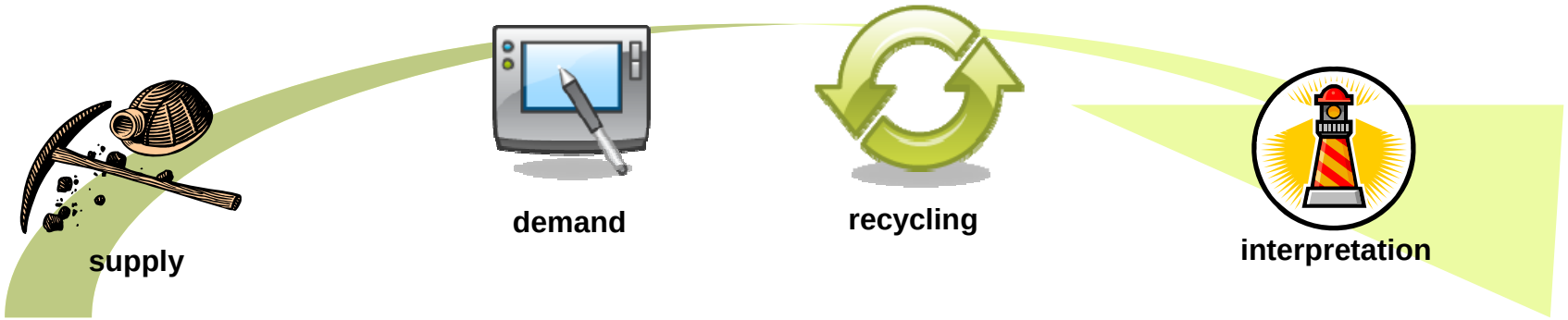


Critical metals for future sustainable technologies and their recycling potential

Workshop on the Recycling of Metals
UNEP Panel on Sustainable Resource Management
24 April 2009, EC, Brussels

Matthias Buchert, Öko-Institut e.V.
m.buchert@oeko.de

Critical metals for future sustainable technologies and their recycling potential

Issued by United Nations Environment Programme (UNEP DTIE)

Funded by EU

Öko-Institut e.V.:
Matthias Buchert, Daniel Bleher, Doris Schüler
Assistance: Nicole Neurohr, Lorenz Hagelüken

Acknowledgement for profound and valuable information:
Umicore Precious Metals Refining, Hoboken, Belgium:
Christina Meskers
Christian Hagelüken
Thierry Van Kerckhoven
Kris Van den Broeck

general objectives

- analysis of future sustainable technologies
  Renewable energies (e.g. solar cells)
  Energy efficient technologies

- considering the use of the following metals:
  Indium (In), Germanium (Ge), Tantalum (Ta), PGM (platinum group metals such as Ruthenium (Ru), Platinum (Pt) and Palladium (Pd)), Tellurium (Te), Cobalt (Co), Lithium (Li), Gallium (Ga) and RE (rare earths)

  - also classified as **'green minor metals'**
    (basis for cleaner technology innovation)

general objectives

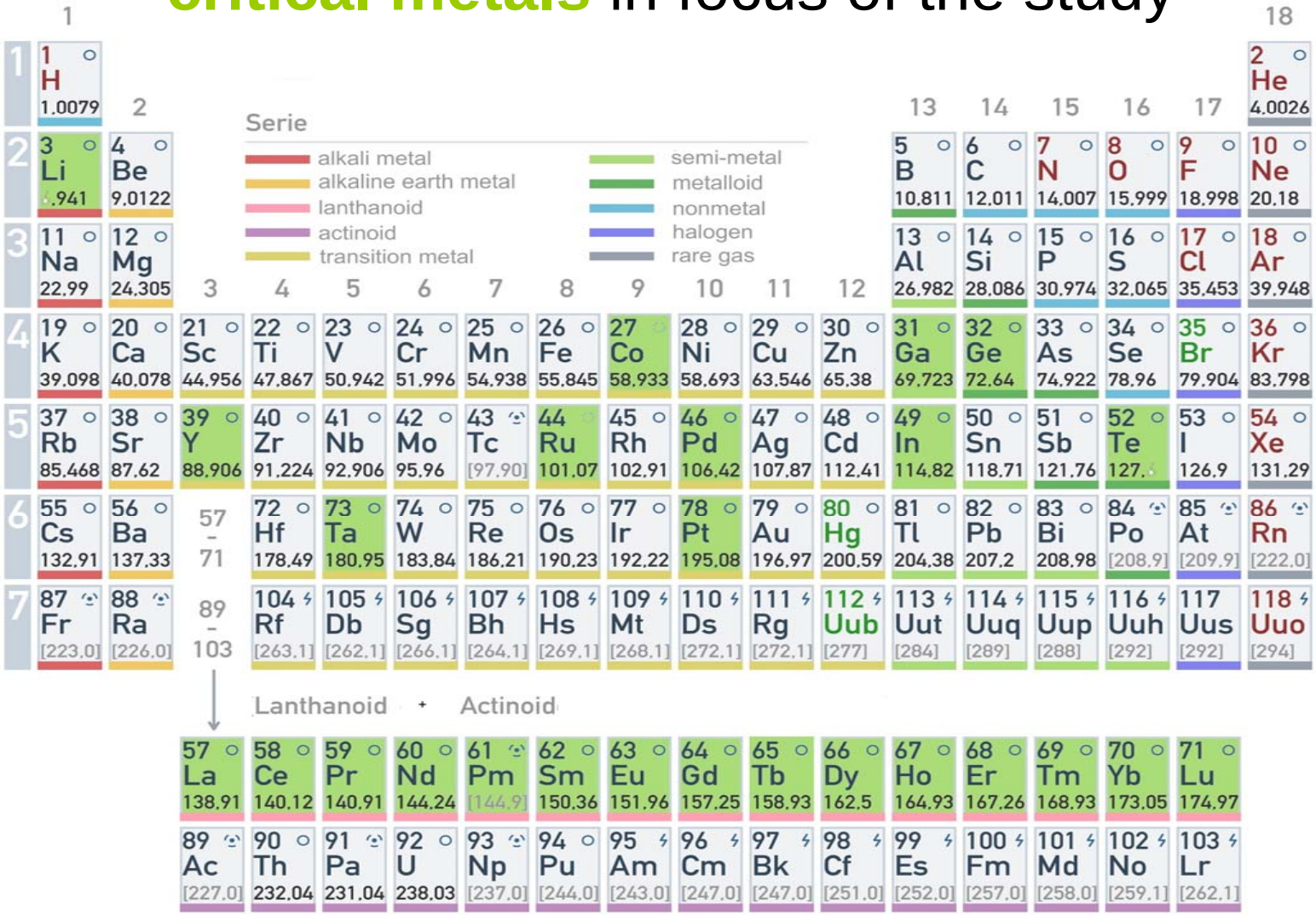
- **actual and upcoming challenges**
  growth rates
  forecasts for demand/supply
  prices
  recycling situation and further potential

  - green minor metals to be regarded as **'critical metals' ?!**
  - predict and monitor the availability of critical metals

- **proposed course of action:**
  policies
  incentives
  funds
  instruments etc.

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

critical metals in focus of the study



specific objectives for critical metals

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

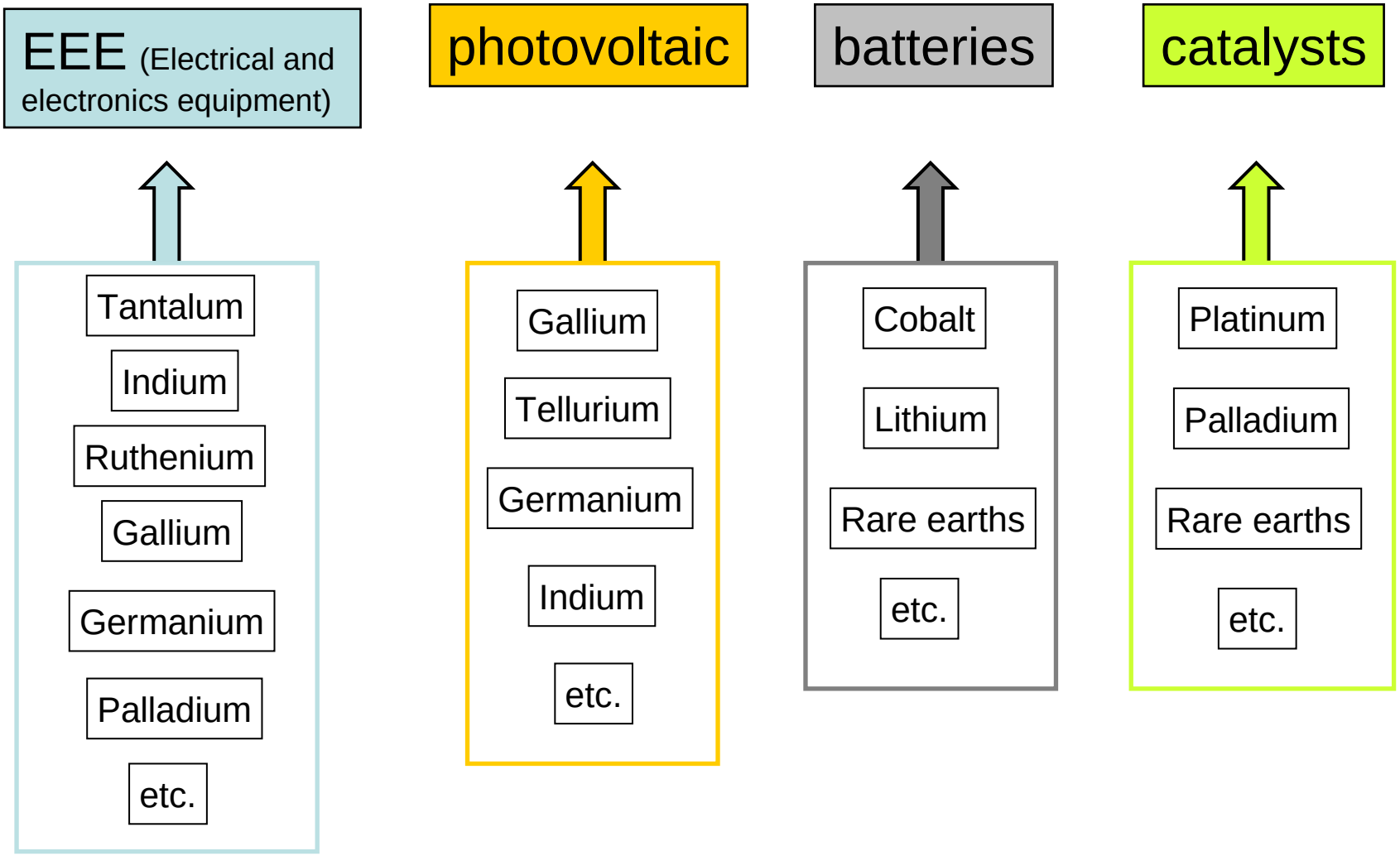
- prioritisation regarding supply and demand:
  - global availability
  - geographical spread
  - prices (possible increasing pressure on supply)
  - growing demand (rising uptake of certain innovative technologies)

- prioritisation regarding recycling:
  - assessment of the recycling potential
  - existing recycling technologies
  - identification of recycling gaps
  - feasibility assessment for innovative recycling technologies / infrastructure

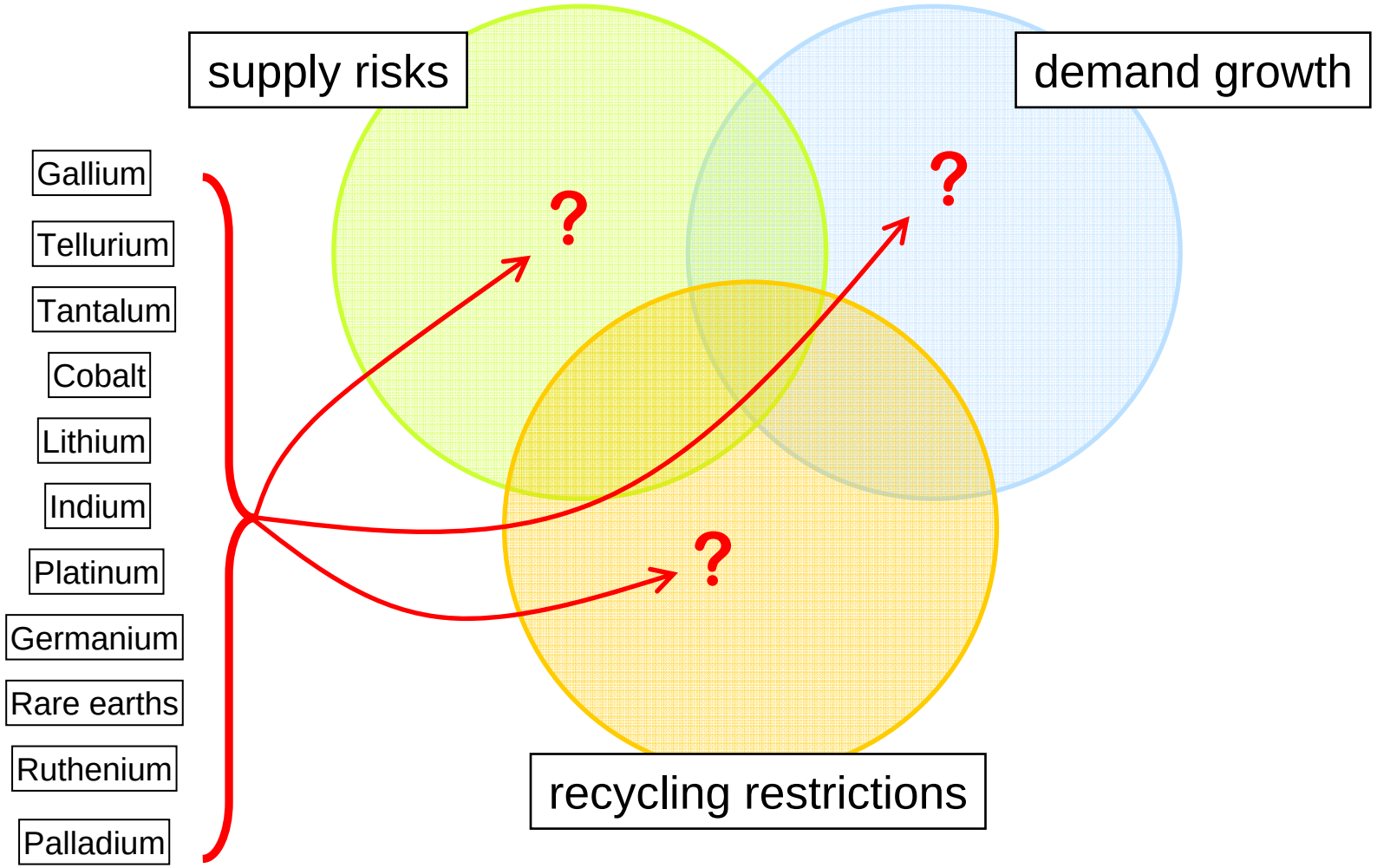
  - **identification of framework conditions to foster technologies for closed-loop recycling systems**

- urgency regarding timeline
  - short-term perspective (next 5 years)
  - mid-term perspective (until ca. 2020)
  - long-term perspective (2050)

Examples for sustainable future technologies & therefore needed metals



matters of concern



Subcriteria for a detailed analysis

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

Demand growth

- Rapid demand growth: > 50% increase of total demand until 2020
- Moderate demand growth > 20% increase of total demand until 2020

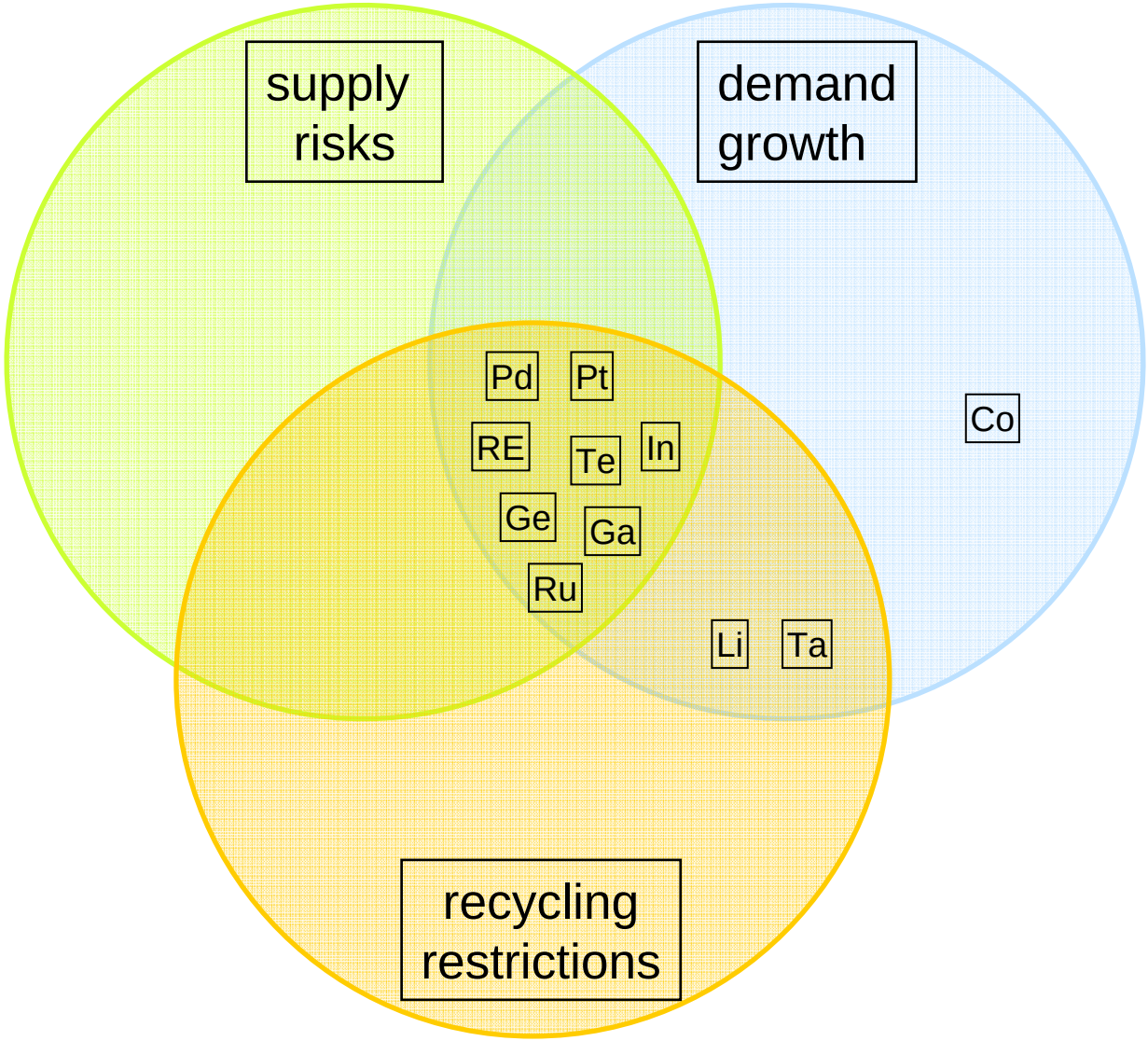
Supply risks

- Regional concentration of mining (> 90% share of the global mining in the major three countries)
- Physical scarcity (reserves compared to annual demand)
- Temporary scarcity (time lag between production and demand)
- Structural or technical scarcity (metal is just a minor product in a coupled production and inefficiencies often occur in the mining process, production and manufacturing)

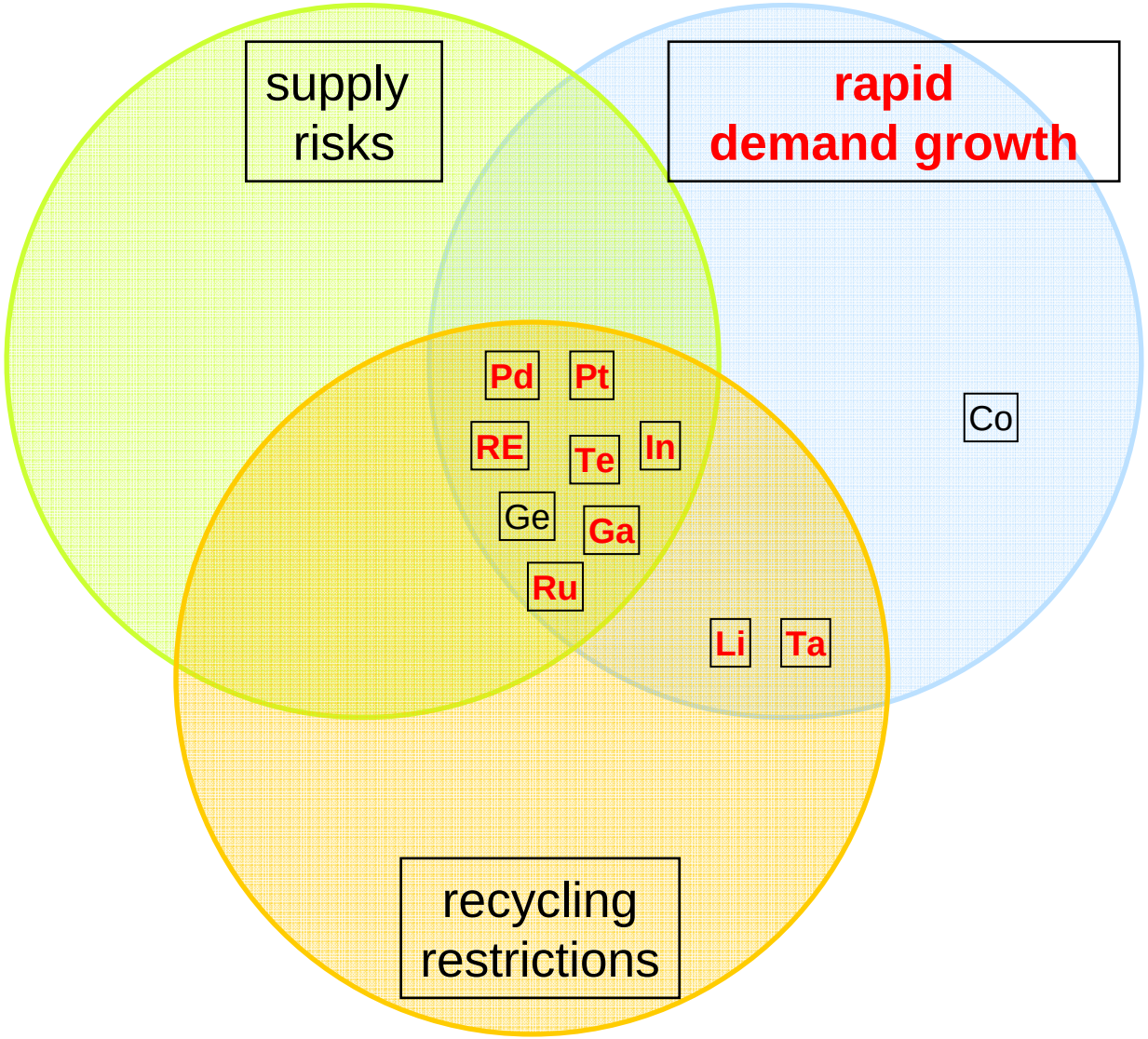
Recycling restrictions

- High scale of dissipative applications
- Physical/chemical limitations for recycling
- Lack of suitable recycling technologies and/or recycling infrastructures
- Lack of price incentives for recycling

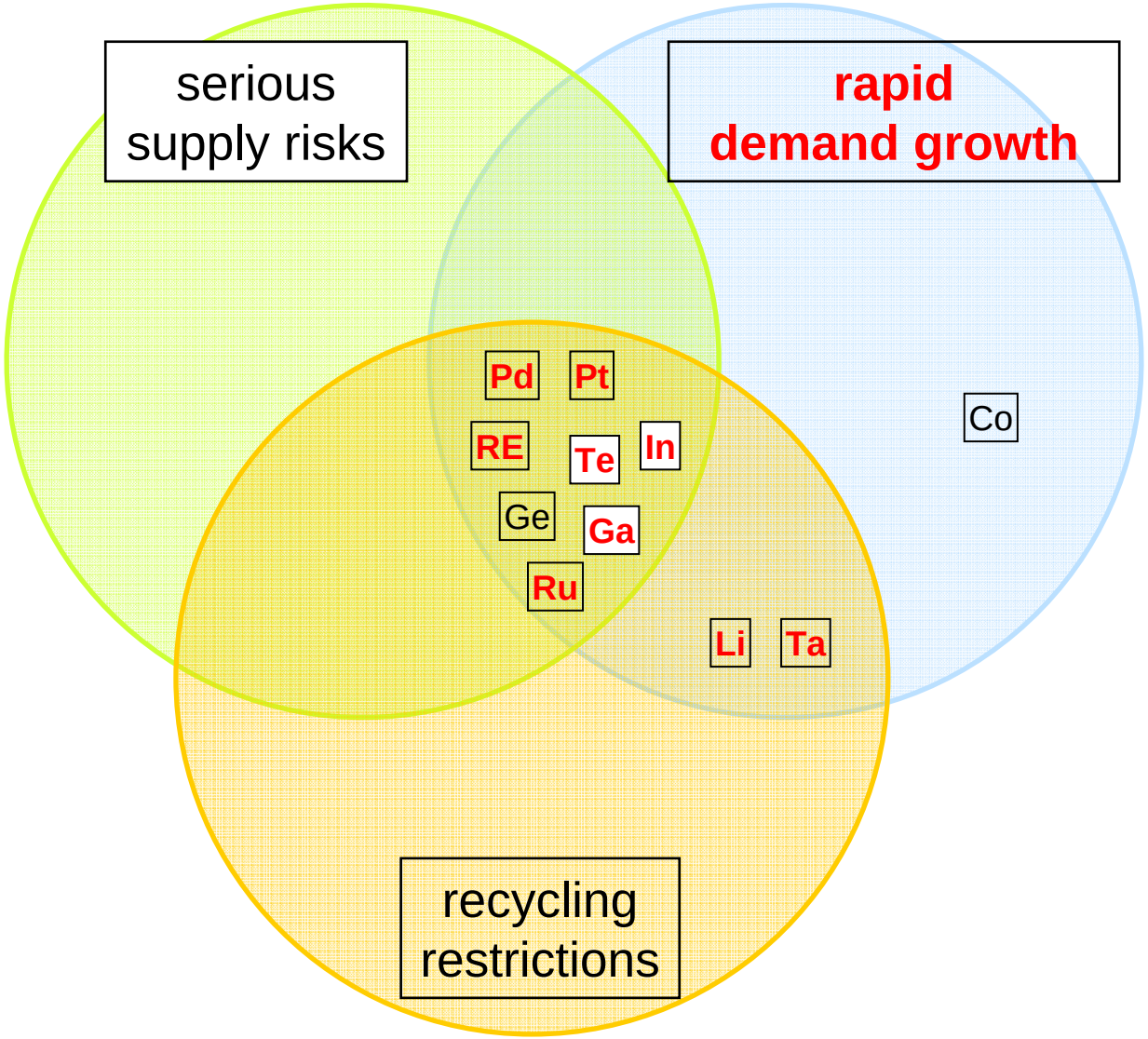
1st step
prioritization of critical metals



2nd step
prioritization of critical metals

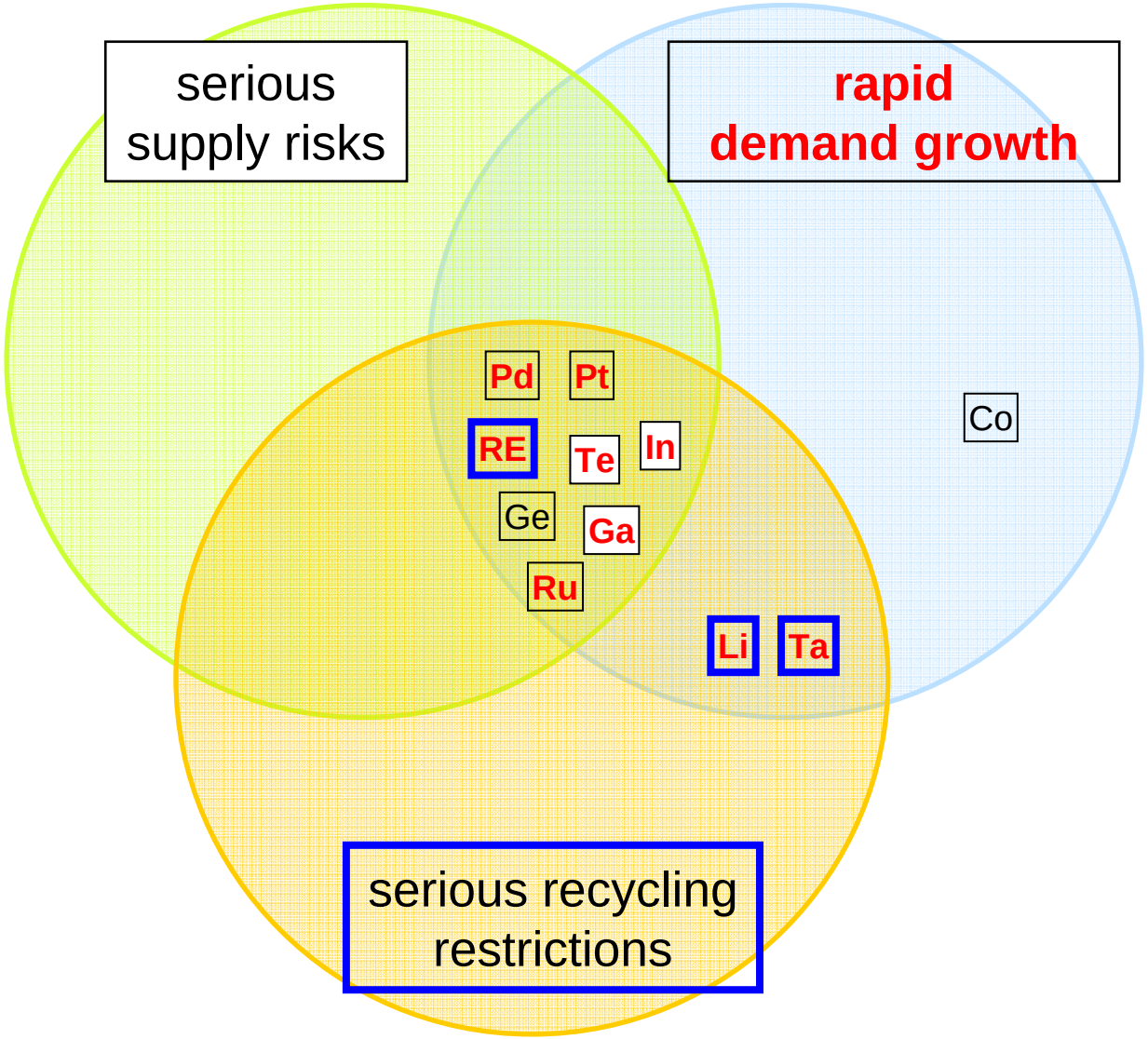


3rd step
prioritization of critical metals



4th step

prioritization of critical metals



4th step

(serious) recycling restrictions

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

	High scale of dissipative applications	Physical/chemical limitations for recycling	Lack of suitable recycling technologies and/or recycling infrastructure	Lack of price incentives for recycling
Tantalum	+	+	+	-
Indium	+	-	+-	-
Ruthenium	+	-	+-	-
Palladium	+-	-	+-	-
Platinum	+-	-	+-	-
Rare earths	+-	+	+	-
Gallium	+	-	+-	-
Tellurium	+	-	-	-
Germanium	+	-	+-	-
Cobalt	+-	-	-	-
Lithium	+-	+	+	+

urgency regarding timeline

timeline	Metal
short-term (within next 5 years) + **rapid** demand growth + **serious** supply risks + moderate recycling restrictions	Tellurium Indium Gallium
mid-term (until 2020) + **rapid** demand growth and + **serious** recycling restrictions or: + moderate supply risks + moderate recycling restrictions	Rare earths Lithium Tantalum Palladium Platinum Ruthenium
long-term (until 2050) + moderate demand growth + moderate supply risks + moderate recycling restrictions	Germanium Cobalt

general recycling aspects

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

pre-consumer recycling

- recycling of production scrap of manufacturing process (new scrap)
- very common for bulk metals like Iron/Steel, Copper, Aluminum etc. as well as for many precious and special metals
- mostly high concentrations of the distinguished metal in new scrap,
- well-known and definite source of waste generation,
- continuous new scrap formation (logistic friendly),
- very often high volumes of new scrap formation (economy of scale).

➢ exceptions in case of:

- material is a quite cheap (lack of economic incentive);
- material is just in a low concentration content of a production scrap (and maybe the matrix material is adverse to existing recycling technologies);
- the application of the material is quite new and the overall (global) metal amounts are very low (lack of economy of scale, e.g. for sputtering technologies).

general recycling aspects

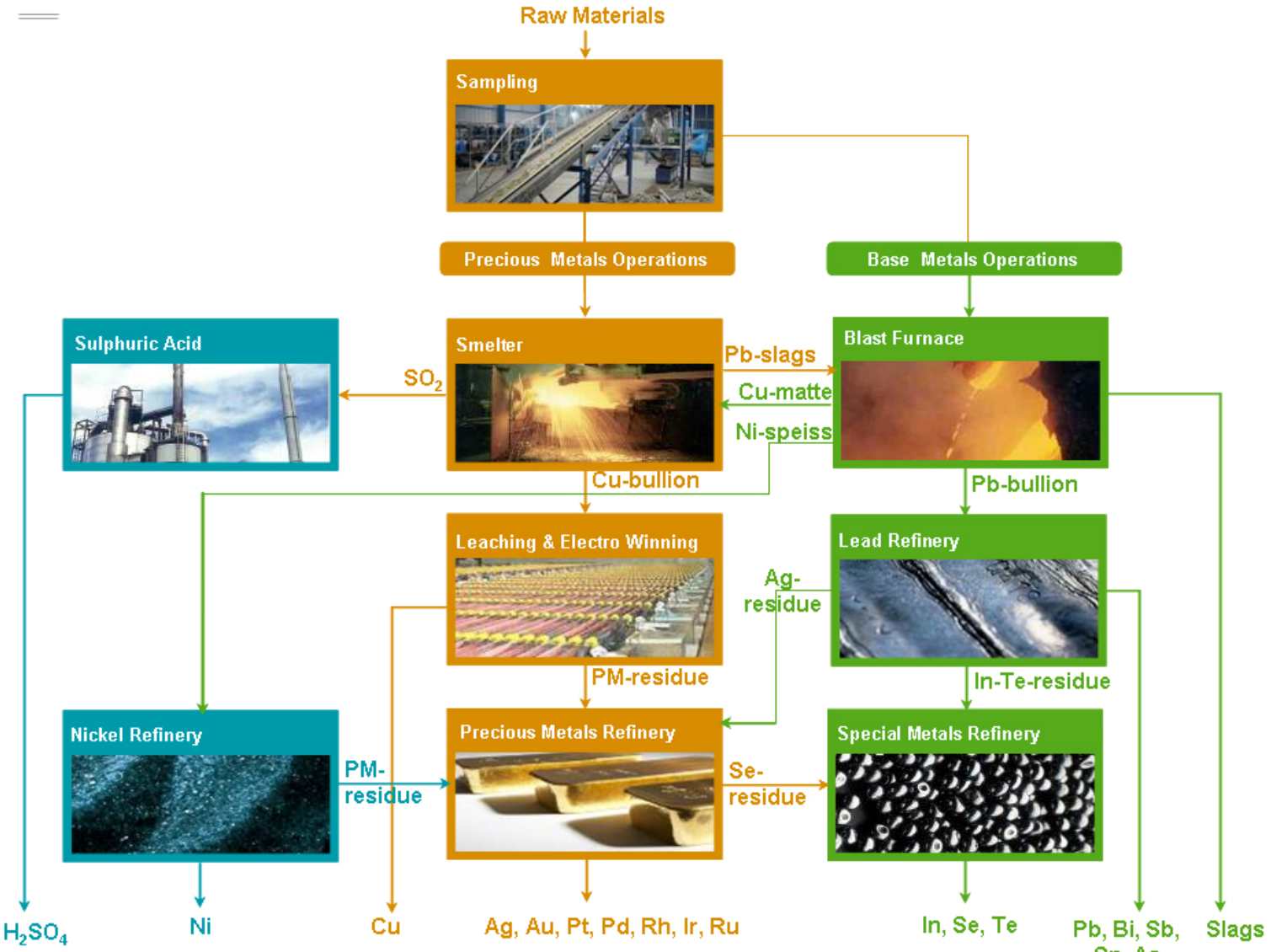
Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

post-consumer recycling (recycling of old scrap)

- low metal concentrations in waste flows: dissipative applications,
- the material is a minor composition in a complex material matrix (many other metals, plastics etc.),
- regarding consumer applications like automotives or EEE: e.g. just about hundred tons of a metal like Platinum are sold in many million single product units per year worldwide incl. emerging or developing countries without sufficient take-back and collection systems for secondary materials.

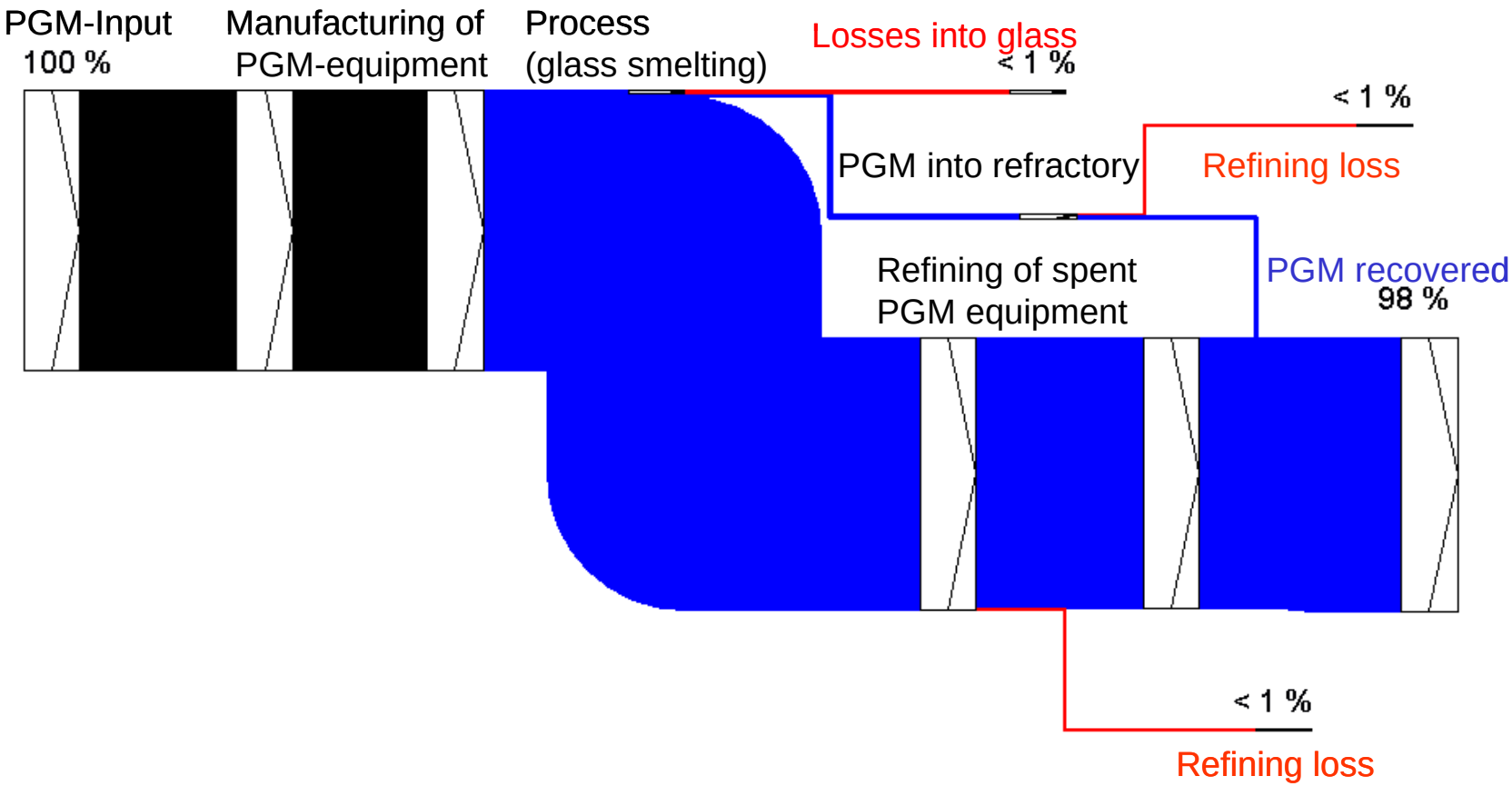
post-consumer automotive catalyst (photo by courtesy of Umicore Precious Metals Refining).

Exemplary refining stream



Material flows and main process units at Hoboken plant (by courtesy of Umicore Precious Metals Refining)

Recycling streams in advanced systems
e.g. PGM in glass industry



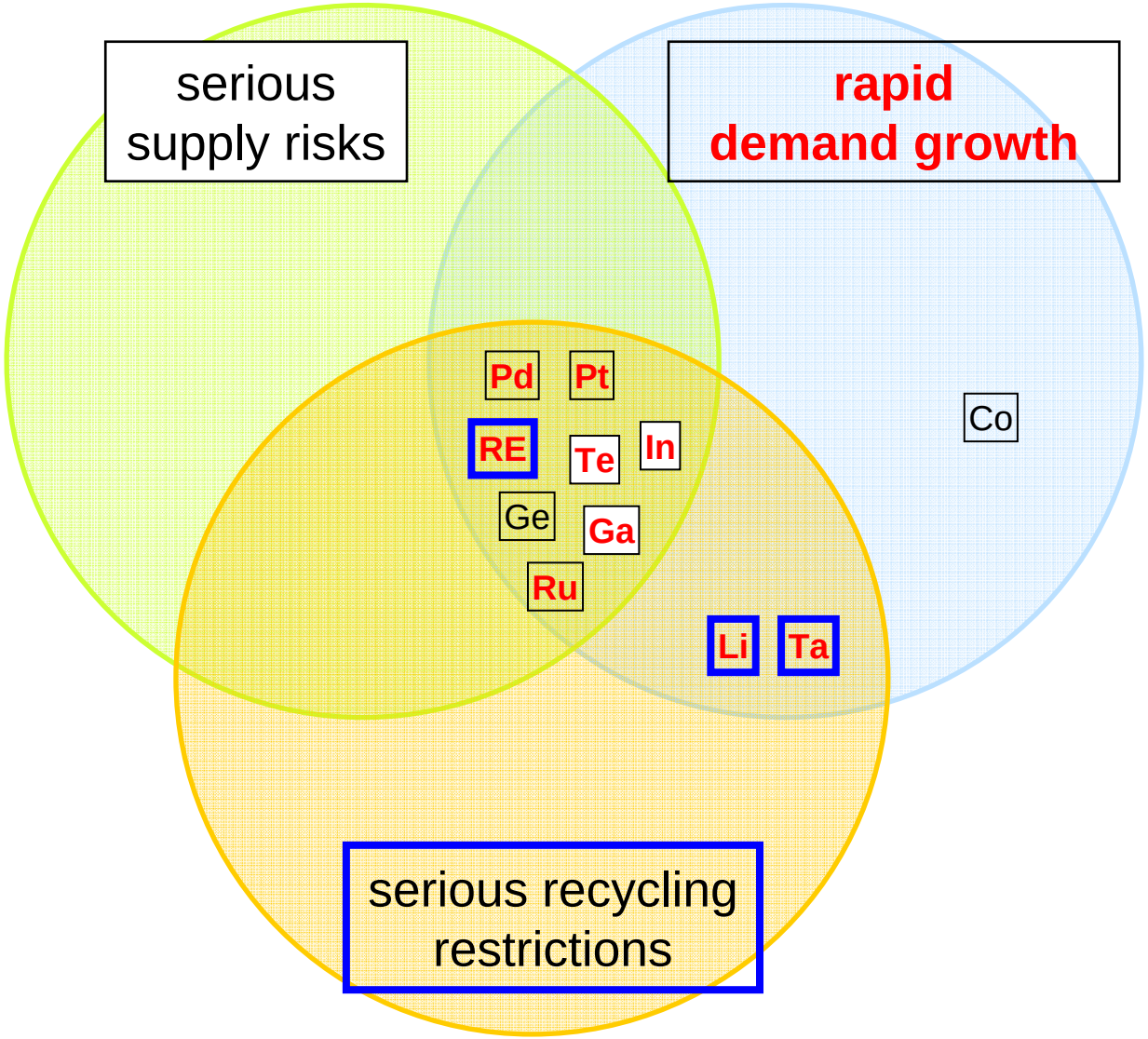
Materials flow of PGMs in the glass industry [GFMS 2005]

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

exemplary results for selected metals due to their recycling aspects

4th step

prioritization of critical metals



Recycling aspects: *Cobalt (Co)*

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

Global recycling rate grew from
4,200t (1995 18%) to 10,000t (2005 20%)

- current pre-consumer recycling:
  Cobalt recycling of new scrap can be regarded as common

- current post-consumer recycling:
  Cobalt post-consumer recycling is widely common

- potential pre-consumer recycling:
  Increasing efficiency

- potential post-consumer recycling:
  Enhanced recycling flows quiet possible: quotas of the European Battery Directive; e.g. Umicore battery recycling process etc.

Further aspects: *Cobalt (Co)*

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

Current demand is partly based on environmental applications:

1. Batteries 23% (3% in 1995);
2. Superalloys 21%;
3. Hard metals (carbides – 11%);
4. Catalysts 11%

Overall moderate growth rates expected (until 2020); (main uncertainty: boom for electric vehicles in the mid-term????)

Enhanced recycling could help to satisfy Co demand in the future

The current cathode material Lithium Cobalt Oxide (LCO) could be gradually replaced through Lithium Nickel Cobalt Manganese Oxide (NMC), Lithium Iron Phosphate (LFP) and Lithium Nickel Cobalt Aluminum Oxide (NCA). LCO contains 60% Cobalt, NMC 10-20% Cobalt, NCA 9% Cobalt and LFP no Cobalt at all

Recycling aspects: *Lithium (Li)*

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

- current pre-consumer recycling:
  insignificant
- current post-consumer recycling:
  insignificant: Li remains as oxides in the slag phase from pyro-metallurgical processes; Canadian company TOXCO runs a cryogenic recycling process
- potential pre-consumer recycling:
  statements about a serious pre-consumer recycling potential are difficult. Perspectives should depend on the production developments of Lithium batteries and the price developments of lithium
- potential post-consumer recycling:
  difficult to predict: depending on growth rates (demand for HEV and EV batteries) and price incentives

Further aspects: *Lithium (Li)*

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

- the reserve base is not a critical issue in the case of Lithium – even if scenarios with high growth rates will be fulfilled

- Lithium demand will probably increase remarkably until 2020 due to battery applications (HEV would give Lithium demand a further huge push)

- the recycling of Lithium to new Lithium products is still a niche. Nevertheless huge growth rates in battery applications, development of recycling legislations in many countries and further technical improvements could deliver moderately higher recycling rates for Lithium – depending mainly on more attractive Lithium prices as incentive for recycling

Recycling aspects: *Indium (In)*

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

- current pre-consumer recycling:
  initiated (Japan, Belgium)

- current post-consumer recycling:
  partly initiated: lack of infrastructure to collect Indium-containing products in many regions of the world

- potential pre-consumer recycling:
  beside possible increments of recycling facilities, the amount of accrued new scrap will rise due to higher production figures

- potential post-consumer recycling:
  depending on world-wide collection systems

Further aspects: *Indium (In)*

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

- Critical issue on the demand side by increasing demand rates in all fields of application

- Extraction of Indium depends on development in Zinc mining sector: could be a bottleneck

- Currently recycling of Indium from LCD and solar cells not sufficiently economic but nevertheless important: e.g. funding systems (fee on new solar cells) could be an issue

- Short-term volatility of Indium supply considered as critical

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

Preconditions for an optimized recycling in the future

- Enlargement of the global recycling capacities for many metals will be necessary in the next 1-2 decades!
  (e.g. PGM, Indium, Tellurium)
- Basic research, development and realization of new recycling technologies on metals with technical recycling problems
  (e.g. Tantalum, Rare earths, Lithium)
- Monitoring and controlling of illegal scrap-exports containing critical metals (e.g. WEEE)
- Know-how transfer and international cooperation regarding increasing stocks of used products in developing countries
  (e.g. old cars containing auto catalysts)

Action for the next 5 – 10 years

- Platinum und Palladium: 70% recycling share of gross demand could be achieved until 2020 (today about 45%)
- Cobalt: Further moderate increase of the recycling percentage: at least 30%
- “New” critical metals Indium, Gallium, Germanium, Tellurium and Ruthenium: appropriate post-consumer recycling infrastructures and well-shaped pre-treatment and refining technologies will be essential
- Tantalum, Lithium and Rare Earths: basic research in suitable recycling processes

Conclusions and recommendations

- Financial support by EU and other authorities regarding new recycling technologies for critical metals
- Special investment programs incl. low interest credits to support the design and realization of large scale recycling plants
- Continuous improvement of the legislation system (e.g. extension of the WEEE Directive regarding photo-voltaic modules
- Establishment of Best Practice Guidelines for the entire recycling value-chain (knowledge input from different stakeholders)
- Know-how and technology transfer and international cooperation regarding increasing stocks of used products in developing countries (e.g. old cars containing auto catalysts)

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

Thank you for your attention!

www.oeko.de