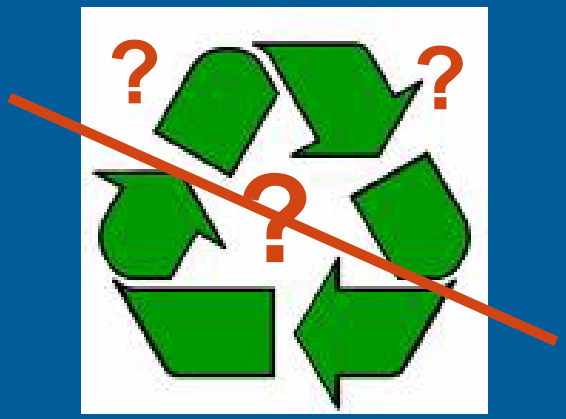
The challenge of open cycles – barriers to a closed loop economy (consumer electronics and cars)



Dr. Christian Hagelüken
Umicore Precious Metals Refining

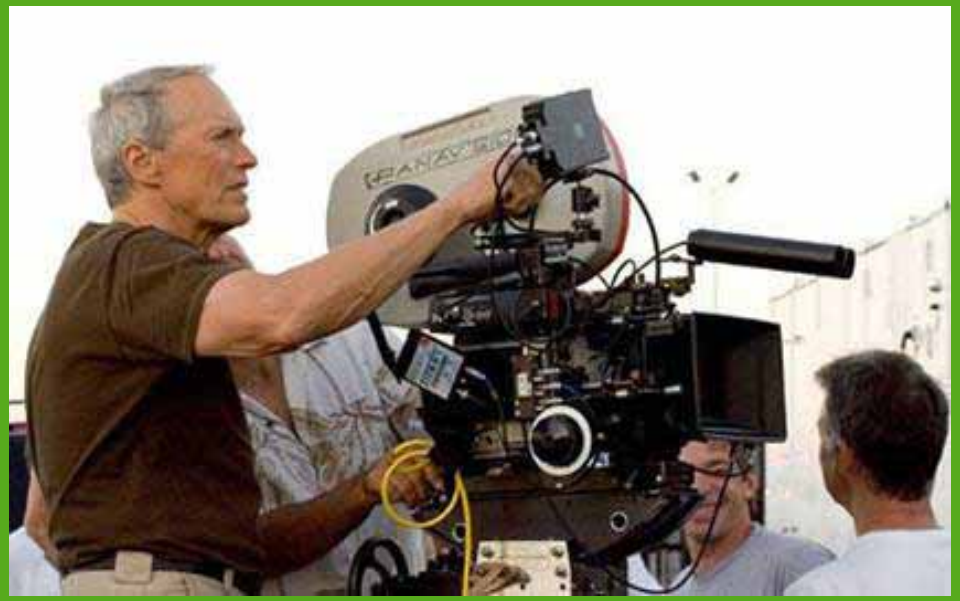
R'07 World Congress
Recovery of Materials and Energy for Resource Efficiency

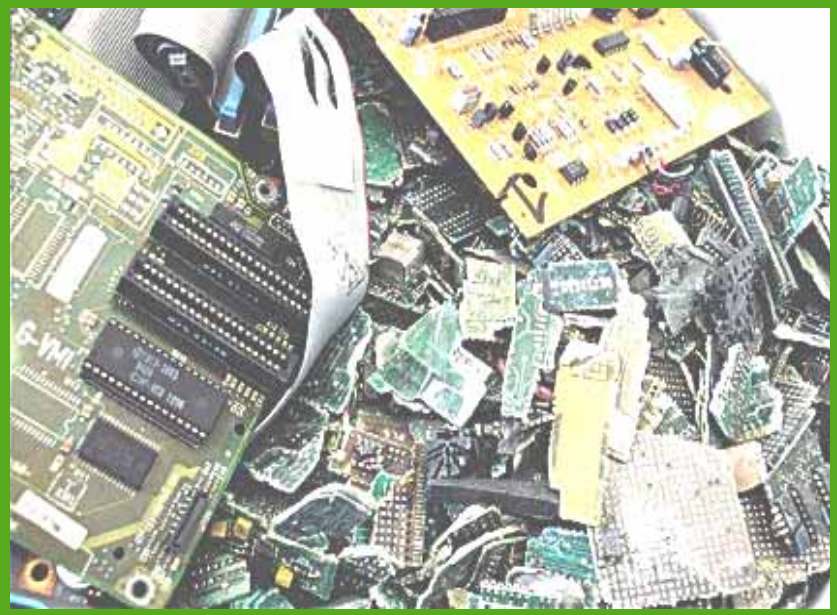
Davos, Switzerland, 3-5 Sept., 2007

New waste strategy:
Making Europe a recycling society

Brussels, 21 December 2005 **IP/05/1673**

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. It will draw on the knowledge that the thematic strategy on resources, also adopted today, will generate. As a first step, the Commission proposes revising the 1975 Waste Framework Directive to set recycling standards and to include an obligation for Member States to develop national waste prevention programmes. This revision will also merge, streamline and clarify legislation, contributing to better regulation. The waste and resources strategies are two of the seven 'thematic' strategies required under the 6th Environment Action Programme (2002-2012).





Recycling Society? - example gold recycling

WEEE- and ELV-directive – the right tools to close the loop?

Directive on Waste Electrical and Electronic Equipment (WEEE) of 27.1. 2003 (2002/96/EC)

article 1 (objectives): The purpose of this Directive is, at a first priority, the prevention of WEEE, and in addition, the reuse, recycling and other forms of recovery of such wastes so as to reduce the disposal of waste. It also seeks to improve the environmental performance of all operators involved in the life cycle of EEE …and in particular those operators directly involved in the treatment of WEEE.

Directive on End-of-Life Vehicles (ELV) of 18.9.2000 (2000/53/EC)

article 1 (objectives): This Directive lays down measures which aim, as a first priority, at the prevention of waste from vehicles and, in addition, at the reuse, recycling and other forms of recovery of end-of-life vehicles and their components so as to reduce the disposal of waste, as well as the improvement in the environmental performance of all the economic operators involved in the life cycle of vehicles and especially the operators directly involved in the treatment of end-of-life vehicles.

- **Resource significance of cars and electronics**
- **Impact factors on metal recycling rates**
- **Life cycle structures – on closed and open cycles**
- **Requirements for a recycling society**
- **Conclusion**

Electronics have a significant impact on metals demand

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		world mine-production*	by-product from	demand for electronics (EEE)*	demand related to mine production	metal price**	Main uses in electro/electronics
		t/a		t/a		€/kg	
silver	**Ag**	20.000	(Pb, Zn)	6.000	**30%**	350	contacts, switches, (leadfree) solders, conductors, MLCC, …
gold	**Au**	2.500	(Cu)	250	**10%**	16.000	bonding wire, contacts, IC
palladium	**Pd**	215	PGM	32	**15%**	8.500	Multilayer capacitors (MLCC), connectors, PWB plating, …
platinum	**Pt**	220	PGM	13	**6%**	29.000	hard disks, thermocouple wires, fuel cells
ruthenium	**Ru**	30	PGM	6	**20%**	18.000	hard disks, resistors, conductive pastes, plasma display panels
copper	**Cu**	16.000.000		4.500.000	**28%**	5	cables, contacts, conductors, transformer, e-motors
tin	**Sn**	275.000		90.000	**33%**	10	(leadfree) solders (incl. other solder uses)
antimony	**Sb**	130.000		*65.000*	**50%**	4	flame retardants, CRT glass
cobalt	**Co**	58.000	Ni, Cu	11.000	**19%**	40	rechargable batteries
bismuth	**Bi**	5.600	Pb,W,Zn	900	**16%**	16	leadfree solders, capacitors, heat sinks, electrostatic screening, …
selenium	**Se**	1.400	Cu	240	**17%**	37	electrooptic, copiers, solar cells, …
indium	**In**	480	Zn, (Pb)	380	**79%**	520	LCD glass, leadfree solders, semiconductors/LED, …
* rounded, source: USGS Mineral commodity summaries 2007							** rounded, as of 03/2007

- Significant use of precious & special metals in electronics
- Importance for increasing functionality (& miniaturisation, lead-free solders)
- Highly dissipated in final product → challenge for recycling

By-product = coupled at ppm level from 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

Electronics - impact on metals demand

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Global sales, 2006 estimates:

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

PC & laptops:

230 M units

per unit

x 1000 mg Ag ≈ 285 t Ag

x 200 mg Au ≈ 46 t Au

x 80 mg Pd ≈ 18 t Pd

x ≈ 500 g Cu ≈ 115,000 t Cu

≈ 60 M laptop batteries*

x 75 g Co ≈ 4500 t Co

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

World Mine Production:

Ag: 20,000 t/a ≈ 3%

Au: 2,500 t/a ≈ 3%

Pd: 215 t/a ≈ 12%

Cu: 15 Mt/a ≈ 1%

Co: 58,000 t/a ≈ 15%

Other relevant metals: In (LCD-screens), Bi+Sn (Pb-free solders), Ru (resistors, hard disks), Sb (flame retardants)

- Although “negligible” metal quantities per piece, the leverage of huge unit sales leads to significant total numbers !
- How much of this will finally be recycled ?
- How efficient are we really in achieving a “recycling society” ?

Vehicles make for more than 50% of global net demand for PGM

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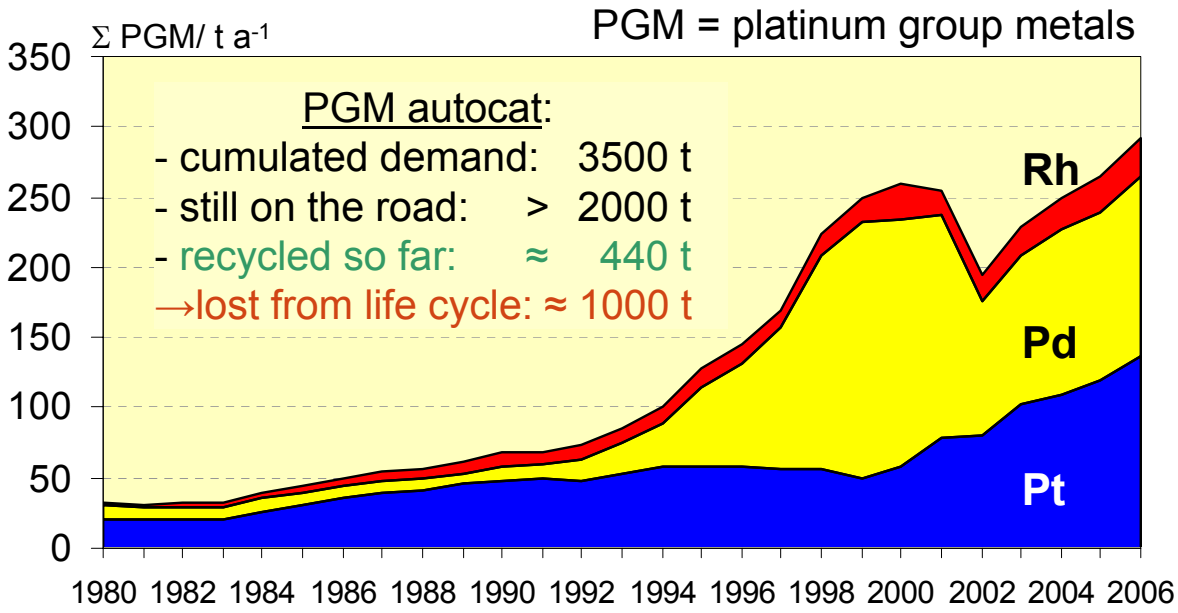
other metals contained (in kg/vehicle)*

built (Europe):	1990 →	2004
weight/vehicle	*900kg*	*1350kg*
• Cu ≈ 1.2%:	11kg →	16kg
• Al ≈ 8%:	70kg →	120kg
• Pb ≈ 1%:	9kg →	13kg
• Steel ≈ 65%:	590kg →	870kg

- + Zn, Sn, Cr, special metals
- + Ag, Au, Pd in car-electronics
- + Pt, Ir in spark plugs & sensors

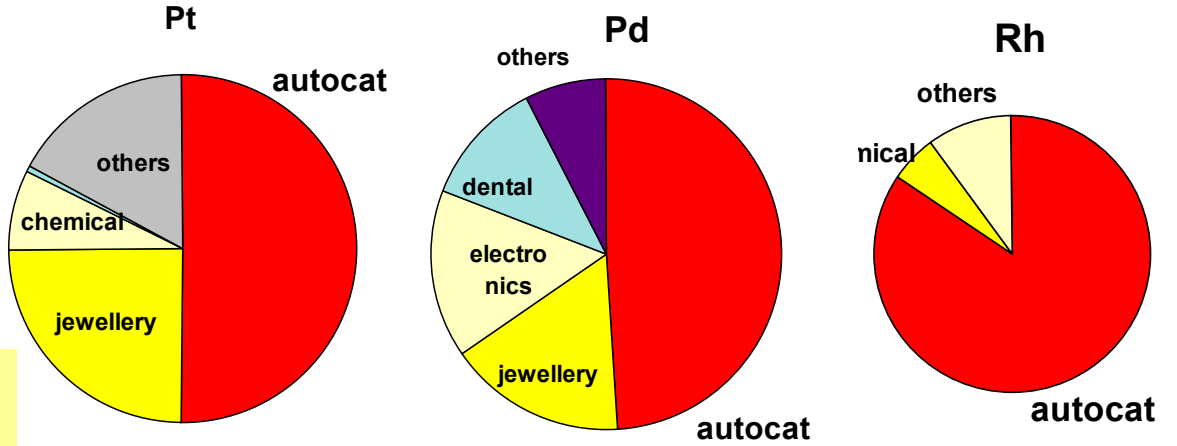
built 1990 ≈ deregistered in 2006
2004 ≈ deregistered in 2020



85% of all PGMs ever mined were extracted after 1980!

Germany only - Metals lost/transferred:
- in shredder residues (450-600 kt; 20% from ELVs)* with 1-2% Cu, 5% NF-metals: 22 -30 kt NF metals
- with 2.5 million ELV-exports: 28 kt Cu, 175 kt Al, 22 kt Pb, 1500 kt steel, 6 t PGM

*source: Daniel Goldmann, VW Sicon



global net demand 2006

→ continuous shift of metal resources from natural deposits into the technosphere …

- **Resource significance of cars and electronics**
- **Impact factors on metal recycling rates**
  - Technical factors
  - Societal & legislative factors
  - Economic factors
  - Structural factors
- **Life cycle structures – on closed and open cycles**
- **Requirements for a recycling society**
- **Conclusion**

Recycling rates - technical factors
(examples for cars and electronics)

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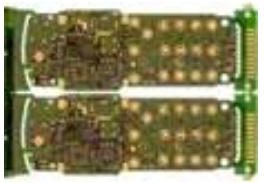
Complexity – the variety of substances in a product

- cars & EEE: large number of components which are complex in itself
- numerous substance combinations, close interlink of valuable & hazardous substances
- increasing use of precious & special metals (improved functionality)



Concentration & distribution

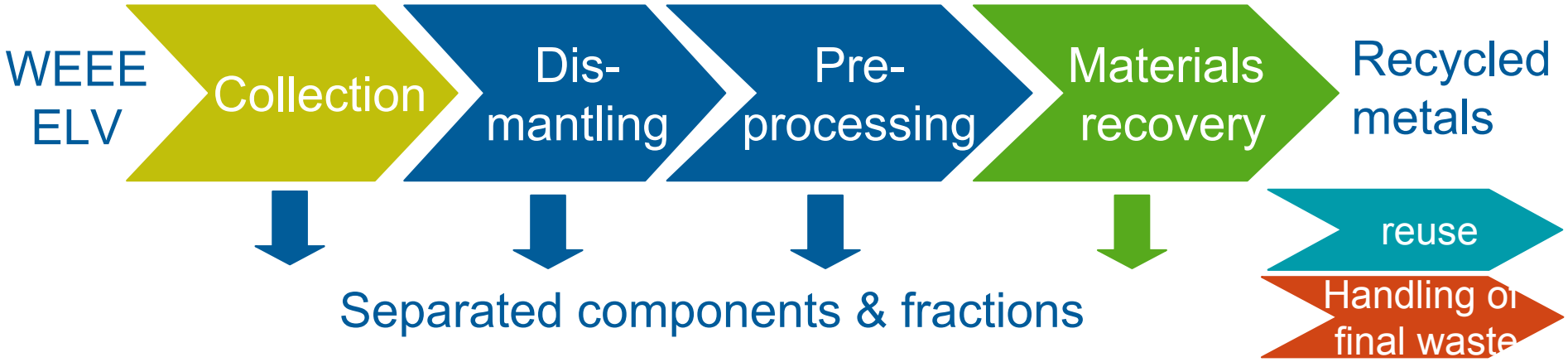
- high concentration (Pb in battery, Al in wheel rim, Cu in alternator) → "easy" to recycle
- ↔ high dissipation (PM & special metals, In in LCD screens) "trace elements" → "difficult" to recycle"

Product design & accessibility of components

- "easy" to remove: car catalyst, battery, wheels, …
- difficult: car electronics, mercury backlights from LCD monitors,…

Complex products require a well organised & dedicated recycling chain

Example: 50% x 90% x 80% x 95% = 34%



- Consider the entire chain & its interdependencies.
- Importance of dismantling & preprocessing, but endprocessing (physical materials recovery) is crucial for value generation & toxic control.
- ! **Success factors**: interface optimisation, specialisation, economies of scale.
- ! Recycling **trace elements** from complex products needs "**high-tech**", large scale processes. Cannot be replicated in any country → international division of labour.
- Recycling technology usually is not the limit factor for high recycling rates

The total recycling efficiency is determined by the weakest step in the chain

Example for “high-tech” metals recovery - Umicore’s Hoboken plant near Antwerp

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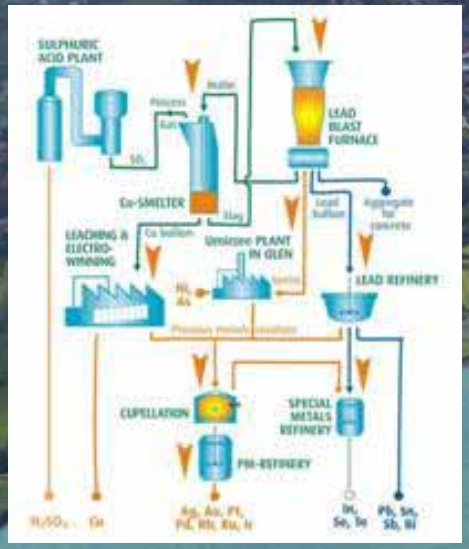

- Unique flowsheet, focus on secondary materials
- Recovering 17 metals: Au, Ag, Pd, Pt, Rh, Ir, Ru, Cu, Pb, Ni, Sn, Bi, Se, Te, Sb, As, In
- Wide range of complex precious metals bearing feed materials
- Market leader (EU) for car catalysts & circuit boards
- Global customer base
- Minimizing waste
- World class environ-mental standards (BAT)
- > 1 billion € investment

Example “low tech” - a „precious metals refinery“ at Bangalore/India (EMPA study)

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Total Au-recovery efficiency only ≈ 20%, while environmental & health damage is dramatic → session D5, Tuesday 11 a.m.

Recycling rates – societal and legislative factors

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Consumer awareness

- legislation
- public campaigns
- providing the appropriate take back infrastructure

Mobilisation of end-of-life products

- hibernating electronics (cell phones, computers etc.)
- incentives, enforcement

Even collected products still escape the recycling chain

- weaknesses in control and enforcement
- structural deficits

Recycling rates – economic factors

Intrinsic (metal) value
- metal content
- metal prices
- yields of recovery process

./.

Total costs of recycling chain
- logistics
- treatment (in subsequent steps)
- environmental compliance

=

Net metal value → recycling incentive

1988-2007

examples for net value*:

- computer main board: 4000 €/t
- mobile phone handset: 6000 €/t
- catalytic converter: 20-70 €/piece
- catalyst ceramic: ≈ 50,000 €/t

* at „smelter gate“, excl. logistics. Large variations depending on quality, especially for autocat

At current metal prices, professional & optimised recycling chains generate a positive net value from cars and certain IT-fractions and mitigate the net recycling costs for others.

Recycling rates – structural factors → the product life cycle

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Car catalysts & mobile phones – the frontrunners for a recycling society ?

- efficient recycling technologies are available
- legislation & consumer awareness is in place
- (highly) economic incentives for recycling

→ > 95% for PGM
→ easy to remove from car, mandatory under ELV directive
→ collectors chase catalysts aggressively at car dismantlers and pay high prices

example autocat

→ Even for expensive PGMs from car catalysts, real recovery rates are only 50%, in Europe even < 40%

If for such "high value" goods recycling rates are low …

…Something must go essentially wrong, other factors must play a role !

→ starting point for research project „Materials flow analysis of PGM"
(Umicore & Öko-Institute, 2001-2005)

→ The main difference is the life cycle structure: closed cycles (industrial goods) vs. open cycles (consumer goods)

- Resource significance of cars and electronics
- Impact factors on metal recycling rates
- **Life cycle structures – on closed and open cycles**
- Requirements for a recycling society
- Conclusion

Lifecycle structures – closed cycles (industrial use) the benchmark for a recycling society

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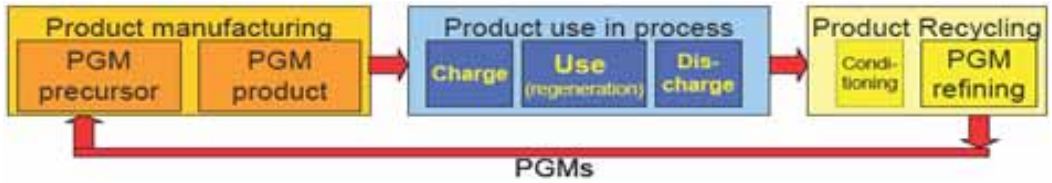
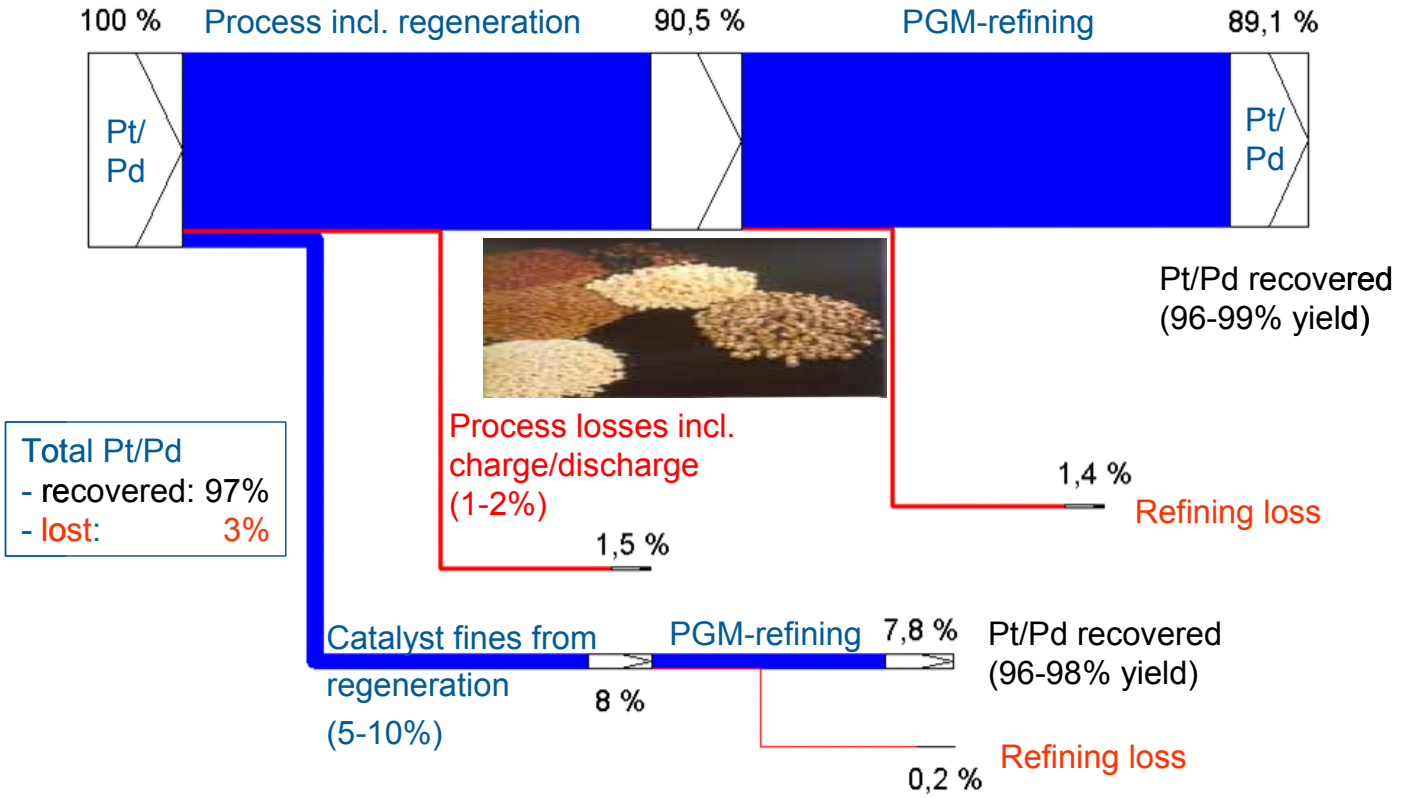
Example: PGM-flows of Pt/Pd catalysts used in oil refining





all %-numbers at single flows refer to 100% initial material; refining yields on input into PGM refinery

→ Inherently efficient; >90% measured efficiency

- Final products typically contain no PGM
- PGMs survive and remain physically at industrial plant
- Provider, user & refiner of PGM product work closely together
- User typically retains ownership of the PGMs
- **Professional handling among all stakeholders, transparent material flows**

Lifecycle structures – open cycles
Recycling reality for mobile phones: < 5%

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Recycling potential 2005*: 400 million units per anno x 100 g = 40,000 t/a

collected | Not collected

%? | %?

Recy-cling[1] | reuse

%?

Use in 2nd life | Exported to deve-loping countries

EOL not collected

Recycling reality[2]: < 500 t (< 5 M) in 2005

Re-export to ESM-recycling today „nil“

Use in “2nd life”

Final end of life

Collec-ted | Not collected

%?

Local ‘backyard recycling’

Stored “in drawer”
(potential for recycling at later stage)

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

Not to scale

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

Recycling reality for autocatalysts: 50% PGM-losses globally, Europe even worse

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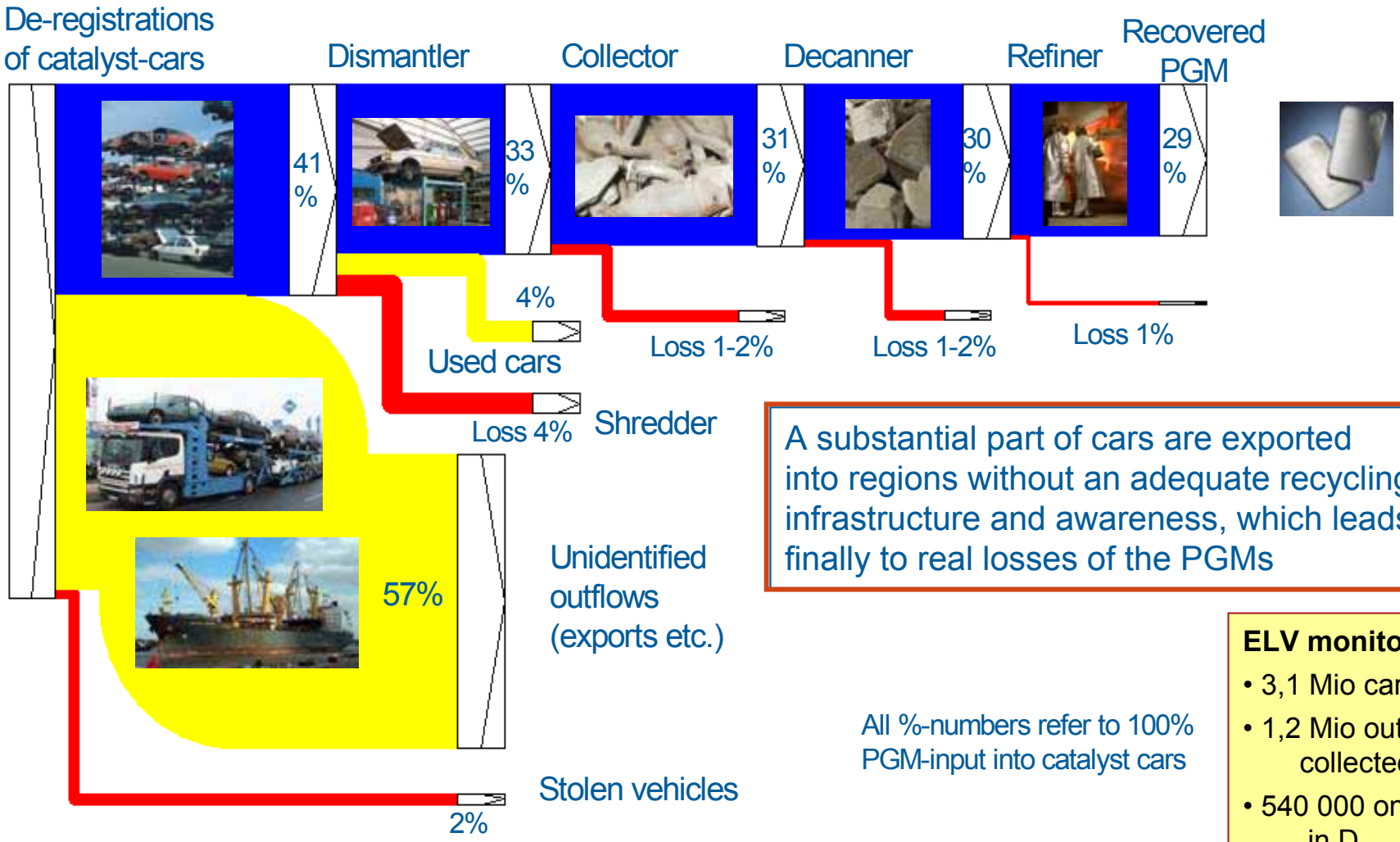
Materials flow of PGMs from autocatalysts in Germany



A substantial part of cars are exported into regions without an adequate recycling infrastructure and awareness, which leads finally to real losses of the PGMs

All %-numbers refer to 100% PGM-input into catalyst cars

ELV monitoring 2004, D

- 3,1 Mio car de-registrations
- 1,2 Mio out of these collected/first treated in D
- 540 000 only final treatment in D

- yellow: outflow from system boundary (e.g. export of ELV); recycling abroad or re-import of catalyst is theoretically possible

Low probability for future PGM-recycling from many export cars

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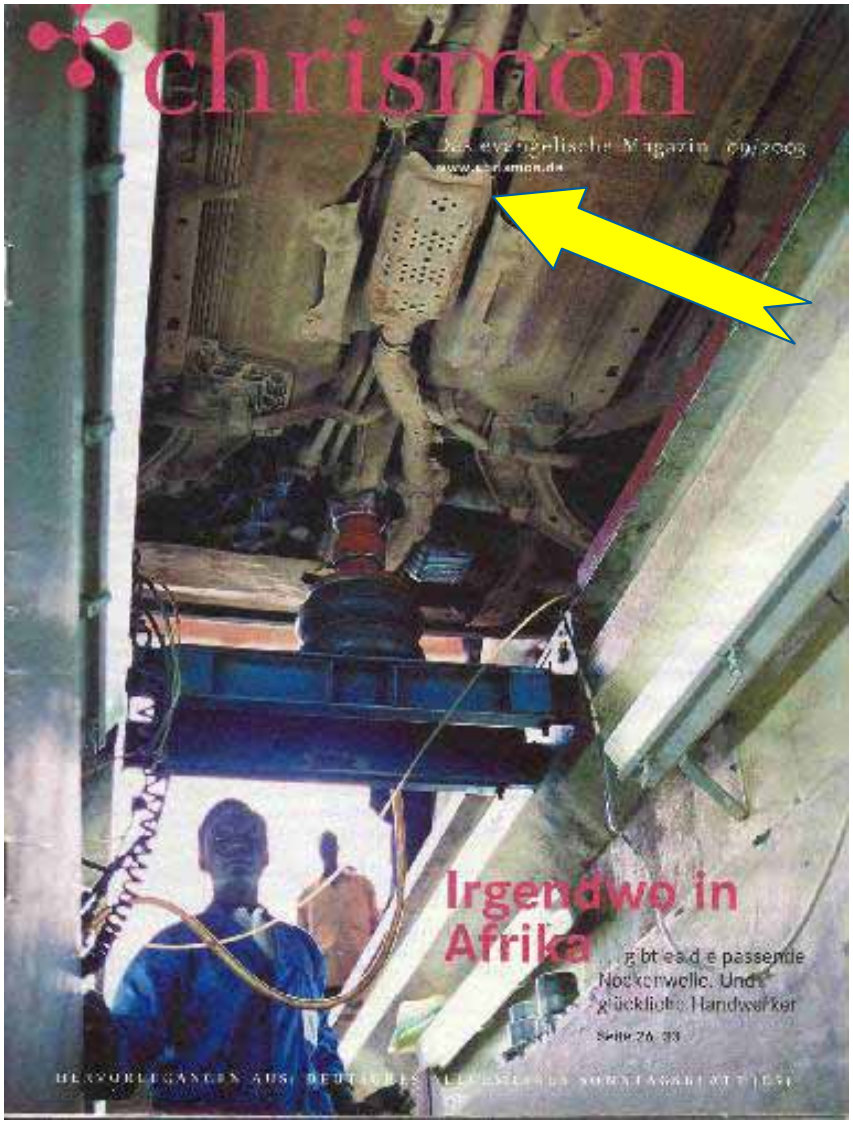
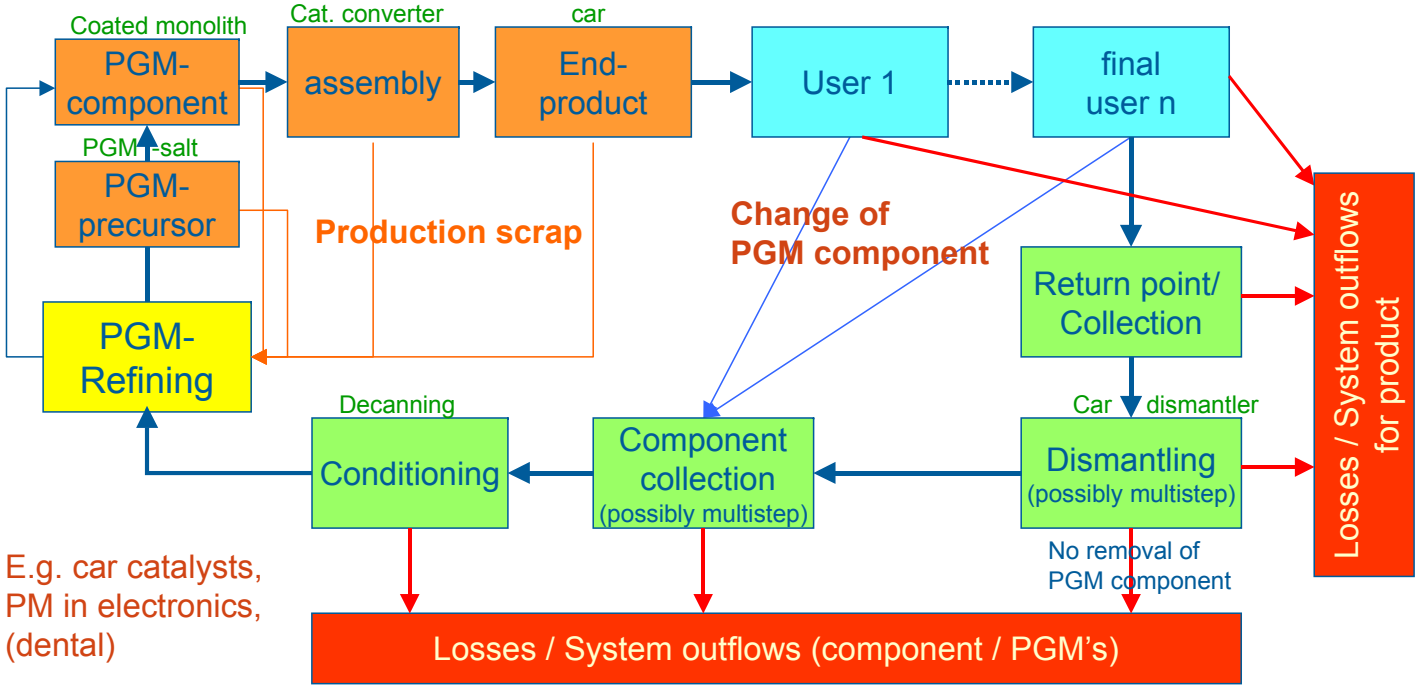
Europe: ca. 1/3 of ELVs are exported

(ACEA 2004)



- exports mainly to Eastern Europe (& beyond) & Africa
- in most of these countries no emission legislation /-control in place
- insufficient car maintenance, bad road conditions
- high probability for destruction of catalyst → emission of ceramic/PGMs (misfire, bumps on converter ...)
- Usually high vehicle lifetime, catalyst has rather no significance (as long as car is still driving)
- insufficient recycling infrastructur, missing awareness for catalyst recycling
- difficult logistical frame conditions

"Open cycles" - recycling from consumer durables ... a complex affair



→ Inherently inefficient, PGM recycling rate < 50% for entire lifecycle

- Multiple changes of ownership, no connection between final owner and product manufacturer
- High product mobility & long life time
- No defined end-of-life → reuse in other regions

- Highly complex structures with numerous opportunities for failure of metals-recovery
- Intransparent material flows, "informal" participants in early "recycling" stages
- Often limited awareness of PM-values & inadequate removal of PM-bearing parts
- Electronics: high dilution of PMs in end product
- High exports of cars, computers etc. to less developed countries with poor recycling infrastructure/awareness

Requirements for a recycling society

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- Consider WEEE & ELV as a valuable resource, not as waste.
- Increase collection, mobilise hibernates (all waste, not just 4 kg WEEE/capita).
- "Design for disassembly" in some areas with complex components (car electronics, LCD screens, …) → limits of shredder technology for trace elements
- Weight based quotes ignore significance of trace elements (precious & special metals). Export losses are not considered in recycling quotes.
- Enforce control to prevent illegal waste exports & non-compliant recycling. → Monitoring throughout the entire recycling chain is needed.
- Consider system boundaries in legislation, e.g. waste hierarchy (reuse → recycling)
- Improve stakeholder cooperation within recycling chain. Benefit from a division of labour & economies of scale.
- 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.
- Investigate global flows and fate of old consumer goods → multinational approach.

Conclusion

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- Underestimation of negative impacts of scrap exports & recycling inefficiencies.
- Demand for precious & special metals is booming (functionality). Only smart interfaces & high tech processes can prevent losses of these trace elements.
- Main constraints are not technical but structural.
- How to gradually change open cycles for consumer goods towards a closed cycle structure ?

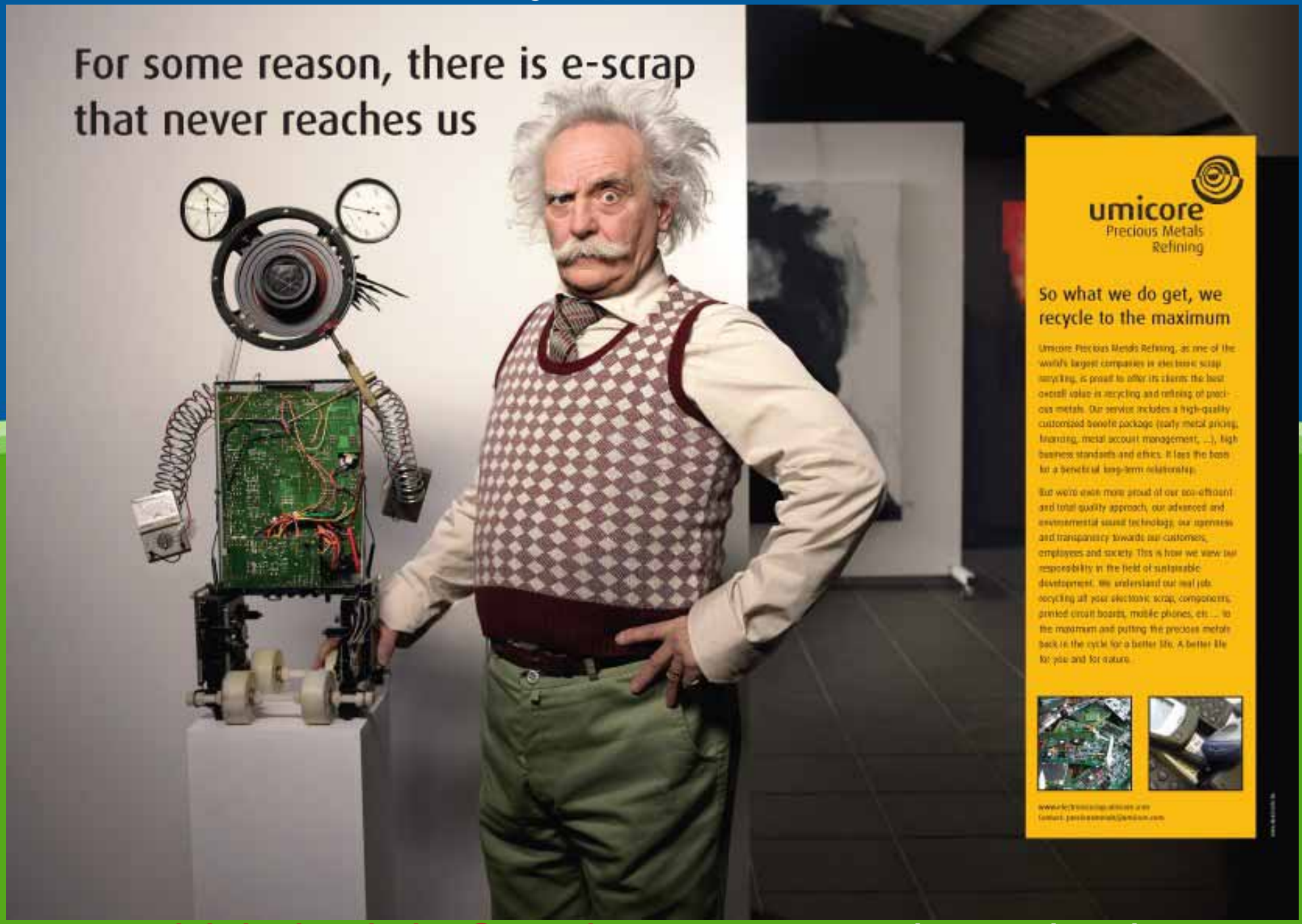
- 1000 years of mining have largely depleted Europe‘s natural metal resources
- Current technosphere & EOL-products are Europe‘s largest resource stock (“mine above ground”). Exporting our waste means shifting/losing our resources.
- Efficient & smart recycling can play a key role to
  - conserve metal resources & enable a regionally more balanced access (supply security)
  - cushion 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.

Thank you for your attention

Umicore Precious Metals Refining
christian.hagelueken@eu.umicore.com
www.preciousmetals.umicore.com

Any questions ?



contact: christian.hagelueken@eu.umicore.com www.preciousmetals.umicore.com

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Institut für angewandte Ökologie
Institute for Applied Ecology

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For more details consult the book:

“Materials Flow of PGMs in Germany”

- Unique
- Immensely detailed
- Highly authoritative

Published in June 2005

- English language, hard copy
- ca 300 pages with over 70 charts & tables
- 100 € / 140 US-$

In German language
“Stoffströme der Platingruppenmetalle”

GDMB Medienverlag 2005
(ISBN 3-935797-20-6)

To purchase a book contact GFMS London

www.gfms.co.uk/publications_materials_flow.htm

For project information and recycling issues:

christian.hagelueken@eu.umicore.com