

Transformation of the steel industry and implications for the slag value chain

NSA, Annual Meeting September 20th, 2023 Thomas Reiche, FEhS-Institute / EUROSLAG



Who we are

- Service provider focused on research, consultancy and advocacy for slag and by-products of the steel industry for 70 years (since 1950)
- Registered non-profit association based in Duisburg at the heart of the European steel industry
- 45 employees with a wide variety of professional backgrounds: Engineers and natural scientists, Technicians (chemistry lab, construction materials etc.),
- 34 member companies from the steel, cement and slag processing industry
- Annual sales of 5.5 million €
- More information on <u>www.fehs.de</u>
- EUROSLAG: European ferrous slag association with 26 members from 16 countries, see <u>www.euroslag.org</u>





The utilization of ferrous slag based products is on a high level in Europe! (figures 2021, total ferrous slag production: 42 million tons (25,2 Mt BFS + 16,8 Mt SFS))





Ferrous slag has already been sucessfully used in various applications for a long time!





To meet the Paris Climate targets the EU has set very ambitious CO₂ reduction targets, which require a fundamental transformation process especially for the integrated route of steelmaking!

- The EU aims to become carbon neutral by 2050 an economy with net zero greenhouse gas emissions.
- First milestone is a reduction of CO₂-Emissions by 55% until **2030** (base year 1990).
- Energy intensive industries like the steel industry aim to become carbon neutral by 2050.
- The steel industry has boosted R & D to manage this tranformation process.





Main focus of the steel industry is to directly avoid CO_2 emissions by using hydrogen instead of coke to reduce iron ore and by replacing any other than green energy with energy from renewable sources.

- Carbon Capture and Usage (CCU)
 Smart
- Storage and Usage of CO₂ (CCS + CCU)
- Reducing CO₂ (H2 in Blast Furnace)
- DRI/HBI in Blast Furnace
- New Processes for hot metal production
 - Direct Reduction
 - HIsarna
 - Plasma smelting
- Combination of different pathways

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Smart Carbon Usage (SCU)	Process integration (PI)
	Carbon capture (, storage) and usage
	CCU (+CCS)

Carbon Direct Avoidance (CDA)	H ₂
	electrical energy

Source: LowCarbonFuture.eu



By replacing the (coke reduction based) integrated BF-BOF route with the (hydrogen reduction based) DRI-EAF route, specific CO_2 emissions can be reduced by about 82%.



 CO_2 Emissions in kg CO_2 / t crude steel of different steel making routes (*incl. emissions for Pellets and DRI/HBI*)

*Source: Lüngen, Hans Bodo: Wege zur Minderung von CO*₂-*Emissionen in der Eisen- und Stahlindustrie in Europa, VDEh, Mai 2021*



Basically, there are 2 different ways of future DRI based crude steel production in a transformed steel industry (DR + EAF / DR + SAF + BOF).





The transformation will result in a substantially different slag mix both in terms of quantities and qualities!

- Decrease in Blast Furnace Slag (GBS/ABS) despite high GBS demand by the cement industry !
- Increase in Electric Arc Furnace Slag (EAF)
 - CO₂ reduction targets
 - General shift towards scrap as raw material
- "New slag types", i.e. DRI based SAF and EAF slags
- R & D to secure for the utilization of these slags!



Source: worldsteel 2018



The cement (and concrete) industry is highly interested in the sustainable supply with (almost) CO₂ free secondary raw materials.

- Cement industry is responsible for 5-8 % of anthropogenic CO₂ emissions
- Emits approx. 800 kg CO₂ per ton of OPC (of which 60 % is unavoidable due to raw material)
- Granulated Blast Furnace Slag (GBFS) is up to now the only iron and steel slag that is established and permitted as a cement constitutent
- Use of GBFS saved in 2021 worldwide about 250 Mio t of CO₂ emissions and about 500 Mio t of natural raw







We have already been doing research on the conditioning of Electric Arc Furnace Slag for several years. The aim is to work on "GBS 2.0" from both scap-based and DRI-based EAF slag.





The research project "SAVE CO2" aims to directly produce a SAF slag for the cement industry without any further treatment steps to be taken.













The DRI quality and the scrap/DRI ratios will have an impact on the EAF slag chemistry and its environmental performance.





The EAF slag will probably have to be optimized to meet the requirements (technological and environmental performance) for cementitious applications.





On-site trials with quartz sand as treating agent and subsequent mobile water granulation resulted in a GBFS with comparable compressive strength.



Treating during tapping







Results from the SAVE CO2 project also reveal the good technological performance of the cement made out of the GBFS 2.0.





When it comes to the chemical composition of main components we expect that DRI based EAF slag will be more similar to scrap based EAF slag, while DRI based SAF slag will be in the range of BF slag.

	BF slag	BOF slag	EAF slag (scrap)	EAF slag (DRI/HBI)	
CaO	34 - 43	43 – 53	20 – 36	slightly higher C/S	
SiO ₂	35 – 40	11 – 18	10 - 18	basicity	
MgO	7 – 16	1-8	3 – 7	planned: higher	
Al ₂ O ₃	8 - 12	1 – 5	4 – 9		
Fe ₂ O ₃	0,1 - 1,0	20 - 31	29 – 48	slightly higher	
MnO	0,1 - 1,0	2,5	4,8		
Ref.: FGSV: Merkblatt	Cr_2O_3 lower				

TiO₂ higher



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	BF slag	SAF slag (DRI)	BOF slag	EAF slag (scrap)	EAF slag (DRI/HBI)
CaO	34 – 43	expected to be	43 – 53	20 – 36	slightly higher C/S
SiO ₂	35 – 40	similar	11 - 18	10 - 18	basicity
MgO	7 – 16		1-8	3 – 7	planned: higher
Al ₂ O ₃	8 – 12		1-5	4 – 9	
Fe ₂ O ₃	0,1 - 1,0		20 - 31	29 – 48	slightly higher
MnO	0,1 - 1,0		2,5	4,8	
		Na ₂ O+K ₂ O higher			Cr ₂ O ₃ lower
		V ₂ O ₅ higher			TiO ₂ higher
		TiO ₂ higher			

Ref.: FGSV: Merkblatt über die Verwendung von Eisenhüttenschlacken im Straßenbau, 2013



To overcome the disbalance between soil/groundwater protection and preservation of natural resources/promotion of circular economy, the regulatory framework has to be pragmatically adapted.

- Due to a low solid Chromium limit value, the utilization of BOF/EAF slags in cementitious and concrete applications is not possible in Germany right now
- Benchmark: Utilization in other European countries allowed, e.g. the Netherlands and Belgium (leaching values instead of solid values)
- Proposal by FEhS-Institute under discussion with both legally responsible institutions and value chain





We will shortly start a research project on the DRI based EAF slag for road construction applications.





We have also started a transformation research project at EUROPEAN level (InSGeP – Gaining knowledge about next generation slags).





- 07/23 06/2027, coordinated by FEhS-Institute
- Investigating existing slags (DRI based EAF)
- Creating synthetic slags (DRI based EAF/SAF)
- Creating slags in pilot plant (HPSR slag)
- Characterization, identifying possible applications and optimization



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



Conclusions

- The transformation of the steel industry will result in a substantially different slag mix, both in terms of quantities and qualities!
- 2. New slag types, i.e. DRI based SAF slag" and "DRI based EAF slag" are already integral part of major research projects, which mainly focus on cementitious applications.
- 3. Most likely the steel industry will have to invest in slag treatment operations (especially for DRI based EAF slag) to meet the technological and environmental performance criteria.
- 4. The regulatory framework has to be adapted to make these new by-products marketable.





Slag based construction materials and fertilizers are best practice examples for circular economy and the preservation of natural resources!





The use of ferrous slags is without any doubt a significant contribution to an effective circular economy!

Prof. Dr. Klaus Töpfer

(former Minister for Environment in Germany and former Executive Director of the United Nations' Environmental Programme)



Thank you very much!

For any questions and support, please contact us: t.reiche @fehs.de , www.fehs.de, www.euroslag.com