OCTOBER 29 30 31

voestalpine Stahl, Linz, Austria

Challenges and Solutions for

Steelmaking Dust Valorization in the Green Steel Transition

ESTEP 2024 Annual Event

Bernhard Voraberger, Christoph Prietl, Pastucha Krzysztof, Gerald Wimmer

30.10.2024

H2 FOR GREEN STEEL 3rd INTERNATIONAL CONFERENCE meets A CIRCULAR ECONOMY DRIVEN BY THE EUROPEAN STEEL

ESTEP European Steel Technology Platform

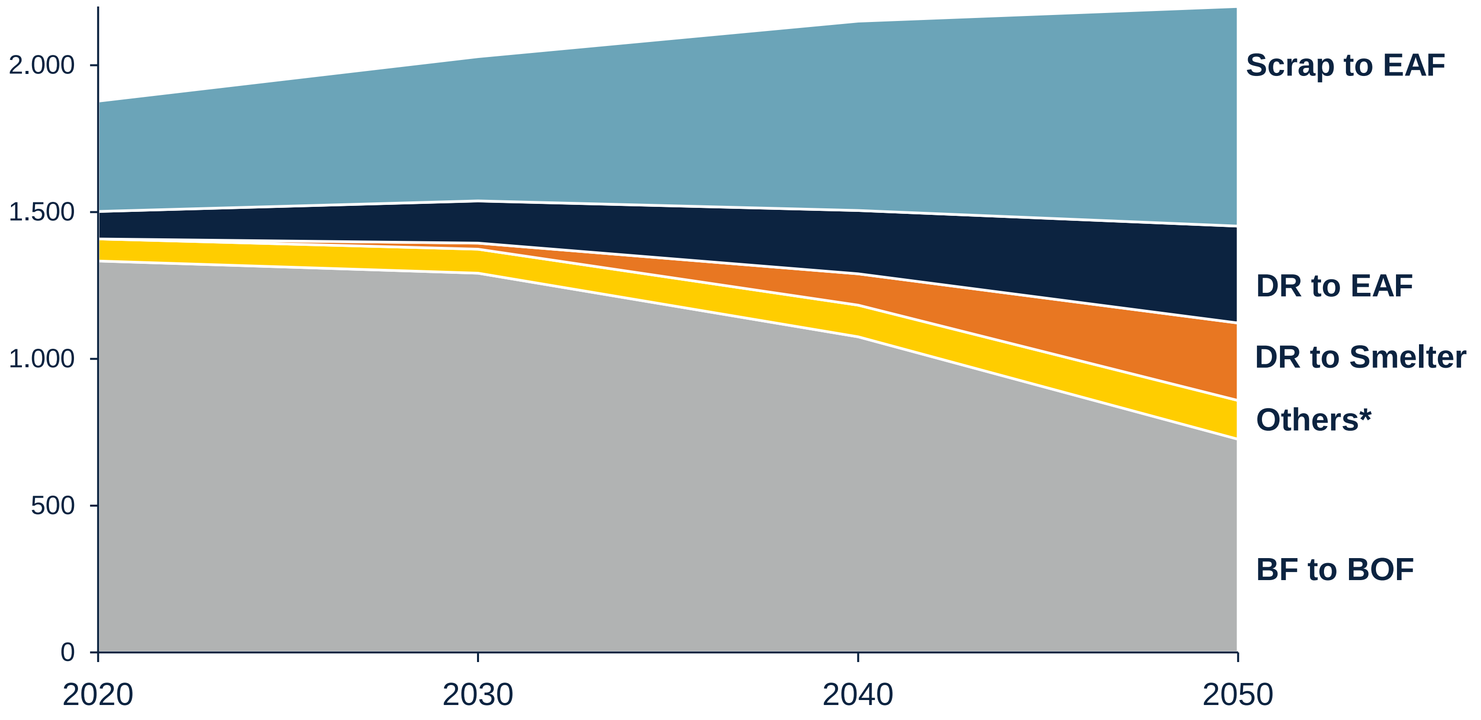
20 years together

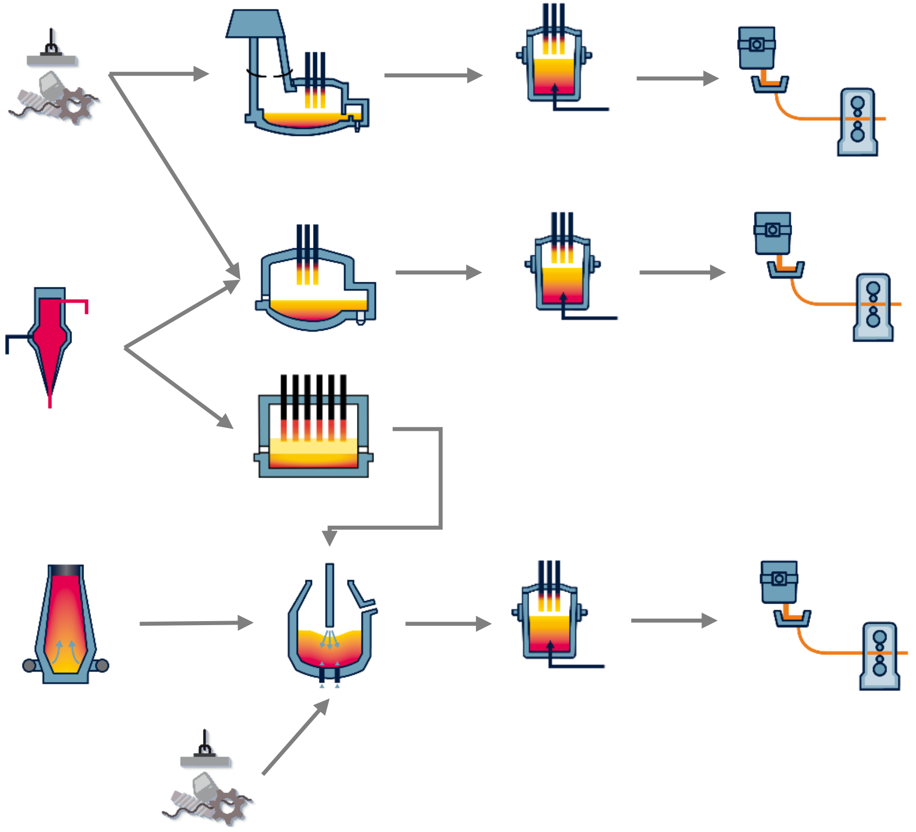
voestalpine ONE STEP AHEAD.

PRIMETALS TECHNOLOGIES

Green Steel transition

Forecast steel production, million tons p.a.





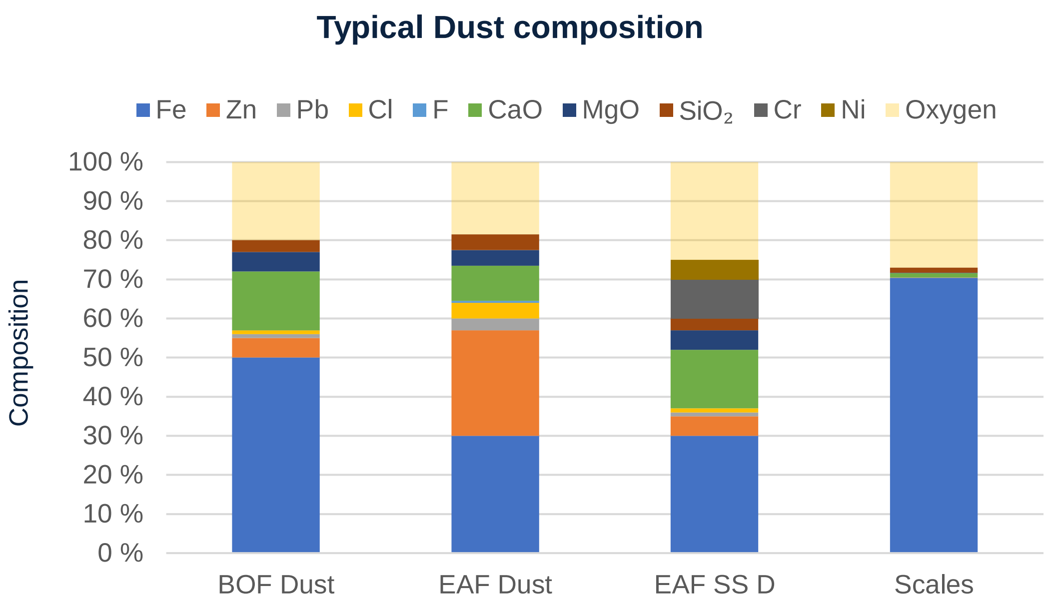
* includes coal based DRI, Induction furnace, Corex/Finex, open-hearth furnaces

Challenges due to green steel transition?

- BF share will decrease
  - Lower amount of BF slag and GBFS → cement industry is looking for alternatives
  - **Less sinter plants in operation → less option for internal recycling of scales, iron rich dusts and sludges**
- DR and EAF share will increase
  - High demand for green electric energy
  - Briquetting solution and recirculation of DR fines will be required
  - **Increased amount of EAF slags and dust to be expected → solution for recycling necessary**
  - **More scrap based EAF steelmaking and more galvanized scrap → higher Zn content in dust and until 2050 scrap based EAF steelmaking will increase to 750 Mtpa**
  - Cleaning and sorting of scrap will be come more important → design scrap

Steel mill dust and current recycling

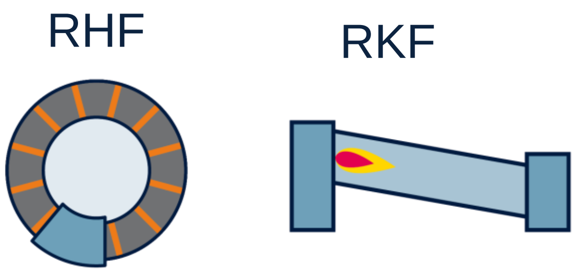
- Steel mill dust contains valuable elements: Zn, Fe, minerals
- Globally large amount of steel mill dust is produced:
  - BOF: 1,300 Mtpa steel → 30 Mtpa dust (2,3 %)
  - EAF: 500 Mtpa steel → 10 Mtpa (2 %)
- Less than 50 % of EAF dust is recycled globally
- In EU 90 % of EAF Dust is recycled with Waelz process (RKF)



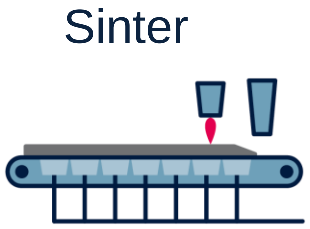
Issues with Waelz process:

- Mainly recover one metal (zinc)
- Generate a low-quality zinc oxide, needs washing
- Produce high amounts of residues (slag) which is not used
- Need centralized solutions to be effective
- Have High CO_2 emissions

External recycling:



Internal Recycling:



Zinc Extraction Process (ZEP) – for high Zn content dust
2 step dust recycling solution for the recovery of iron and high-quality zinc

Input material:

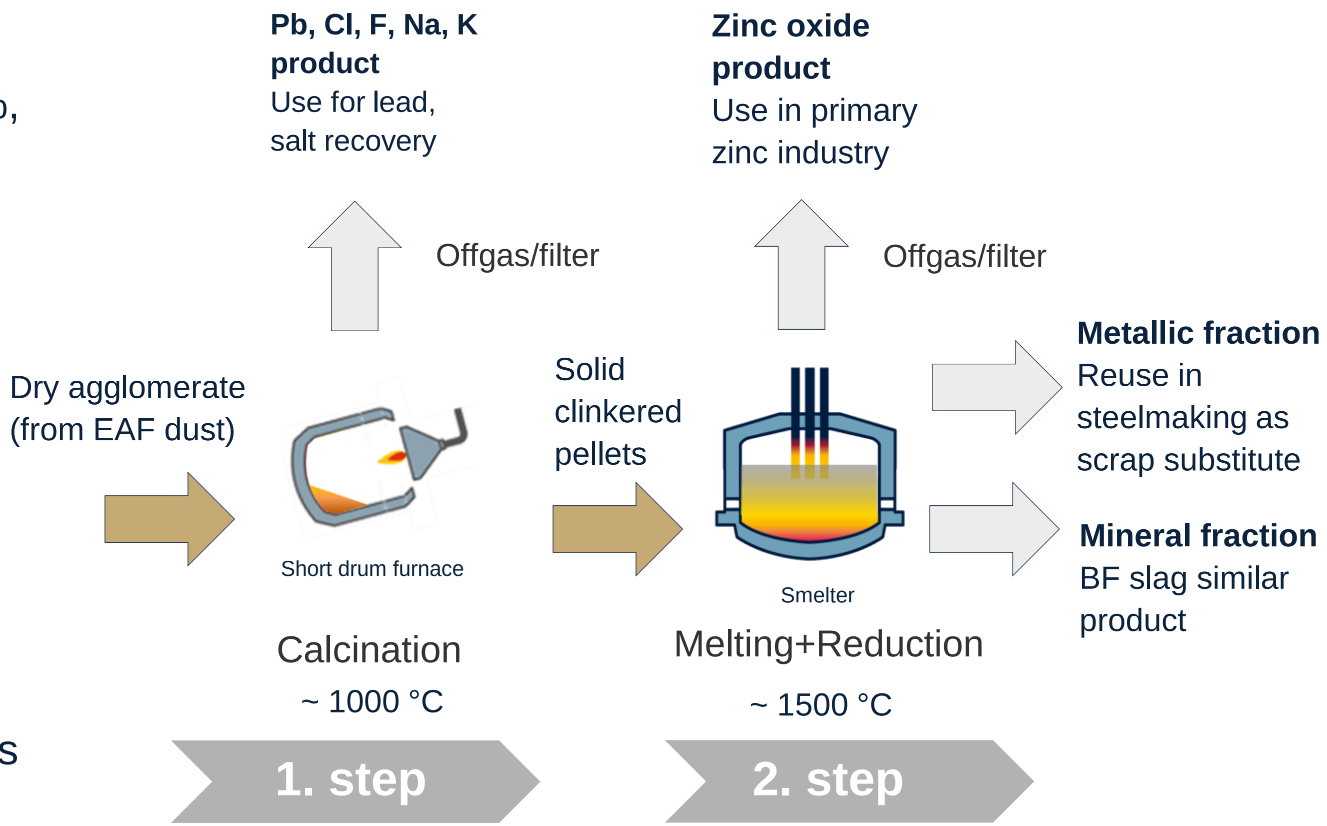
- Dry agglomerate prepared from EAF dust
- Scrap based EAF dust with high Zn content (Zn > 20 %, ZnO > 25 %)

Recycling process – combination of two plant units:

- Short drum furnace
- Melting & reduction unit

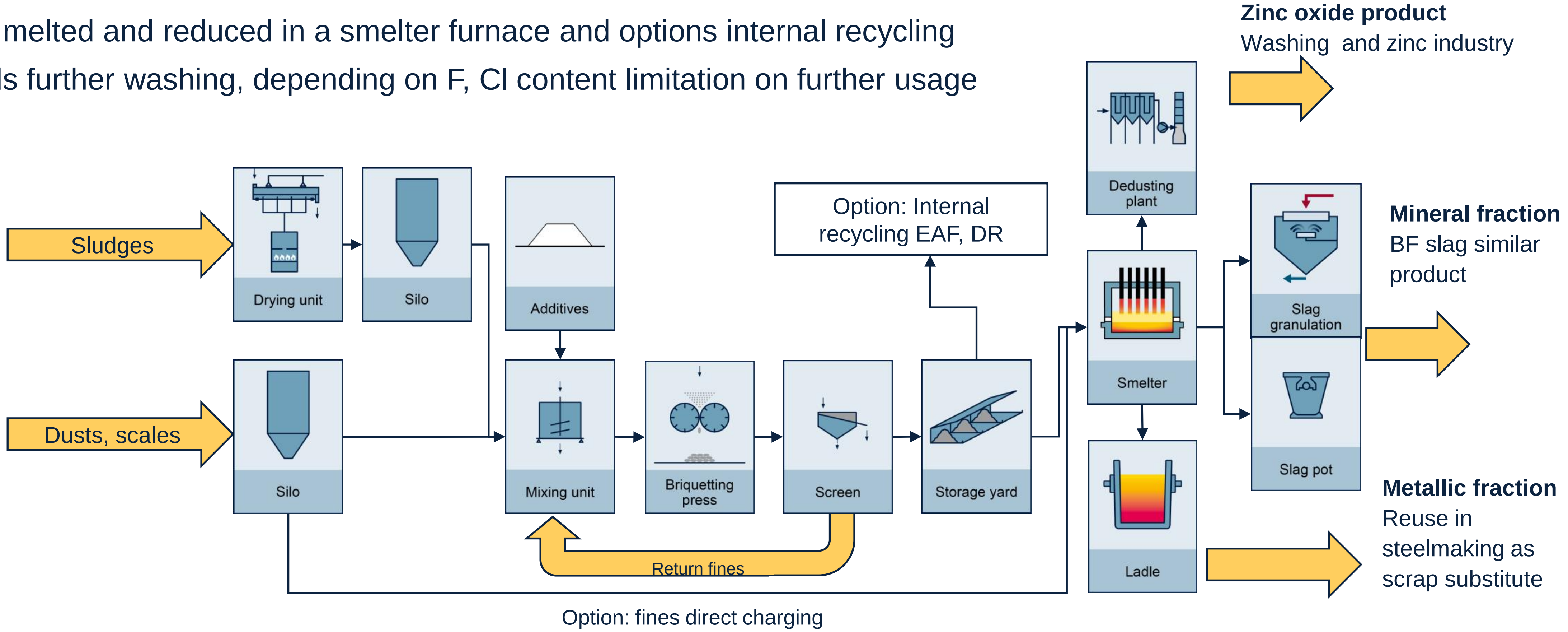
Output materials:

- 4 different output products, suitable for further use
- Halogen contamination is removed in 1. step ⇨ higher ZnO quality ⇨ direct usage in primary zinc industry
- Recovered iron/metal can be directly reused in steelmaking as scrap substitute ⇨ lower CO_2 emissions



Zinc Extraction Process (ZEP) – for low Zn content dust
1 step dust recycling solution for the recovery of iron and zinc

- Input material: iron bearing dust with low Zn content: Zn<10% (ZnO<13%), BOF, BF Dust, Scales
- Dust preparation (drying, agglomeration) or fines charging
- all dust is melted and reduced in a smelter furnace and options internal recycling
- ZnO needs further washing, depending on F, Cl content limitation on further usage

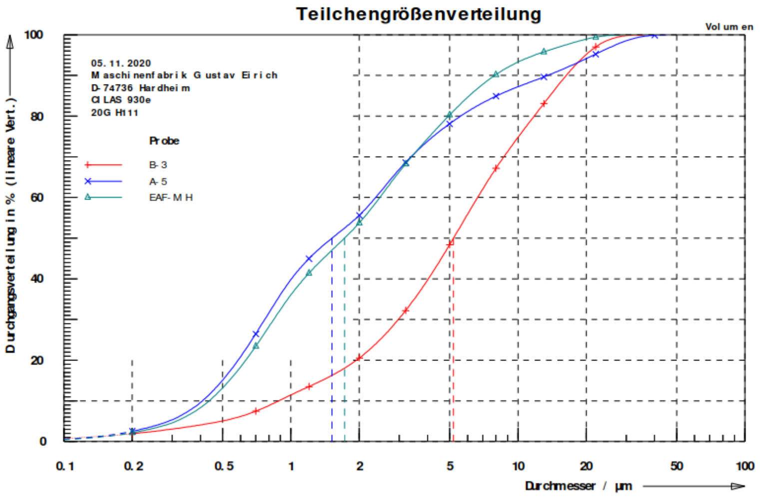


Dust agglomeration

different options based on requirements and dust composition

EAF Dust:

- Grain size D_{90} ~ 15 µm, D_{50} ca. 2 – 5 µm
- halogens in combination with H_2O improves the necessary binding forces → no / less binder
- Highest strength: pelletizing and briquetting

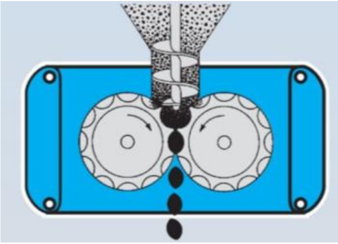


Granulation

Extrusion

Pelletizing

Briquetting



1. Step: calcination in short drum furnace
Oxidizing treatment at 1000°C

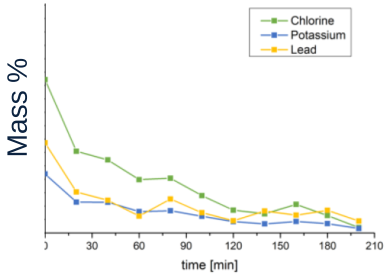
Lab scale testing

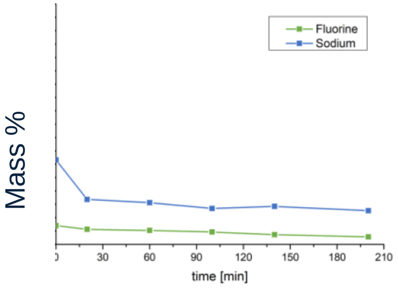
200 g, 2018

40 kg, 2019

Large scale testing

Mass [%]	Before	after
Cl	4,56	0,30
F	0,46	0,05
Pb	2,79	0,31
K	1,51	0,28

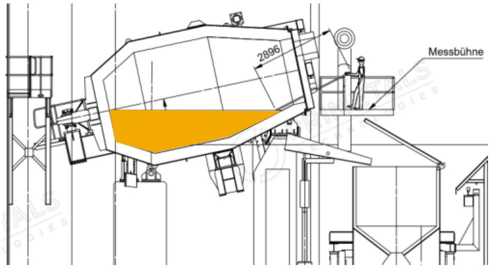


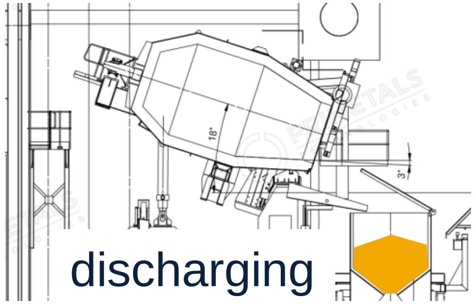


Evaporation of elements

Prototype

Dust Input	27.000	t/a
bulk density	1,5	kg/dm³
Process time	5	h
Weight per batch	19,0	t
Output	3,9	t/h
Volume per batch	10,0	m³
Furnace volume	40,1	m³
Burner power	5,0	MW

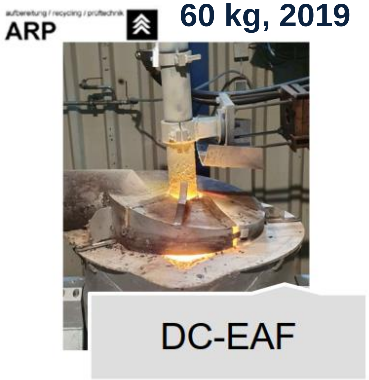




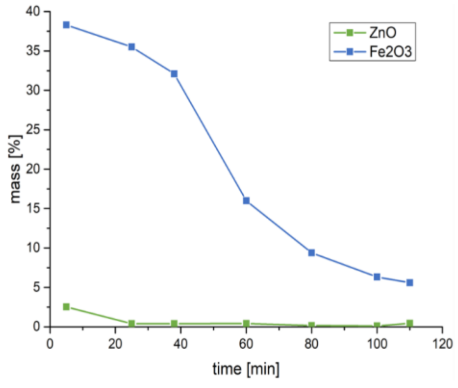
2. Step: melting and reduction in smelter furnace vaporization of Zn, seperation of metal and slag

Lab scale testing

60 kg, 2019



Zn, Fe reduction

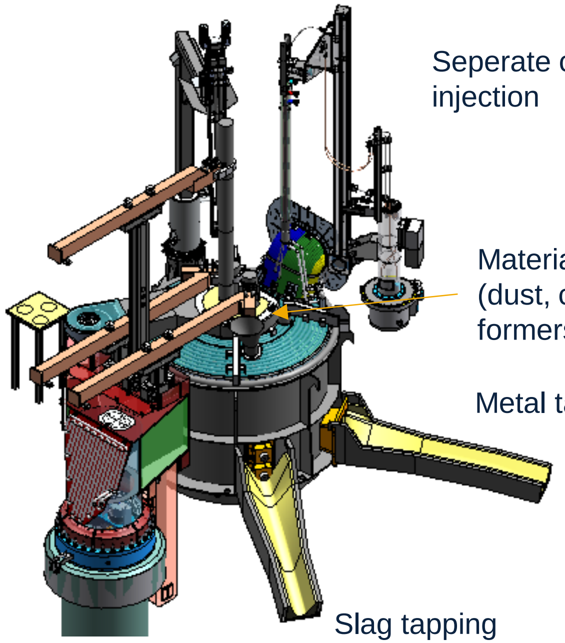


Large scale testing

800 kg, 2020-21

Offgas sample:
ZnO > 90 %
F < 0,01 %
Cl < 0,17 %
Pb < 0,27 %
K < 0,33 %

Dust Capacity	27.000	t/a
Slag tapping	3 – 6	h
Metal tapping	5-10	h
Metal production	0,7-2	t/h
Furnace diameter	3,2	m
Coal injection lance	900	kg/h
Trafo Power	10	MVA



Seperate coal injection

Material addition (dust, carbon, slag formers)

Metal tapping

Slag tapping

Products for EAF dust

100 % EAF dust

EAF dust	
ZnO	10 – 45 %
S	0,2 – 1 %
Fe_2O_3	20 – 45 %
MnO	1 – 5 %
CaO	2 – 15 %
Al_2O_3	0,6 – 2 %
MgO	1 – 7 %
SiO_2	2 – 7 %
Pb	0,5 – 4 %
K	0,5 – 4 %
Na	0,5 – 4 %
Cl	0,5 – 6 %
F	0,1 – 1 %
Rest	1 – 5 %

Typical composition

33 % Zinc oxide

ZnO product	
ZnO	~ 95 %
Fe_2O_3	~ 2 %
Rest incl.:	~ 3 %*
Cl	0,17 %
F	0,01 %
Pb	0,27 %
K	0,33 %

*Mg, Cu, Na, Ni, Si, not mentioned

Standard quality > 90 % ZnO (0,72*LME* Yield)

low Pb, low Cl, low F

alternative: upgrade to high quality ZnO or $ZnSO_4$ (1,1 * LME)

Primary zinc industry

29 % Metal

Metallic product	
C	2 – 3 %
Si	~ 0,1 %
Mn	0,2 – 0,4 %
P	0,1 %
S	0,5 – 1,5 %
Ni	0,1 – 1,5 %
Cu	0,1 – 1,5 %
Sn	0,1 – 1 %
Fe	Rest

Low quality scrap equivalent → dilution

Off take aggreement with steel mill

Steel making industry

26 % Slag

Mineral product	
CaO	20 – 35 %
MgO	4 – 12 %
Al_2O_3	3 – 6 %
SiO2	15 – 30 %
MnO	4 – 10 %
S	1 – 3 %
Na_2O	1 – 3 %
FeO	< 5 %
Rest	2 – 6 %

depending on local regulations possible usage in construction and building industry

Worst case easy to dump

Road construction and building industry

12 % Lead chloride

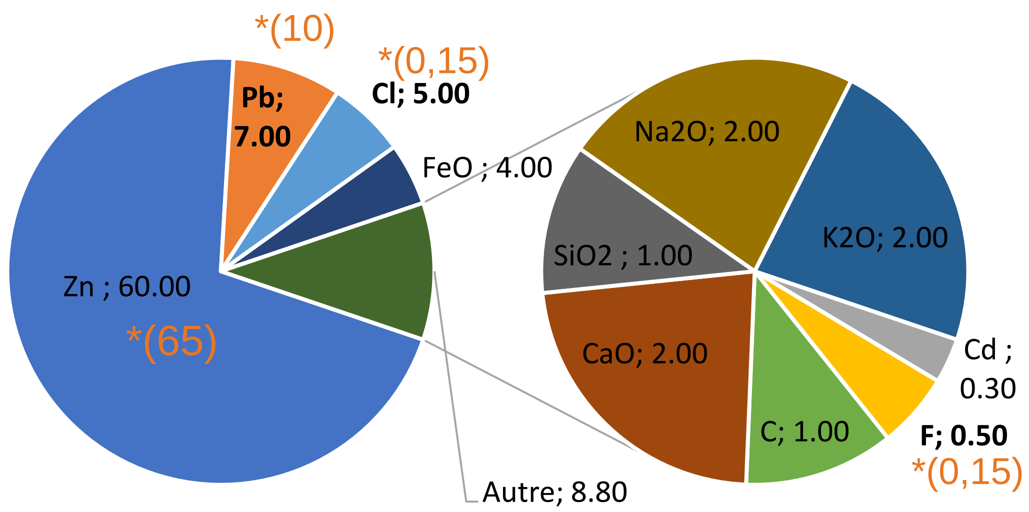
Halogene product	
Pb	10 – 35 %
Na	10 – 25 %
K	10 – 20 %
Cl	30 – 45 %
F	0 – 10 %
Rest	~ 2 %

Lead recovery and salt production

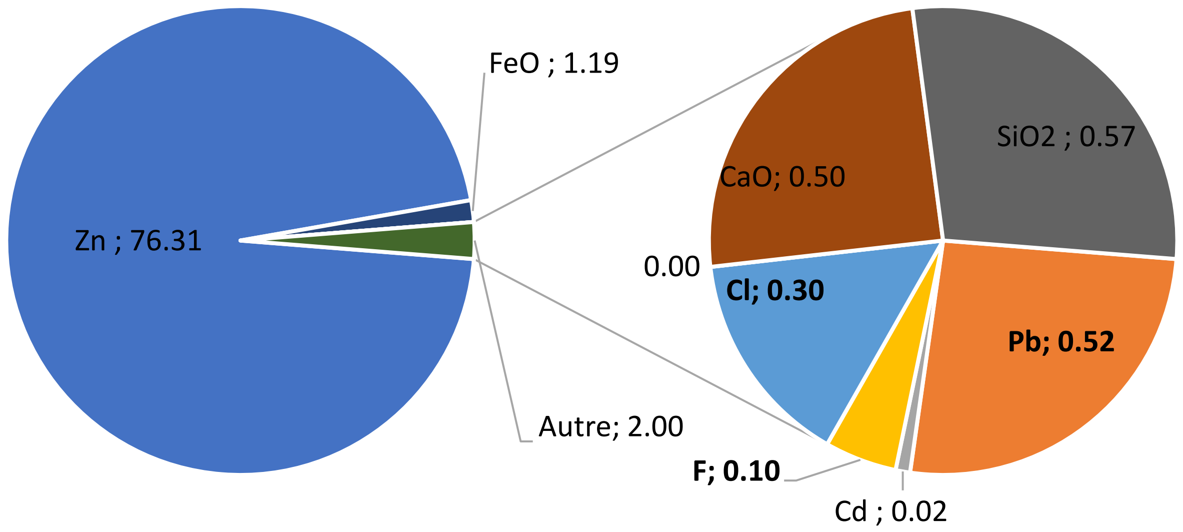
Chemical industry

Zinc oxide product comparison (wt %)

Waelz Oxid *(after leaching)

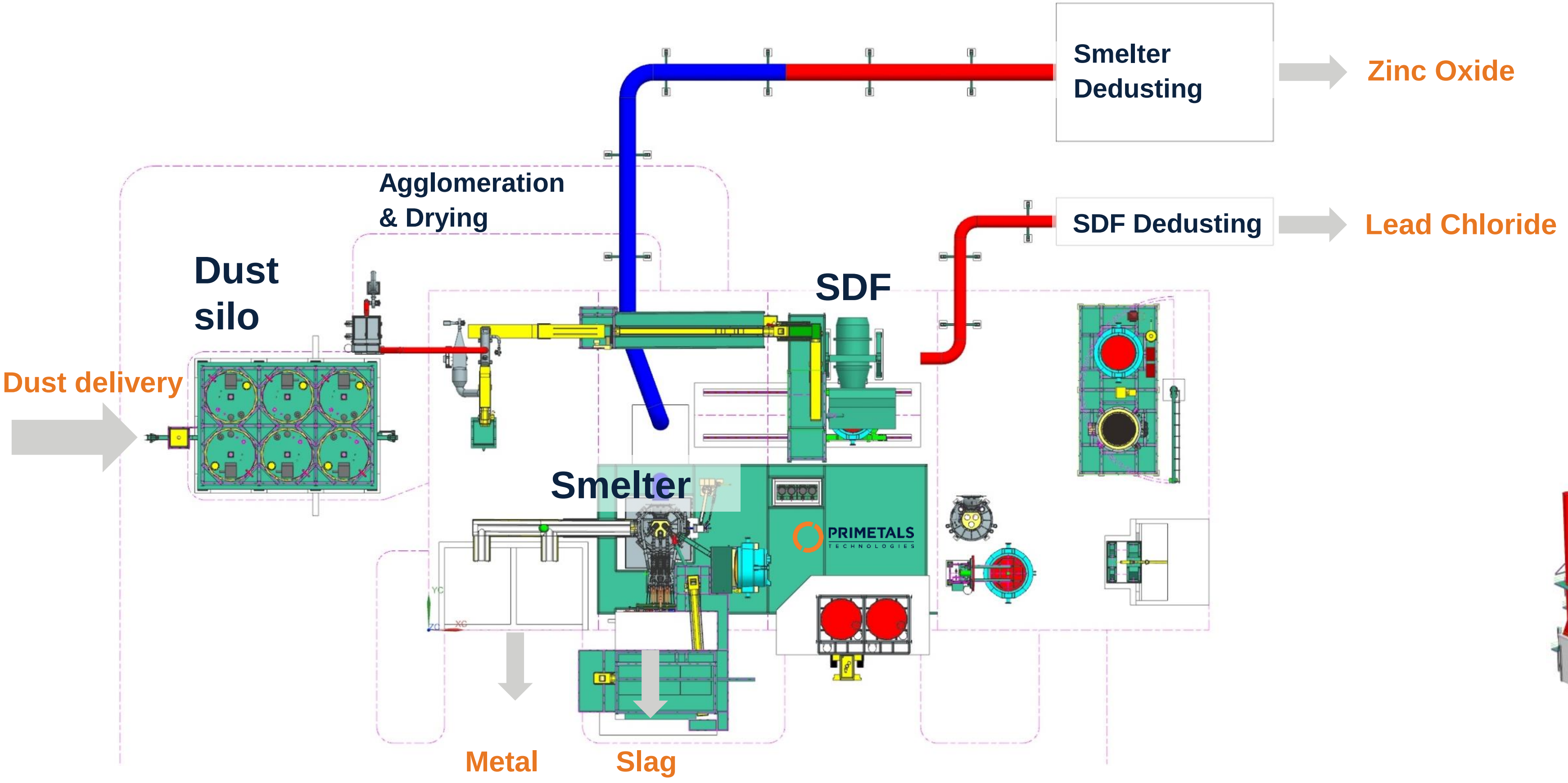


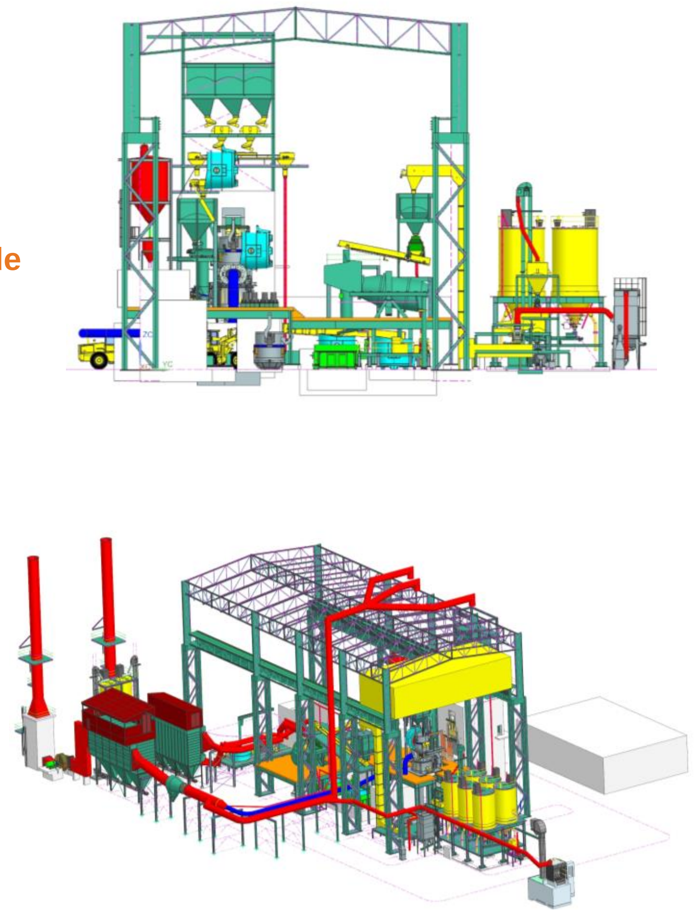
ZEP ZnO Product



- F, Cl need to be very lower for electrowinning, heavy metals need to be removed
- With ZEP process clean zinc oxide can be produced without washing
- Much higher Zn content and therefore higher yield with ZEP

Plant design, Capacity 30.000 t/year

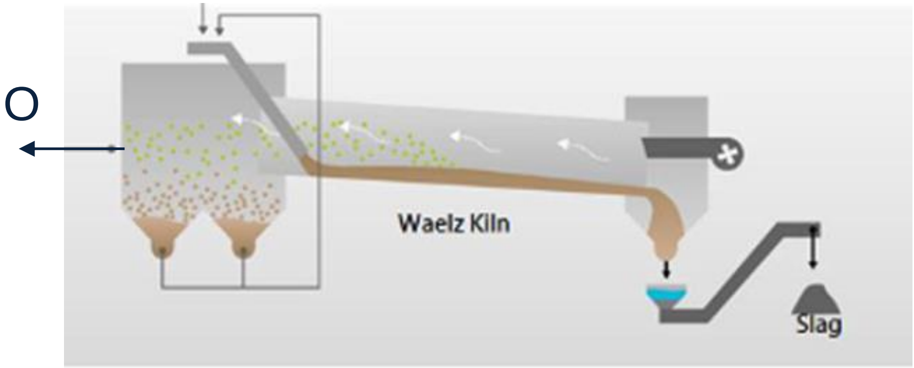


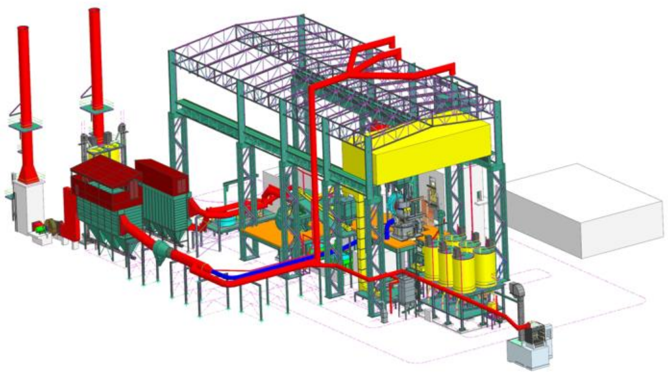


Space requirement: 2100 m² for building, total area around 5000 m²

Waelz process vs. ZEP

ZnO





Mainly large central units ~ 120 ktpa

Washing necessary and F will remain → **lower Zn Quality**

Continuous process

~ 90 % market share on EAF dust recycling

By products need to be landfilled (large amount of solid slag generated, > 60 % dust input)

Lower Zn recovery > 90 %

High CO_2 emissions

Smaller Decentral or central unit (less transportation) **~ 20 – 60 ktpa**

Cl, F, Pb removed in first step → **high Zn Quality,** no washing

semi continuous process (**batch wise**)

Reuse of metallic product in steel making (dilution due to S content)

Reuse of mineral product for road construction (liquid slag generated which can modified)

Higher Zn recovery > 96 %

Option to be CO_2 neutral with green electricity and H_2 for burner

Consumption figures & CO_2 emission

ZEP / ZEP green

Carbon: 156 kg/t per ton input

Carbon only for reduction of Zn and Fe, Zep green with 80 % biochar and H_2 burner

Electrical energy

1723 | 2649 kWh/t dust, 5414 | 8324 kWh/t Zn

CO_2 emission (grid factor 80 g/kWh)

839 | 331 kg/t dust, 2638 | 1040 kg/t Zn

Waelz process

Carbon: 200 kg/t input EU (270 kg/t in USA)

Carbon for heating and Zn reduction, autothermal process

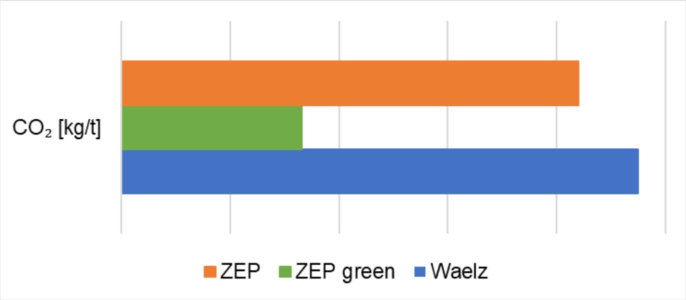
Limited usage of Biochar due to higher reactivity

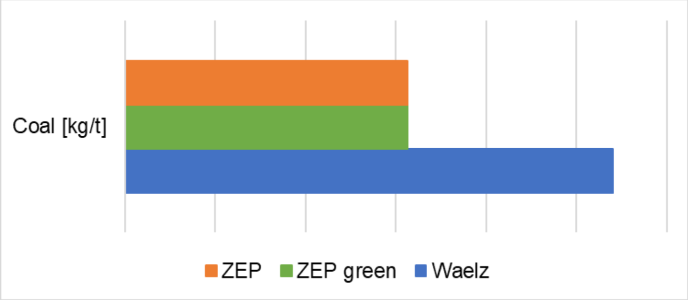
Electrical energy

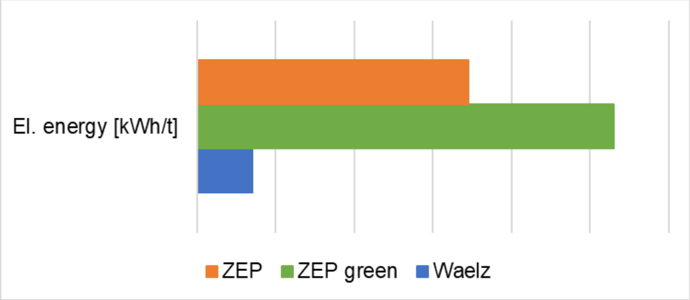
352 kWh/t dust, 1592 kWh/t Zn

CO_2 emission (grid factor 80 g/kWh)

949 kg/t dust, 4291 kg/t Zn in EU (SDHL)

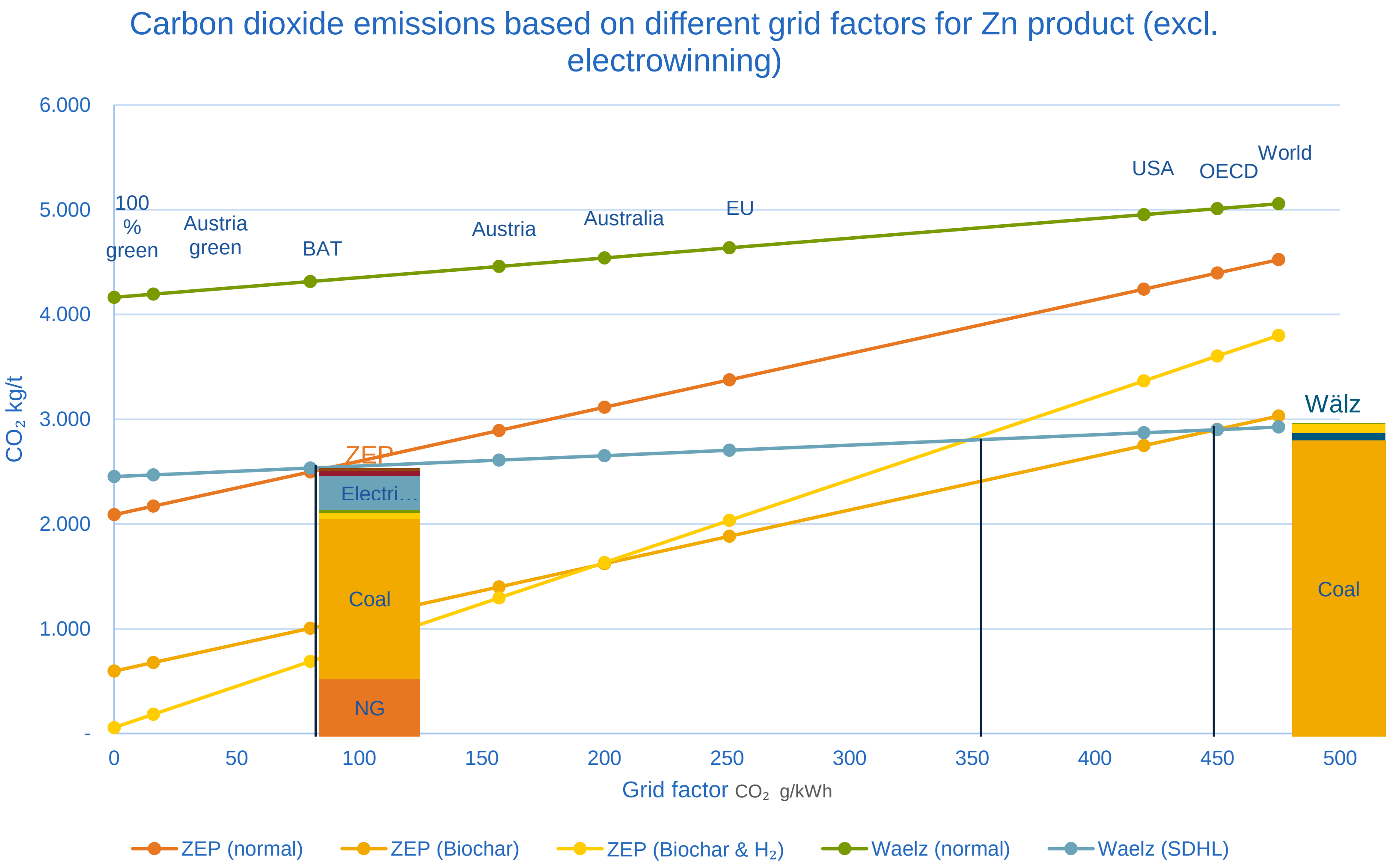






CO_2 Emissions

- For green electric energy (< 80 g CO_2/kWh) ZEP process will have lower CO_2 emission than Waelz process
- With the use of biochar as reducing agent break even will be increased to above 350 g CO_2/kWh
- With the use of H_2 burner even further
- Utilization of biochar in Waelz process challenging due to higher reactivity → more limitation than in Smelter furnace



Conclusion

Green transition challenge

- Scrap and EAF share in steelmaking will increase → more Zn dust
- Less internal recycling options with ongoing green steel transformation → alternative to sinter plant required

Current recycling processes like Waelz process have limitations:

- < 20 % of ZnO produced can be used in primary zinc industry due to contamination with halogens (F, Cl, etc.)
- > 60 % of solid iron rich slag is generated which need to be land filled
- High CO_2 emissions

New ZEP process offers zero waste solution for iron and zinc containing dust:

- Flexible: for high as well as low Zn containing dust
- Clean: Halogen, lead contamination is removed in 1. step → higher ZnO quality (no washing)
- Circular: Less amount of liquid slag is generated which can be modified in smelter for further usage in construction
- Circular: Iron and metal fraction is recovered and can be directly reused in steelmaking as scrap substitute
- Green: lower CO2 emissions with renewable electric energy
- Process development has been finalized and successfully proven, Industrial scale plant in planing

THANK YOU

Bernhard Voraberger
Head of Technology Converter Steelmaking
T +43 (732) 6592-4087
E Bernhard.voraberger@primetals.com

Primetals Technologies Austria
Turmstrasse 44
4031 Linz
Austria

primetals.com