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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

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

European Commission

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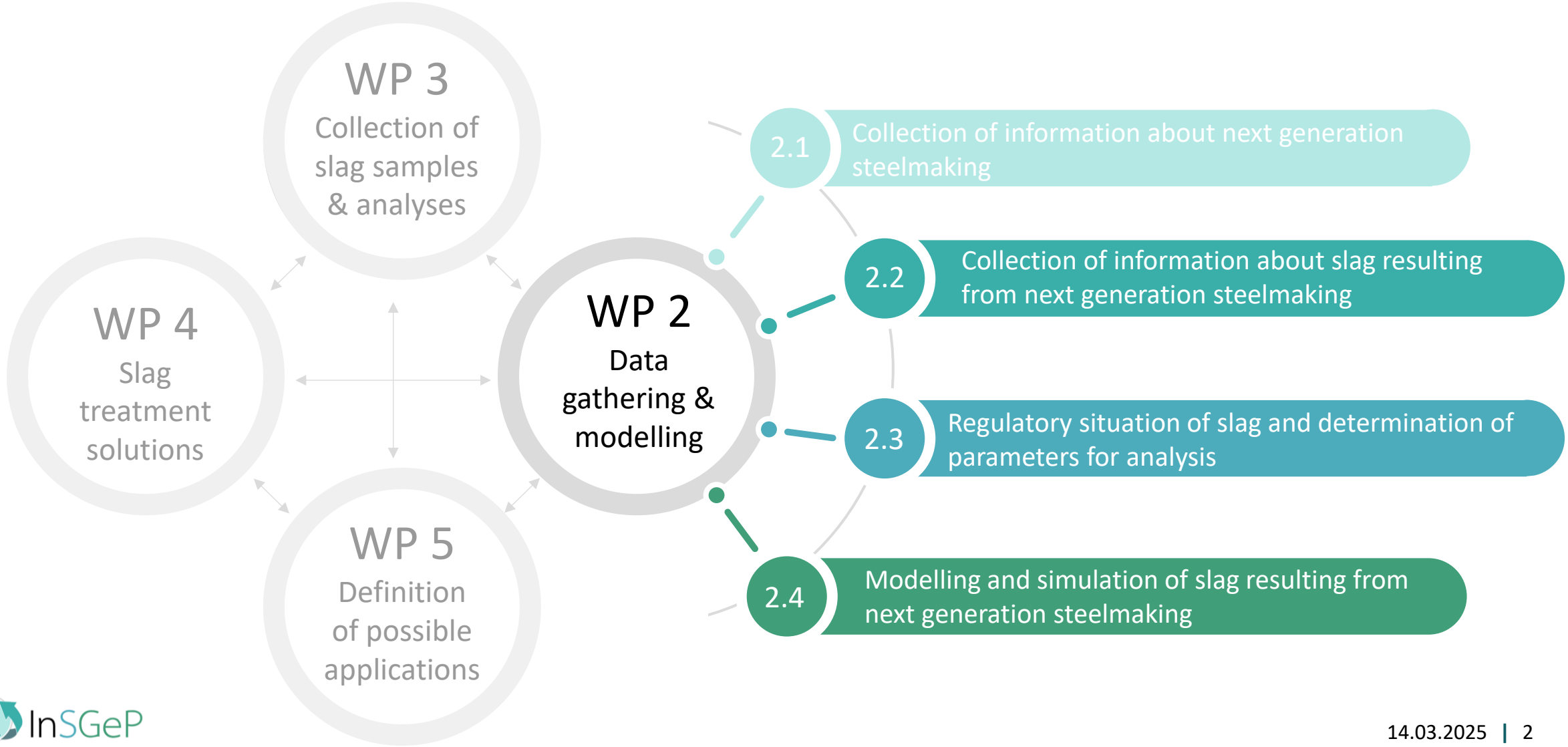
Project Structure

WP2 Data gathering about slag produced from next generation steelmaking



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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**

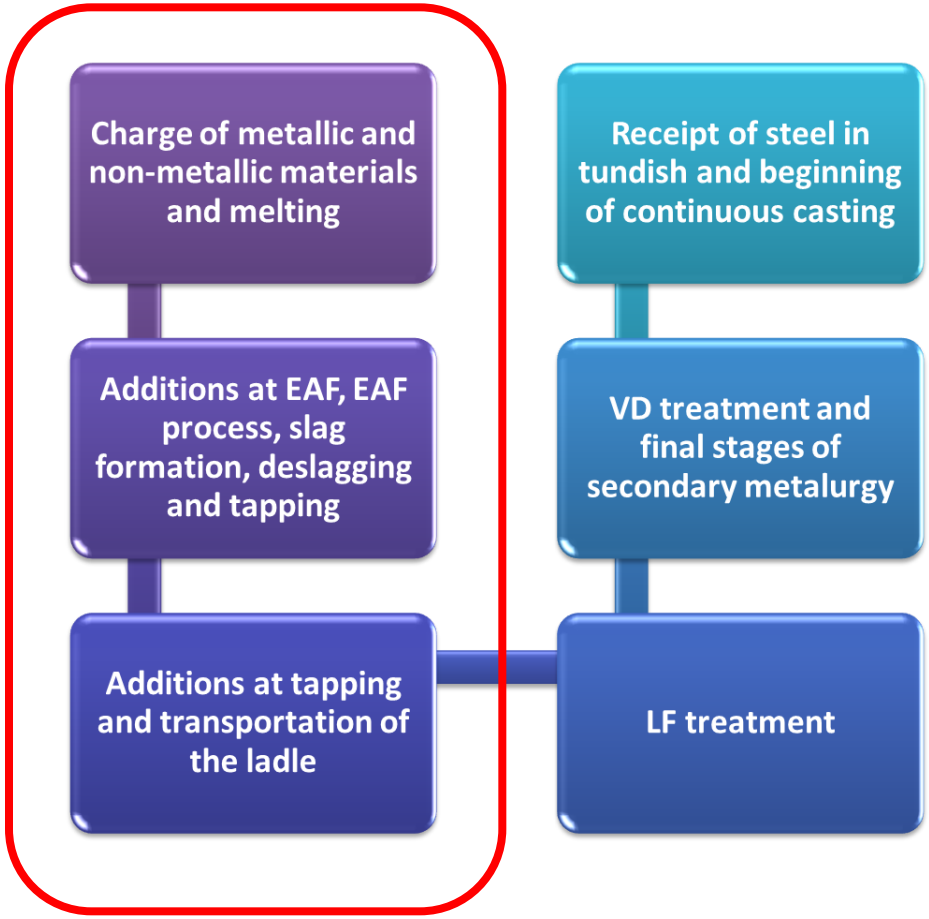
- **Solutions for counteracting negative effects can be analysed**

- 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



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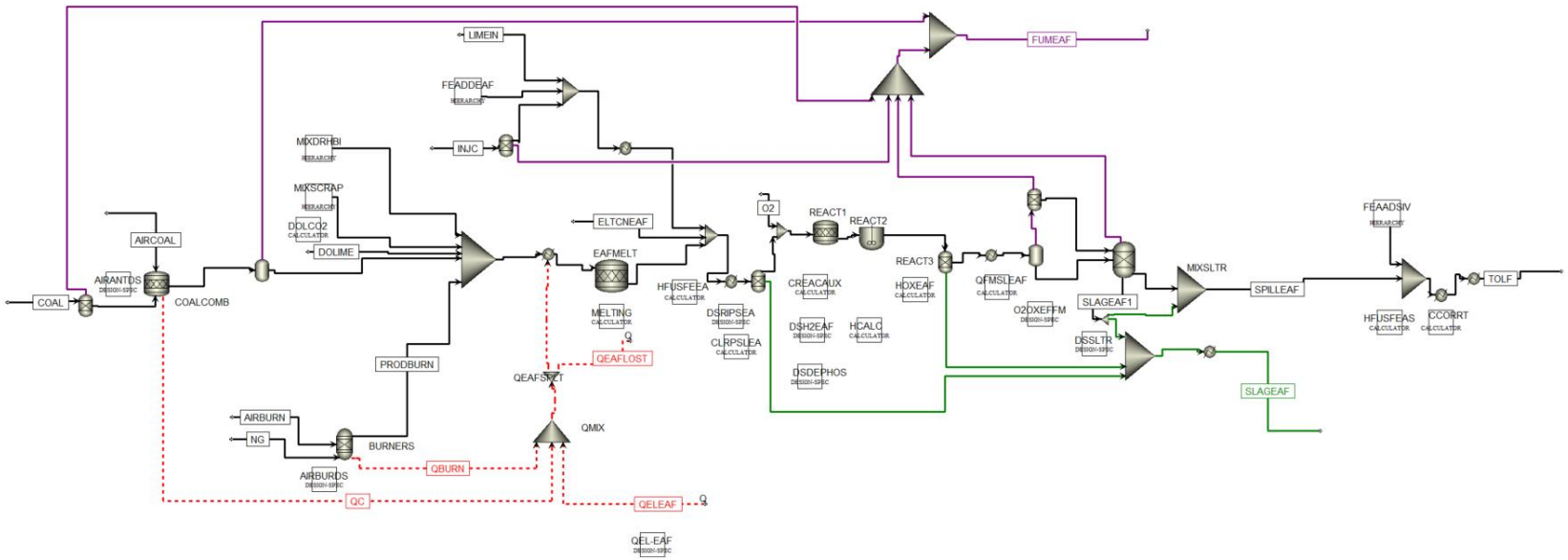
Flowsheet model of EAF-based steelmaking route

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



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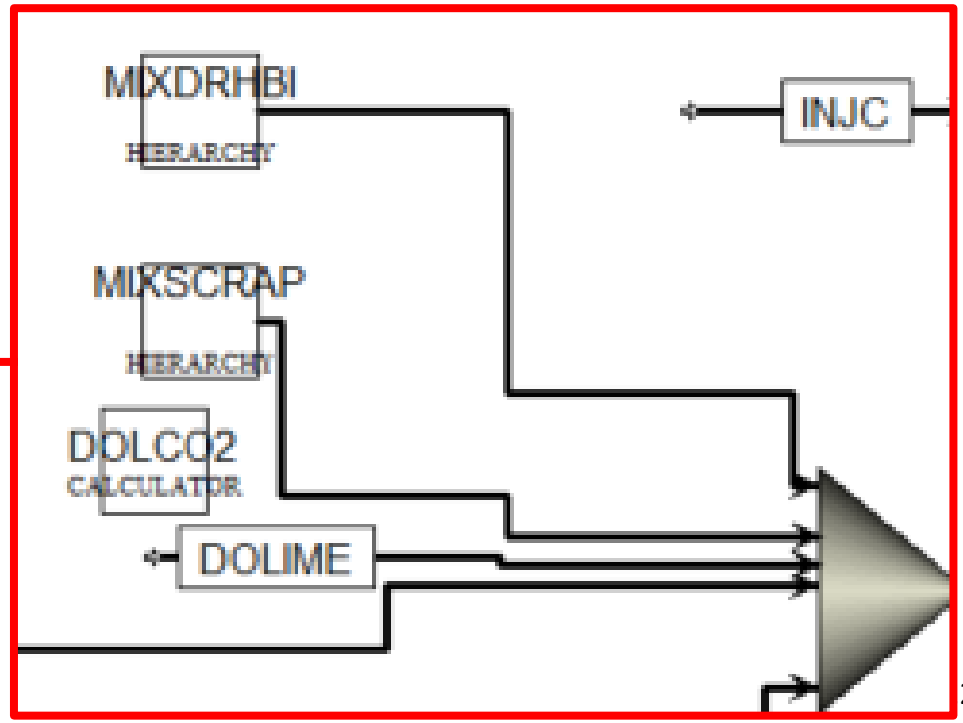
Added hierarchycal block Including streams of HBI and DRIs of different qualities and temperatures:

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



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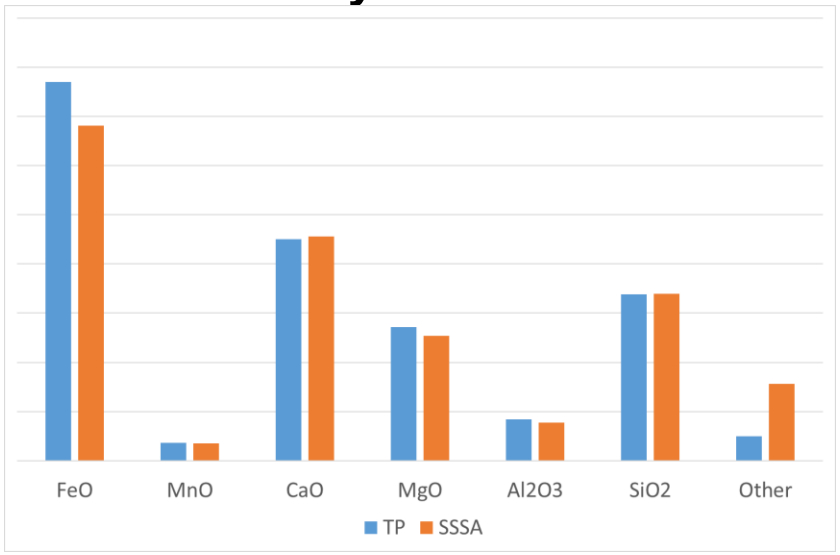
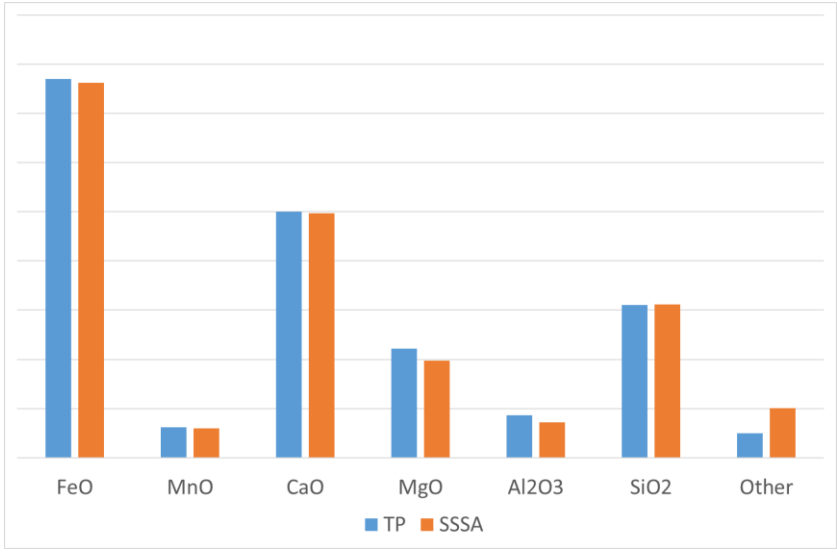
Flowsheet model of EAF-based steelmaking route

Validation

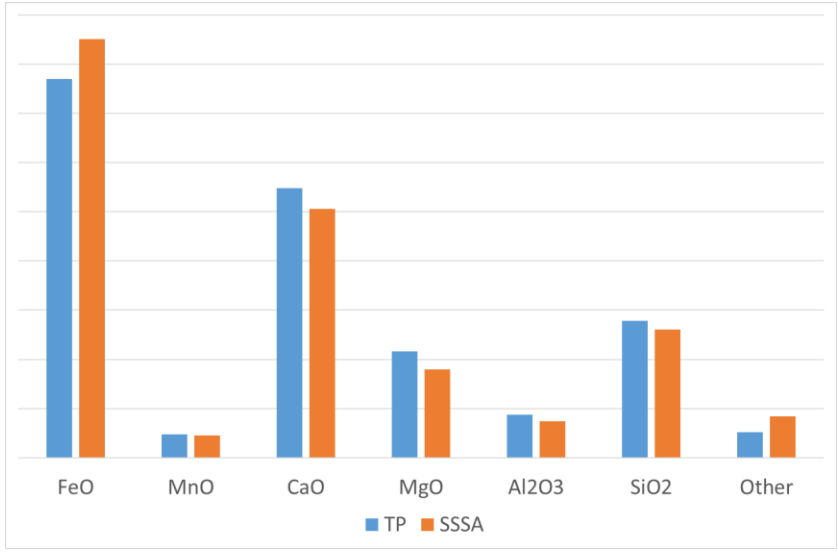
- **Example of validation results** comparing slag compositions of Technology Provider Data and flowsheet model (values are not reported for confidentiality reasons) → **model has a good accuracy**



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

- **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

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**

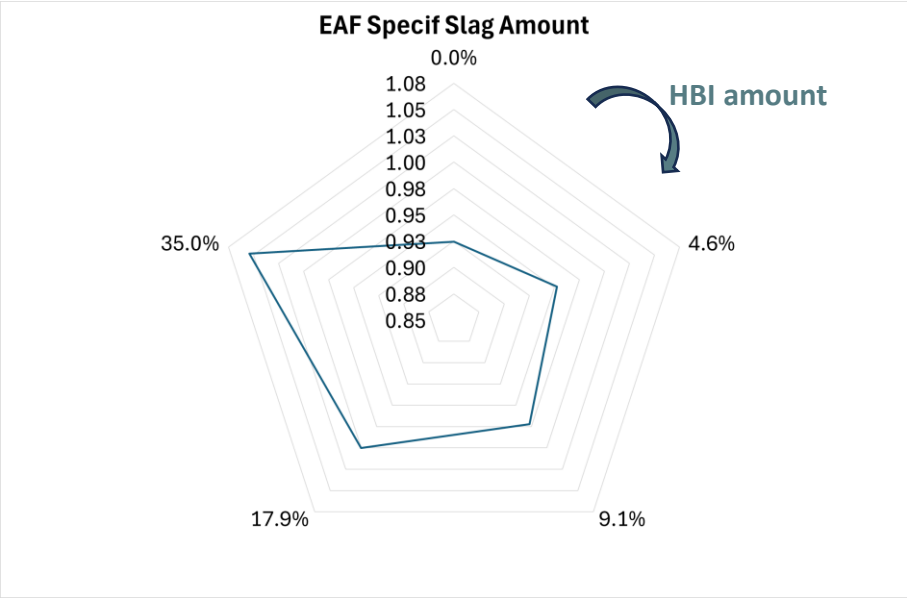
- Besides the composition and the amount of EAF slags, depending on the scenario, the following further parameters are monitored:
  - Tapped steel composition (especially in terms of tramp element, e.g. P)
  - EAF electricity
  - Resource consumptions

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)

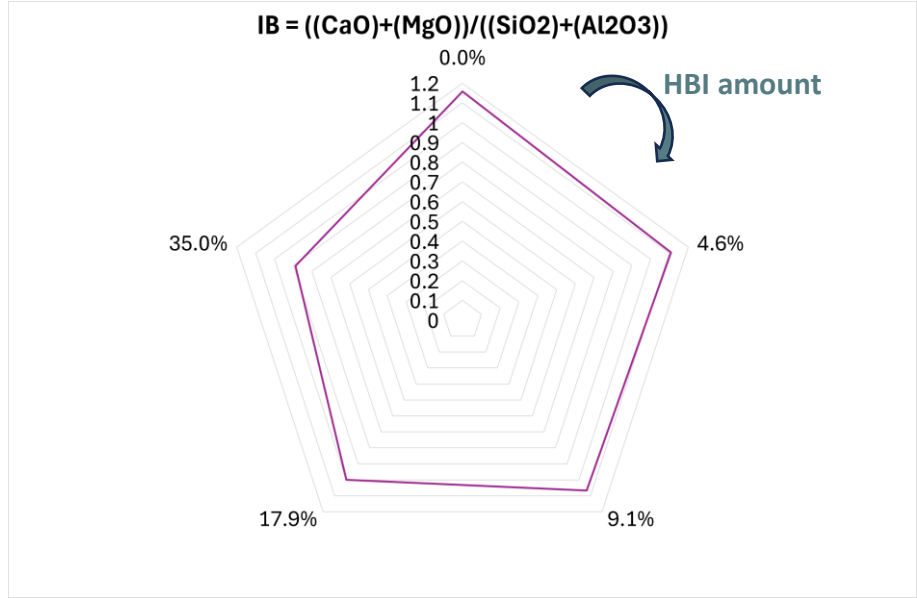
- **By ensuring the same amount of fed iron**
- **Keeping fixed all the other inputs (e.g. non-metallic charge materials and additions)**



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

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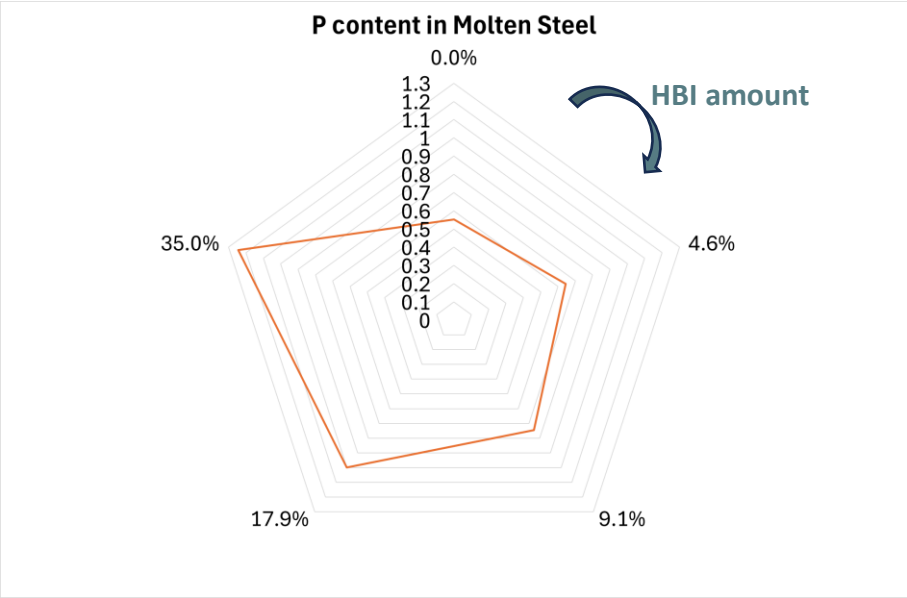
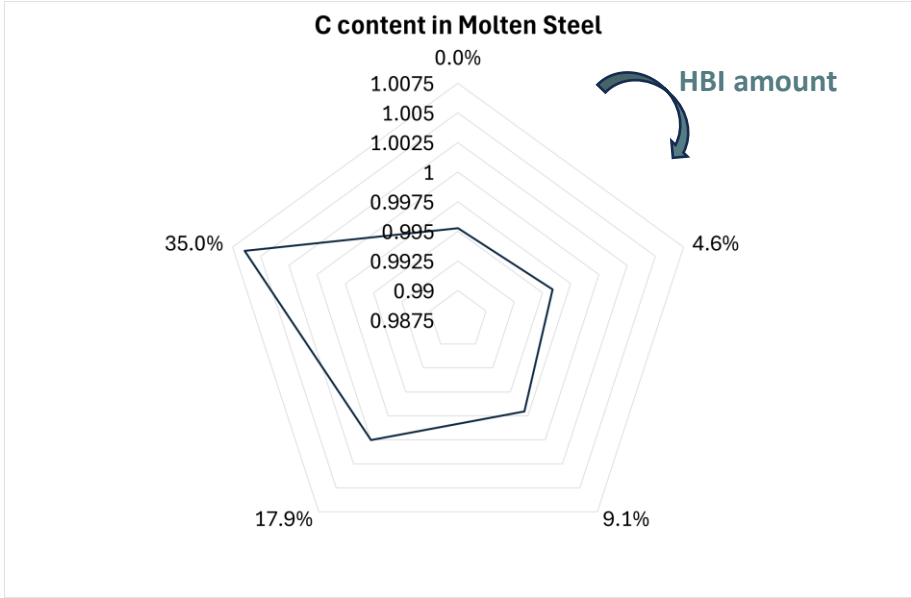


Effects on molten steel
Increasing HBI:

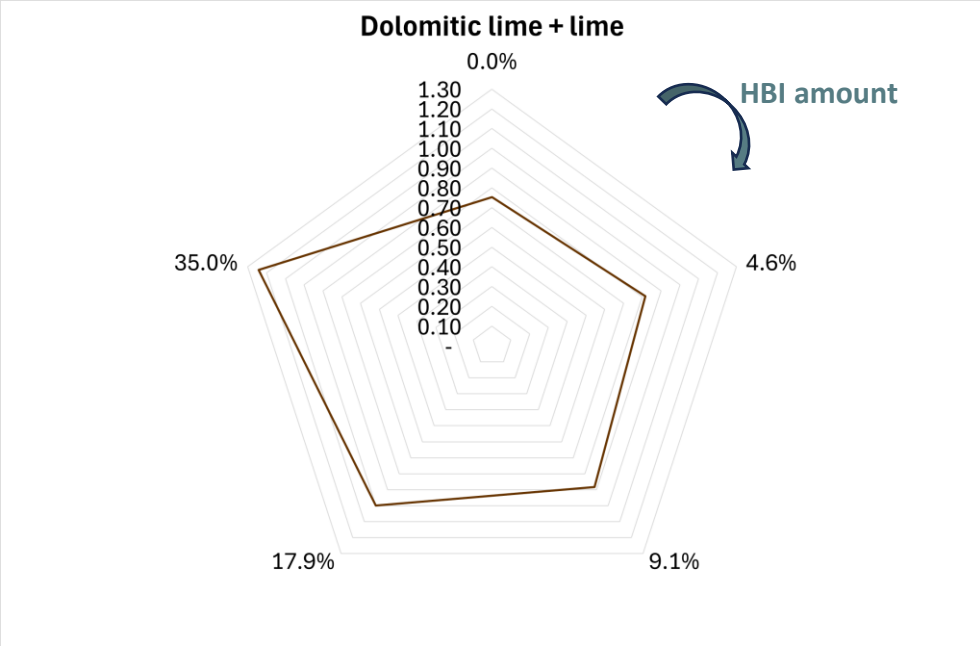
- **P content increases** because of more acidic slag
- **C content is almost stable** (reported variation is small)
- **S content slightly increases** because of IB decrease and FeO increase in slag



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**

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)

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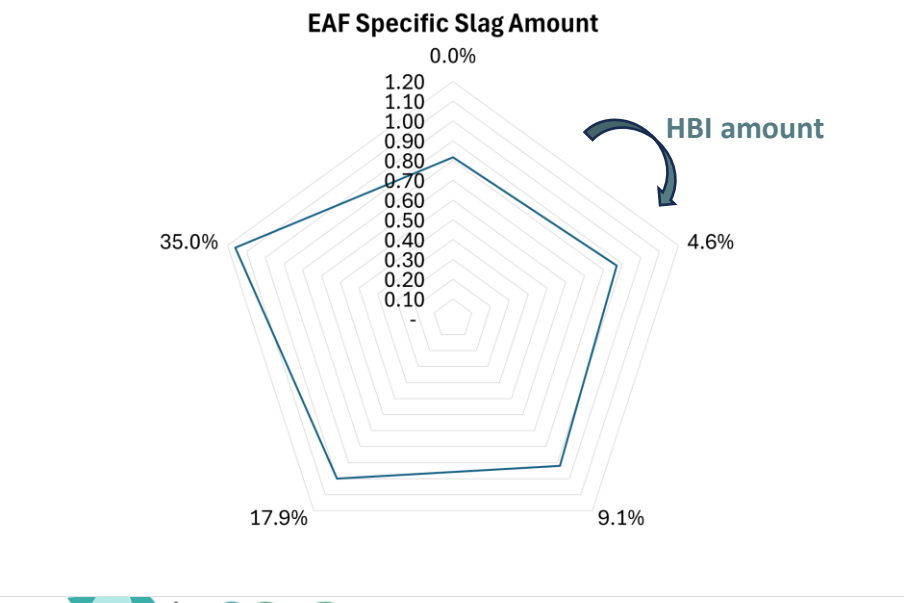


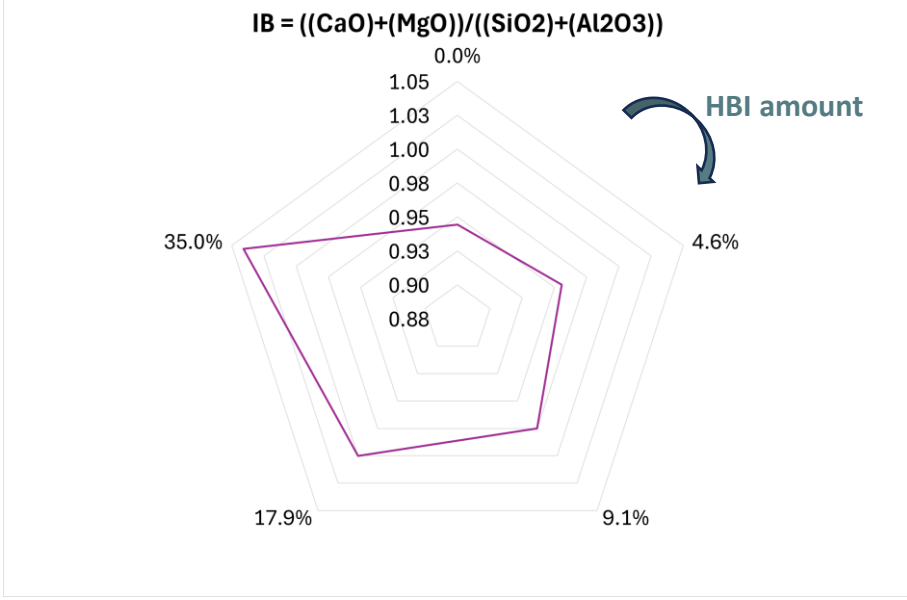
Effects on EAF slag

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**

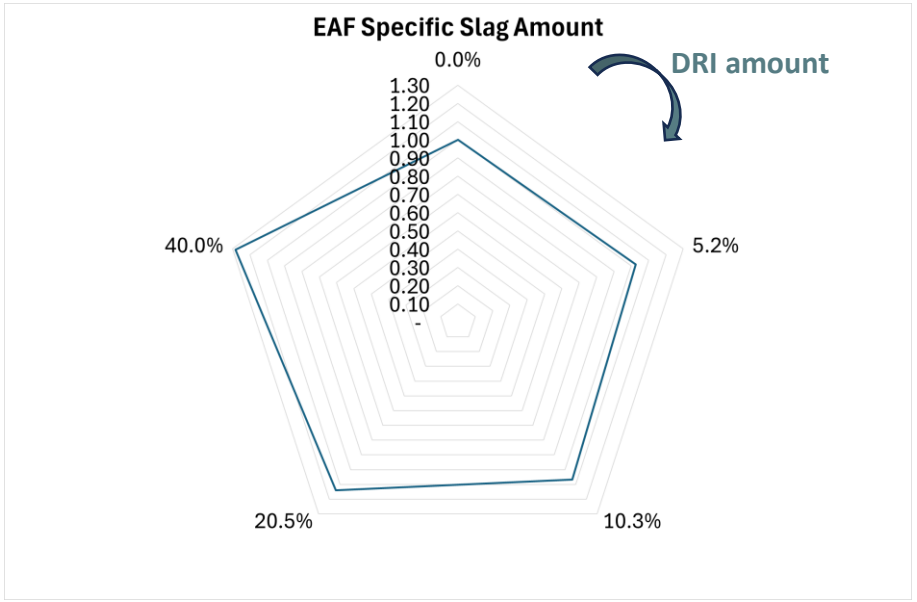


Flowsheet model of EAF-based steelmaking route

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)

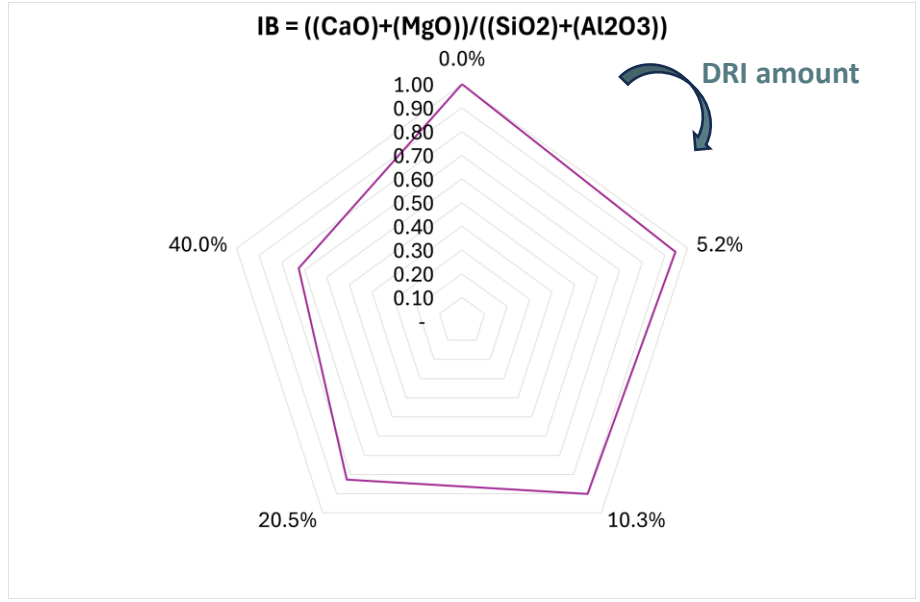
- **By ensuring the same amount of fed iron**
- **Keeping fixed all the other inputs (e.g. non-metallic charge materials and additions)**



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



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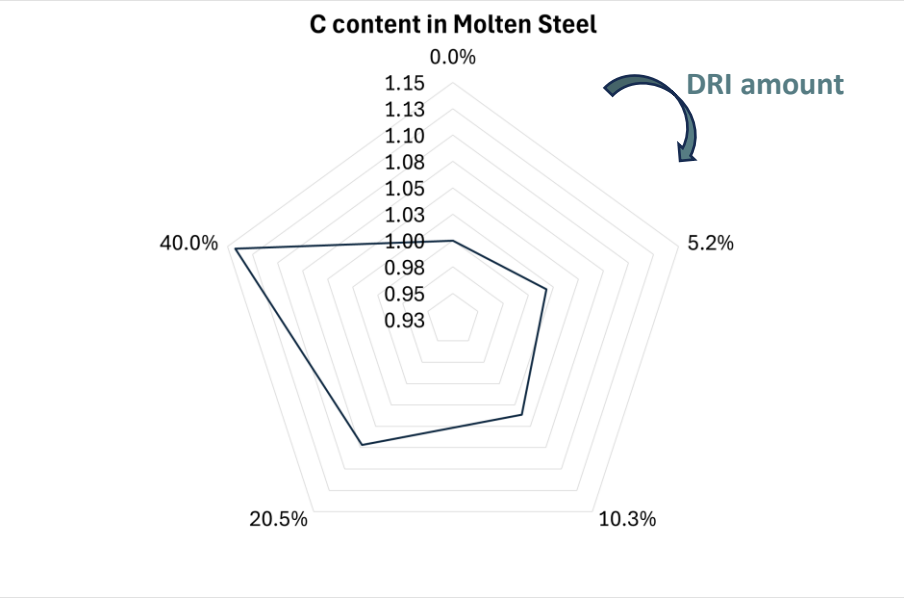


Effects on molten steel

Increasing DRI:

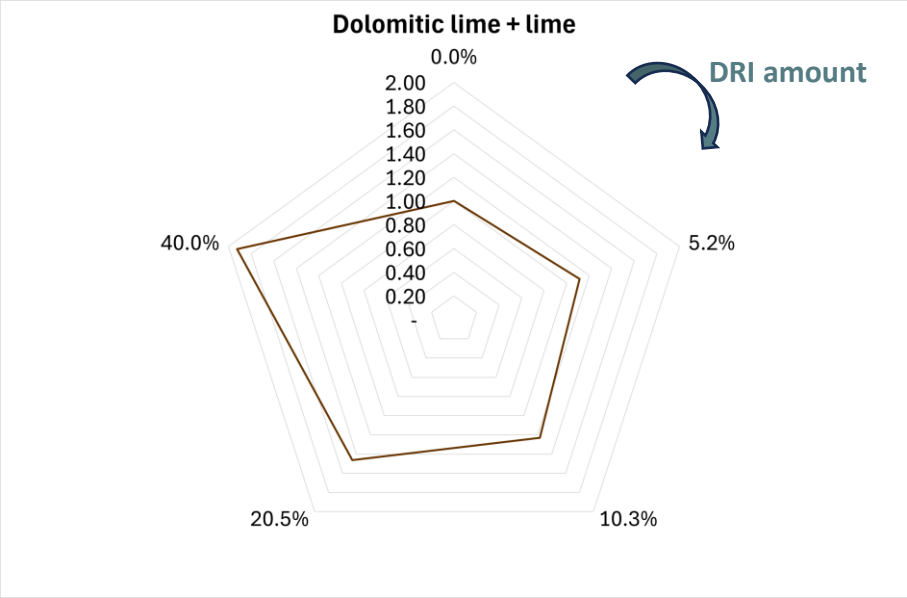
- **C content increases**
- **Low variations are observed on P content** because DRI mix holds a lower P content than used scrap mix and compensate the IB decrease
- **Negligible variations on S content**

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**

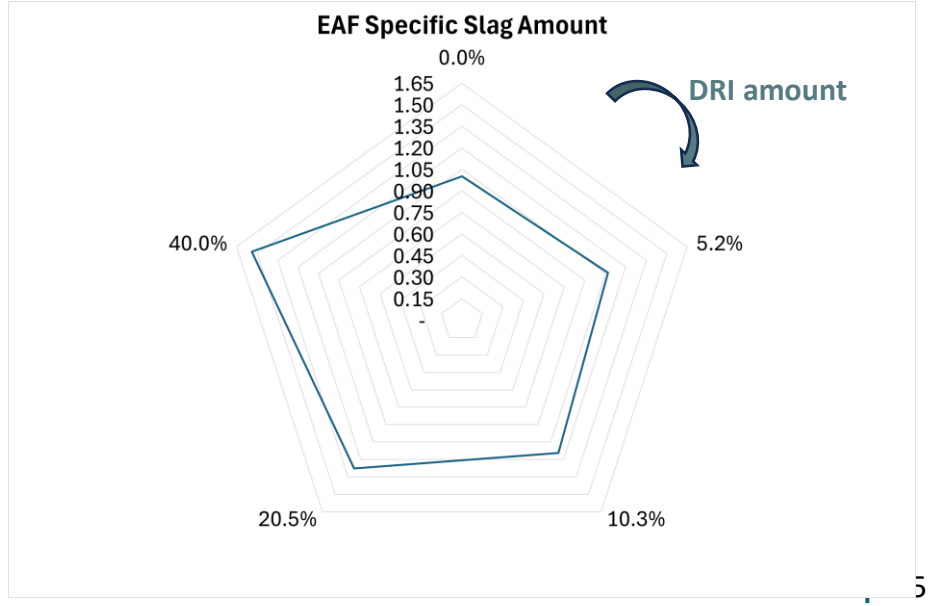
Effects on EAF slag

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**

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