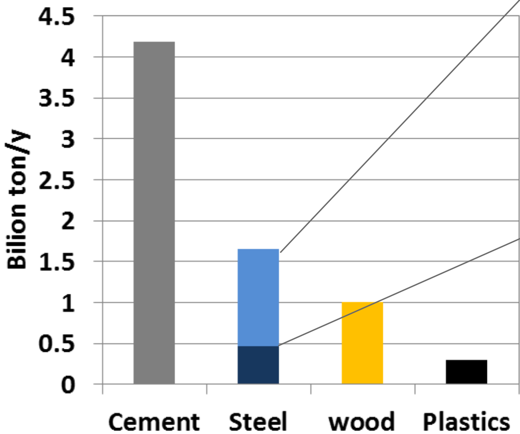
The carbon cost of Slag production in the blast furnace

April 16th, 2015 4th Slag valorization symposium Leuven

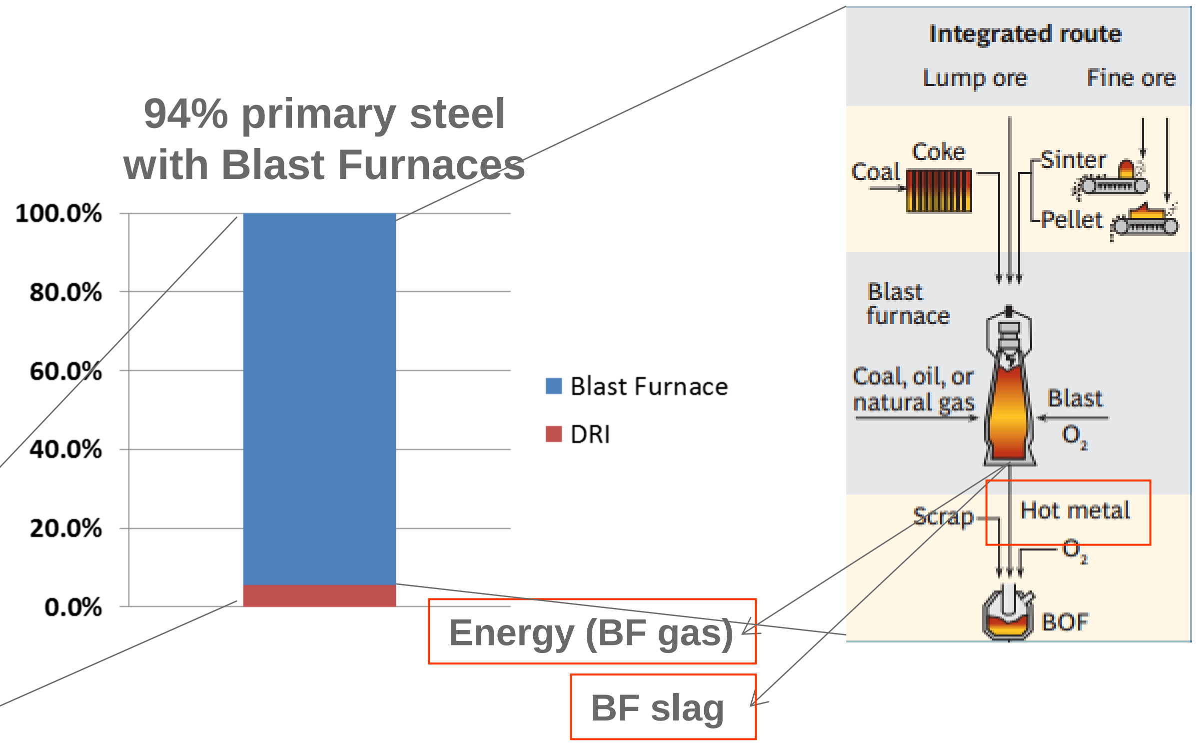
Place of the Blast furnace in the material production Worldwide

4 most important materials



94% primary steel with Blast Furnaces

1 process 3 product streams



- The Blast furnace produces 94% of all primary steel worldwide
- It produces 3 different streams simultaneously

Why do we want to know the carbon cost of slag production in the Blast Furnace?

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There are basically 4 fundamental reasons why we need to determine the CO_2 value/ cost of slag

1. To measure and compare process performance
2. To determine the best possible production options & technologies
3. To decide on the desirability for society to demand better raw materials quality
4. To determine the life cycle impact of steel

Measuring and comparing process performance

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- There are two parameters that make benchmarking in primary steel making difficult: raw materials quality (can be measured by total BF slag production – granulated or not) and scrap
  - Both need to be neutralized for meaningful comparison
  - Slag burdens in BF vary from 160kg/tHM to more than 600kg/tHM
  - The amount of slag and BF gas needs to be neutralized in order to judge the performance of the BF on hot metal level
    - BF produces 3 flows each with their own carbon cost: Hot metal; BF gas and BF slag
      - Footprint of BF gas quite simple: natural gas equivalent (best available alternative
      - Hot metal footprint = total carbon footprint – BF gas – BF slag
  - Example: how to tell Kazakh BF (650kg/t slag) manager how much coke is reasonable compared to the EU peers?

Determining the best production options & technologies

- BF route allows to produce ‘Granulated Blast Furnace slag’
  - Other technologies (EAF based) can only produce ‘stones’
- Hence for equal performance a BF operation should be preferred

How unequal the performance should become before the non-BF route would become more attractive?

- Everything depends on the CO_2 cost of GBFS production…
- A criterion could be the CO_2 cost of technologies to convert non-granulatable slag in granulatable (ZEWA project)
- In SA consultants propose to use DRI/EAF as bench for primary steel making

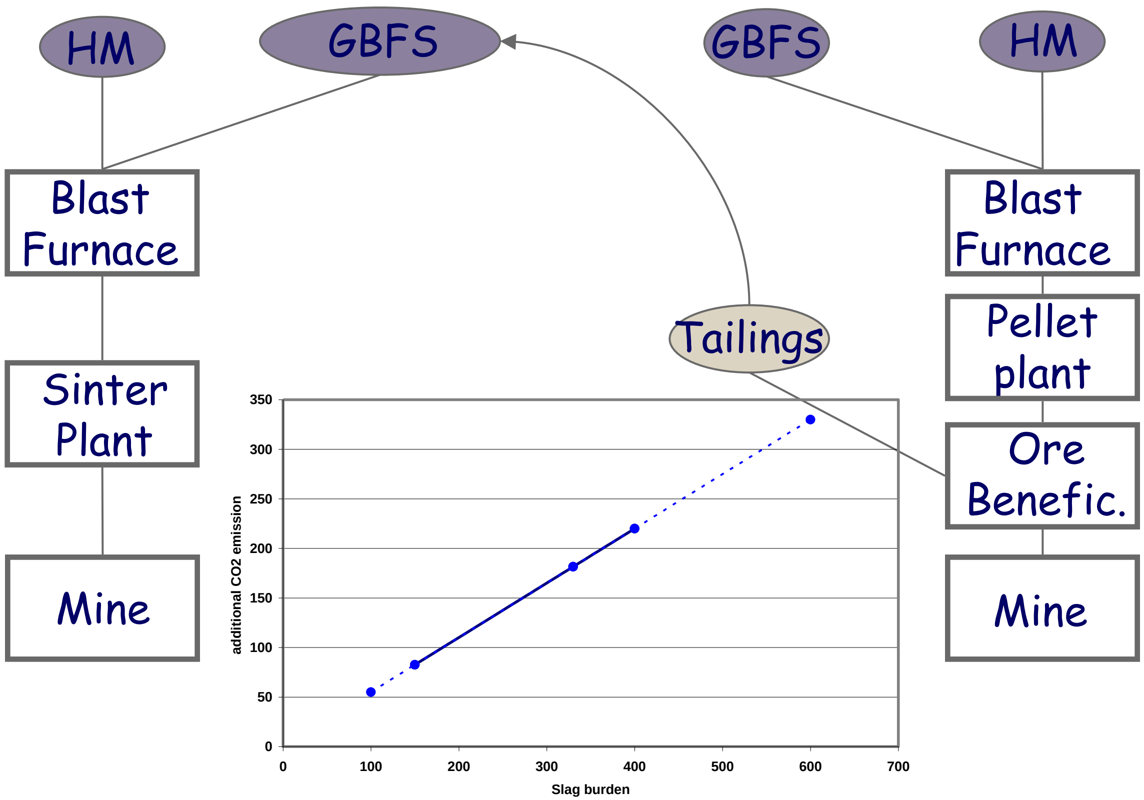
Without the CO_2 valorization of slag DRI/EAF would receive undue advantage

To decide on the desirability for society to improve raw materials quality

- Should the production of granulatable slag be discouraged?
  - We can benificiate ores & coal more and produce less slag
  - Use pellets instead of sinter
- 2 scenarios to compare: Which is the more desirable?
  - Minimize slag volume increase tailings volume produce more cement
  - Minimize tailing ponds use more GBFS produce less cement
- If CO2 cost of slag production ≤ CO2 of eq. cement production no reason to decrease (on the contrary)

If CO2 cost of GBFS < Equivalent clinker production: no need to reduce GBFS

Subdivision of HM and slag production



To determine the life cycle impact of steel

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- So far most (WSA etc.) LCA systems use ‘system expansion’ i.e. the CO2 cost for clinker is attributed to GBFS (900kg/tGBFS)
  - Over time this is not tenable – a given sector should not have to depend on another for determining its footprint
  - Cement can/ will improve its performance = exogenous data are unfit for allocation they change all the time
  - If GBFS is more efficient than clinker the benefit should be for the customer not the producer
- Using the real impact leaves interest for the user as well as for the producer
  - Data analysis showed the value to be extremely robust

Low CO2 values for GBFS should lead to an obligation to use GBFS over clinker for the cement user but also to a decrease of production for the steel maker since the steel footprint is too high => SSAB becomes EU champion

Methodology

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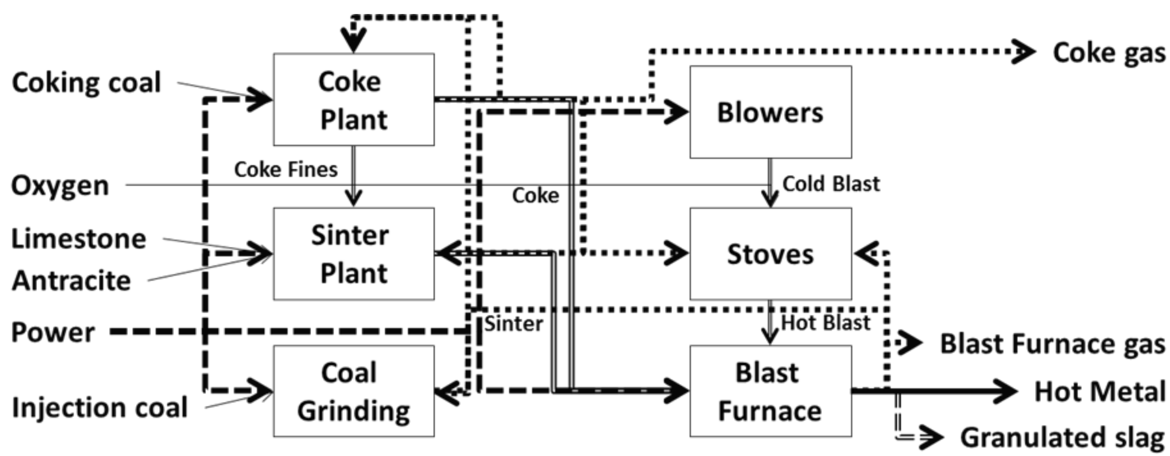
- Previous attempts to derive the impact of different slag burdens by correlation studies of different BF operations failed
  - Too many other operational variables make the direct measurement of the slag impact on carbon emissions impossible
- We considered a «differential approach»: adding a marginal quantity of gangue how much will the carbon input of the BF change?
  - The mathematical BF model (MMBF) needs to calculate the new equilibrium (more slag = more carbon-in = also more BF gas)
  - The emissions of the sinter plant increase because more gangue requires more limestone/ dolomite to adjust slag basicity – only carbon content needs considering

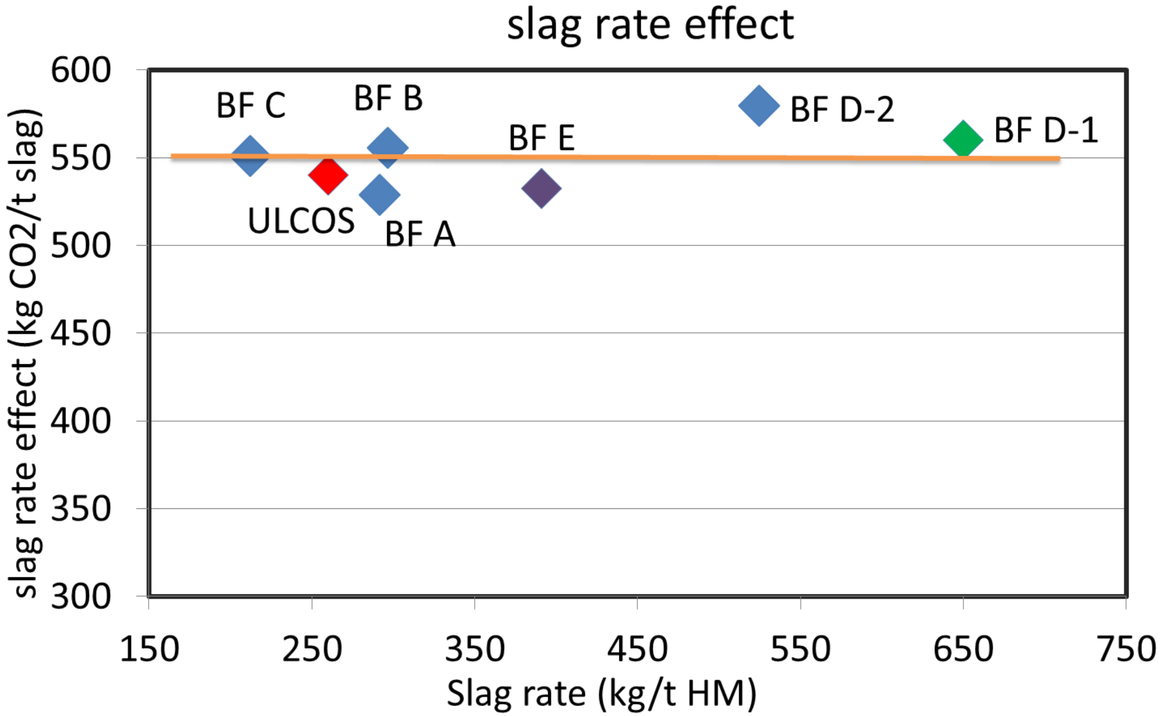
Data – Calculations - results

- Comparison of standard operation with +50kg/tHM slag
- Coke input was allowed to vary (PCI variation is similar)
- Flame temperature is required to remain the same
- Upstream requirements for additional coke production and limestone consumption are added into iron making plant model



Results

- For 5 different BF the real CO2 impact was calculated using a differential reasoning
- Result is remarkably robust and independent of the raw material mix used (sinter, pellets, lump ore)
- Application of correction seems to effectively account for the impact of slag quantity



Conclusion

- The integrated steelmaking plant is co-producing valuable slag and synthetic gas with hot metal. The positive impact on the GHG emissions (avoidance in other sectors) is key when setting up a deep-decarbonisation roadmap.
- The impact of Granulated Blast Furnace slag on GHG has been measured based on real data :
  - Present analysis shows 550kgCO2/t slag to be a robust value representing the actual cost for producing slag through the BF. The value is proposed to be used for LCA evaluations.
  - This value is indispensable for benchmarking of BF operations on Hot Metal level and it allows for a reasonable comparison of very different steel making routes (DRI/ EAF)
  - The value is much lower than the benchmark value for producing grey clinker (766kgCO2/t). No reason to discourage the production of slag on the condition it is granulated and used as clinker substitute avoiding huge tailing ponds
- The global emissions of the BF route are thus for ca 10% avoided emissions in an other sector (cement). The same approach can be applied towards CCU (re-use of waste carbon) in case of production of fuels and chemicals.