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STOTEN (Science of the Total Environment) Special Issue Natural Resources: Part I

A first collection of short papers selected from the World Resources Forum 2011

World Resources Forum

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Editorial

Global resource use and its implications for the economy, the environment and the wellbeing of mankind are being given recognition as one of the key challenges in modern economic policy. Increasingly, business leaders are considering how to guide their companies to a future of doing more with less. Government leaders are discussing policy proposals in this direction. NGO leaders and scientists from all over the world are seeking optimal ways to influence this process with the best available insights.

The World Resources Forum (WRF) has established itself as the global science-based platform for sharing knowledge about the economic, political, social and environmental implications of natural resource use. WRF promotes innovation for resource productivity by building bridges among researchers, policymakers, business, SMEs, NGOs and the public. Our flagship activity is the bi-annual WRF Conference. "Shaping the Future of Natural Resources—Towards a Green Economy" was the motto of WRF 2011. The topics of the scientific sessions were security of supply, growth and innovation, assessment methods and indicators, the social dimension of resources, as well as communication and education.

Inspired by the discussions and scientific contributions at WRF 2011, we decided to collaborate with a high profile scientific journal to publish a Special Issue on Natural Resources. An excellent partnership with Science of the Total Environment (STOTEN) was then established in 2012. The call for short paper contributions was launched and a limited number of preselected papers were submitted to the regular STOTEN review process. Today, we are proud to present you a first set of papers. A second set of papers is in preparation to be published in the near future.

We hope that the reader of STOTEN will appreciate these publications which should contribute to the important, but difficult and sometimes controversial discussions about Natural Resources.

Christian Ludwig
Guest Editor
Paul Scherrer Institut (PSI), Switzerland
École Polytechnique Fédérale de Lausanne (EPFL), Switzerland

Martin Lehmann
Guest Editor
World Resources Forum (WRF), Switzerland

Xaver Edelmann
Guest Editor
World Resources Forum (WRF), Switzerland
Empa, Swiss Federal Laboratories for Materials Science and Technology, Switzerland

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Critical materials and dissipative losses: A screening study

Till Zimmermann *, Stefan Gößling-Reisemann

University of Bremen, Faculty of Production Engineering, Department for Technology Design and Development and artec | research center for sustainability studies, DE-28359 Bremen, Germany

HIGHLIGHTS

- The presented work analyses dissipative losses of critical materials according to the EU definition.
- A classification scheme for dissipative losses considering stage of occurrence and receiving medium is presented.
- A screening showed that for all assessed critical materials dissipative losses occur in a rather significant scale.
- Assessing dissipation is a data intensive endeavor. Detailed MFAs are required here.
- Based on a prioritization of dissipative losses, optimization measures can be developed.

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Critical materials
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ABSTRACT

This study deals with dissipative losses of critical materials between the life-cycle stages of manufacturing and end-of-life. Following the EU definition for critical materials, a screening of dissipative losses for the respective materials has been performed based on existing data and the most significant data gaps have been identified. Furthermore, a classification scheme for dissipative losses (dissipation into environment, dissipation into other material flows, dissipation to landfills) and for assessing their degree has been developed and a first qualitative assessment applying this classification scheme has been performed.
In combination with existing criticality assessments, the results can be used to generate a map of metals indicating future research needs for analyzing metal dissipation in detail. The results include quantitative estimates of dissipative losses (where feasible) along the chosen life-cycle stages, and discuss research needs for analysis and avoidance of dissipative losses for improved resource efficiency.

1. Introduction

The criticality of materials is a field of research of increasing attention. There are various studies on criticality available (e.g. Erdmann and Behrendt, 2011; European Commission, 2010; National Research Council, 2007; Reller et al., 2009). A review of existing criticality studies is presented in (Erdmann and Graedel, 2011). Within these studies, criticality of a material is assessed based on the consequences of a supply shortage of this material and its supply risks. In some studies, environmental implications are added as a third dimension.

According to an EU study 14 materials are to be considered as critical within the EU (if platinum group metals (PGM) and rare earths are each counted as one). In this study, the criticality definition is as follows: "a *raw material is labeled 'critical' when the risks of supply shortage and their impacts on the economy are higher compared with most of the other raw materials*" (European Commission, 2010). The following materials fall under the EU definition (European Commission, 2010):

Antimony	Gallium	Magnesium	Rare Earths
Beryllium	Germanium	Niobium	Tantalum
Cobalt	Graphite	PGM	Tungsten
Fluorspar	Indium		

These materials are of particular importance for a wide range of future and high-tech applications. They are for example essential for batteries (antimony, cobalt), electrical and electronic equipment (EEE) (beryllium, gallium, tantalum,…), special alloys (cobalt, magnesium, niobium, PGM, tantalum, tungsten…), permanent magnets (rare earths), catalysts (PGM, cobalt, germanium, rare earths…) or photovoltaic cells (gallium, tellurium, indium, germanium) among other applications.

The production of most of these materials is concentrated in only a few countries like China (antimony, fluorspar, gallium, indium, rare

* Corresponding author. Tel.: +49 421 218 64893; fax: +49 421 218 98 64893.
E-mail address: tillz@uni-bremen.de (T. Zimmermann).

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Uncovering the end uses of the rare earth elements

Xiaoyue Du [a,b,*], T.E. Graedel [b]

[a] Swiss Federal Laboratories for Materials Science and Technology (EMPA), Lerchenfeldstrasse 5, 9014 St. Gallen, Switzerland
[b] Yale University, 195 Prospect Street, New Haven CT 06511, USA

HIGHLIGHTS

- We have derived the first quantitative end use information of the rare earths (REE).
- The results are for individual REE from 1995 to 2007.
- The end uses of REE in China, Japan, and the US changed dramatically in quantities and structure.
- This information can provide solid foundation for decision and strategy making.

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ABSTRACT

The rare earth elements (REE) are a group of fifteen elements with unique properties that make them indispensable for a wide variety of emerging and conventional established technologies. However, quantitative knowledge of REE remains sparse, despite the current heightened interest in future availability of the resources. Mining is heavily concentrated in China, whose monopoly position and potential restriction of exports render primary supply vulnerable to short term disruption. We have drawn upon the published literature and unpublished materials in different languages to derive the first quantitative annual domestic production by end use of individual rare earth elements from 1995 to 2007. The information is illustrated in Sankey diagrams for the years 1995 and 2007. Other years are available in the supporting information. Comparing 1995 and 2007, the production of the rare earth elements in China, Japan, and the US changed dramatically in quantities and structure. The information can provide a solid foundation for industries, academic institutions and governments to make decisions and develop strategies.

1. Introduction

The rare earth elements (REE) are a group of metals comprised of yttrium and fourteen lanthanide elements: lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), and lutetium (Lu). Promethium is absent from REE ores and generally excluded because all of its isotopes are radioactive with short half-lives. The REE are important in a growing number of critical technologies due to their unique physical and chemical properties. For example, neodymium and dysprosium are vital to high-performance permanent magnets, and yttrium is a promising raw material for superconductors and laser technology (Angerer et al., 2009). When these intermediate products are incorporated in final products such as wind turbines, hybrid electric vehicles, or defense applications, REE provide performance that is currently irreplaceable by other materials (Stone, 2009), at least without some decrease in performance. As modern technological innovations drive an increase in demand of the REE, these potential critical materials require special attention from the perspective of future availability and sustainability.

China has played a dominant role in REE mining and production for the past two decades; other countries such as Japan and the US are almost completely dependent upon imports from China with respect to REE resources. China also has been increasing REE consumption in its domestic manufacturing industries, an activity that has the potential to decrease exports to the rest of world. Because very little mining and production activities are ongoing outside China, some countries are gradually losing the capability of mining and processing these ores and of manufacturing REE products. A gap in the supply chain has thereby been created due to their diminished domestic manufacturing infrastructure, especially at the critical early life stages. For example, there is no facility producing NdFeB permanent magnet powders in the US, and Europe constituted only 2% of 2007 global production compared to 76% in China and 19% in Japan (Liu and Xie, 2008). The potential conflict between domestic consumption surpassing production in China, rapid increases in global REE demand, and difficulty in opening new mines and achieving

* Corresponding author at: Swiss Federal Laboratories for Materials Science and Technology (EMPA), Lerchenfeldstrasse 5, 9014 St. Gallen, Switzerland. Tel.: +41 587657851.
E-mail address: xiaoyue.du@empa.ch (X. Du).

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Sustainable governance of scarce metals: The case of lithium

Timothy Prior [a,c,*], Patrick A. Wäger [b], Anna Stamp [b,d], Rolf Widmer [b], Damien Giurco [c]

[a] Center for Security Studies (CSS), ETH Zürich, Switzerland
[b] Technology and Society Laboratory, Empa - Swiss Federal Laboratories for Materials Science and Technology, St. Gallen, Switzerland
[c] Institute for Sustainable Futures, University of Technology, Sydney, Australia
[d] Institute for Environmental Decisions, ETH Zürich, Switzerland

HIGHLIGHTS

- Lithium is a geochemically scare metal, but demand is forecast to increase in future
- We explore sustainable lithium governance implications for Australia and Switzerland
- One governance mechanism is the 'servicization' of the lithium value chain
- We explore one actual, and two hypothetical lithium service business models
- 'Servicizing' a commodity would require fundamental innovations in minerals policy

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ABSTRACT

Minerals and metals are finite resources, and recent evidence suggests that for many, primary production is becoming more difficult and more expensive. Yet these resources are fundamentally important for society—they support many critical services like infrastructure, telecommunications and energy generation. A continued reliance on minerals and metals as service providers in modern society requires dedicated and concerted governance in relation to production, use, reuse and recycling. Lithium provides a good example to explore possible sustainable governance strategies. Lithium is a geochemically scarce metal (being found in a wide range of natural systems, but in low concentrations that are difficult to extract), yet recent studies suggest increasing future demand, particularly to supply the lithium in lithium-ion batteries, which are used in a wide variety of modern personal and commercial technologies. This paper explores interventions for sustainable governance and handling of lithium for two different supply and demand contexts: Australia as a net lithium producer and Switzerland as a net lithium consumer. It focuses particularly on possible nation-specific issues for sustainable governance in these two countries' contexts, and links these to the global lithium supply chain and demand scenarios. The article concludes that innovative business models, like 'servicizing' the lithium value chain, would hold sustainable governance advantages for both producer and consumer countries.

1. Introduction

Today's global society is dependent on minerals and metals. These resources provide important services for people, communities, businesses and nations. People have come to expect that these resources will be available when society requires them. However, by their very nature minerals and metals are finite resources, and recent evidence suggests that for many, primary production is becoming more difficult and more expensive (Giurco et al., 2010; Mudd and Ward, 2008; Prior et al., 2012).

A continued reliance on minerals and metals as service providers in our society requires dedicated and concerted governance in relation to production, manufacturing, use, and recovery (Cooper and Giurco, 2011). However, governance measures must reflect the services these resources supply to society, and consequently, how these resources are ultimately valued (socially, technically or economically) by society. The services these resources provide, and therefore the value that is attributed to them, differs between 'resource producing' and 'resource consuming' countries, and is explored more fully in this article.

Lithium provides a good case study to compare governance strategies between a net raw materials producing and a net consuming country for several reasons. Firstly, lithium is a geochemically scarce metal, being found in concentrations on average lower than 0.01% by weight in the Earth's crust (Garrett, 2004; Skinner, 1976; Wäger et al., 2010).

* Corresponding author at: Center for Security Studies (CSS), ETH Zürich, Haldeneggsteig 4, 8092 Zürich/Switzerland. Tel.: +41 44 632 63 74.
E-mail address: tim.prior@sipo.gess.ethz.ch (T. Prior).
URL: http://www.css.ethz.ch (T. Prior).

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The end of cheap uranium

Michael Dittmar *

Institute of Particle Physics, ETH, 8093 Zurich, Switzerland

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ABSTRACT

Historic data from many countries demonstrate that on average no more than 50–70% of the uranium in a deposit could be mined. An analysis of more recent data from Canada and Australia leads to a mining model with an average deposit extraction lifetime of 10 ± 2 years. This simple model provides an accurate description of the extractable amount of uranium for the recent mining operations.

Using this model for all larger existing and planned uranium mines up to 2030, a global uranium mining peak of at most 58 ± 4 ktons around the year 2015 is obtained. Thereafter we predict that uranium mine production will decline to at most 54 ± 5 ktons by 2025 and, with the decline steepening, to at most 41 ± 5 ktons around 2030. This amount will not be sufficient to fuel the existing and planned nuclear power plants during the next 10–20 years. In fact, we find that it will be difficult to avoid supply shortages even under a slow 1%/year worldwide nuclear energy phase-out scenario up to 2025. We thus suggest that a worldwide nuclear energy phase-out is in order.

If such a slow global phase-out is not voluntarily effected, the end of the present cheap uranium supply situation will be unavoidable. The result will be that some countries will simply be unable to afford sufficient uranium fuel at that point, which implies involuntary and perhaps chaotic nuclear phase-outs in those countries involving brownouts, blackouts, and worse.

1. Introduction

Nuclear fission energy in industrial societies is often proposed as a long term replacement for the limited fossil fuel resources and as a solution to the environmental problems related to their use. However, even 50 years after commercial nuclear fission power began, nuclear reactors produce less than 14% of the world's electric energy, which itself makes only about 16% of our final energy demand.[1] More than 80% of the 440 nuclear power plants, with a capacity of 374 GWe,[2] are operated in the richer OECD countries, where they produce about 21% of the annual electric energy.[1] The relatively small nuclear energy contribution today indicates that even a minor transition from fossil to nuclear fuel for generating electric energy over the next 20 to 30 years would require significant increases in the use of nuclear fuel.

During the last few years a “nuclear energy renaissance” strategy was discussed in many countries. However, after the 2011 Fukushima disaster, the enthusiasm to build new reactors has slowed down in most countries and even the planning for some replacement strategies for the aging existing nuclear power plant in most OECD countries has been brought essentially to a standstill. From the 68 reactors currently under construction in 14 countries, one finds that 46 of them are build in just three countries — China, India and Russia.[2] As a result, even the Word Nuclear Association (WNA) can imagine at most a worldwide nuclear growth scenario of 1–2%/year during the next 10–15 years.[3] Among the many problems related with this small growth scenario is the little discussed but fundamental issue of uranium fuel supply.[4]

In this paper we present our findings about the future uranium supply. Our results are obtained from a study of deposit depletion profiles from past and present uranium mining. Our analysis shows that the existing and planned uranium mines up to 2030 allow at most an increase of the uranium supply from 54 ktons (54000 t) in 2010[5] to 58 ± 4 ktons in 2015. Furthermore, the data indicate that after 2015 production will decline by at least 0.5 ktons/year. The annual uranium supply around 2025 and 2030 is thus predicted to reach at most 54 ± 5 ktons and 41 ± 5 ktons respectively. These numbers are not even anywhere near the present global usage, about 68 ktons/year, and imply significant shortages over coming decades. We thus predict an end of the current situation of cheap uranium and a voluntary or forced worldwide nuclear phase-out scenario. It is in fact roughly consistent with the new policies, following the Fukushima accident, proposed in May 2011 by the governments in Germany and Switzerland.

We start our analysis with countries where uranium mining was stopped or reduced to about 10% of the past production levels because of depletion (Section 2). The more accurate recent mining data from Canada and Australia are used to formulate a simple and accurate mining and depletion model (Section 3). In Section 4 this

* Tel./fax: +41 227673585.
E-mail address: Michael.Dittmar@cern.ch.

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Sustainable use of phosphorus: A finite resource

Roland W. Scholz [a,*], Andrea E. Ulrich [a], Marjatta Eilittä [b], Amit Roy [b]

[a] ETH Zurich, Institute for Environmental Decisions, Universitaetstrasse 22, 8092 Zurich, Switzerland
[b] IFDC, International Fertilizer Development Center, Muscle Shoals, AL 35662, USA

HIGHLIGHTS

- Phosphorus is an essential (non-substitutable) nutrient for food security
- Phosphate rock is a finite, non-renewable resource with a high static lifetime
- The highly dissipative nature of phosphorus asks for closing fertilizer loops
- Avoiding economic and not physical scarcity is the challenge in the next centuries
- Sustainable phosphorus management asks for transdisciplinary processes

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Transdisciplinarity

ABSTRACT

Phosphorus is an essential element of life and of the modern agricultural system. Today, science, policy, agro-industry and other stakeholder groups are increasingly concerned about the sustainable use of this resource, given the dissipative nature of phosphorus and difficulties in assessing, evaluating, and coping with phosphorus pollution in aquatic and terrestrial systems. We argue that predictions about a forthcoming peak, followed by a quick reduction (i.e., physical phosphate rock scarcity) are unreasoned and stress that access to phosphorus (economic scarcity) is already, and may increasingly become critical, in particular for smallholders farmers in different parts of the world. The paper elaborates on the design, development, goals and cutting-edge contributions of a global transdisciplinary process (i.e. mutual learning between science and society including multiple stakeholders) on the understanding of potential contributions and risks related to the current mode of using phosphorus on multiple scales (Global TraPs). While taking a global and comprehensive view on the whole phosphorus-supply chain, Global TraPs organizes and integrates multiple transdisciplinary case studies to better answer questions which inform sustainable future phosphorus use. Its major goals are to contribute to four issues central to sustainable resource management: i) long-term management of biogeochemical cycles, in particular the challenge of closing the phosphorus cycle, ii) achieving food security, iii) avoiding environmental pollution and iv) sustainability learning on a global level by transdisciplinary processes.

1. Phosphorus and the “finity” debate

Phosphorus—indispensable for plant, human and animal life—plays an essential role in soil fertility and world food security. Its major source in current use, phosphate rock, is a non-renewable resource. For long, phosphorus has not received the adequate public and scientific attention and discussions have been mostly limited to its role as an aquatic pollutant. Recently, interest in phosphorus emerged from applications of Hubbert curve on its availability, and the assertion of a peak phosphorus in a few decades. Follow-up analyses, however, have shown that the Hubbert curve approach does not provide robust predictions (Vaccari and Strigul, 2011), that there is no symmetric dynamics of rise and decline of production for any mineral on the world scale (Rustad, 2012) and that the dynamics of resources and reserves are not properly acknowledged by the Hubbert curve applications (Scholz and Wellmer, 2013). The estimated world phosphorus reserves increased from 15 Gt phosphate rock in 2008 to 71 Gt in 2011 (Van Kauwenbergh, 2010; Jasinski, 2009, 2012). New reserves, including those offshore, have been identified and their use initiated (Midgley, 2012).

Phosphorus is a low-cost commodity. Each person consumes annually about US $6 worth of rock phosphate per year (Scholz and Wellmer, 2013). Given increasing efficiency of mining technology, some of the underground mines which have been closed in the

* Corresponding author at: Fraunhofer ISC, Project Group Materials Recycling and Resource Strategies IWKS, Member of the Expert Group, Brentanostrasse 2, D 63755 Alzenau, Germany. Tel. +49 6023 32039 818.
E-mail address: roland.scholz@env.ethz.ch (R.W. Scholz).

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Assessing global resource utilization efficiency in the industrial sector

Marc A. Rosen

Faculty of Engineering and Applied Science, University of Ontario Institute of Technology, 2000 Simcoe Street North, Oshawa, Ontario, Canada L1H 7K4

HIGHLIGHTS

- ► The global industrial sector and its industries are assessed by using energy and exergy methods.
- ► Global industrial sector efficiencies are evaluated as 51% based on energy and 30% based on exergy.
- ► Exergy analysis shows global industrial energy to be less efficient than does energy analysis.
- ► A misleadingly low margin for efficiency improvement is indicated by energy analysis.
- ► A significant and rational margin for efficiency improvement exists from an exergy perspective.

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ABSTRACT

Designing efficient energy systems, which also meet economic, environmental and other objectives and constraints, is a significant challenge. In a world with finite natural resources and large energy demands, it is important to understand not just actual efficiencies, but also limits to efficiency, as the latter identify margins for efficiency improvement. Energy analysis alone is inadequate, e.g., it yields energy efficiencies that do not provide limits to efficiency. To obtain meaningful and useful efficiencies for energy systems, and to clarify losses, exergy analysis is a beneficial and useful tool. Here, the global industrial sector and industries within it are assessed by using energy and exergy methods. The objective is to improve the understanding of the efficiency of global resource use in the industrial sector and, with this information, to facilitate the development, prioritization and ultimate implementation of rational improvement options. Global energy and exergy flow diagrams for the industrial sector are developed and overall efficiencies for the global industrial sector evaluated as 51% based on energy and 30% based on exergy. Consequently, exergy analysis indicates a less efficient picture of energy use in the global industrial sector than does energy analysis. A larger margin for improvement exists from an exergy perspective, compared to the overly optimistic margin indicated by energy.

1. Introduction

Designing efficient energy systems is a significant challenge, in light of economic, environmental and other objectives and constraints, such as the world's finite natural resources and large energy demands. It is therefore important to understand actual efficiencies and limits to efficiency, which quantify margins for efficiency improvement. Energy analysis yields energy efficiencies that do not provide limits to efficiency and is thus inadequate. Exergy analysis, however, is a beneficial and useful tool that permits meaningful and useful efficiencies for energy systems to be determined, and losses to be clarified.

Exergy analysis is often used, sometimes with great benefit, in the analysis and design of engineering technologies and systems, but it can also be applied to agglomerations of systems like regional, national and global systems as well as sectors of the economy. Insights can thereby be attained that are particularly important for identifying limits to efficiency and margins for efficiency improvement. By describing the use of energy resources in society in terms of exergy, important knowledge and understanding are gained, and areas are better identified where large improvements can be attained by applying measures to increase efficiency (Reistad, 1975; Wall, 1990). Such insights can help identify and prioritize areas in which technical and other improvements should be undertaken in regions and countries, and in economic sectors.

During the past few decades, exergy has been increasingly applied to regions, nations and the world, as well as economic sectors, by using the methodology described above or variations or extensions of it. Exergy-based analyses have been carried for the world (Nakicenovic et al., 1996), as well as numerous countries, e.g., Canada. Turkey and Saudi Arabia (Dincer and Rosen, 2007), as well as the United States (Reistad, 1975; Ayres et al., 2003), China (Chen and Qi, 2007), the United Kingdom (Gasparatos et al., 2009; Warr et al., 2008) and the Netherlands (Ptasinski et al., 2006). Some regional, national and global studies have focused on particular sectors, including the industrial sector (Utlu and Hepbasli, 2007, 2008; Hepbasli and Ozalp, 2003; Oladiran and Meyer, 2007).

E-mail address: Marc.Rosen@uoit.ca.

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Towards a dynamic assessment of raw materials criticality: Linking agent-based demand — With material flow supply modelling approaches

Christof Knoeri [a,*], Patrick A. Wäger [b], Anna Stamp [b], Hans-Joerg Althaus [b], Marcel Weil [c,d]

[a] Sustainability Research Institute, School of Earth & Environment, University of Leeds, LS5 9JT Leeds, UK
[b] Technology and Society Laboratory, Empa, Swiss Federal Laboratories for Materials Science and Technology, CH-8600 Duebendorf, Switzerland
[c] Institute for Technology Assessment and Systems Analysis, Karlsruhe Institute of Technology (KIT), D-76021 Karlsruhe, Germany
[d] Helmholtz-Institute Ulm for Electrochemical Energy Storage, Albert-Einstein-Allee 11, 89081 Ulm, Germany

HIGHLIGHTS

► Current criticality assessment methods provide a 'snapshot' at one point in time.
► They do not account for dynamic interactions between demand and supply.
► We propose a conceptual framework to overcomes these limitations.
► The framework integrates an agent-based behaviour model with a dynamic material flow model.
► The approach proposed makes a first step towards a dynamic criticality assessment.

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Conceptual framework

ABSTRACT

Emerging technologies such as information and communication-, photovoltaic- or battery technologies are expected to increase significantly the demand for scarce metals in the near future. The recently developed methods to evaluate the criticality of mineral raw materials typically provide a 'snapshot' of the criticality of a certain material at one point in time by using static indicators both for supply risk and for the impacts of supply restrictions. While allowing for insights into the mechanisms behind the criticality of raw materials, these methods cannot account for dynamic changes in products and/or activities over time. In this paper we propose a conceptual framework intended to overcome these limitations by including the dynamic interactions between different possible demand and supply configurations. The framework integrates an agent-based behaviour model, where demand emerges from individual agent decisions and interaction, into a dynamic material flow model, representing the materials' stocks and flows. Within the framework, the environmental implications of substitution decisions are evaluated by applying life-cycle assessment methodology. The approach makes a first step towards a dynamic criticality assessment and will enhance the understanding of industrial substitution decisions and environmental implications related to critical metals. We discuss the potential and limitation of such an approach in contrast to state-of-the-art methods and how it might lead to criticality assessments tailored to the specific circumstances of single industrial sectors or individual companies.

1. Introduction

Emerging technologies such as information and communication-, renewable energy generation-, and energy storage-technologies are expected to increase the demand for geochemically scarce metals[1] significantly in the near future (Angerer et al., 2009; Wäger et al., 2010, 2012; Weil et al., 2009). Recently, concern over disruptions to raw materials supplies has risen in the light of China's export restrictions – that controls 95% of the global supply of rare earth elements (REEs)[2] (Corfield, 2010; Du and Graedel, 2011) – causing the availability of these commodities to drop by 40% between 2009 and 2010 (from 50,149 to 30,258 metric tons) (Danlu, 2012; Yang, 2012; Yu, 2010). This demonstrates the vulnerability of high-tech industries in the EU economy in times of acute supply disruption (Kooroshy et al., 2010). For the ICT-, aerospace-, automotive- and electronics industries, there is a risk that supply disruptions will constrain technological progress in the near future. For this reason REEs and other geochemically scarce metals, such as platinum group metals (PGMs)[3] are often referred

* Corresponding author. Tel.: +44 113 343 2663.
E-mail address: c.knoeri@leeds.ac.uk (C. Knoeri).
[1] A metal is considered as "geochemically scarce" when it occurs at an average concentration in the earth's crust below 0.01 wt.% (Skinner, 1979).
[2] The Rare Earth Elements (REEs) family includes 17 chemical elements: scandium (Sc), yttrium (Y) and the 15 lanthanides (La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu).
[3] The Platinum Group Metals (PGMs) family consist of 6 elements: iridium (Ir), osmium (Os), palladium (Pd), platinum (Pt), ruthenium (Ru) and rhodium (Rh).

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A Footprint Family extended MRIO model to support Europe's transition to a One Planet Economy

Alessandro Galli [a,*], Jan Weinzettel [b], Gemma Cranston [a], Ertug Ercin [c]

[a] Global Footprint Network, Geneva, Switzerland
[b] Industrial Ecology Programme, Norwegian University of Science and Technology, 7491 Trondheim, Norway
[c] University of Twente, Enschede, The Netherlands

HIGHLIGHTS

► The paper describes, from a theoretical point of view, a suite of indicators named "Footprint Family".
► It provides a technical description of the MRIO model created to operationalize the Footprint Family concept.
► It discusses on how policy-makers and civil society can best use the model's outcomes.
► It lists pros and cons of the model and gives indications on how to improve it to track a wider range of human impacts.

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Footprint Family
Modeling
Multi-regional input–output

ABSTRACT

Currently, the European economy is using nearly three times the ecological assets that are locally available. This situation cannot be sustained indefinitely. Tools are needed that can help reverse the unsustainable trend. In 2010, an EC funded One Planet Economy Network: Europe (OPEN:EU) project was launched to develop the evidence and innovative practical tools that will allow policy-makers and civil society to identify policy interventions to transform Europe into a *One Planet Economy*, by 2050.

Building on the premise that no indicator alone is able to comprehensively monitor (progress towards) sustainability, the project has drawn on the Ecological, Carbon and Water Footprints to define a *Footprint Family* suite of indicators, to track human pressure on the planet. An environmentally-extended multi-regional input–output (MRIO) model has then been developed to group the Footprint Family under a common framework and combine the indicators in the family with national economic accounts and trade statistics.

Although unable to monitor the full spectrum of human pressures, once grouped within the MRIO model, the Footprint Family is able to assess the appropriation of ecological assets, GHG emissions as well as freshwater consumption and pollution associated with consumption of specific products and services within a specified country. Using MRIO models within the context of Footprint analyses also enables the Footprint Family to take into account full production chains with technologies specific to country of origin.

1. Introduction

Over the last half century, nations throughout the world have changed dramatically; most have undergone significant economic growth, better welfare provisions and reductions in poverty (UNDP, 2006; UNEP, 2007). Despite some of the obvious benefits of such change, there have been negative consequences upon natural ecosystems, the biosphere and the many species that inhabit it (Butchart et al., 2010; Ellis et al., 2010; Lenzen et al., 2012a). The future ability of our natural capital to provide for humanity is being degraded as the demands upon natural systems rapidly increase due to the swelling global economy and the need to attain better standards of living (Goudie, 1981; Haberl, 2006; Nelson et al., 2006; Rockström et al., 2009). Barnosky et al. (2012) have argued that a planetary-scale critical transition is approaching as a result of the many human pressures, and that tools are needed to detect early warning signs and forecast the consequences of such pressures on ecosystems.As one of the world's largest economies, Europe has been characterized by trends of growth in the last decades so that Europe overall demand on the biological capacities of the planet has risen by more than 70% since 1961 (WWF, 2012).

The accumulation of human pressure is fundamental to many environmental issues and world leaders face the challenge of selecting appropriate policies and investments to prevent further detrimental effects (Bauler, 2012; Heink and Kowarik, 2010; Moldan et al., 2012). A broad range of empirical measurements exists that can be used to identify the driving forces behind impacts and select policies

* Corresponding author. Tel.: +39 346 6760884.
E-mail address: alessandro@footprintnetwork.org (A. Galli).

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Sustainable resource use requires "clean cycles" and safe "final sinks"

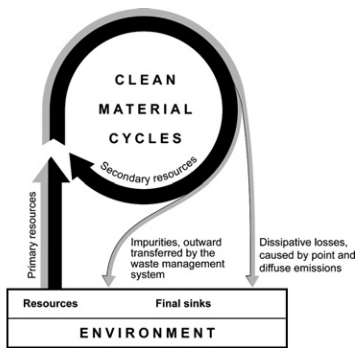
Ulrich Kral *, Katharina Kellner, Paul H. Brunner

Institute for Water Quality, Resource and Waste Management, Vienna University of Technology, Karlsplatz 13/226, 1040 Vienna, Austria

HIGHLIGHTS

► Present recycling policies focus too much on maximizing recycling rates.
► Hazardous materials are kept in cycles instead of eliminating them from cycles.
► New priorities must be set to establish clean cycles.
► A clean cycle strategy results in residues that must be disposed of in sinks.
► Waste management must supply suitable sinks for substances eliminated from cycles.

GRAPHICAL ABSTRACT



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ABSTRACT

In order to fulfill the objectives of environmental protection, today's focus on quantitative recycling rates must be amended by a more qualitative approach. Because modern products represent a mix of numerous and sometimes hazardous substances, ways must be explored to remove detrimental substances during recycling and to establish "clean cycles". On the one hand, such a "clean cycle" strategy will result in better recycling qualities of secondary products and less dissipation of hazardous substances during further product use. On the other hand, the elimination of hazardous substances during recycling requires sinks for the disposal of the eliminated materials. These topics are presented in general as well as by case studies. In particular, the sink issue is addressed, differentiating between sinks and final sinks and discussing the challenge to supply appropriate final sinks for all materials that cannot be recycled.

1. Introduction

On a global scale, there's a continuous increase of material extraction from the earth's crust (Weber et al., 2011), resulting in large accumulations of materials particularly in urban areas. While the anthropogenic material stocks are growing, the amount of waste flows and emission rates increase with a certain delay. To satisfy contemporary resource needs and to decrease environmental loadings, an obvious solution is to recycle as much as possible in order to substitute primary resources. Therefore, European legislation aims to increase recycling rates continuously. This quantitative approach does not take into account the presence of unwanted substances ending up in the second generation products. To avoid this, a so called "clean cycle" strategy is proposed.

2. "Clean cycle" strategy

Sustainable resource use is characterized by an ecologically acceptable impact on nature. Recycling strategies play a key role by

* Corresponding author.
E-mail addresses: ulrich.kral@tuwien.ac.at (U. Kral), katharina.kellner@tuwien.ac.at (K. Kellner), paul.h.brunner@tuwien.ac.at (P.H. Brunner).

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Eco-innovations for waste prevention — Best practices, drivers and barriers

Henning Wilts [a,*], Günter Dehoust [b], Dirk Jepsen [c], Florian Knappe [d]

[a] Wuppertal Institute, Research Group Material Flows and Resource Management, Germany
[b] Öko-Institut e.V., Germany
[c] Ökopol, Germany
[d] IFEU, Germany

HIGHLIGHTS

- Material flow eco-innovations as strategic goal of waste prevention programs
- Neglection of barriers in the analysis of incentives for waste prevention
- Assessment of cost cutting potentials

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Waste prevention
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ABSTRACT

Several studies in Germany aimed at the development of a sound database on existing waste prevention measures by public bodies at the local, regional and federal levels. These results are the starting point for the creation of a national prevention program, which has to be presented by all European Member States until the end of 2013 — due to the revised European Waste Framework Directive.
Based on this empirical foundation, this paper draws conclusions with regard to drivers and barriers for eco-innovations in the field of waste prevention. The analysis shows that an optimized adaptation of information on waste prevention to the needs of specific target groups is still missing but could be a relevant driver. With regard to barriers the results of the study show that waste prevention is by no means always a win–win-situation. Institutional frameworks are missing to coordinate the different interests and for the exchange of experiences that could help to realize learning effects regarding innovation approaches.

1. Introduction

Defining the prevention of waste as top priority of the waste hierarchy – as confirmed by the revised Waste Framework Directive (WFD, Directive 2008/98/EC) – is much more than a simple amendment of ways on how to deal with waste. It is nothing less than a fundamental change of the socio-technical system of waste infrastructures with all its economic, legal, social and even cultural elements (see Berkhout et al., 2003) and requires a transition from end-of-pipe technologies towards an integrated management of resources (see ISWA, 2011). Facing the dimension and complexity of this task it is not surprising that waste prevention as policy approach so far has not gained sufficient relevance within the European Union (see Gentil et al., 2011). The WFD therefore obligates the Member States to develop national waste prevention programs (NWPPs) as a new policy instrument.

Given the differences between aspirations and reality in waste prevention so far, this paper wants to highlight the challenges of such programs with regard to two questions: what could be specific measures to tackle the generation of waste and what are relevant drivers and barriers for waste prevention?

The focus of this paper is less on the waste management system itself (e.g. landfill bans could of course influence the balance between disposal, recycling and prevention), but on the generation of waste in the first place. Therefore waste prevention is put into the context of eco-innovations in production and consumption that potentially might reduce environmental impacts and at the same time save costs for the different actors alongside the value chain (see Berkhout et al., 2003).

The paper is structured as follows: Section 2 describes the background of waste prevention and national waste prevention programs and their links to eco-innovations. Section 3 analyzes three specific case studies of waste prevention approaches with regard to drivers and barriers. The final Section 4 draws conclusions with regard to the two research questions developed above and identifies further

* Corresponding author at: Wuppertal Institute, Döppersberg 19, 42103 Wuppertal, Germany. Tel.: +49 202 2492 280.
E-mail address: henning.wilts@wupperinst.org (H. Wilts).

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Secondary resources and recycling in developing economies

Lakshmi Raghupathy *, Ashish Chaturvedi

ASEM – Advisory Services in Environment Management, GIZ - Deutesche Gesellschaft Für International Zusammenarbeit, B5/2 Safdarjung Enclave, New Delhi 110029, India

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Green economy

ABSTRACT

Recycling of metals extends the efficient use of minerals and metals, reduces pressure on environment and results in major energy savings in comparison to primary production. In developing economies recycling had been an integral part of industrial activity and has become a major concern due to the handling of potentially hazardous material without any regard to the occupational health and safety (OH&S) needs. With rising awareness and interest from policy makers, the recycling scenario is changing and the large scale enterprises are entering the recycling sector. There is widespread expectation that these enterprises would use the Best Available Technologies (BAT) leading to better environment management and enhanced resource recovery. The major challenge is to enhance and integrate the activities of other stakeholders in the value chain to make recycling an economically viable and profitable enterprise. This paper is an attempt to propose a sustainable model for recycling in the developing economies through integration of the informal and formal sectors. The main objective is to augment the existing practices using a scientific approach and providing better technology without causing an economic imbalance to the present practices. In this paper studies on lead acid batteries and e-waste recycling in India are presented to evolve a model for "green economy".

1. Introduction

Mining and metallurgy is known from time immemorial. The un-sustained mining practices have led to the over exploitation of natural resources causing extensive environmental degradation. It is well known that the primary metal production requires virgin material sources, involves lengthy processes that are energy intensive. The recycling and secondary metal production on the other hand, conserves the natural resources, the process is shorter, requires less energy and there is substantial reduction in the waste destined for disposal. It is also proven that the percentage recovery of metals from the secondary sources is higher than the primary production (Schluep et al., 2009).

Metals have the unique quality for being reused and recycled without much alteration to the natural form, which has been fully exploited, but the process by which such metals are recycled or reprocessed is becoming a major environmental concern. At this juncture there is a need to encourage Environmentally Sound Technologies (EST) for recycling of metals especially the non-ferrous metals to facilitate the recycling process and taking adequate measures to ensure that there is no adverse effect on the environment and human health. Recycling, though, has become an integral part of the system but there is a need to evolve appropriate technologies for recycling by optimizing the process to achieve best results. Metal recycling and secondary processing is invariably associated with the economics of recycling. In most of the developing countries recycling activities are carried out in the unorganized sector using highly polluting technologies leading to extensive damage to the environment. These also pose health hazards due to handling of hazardous substances and poor work place environment (MAIT-GTZ study, 2007).

2. Recycling and secondary resource

Recycling has assumed global importance in view of the need to conserve natural resources. Considering the need to recover metals from the wastes and secondary sources there has been intense advocacy for recycling especially the ferrous and non-ferrous metals. In this process a number of countries have set up recycling facilities and are able to recycle not only indigenously generated wastes but they also import wastes from other countries for recycling. Globally recycling of aluminium, brass, copper, lead, nickel, tin etc. has gained importance over the last two decades. The scenario was different two decades ago where in the developing nations including India were being made as dumping ground for the waste generated by the developed nations. However, in this process there was an awakening in these poor nations of the possibility recovery of material from the waste and making it a profitable venture (Gaule et al., 2005; Hagelueken and Meskers, 2008). Today scenario has changed as scrap and wastes containing copper, lead, zinc etc., have become important secondary resources the world over. Some of the developed nations have set up "State of the Art" facilities using environmentally

* Corresponding author. Tel.: +91 9818967335.
E-mail addresses: lakshmi.raghupathy@asemindia.com, lraghupathy23@gmail.com (L. Raghupathy).

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Effective management of combined renewable energy resources in Tajikistan

Khasan S. Karimov [a,b,*], Khakim M. Akhmedov [b], Muhammad Abid [a], Georgiy N. Petrov [b]

[a] GIK Institute of Engineering Sciences and Technology, Topi, Pakistan
[b] Academy of Sciences of the Republic of Tajikistan, Dushanbe, Tajikistan

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Mutual supplementary
Irrigation

ABSTRACT

Water is needed mostly in summer time for irrigation and in winter time for generation of electric power. This results in conflicts between downstream countries that utilize water mostly for irrigation and those upstream countries, which use water for generation of electric power. At present Uzbekistan is blocking railway connection that is going to Tajikistan to interfere to transportation of the equipment and materials for construction of Rogun hydropower plant. In order to avoid conflicts between Tajikistan and Uzbekistan a number of measures for the utilization of water resources of the trans-boundary Rivers Amu-Darya and Sir-Darya are discussed. In addition, utilization of water with the supplement of wind and solar energy projects for proper and efficient management of water resources in Central Asia; export-import exchanges of electric energy in summer and winter time between neighboring countries; development of small hydropower project, modern irrigation system in main water consuming countries and large water reservoir hydropower projects for control of water resources for hydropower and irrigation are also discussed. It is also concluded that an effective management of water resources can be achieved by signing Water treaty between upstream and downstream countries, first of all between Tajikistan and Uzbekistan. In this paper management of water as renewable energy resource in Tajikistan and Central Asian Republics are presented.

1. Introduction

Rational utilization of hydro, wind and solar energy in Central and Southern Asia is an important problem today. It is connected on one hand with an opportunity of use of a huge renewable energy potential for the production of electric power, and on the other hand with the necessity of the preservation and improvement of ecology of environment by the prevention of pollution of reservoirs, ground and air by different kinds of wastes of non-renewable energies utilization and decrease in the cutting down of woods (Sirojev, 1984). Around 75% population of these countries live in the countryside and mountain territories where there is shortage of energy resources, but there are a lot of rivers that are the major source of hydro power.

Countries like Tajikistan, Kyrgyzstan and Pakistan possess great potentialities of utilization of energy of the sun, water and biomass. Furthermore, traditional life style of inhabitants of villages, where practically, in each yard there is the availability of water resources and hydro-power origin for production of electric power. However, till to-date these potentialities in the countries are not used to their reasonable potential. Absence of energy is directly affecting the population resulting in substantial lower standard of living, in general to the inhabitants of villages and specifically living in the mountain areas (Sirojev, 1999; Renewable energy in Kyrgyz Republic, 2010; Zaigham and Nayyer, 2005).

In Central Asia the problem of water is one of the most important problems of present days. Tajikistan and Kyrgyzstan, as upstream countries, are situated in the catchment area of rivers Amu-Darya and Sir-Darya; and Uzbekistan, Turkmenistan and Kazakhstan, as downstream countries, are in the zone of utilization of water resources (Karimov et al., 1995). At the same time water is needed mostly in summer time for irrigation and in winter time for generation of electric power. It can bring to conflicts between countries that utilize the water mostly for irrigation and those that use water for generation of electric power.

In utilization of renewable energy resources (RER), different schemes of combined or mutual supplementary utilization of wind-solar energy, hydropower-wind energy, hydro-wind and solar energy utilization were discussed and developed (China new and renewable energy, 2000; Marupov et al., 1999). Combined schemes have a number of advantages as reliability of the power supply, stability of output parameters as power, voltage, frequency, effective management of the resources etc. As is known Tajikistan has very few gas and oil (Petrov and Leonidova, 2001). There are relatively rich reserves of the coal, but is less utilized because of lack of good roads in the mountains and/or modem equipment for production. In this paper data on hydro and wind power resources of Tajikistan, Kyrgyzstan and Pakistan are presented. As an example, the

* Corresponding author at: GIK Institute of Engineering Sciences and Technology, Topi, Pakistan.
E-mail address: khasansangink@gmail.com (K.S. Karimov).

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Urban infrastructure and natural resource flows: Evidence from Cape Town

Katherine Hyman *

African Centre for Cities, University of Cape Town, South Africa

HIGHLIGHTS

- This paper provides the empirical evidence for the theoretical notion of decoupling at the city scale.
- It demonstrates the value of using urban infrastructure as an intervention point for decoupling strategies.
- It shows the potential for achieving sustainable urban development by reducing socio-economic metabolic flows.
- It shows the value of an intermediary for activating successful purposive interventions for sustainable urban transitions.

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Socio-technical system
Urban transitions

ABSTRACT

The current economic development trajectory is fundamentally unsustainable. However, decoupling economic growth from excessive natural resource consumption can be adopted as a means to deviate from this current trajectory. Decoupling enables economic growth and human development through non-material growth, without the environmental and social casualties of the incumbent model. Cities are the current and future context for socio development as well as a significant part of the cause and solution to sustainability challenges. Cities account for the majority of production and consumption activities leading to environmental degradation, and they are also the primary location for economic, institutional, and human capital. Innovative responses to global challenges generally emerge during the interaction between these kinds of capital. This paper presents the case of three of Cape Town's resource flows namely; electricity, water and solid waste, as mediated by networked urban infrastructure, to demonstrate the possibility of urban scale decoupling. Conclusions indicate that while decoupling can occur at the city scale, it is unlikely to be sufficient for the realization of sustainable urban development. Purposive interventions are therefore critical for successful, sustainable urban transitions.

1. Introduction

Environmental degradation, climate change and natural non-renewable resource constraints are symptomatic of the unsustainability of the current resource-intensive global economy. When the challenge of non-renewable resource constraints is juxtaposed alongside the threat of climate change and eco-system degradation, it is clear that an alternative, resource-light approach to development is imperative. The 2008 global economic crisis brought further attention to the necessity of ending a mode of consumption financed by undervalued debt. Reducing consumption by investing in alternative, clean energy and sustainable material resources offers an opportunity for sustained economic growth and development. Infrastructure, as the mediator of resource flows has substantial scope to stimulate a transition to a resource-light economy while the city provides the ideal scale to intervene (Guy et al., 2001). Investments in the *right* networked urban infrastructures provide an opportunity for the continued reproduction of the global economy in an ecologically sustainable manner (Pennell et al., 2010).

Fittingly, the locations of these investments are the urban centres of the developing world. African and Asian cities will house the bulk of future population growth, estimated to be three billion by 2050 (UN-Habitat, 2008). The significance of this lies in the fact that these cities are largely informal and designed in an ad hoc manner. Moreover, they have little, or no services connecting large portions of the population to the socio-economic urban metabolism[1] that underpin the urban economy, and therefore the global economy.

* Environmental and Geographical Science Building, University of Cape Town, Rondebosch, Cape Town 7701, South Africa. Tel.: +27 79 896 26166.
E-mail address: katherinehyman@gmail.com.

[1] Urban metabolism is the "…the sum total of the technical and socio-economic processes that occur in cities, resulting in growth, production of energy, and elimination of waste" (Kennedy et al., 2007:44).

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