Opportunities & challenges to recover scarce and valuable metals from electronic devices

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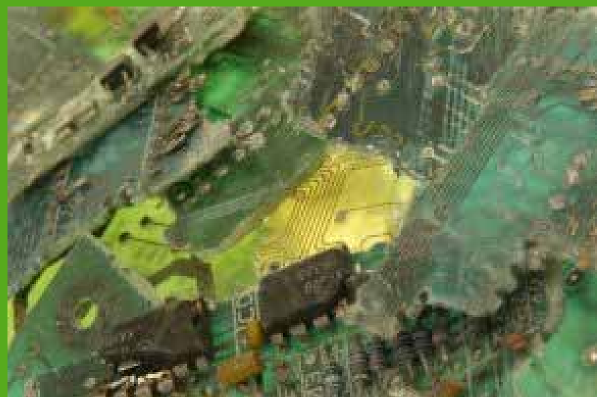
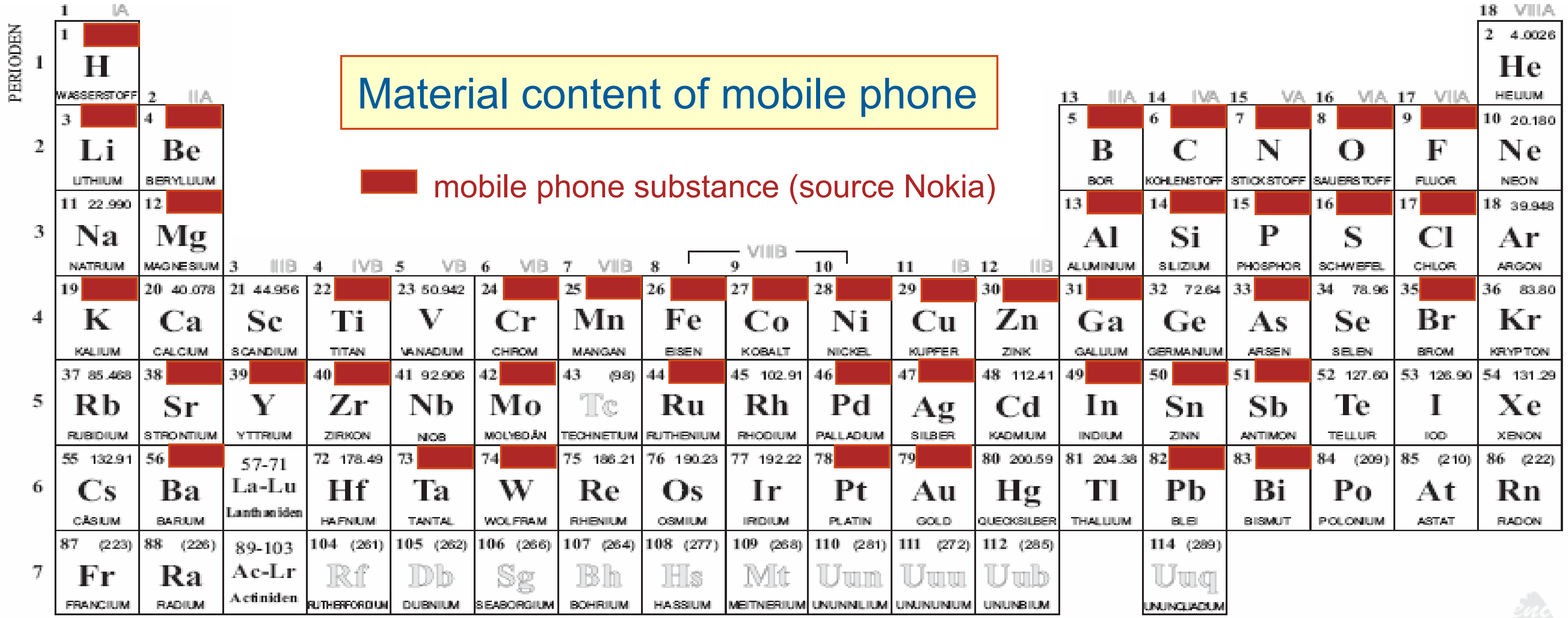


Electronics contain up to 60 elements
- a complex mix of valuables & hazards



- demand (and prices) of special & precious metals have increased significantly (specific metal properties are needed for more functionality)
- their primary production requires significant amounts of energy and resources
- “concentration” in specific components like circuit boards
- new material combinations compared to their natural occurrence & dissipation in final product (e.g. computers, cell phones, cars etc.) make recycling challenging

Impact on metals demand
- 2 prominent examples

Global sales, 2006:

a) Cell phones:

1000 Million units

x 250 mg Ag ≈ 250 t Ag

x 24 mg Au ≈ 24 t Au

x 9 mg Pd ≈ 9 t Pd

x 9 g Cu ≈ 9000 t Cu

1000 M x 20 g/battery*

x 3.8 g Co ≈ 3800 t Co

* Li-Ion type

b) PC & laptops:

225 M units

x 1000 mg Ag ≈ 225 t Ag

x 220 mg Au ≈ 50 t Au

x 80 mg Pd ≈ 18 t Pd

x ≈ 500 g Cu ≈ 113,000 t Cu

≈ 75 M laptop batteries*

x 65 g Co ≈ 4900 t Co

** Li-Ion type is > 90% used in modern laptops

World Mine Production / a+b share

Ag: 20,000 t/a ► 2.5%

Au: 2,500 t/a ► 3%

Pd: 230 t/a ► 12%

Cu: 16 Mt/a ► 1%

Co: 58,000 t/a ► 15%

- Although "negligible" metal quantities per piece, the leverage of huge unit sales leads to significant total numbers !
- value of these five metals at 2006 prices: 2.8 billion US-$
- CO_2 burden for producing these metals (primary): 2.1 million t CO_2
- How much of this will finally be recycled ?

2006	t	$/kg	Mio $	1000 t CO2
Ag	475	371	176	68
Au	74	19.355	1.432	1.257
Pd	27	10.288	278	253
Cu	122.000	6,73	821	415
Co	8.700	15,22	132	66
			2.840	**2.060**

Sales of electronic devices – a booming market

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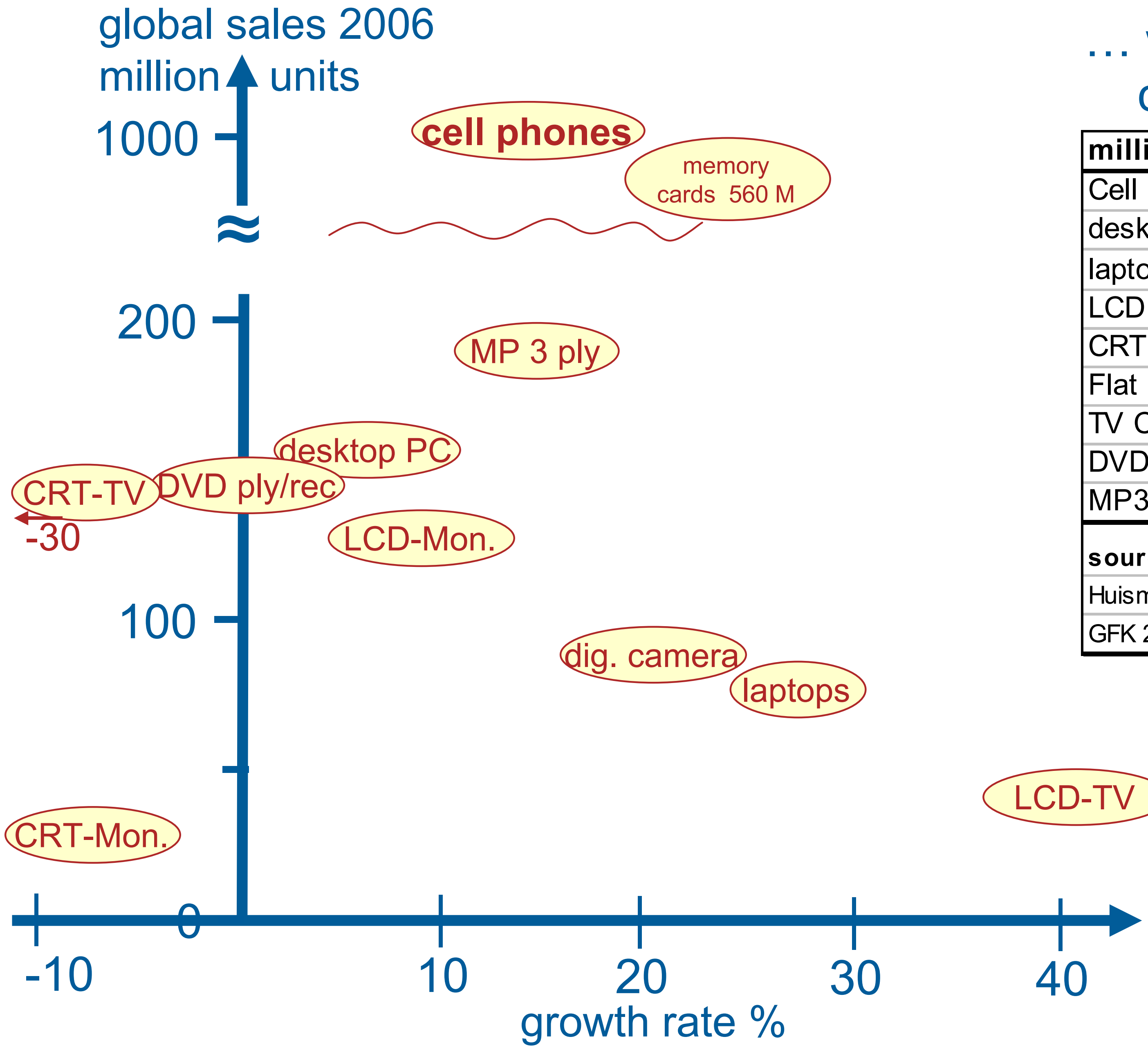

… with significant contributions from Europe

million units 2006	world	EU 25	% EU
Cell phones	1000	*200*	20%
desktop computers	150	28	19%
laptop computers	75	28	37%
LCD Monitors	135	32	24%
CRT monitors	32	2	6%
Flat Panel TVs	45	20	44%
TV CRT	142	16	11%
DVD players/rec.	125	*40*	32%
MP3 players	180	35	19%
sources:			***25%***
Huisman, Kühr et al: WEEE review , 2007			
GFK 2007; Gartner 2007			

metals demand for EEE will grow further

Environmental impact of metal production: CO_2

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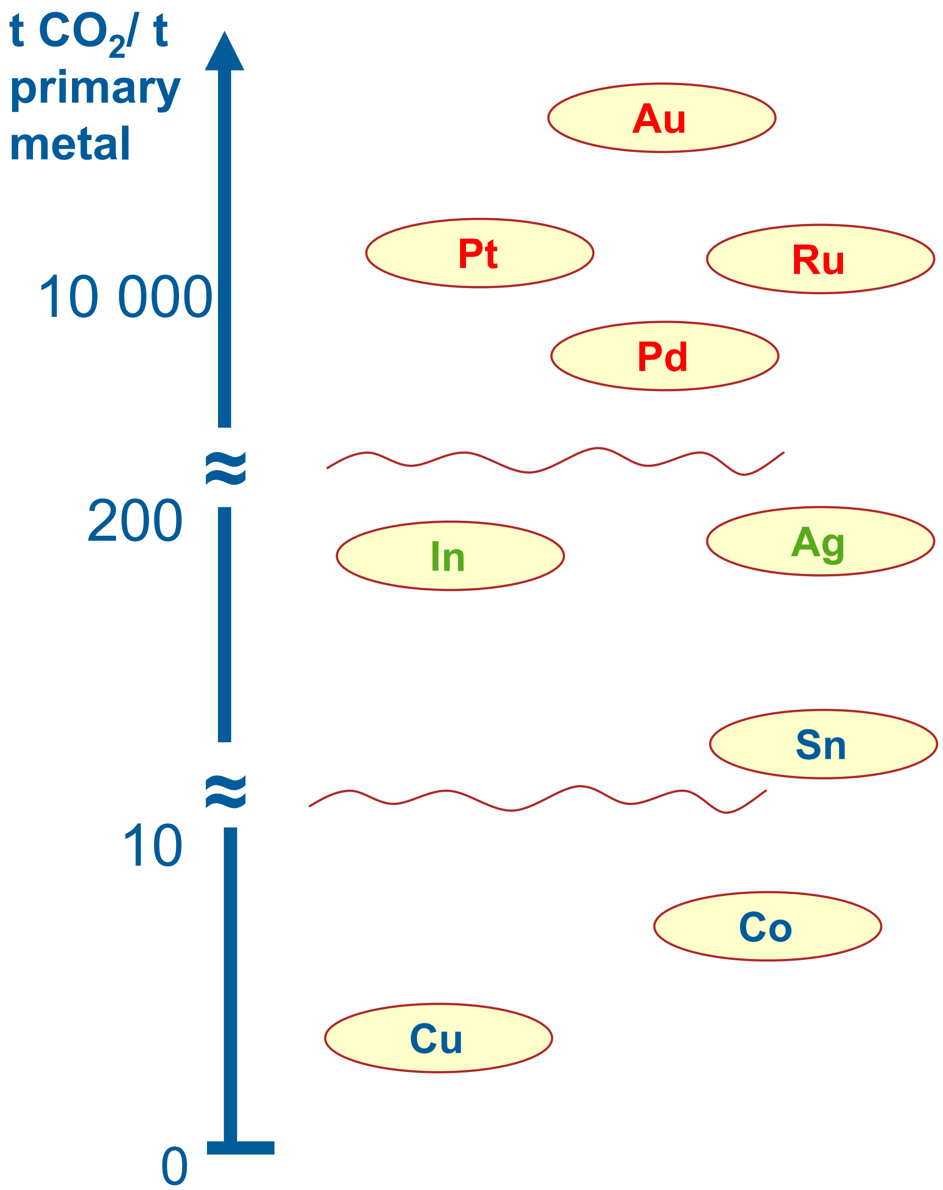

CO_2-emissions of Primary Production:

Important EEE metals	demand for EEE t/a (2006)	data for primary production [t CO_2/t metal]	CO_2 emis-sions [Mt]
Copper	4 500 000	3.4	15.30
Cobalt	11 000	7.6	0.08
Tin	90 000	16.1	1.45
Indium	380	142	0.05
Silver	6 000	144	0.86
Gold	300	16 991	5.10
Palladium	32	9 380	0.30
Platinum	13	13 954	0.18
Ruthenium	6	*13 954*	0.08
CO_2 total [t]			**23.41**

source: ecoinvent 2.0, EMPA/ETH-Zürich, 2007

additional impacts from SO_2, land use, waste-water etc.

Metals recycling creates a huge CO_2 benefit

Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

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Example:

Umicore Precious Metals Refining, Hoboken/Belgium (UPMR):

- recovered metals 2006: 75,000 t*
- total CO_2 impact of UPMR in 2006: 0.28 Mt
- total CO_2 impact primary production**: 1.28 Mt

► CO_2 saved due to recycling*: 1.00 Mt

*from treatment of 300,000 t of recyclables & smelter by-products.
Output: 1100 t Ag, 32 t Au, 32 t PGM, 70,000 t Cu/Pb/Ni, 4100 t Sn/Se/Te/In/Sb/Bi/As

**if these metals would have come from primary production, calculated with ecoinvent 2.0:

the unavoidable "black box approach" of the UPMR calculation mixes the CO_2 impacts of very low grade materials (e.g. slags, flue dusts) with richer ones from recycling of consumer goods (e.g. circuit boards, catalysts)
► for recycling of electronics the CO_2 benefit compared to mining is even higher!

Example for “high-tech” metals recovery – a lot can be achieved

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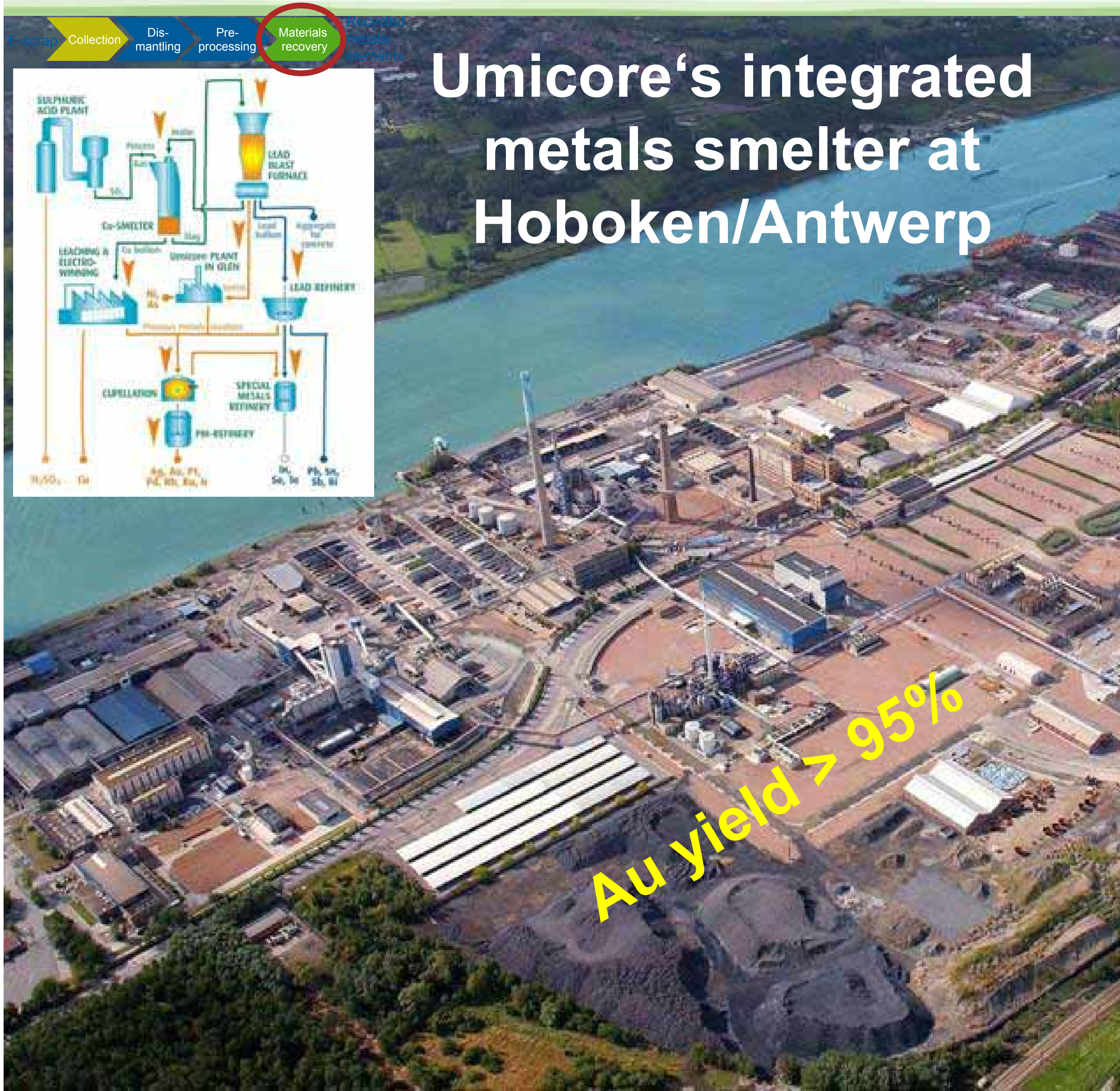

- Unique flowsheet, focus on secondary materials with precious metals (PM)
- Recovering 17 metals:
  Au, Ag, Pd, Pt, Rh, Ir, Ru,
  Cu, Pb, Ni, Sn,
  Bi, Se, Te, Sb, As, In

  recovered metal value (2006):
  PM: 2000 M$, others 300 M$
- 300,000 t/a of complex PM bearing feed materials
- high purity metal output
- Global supply base
- Minimizing waste
- World class environmental standards (BAT)
  ISO 14001 & 9001
- > 1 billion € investment

Example "low tech"
– Gold recycling in Bangalore/India …

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Total Au-recovery efficiency only ≈ 25%, while environmental & health damage is dramatic (Rochat, Keller, EMPA 2007)

foto: EMPA/CH

… this takes place in large parts of the world today!

Recycling potential vs reality

The potential: Value of electronics sales worldwide (2006)

- metals worth > 40 billion US-$ (EU > 10 billion $)
- CO_2 emissions of primary production: > 23 million t (EU > 6 M$)
- potential CO_2 saving at 80% metals recycling: > 14 million t (EU 4 Mt)

The reality for Europe*:

> 60% are not properly recycled, metals are lost (exports, trash bin, …)

- 70% for IT &Telecom (3a), small household appliances (2, 5a, 8)
- 65% for CRT (3b, 4b)
- 60% for consumer electronics (4a)

*source: Huisman, Kühr et. al: WEEE review report, 2007

Europe

- **losing annually > 10 billion $ of metals value**
- **wasting a CO_2 saving potential of at least 4 million t CO_2**

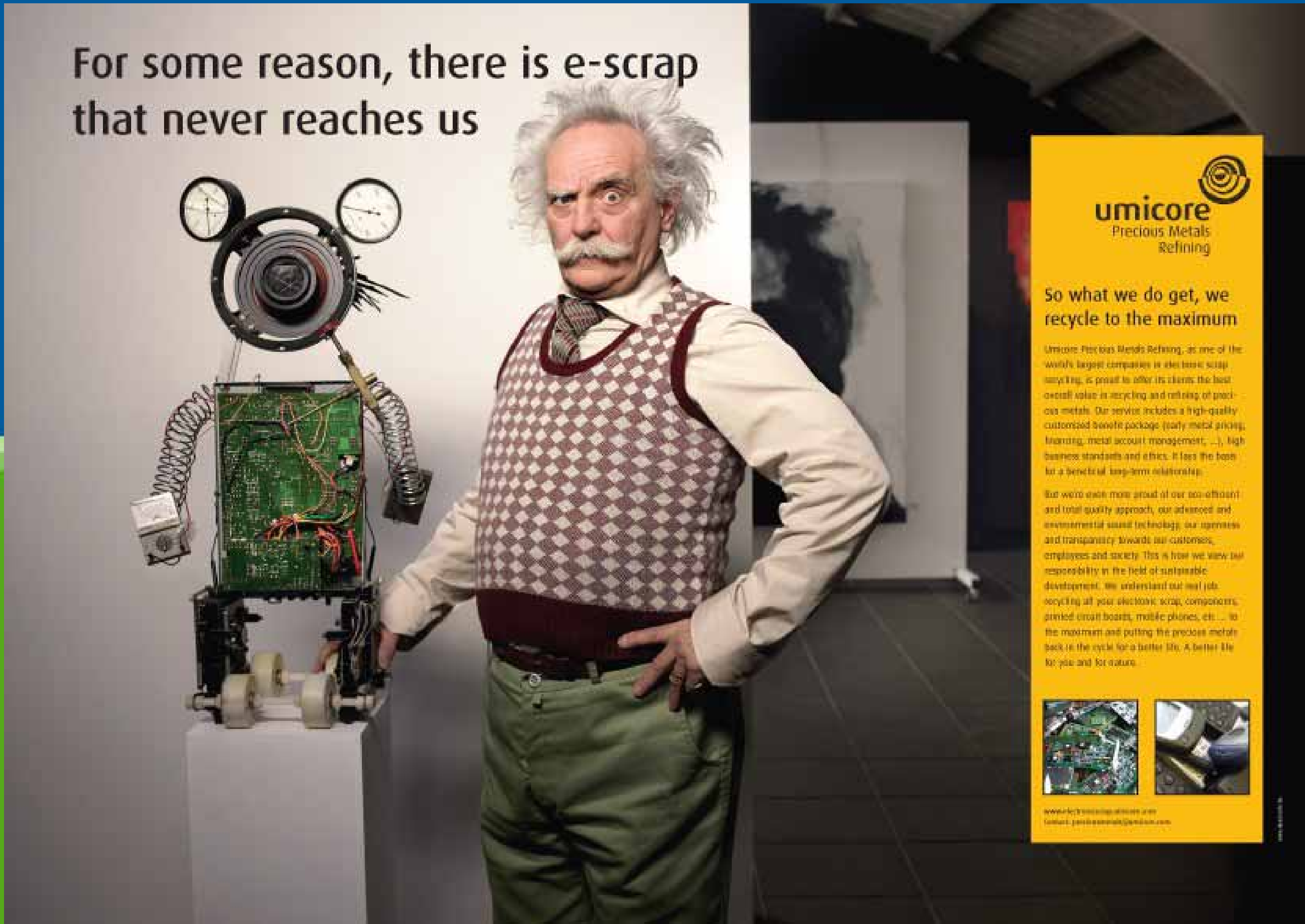
Conclusion

- Booming demand for precious & special metals (functionality)
  EEE as major driver for some metals. Mining those metals is energy intensive.
- Efficient recycling technologies exist but only smart interfaces & high tech processes can prevent losses of these trace elements.
- Main constraints are structural, not technical →"open cycles" for consumer goods
- Efficient recycling & responsible mining are needed to meet future metals demand

- Europe's largest resource stock: our technosphere & EOL-products ("mine above ground").
- Effective recycling can play a key role to
  - conserve metal resources & enable a regionally more balanced access (supply security)
  - mitigate metal price increase / volatility
  - contribute significantly to a reduction of energy use & emissions

If things don't change, future secondary metals supply will be much lower than anticipated & the „recycling society" will be just a nice buzzword. However, if we do it the right way, a lot can be achieved!

Thanks for your attention



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annex

EEE have a significant impact on metals demand

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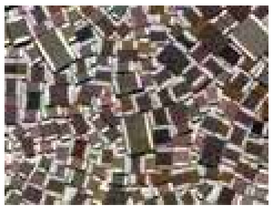
important EEE metals		world mine-production*	by-product from	demand for EEE	demand related to mine production	metal price**	value of EEE use	Main uses in electro/electronics
		t/a		t/a		$/kg	billion $	
silver	**Ag**	20.000	(Pb, Zn)	6.000	**30%**	371	2,2	contacts, switches, (leadfree) solders, conductors, MLCC, …
gold	**Au**	2.500	(Cu)	300	**12%**	19.350	5,8	bonding wire, contacts, IC
palladium	**Pd**	230	PGM	32	**14%**	10.288	0,3	Multilayer capacitors (MLCC), connectors, PWB plating, …
platinum	**Pt**	220	PGM	13	**6%**	36.748	0,5	hard disks, thermocouple wires, fuel cells
ruthenium	**Ru**	30	PGM	6	**20%**	6.162	0,0	hard disks, resistors, conductive pastes, plasma display panels
copper	**Cu**	15.000.000		4.500.000	**30%**	7	30,3	cables, wires, connectors, conductors, transformers, e-motors
tin	**Sn**	275.000		90.000	**33%**	9	0,8	(leadfree) solders
antimony	**Sb**	130.000		*65.000*	**50%**	5	0,3	flame retardants, CRT glass
cobalt	**Co**	58.000	Ni, Cu	11.000	**19%**	36	0,4	rechargable batteries
bismuth	**Bi**	5.600	Pb,W,Zn	900	**16%**	11	0,01	leadfree solders, capacitors, heat sinks, electrostatic screening, …
selenium	**Se**	1.400	Cu	240	**17%**	52	0,01	electrooptic, copiers, solar cells, …
indium	**In**	480	Zn, (Pb)	380	**79%**	822	0,3	LCD glass, leadfree solders, semiconductors/LED, …
						total	**41,0**	
* rounded, source: USGS Mineral commodity summaries 2007; GFMS; JM-Platinum								** avg. 2006

By-product = coupled at ppm level to major metals Cu, Zn, Pb, etc, no own mines are existing.

⇒ increase of supply only in parallel with major metals

⇒ No price elasticity of minor metal





In spite of all efforts
- mobile phone recycling largely fails today

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Recycling potential 2006*: 400 million units per anno x 100 g = 40,000 t/a

collected | Not collected

%? %?

Recy-cling¹ | reuse

%?

Use in 2nd life | Exported to developing countries

EOL not collected

Recycling reality²:
< 1000 t
(< 10 M)
in 2006

Stored "in drawer"
(potential for recycling at later stage)

Use in "2nd life"

Final end of life

Collec-ted | Not collected

%?

Local 'backyard recycling'

Re-export to ESM-recycling

Disposed with household waste
(unrecoverable loss)

¹ 25-35% of professionally collected phones are not fit for reuse and sent directly to recycling.

² global quantities treated for material recovery efficiently and environmentally sound

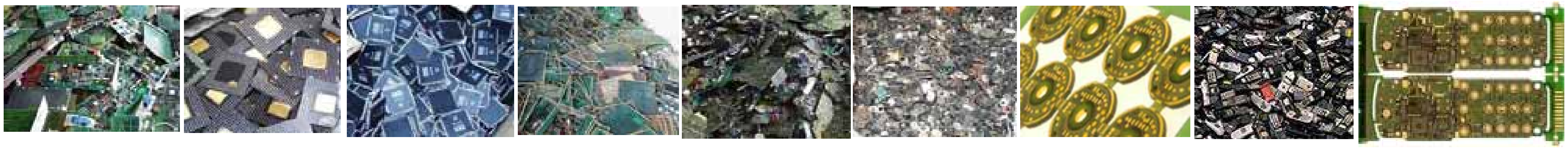
³ uncontrolled release of fumes, effluents and waste

Global Sales of new phones:
2001: 400 M
2003: 500 M
2004: 650 M
2005: 800 M
2006:1000 M
2007:1150 M estimate

Not to scale

E-scrap treated at Umicore

All parts, components, fractions that contain precious metals (PM):



- Printed circuit boards (from end-of-life scrap or production residues)
  - computer boards, cell phone boards, boards from hard disk drives, etc.
  - TV- / monitor boards, audio boards after removal of large iron and aluminum parts
  - unpopulated boards with PM

- PM bearing components: IC, multi layer capacitors (MLCC), contacts, etc.
- mobile phone handsets and other small devices with a relatively high PM content (after removal of battery)
- Fractions with a high circuit board content (e.g. after shredding and sorting)
- Other output-fractions from mechanical preprocessing with PMs
- Li-Ion & NiMH batteries (in dedicated business line)

What do we not treat – examples:

- entire devices if > 15 cm
- copper cables
- mere plastic scrap (casings, …)
- CRT-glass
- CRT yokes

Energy balance of circuit board treatment in the Umicore process

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- mixed plastics from the feed substitute coke (reducing agent) & fuel (energy)
- 1 kg of boards contains 9.600 kJ of energy
- Smelting of boards asks for 1.500 kJ/kg
- Further treatment and refining of all metals contained in 1 kg of boards needs 6.500 kJ/kg
- Surplus replaces primary energy in the smelter
- Heat in smelter is recovered as steam and reused in the plant
- process layout & extensive offgas treatment safely prevent hazardous emissions
- all input & output streams are analysed, mass & energy balances are available (see annex)

<u>Positive energy balance</u>:
WEEE-feed contains more than enough energy for entire refining process, no extra CO_2 is generated!

Average composition from 150 t of mobile phone handsets recovered at Umicore

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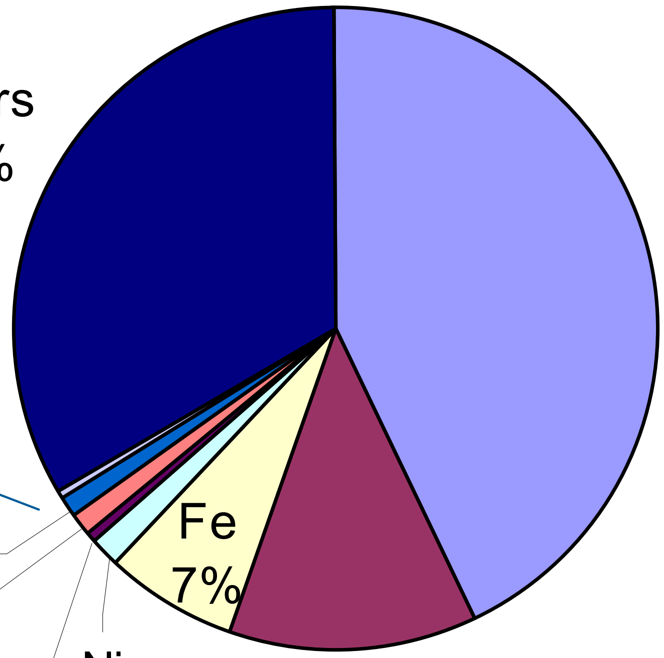


avg. content of precious metals (PM)

	g/t
Ag	3512
Au	341
Pd	144
Pt	4
total	4001

Ag, Au, Pd, Pt, Cu, Pb, Bi: recovered with > 95% yield in Umicore process

additionally recovered: Sn, Ni, In, Sb, As

Does the recycling society solve it all?

New EU waste strategy: Making Europe a recycling society

Brussels, 21 December 2005

The European Commission today proposed a new strategy on the prevention and recycling of waste. This long-term strategy aims to help Europe become a recycling society that seeks to avoid waste and uses waste as a resource. …

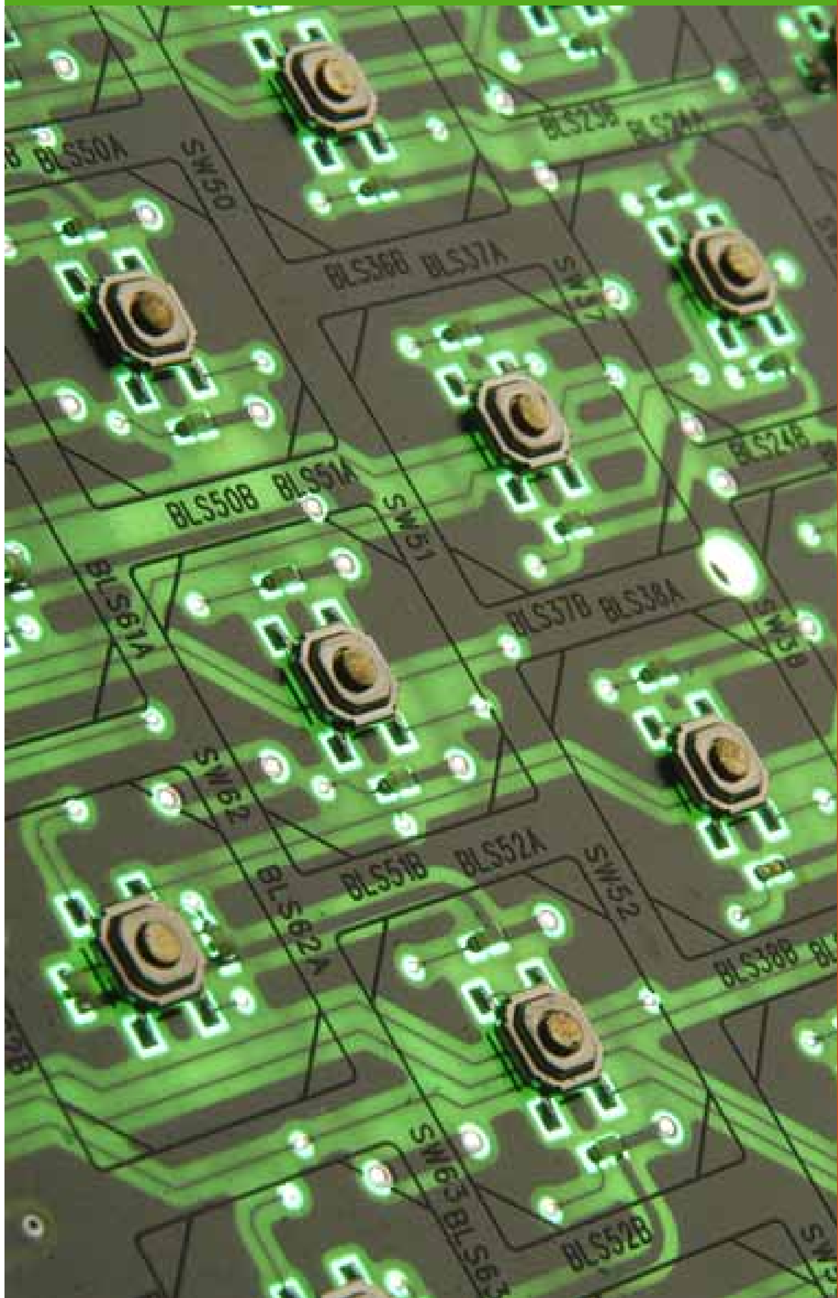
Impact factors on real recycling rates

- Technology
- Society:
  awareness & legislation
- Economics
- Lifecycle structure

► Status Quo in the EU

- available, but often not used; weak interfaces
- frame conditions widely okay, but weak enforcement; low resource awareness
- high metal prices are good incentive
- challenge of open cycles, exports of (used) WEEE, missing transparency, etc.

Where do losses occur ?



- EEE are not collected
- Collection but:
  - Export as legitimate “reuse” in region, where recycling fails at real EOL
  - Illegal export, disguised as reuse (sham reuse)
  - Removal of devices/components at municipal collection points or at subsequent steps in the recycling chain
- Losses within the recycling chain due to :
  - Wrong sorting („cell phones mixed with tools“)
  - Losses during mechanical processing (e.g. precious metals into dust, plastics, Fe- or Al-fraction)
  - Suboptimal interfaces to end processors
  - Losses at end-process

→ Dissipation of precious & special metals in end-products hampers recyclability

→ Thermodynamic constraints prevent recovering of “all” metals

What are the effects on …

European Recyclers

- lost revenues from missing WEEE arisings
- underutilization of plants
- missing investment security: preparing for future arisings would require plant expansions – but only if WEEE is not escaping

Electronics Manufacturers

- are faced with increasing metal prices (more recycling would improve supply/demand balance and mitigate price development)
- might be faced with (temporary) supply problems for certain metals
- are risking their image of sustainable production and proper EOL management

Importing Countries of (illegal) WEEE shipments

- create severe & long-term environmental damage from dumping or backyard recycling
- expose their population to significant health risks
- are risking their image of becoming modern industrialising societies

What needs to be done …

- Consider WEEE as a valuable resource, not as waste.
- Weight based quotes ignore significance of trace elements (precious & special metals). Export losses are not considered in recycling quotes.
- Improve collection (all waste, not just 4 kg WEEE/capita) and ensure that (collected) WEEE does not escape as illegal export or in non-compliant recycling channels (enforcement).
- Improve treatment & stakeholder cooperation within recycling chain: use BAT processes, check input-output streams & real recovery rates achieved.
- IPR does not end at collection and first treatment plant: follow the material throughout the chain and ensure proper treatment. Report must focus on the recovered instead of on the collected material.
- Create a global recycling society: infrastructure in developing countries plus international cooperation in recycling. Promote re-export of critical waste fractions to certified environmentally sound recovery plants. Benefit from a division of labour & economies of scale.

Requirements for a global recycling society

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- Set up local infrastructures in developing & transition countries, ensuring that (re-)used EEE finally is channelled into appropriate recycling chains.
- Local collection, dismantling and recycling of many components can be very effective if right structures are used → training! (consider also the social dimension)
- “Mining” complex WEEE fractions requires “high tech” processes & specialisation
- For these, economies of scale & adequate infrastructure are key to success.
  It does not make sense to replicate large and expensive plants in every country.
  ► International division of labour needed to treat critical e-scrap fractions.

- Recovered metals can be credited back to countries of origin (“toll refining”)
  → no loss of resources from a country’s perspective.
- No landfill, incineration, backyard recycling or treatment in plants without proper off-gas and waste water handling.

spot the difference

Foto BAN