WeCo mettop UrbanGold recycling for a green future

COMBINED COMPETENCE UNDER ONE ROOF

Green Copper Production – Decreasing CO_2 Footprint and E-Waste Recycling

Dr. Andreas Filzwieser

Introduction

Trends & Challenges

Major Current Global Trends

Urbanization & Household Electrification

- Billions of people are now thriving in developing economies, helping to drive economic growth and consumption

Electric Vehicle

- Electrification, including but not limited to EVs, is absolutely necessary for the global zero carbon transition over this century

Energy Transition

- Cleaner energies to play a predominant role in an unavoidable economic model based on sustainability

Copper role in World´s Unprecedented Urban Growth

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An average single-family home (50 m²) uses 1kg of copper per m²

Building wire

23 kg

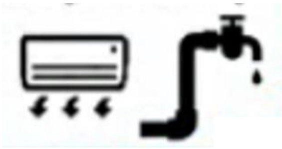
Build-in applications

5 kg

Plumbers´ brass goods

3 kg

Heating, AC and Plumbing



18 kg

Builders Hardware

1 kg

Other wire and tube

1 kg

- **1.6 billion additional urban residents**

400 million
New Housholds
+
Renovation of existing ones

30 Mt

Additional Copper Usage through 2040

Source: World Semis End Use Data – International Copper Alliance

EV Outlook Supports Long-term Copper Demand

23kg ICE

40kg Hybrid EV

60kg Plug-in HEV

83kg Battery EV

89kg Hybrid E-Bus

224-369kg Batt. E-Bus

- World HEV+PHEV+BEV stock grow from ~4 million to ~500 million
- Average copper per HEV (40kg), PHEV (60kg) and BEV (80kg)

42 Mt

Additional Copper Usage through 2040

Source: The Electric Vehicle Market Copper Demand, June 2017

Copper in the Sustainable Power Generation

Green power generation technology is more copper intensive than conventional sources

x2

x4

x2

- Additional power **renewable** generation **capacity** of **5,000 GW** (Substitution + New Capacity) by 2040
- Associated **grid development** needed both due to new capacity and substitution

49 Mt

Additional Copper Usage through 2040

Source: World Energy Outlook 2020

Three Key Drivers to Transform the Copper Market

121 Mt

Additional Copper Usage through 2040

- **30 Mt** — Houshold & Urbanization
- **42 Mt** — Electric Vehicle
- **49 Mt** — Power Generation Transition

Three Key Drivers to Transform the Copper Market

mettop

121 Mt

Additional Copper Usage through 2040

30 Mt

42 Mt

49 Mt

Houshold & Urbanization

Electric Vehicle

Power Generation Transition

Yearly production refined copper 2022: **26 Mt**

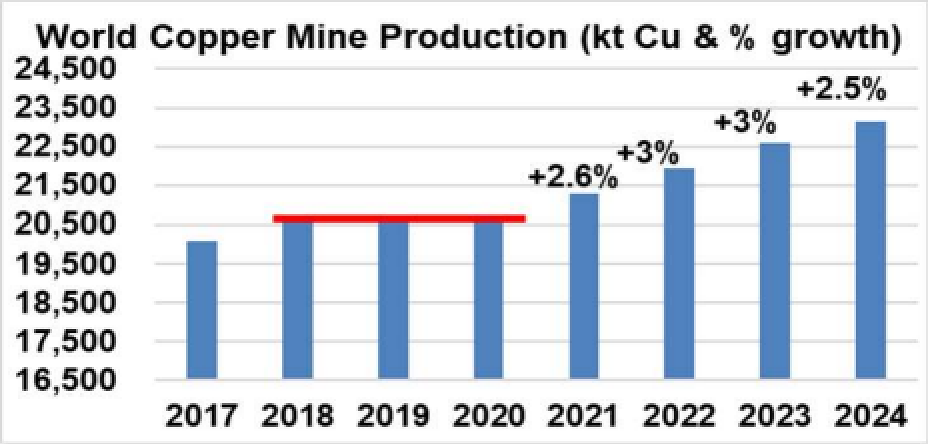
Will Copper Supply catch up with Demand?

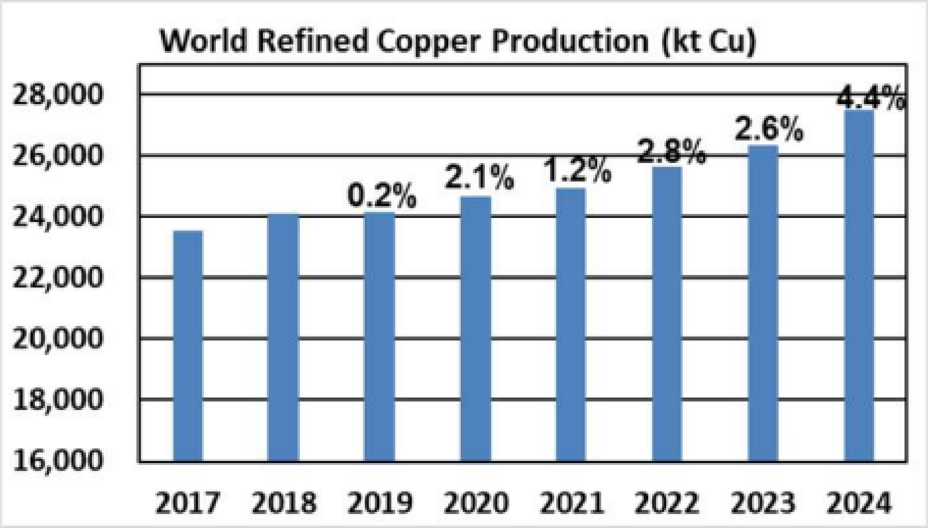
- **Copper mine production in 2023 / 2024 forecasted to increase by 3% / 2.5% whilst consumption will by 1.4% / 2.8%**

  - Concentrate balance to be in deficit again in 2023

- **Risk of mine supply disruption remains high:**

  - Social and political risks in major products: electronics, labor negotiations, natialisations…





Source: Copper Concentrate Outlook Q22021

Will Copper Supply catch up with Demand?

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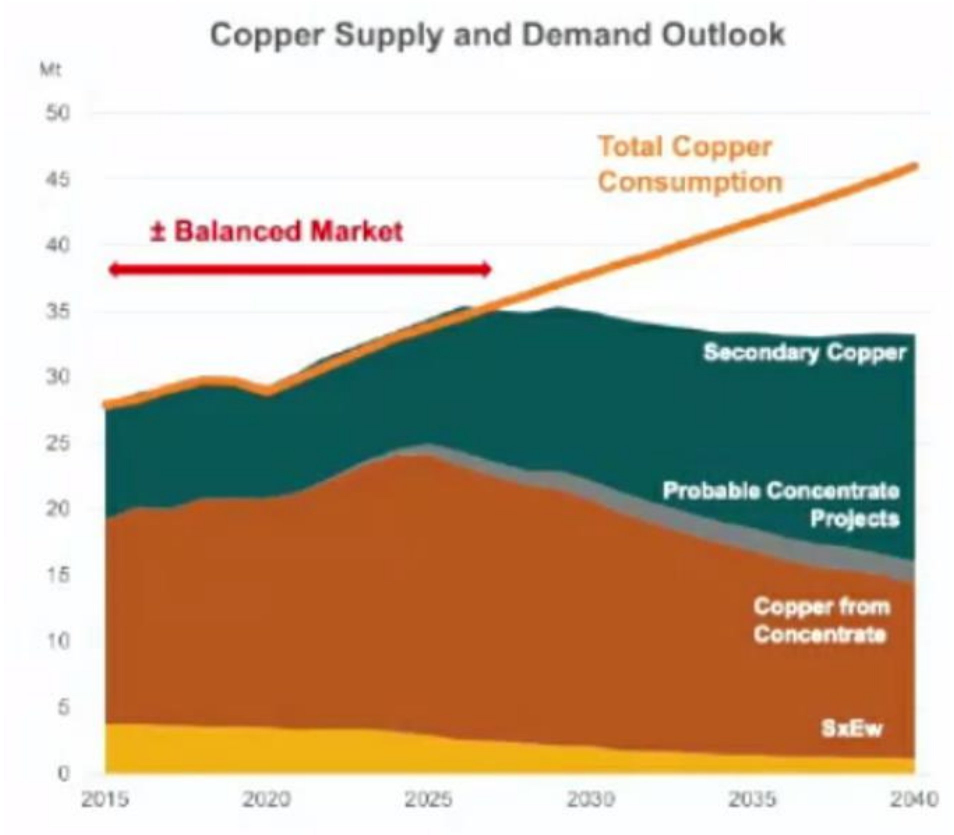
  - Concentrate balance to be in deficit again in 2023
- Risk of mine supply disruption remains high:
  - Social and political risks in major products: electronics, labor negotiations, natialisations…
- **Supply and demand gap to grow beyond 2026**
  - More mining projects and secondary copper needed to meet copper growing demand



Source: Copper Concentrate Outlook Q22021 meTop

ICSG Press Release 28 April 2023

World Refined Copper Usage and Supply Forecast

Thousand metric tonnes, copper

INTERNATIONAL COPPER STUDY GROUP

FORECAST TO 2024

REGIONS	COPPER MINE PRODUCTION			REFINED COPPER PRODUCTION			REFINED COPPER USAGE		
('000 t Cu)	2022	2023	2024	2022	2023	2024	2022	2023	2024
Africa	3,252	3,501	3,756	2,163	2,291	2,487	177	181	193
N.America	2,514	2,483	2,610	1,633	1,594	1,705	2,267	2,265	2,320
Latin America	8,542	9,284	9,680	2,581	2,431	2,608	385	372	391
Asean-10	1,078	1,083	1,088	494	462	582	1,193	1,249	1,309
Asia ex Asean/CIS	2,685	2,827	3,019	14,130	14,638	15,212	18,012	18,220	18,762
Asia-CIS	948	964	995	515	514	549	107	106	107
EU	786	788	794	2,569	2,697	2,757	3,101	3,159	3,194
Europe Others	1,223	1,269	1,477	1,156	1,356	1,428	827	872	902
Oceania	895	931	965	401	435	445	5	5	5
TOTAL	21,922	23,131	24,384	25,641	26,419	27,773	26,072	26,431	27,183
World adjusted 1/ 2/	21,922	22,578	23,153	25,641	26,317	27,480	26,072	26,431	27,183
% change	3.0%	3.0%	2.5%	2.8%	2.6%	4.4%	3.4%	1.4%	2.8%
World Refined Balance (China apparant usage basis)							**-431**	**-114**	**298**

1/ Based on a formula for the difference between the projected copper availability in concentrates and the projected use in primary electrolytic refined production.
2/ Allowance for supply disruptions based on average ICSG forecast deviations for previous 5 years.

Major Current Global Challenges

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Mine Production Increase behind Demand Increase

- Recycling will play a more important role in future

CO_2 Regulations world wide

- CO2 certificates will be in place

Hydrogen will play an important role

- Green hydrogen will partly replace natural gas

Circular Economy: A Key Contributor to Sustainable Development

- **Secondary raw materials are vital to satisfy world´s demand of metals**

  Copper scrap accounts for ~30% of total copper consumption

- **Recycling is a key part of a de-carbonized world**

  It requieres less energy in the process, reduces carbon footprint and contributes to the responsible use of a primary resources

Metal Recycling Rates and CO_2 Reduction

Copper	44%	30%	65%
Aluminium	57%	35%	92%
Steel	56%	35%	58%

Copper Recycling – high grade material

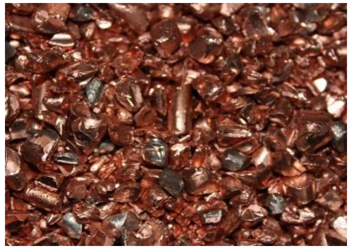
Raw Material Mix

SCRAP PRODUCT	DESCRIPTION
#2 Birchcliff	Misc. tubing, burnt wire and copper w/connectors
#3 Cu	Flashing, Roofing Cu
Shredded Cu	Ferrous Shredders
Leaded # 3	Roofing Cu
Cobra-99.5% Cu	#2 Chops from Wire and Cable-12g
Cobra-98% Cu	#2 Chops from Wire and Cable-12g
Cobra-94% Cu	#2 Chops from Wire and Cable-12g
Cobra-92%	#2 Chops from Wire and Cable-12g, circuit boards
Cu Windings- High in enamel	Shredded Electric Motors and Transformers
Cu Radiators	Cooling Systems
Cu Turnings	Machining-Fine
Ni Plated Alloy	Bare Wire
CDA194	Wire and Punchings
CDA 162	Wire and Punchings
Alloy Scrap	Silicon Br - Wire and Machine Parts
Alloy Scrap	Aluminum Bronze - Machine Parts
Cu/Al Rad Chops	Heavy ga. Cu Chops
	TOTAL










Recycling – state of the art

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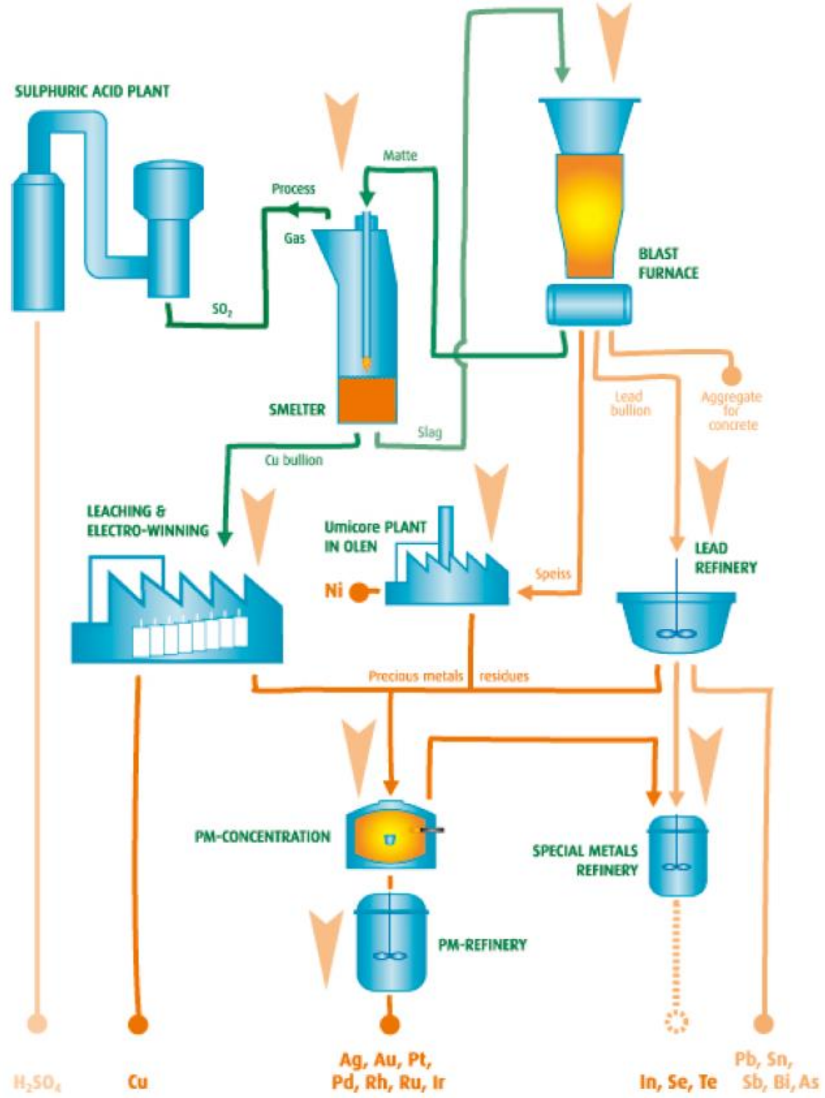
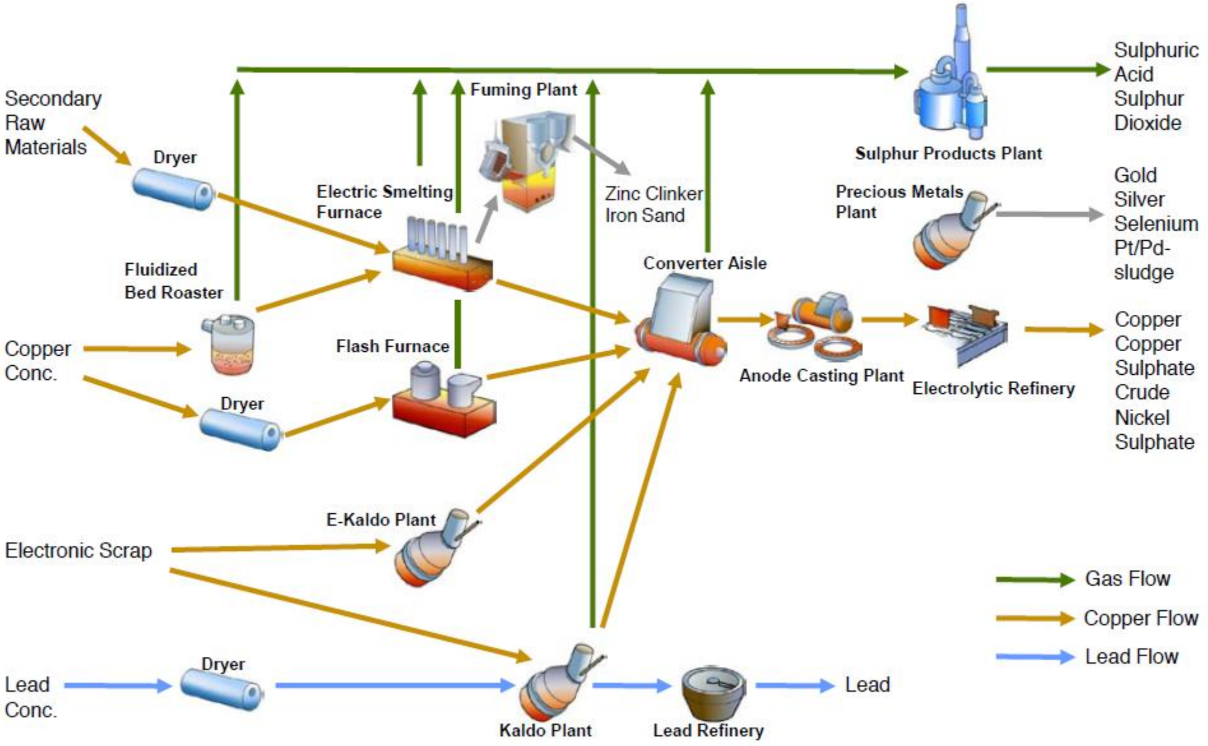
Umicor, Belgium

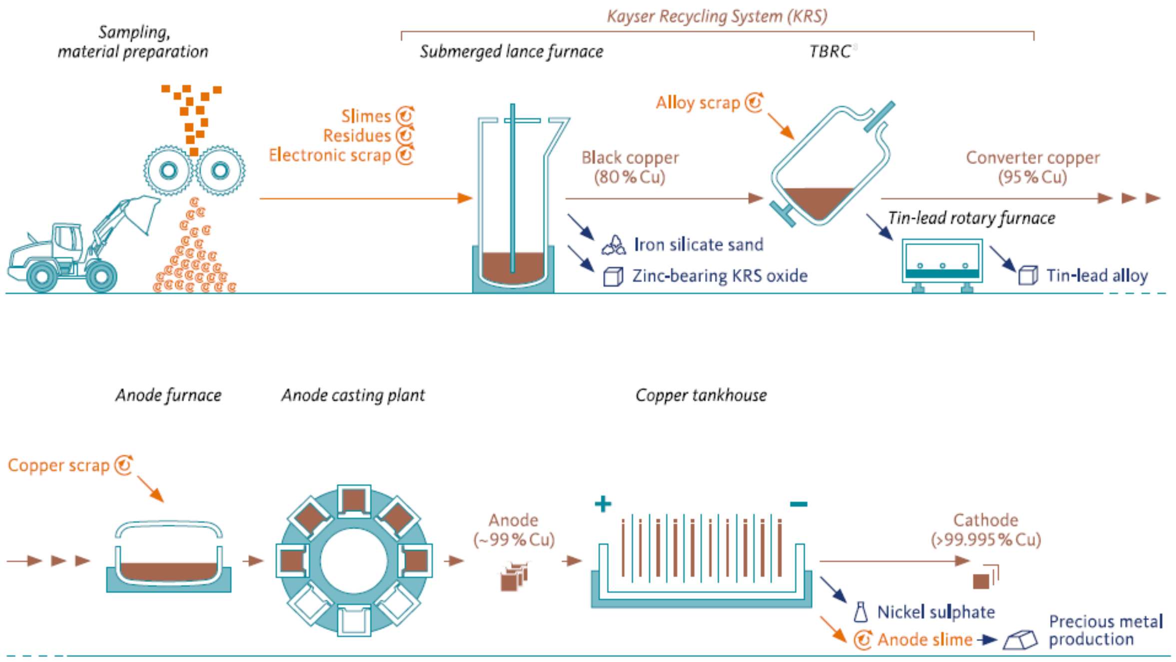


New Boliden, Rönnskar, Sweden

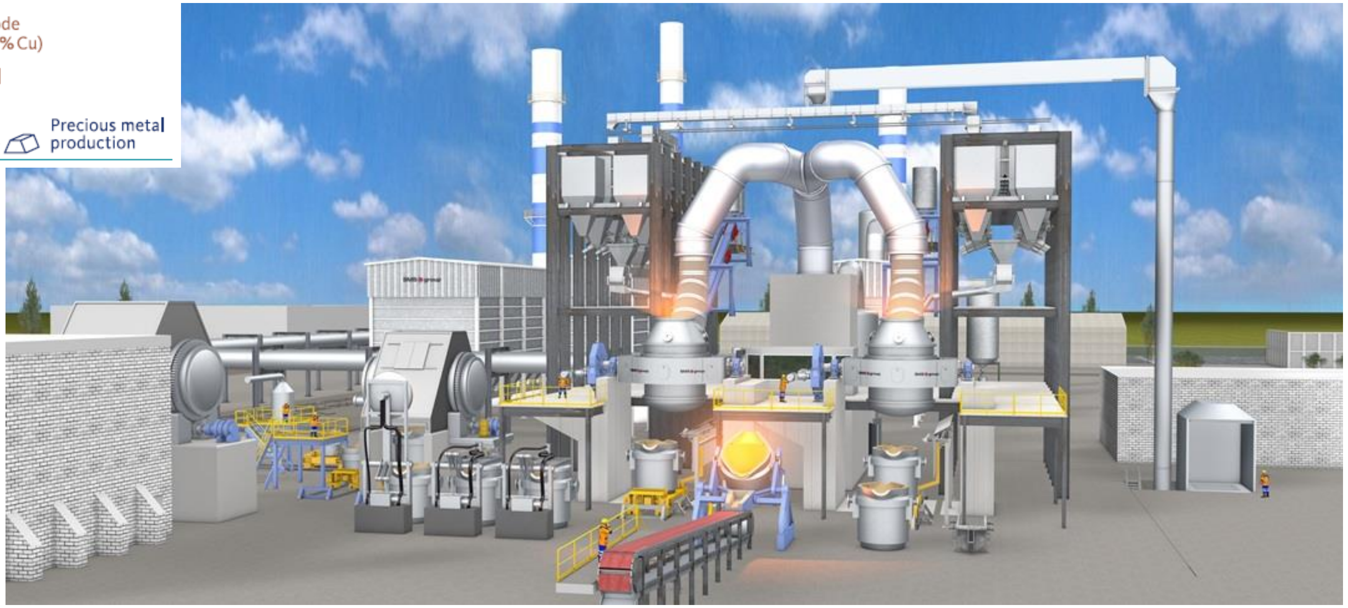


Recycling – state of the art

Aurubis Lünen, Germany



Aurubis Richmond, USA



E-Waste Recycling – low grade material

- WEEE = Waste of Electrical and Electronic Equipment

- Quantities:

WEEE	Year	Generated	Collected	Coll. rate
Europe	2019	12.0 Mt	5.1 Mt	42.5%
Asia	2019	25.0 Mt		
Global	2019	53.6 Mt	9.3 Mt	17.4%
Global	2030	*74.7 Mt*	*18.7 Mt ?*	*25% ?*

- Mechanical treatment: shredding and classification
- Three qualities of WEEE concentrate: low-grade, mid-grade, high-grade
- Usable non-ferrous fraction 25% of the total WEEE

From old appliances to secondary raw materials

What is e-waste?

Upper row: notebooks, hard drives, chips, CRT monitors, small IT, mixed small equipment
Lower row: power adapter, fridges, lamps, cables, washing machines, PCBs

Advanced E-Waste Recycling

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The King's Class of Recycling

Automotive shredder fractions

Insulated wire

Shredder light fractions and dusts

E-waste (shredder) fractions
PCBs and e-waste components

Slags, drosses, and skimmings

PM containing materials

Waste incineration fractions

Metallic scrap
Alloy scrap (brasses/bronzes)
Cable scrap

From old appliances to secondary raw materials

Mechanical pre-treatment

Shredder fraction:
Cu coarse (approx. 70% Cu)

Shredder fraction:
Cu fine (approx. 65% Cu)

From old appliances to secondary raw materials

Mechanical pre-treatment

Shredder fraction:
Cu wet (approx. 15% Cu)

Shredder fraction:
shredder fines/ light shredder fraction/ fluff (approx. 10% Cu)

From old appliances to secondary raw materials

Mechanical pre-treatment

Shredder fraction:
PCBs shredded (approx. 9% Cu)

Shredder fraction:
Pellets 40 mm (approx. 1.3% Cu)

Challenge

These usable non-ferrous fractions sum up to approximately 25% of the total WEEE mass and form the so called WEEE concentrate, consisting of the most valuable metals such as copper, nickel, lead, tin, zinc, and precious metals. The arising mid- to high-grade shredder fractions are often co-processed in conventional copper smelters, as their organic content (mostly plastics) is less than one third of the total amount. An even higher organic content would require a far greater amount of cooling scrap – or would result in a potentially fatal overheating of the furnace. Another limit is the available off-gas treatment system specifically designed for a copper smelter – and not for smelting raw materials containing large amounts of hazardous substances such as chlorine, bromine, or dioxins/furans. The low- to mid-grade shredder fractions often fall under these limitations and cannot or only minimally be processed. Furthermore, due to changing consumer behaviour, which calls for cheaper appliances, and generally shorter product life cycles, the concentration of valuable metals in appliances will decrease despite the significant increase in electrical and electronic equipment (EEE) . Highly efficient and more complex mechanical pre-treatment and optimized metallurgical processes are necessary in order to be able to process the shedder fractions and continue to achieve the same yields to which the industry is accustomed due to higher valuable metal contents in older devices.

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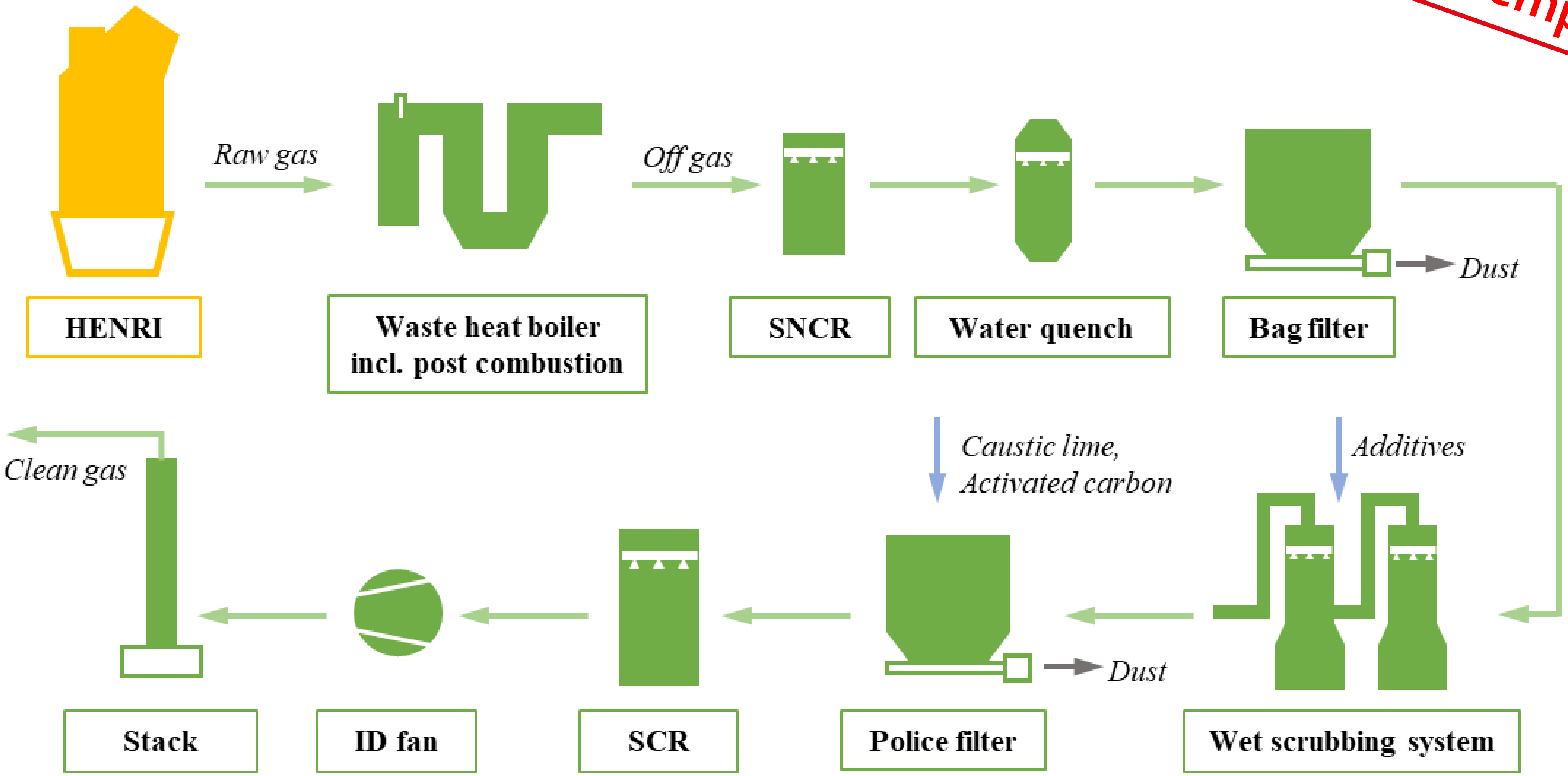
Offgas system

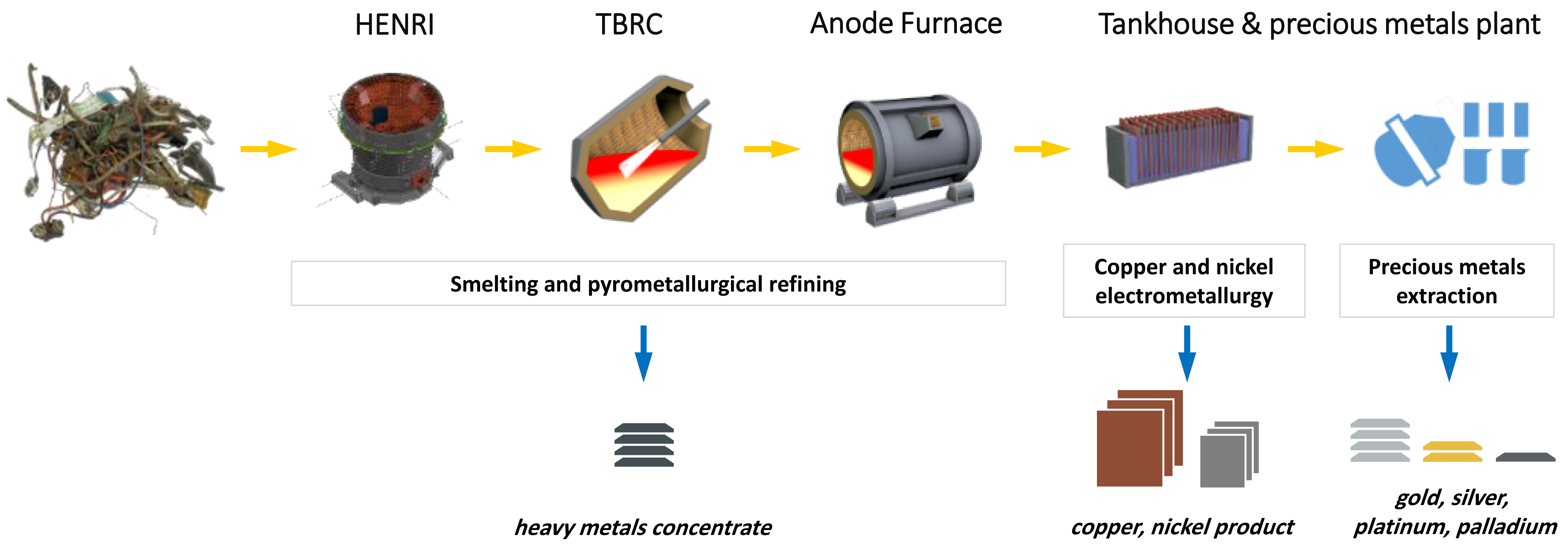
Exemplary!



Process flow scenarios

Process flow diagram full recycling plant

- Starting with the raw material, the metal phase is then always transferred to the following refining unit

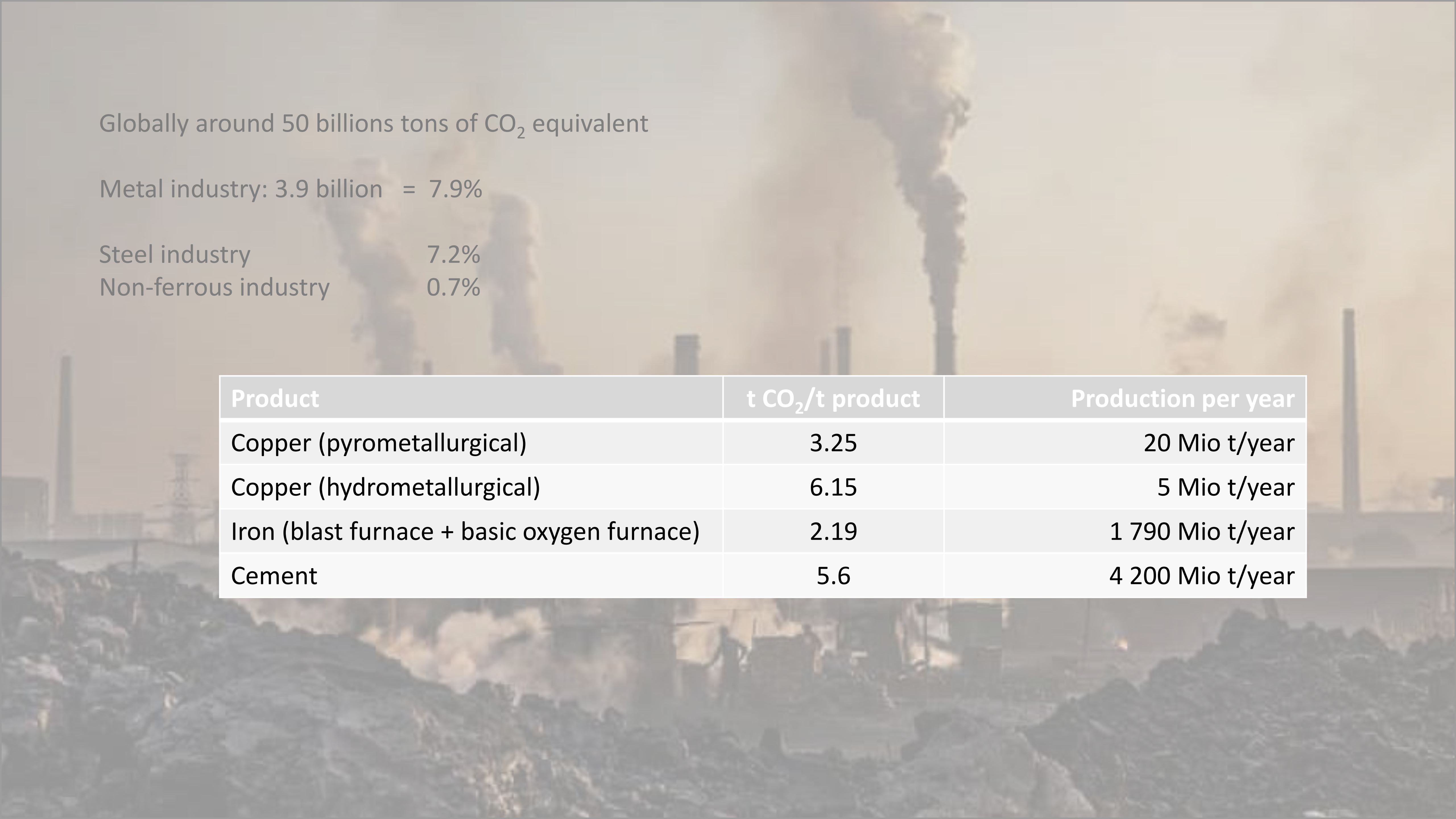


CO_2 Emission

Globally around 50 billions tons of CO_2 equivalent

Metal industry: 3.9 billion = 7.9%

Steel industry	7.2%
Non-ferrous industry	0.7%



Globally around 50 billions tons of CO_2 equivalent

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Steel industry 7.2%
Non-ferrous industry 0.7%

Product	t CO_2/t product	Production per year
Copper (pyrometallurgical)	3.25	20 Mio t/year
Copper (hydrometallurgical)	6.15	5 Mio t/year
Iron (blast furnace + basic oxygen furnace)	2.19	1 790 Mio t/year
Cement	5.6	4 200 Mio t/year

European Green Deal

The European Green Deal is a set of policy initiatives by the European Commission with the overarching aim of making Europe climate neutral in 2050. An impact assessed plan will also be presented to increase the EU's greenhouse gas emission reductions target for 2030 to at least 50% and towards 55% compared with 1990 levels.

- CO_2 Emissions Trading
- Carbon Border Adjustment
- Energy Taxation Directive

Driving Forces II

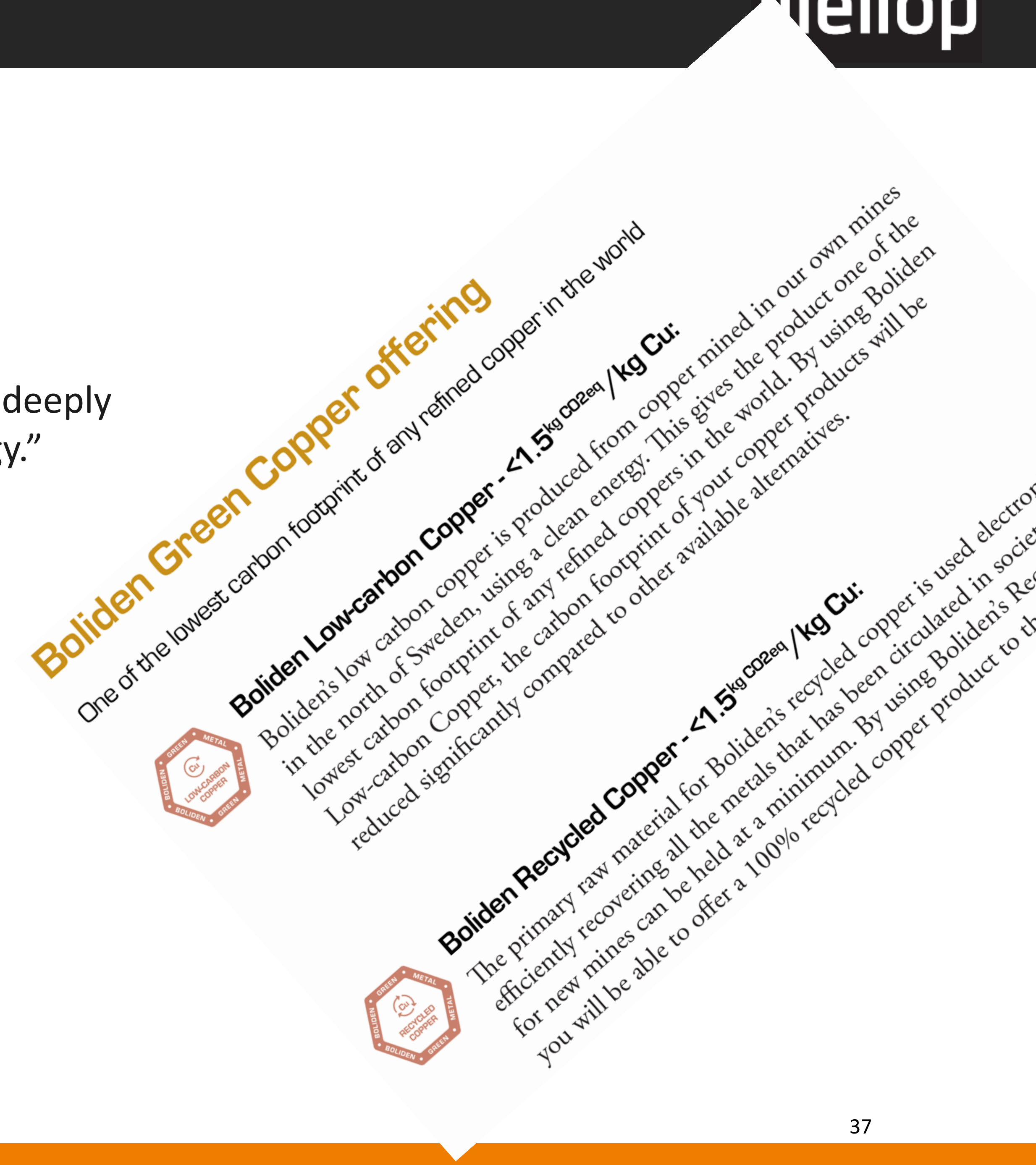
Pressure from the Market

Wieland: “We want to anchor sustainability even more deeply as an integral part of our business and company strategy.”

Apple: “We look for 100% recycled materials.”

We simply have to be competitive

CO_2 footprint has to be equal or better


Boliden Green Copper offering

One of the lowest carbon footprint of any refined copper in the world

Boliden Low-carbon Copper - <1.5 $^{kg\ CO2eq}$ /kg Cu:

Boliden's low carbon copper is produced from copper mined in our own mines in the north of Sweden, using a clean energy. This gives the product one of the lowest carbon footprint of any refined coppers in the world. By using Boliden Low-carbon Copper, the carbon footprint of your copper products will be reduced significantly compared to other available alternatives.

Boliden Recycled Copper - <1.5 $^{kg\ CO2eq}$ /kg Cu:

The primary raw material for Boliden's recycled copper is used electron
efficiently recovering all the metals that has been circulated in societ
for new mines can be held at a minimum. By using Boliden's Re
you will be able to offer a 100% recycled copper product to th

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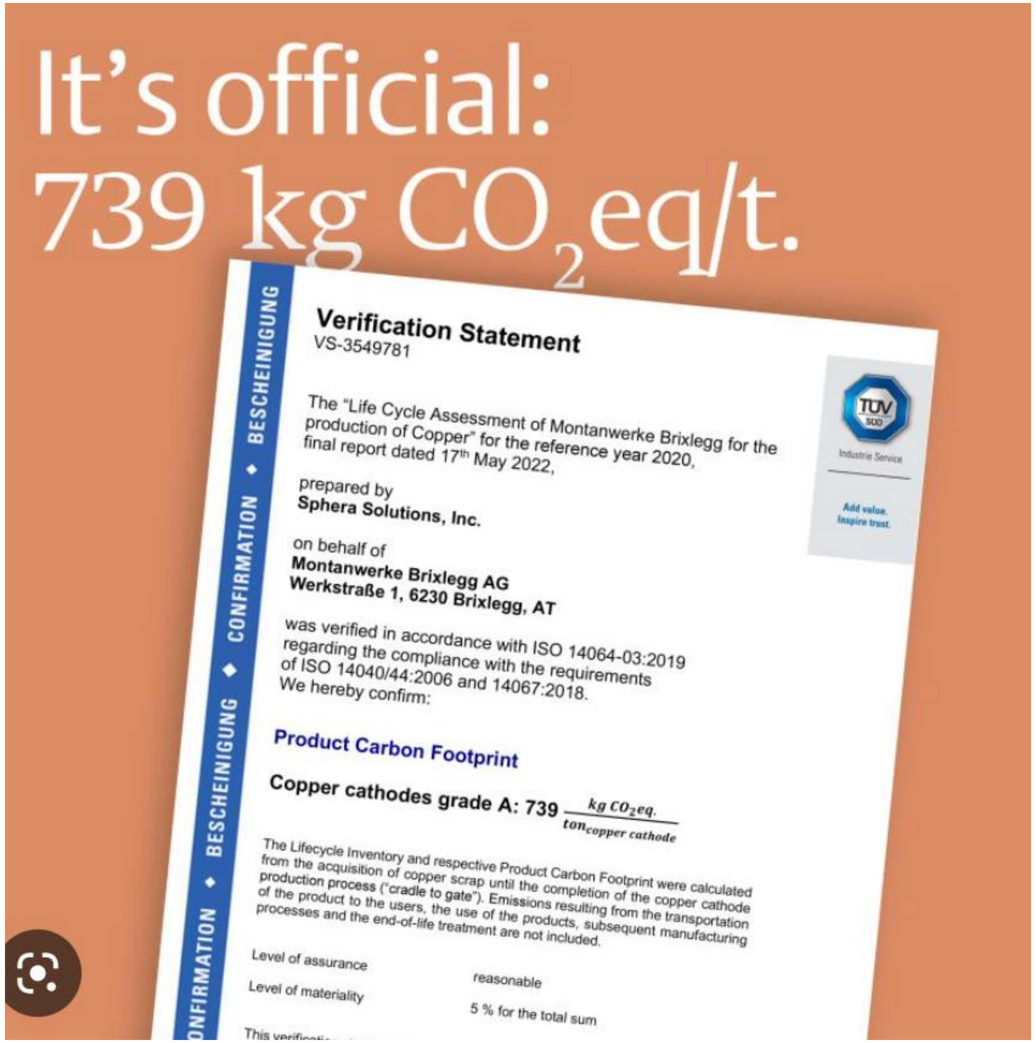


What to do?

CO_2 Reduction

- **Prozess Optimisation to increase Productivity**
- **Heat Recovery**
- **Hydrogen**
- **Auxiliary materials**
- **Raw material mix (secondary material)**

CO_2 Reduction

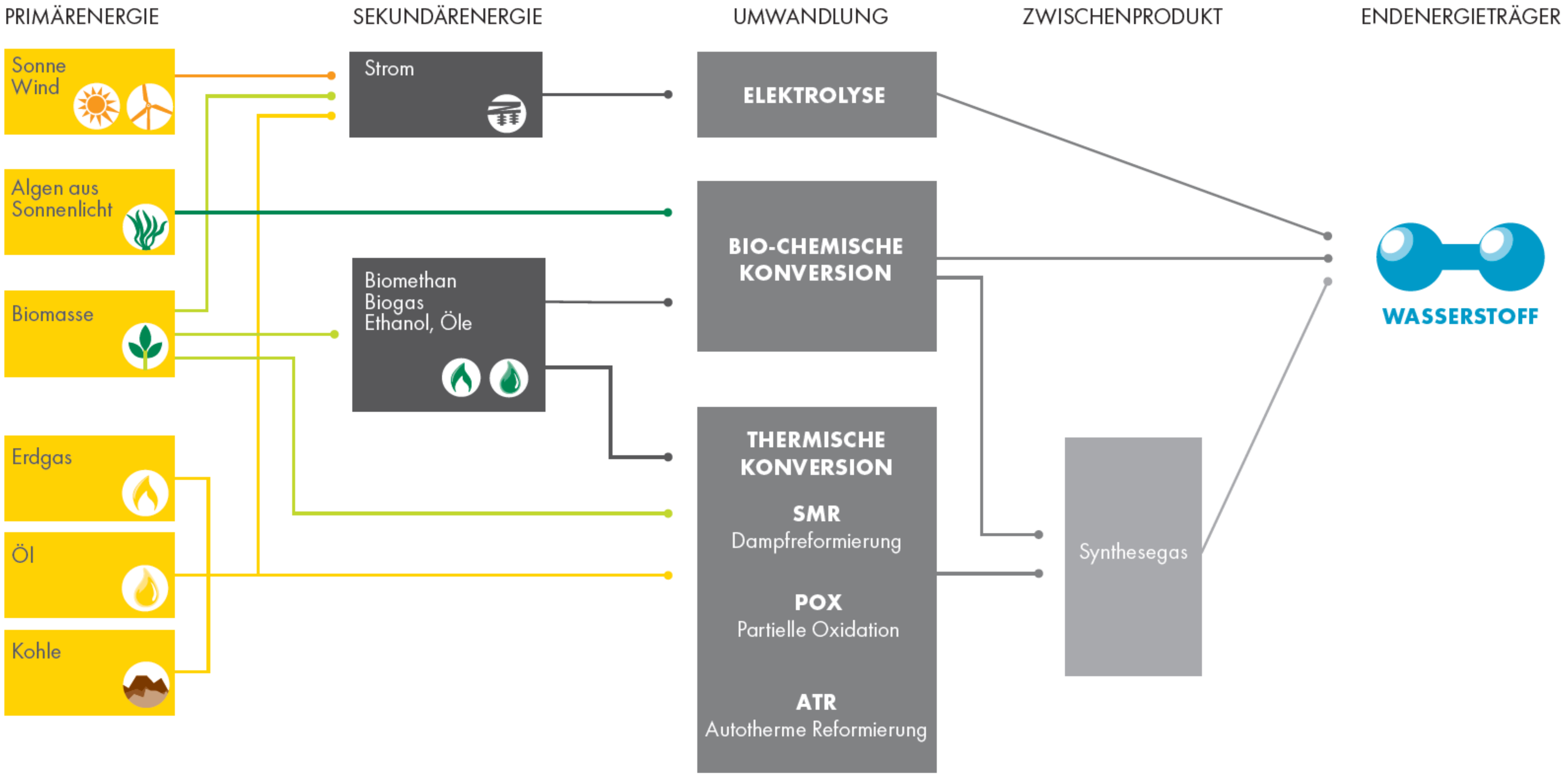
- Prozess Optimisation to increase Productivity
- Heat Recovery
- **Hydrogen**
- Auxiliary materials
- Raw material mix (secondary material)

Press Release

Aurubis: First copper anodes produced with hydrogen

- » Successful start to the series of hydrogen tests at the multimetal company's Hamburg plant
- » CEO Roland Harings: "Hydrogen is the energy source of today"
- » First Mayor of Hamburg Peter Tschentscher: "Hamburg is optimally positioned as a forward-looking region for hydrogen"

Hydrogen Production



95% comes from fossil fuels

Quelle:
Shell Wasserstoff Studie 2017

RAW MATERIAL | CO2 FREE | MULTI ELEMENT

Zn Ga Sn Ge Ni Bi Cu Pd Re Au Sb Pt Ag REE Co Li

Mobile Phones, TV, …

Coins | E - Vehicles | Slags and Residues | Photovoltaic cells

Waste incineration ASHES | Smart home & Internet of Things | Windsysteme | End of Life V. | Jewellery

Heatpumps | E-Sports & Gaming | (Li-)Batterien | Sports equipment | Urban Mobility | Katalysatoren

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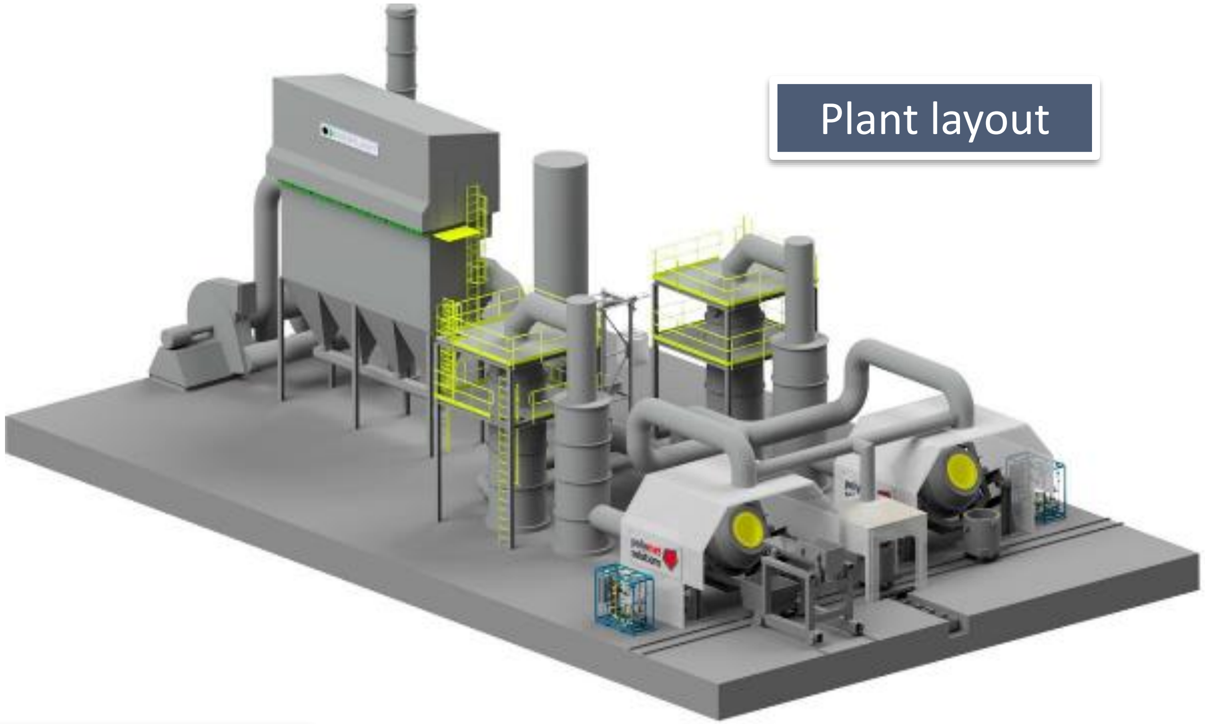
Thank You!

PROCESS DESIGN / PROCESS ENGINEERING

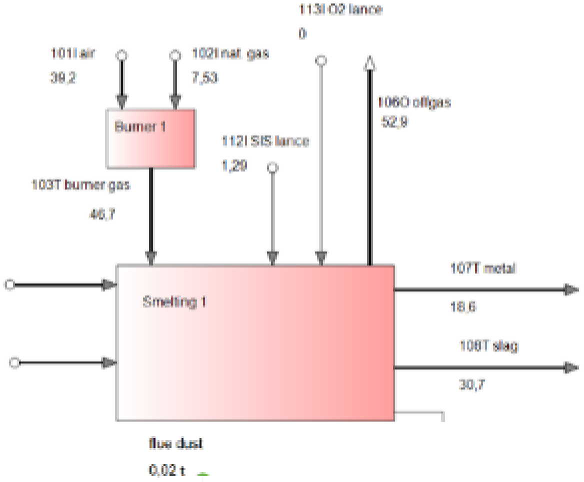
SMELTING & REFINING OF COPPER SCRAP

Plant layout



Refining slags		
Output Year	1 470	tpa
Output Batch	1 480	kg/batch
Ag	0,0000	wt.-%
Al_2O_3	1,0868	wt.-%
As_2O_3	0,0000	wt.-%
CaO	0,3381	wt.-%
Cr_2O_3	1,0471	wt.-%
Cu_2O	24,2981	wt.-%
FeO	45,4430	wt.-%
MgO	0,0483	wt.-%
NiO	0,3412	wt.-%
P_2O_5	0,2335	wt.-%
PbO	0,3825	wt.-%
Sb_2O_3	0,0000	wt.-%
SiO_2	25,3862	wt.-%
SnO	0,6574	wt.-%
SnO_2	0,3809	wt.-%
TiO_2	0,0000	wt.-%
ZnO	0,3569	wt.-%
Others, each	present	wt.-%
Total	100,00	wt.-%

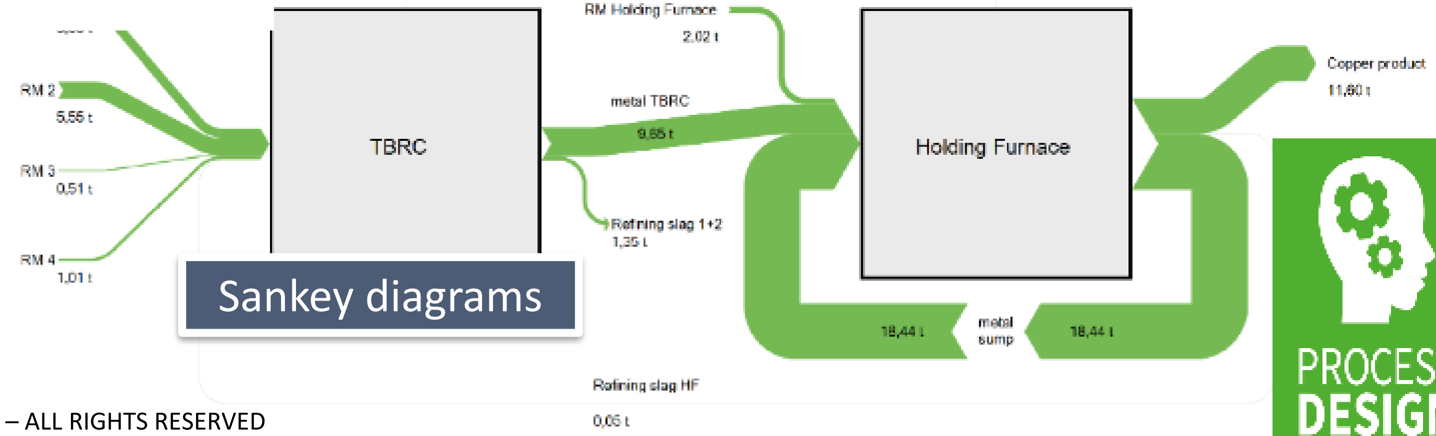
M&E balance



Process design

Step No.	1	2	3
Step Name	**Smelting**	**Refining 1**	**Refining 2**
Continuance of metal phase	remains	remains	HF
Continuance of slag phase	remains	removed	removed
Process time [h]	1,79	0,37	1,04
Burner lambda [-]	1,05	1,20	1,20
Bath Temperature [C°]	1.200	1.205	1.195
Fe/SiO2 ratio [-]	1,40	1,40	1,40
Oxygen in Metal [ppm]	1.500	5.000	8.000

Sankey diagrams



PROCESS DESIGN

CONSULTING SERVICES

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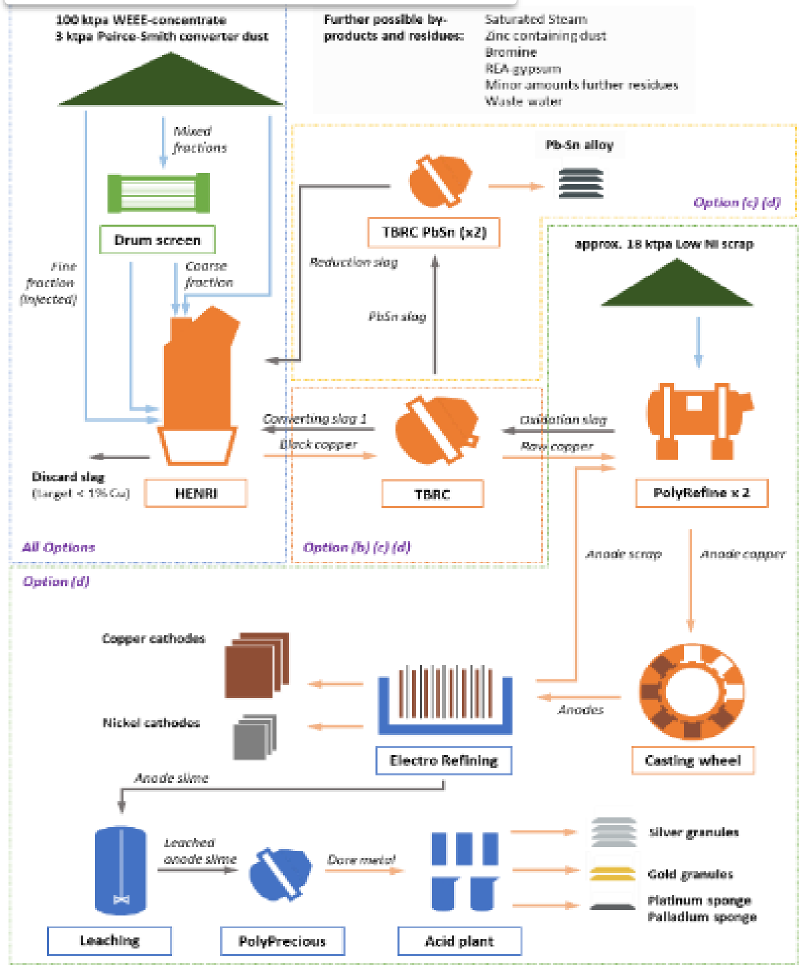
TECHNICAL ASPECTS

Process flow diagrams

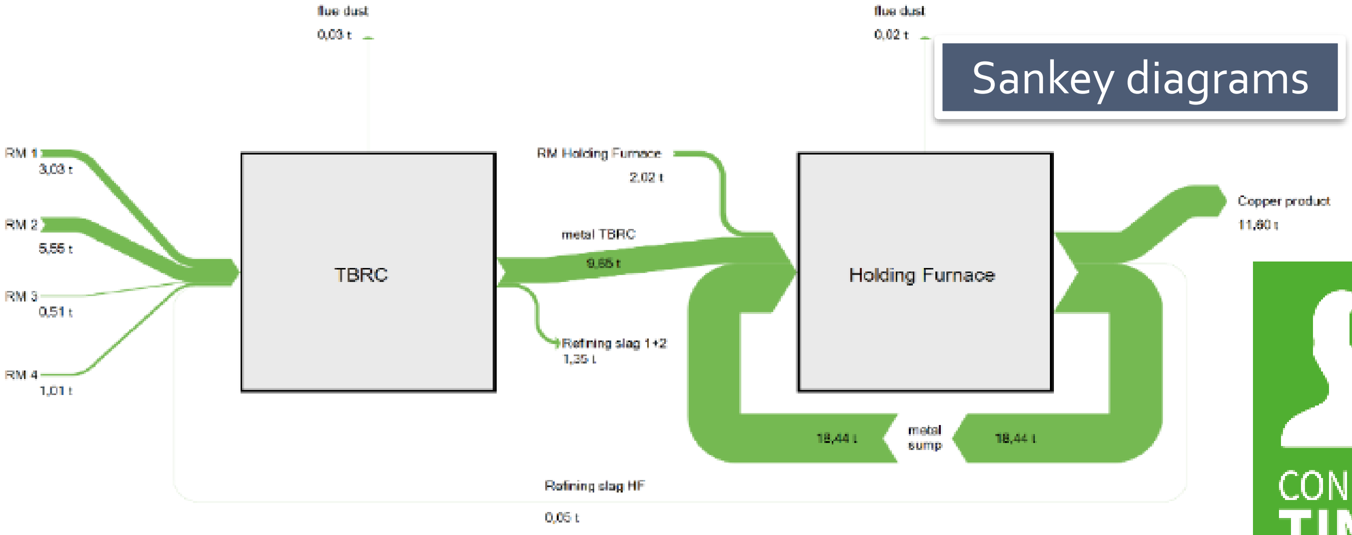


Cost-benefit analysis

Wichtigkeit			
10	6	3	1
Notwendig	Sehr wichtig	Vorteilhaft	Gewünscht

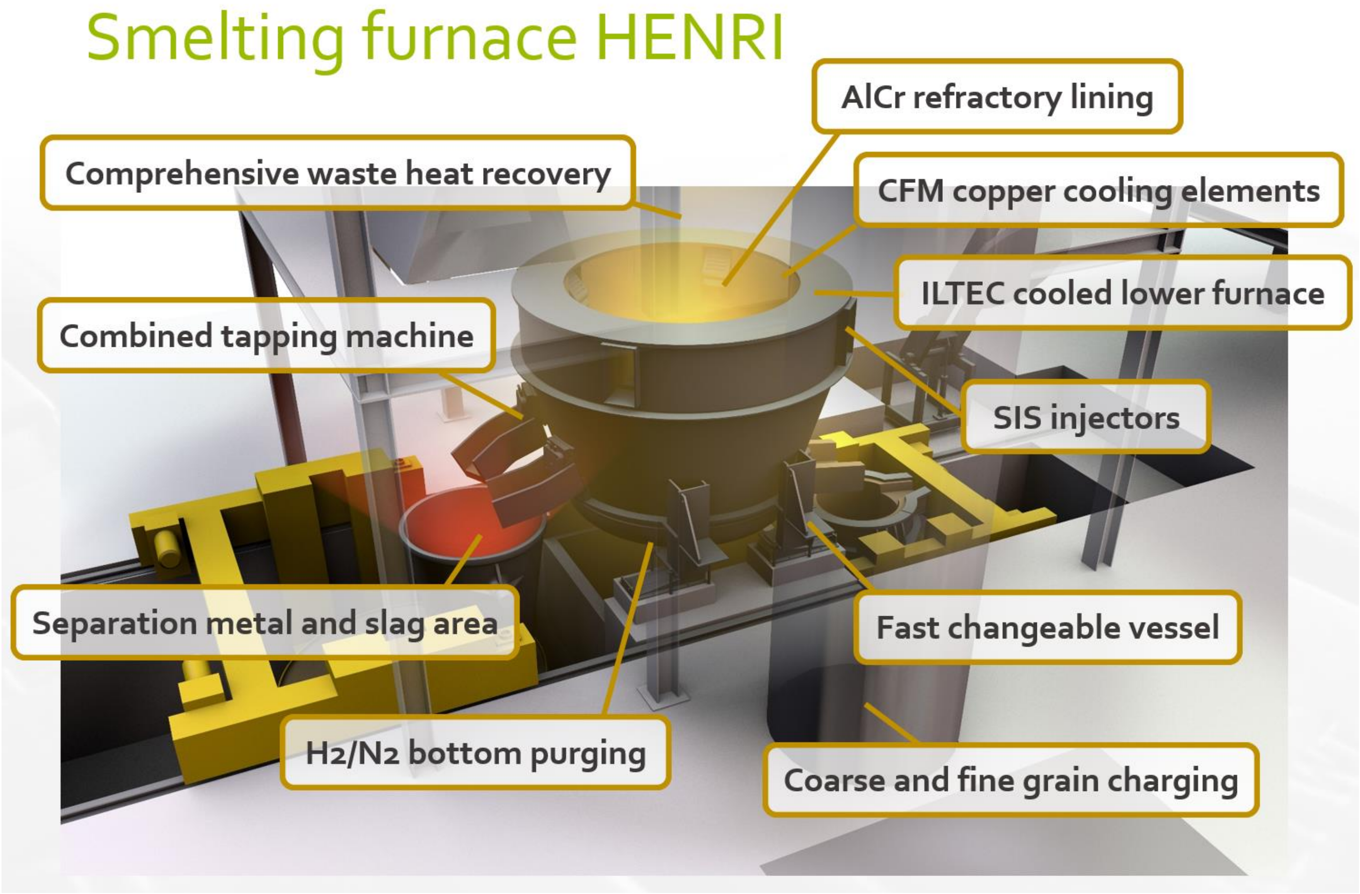
Nr.		Sekundärrohstoff	Eignung: 10 Perfekt	7 Gut	4 Mittel	2 Schlecht	0 Nicht	W	max	Rohstoff 1		Rohstoff 2		Rohstoff 3	
1		Kriterien							460	2.	238	1.	280	3.	169
1	1	Wertstoff-Gehalt	> 70%	< 70%	< 25%	< 10%	< 1%	3	30	7	21	4	12	7	21
1	2	Wertstoff-Wert/to	> 10.000€	> 2.000€	> 500€	> 100€	> 0€	10	100	7	70	10	100	7	70
1	3	Problemstoff-Gehalt	Spuren	< 100 ppm	< 1000 ppm	< 1%	> 1%	6	60	7	42	7	42	4	24
1	4	Potentielle Wertschöpfung	> 50%	> 25%	> 15%	> 5%	< 5%	6	60	2	12	7	42	2	12
1	5	Aufbereitungsaufwand	Sehr niedrig	niedrig	mittel	hoch	sehr hoch	3	30	10	30	7	21	2	6
1	6	Umweltverträglichkeit	Sehr hoch	hoch	mittel	niedrig	sehr niedrig	6	60	7	42	7	42	2	12
1	7	Verfügbare Menge	Sehr hoch	hoch	mittel	niedrig	sehr niedrig	3	30	7	21	7	21	2	6
1	8	Komplexität der Verbindungen	sehr niedrig	niedrig	mittel	hoch	sehr hoch	3	30	0	0	0	0	2	6
1	9	Wettbewerbsintensität	sehr niedrig	niedrig	mittel	hoch	sehr hoch	6	60	0	0	0	0	2	12

Sankey diagrams

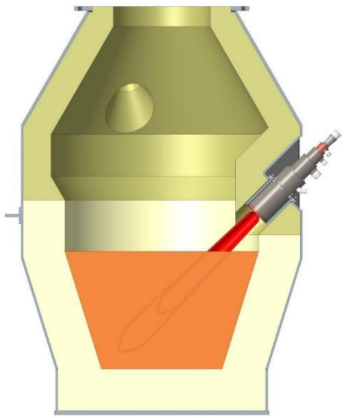


CONSULTING

HENRI



- ✓ Optimized smelter
- ✓ Highest plastic rate in raw material



Advanced E-Waste Recycling

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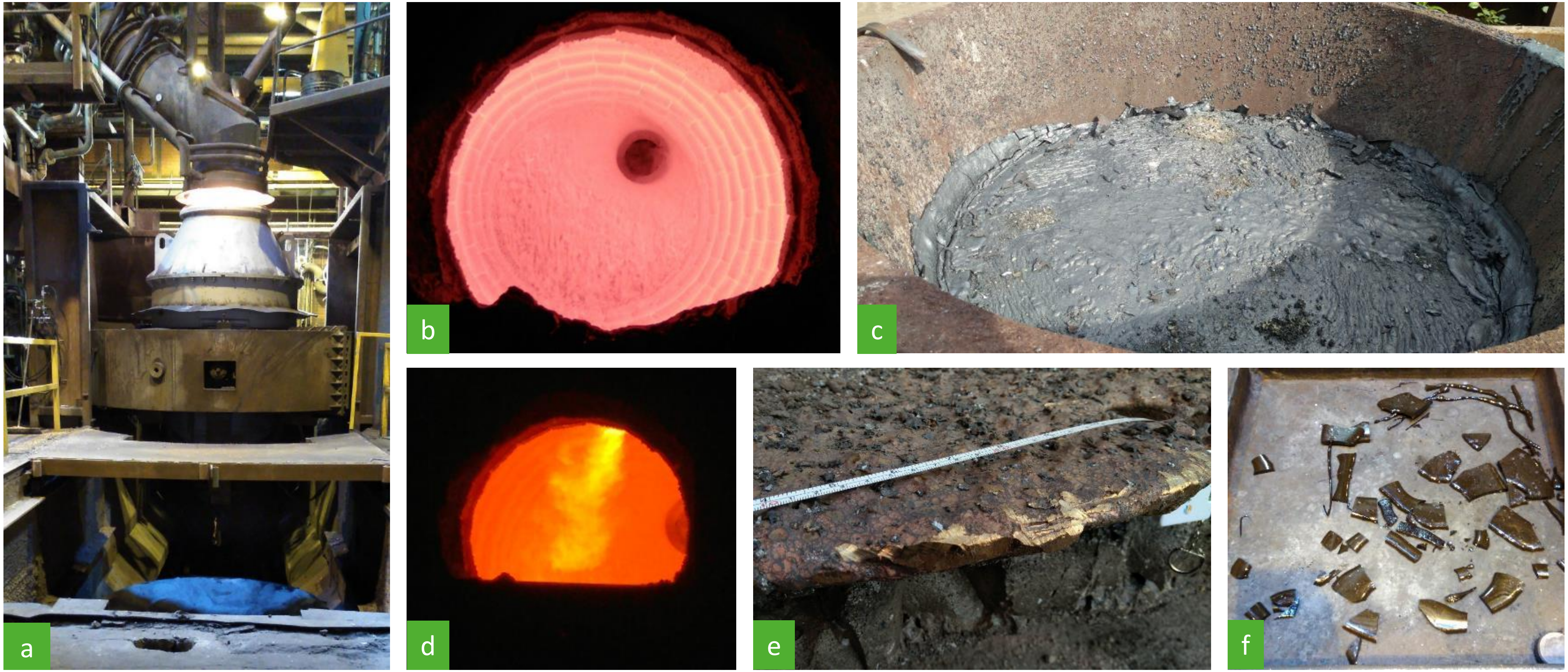
Semi-industrial scale pilot tests



METALLURGICAL RECYCLING

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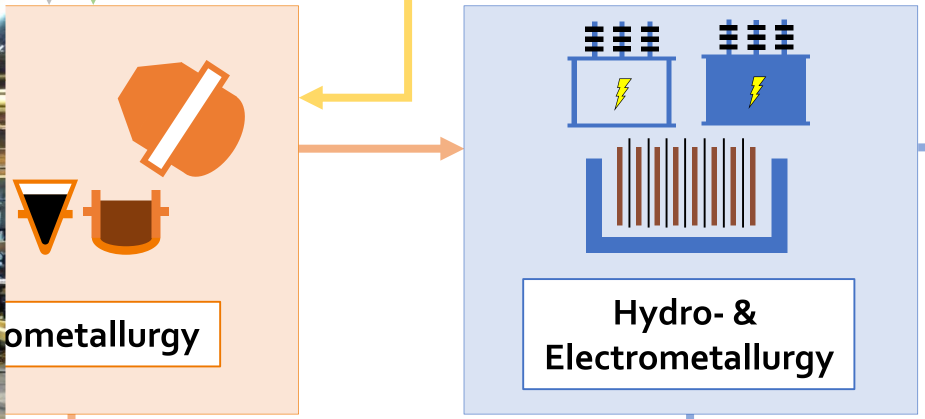






Recycling

From secondary raw materials to pure metals

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Smelting WEEE in short

- Charging of the shredder fractions into a 1,250°C hot metallurgical furnace
- Combustion of organic material und melting of metallic material
- Target: smelting and accumulating all metals in a mixed copper alloy
- Subsequent refining stages up to technical pure copper (and precious metals if desired)
- While smelting:
  - forming of a metallic (Me) and an oxidic phase (MeO)
  - metal phase below and slag phase above (reason: density)

From secondary raw materials to pure metals

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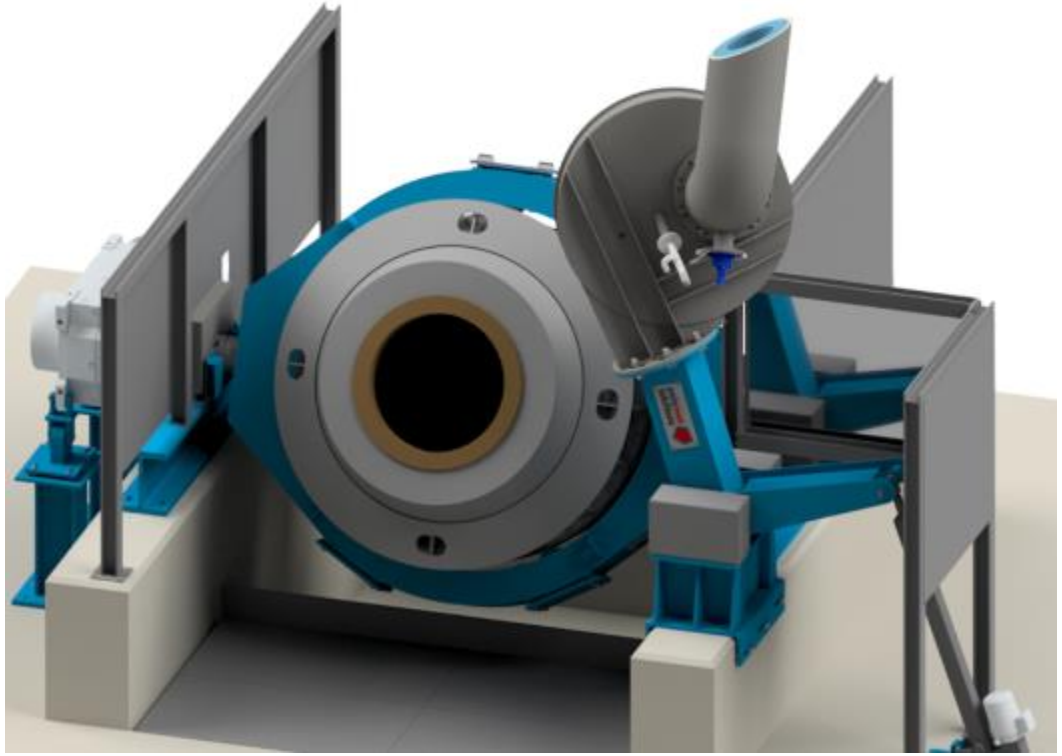
Slag Reduction Step

- Metal droplets get into the slag during smelting
- Target: recovery of valuable metals from the slag
- Reduction with process gases:
  - Gas purging through bottom of furnace, H_2
  - Burner/lances from above into the furnace, H_2
- Also: “waiting” and giving the metal droplets time to move down into the metal phase due to gravity/density
- Casting of slag into pointed buckets → accumulation in tip of bucket, after solidification easy to be knocked of with a hammer

From secondary raw materials to pure metals

Pyro-Metallurgical Refining

- Target: removal of impurities from the copper alloy
- Phase 1: multi-staged oxidizing with air blown into the melt, so called “slagging” of impurities (less noble elements oxidize earlier due to higher oxygen affinity)
- Phase 2: decreasing the oxygen content in the melt with reduction gases (H_2) from approx. 0.8-1.0% O_2 down to less than 0.1% O_2
- Phase 3: melt tapping + anode casting



Converter for oxidation (TBRC)

From secondary raw materials to pure metals

Pyro-Metallurgical Refining

Anode furnace for pyrometallurgical refining

Casting of copper anodes

From secondary raw materials to pure metals

UrbanGold
recycling for a green future

Electro-Metallurgical Refining

- Target: from anode copper 99.0% to cathode copper 99.99%, separation of all elements except copper
- Part 1: dissolving of anodes and depositing of copper
  - non-copper elements dissolve in electrolyte (less noble elements) or fall down as slime (nobler elements)
- Part 2: removal of anode slime by pumping out
  - anode slime (AS) is basis for precious metals,
    consisting mainly of Cu, Pb, Sn, (Se, Te , Sb, As), precious metals

From secondary raw materials to pure metals

Electro-Metallurgical Refining

Tankhouse with several electrolysis cells

Mettop BRX System
(lateral inlet and cathode spacers)

From secondary raw materials to pure metals

UrbanGold recycling for a green future

Precious Metals Plant

- Anode slime in cell: (before pumping out)

From secondary raw materials to pure metals

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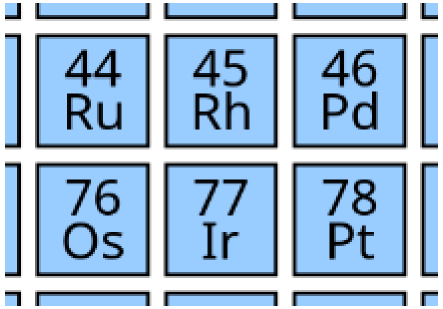
recycling for a green future

Precious Metals Plant

- Target: extracting precious metals from the anode slime
- Part 1: removal of copper (hydro-metallurgical refining)
- Part 2: removal of lead (pyro-metallurgical refining)
- Part 3: separation of Ag / Au / PGMs (electrical & chemical refining)
  - PGM = platinum group metals:

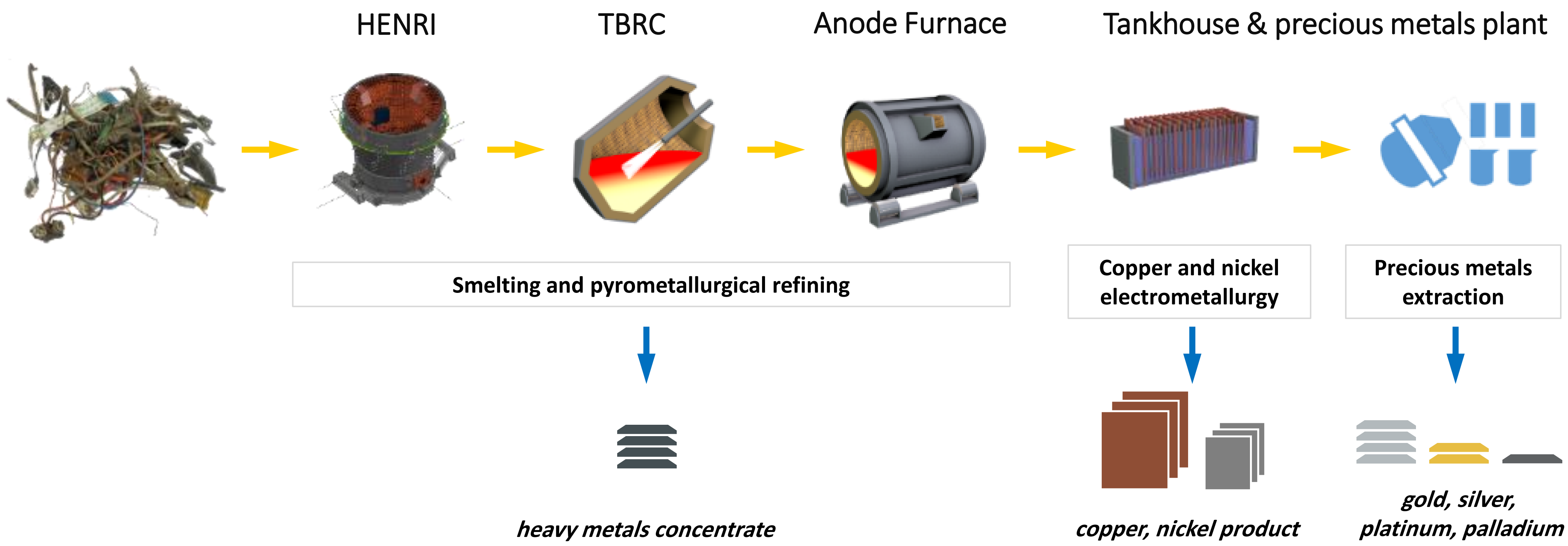


44	Ru	Ruthenium	in ores
45	Rh	Rhodium	in ores
46	Pd	Palladium	in WEEE
76	Os	Osmium	in ores
77	Ir	Iridium	in ores
78	Pt	Platinum	in WEEE

Process flow scenarios

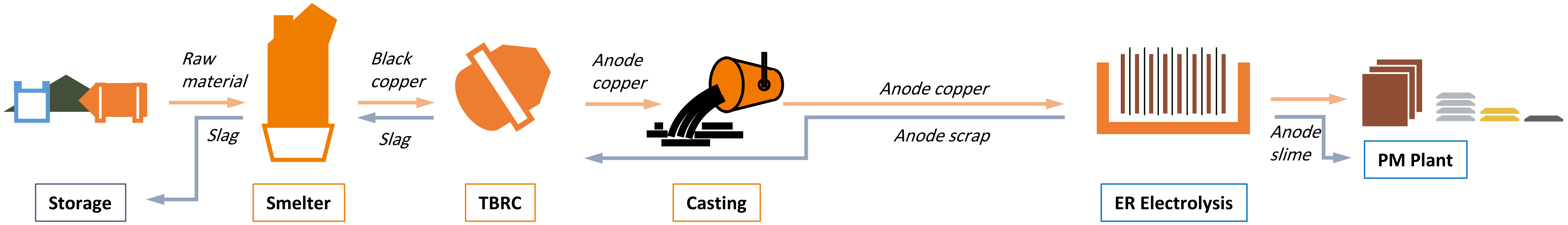
Process flow diagram full recycling plant

- Input: all grades of WEEE concentrates, PCB scrap, shredder residues, slimes (dry), slags and dusts



Economic Considerations

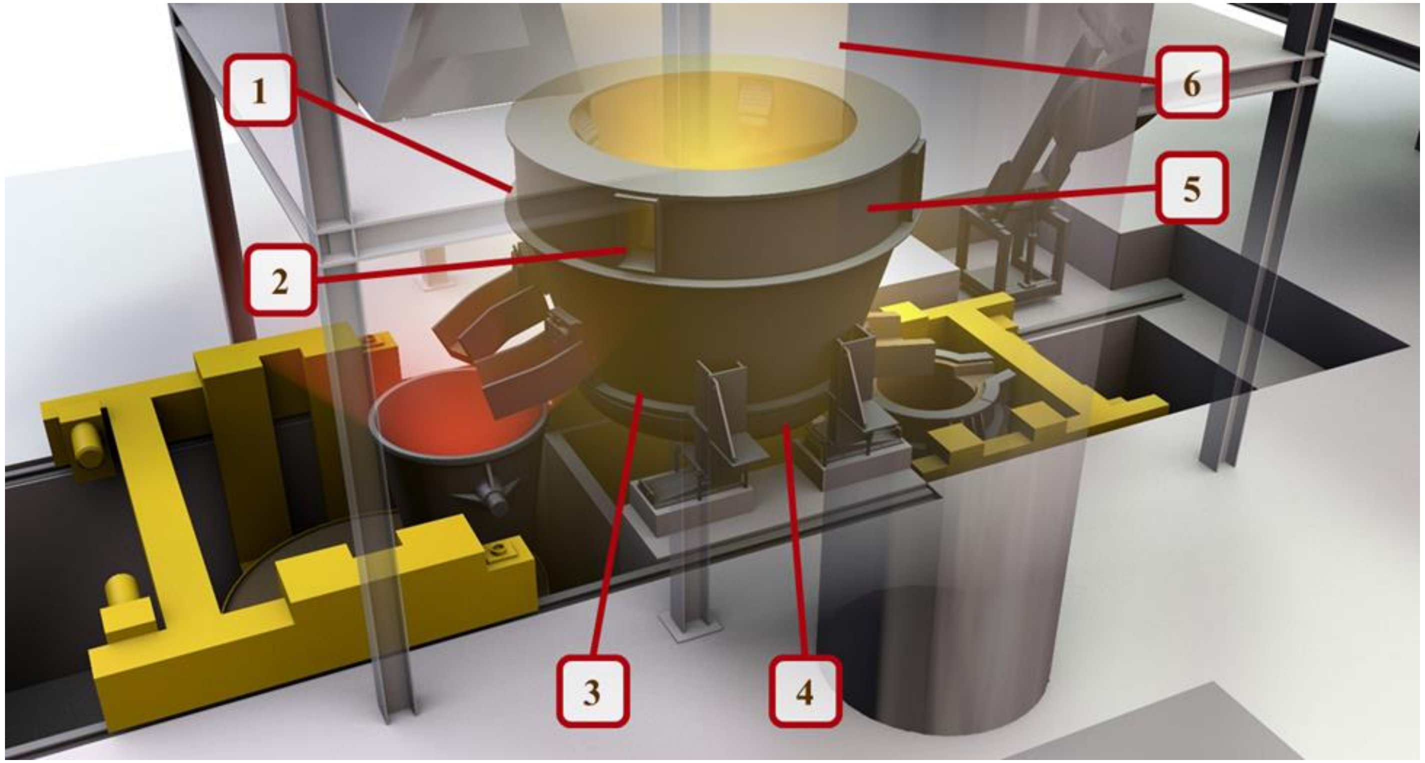
- General facts
  - Economy of scale promotes installation of huge facilities
  - Big facilities require a corresponding large feedstock catchment area
  - Decisive cost factor of metallurgical e-waste processing is the feed stock
- Benefits of small scale smelters
  - Focussing on the local feed stock
  - Limited infrastructure requirements
  - Focussed operation reduced to the essentials
  - Manageable & reasonable CAPEX



12 000 – 25 000 tpa raw material → ca. 5 000 tpa Anode copper →

- 3 800 t Cu
- 14 t Ni
- 330 kg Au
- 3 150 kg Ag
- 120 kg Pd

Design and benefits of the HENRI MiniSmelter



#	Furnace module
1	Fast changeable vessel
2	Supersonic burner and injector
3	H_2/N_2 bottom gas purging
4	Safe cooling below bath level with ILTEC
5	CFM copper cooling elements
6	Waste heat recovery

Modular design to be customized for your raw material mix