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Recycling of technology metals
Opportunities & limitations

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Capital Markets Event on Recycling – 18-19 Nov 2010

Agenda

- Technology materials scarcity
- Urban mining
- The recycling chain
- Impact of legislation
- Conclusion

Technology materials scarcity

What are technology metals?

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La-Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
K	Ca	Ac-Lr	Rf	Db	Sg	Bh	Hs	Mt									

Precious metals	Semiconductor materials	Rare earth elements (REE)	Technology metals	EU critical materials (RMI)

Technology metals are used in a wide range of technological applications

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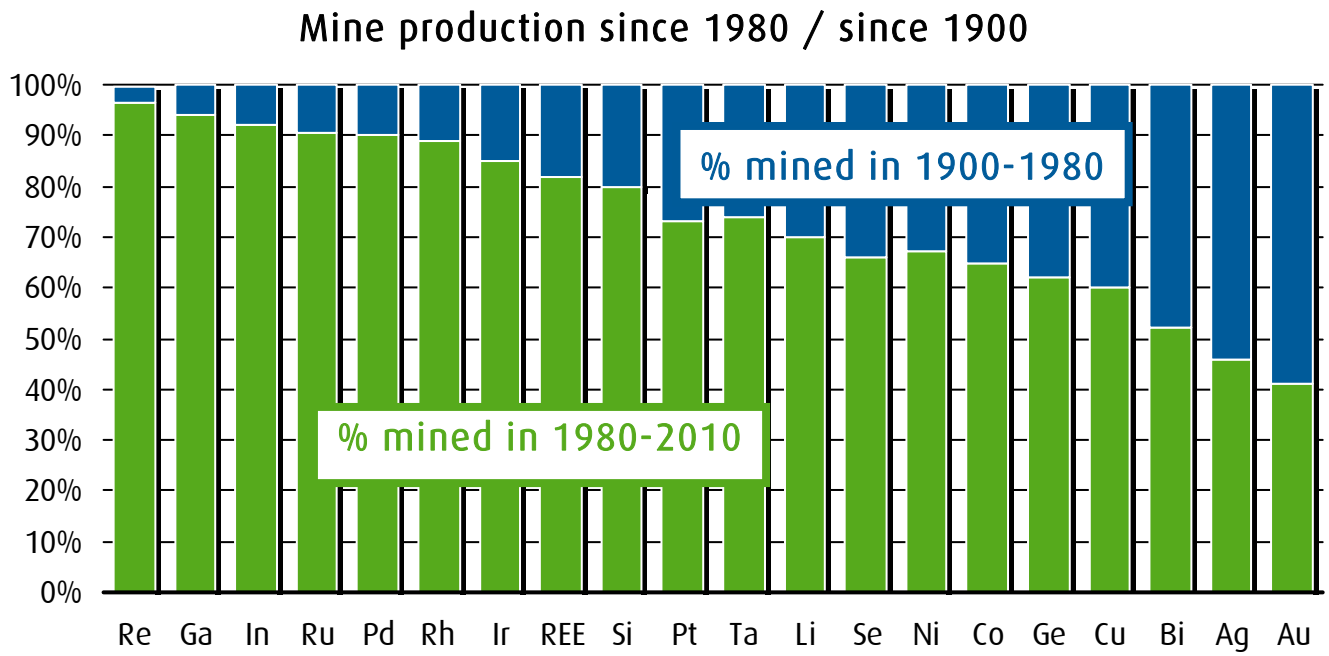
Recent boom in demand for most technology metals



REE = Rare Earth Elements

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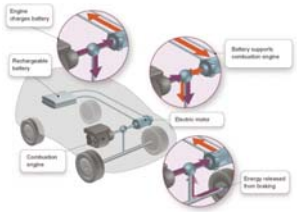
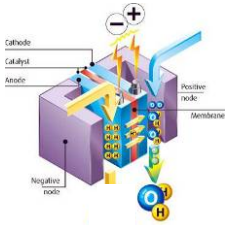
Emerging technologies will further boost demand for technology metals

Multiple examples:

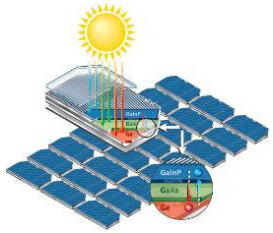
- **Electric vehicles & batteries**
  cobalt, lithium, rare earth elements, copper



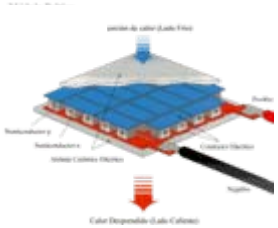
- **Fuel cells**
  platinum, (ruthenium, palladium, gold)



- **Photovoltaic (solar cells)**
  silicon, silver, indium, gallium, selenium, tellurium, germanium



- **Thermo-electrics, opto-electronics, LEDs, ...**
  bismuth, tellurium, silicon, indium, gallium, arsenic, selenium, germanium, antimony, ...



- ...

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Substitution possibilities are limited

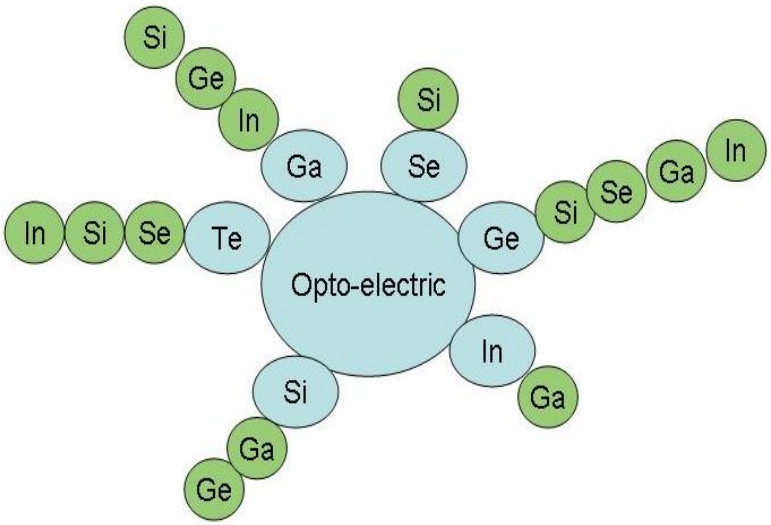
Challenge to maintain performance which is often based on specific critical-chemical substance properties

Potential substitute often comes from same metal family
→ Substituting scarce In by scarce Ga ?

Consider side effect of substitution

- Toxicity
- Recyclability
- Price effects
- Performance impact

Example: Opto-electric applications



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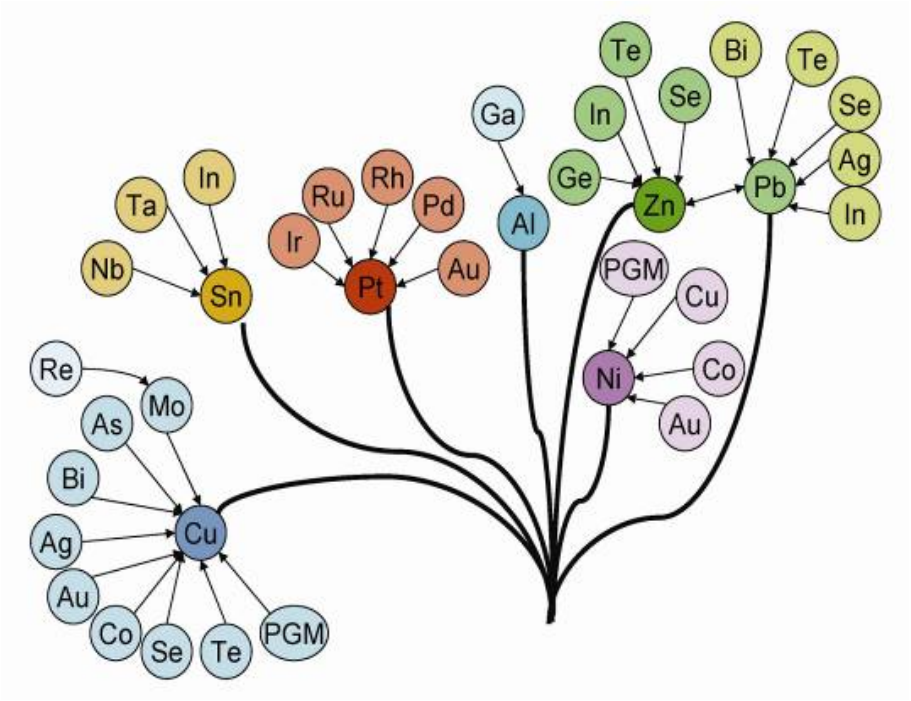
Technology metals mainly come as a mining by-product



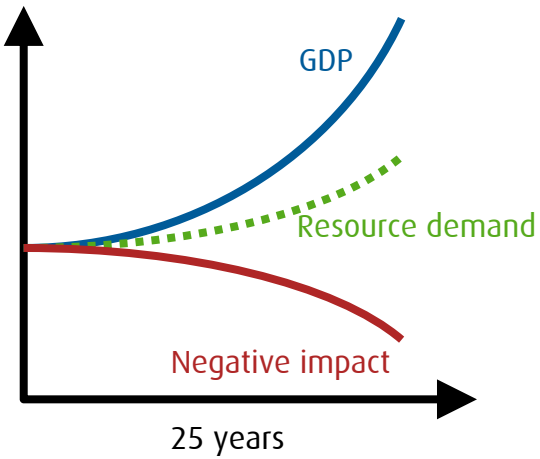
C. Hagelüken, C.E.M. Meskers: Complex lifecycles of precious and special metals *in* Linkages of Sustainability. Strüngmann Forum Report vol. 4. T. Graedel, E. van der Voet (eds.) Cambridge, MA, MIT Press 2009.

Many "technology" metals come as a by-product from primary mining for "base" metals

Supply of many "technology metals" is price-inelastic:

- Increased demand can only be met by primary production if demand for major metal rises accordingly
- Short term demand surges lead to price peaks (see Ir, Ru, In)

"Smarter" growth will require more technology metals



Source: "Next steps for EU waste and resource Policies", R. v.d.Vlies, DG Env., Brussels, 17/06/2009

The EU resources strategy

- Decoupling growth from impact
- From protection to environment
- From effectiveness to efficiency

EU strategy is useful & realistic for base metals, especially if used in infrastructure

EU resources strategy creates issues

- Technical solutions to improve resource efficiency & mitigate climate impact rather need more than less precious/special metals (PV, EV, catalysis etc.)
- Primary supply of by-product technology metals will drop in case of:
  - Successful decoupling for base metals (Cu, Ni, Al, Pb)
  - Improved recycling of base metals
  - Supply restrictions for lead, nickel, etc.

Resource efficiency needed to deal with scarcity of technology metals

Demand is growing

- Global growth
- Demand for technology metals well above GDP
- Limited substitution possibilities

Supply is limited

- Worldwide primary supply (from mining) is limited
- Mining possibilities limited by the coupling of technology metals with base metals
- Mining creates geopolitical dependence
- Short term supply often impacted by speculation on commodities

⇒ **RECYCLING is essential to preserve RESOURCE EFFICIENCY**

Urban mining

Urban mining "deposits" can be much richer than primary mining ores

Primary mining

- ~5 g/t Au in ore
- Similar for PGMs

Urban mining

- 200-250 g/t Au in PC circuit boards
- 300-350 g/t Au in cell phones
- 2000 g/t PGM in automotive catalysts

Low loadings per unit, but volume counts
Example: Metal use in electronics

Global sales, 2009

a) Mobile phones						
1300 million units/ year						
X	250	mg	Ag	≈	325 t	Ag
X	24	mg	Au	≈	31 t	Au
X	9	mg	Pd	≈	12 t	Pd
X	9	g	Cu	≈	12,000 t	Cu
1300 million Li-Ion batteries						
X	3.8	g	Co	≈	4900 t	Co

b) PCs & laptops						
300 Million units/year						
X	1000	mg	Ag	≈	300 t	Ag
X	220	mg	Au	≈	66 t	Au
X	80	mg	Pd	≈	24 t	Pd
X	~500	g	Cu	≈	150,000t	Cu
~140 million Li-ion batteries						
X	65	g	Co	≈	9100 t	Co

a+b) Urban mine				
Mine production	/ share			
Ag:	21,000	t/a	▶	3%
Au:	2,400	t/a	▶	4%
Pd:	220	t/a	▶	16%
Cu:	16	Mt/a	▶	<1%
Co:	75,000	t/a	▶	19%

Tiny metal content per piece → Significant total demand

Other electronic devices add even more to these figures

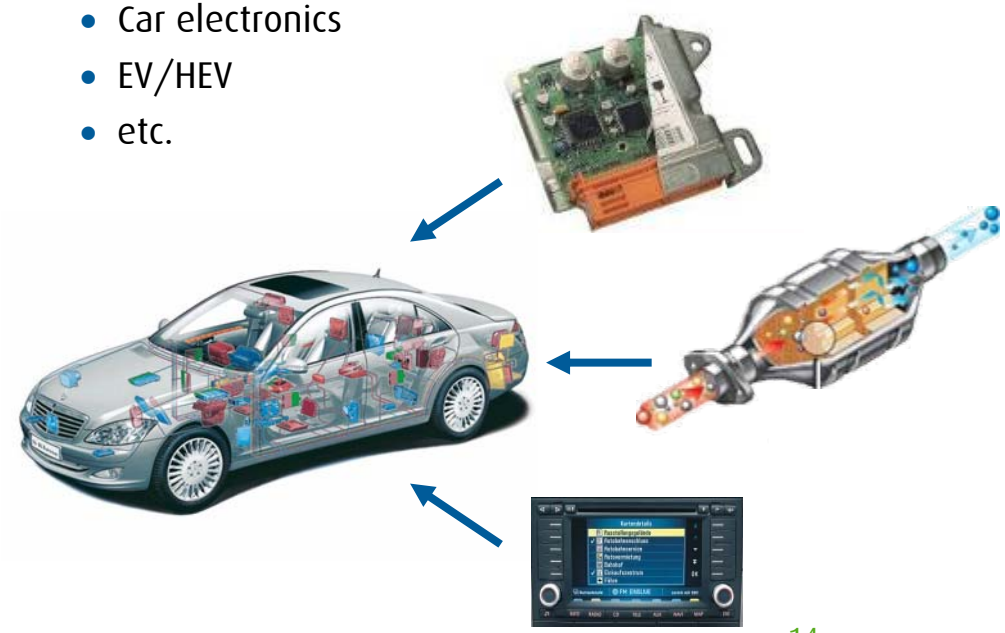
Significant amounts of metals locked up in the urban mine
Example: Metal use in automotive

Large total volumes

- Global sales in 2009 of some 57 million cars
- Current car fleet of some1.3 billion

Demand for "technology metals" rises in modern vehicles

- Car electronics
- EV/HEV
- etc.



Metal demand in automotive

	in 1000 t/a	Share of primary production *
Steel	100,000	10 %
Al	7 300	30 %
Pb**	7 000	170 %
Cu	1 900	12 %
Ni	140	10 %
…		
Pt***	0.12	65 %
Pd***	0.14	> 60 %
Rh***	0.03	110 %

2008 data (rounded)
* >100% → additional supply from recycling
** Pb use in batteries (mainly automotive)
*** Pt, Pd, Rh mainly in autocatalysts

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Urban mining offers significant environmental advantages

Urban mining prevents impact from non-recycling

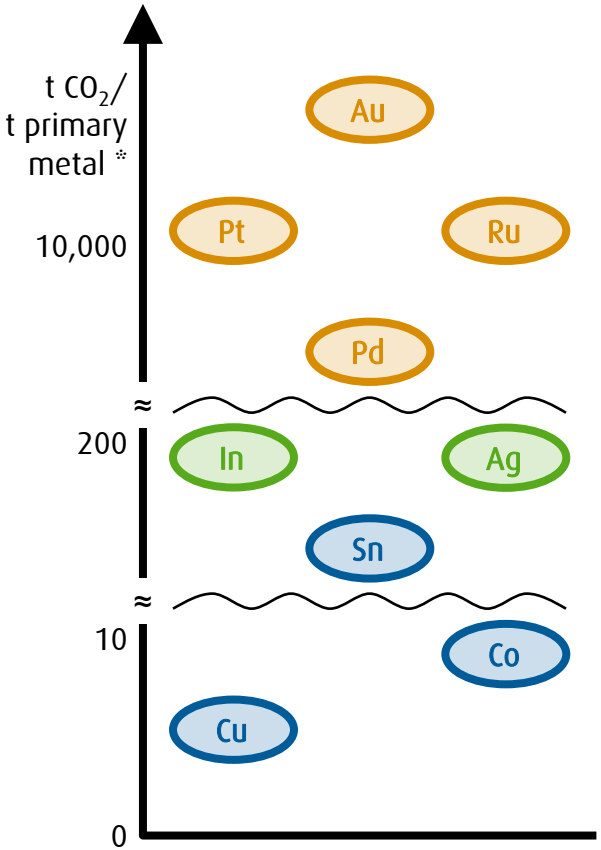
- Hazardous emissions
- Land use

Recycling mitigates environmental impacts of mining

- Less energy consumption/CO_2 production
- Less land & water use
- Less pressure on ecological in sensitive areas

Recycling lowers CO_2 footprint for majority of metals

- Example of gold mining in South Africa:
  Concentration of 5 g/t; 3000m underground
- Example of Umicore Hoboken:
  70,000 t metals produced ≈ 1M t CO_2 saving potential vs primary metal production



* Source:
Ecoinvent 2.0, EMPA/ETH-Zürich, 2007

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Urban mining offers ethical sourcing possibilities

Manufacturers are explicitly looking for refiners with excellent environmental performance

Manufacturers increasingly focus on effective and transparent recycling chains via auditing, including the end-processor

Manufacturers are increasingly concerned about preventing sourcing of metals from conflict areas, particularly Ta, Co, Sn, (Au)

Pressure from civil society increases to avoid substandard (e-scrap) recycling processes and use of metals from conflict areas

⇒ **Leads to push for supply and recycling chain transparency including the metals mining & refining sector**

⇒ **Urban mining responds to some of these demands**

Recycling chain

Primary mining vs secondary recycling

Primary mining

Raw materials come from ore deposits, which are large in size and geographically fixed

Mature market structure

- Stakeholders: Usually large mining & metallurgical companies
- Material flows: Concentrates often shipped to smelters that source globally
- Transparency: High; Official business with relatively good statistical data

Primary mining vs secondary recycling

Secondary recycling

Raw materials supply is smaller in size and dissipated over many consumers/locations

More challenging structure with needs for change

- Stakeholders: Consumers ↔ Businesses
  - Collection, dismantling & pre-processing: Municipalities, scrap yards and dealers, waste management companies
  - Smelting & refining: Large metallurgical companies, backyard recyclers, traders and "pseudo refiners"
- Material flows: Complex fractions from pre-processing partly to smelters, but often to less efficient local treatment or "backyard" operations in developing countries
- Transparency: Low; Many hidden flows; Lots of informal or shady business with poor statistical data

Specialty metals recycling is more complex than in the movies

Technical accessibility of relevant components

- E.g. electronics in modern cars, REE-magnets in electric motors, ...
- Need for "Design for disassembly", sorting & "pre-shredder" separation technologies

Thermodynamic challenges & difficult metal combinations for "trace elements"

- Laws of Nature cannot be broken
- E.g. rare earth elements, tantalum, gallium, beryllium in electronics, lithium in batteries
- Need for recyclability consideration in development of new material combinations

Material quality requirements need to be met

From: Disney/Pixar www.wall-e.com

Mass recycling vs specialty metals recycling

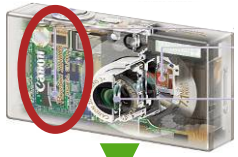
Bottle glass

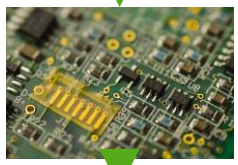
Green glass
White glass
Brown glass

Steel scrap

+

Circuit boards





Specialty metals

Autocatalysts

PGMs

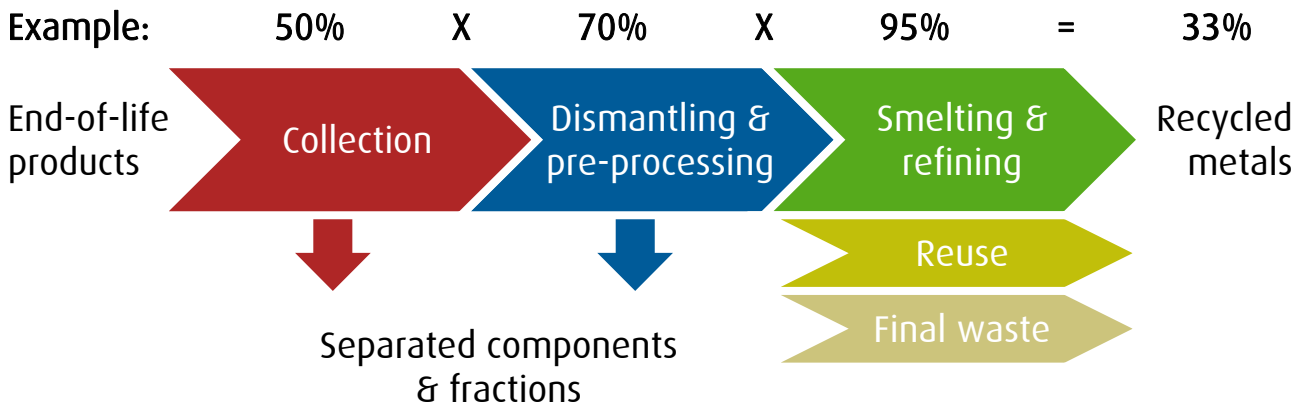
- "Mono-substance" materials without hazards
- Trace elements remain part of alloys/glass

Recycling focus on mass and costs

- "Poly-substance" materials, incl. hazardous elements
- Complex components as part of complex products

Recycling focus on value recovery from trace elements

Recycling chain
System approach is key

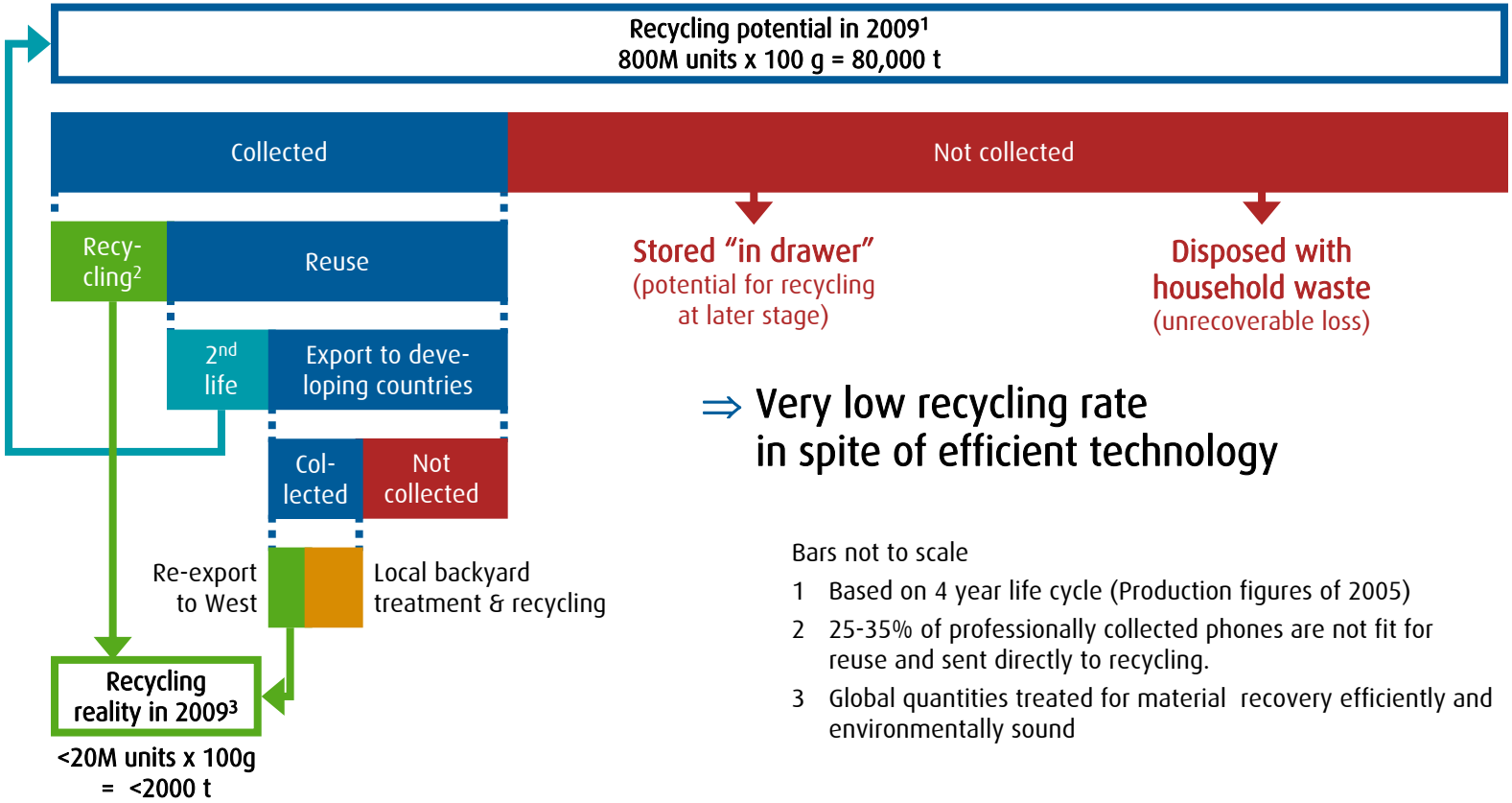


- Consider the entire chain & its interdependences
- Precious metals dominate economic & environmental value ⇒ minimise PM losses
- Mass flows ≠ flows of technology metals
- Success factors ⇒ interface optimisation, specialisation, economies of scale

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

Inefficiencies severely limits recycling possibilities

Example of mobile phones



⇒ Very low recycling rate in spite of efficient technology

Bars not to scale

1 Based on 4 year life cycle (Production figures of 2005)

2 25-35% of professionally collected phones are not fit for reuse and sent directly to recycling.

3 Global quantities treated for material recovery efficiently and environmentally sound

Western recycling chain competes with inefficient backyard recycling in developing countries

Example of e-scrap

WEEE from Europe:

- 60% WEEE not properly recycled, metals are lost (exports, trash bin, ...)*
- 70% for IT & telecom, small household appliances*
- Loss of metals > 5 billion US-$

Backyard "recycling" in Asia & Africa

- High metal losses (Au-yield ≈ 25%)
- Dramatic environmental & health impact
- Failing law enforcement

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

Room for improvement in the recycling chain

Example of gold recycling

Collection		Dismantling & pre-processing		Smelting & refining		
	→		→			
80%	X	50%	X	50%	=	20%
	→		→			
50%	X	25%	X	95%	=	12%

Are we doing much better in "the West" today?

Figures are illustrative

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*Illustrative figures

Economic recycling challenges

Most precious metals containing waste materials have a positive net value

- Value of metals contained outweighs cost of recycling

Specialty metals containing waste materials may have negative net value in the absence of certain "paying metals" in the same metal feed

- Value/price of metal not sufficient to compensate for cost of recycling
- Negative net value due to low critical metal concentrations in products
- E.g. lithium in batteries, indium in LCDs & PV-modules

→ Create economic recycling incentives (subsidies) & improve technology (costs & efficiency)

Dissipative use inhibits economic recycling (regardless of price level)

- E.g. silver in textiles or RFID chips

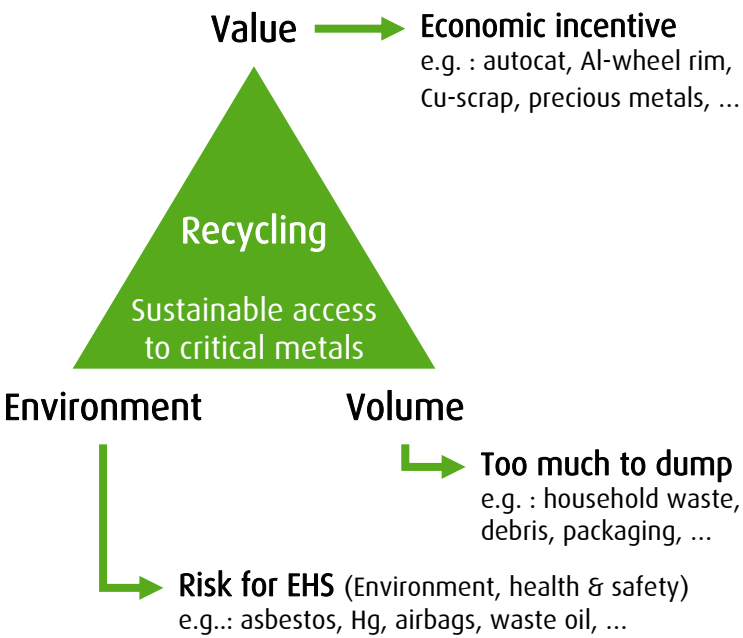
→ Avoid dissipative use or look for non-critical substitutes

⇒ **Legislative initiatives required in certain cases**

Impact of legislation

Legislation needed for certain recycling drivers

Criticality, a new driver for recycling?



Current recycling-drivers

- Value:
  - Taken care of by the market, pays for itself
  - Set EHS frame conditions!
- EHS & volume
  - Society driven
  - Negative net value

Driven by legislation

Future recycling drivers:

- "Critical metals"
  - Macro economic significance
  - Enhanced recycling worthwhile also without volume or EHS risks

Waste legislation

Basel Convention

- Regulates transboundary movement of hazardous waste
- Implemented in the EU through the **Waste Shipping Directive**

European waste legislation is based on the **Waste Framework Directive (WFD)**

- Contains the definitions of waste, recovery and recycling and sets out the waste hierarchy
  - **Prevention → Re-Use → Recycling → Other Recovery (e.g. energy recovery) → Disposal**
- Includes end-of-life (EoL) legislation, which regulates specific waste streams
  - **WEEE** (Waste Electrical & Electronic Equipment), **ELV** (EoL Vehicles) and **Battery** Directives
  - Defines producer responsibility and specifies mandatory recycling rates

In the USA, the definition of waste (RCRA) is similar to the WFD definition, but there is a long list of exclusions, including scrap metal and shredded circuit boards.

Legislation is also implemented in other countries and regions

Umicore actively engages with authorities and other stakeholders to make the legislative framework work more effective and efficient

Resource legislation
Raw Materials Initiative (RMI) in the EU

The Raw Materials Initiative

1) Ensure access to raw materials
2) Set the right framework conditions
3) Boost overall resource efficiency and promote recycling to reduce the EU's consumption of primary raw materials and decrease the relative import.

Recycling recommendations developed in the RMI critical metals group

- Mobilising relevant EoL products for proper collection instead of stocking, landfill or incineration
- Improving overall organisation, logistics & efficiency of recycling chains by focusing on interfaces and system approach
- Preventing illegal exports of relevant EoL products & increasing transparency in flows
- Promoting R&D on system optimisation & recycling of technically challenging products & substances

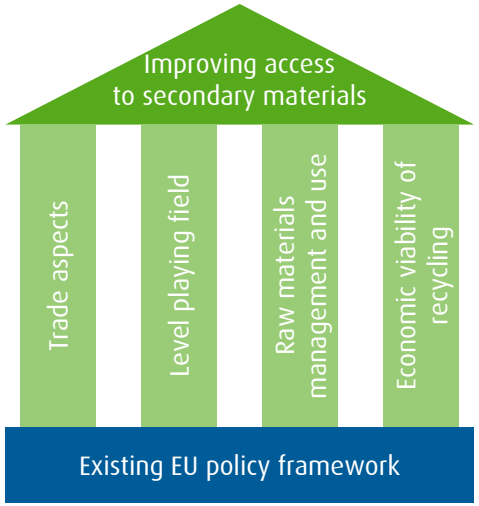
Umicore involvement

- Umicore directly participated as expert member of the critical metals work group and indirectly involved through Eurometaux RMI task force, chaired by Umicore
- Ongoing intensive dialogue between Umicore and EU commission/parliament about RMI follow up

Additional/ specific recycling recommendations developed by the Eurometaux RMI task force

10 concrete proposals under 4 pillars

1) Enforcing trade-related aspects of environmental legislation
   - Customs identification of second hand goods
   - Improved enforcement of Waste Shipment Regulation
   - End-of-Waste
2) Ensuring level playing field for processing secondary raw materials
   - Certification scheme of collection, pre-processors & refiners of waste & secondary RM
   - Facilitate & encourage the re-shipping of complex materials to BAT-recycling plants in Europe
3) Improving management of raw materials and their efficient use
   - Promote the efficient collection and recycling of rechargeable batteries
   - The eco-leasing concept
   - Better recycling data
   - Research on recyclability
4) Economic viability of recycling



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To what extent does current legislation help?

Legislation helps

- Awareness raising, supportive legal framework
- Development of take-back infrastructure, collection targets, EU wide reporting
- Resource aspect of recycling is on the radar screen now, beyond the traditional waste/environmental aspects

Legislation can be improved

- Weak enforcement of legislation
  - Poor monitoring of end-of-life flows
  - Illegal exports
- Collection targets not ambitious enough, collection remains well below potential
  - Mass-based targets don't help for technology metals ("trace elements")
- Neither clear definitions nor reliable supervision of recycling standards exist

Conclusion

Conclusions

Scarcity of technology materials is created by a number of factors

- Urban mining offers a credible solution to the scarcity issue

Recycling of specialty metals requires a different approach than primary refining and recycling of “mono-substance“ products

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

- High-tech end–refining processes like Umicore Hoboken are of key importance
- Successful recycling requires a sound understanding of the overall system and interdisciplinary approach

Legislation is necessary for certain recyclable materials

- Enforcement of legislation still shows room for improvement

Forward-looking statements

This presentation contains forward-looking information that involves risks and uncertainties, including statements about Umicore's plans, objectives, expectations and intentions.

Readers are cautioned that forward-looking statements include known and unknown risks and are subject to significant business, economic and competitive uncertainties and contingencies, many of which are beyond the control of Umicore.

Should one or more of these risks, uncertainties or contingencies materialize, or should any underlying assumptions prove incorrect, actual results could vary materially from those anticipated, expected, estimated or projected.

As a result, neither Umicore nor any other person assumes any responsibility for the accuracy of these forward-looking statements.

Christian Hagelüken

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Christian Hagelüken holds university degrees in mining engineering and industrial engineering from RWTH Aachen, Germany, where he also received his PhD in 1991.

Christian Hagelüken heads the business development & market research department of Umicore's Precious Metals Refining. Prior to his present occupation he held various management positions within the precious metals department of Degussa AG, part of which was acquired by Umicore in 2003.

Christian has over 20 years experience in (precious) metals recycling and sustainable metals management, representing Umicore in various associations and working groups.