Measuring material scarcity- limited availability despite sufficient reserves

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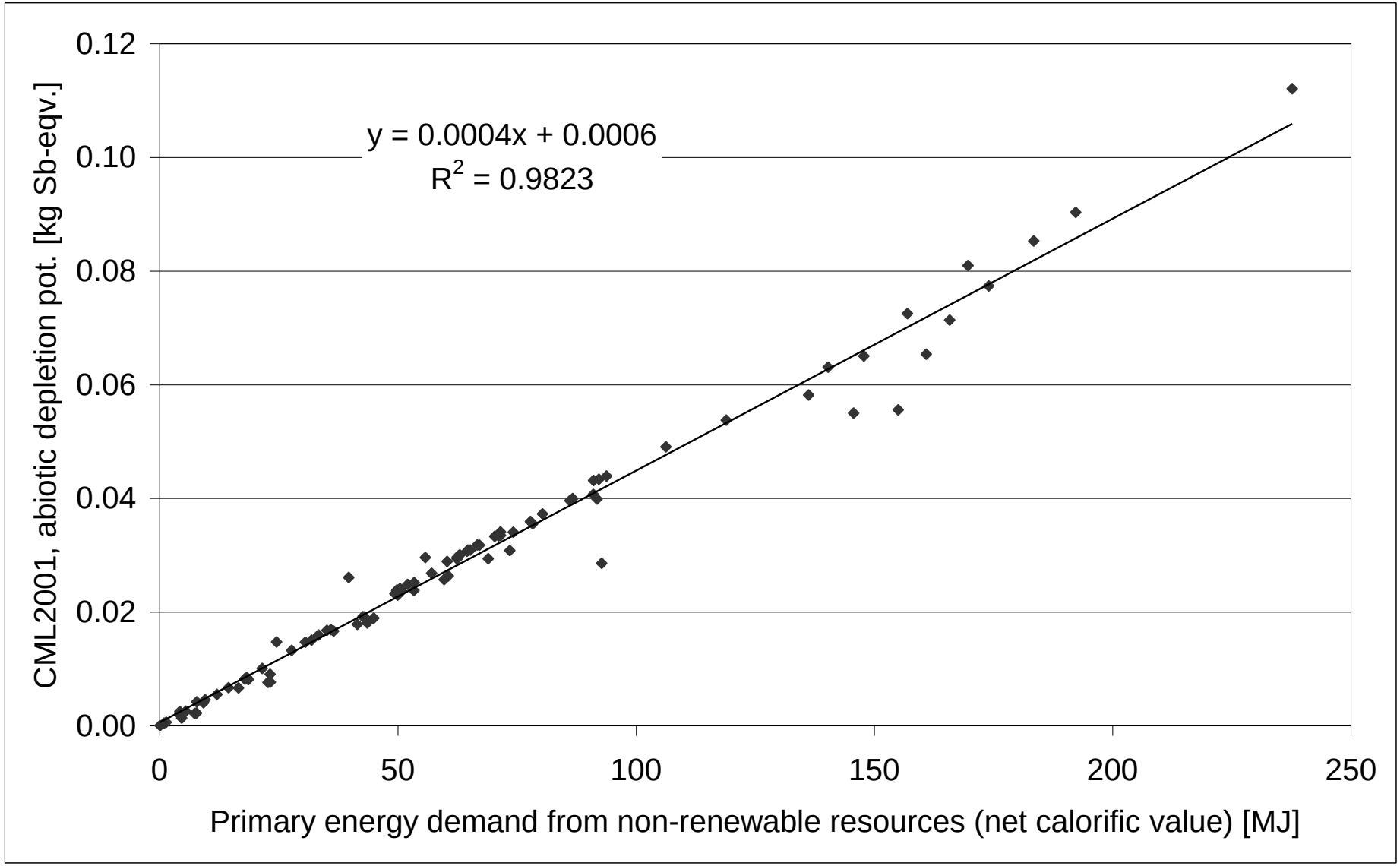
Introduction

- Resource availability is of strategic relevance for a sustainable development
- Relevant for decision makers → resource availability is relevant to attain business objectives
- But how to assess the availability of a specific material or resource?
- How to enhance current resource assessment within LCA?

Assessment of raw material consumption

- In environmental assessment methods like LCA there are currently only few indicators which focus on consumption of resources
  - Primary energy demand (PED)
  - Depletion of abiotic resources (ADP) (Guinee et al. 2002)
  - EDIP, resources (EDIP) (Hauschild and Wenzel 1998)
  - Surplus energy (SE) (Goedkoop and Spriensma 2001)
  - Ecological scarcity method (ESM) (Frischknecht et al. 2009)
- A correlation analysis was accomplished for 100 materials from the GaBi and Ecoinvent database to compare the results obtained by these indicators

Background: Correlation analysis



Berger and Finkbeiner (2010):Correlation analysis of life cycle impact assessment indicators measuring resource use

Background: Conclusions from correlation analysis

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- Significant linear correlations can be explained by two facts:
  - All indicator results are dominated by the consumption of fossil energy
  - Some characterization models provide a general characterization factor for fossil fuels that is ‘translated’ for individual energy carriers based on net calorific value

- Shortcomings of existing indicators:
  - As all indicators are dominated by the consumption of fossil energy, materials perceived as scarce are not “visible” in the indicator result
    e.g.: rare earth metals are not relevant in assessment of electric vehicles

Motivation 1

- Area of protection “resource provision capability for human welfare”
  - Human welfare is high interest as per definition of the area of protection
- LCA is a tool focusing on the production and provision of products or services → product perspective
- Economic aspects should be included into the assessment
  - Global economy depends on resource inputs extracted from the environment and easy access to these resource is often seen as a precondition for economic development as the availability of physical resources limits the scale of human activities
  - Depletion of resources could lead to collapse of industrial production

Udo de Haes et al. (2002): Life Cycle Impact Assessment: Striving towards Best Practice

Motivation 2

- New Challenges:
  - Specialization and outsourcing have made supply chains longer and globalization has dispersed them geographically
  - Increasing complexity of supply chains is a source of disruption
  - Monopolistic control of resources or changes in government policies
  - …
- The assessment of material use and availability is of major importance to secure future resource supply
- So far, no conclusion about the actual availability or criticality of metallic resources, like lithium or rare earth elements

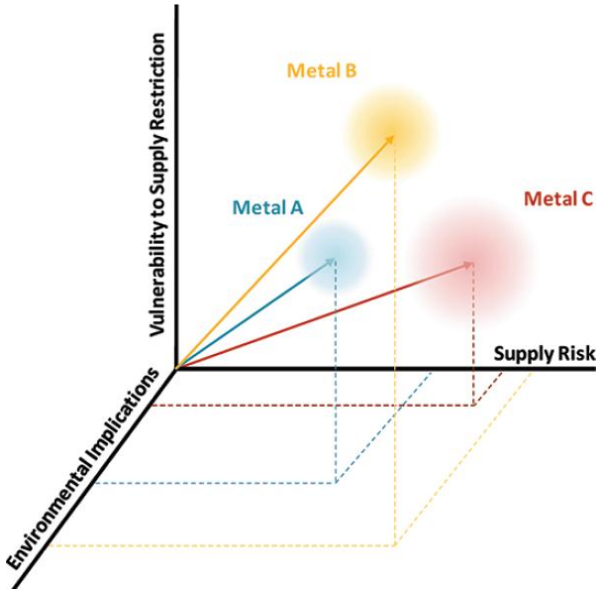
Economic raw material availability

- Resources can become scarce for more reasons than geological ones

Aspect	Indicators
Reserves	1/depletion time
Secondary production	New material content
Country concentration	Herfindahl Index (HHI)
Stability	World Governance Indicators (WGI), scaled
Company concentration	Herfindahl Index (HHI)
Trade barriers	%-share of production under trade barriers
Expected demand growth	% per year until …
Substitutability	% substituted per year (positive and negative)
Companion Metal Fraction	% produced as by-product
Anthropogenic Reserves	Depletion time (compared to production)

Economic raw material availability

- Several studies are currently assessing these additional aspects
  - National Research Council
  - European Commission
  - Center of Industrial Ecology, Yale University
  - VDI
  - KfW, IZT
  - → Different approaches and different criteria
- Criticality has several dimensions
  - Availability
  - Vulnerability
  - Environmental aspects



Graedel et al. (2011): Methodology of Metal Criticality Determination, Center for Industrial Ecology, Yale University ; EU (2010) Critical Raw Materials for the EU; National Research Council (2008): Minerals, Critical Minerals and the U.S. Economy; Fraunhofer IZT (2011): Materialien für Zukunftstechnologien

Economic raw material availability

- In order to assess raw material scarcity, each indicator value is related to a "criticality threshold" above which scarcity is expected

  → distance-to-target method: $\frac{current\ value_i}{threshold_i}$

- The different availability aspects are combined to a single "economic raw material availability index" by multiplying them with each other

$$Economic\ raw\ material\ availability\ index = \prod_i \left(\frac{current\ value_i}{threshold_i}\right)^2$$

- By taking the square of this ratio, an exceeding of the threshold is weighted disproportionate
- It should be noted, that values below 1 are set to 1 in order to avoid the offsetting of critical aspects

Economic raw material availability

- Determination of thresholds/targets above which availability is expected to be uncertain:

Indicator	Target	
HHI	0.1	If the resulting figure is above a certain threshold then economists consider the market to have a high concentration (USA e.g. 0.25)
WGI	0.33	Displaying governance performance (value of Germany: 0.2)
Demand growth	0.01	Assumption
Trade barriers	0.25	Assumption
New material content	0.25	Goals for recycling
Depletion time	40	Reserve to production ratio (years)

- Targets are chosen rather conservative in order to have an „early alert“
- Adjustment of targets leads to different results

Case study

- In order to illustrate the methodology described above, four raw materials are assessed:
  - Aluminum
  - Copper
  - Rare earth metals
  - Silver
- First, scarcity is determined based on geologic availability only by means of "abiotic depletion potential"

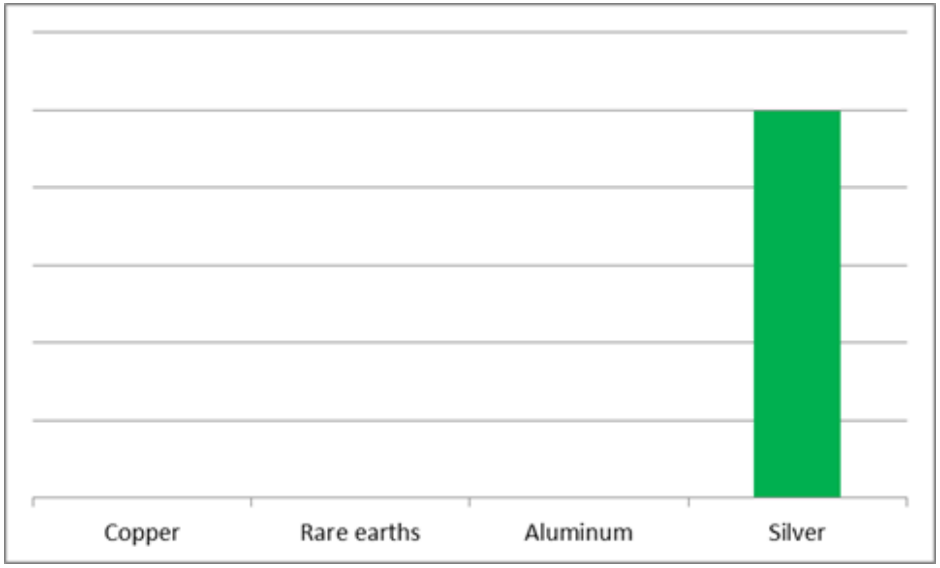
$$ADP_{i,reserves} = \frac{\text{extraction rate i}}{(\text{reserve}_i)^2} \cdot \frac{(\text{reserve antimony})^2}{\text{extraction rate antimony}}$$

- Second, material scarcity is evaluated by means of the newly developed "economic raw material availability index"

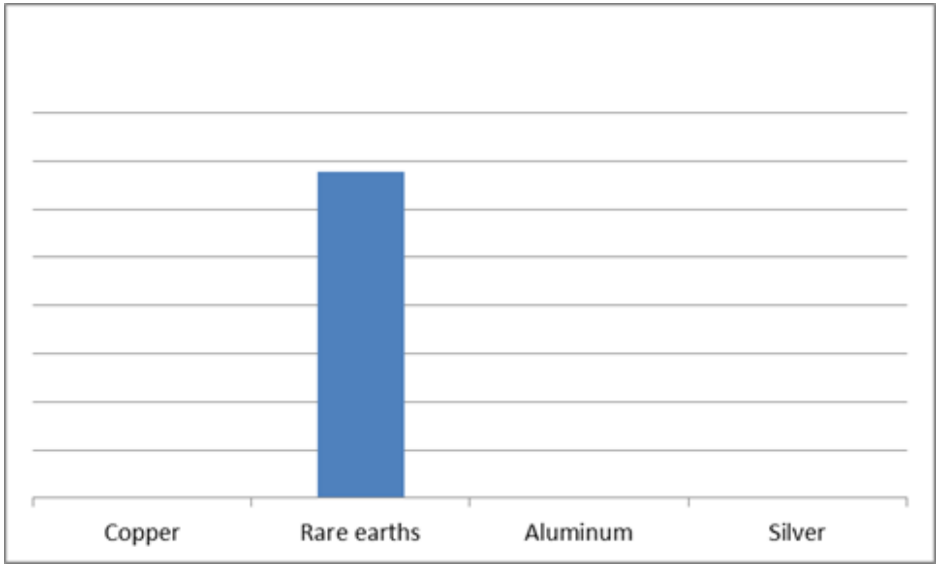
$$Economic\ raw\ material\ availability\ index = \prod_i \left(\frac{current\ value_i}{threshold_i}\right)^2$$

Results

Geological availability only



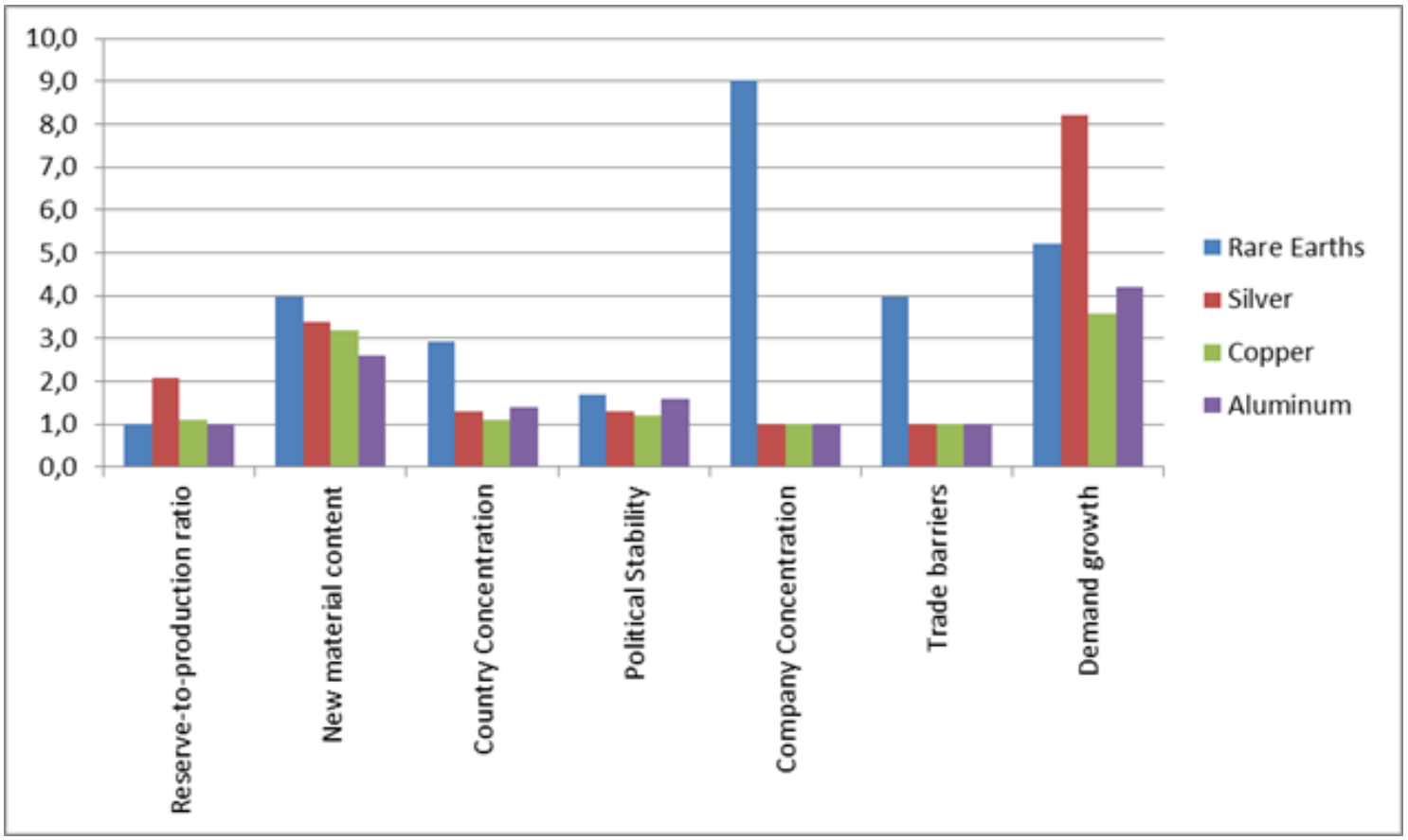
Economic raw material availability



→ Availability of materials differs significantly when economic aspects are taken into account in addition to geologic availability

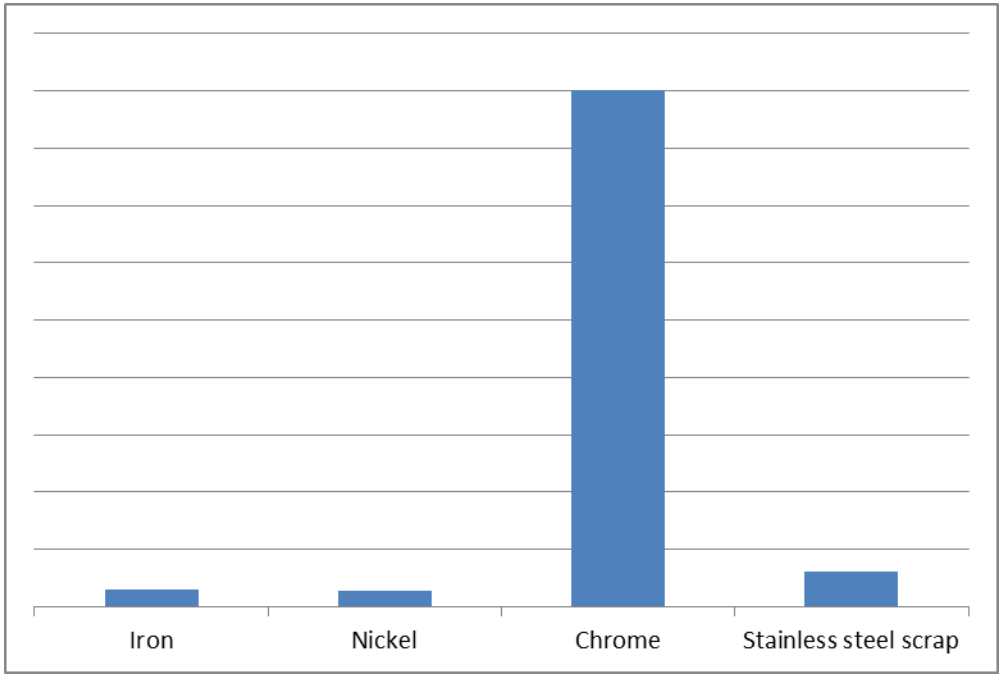
Results

- Relevance of the individual aspects with regard to the different materials



Additional Considerations

- Availability of scrap is key factor → special characteristic of stainless steel production
  - Scrap has to be considered as a resource
  - Availability of scrap is of relevance
- Focus on main „inputs“ for stainless steel production



Conclusions and Challenges

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- The aim of this study is, to enable an assessment of resources beyond the geological availability by including economic indicators and thus to deliver additional decision support
- By identifying, quantifying, and aggregating different economic raw material availability aspects, more realistic material scarcity assessments are promoted
- With the help of these results critical aspects can be identified
  - Supply safety
  - Reduction of supply risks
  - Avoidance of dependencies
  - Build up of long term relations
- Identification of significant parameters/criteria and bottlenecks is crucial for strategic decisions
- Adjustment of targets leads to different results

Conclusions and Challenges

- All stages of the supply chain have to be assessed for the determination of criticality (mining, refining, etc.) → so far this is not considered
- There are other aspects which limit raw material availability but which could not be quantified so far:
  - Minor vs. Major metal
  - Societal acceptance
  - Environmental & social aspects
  - Price elasticity of demand and supply
  - Capacity utilization (production)
  - Scarcity of energy carriers
  - Logistic constraints
  - Sensitivity to natural disasters
  - Acceptance of mining projects
  - Price volatility

Thank you for your attention!

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