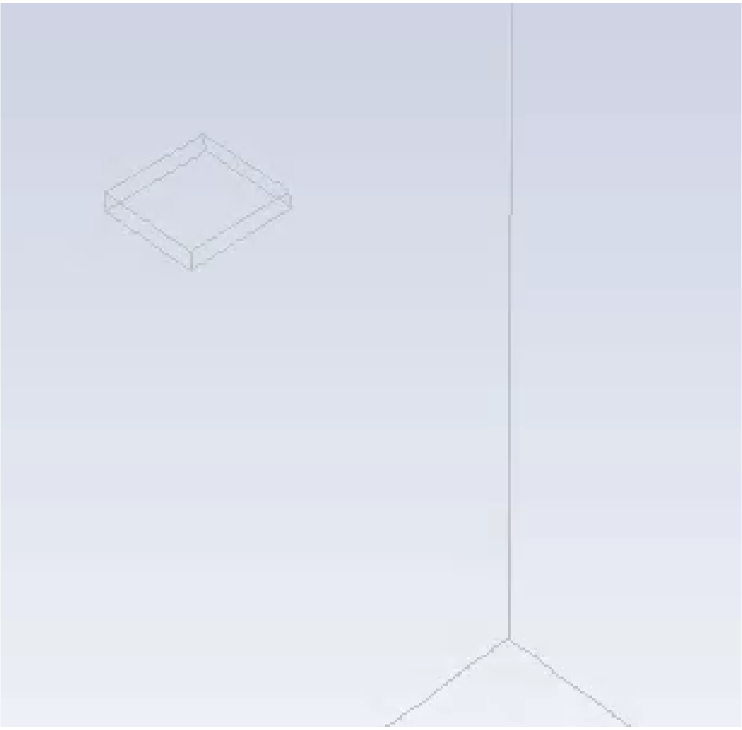
The CFD results confirm the success of the new configuration in terms of jet stability.

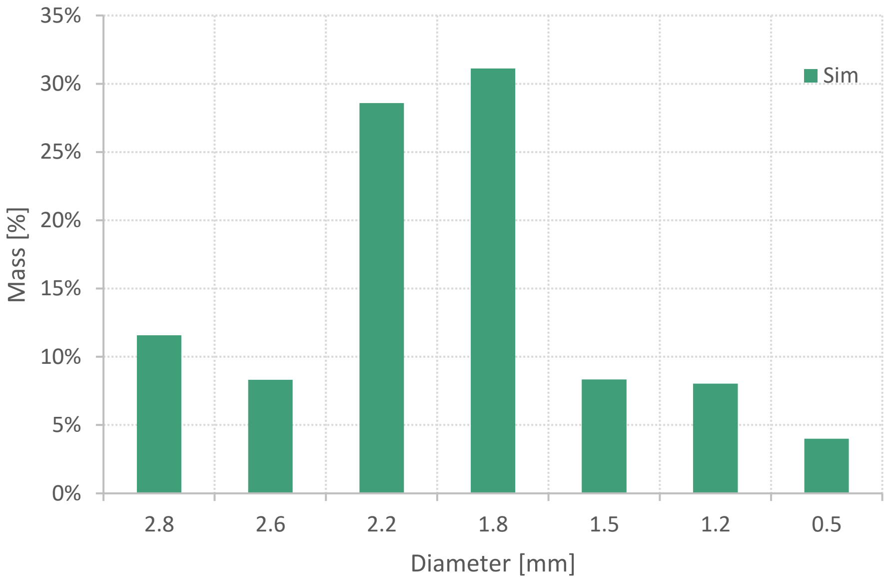
Simulation of New Configuration





Simulation of New Configuration - RESULTS

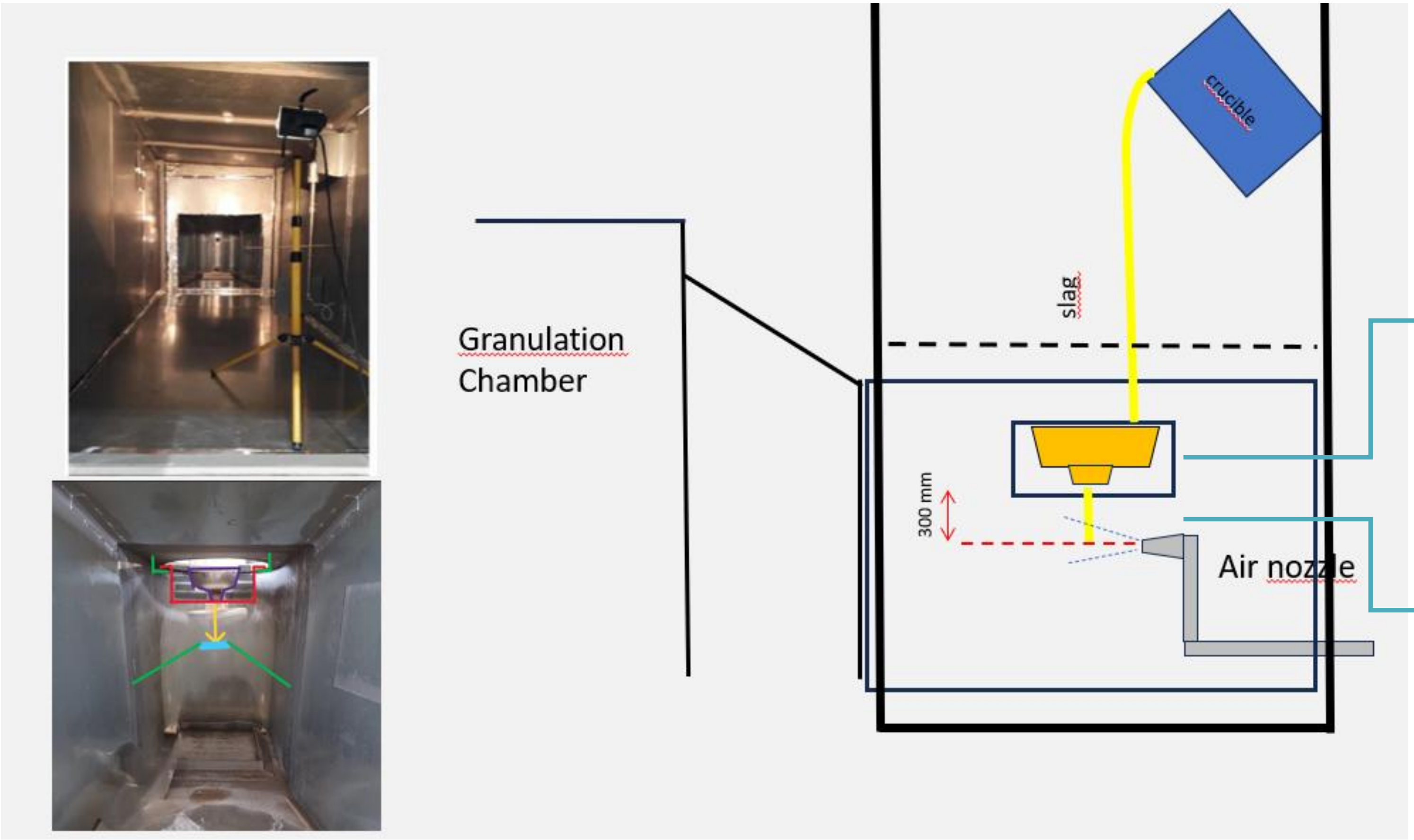




Average diameter		
CFD	1.98	mm

Modification of Rina-CSM Pilot Plant

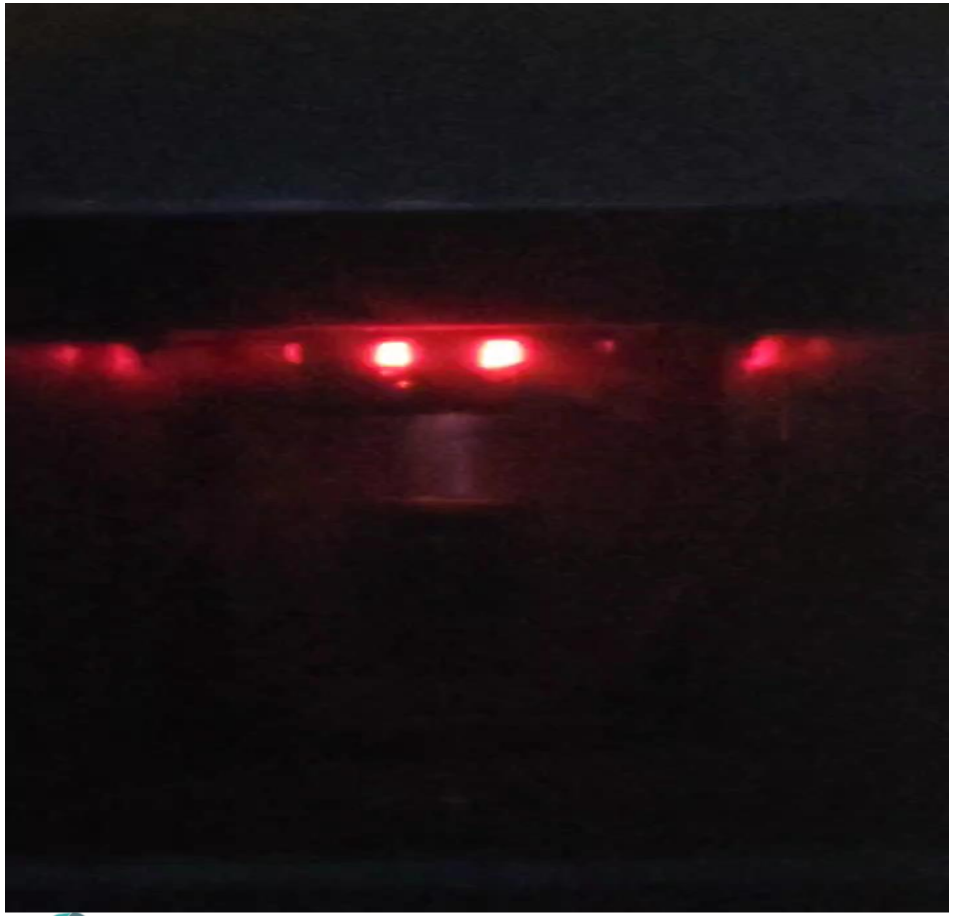
The pilot plant has been improved according to simulation carried out by Tenova



Continuous slag flow

Granulation Test @ Rina-CSM Pilot Plant

Testing of dry slag granulation: 100% DRI



Input quantity:
15 Kg di Fe+ 5 Kg slag

Average diameter		
Exp	1.86	mm
CFD	1.98	mm

tenova

Next steps

T 4.3

Testing of dry slag granulation

- CFD Simulation of DPM
- Granulometry distribution comparison
- Test on others slag samples
- Creation of granulated slag for utilization test

InSGeP

InSGeP

Valorization of EAF slags from DRI melting with dry granulation process

Marta Guzzon - Tenova

European Commission

The research leading to these results has received funding from the European Union's Research Fund for Coal and Steel research programme under grant agreement number: 101112665

InSGeP

Market analysis and stakeholder consultation

Parinaz Seifollahzadeh, K1-MET

05.03.2025

1st InSGeP workshop - Investigations of Slags from Next Generation Steel Making Processes

European Commission

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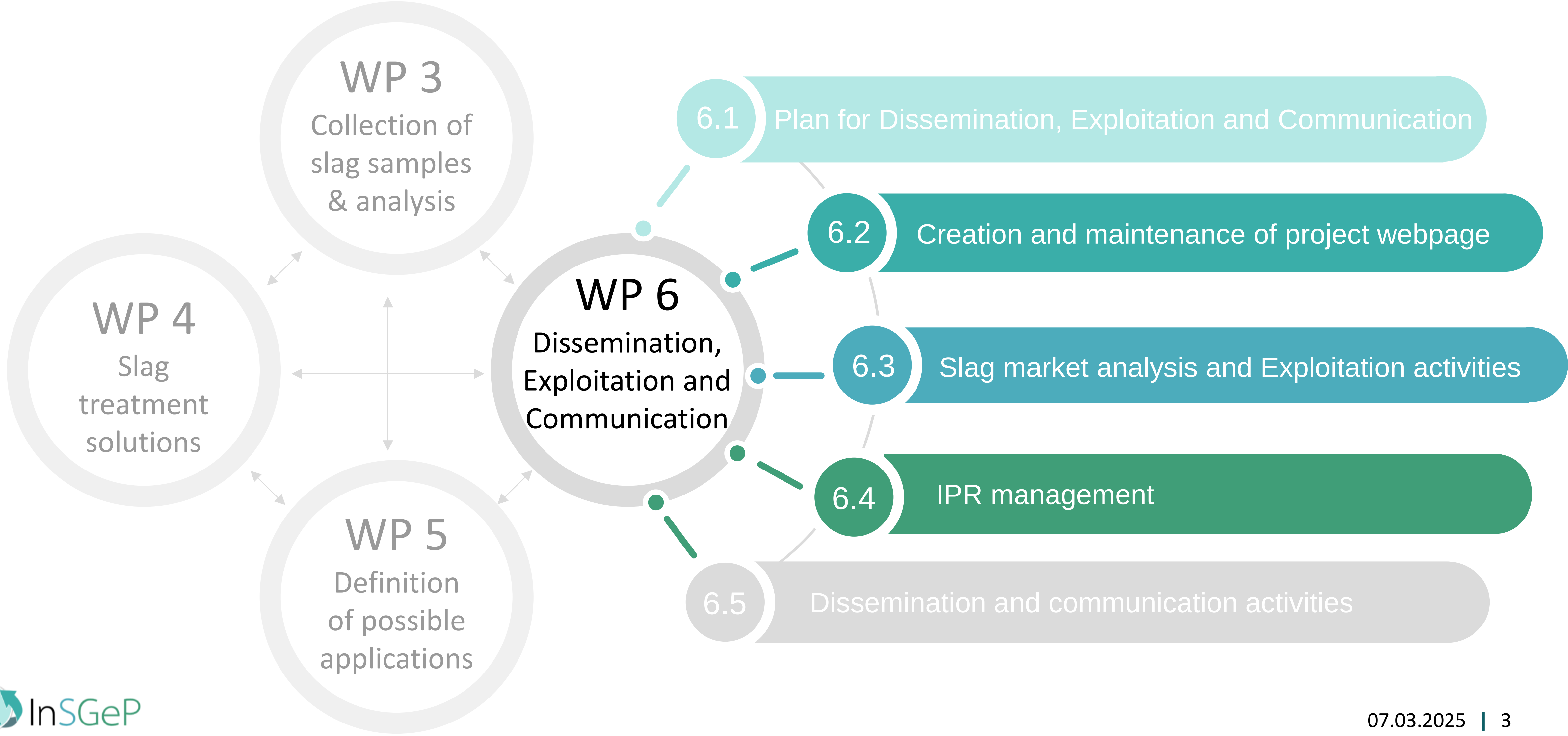
Project Structure

WP6 – Dissemination, Exploitation and Communication



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Historical Introduction

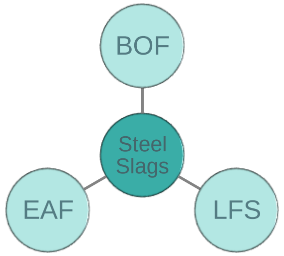
Types of slag available on the market & Fields of slag utilization

350 B.C, Greece	1589-1652[1,2]	1813, England[3]	1862-1865	World War I & II
dry out wounds[1]	cannon balls	1st use in road construction	discovery of hydraulic activity, cement[1,2]	Increase in steel production

cannon balls

Fields of slag utilization

a. Cement/Concrete: BF slag to substitute primary material to decrease CO_2-emission
b. Road construction: minor usage of BF slag, BOF, EAF and ladle furnace slag depending on regional regulations
c. Agriculture and soil amendment: BF, BOF and ladle furnace slag, again regulations concerning hazardous elements are important
d. Metallurgical use (internal recycling): mostly BOF slag, but pay attention to build up of phosphorous
e. Other applications: e.g. marine fertilizers, 3D printing and more



*BF: Blast furnace slag
*BOF: Basic oxygen furnace slag
*EAF: Electric arc furnace slag
*LFS: Ladle furnace slag / Secondary metallurgical slag

1. EUROSLAG, Online: www.euroslag.com (accessed on 16 February 2024).
2. Matthes W., Vollpracht A., Villagrán-Zaccardi Y. et al.: Ground Granulated Blast-Furnace Slag, in: Properties of Fresh and Hardened Concrete Containing Supplementary Cementitious Materials, pp. 1 - 53, 2018.
3. Pasetto, M., Baliello, A., Giacomello, G. et al.: The Use of Steel Slags in Asphalt Pavements: A State-of-the-Art Review. Sustainability 2023, 15, 8817.

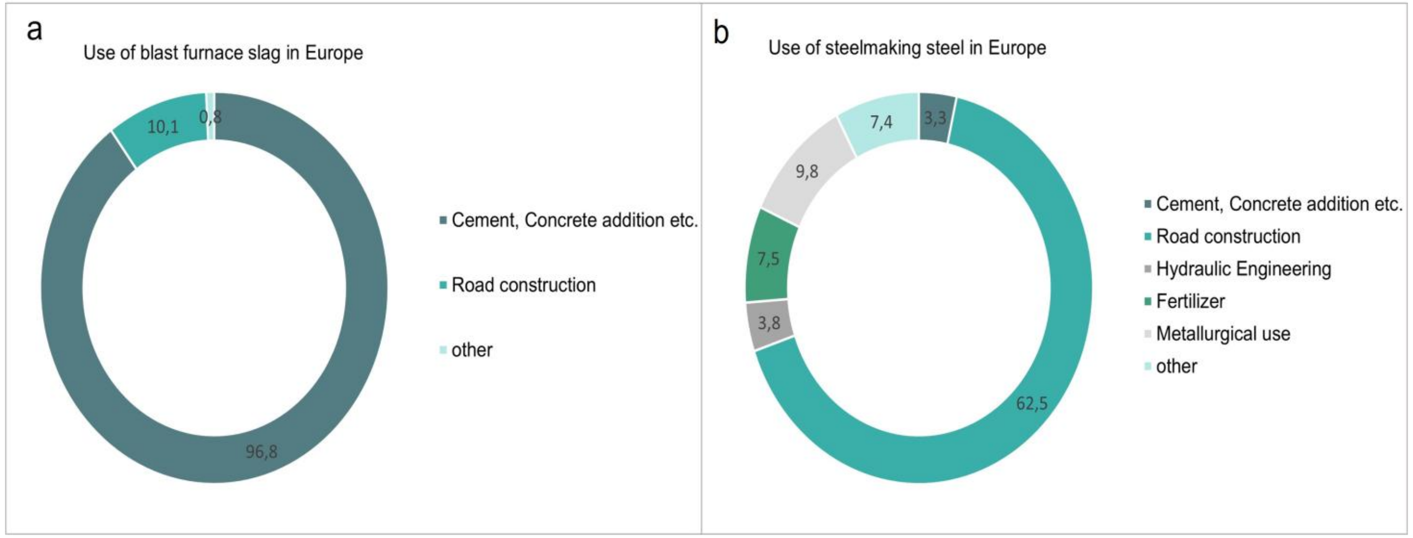
Slag utilization in different parts of the world

a. Europe
b. USA
c. Japan:
d. China:

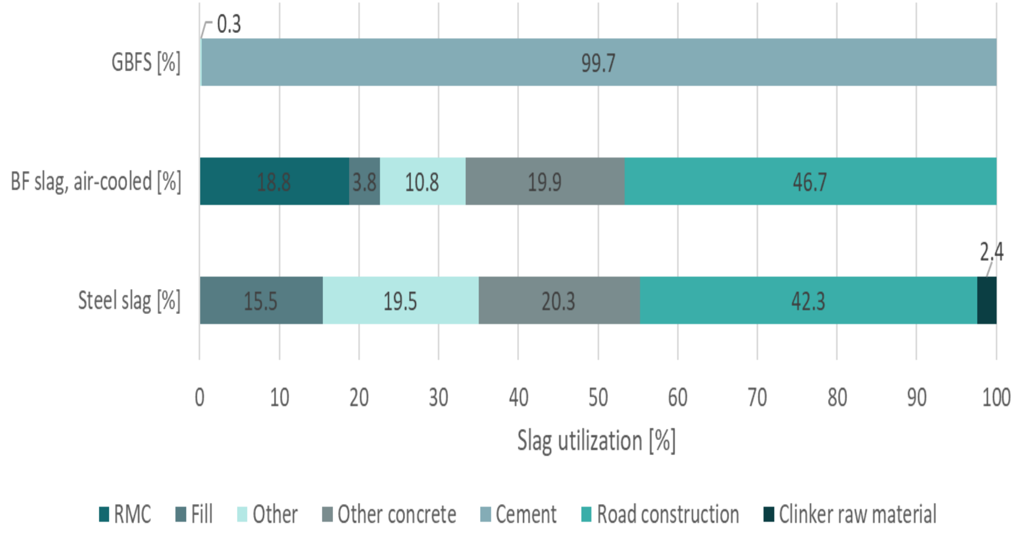
Slag utilization in different parts of the world

Europe, USA

The recycling rate of blast furnace slag in Europe is quite impressive ~ 99%[5]



Utilization of BF slag (a) and steel slag (b) in [%] in Europe (2023)[1]



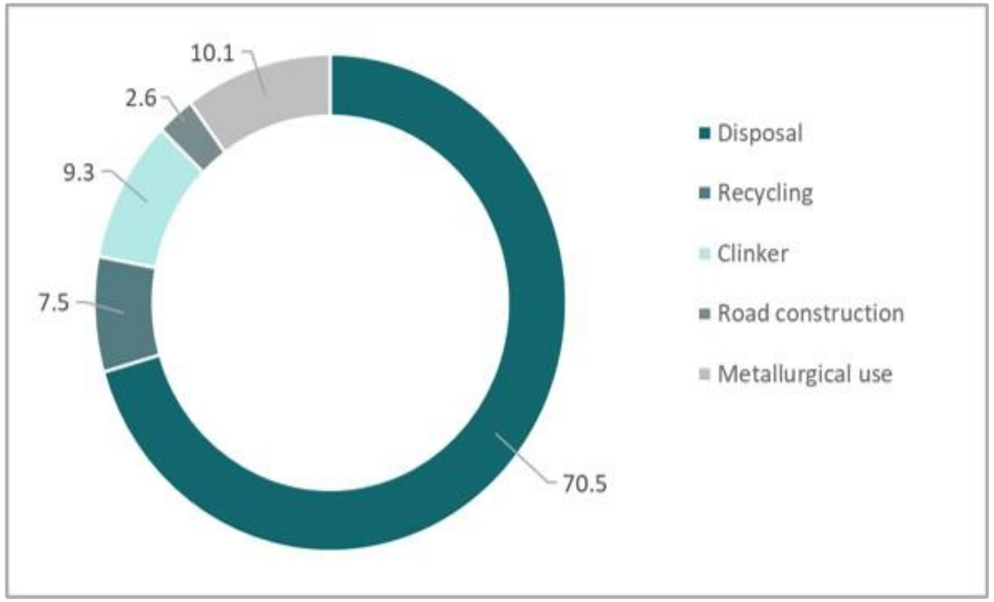
Recycling of slag in the United States (2016) [4]

1. EUROSLAG, Online: www.euroslag.com (accessed on 16 February 2024).
4. Harder J.: Valuable by-products: Slag recycling, in recovery Recycling Technology Worldwide, 2,2020, 2020.
5. https://www.recovery-worldwide.com/en/artikel/slag-recycling-3528047.html

- GBFS: Granulated Blast Furnace Slag
- RMC: Rigid Metal Conduit

Slag utilization in different parts of the world
China

Till 2017 mostly landfilled but rapid development



Overview of valorisation of steel slag in China (2017)[6,7]

6. Harder J.: Valuable by-products: Slag recycling, in: recovery Recycling Technology Worldwide, 2,2020, 2020.
7. Guo, J., Bao, Y., and Wang, M.: Steel slag in China: Treatment, recycling, and management. Waste management, 78, 318-330, 2018.

Slag utilization in different parts of the world

Japan[8]

In Japan, the BF slag achieves a recycling rate of 100 %

Slag type		Applications
BF slag	Air-cooled slag	Road base course material
		Coarse aggregate for concrete
		Cement clinker raw material (replacement for clay)
		Raw material for rock wool
		Calcium silicate fertilizer
	Granulated slag	Raw material for Portland BF slag cement
		Blending material for Portland cement
		Concrete admixtures
		Raw material for cement clinker (replacement for clay)
		Material for civil engineering works, ground improvement material (backfill material, earth cover material, embankment material, road subgrade improvement material, sand compaction material, ground drainage layers, etc.)
		Fine aggregate for concrete
		Calcium silicate fertilizer
		Soil improvement

Air-cooled slag

Granulated slag

Slag type		Applications
Steel slag	Converter slag, EAF slag	Aggregate for asphalt concrete
		Base course material
		Material for civil engineering works, ground improvement material (material for sand compaction piles)
		Raw material for cement clinker
		Fertilizer and soil improvement

Converter

Electric arc furnace

Steelmaking slag (converter slag)

8. Nippon: Online: https://www.slg.jp/pdf/Amounts%20of%20Blast%20Furnace%20Slag%202017FY.pdf (accessed on 12 April 2024).

Stakeholder survey

Trends and developments

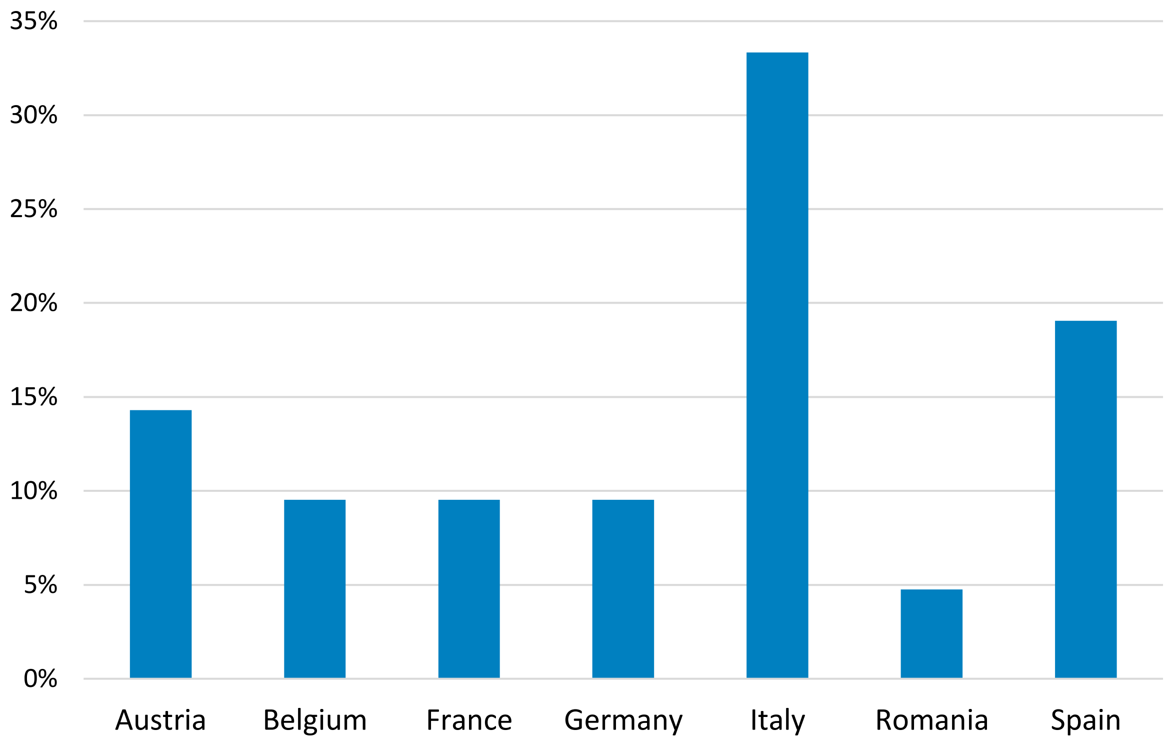
37 participants started the survey of which

- 36 participants (97 %) agreed and
- 1 participant (3 %) disagreed

to the confidentiality disclaimer

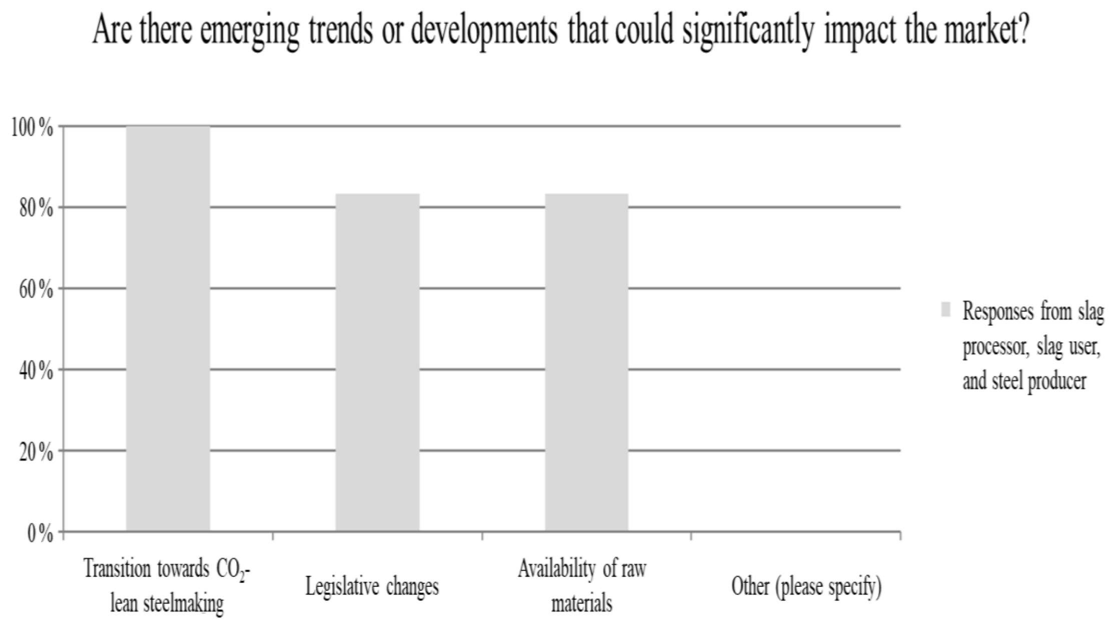
Stakeholder groups:

- Slag processor
- Slag user
- Steel producer
- Scientific community
- Government & regulatory body ✗



Allocation of participants by country

Trends and developments



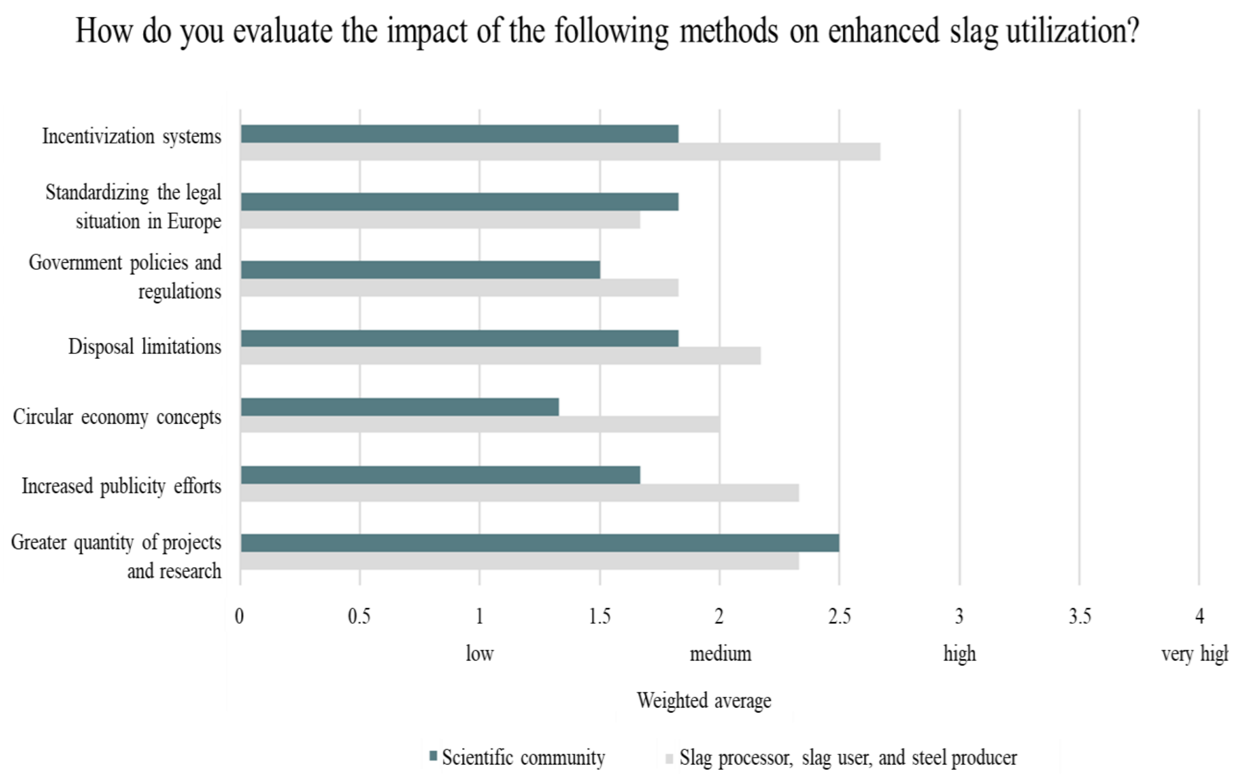
Emerging trend or developments on the slag market

How stakeholders envision the future of slag utilization in their industries:

- Almost everyone agrees that the transition towards CO_2-lean steelmaking and the legislative situation have an influence
- Slag processors, slag users and slag producers aim at the reuse of slag within their own production process
- They want to Proceed with the handling of the slag as a product and offer it to the market
- Higher value applications making greater use of the slags' potential as technical material (including CO_2 capture potential and hydraulic properties of the slags)
- Utilization of EAF slag as an artificial aggregate to replace raw material (e.g. basalt)
- Utilization of steel slag in cement process to replace Ordinary Portland Cement (OPC)
- Utilization of white slag as additives for cements and mortars
- Utilization of black slag to replace gravel and basalt

Stakeholder survey

Drivers influencing the growth of the slag market

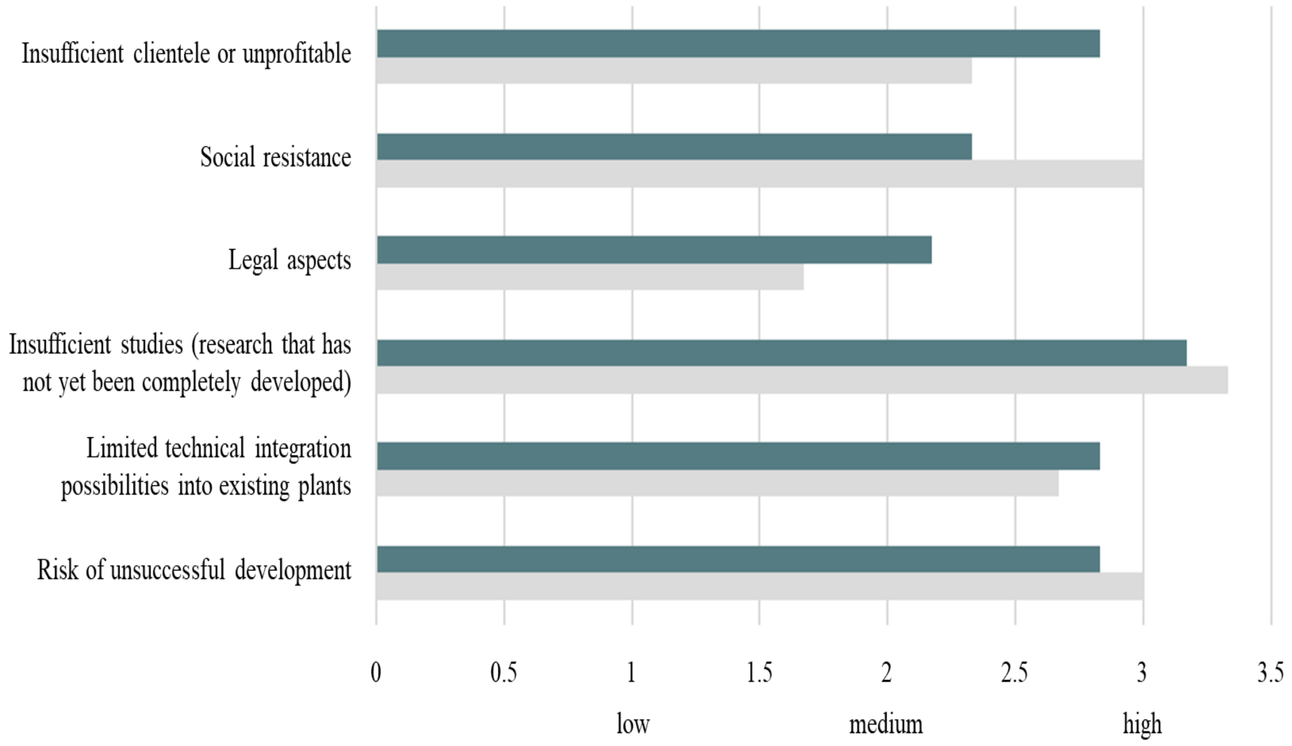


Identification of key drivers influencing the slag market

- Although the group consisting of slag processors, slag users, and steel producers opted for the implementation of incentive systems, the scientific community deems it necessary to undertake more projects and research.
- Scientific community predicts development of novel application, adaptation of slag utilization to new steel production routes
- Demand for building material rises a more slag is needed for cement and road construction
- Increasing awareness for environmental sustainability makes slag even more needed
- Governments enforce circularity and sustainability
- More research a more ways to utilize slag

Stakeholder survey

Challenges and market barriers



Challenges and market barriers

- Risk of spending money on unsuccessful developments
- Environmental limitations and regulations due to chemical compounds
- Lack of awareness concerning the possibilities for the usage of slag
- Varying quality of slag is a problem for industries utilizing slag
- Instability of prices due to economic situation and raw materials
- Integration into existing plants should be possible

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Market analysis and stakeholder consultation

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European Commission

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