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Federal Ministry of Education and Research

NuKoS

CO2WIN Use Carbon Sustainably

Utilization of carbon dioxide in slags from steel and metal production

02/2020 – 01/2023

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NuKoS consortium

Research & Development

INSTITUT FÜR BAUSTOFF FORSCHUNG fehs

Fraunhofer UMSICHT

SME

WAGRO Systemdichtungen

WOLF BEHÄLTER- UND APPARATEBAU

large scale enterprises

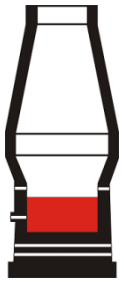
thyssenkrupp

spenner

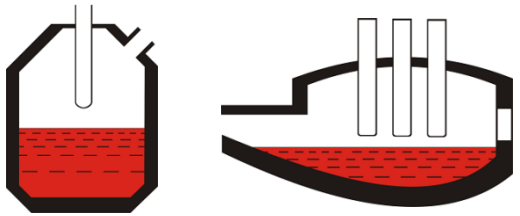
LOESCHE

UNIKA® KALKSANDSTEIN

Production and usage of iron and steel slags in Germany 2019

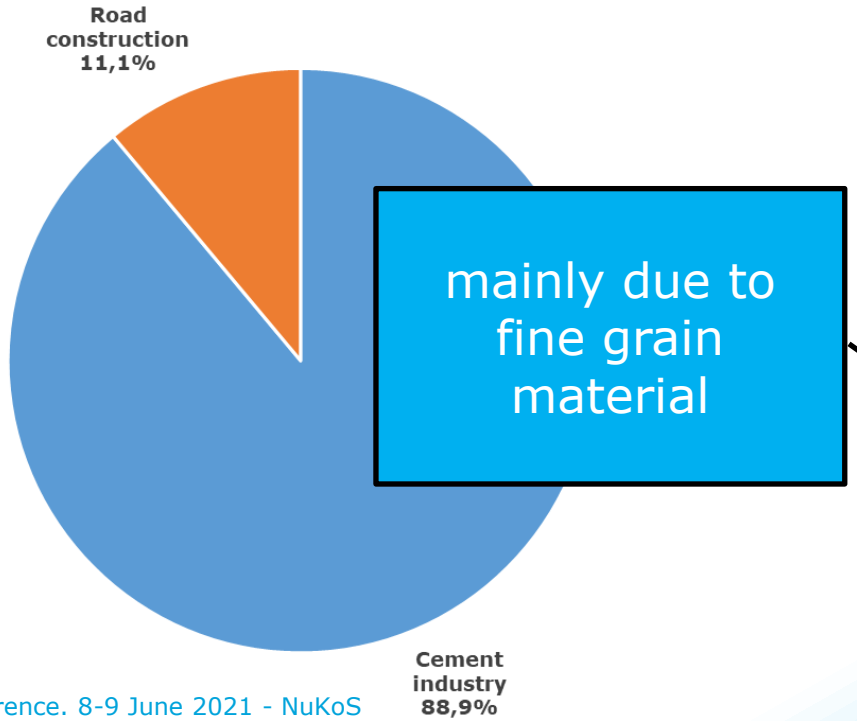


12.22 Mio. t

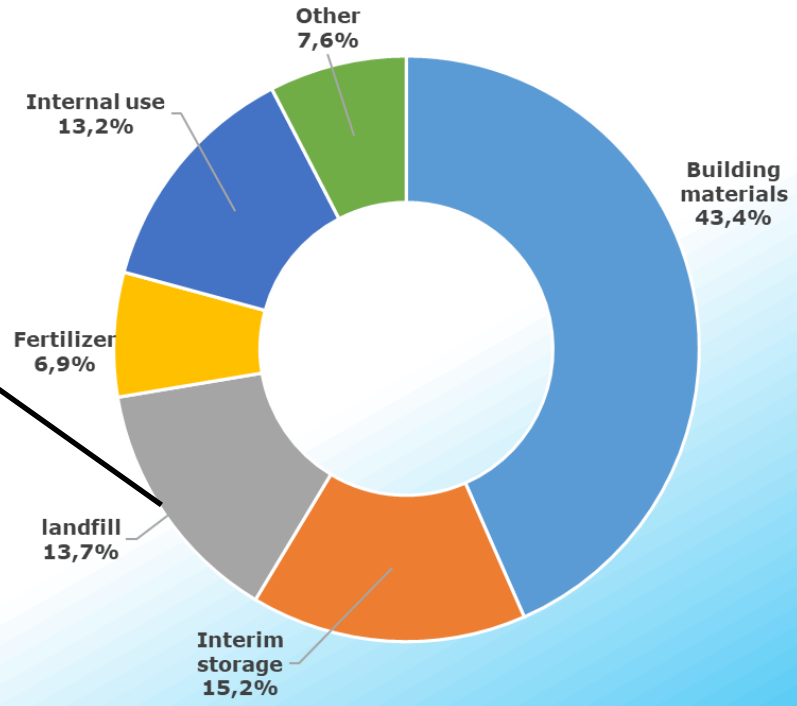


7.21 Mio. t blast furnace slag

5.01 Mio. t steel slag



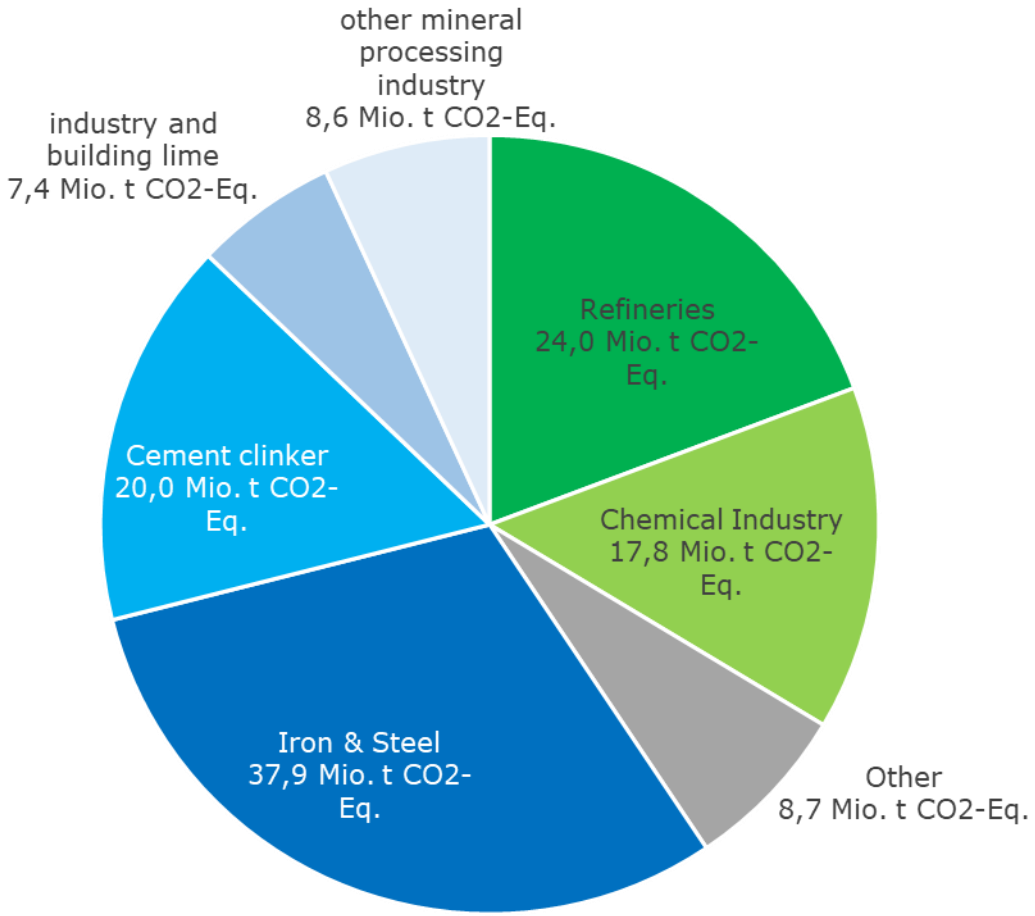
mainly due to fine grain material



thereof:

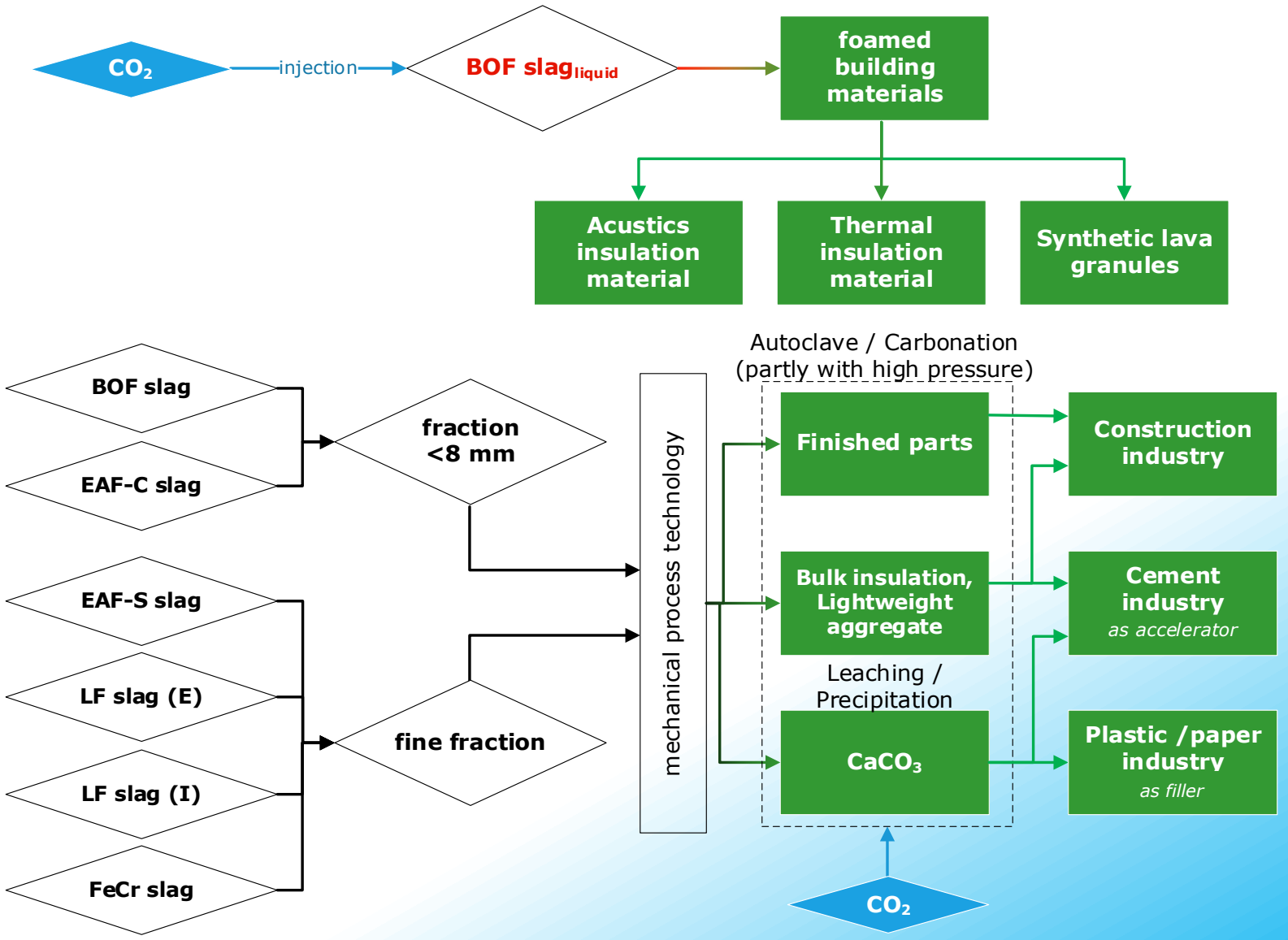
Road construction:	85.0 %
Earth works:	7.7 %
Track construction:	2.0 %
Water construction:	2.3 %
Other:	5.7 %

CO_2 Emissions of German industry 2018 (without electrical power generation)



based on UBA: on German Federal Environmental Agency (2019)

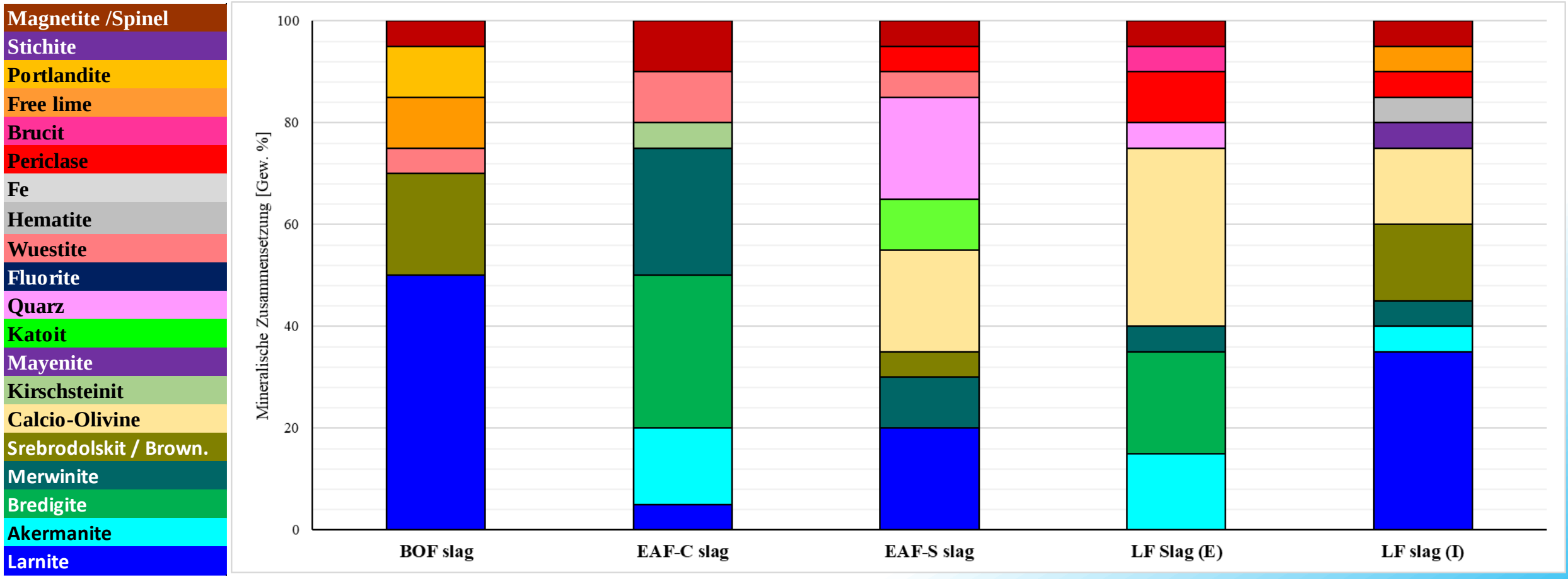
NuKoS Flowchart



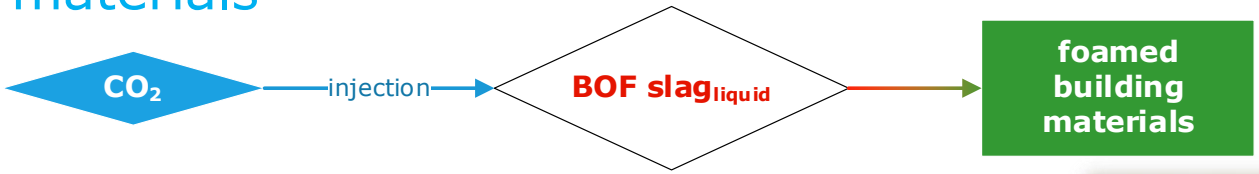
Basic characterization

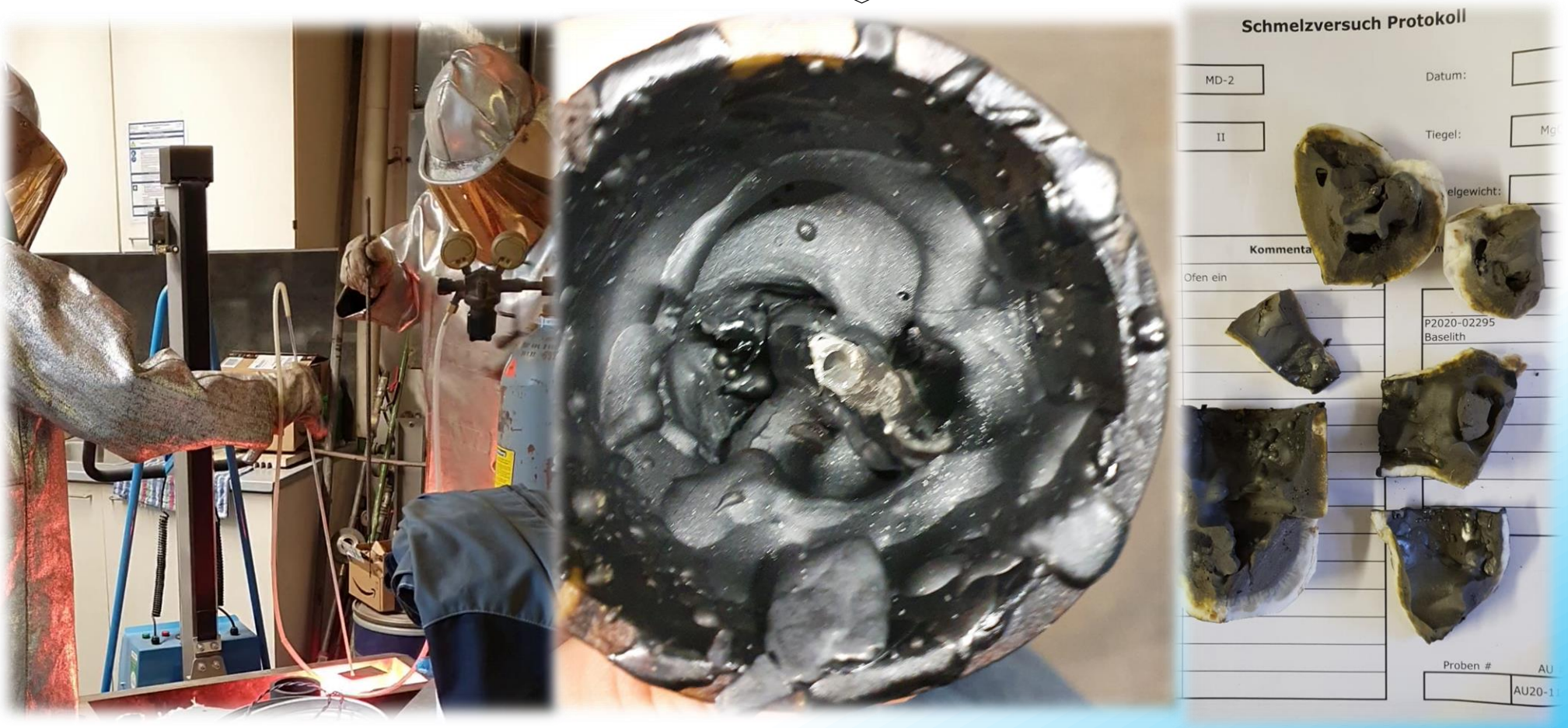
		BOF slag	EAF-C slag	EAF-S slag	LF slag (E)	LF slag (I)	FeCr slag
Al_2O_3	wt.-%	4.86	8.89	8.62	10.9	11.1	6.47
CaO	wt.-%	44.3	28.8	32.8	42.5	44.8	43.7
Cr_2O_3	wt.-%	0.22	1.49	7.24	0.14	0.12	7.13
Fe_{total}	*wt.-%*	*17.7*	*15.6*	*9.21*	Fe_2O_3 calculated from Fe_{total}		
$Fe_{met.}$	wt.-%	1.57	0.5	0.1			
FeO	wt.-%	8.35	15.9	4.99			
Fe_2O_3	wt.-%	13.8	3.9	7.48	4.01	14.3	0.95
CO_2	wt.-%	1.1	0.21	1.0	1.9	0.58	1.1
MgO	wt.-%	5.41	12.6	10.1	11.2	6.81	13.7
MnO	wt.-%	2.16	5.18	3.03	1.05	4.99	0.13
P_2O_5	wt.-%	1.48	0.29	0.083	0.039	0.76	<0.020
S	wt.-%	0.12	0.21	0.22	0.94	0.67	0.14
SiO_2	wt.-%	11.3	17.1	17	19.9	13.1	25.2
TiO_2	wt.-%	0.91	0.69	0.38	1.07	0.48	0.16
H_2O	wt.-%	2.54	< 0.03	4.41	4.43	0.63	2.01
LoI (950 °C)	wt.-%	1.9	-1.97	4.95	5.68	-0.62	2.46

Basic characterization



Foamed building materials

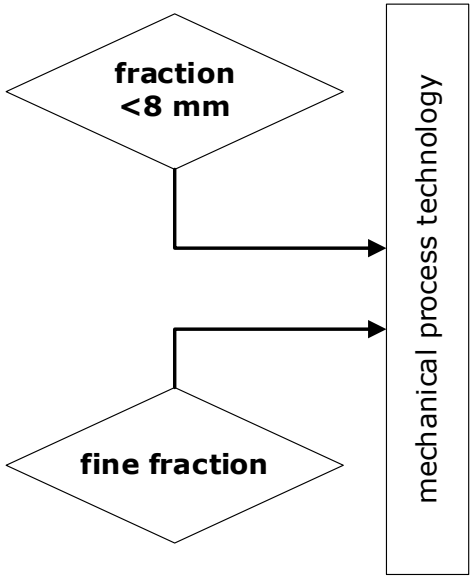




Foamed building materials

Multi injection lance system

Mechanical pre-treatment of already solidified slags



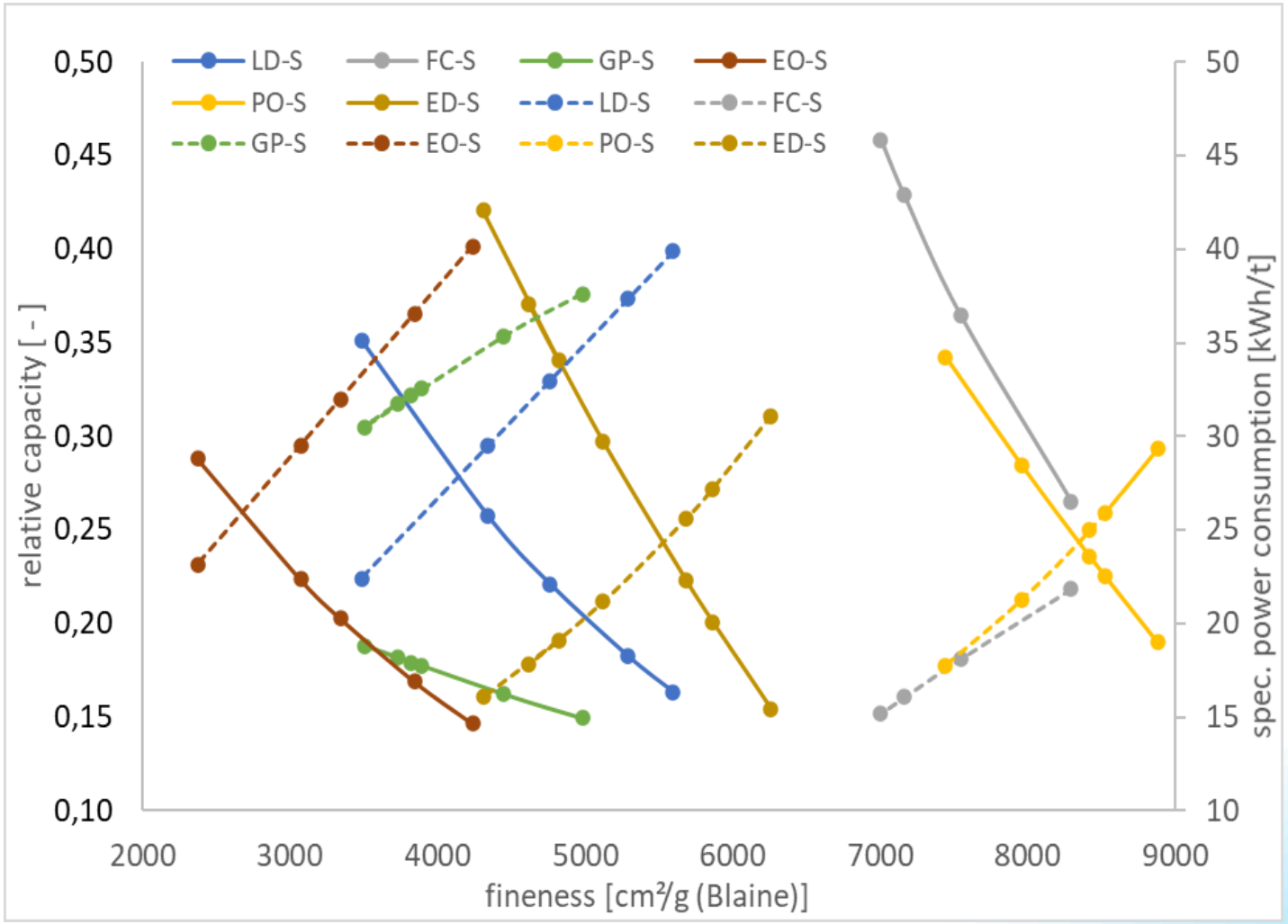
LOESCHE pilot plant LM 3,6/2

→ Magnetic seperated material

→ Reject

→ Product

Mechanical pre-treatment of already solidified slags



LD-S: BOF slag
EO-S: EAF-C slag
ED-S: EAF-S slag
PO-S: LF slag (E)
GP-S: LF slag (I)
FC-S: FeCr slag

Substituting virgin materials in construction industry

Autoclave / Carbonation
(partly with high pressure)

Finished parts → **Construction industry**

Carbonation of

- 100 % slag
- calcareous sandstone, slag substitutes graywacke
  - Regular process for sand-lime brick
- calcareous sandstone, slag substitutes graywacke
  - no autoclave

Substituting virgin materials in construction industry

Autoclave / Carbonation
(partly with high pressure)

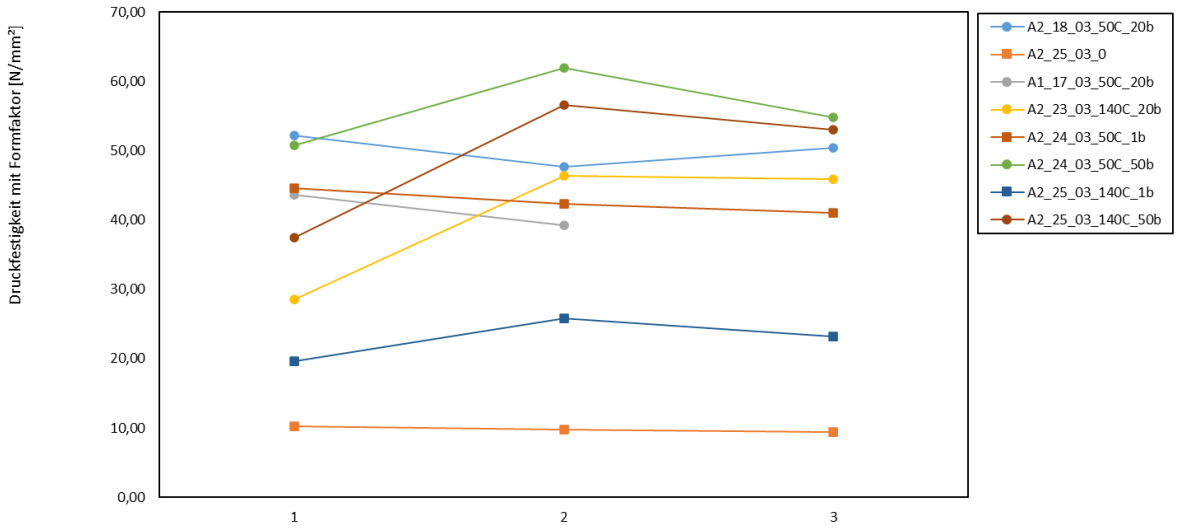
Finished parts → **Construction industry**

hydrothermal hardening
with coarse material

100 % slag

Substituting virgin materials in construction industry

Increasing BOF slag ratio (substituting graywacke)
0 - 100 %



Parameter Carbonation			
	Pressure [bar]		
Temperature [°C]	1	20	50
50	42,63	50,06	55,85
140	22,88	40,26	49,02
Ref, w/o treatment	9,80		
DFK	[N/mm²]		

Pelletizing and hardening without binder

Bulk insulation, Lightweight aggregate

→ **Construction industry**

→ **Cement industry** *as accelerator*

Extraction of calcium carbonate

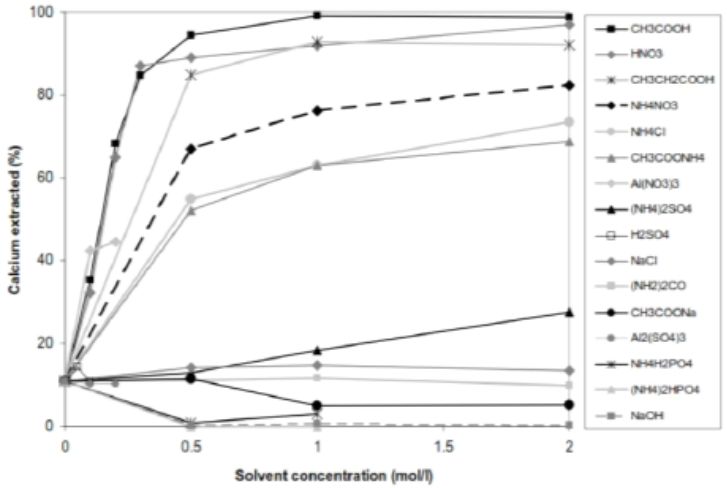
Leaching / Precipitation

$CaCO_3$ → **Plastic /paper industry** *as filler*

63 ml high pressure cell

500 ml stirrer vessel

Extraction of calcium carbonate



Challenging:

Extracting agent with high selectivity is corrosive

Extracting agent with high extraction rate destroys $CaCO_3$

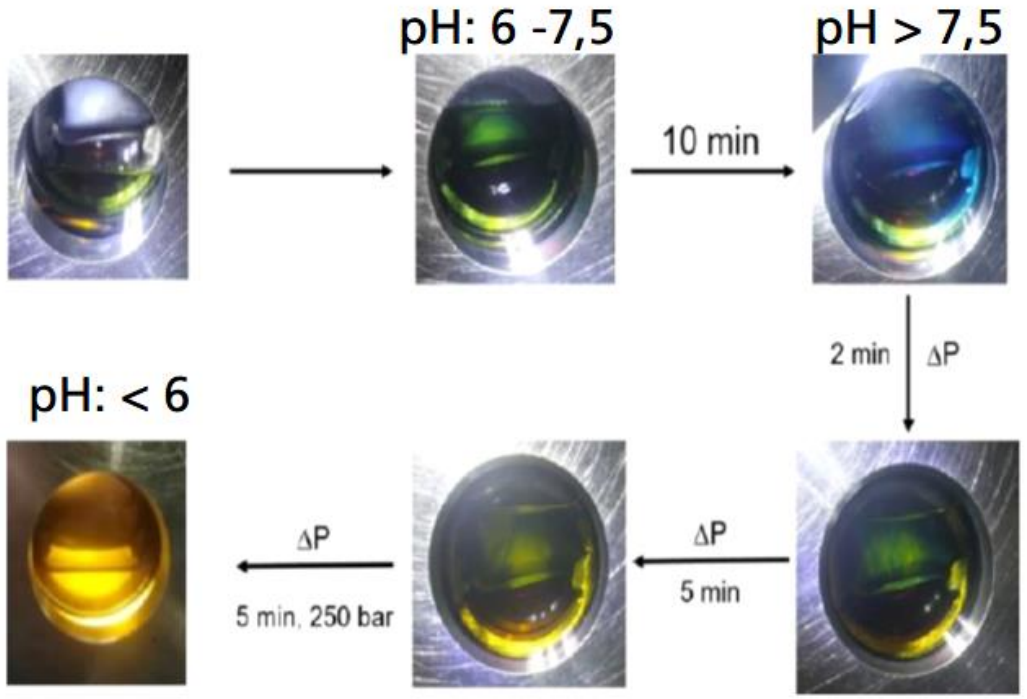
Parameters	Variation
Pressure	10 bar, 50 bar, 100 bar, 150 bar, 250 bar
Water-solid ration	28 g/L and 40 g/L
Temperature	20°C, 40 °C and 60 °C
pH-value(high pressure)	≤ 6
Additive	Acetic acid (0,1 mol/L)

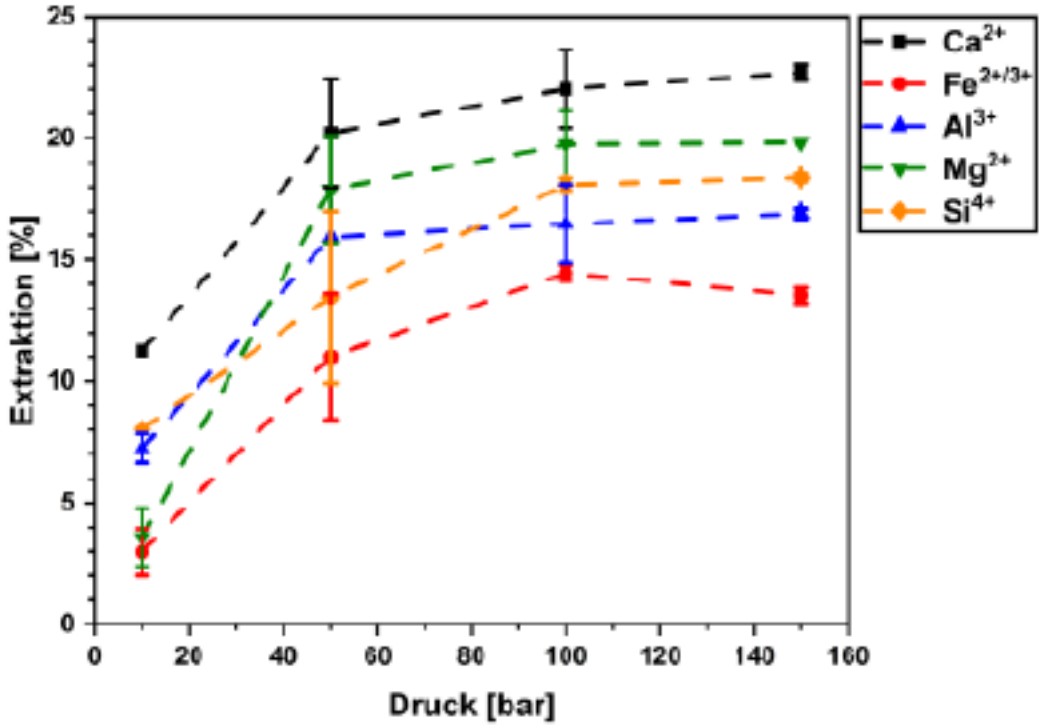
Extraction of calcium carbonate

6 g slag in 50 ml water + 1ml indicator

Trials at 20 bar and 250 bar CO_2

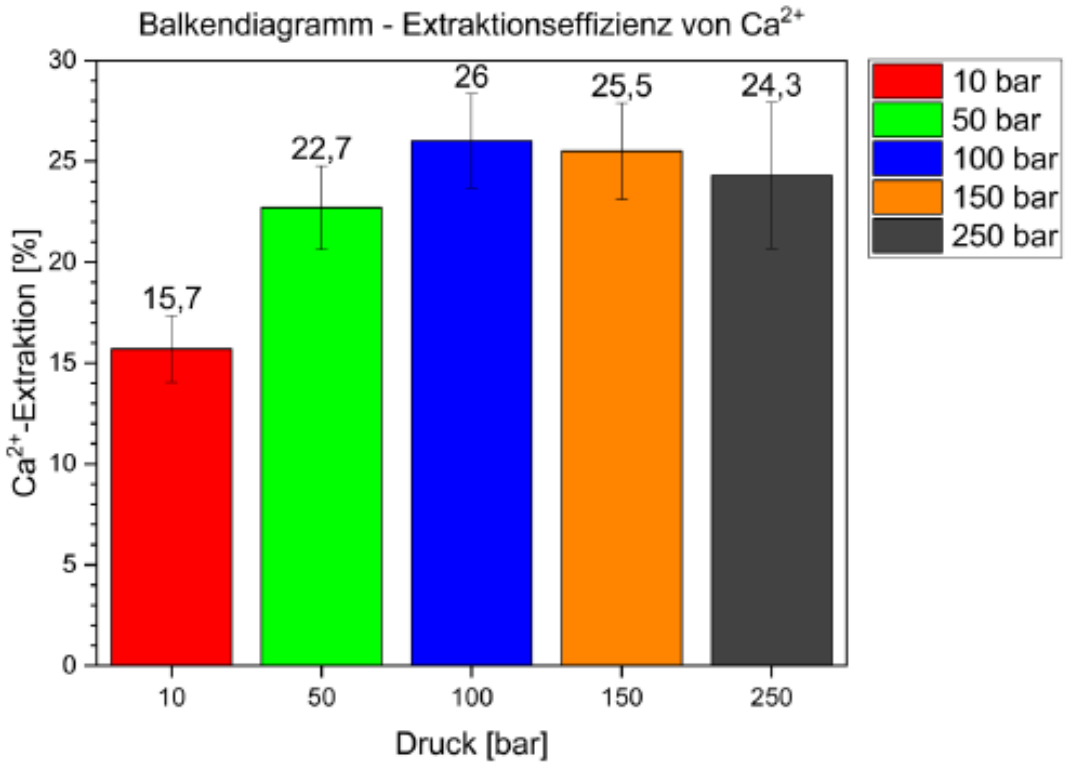
pH <6

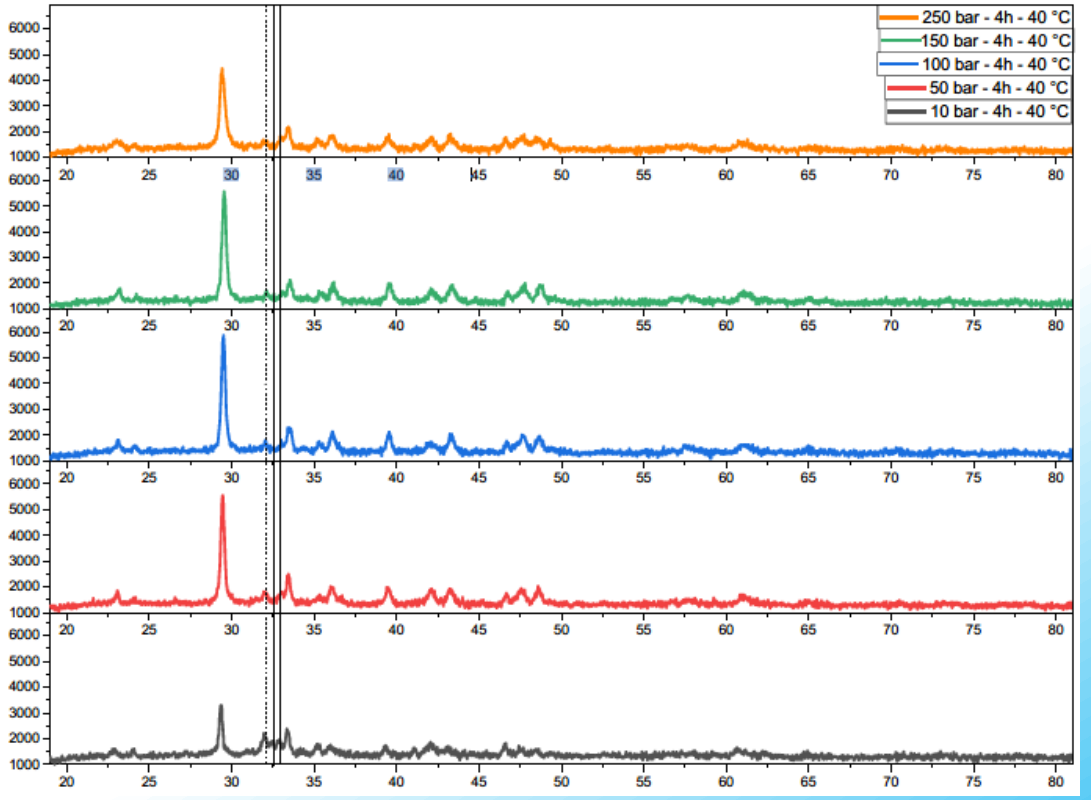




- Between 50-150 bar no signification increase of extraction
- Also formation of other hydrogen carbonates

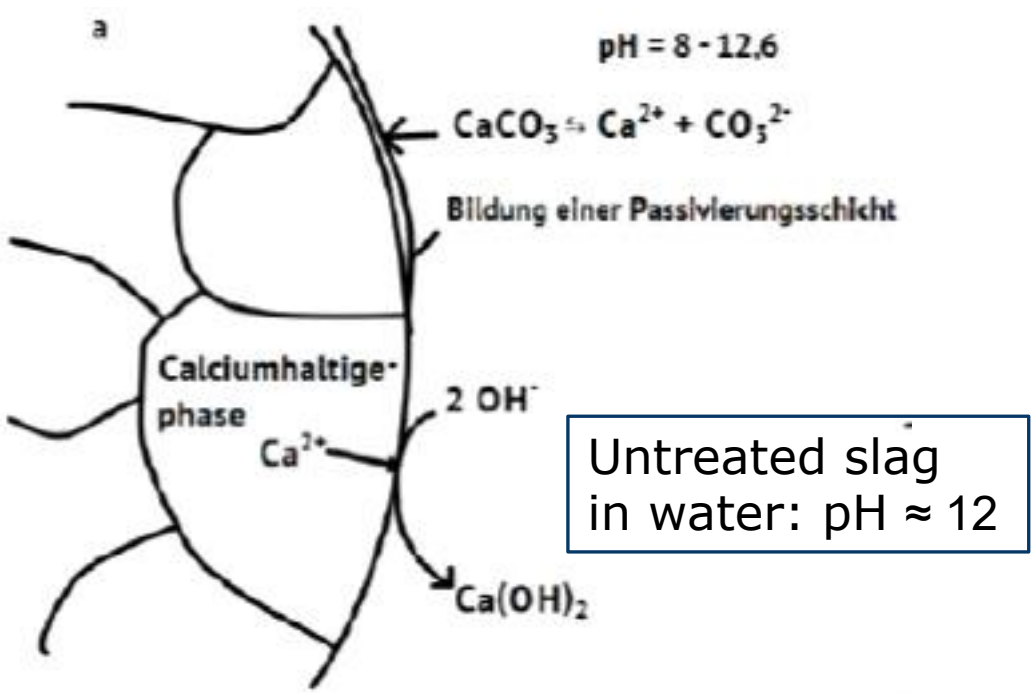
Extraction of calcium carbonate





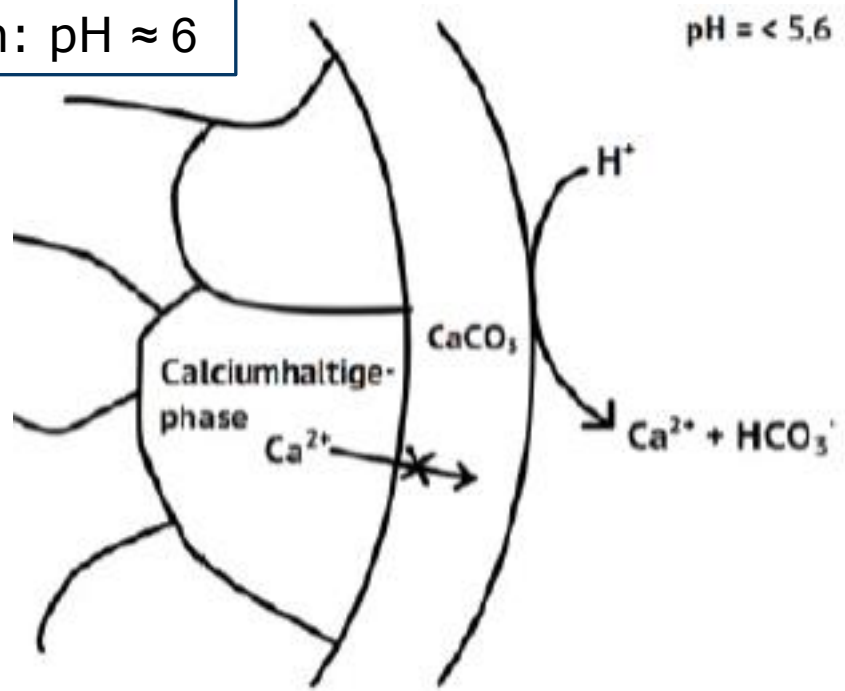
Larnite decreases with higher pressure
Calcite increases by higher pressure

Extraction of calcium carbonate



Untreated slag in water: pH ≈ 12

CO_2 pressurized slag-water-Suspension: pH ≈ 6



Next steps

- Laboratory trials for all process ways in NuKoS
- Preparing upscaling for next year
- Pilot tests with molten BOF slag (up to 5 t of material)
- Pilot tests with carbonation

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