Why are waste to energy plants so crucial for the circular economy?

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CEWEP RESIDUES CONFERENCE – ASH TO RESOURCE, MECHELEN, BELGIUM 25.09.2023

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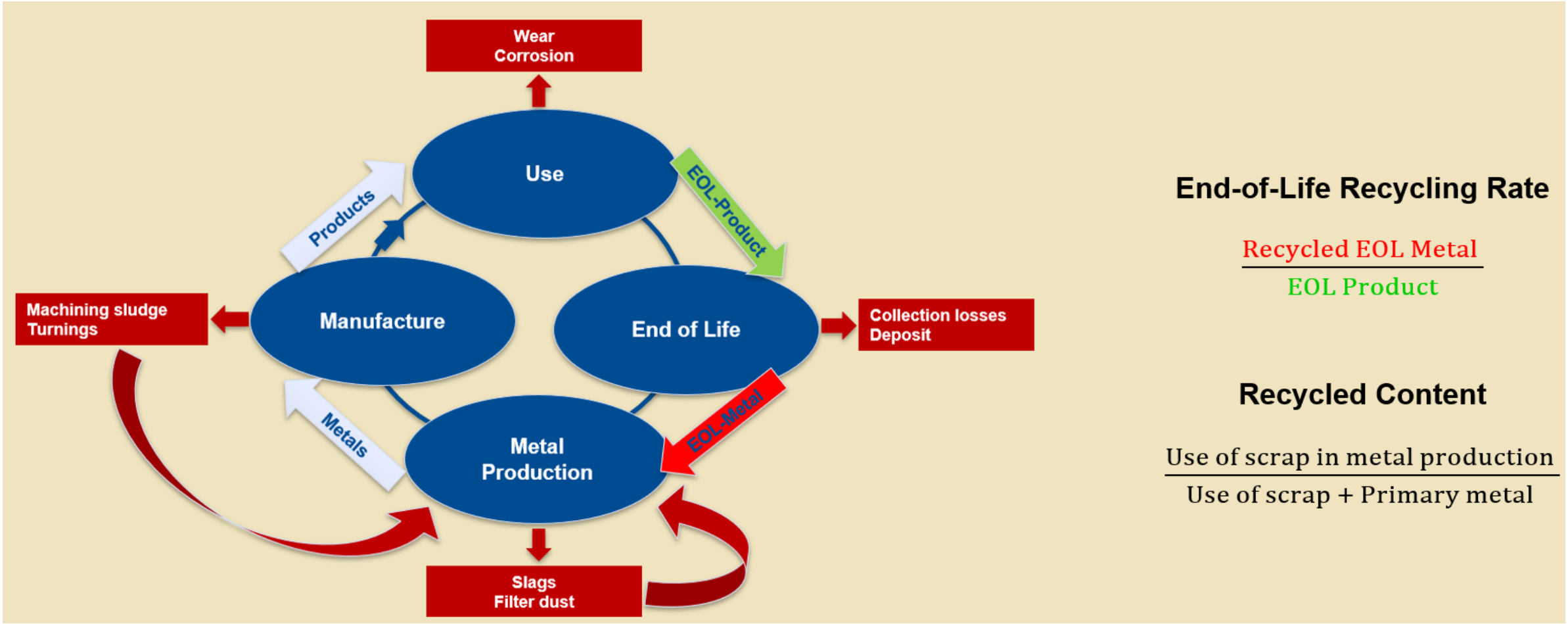
Fundamentals of realizing a circular economy

Deike, R.; Winstermann; P.: *The Special Importance of Metals in a Circular Economy*, 62nd International Foundry Conference 2022, PORTOROZ 15.09.2022
https://doi.org/10.17185/duepublico/78969

What is the difference between the recycling rate and recycled content? Are complete cycles possible?



End-of-Life Recycling Rate

$$\frac{\text{Recycled EOL Metal}}{\text{EOL Product}}$$

Recycled Content

$$\frac{\text{Use of scrap in metal production}}{\text{Use of scrap + Primary metal}}$$

Deike, R.; Rabelo de Lima;A.R.: *Recycling of residual material from metallurgical processes towards a circular economy*, 8th Simpósio Brasil-Alemanha Desenvolvimento Sustentável, Porto Alegre, Brasil, 03.10.2017

The foundry industry is working in nearly closed raw material cycles

Foto: Soschinski/BDG

Deike, R., 2020. Bedeutung der Gießerei-Industrie in einer Circular Economy. https://doi.org/10.17185/duepublico/71307

Responsible raw material consumption

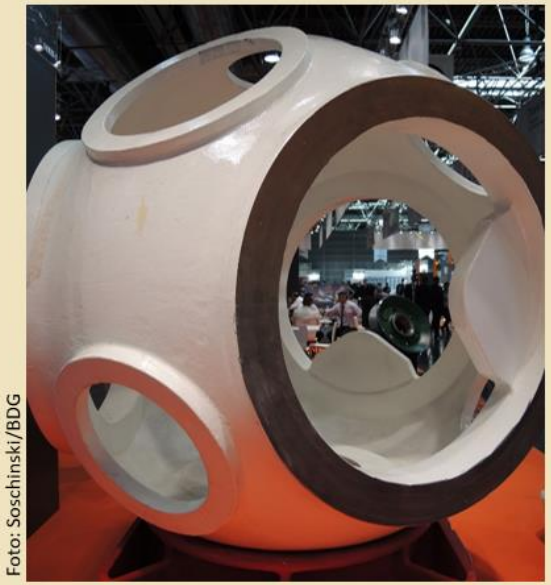


Foto: Soschinski/BDG

Foto: Soschinski/BDG

Deike, R., 2021. Die Bedeutung energieintensiver metallurgischer Betriebe: Unter dem Aspekt des Recyclings von Eisen, Stahl und NE-Metallen. https://doi.org/10.17185/duepublico/74510

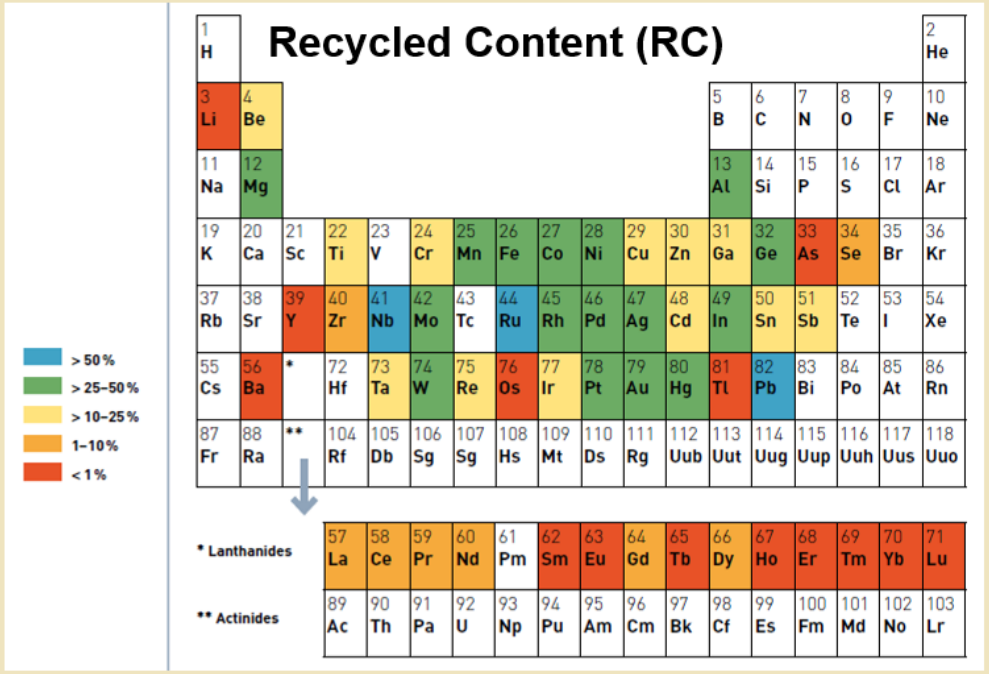
12 RESPONSIBLE CONSUMPTION AND PRODUCTION

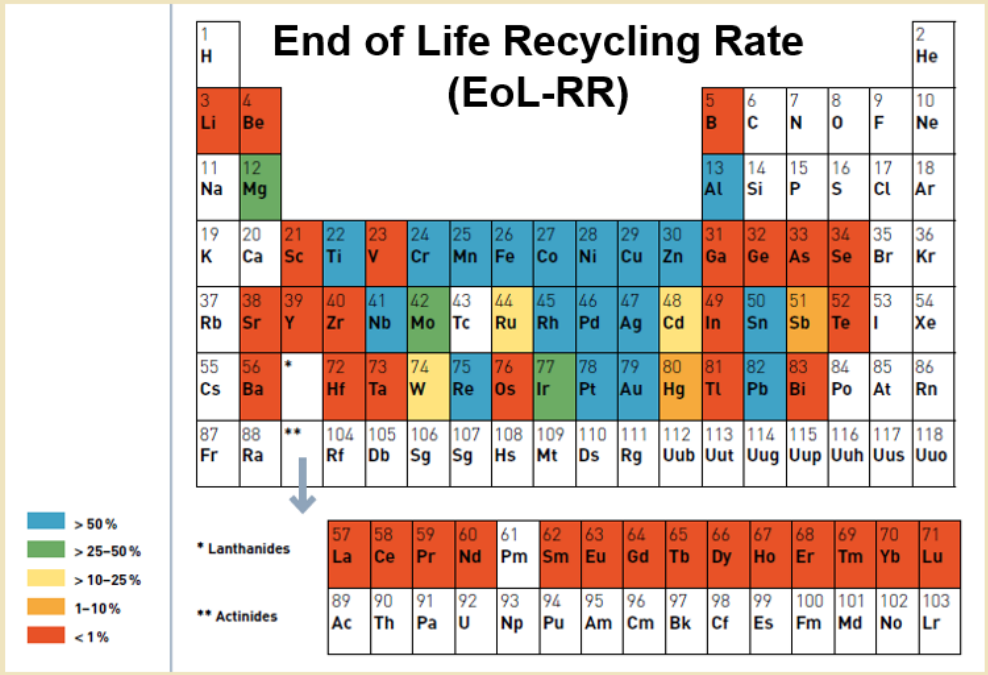
With end of life the process starts again in a closed loop

For the production of products for future industries

Deike, R.; Winstermann; P.: *The Special Importance of Metals in a Circular Economy*, 62nd International Foundry Conference 2022, PORTOROZ 15.09.2022 https://doi.org/10.17185/duepublico/78969

Why are recycled contents and EoL-recycling rates of other elements much lower?



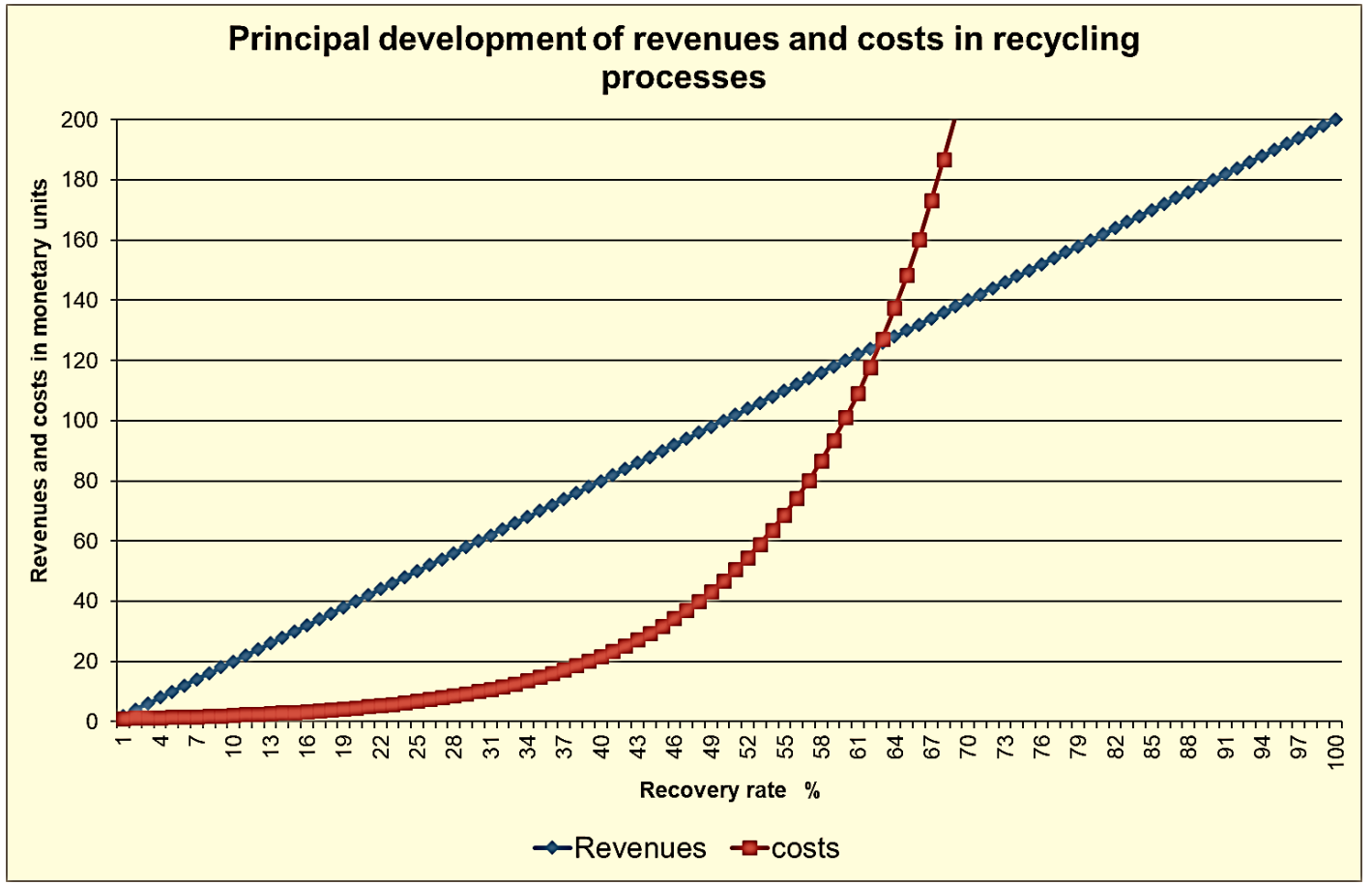


In periods of economic growth, the primary metal share grows faster than the secondary share, so that the recycled content (RC) decreases and is substantially smaller than the EoL-recycling rate. In addition the recycled content is dependent on the availability of secondary raw material.

UNEP International Resource Panel: Recyling rates of metals, 2011, https://wedocs.unep.org/20.500.11822/8702

Deike, R.; Winstermann; P.: *The Special Importance of Metals in a Circular Economy*, 62nd International Foundry Conference 2022, PORTOROZ 15.09.2022
https://doi.org/10.17185/duepublico/78969

What is the main problem of recycling?



Deike, R.: *Die Bedeutung von Eisen und Stahl für die Circular Economy*. stahl., Sonderdruck Nr. 1-2 | 2023, S. 3-10., https://doi.org/10.17185/duepublico/78771

According to R. Bunge,: *Recycling ist gut, mehr Recycling ist besser – oder nicht?,* Berliner Recycling und Rohstoffkonferenz, Berlin 08.03.16

Deike, R.; Winstermann; P.: *The Special Importance of Metals in a Circular Economy*, 62nd International Foundry Conference 2022, PORTOROZ 15.09.2022

How can the problem of recovering valuable metals from dissipative distributions be solved?

We need processes :

- **with effective collection logistics,**
- **that enable highly sophisticated, dependable, and large material throughputs,**
- **that reduce the volume of dissipative distribution,**
- **with strictly controlled emissions and proper protection of the environment,**
- **that generate different products at the end, for which a demand exists.**

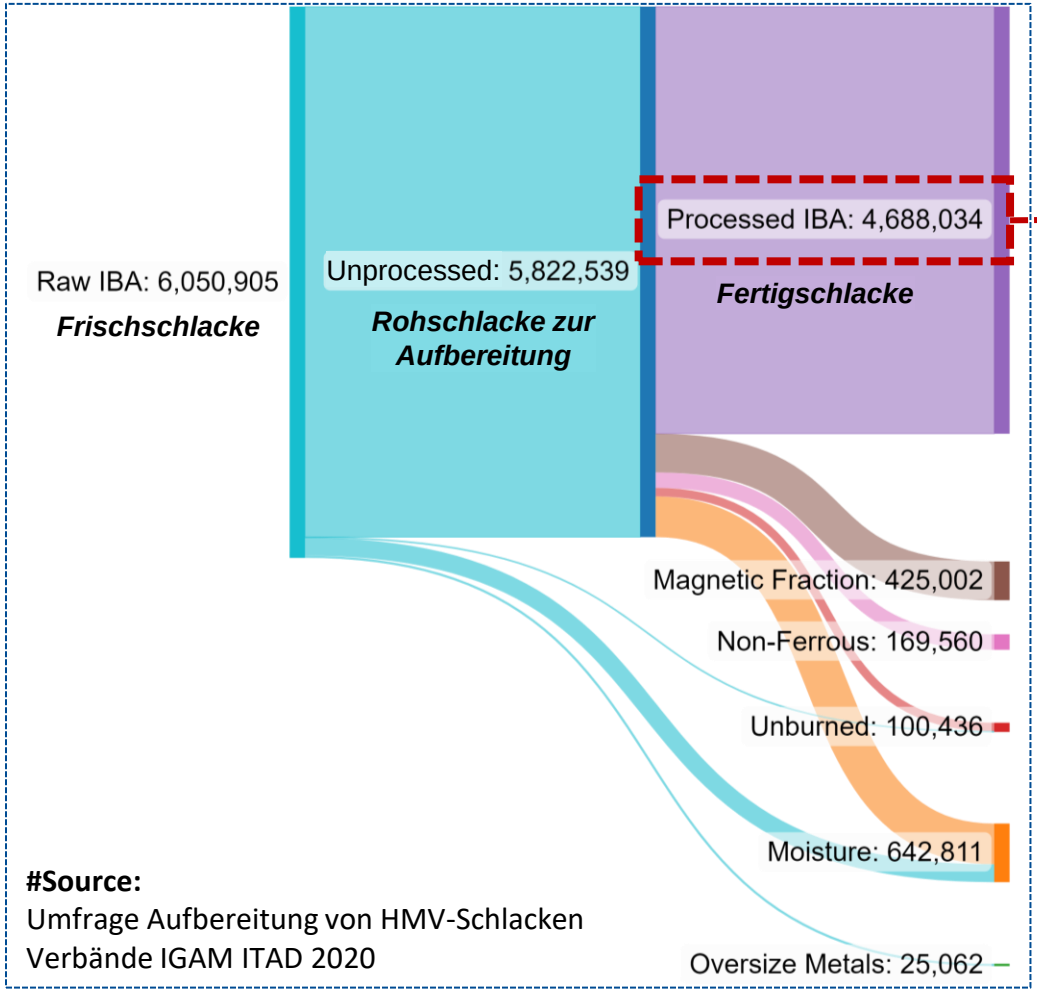
EMSARZEM

Alternative perspective to valorize the municipal waste incinerator bottom ash for metals and cement industries

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung
FONA
Forschung für Nachhaltigkeit
ReMin
Ressourceneffiziente Kreislaufwirtschaft
Bauen und Mineralische Stoffkreisläufe

Definition and purpose

Annual Volume of IBA in Germany



#Source:
Umfrage Aufbereitung von HMV-Schlacken
Verbände IGAM ITAD 2020

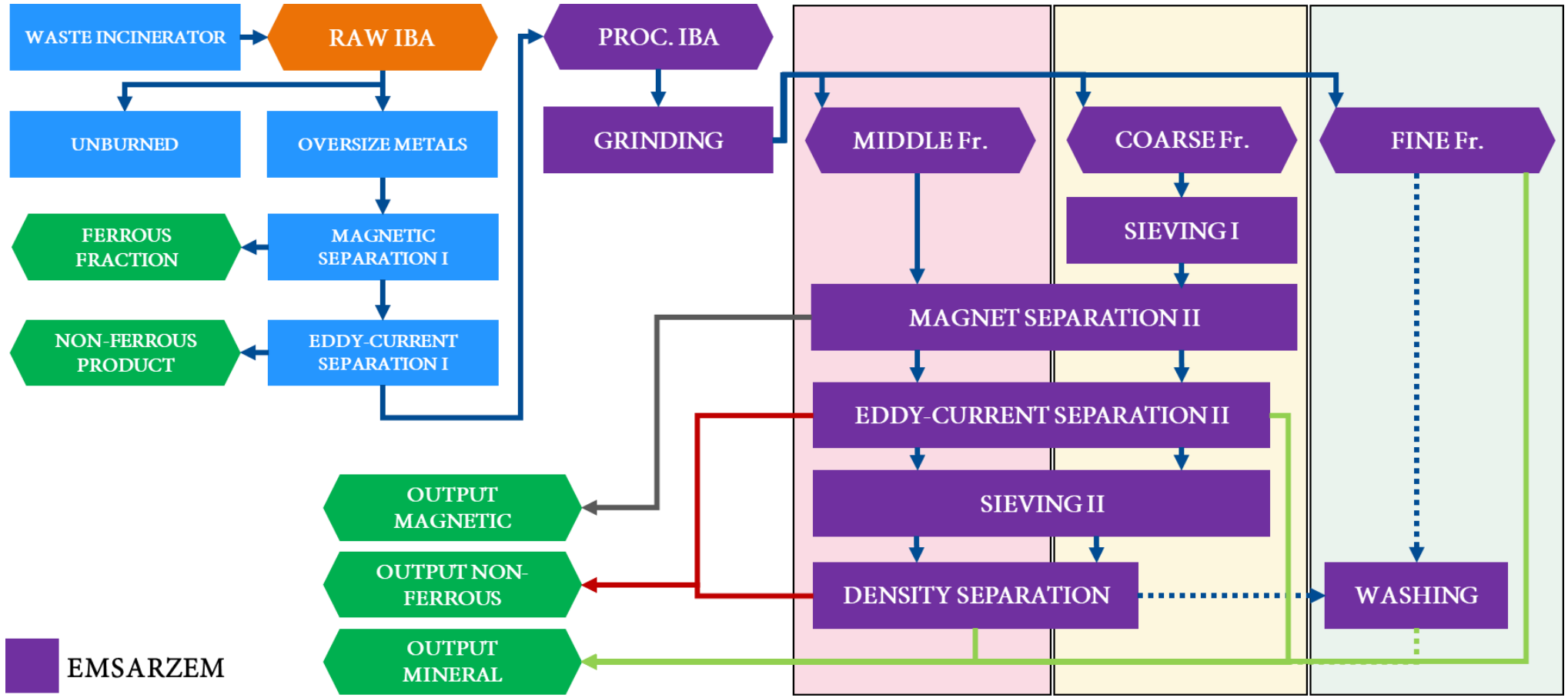
Processed IBA Fraction 0-10 mm

PROJECT PURPOSES

- **Metals separation**
- **Production of a clean mineral product that can be used as raw material in clinker production in cement industry**

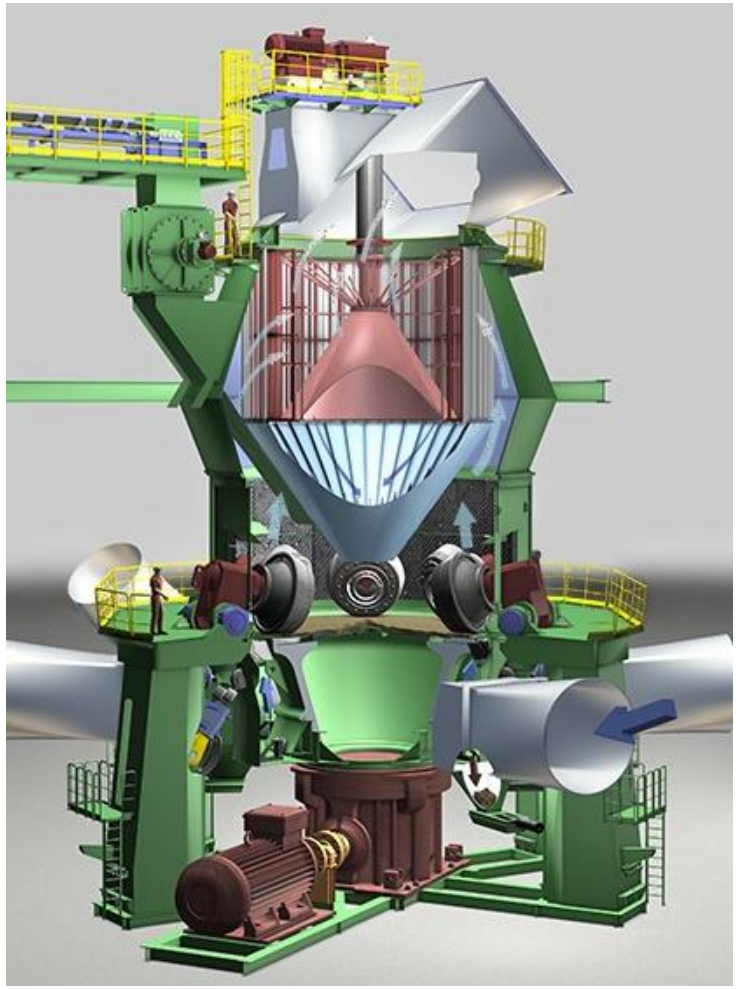
Adhiwiguna, I.; Deike, R.; Warnecke, R.: *EMSARZEM Alternative Perspective to Valorize the Municipal Waste Incinerator Bottom Ash for Metals and Cement Industries*, FEMS EUROMAT 2023, Frankfurt Germany, 06.09.2023

Process scheme



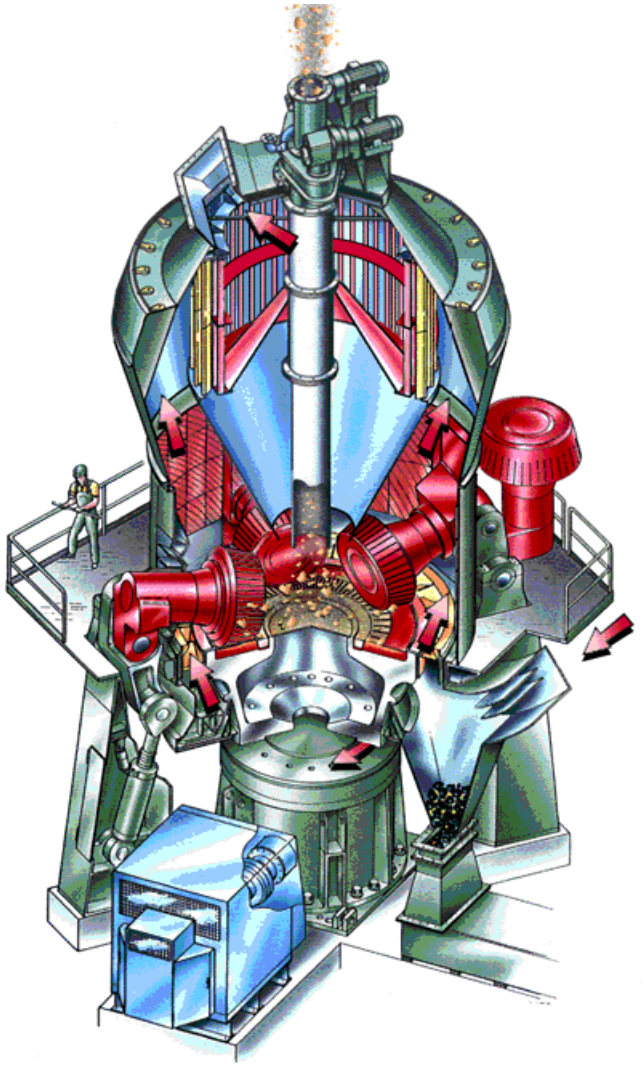
Adhiwiguna, I.; Deike, R.; Warnecke, R.: *EMSARZEM Alternative Perspective to Valorize the Municipal Waste Incinerator Bottom Ash for Metals and Cement Industries*, FEMS EUROMAT 2023, Frankfurt Germany, 06.09.2023

Grinding the first concentration step



Loesche – VRM

For grinding solid fuels, cement raw materials, cement products, minerals and ores.



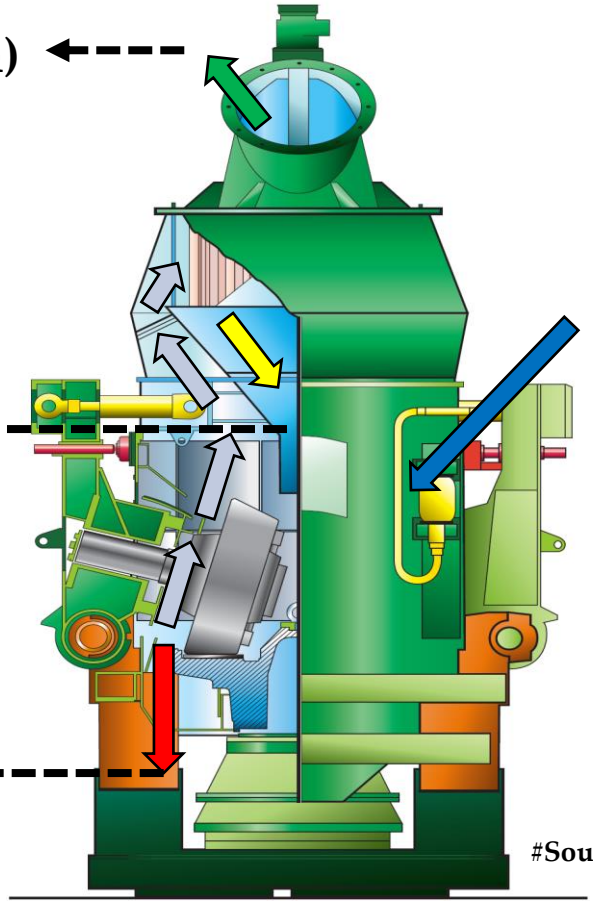
Deike, R.; Ruhkamp, W.; Adhiwiguna, I.; Warnecke, R.: *Einsatz von Rostasche –Feinfraktion < 10 mm als Rohstoff für die Herstellung von Zement und Beton*, BKMNA 24, Berliner Konferenz Mineralische Nebenprodukte und Abfälle, Berlin, 12-13.06.24

Grinding as the first concentration step

Sichterfeingut (Fine Fraction)

Grieße (Middle Fraction)

Reject (Coarse Fraction)

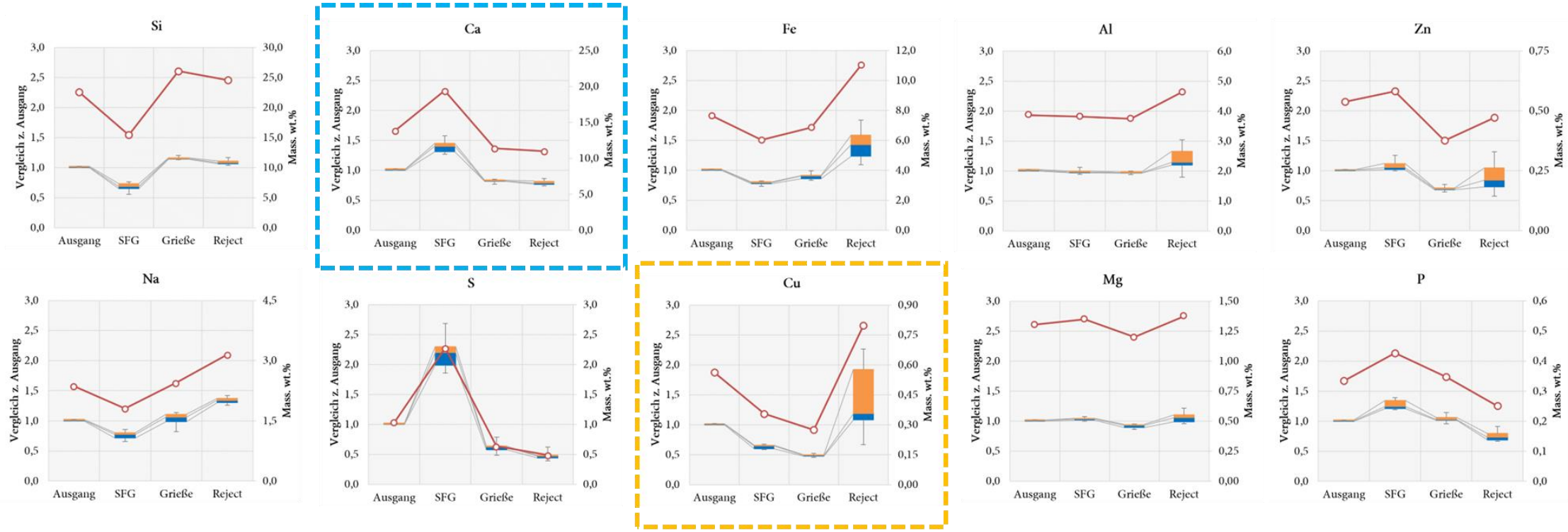


INPUT: Fertigschlacke (Processed IBA)

#Source: LOESCHE Milling Machine

Adhiwiguna, I.; Deike, R.; Warnecke, R.: *EMSARZEM Alternative Perspective to Valorize the Municipal Waste Incinerator Bottom Ash for Metals and Cement Industries*, FEMS EUROMAT 2023, Frankfurt Germany, 06.09.2023

Change in chemical composition after grinding

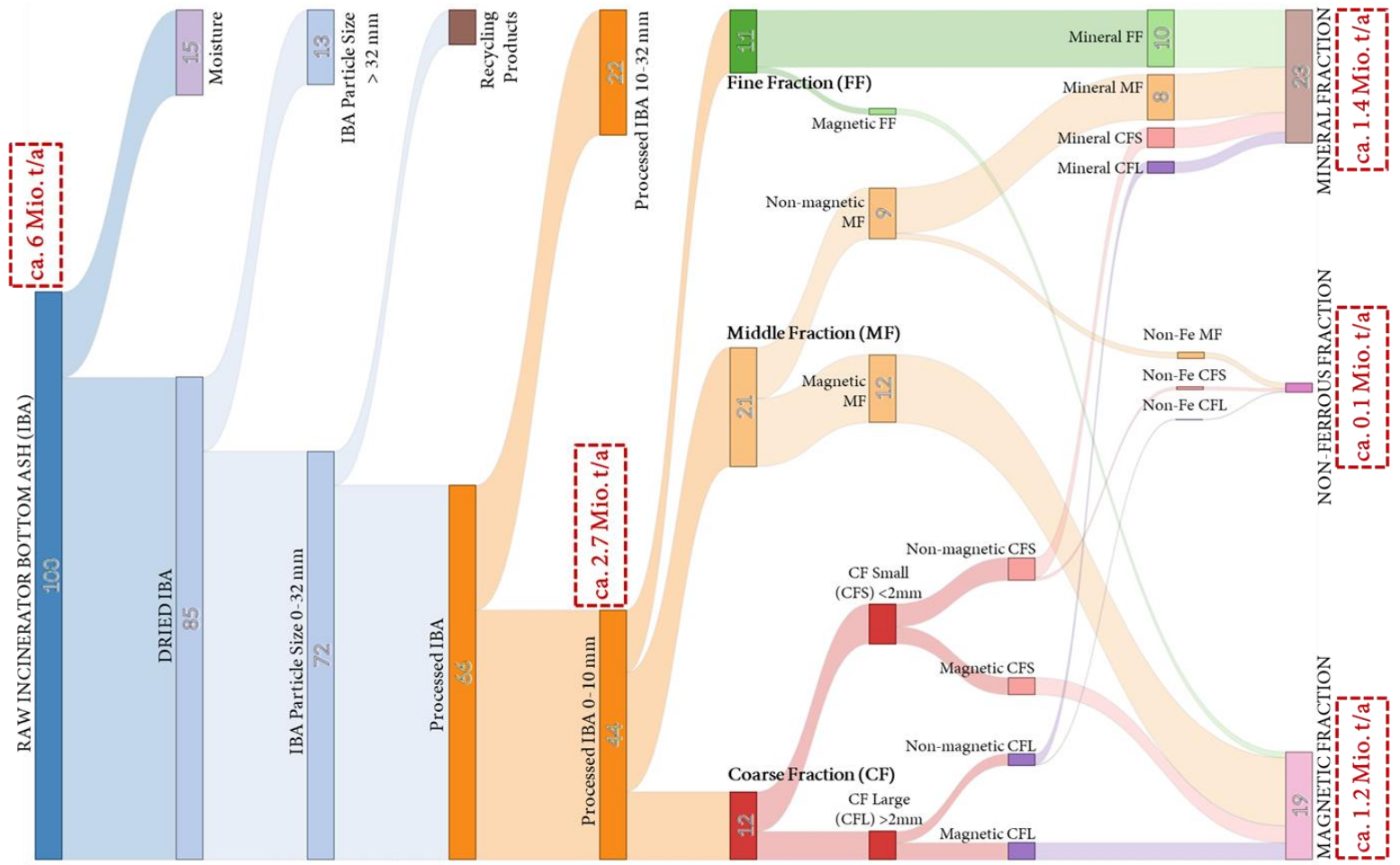


#analysed by Verein Deutscher Zementwerke e.V.

Adhiwiguna, I.; Deike, R.; Warnecke, R.: *EMSARZEM Alternative Perspective to Valorize the Municipal Waste Incinerator Bottom Ash for Metals and Cement Industries*, FEMS EUROMAT 2023, Frankfurt Germany, 06.09.2023

Mass balance based on 6 Mio. t/a

After Grinding, Magnetic and Eddy Current Separation



Output Mineral:
Cement Clinker & Concrete Production

Output Non-Ferrous:
Non-Ferrous Metals Industry

Output Magnetic:
Ferrous & Non-Ferrous Industry

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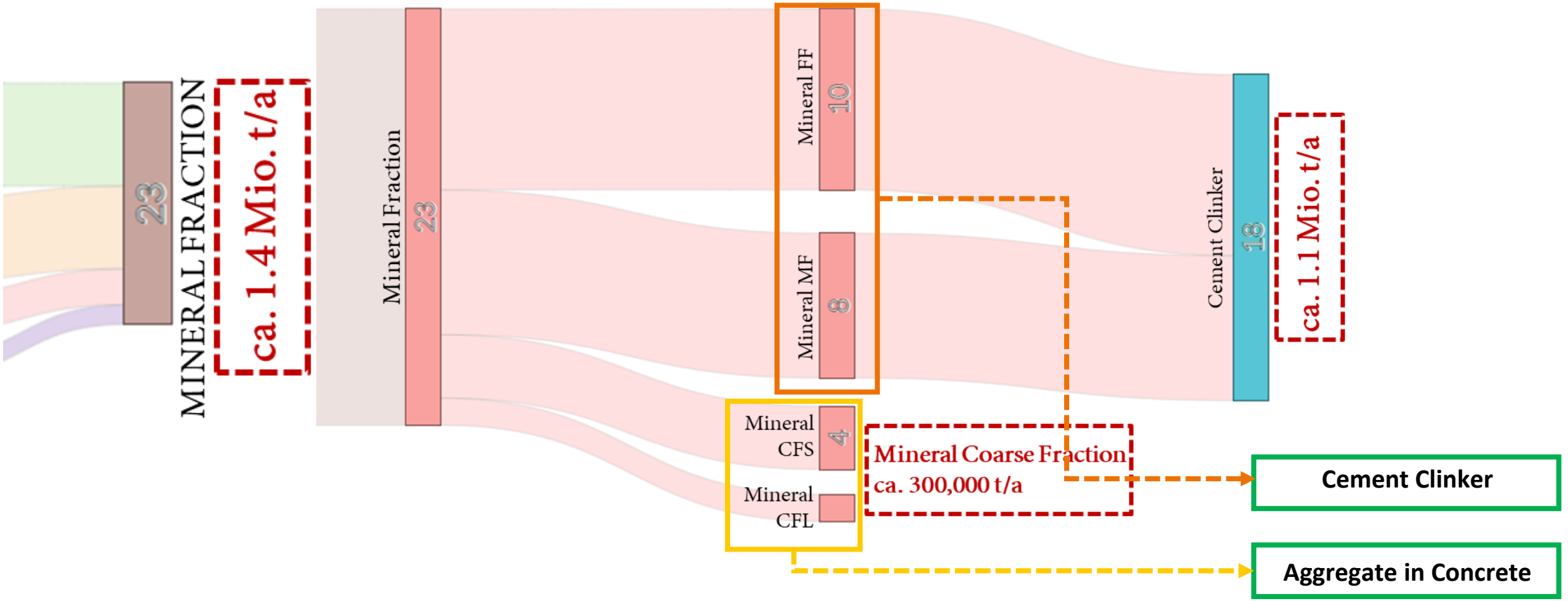
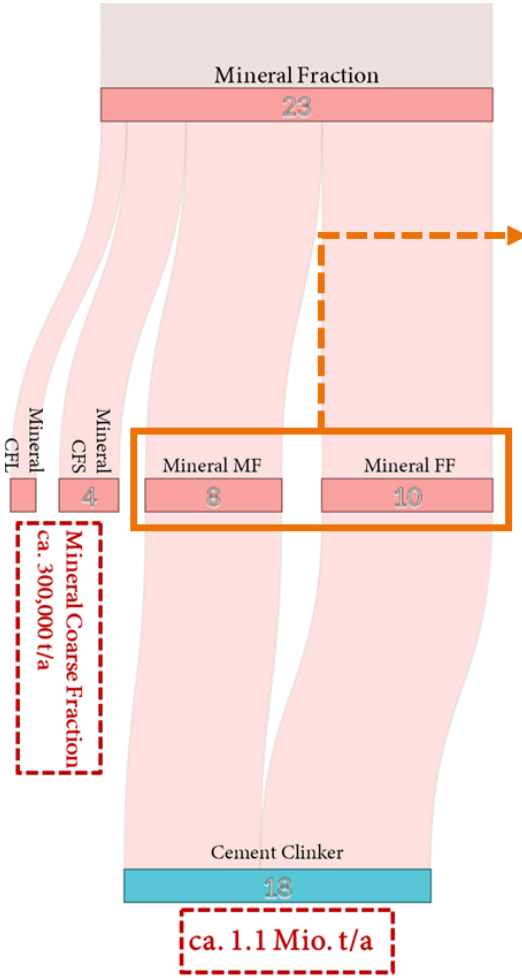
Output Mineral as raw material for the cement industry and concrete production

Expected valorization of the mineral fraction



Adhiwiguna, I.; Deike, R.; Warnecke, R.: *EMSARZEM Alternative Perspective to Valorize the Municipal Waste Incinerator Bottom Ash for Metals and Cement Industries*, FEMS EUROMAT 2023, Frankfurt Germany, 06.09.2023

Mineral FF/MF as material in cement clinker



CHEMICAL COMPOSITION DIFFERENCES

Sample	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	TiO_2	P_2O_5	SrO
Raw Meal (RM)	**16.6**	6.0	2.5	**71.2**	0.91	0.6	1.1	0.12	0.32	0.01	0.3
Min. FF (MVS)	**34.4**	8.4	5.4	**30.0**	2.5	7.7	1.4	2.6	1.9	1.5	0.08
Min. MF	**64.3**	5.1	2.1	**14.3**	1.6	1.3	1.1	3.4	1.0	0.7	0.04

EXPECTED MIXTURE PROPORTION OF IBA IN BLENDING MATERIALS

Sample	Additive (%)	XRF - Analysis				XRD - Analysis				
		SiO_2	Al_2O_3	Fe_2O_3	CaO	C_3S	C_2S	C_3A	C_4AF	KSt.
100% (RM + 1%SiO_2)	-	22.85	5.72	1.85	66.82	57.3	22.3	12.0	5.6	92.9
98% (RM) + 2% MVS	0.4 SiO_2	22.54	5.87	2.10	66.35	56.4	22.1	12.0	6.4	92.9
96% (RM) + 4% MVS	0.5 CaO	22.36	5.91	2.27	66.18	56.5	21.5	11.8	6.9	93.1
94% (RM) + 6% MVS	1.6 CaO	22.38	5.76	2.36	66.06	56.8	21.3	11.3	7.2	93.1

#conducted by Wilhelm-Dyckerhoff-Institut für Baustofftechnologie

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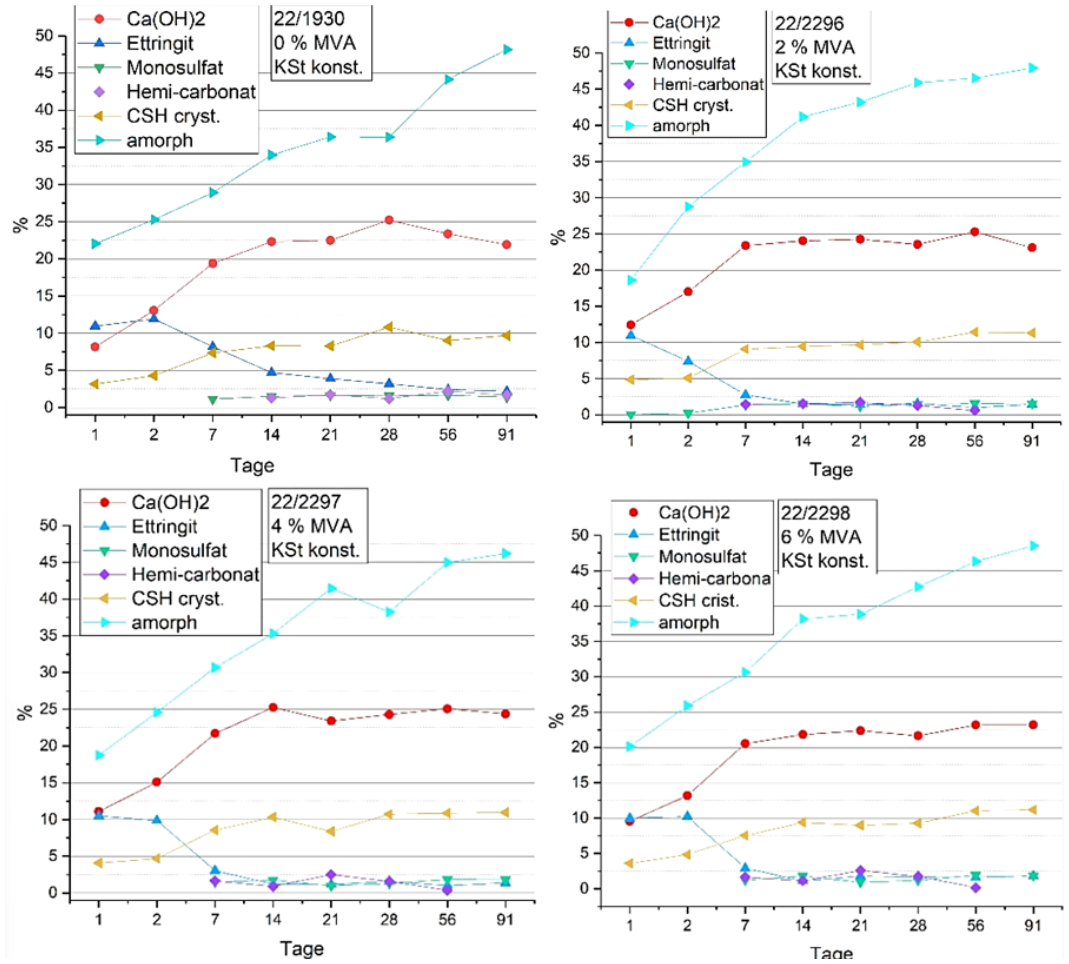
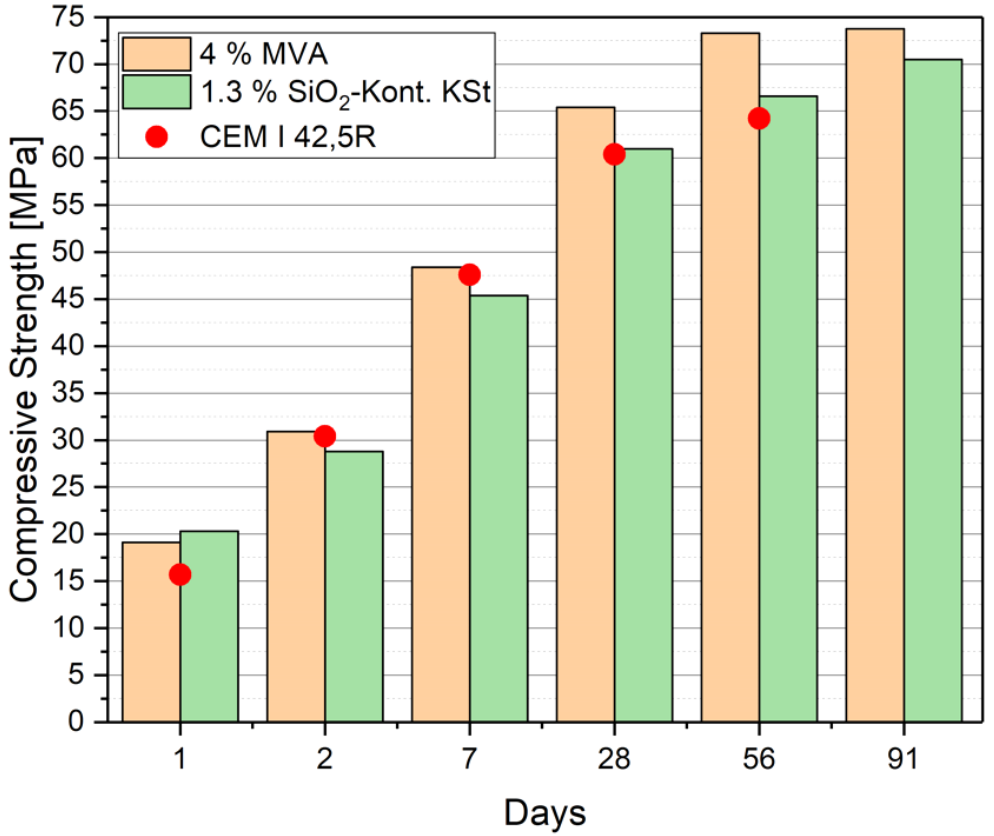
Hydration & compression test of cement





#conducted by Wilhelm-Dyckerhoff-Institut für Baustofftechnologie

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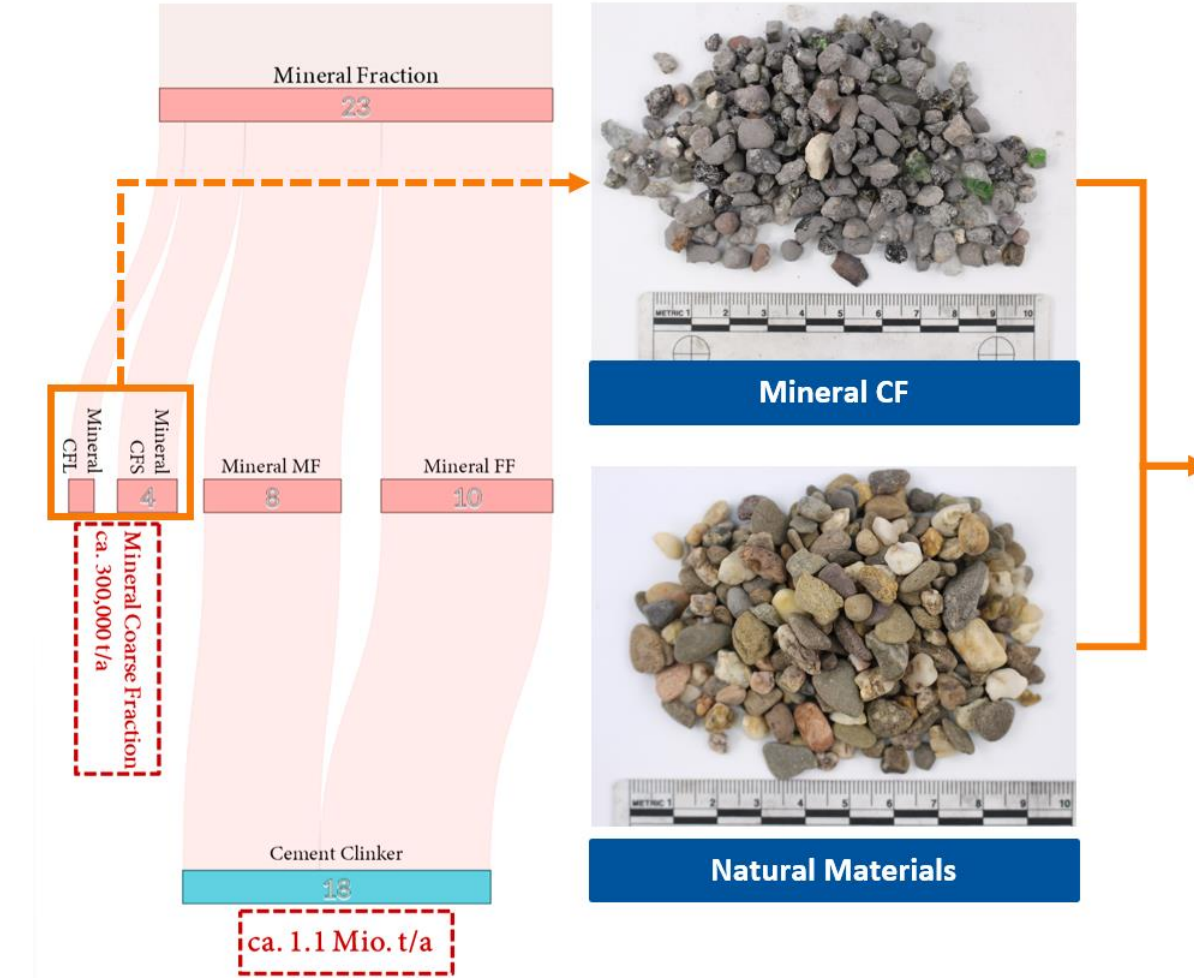
Mineral CF as aggregate in concrete



Mineral CF

Natural Materials

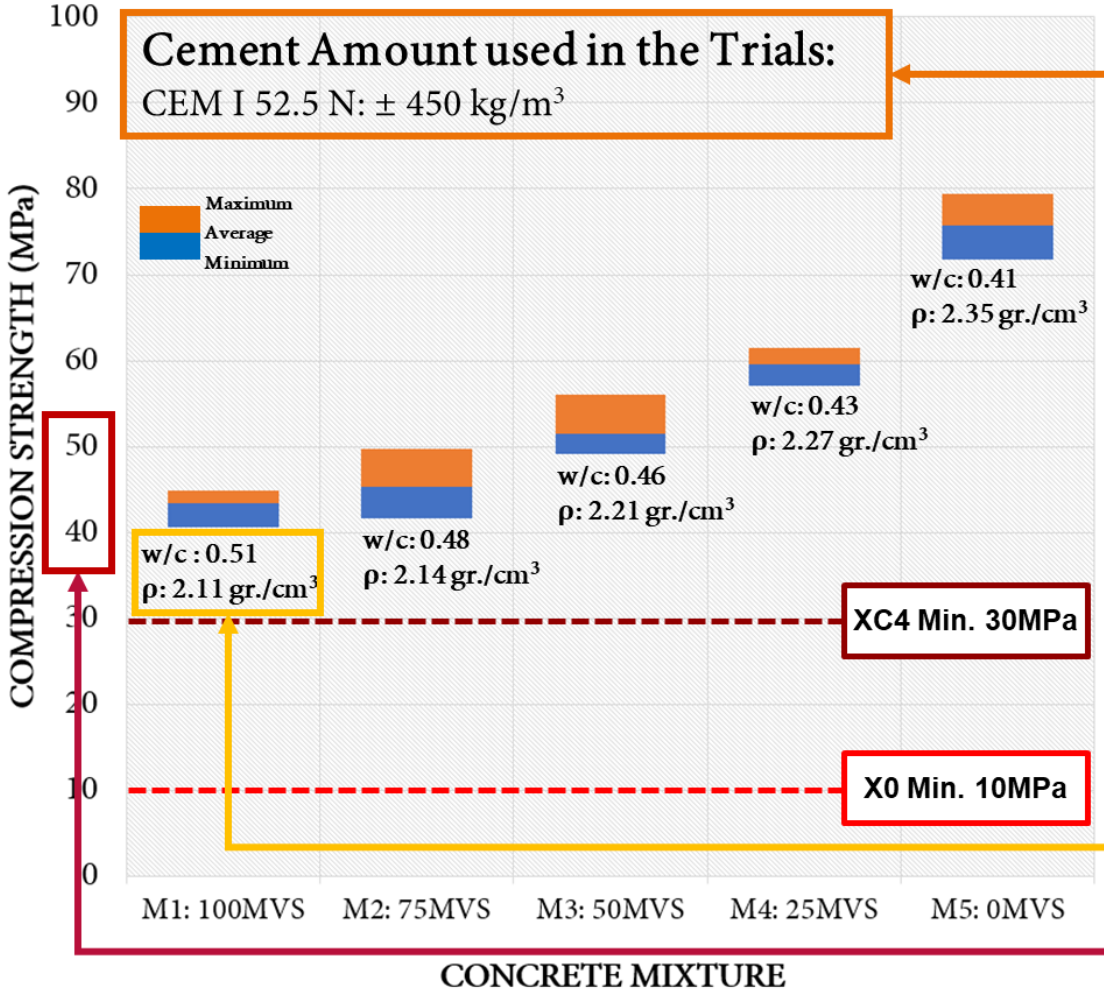
Concrete Samples

Concrete Sample Compression Strength Test

#conducted in:
Institut für Materialwissenschaft
Universität Duisburg Essen

Adhiwiguna, I.; Deike, R.; Warnecke, R.: *EMSARZEM Alternative Perspective to Valorize the Municipal Waste Incinerator Bottom Ash for Metals and Cement Industries*, FEMS EUROMAT 2023, Frankfurt Germany, 06.09.2023

Compression test of concrete



min. c: minimum cement (kg) for 1 m³ of concrete

Expositionsklassen (Umwelteinwirkungen, „Angriffe") *Exposure classes (environmental effects, "attacks")*				Betontechnische Maßnahmen („Widerstände") *Concrete technology measures ("resistances")*		
Klassenbez. *class designation*		Einwirkung und Beanspruchung *effect and stress*		Max. w/z *max. w/c*	Min. z *min. c*	f_{ck}, cube *f_{ck}, cube*
XO		kein Angriff *no attack*	kein Betonangriff *no concrete attack*	keine Anforderung *no requirement*	keine Anforderung *no requirement*	C8/10 *C8/10*
XC	1	H_2O	trocken *dry*	0,75	240	C16/20
	2		ständig nass *constantly wet*	0,75	240	C16/20
	3	CO_2	mäßig feucht *moderately moist*	0,65	260	C20/25
	4	Carbonatisierung *carbonation*	nass / trocken *wet / dry*	0,60	280	C25/30

Grube, H., & Kerkhoff, B. (2001). Die neuen deutschen Betonnormen DIN EN 206-1 und DIN 1045-2 als Grundlage fuer die Planung dauerhafter Bauwerke.

Max. w/c: maximum water to cement ratio in concrete

C25/30: minimum strength of concrete samples for cylinder (25 MPa) and cube (30 MPa) sample

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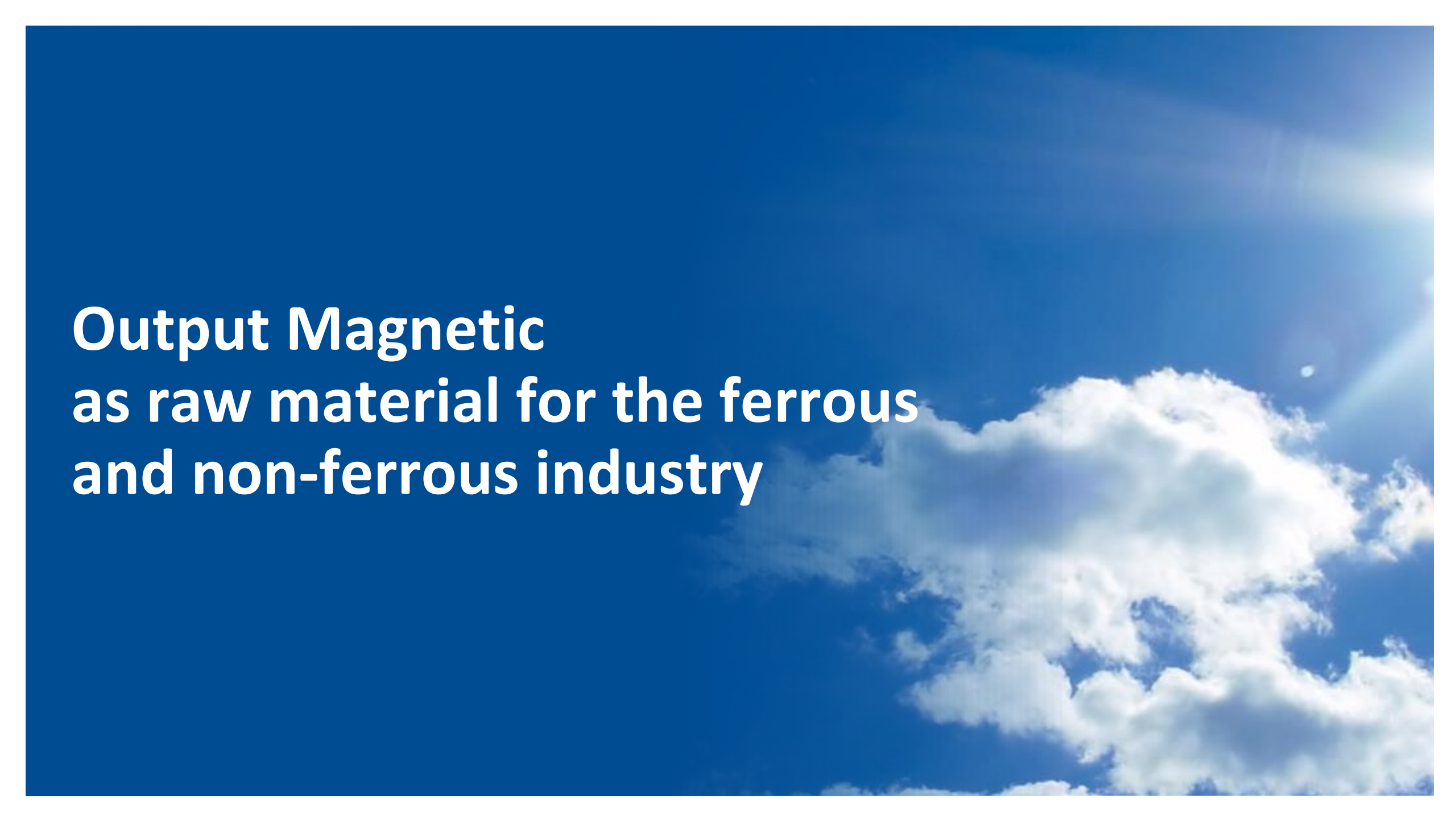
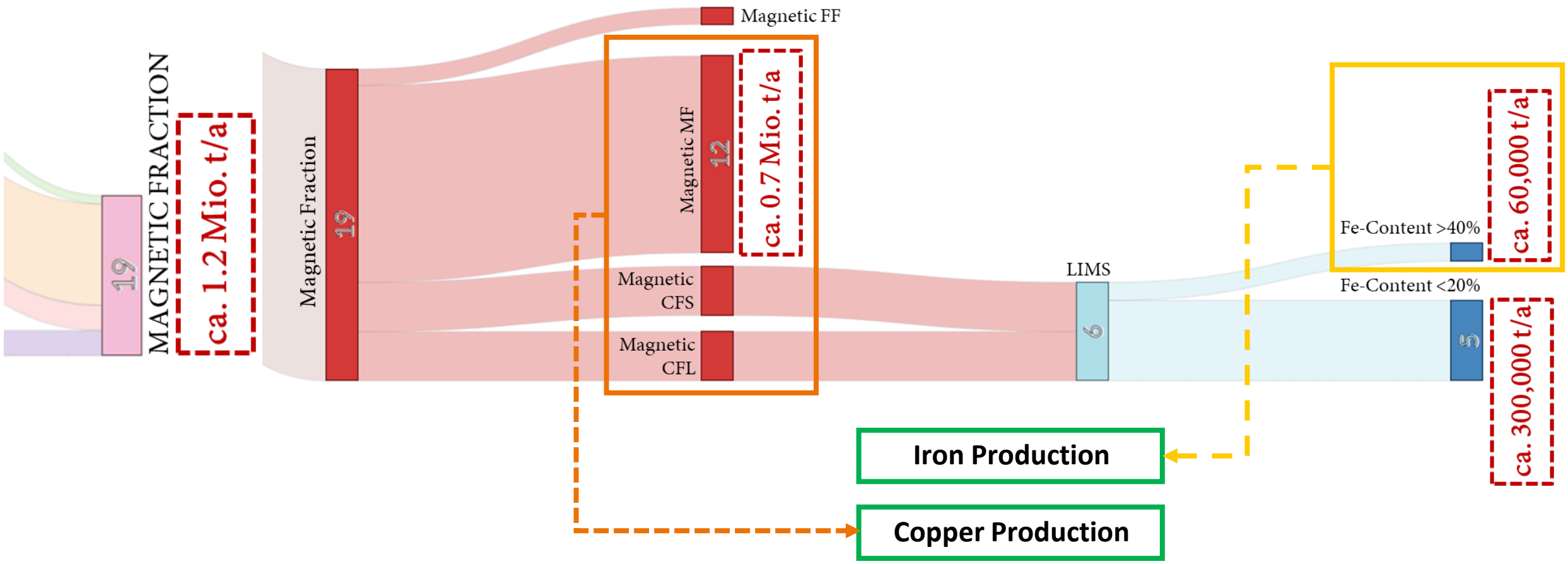
Output Magnetic
as raw material for the ferrous and non-ferrous industry

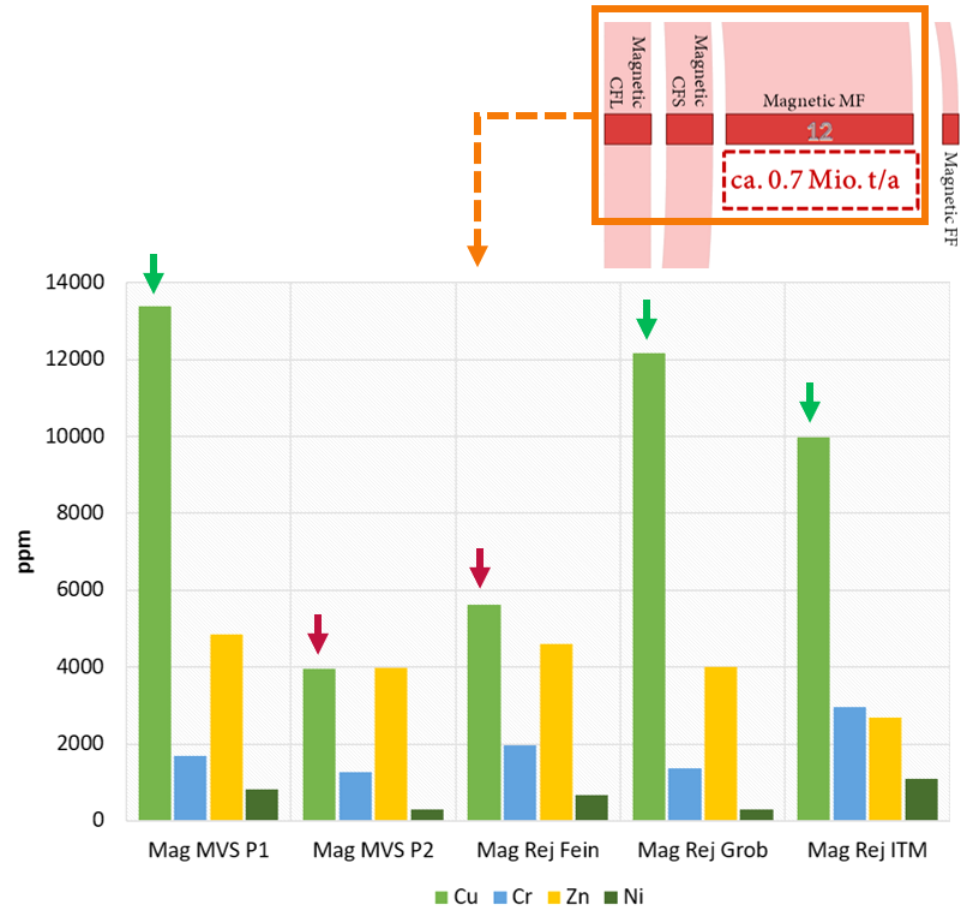


Expected valorization of the magnetic fraction

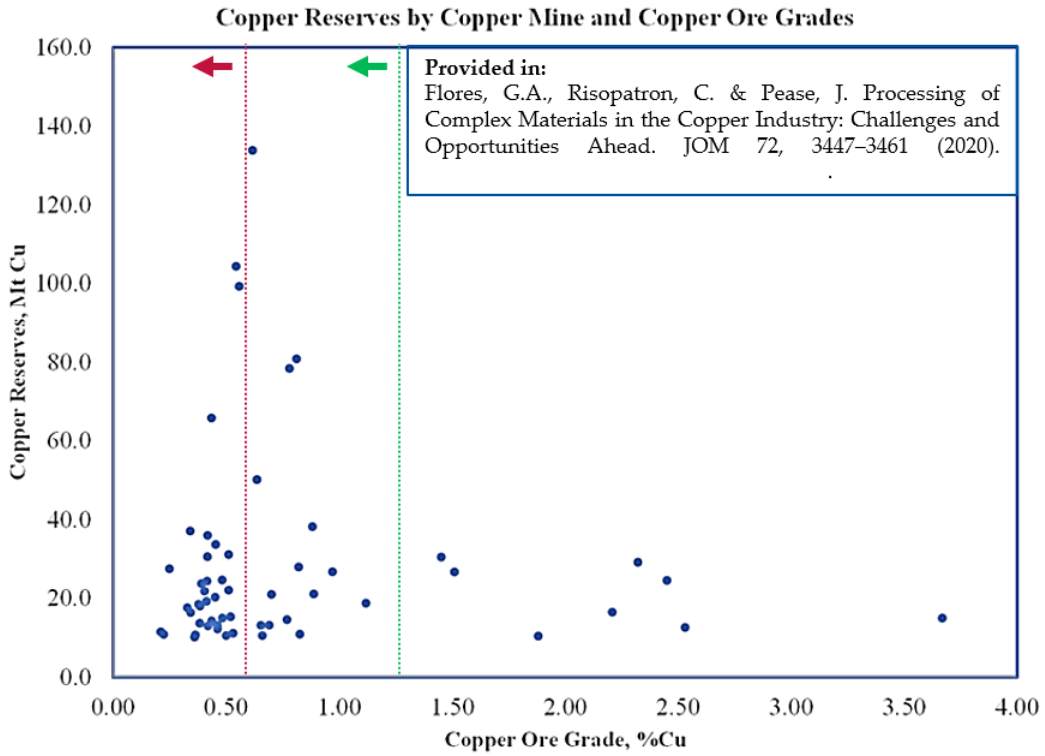


Adhiwiguna, I.; Deike, R.; Warnecke, R.: Copper in MSW incinerator bottom ash, GDMB Technical copper committee, Essen, 26.10.2023

Magnetic fraction for the Cu-production



Composition of Trace Elements in Magnetic Fractions

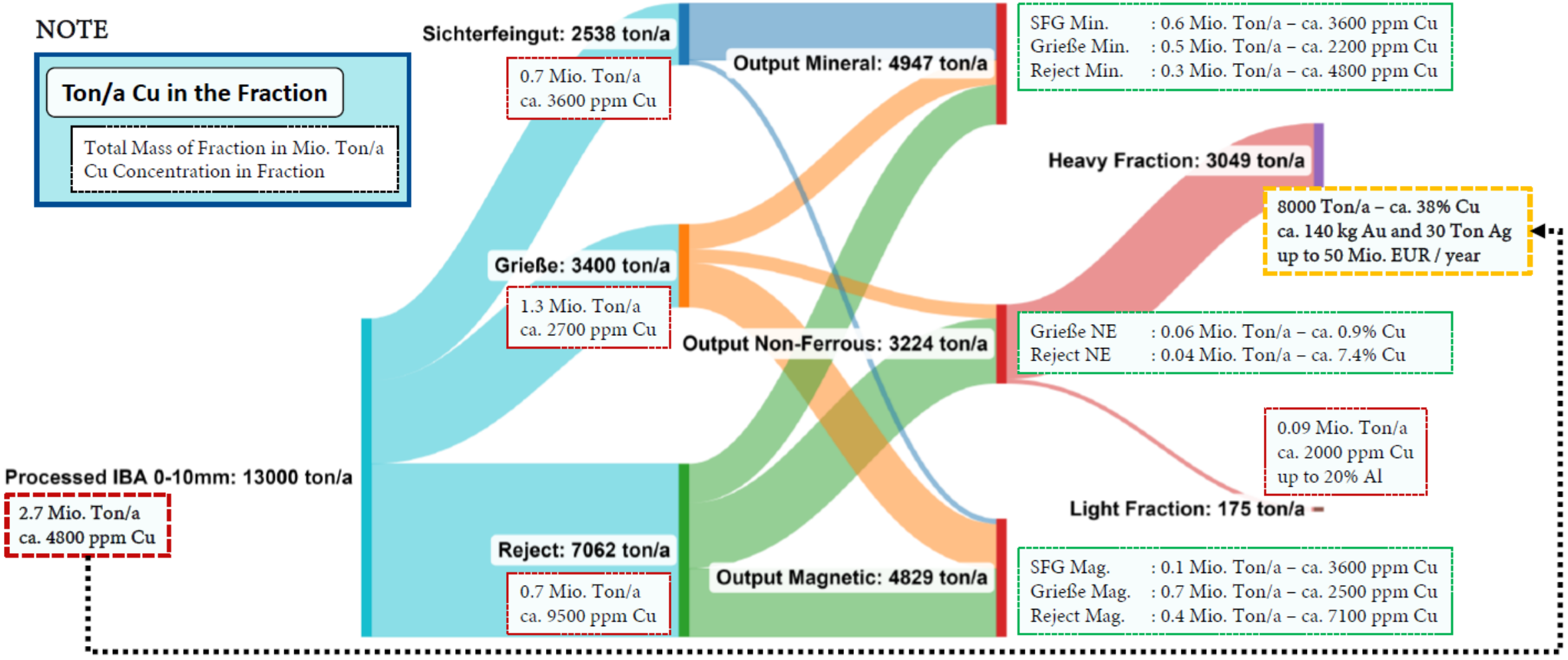


Copper Ore Grade from Ranked Top Reserves Cu-Mines Worldwide

Adhiwiguna, I.; Deike, R.; Warnecke, R.: Copper in MSW incinerator bottom ash, GDMB Technical Copper Committee, Essen, 26.10.2023

Output Non-Ferrous as raw material for the non-ferrous metal industry

Expected valorization of the Non-Fe Fraction



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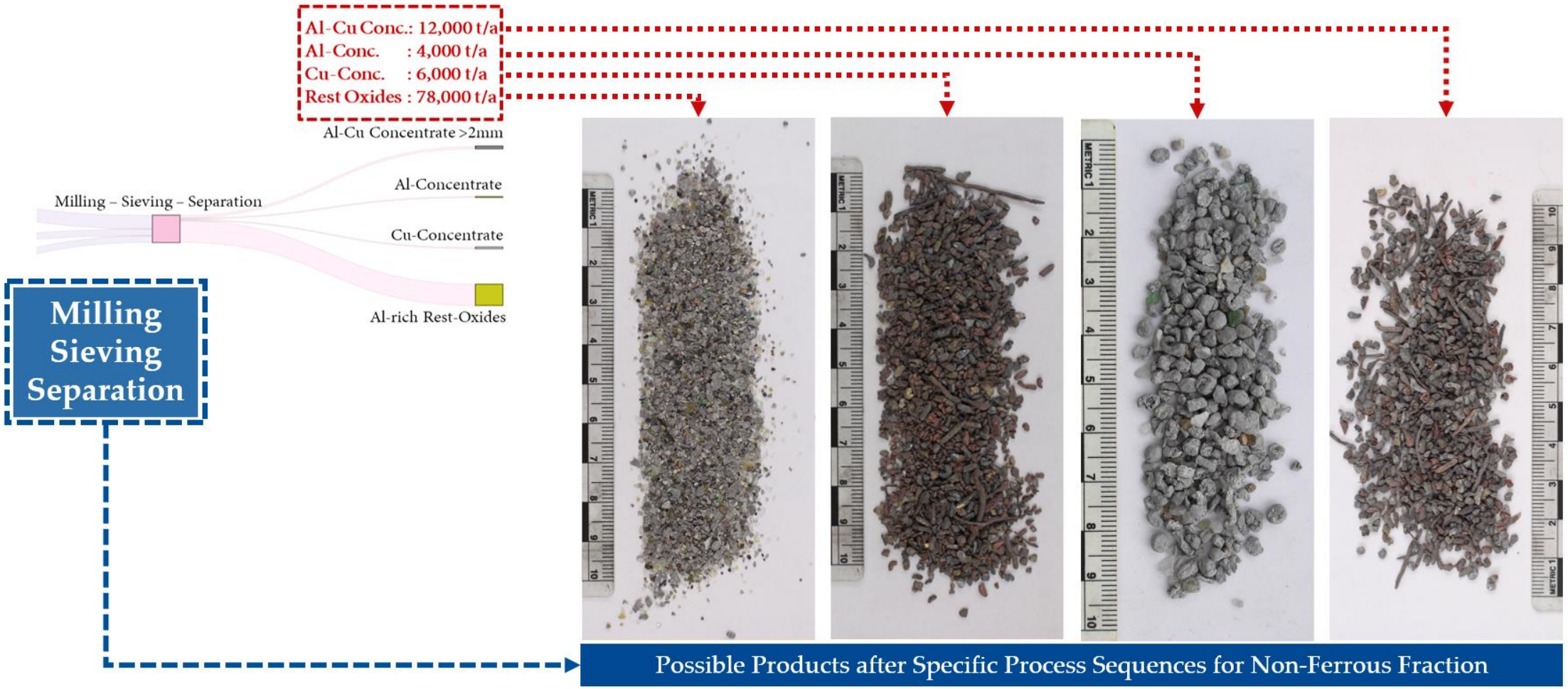
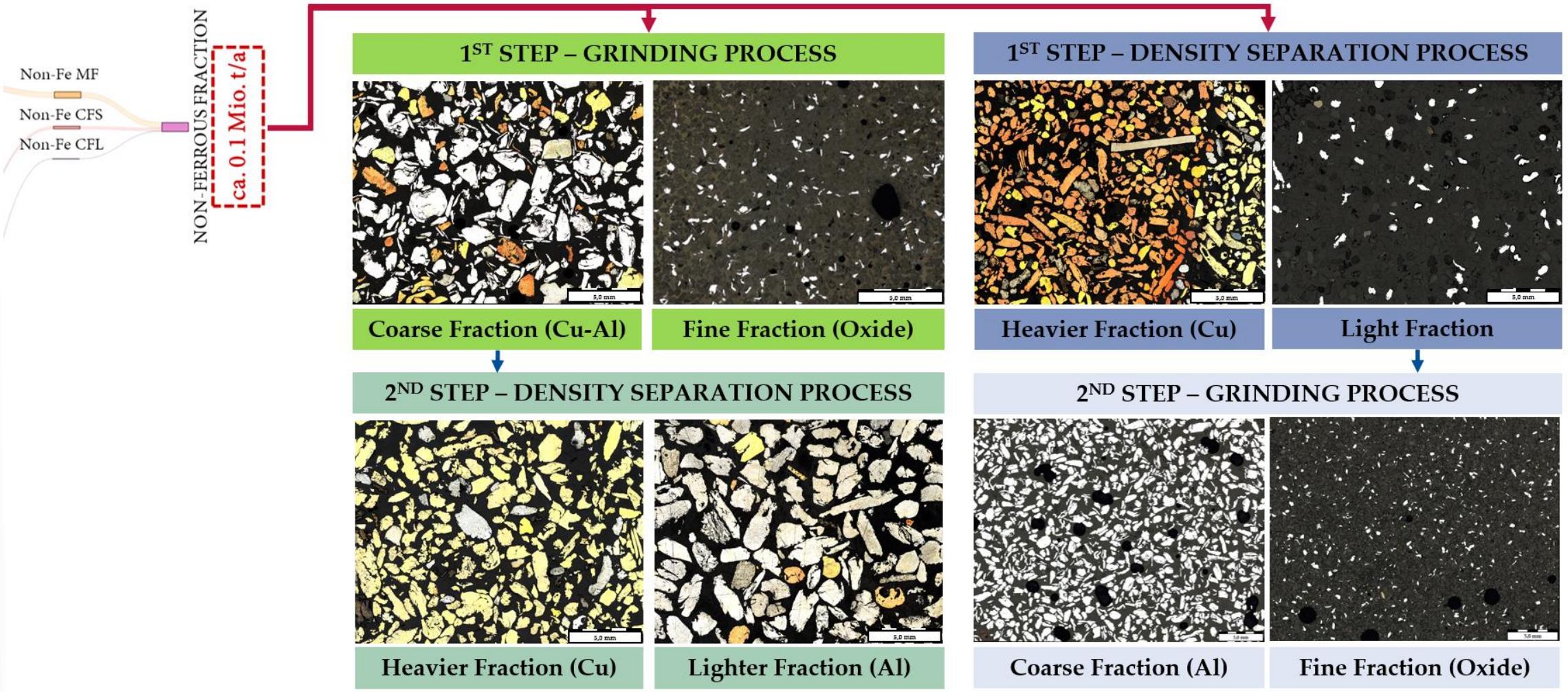
Metal recovery from Non-Ferrous Fraction



Adhiwiguna, I.; Deike, R.; Warnecke, R.: Copper in MSW incinerator bottom ash, GDMB Technical copper Committee, Essen, 26.10.2023

Classification of recovered metals



Adhiwiguna, I.; Deike, R.; Warnecke, R.: Copper in MSW incinerator bottom ash, GDMB Technical copper Committee, Essen, 26.10.2023

Summary

Summary

Based on pilot scale tests:

1. It is possible to **grind the processed incinerator bottom ash** *(Fertigschlacke)* without any noticeable problem.
2. It is possible **after further separation process sequences** from an estimated 2.7 Mio. t/a processed IBA (*Fertigschlacke*) 0-10 mm to produce the following valuable products:
   - **Output Mineral** : theoretically ca. 1.4 Mio. t/a
   - **Output Magnetic** : theoretically ca. 1.2 Mio. t/a
   - **Output Non-Ferrous** : theoretically ca. 0.1 Mio. t/a

Summary

Based on current laboratory trials:

1. Using the output mineral in cement clinker and concrete production is promisingly possible**.**
2. It is provenly possible to increase the **iron content of output magnetic for iron production.**
3. It is rationally possible to develop the next assessment to extend the use of **output magnetic in copper production** since the copper concentration is comparable to the copper ore.
4. It is technically possible to separate the **non-ferrous output into different products for further recycling in the respective non-ferrous metal industries**.