WORLD RESOURCES FORUM

BOOSTING RESOURCE PRODUCTIVITY

by Adopting the Circular Economy

Christian Ludwig and Cecilia Matasci (Eds.)

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Boosting Resource Productivity by Adopting the Circular Economy

Christian Ludwig
Cecilia Matasci

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Cover
Markus Fischer, PSI
A creative assembly of photographs and symbols representing the importance of establishing a circular economy for solving the trade-off between a healthy environment and a prosperous, but resources intensive, society.

Foreword

The 2030 Agenda for Sustainable Development is a global confirmation of the criticality of natural resources for sustainable development. The sustainable and efficient management of natural resources is now more than ever an imperative for the achievement of at least 12 out of the 17 United Nations Sustainable Development Goals (SDGs) and is thus a key factor for the further prosperous development of mankind. Advances in terms of economic and social development over the last century have been largely achieved through intensive, inefficient and unsustainable use of our planet's finite natural resources. Progress towards sustainable development will ultimately depend on a shift towards a more responsible management of these natural resources, which underpin the well-being of humanity, the environment, as well as of the world economy.

The World Resources Forum (WRF) is the science-based platform for connecting and fostering knowledge exchange on resources management amongst business leaders, policy-makers, scientists, NGOs, and the public. Through the dissemination of relevant research findings, scientific discussions and to foster implementation of resource efficiency indices, WRF helps to propose innovative approaches and new solutions to tackle the many challenges. According to above needs and tasks, the World Resources Forum has put in the years 2015 and 2016 the focus on the following four topics:

1. Targets, Indicators and Benchmarks for Resource Efficiency
2. Technological Innovation, Business and Finance
3. Circular Economy and Decoupling
4. Lifestyles and Education

In previous conferences many high standard scientific presentations have contributed to very interesting discussions. After an evaluation, the best presentations have been selected and theirs authors invited to submit a manuscript for the publication in this book. The book is now arranged to make an additional contribution to the topics which were in the program of WRF 2015 and WRF LAC 2016, and is accordingly structured in four parts (1-4). An additional part presents contributions and views of private organizations.

Before any actions can take place, reasonable targets need to be set. In this context new and important indicators and benchmarks for resource efficiency are presented in Part 1. The various papers focus, but not exclusively, on resources efficiency for different materials and goods, renewable energy and climate change.

Incentives are often not necessary for taking action if the development can be justified with economic benefits. With large expected profits for companies, technological innovations will be implemented at a fast pace. Part 2 of this book therefore is dedicated to technological innovations, business and finance. Innovation for sustainability, e-mobility, business planning tools are discussed.

If our current economic system does not solve the problems, then new approaches have to be developed. If necessary, the rules have to be changed to achieve a sustainable economy, in which economic growth and resource use are decoupled from each other. Following this perspective, Part 3 is dedicated to circular economy and decoupling and offers insights into country and regional studies, research on policies as well as case studies from businesses.

Our society is an indispensable factor in increasing resource efficiency. Changing lifestyles and strengthening education are cornerstones in making the necessary change towards a sustainable resource management system. In Part 4 sustainable lifestyles, household consumption, ecological footprints, as well as building up awareness for an efficient and conservative use of resources through education are discussed.

Finally, it is important that research is implemented by the economy. Part 5 presents contributions and views of private organisations and shows success stories.

We are pleased to see that the content of this book contains valuable information which contributes to the important discussion for achieving the Sustainable Development Goals and with it a global sustainable resource management system.

I would like to take this opportunity to thank the Managing Director of WRF, Bas de Leeuw, for his collaboration, the WRF team for the organisation of the conferences, the Editorial Manager Géraldine Mercier for her technical assistance during the realization of this book and the Editors Prof. Christian Ludwig and Dr. Cecilia Matasci for the outstanding work.

I wish you enjoyable reading.

Dr. Xaver Edelmann

President World Resources Forum

St. Gallen, WRF Secretariat, October 2017

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Part I

Targets, Indicators and Benchmarks for Resource Efficiency

1. RESOURCE EFFICIENCY AND SUSTAINABLE MANAGEMENT OF NATURAL RESOURCES AND RAW MATERIALS: THE NEED FOR A COMMON UNDERSTANDING OF THE TERMINOLOGY IN POLICY MAKING

Jo Dewulf ✉, Lorenzo Benini, Lucia Mancini, Serenella Sala,
Gian Andrea Blengini, David Pennington

Abstract

Policy makers set out a range of initiatives with the buzzwords ‘natural resources’, ‘raw materials’, ‘resource efficiency’, and ‘sustainable management’ of natural resources and raw materials. An analysis of the practice highlights that there are quite different interpretations of the terminology used. In this contribution, we bring proposals for coherent definitions of ‘natural resources’ and ‘raw materials’, a systematized framework for ‘resource efficiency indicators’ and a holistic set of sustainability concerns to understand the coverage and positioning of assessment methods for ‘sustainable management’ of raw materials production and supply.

Keywords: natural resources, raw materials, resource efficiency

Introduction

Natural resources and raw materials are key in our modern industrial society. Given the growing worldwide demand, it is of no surprise that they are of interest in business, policy and research today. As the interest has grown in the topic, different institutes and organisations approach them from their own background and viewpoint, resulting in sometimes very different interpretations of the terminology used, depending on the context (e.g. trade, enterprises, environment, …) and the object of the policy (products, organisations, regions, …).

For example, the OECD sees ‘natural resources’ as natural assets occurring in nature that can be used for economic production or consumption, whereas the EU Thematic Strategy on the sustainable use of ‘natural resources’ and the Roadmap for a resource-efficient Europe also encompasses all environmental media and processes that can be affected by the production, use and disposal of economic goods and services.

Similarly, ‘raw materials’ are considered as they occur in the natural environment (COM (2005) 670 final); others consider them to be processed natural resources or even processed waste (COM (2008) 699 final).

Definition of ‘resource efficiency’ is equally diverse, e.g. from emission reduction in policy (Resource efficient Europe flagship initiative) to process efficiency in engineering. The toolbox for assessing the sustainable management of natural resources and raw materials is far from coherent, with tools offering typically a narrow focus on one of the sustainability pillars, either with an environmental (e.g. Product Environmental Footprint), economic (e.g. Criticality) or social/societal (e.g. conflict minerals) focus.

Based on our recent work on the topic, we propose a coherent set of definitions of natural resources and raw materials, resource efficiency indicators, and a holistic set of sustainability concerns to understand the coverage and positioning of assessment methods for ‘sustainable management’ of raw materials production and supply.

Natural Resources versus Raw Materials

Different stages can be identified along the life cycle of a product, starting from the asset of natural resources in the environment, through to the production of products and services bringing functionality to fulfil human needs, followed by end-of-life waste management (Dewulf et al., 2015a, b). We identify first the asset of natural resources in the natural environment, supplying natural resources to the primary production sector. This primary production sector transforms natural resources into raw materials and primary energy carriers to feed the manufacturing sector. The latter sector produces goods and services for the end-users. Finally, products end up in waste. At the so-called end-of-life phase eventually energy and/or materials can be recovered, e.g. through incineration with heat and electricity production, and recycling, respectively.

Natural resources are just at the cradle. Resources occur in the natural environment at the location where humans extract or harvest them. Removal deprives them from the environment and can interfere with ecosystems (or exclude others from using them). Based on a recent review, we can differentiate the following assets of natural resources (Dewulf et al., 2015a, b):

- Land area
- Sea area
- Flow energy resources (solar irradiation, water, wind and tidal currents)
- Water
- Metallic ores
- Minerals (for industrial and construction applications: so called industrial minerals and construction materials)
- Fossil fuels
- Nuclear ores
- Atmosphere/air
- Natural biomass (natural flora and fauna)

The first two listed can be grouped as ‘space’. The other are repositories of energy and/or materials, including atmosphere/air, e.g. for sourcing noble gases. Natural resources can be classified in several ways. Some authors divide them into renewable and non-renewable, into biotic and abiotic, and others into exhaustible and inexhaustible. Typically flow energy resources, metallic ores, minerals, fossil fuels and nuclear ores are considered as abiotic resources. Natural biomass represents the biomass generated from and renewed by natural biotic processes performed by ecosystems without human intervention for their production, as distinct from biomass produced by agricultural systems. Based on their key characteristics, another valuable type of classification is according to: stocks versus funds versus flows. Stocks are deposits of minerals and metals generated by long-term geological processes: they are non-renewable. Organic stocks such as coal are similarly exhaustible. Funds are naturally occurring materials, e.g. fish. They are renewable but exhaustible when exploited beyond their regeneration capacity. Flows are solar, water, wind or geothermal energy streams that are renewed and considered non-exhaustible as they are generated continuously with a long-time perspective, although they are not unlimited.

The aforementioned classifications typically reflect the function of usage by man, albeit that they are part of the natural ecosystem and may have some functions there as well. However, this latter perspective is out of the focus in this framework.

In the primary production sector, natural resources at the cradle are transformed into base products, typically the first market commodities. We have named these (primary) (non-energy) raw materials or primary energy carriers (or (primary) energy raw materials), depending on their further applications. Raw materials will have in the end mainly material functions (e.g. refined metal). Primary energy carriers (e.g. natural gas) are mainly used as a utility for heating, cooling, pressurizing, transportation etc. Primary energy carriers are basically the first marketable element in energy supply chains. They are the first traded energy form as the primary production sector typically transforms the natural resources into a form that can be supplied to further use elsewhere after trade.

We can distinguish a number of raw materials groups:

- Terrestrial biomass for food and material applications
- Aquatic biomass for food and material applications
- Raw materials derived from water bodies
- Raw materials derived from the atmosphere
- Metals
- Minerals and mineral materials (Industrial minerals and construction materials)
- Raw materials from fossils

Similarly, we can identify the following types of primary energy carriers:

- Terrestrial biomass for energy applications
- Aquatic biomass for energy applications
- Renewable energy from flow resources: solar, hydropower, wind and tidal (electricity or heat)
- Fuels from fossils
- Nuclear energy

The systematization presented here provides a holistic view of primary raw materials and energy carriers clarifying their origin and their further application. At the same time, it reflects the nature in terms of biotic versus abiotic and renewable versus non-renewable; this is relevant in terms of some specific sustainability concerns.

Resource efficiency indicators and a holistic set of sustainability concerns for 'sustainable management' of raw materials production and supply

Resource efficiency indicators have been developed for systems situated at different levels of economic activity: from the micro-scale of specific processes and products to the meso- and macro-scale of sectors and countries. At micro-scale, some indicators analyse products and processes in a gate-to-gate perspective, while others consider a full life cycle perspective. The same difference is present at macro-scale: some indicators evaluate resource efficiency in a national or regional perspective, while others consider a more global perspective by including resources that are embodied in imported products. With the current increasing awareness of the role of natural resources, a clear systematization of these indicators is needed, in order to increase their capability of giving insight into efficiency issues and to promote their proper use among the broad range of applications for 'resource efficiency': from technical indicators in engineering to macro-scale indicators in governmental policies.

It is essential to make a distinction among resource efficiency indicators. We propose a framework that provides five types of resource efficiency indicators, organized in a two-level approach (Huysman et al., 2015). Level 1 indicators define an efficiency that originates from engineering: the ratio between the useful outputs (or benefits) and the inventoried flows. The inventoried flows can be both inputs (resources) and outputs (emissions):

(1) In case the inventoried flows are inputs, we obtain 'resource efficiency at flow level'.

(2) In case the inventoried flows are emissions, we obtain 'emission efficiency at flow level'.

Level 2 is linked to the eco-efficiency concept and defines efficiency as the ratio between the intended effects (or benefits) and environmental impacts, assessed through specific impact assessment models. There are three possibilities:

(3) When the environmental impact in the denominator is derived from resource flows, the resulting efficiency is called 'resource efficiency at impact level'.

(4) When the environmental impact in the denominator is derived from emission flows, the resulting efficiency is called 'emission efficiency at impact level'.

(5) When the denominator represents an overall environmental impact, derived from both resource flows and emission flows, the resulting efficiency is called 'overall efficiency at impact level'.

The efficiencies that are solely based on resource flows (1, 3) can be considered as 'resource efficiency indicators *in sensu stricto'* (in strict sense). The efficiencies that are based on both resource flows and emission flows (5) can be considered as 'resource efficiency indicators *in sensu lato*' (in broad sense). The efficiencies that are solely based on associated emissions (2, 4), although used by some authors in a resource efficiency context in the broadest sense of the term, are basically emission efficiency indicators.

Sustainability management of natural resource and raw materials need a multi-criteria decision analysis, encompassing typically environmental, social and economic dimensions. Typical frameworks are Material Flow Analysis, Substance Flow Analysis, Energy Analysis, Exergy Analysis, Environmental Extended Input Output Analysis, (Hybrid) LCA, Risk Analysis, Life Cycle Costing, Cost-Benefit Analysis, Eco-Efficiency Analysis, and Social LCA. Other relevant concept and themes are the ecosystem services framework, sourcing from conflict zones and criticality. Despite their differences in scope, there is overlap and complementarity in these frameworks. We therefore identified a comprehensive set of sustainability concerns in the many frameworks with the aim to cover different and mutually exclusive sustainability concerns, as holistically as possible.

For the sake of a consistent, complete and comprehensive sustainability assessment for natural resource and raw materials management, we organize ten sustainability concerns into four Areas of Concern:

- Environmental concerns: (1) Threats for natural habitats (at the withdrawal site of natural resources); (2) Impact of emissions on ecosystem quality (along the life cycle).
- Technical/technological concerns: (1) Decreasing physical availability in nature; (2) Technical efforts; (3) Lack of alternatives.
- Economic concerns: (1) Market stability/volatility; (2) Geopolitical issues.
- Social/societal concerns: (1) International Regulations; (2) Labor conditions; (3) Impact of emissions on human health (along the life cycle).

Conclusions

As natural resources and raw materials continue to receive a growing attention and are of interest in many sectors of the society that typically have their own understanding of these subjects and of issues like resource efficiency and sustainable management, a more common definition and understanding could be advantageous. The current contribution provides a proposal and starting point in this context.

2. ON THE ROAD TO A RESOURCE EFFICIENT EUROPE: RECENT FINDINGS FROM POLFREE RESEARCH

Martin Distelkamp ✉, Bernd Meyer, Mark Meyer

Abstract

Concerning the use of natural resources in terms of raw materials, water, land and soil as well as with regards to CO_2 emissions, the European Union (EU) aims at achieving ambitious targets (European Commission 2011). It is rather unambiguous that a socio-economic transition is needed in order to achieve these objectives, but to which extent? For an illumination of this topic, the POLFREE project arranged simulation studies by means of the global economy-energy-environment model GINFORS. GINFORS represents an environmentally extended dynamic Multi-Region Input-Output (MRIO) model (for methodological details see Meyer et al. 2013). In order to assure a comprehensive modelling of biotic resource categories like land use or water, GINFORS was linked with the global vegetation model LPJmL in these studies (see, e.g., Popp et al. 2011 for a previous implementation of LPJmL to an integrated modelling framework). This integrated assessment approach facilitates the linked modelling of biotic resource availabilities and global economic developments under alternating climate regimes.[1]

Our paper discusses selected quantitative findings from this research that have been presented at the World Resources Forum (WRF) 2015 in Davos. Shown are development paths up to 2050 for core environmental and economic indicators for the world, the European Union and particular country groups. Overall, these results indicate that absolute decoupling of economic growth from resource extractions is possible on a global scale, if a large-scale, diverse and ambitious environmental policy mix is implemented soon and continuously tightened.

Keywords: sustainability, resource use, decoupling, simulation modelling, integrated assessment modelling, economy-energy-environment modelling, multi-region input-output (MRIO) analysis, global vegetation model

Introduction

The research project POLFREE is dedicated to the policy goal of a resource efficient and climate neutral Europe (see http://www.polfree.eu/ for further project details and additional project outputs). Hence, it addresses multiple dimensions of international environmental policy. Until now, target scenarios of European environmental policy have usually been modelled in an elaborated way either for selected aspects of climate policy (see, for e.g., Kriegler et al. 2015) or for selected material categories (see, e.g., European Comission 2014). Compared to this current state of research, our objective might be regarded as rather comprehensive as it

[1] The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 308371. The authors would like to thank Frank Hohmann (GWS) and Tim Beringer (IASS) for their valuable support over the course of these project activities. In case of Tim Beringer we are also indebted for significant inputs to this manuscript with regards to the description of LPJmL and the provision of relevant references. Nevertheless, any remaining errors are the sole responsibility of the authors.

involves the simulation of complex interrelations between resource efficiency and climate policy measures.

This research objective demands for an in-depth modelling of the interactions between economic growth, resource availabilities and price dynamics. Within POLFREE, we were able to proceed in this direction by linking a global economic-environmental model (GINFORS) to a global vegetation model (LPJmL). Concerning biotic resource categories, this modelling approach facilitates comprehensive global analyses which map feedbacks from the services of nature on socio-economic relations with deeply detailed geographical, economic and environmental differentiations. Compared to previous own studies (see, e.g., Meyer 2011) our simulation setup has therefore been broadened significantly. The economic-environmental model explains economic developments and the accompanied pressures on emissions and extractions of biotic and abiotic materials. LPJmL projects land use productivity and the availability of water in relation to CO_2 emission paths generated by the economic development.

Whereas technical details of the linking-approach have already been outlined by Beringer et al. (2014), this paper focuses on the achieved outcomes. Section 2 briefly summarises the simulation setup which considered three alternative economy-energy-environment scenarios. Selected findings from the scenario "Global cooperation" are outlined in Section 3. Section 4 concludes.

Simulation setup

Parametrised scenarios

Three distinct resource-efficient, low-carbon scenarios, developed by the POLFREE project (see Jäger and Schanes 2014 for details), were assessed by the models. A set of about 30 different policy instruments (information, economic and regulation instruments) were allocated to each of the three alternative scenarios ("Global Cooperation", "EU Goes Ahead" and "Civil Society Leads"), with different governance and international cooperation assumptions. Each scenario was designed to meet, through different strategies, the following overarching targets for the EU:

- A reduction of CO_2 emissions by -80% compared to 1990,
- A reduction of the average cropland footprint by -30% compared to 2005,
- A reduction of abiotic Raw Material Consumption (RMC) to 5 tons per capita,
- A reduction of national water exploitation indices to less than 20% in all EU countries.

The "Global Cooperation" Scenario

This paper focuses only on core results of scenario "Global Cooperation" in comparison to the results of a reference scenario under business-as-usual conditions. In the "Global Cooperation" scenario it is assumed that all countries co-operate through international agreements and harmonized economic and regulatory policy instruments to pursue decarbonisation and a resource-efficient global economy. All countries around the world are not only committed to achieving ambitious environmental targets like presented above for the EU, they also act co-operatively in common purpose.

The main instruments of the applied policy mix can be summarized as shown in the following box:

The policy mix (main instruments)

Climate policy is focusing on the inputs of fossil fuels and has four pillars:

- An upstream carbon tax for all industries,
- A regulation of the share of renewables in electricity production,
- A set of regulations and economic instruments favouring e-mobility and
- Subsidies for investment in the energy efficiency of buildings.

Decoupling of economic development and the use of ores and non-metallic minerals is targeted by:

- The regulation for recycling of ores and non-metallic minerals,
- An upstream tax on ores and non-metallic minerals and
- A public innovation fund for the material efficiency.

Sustainable agricultural land and water use is targeted by:

- A regulation for water abstraction of agriculture,
- An information program to avoid food waste,
- A tax on meat consumption and
- An information program to reduce the yield gap in agriculture.

Additional tax revenues are used for a reduction of taxes on goods and services with low carbon and resource contents.

Source: Meyer et al. 2016b, p. 5

It has to be stressed, that the empirical assessment of this comprehensive policy mix in the model essentially has been facilitated by expertise established in an own work-package of the POLFREE project (see Wilts et al. 2015).

The global economic-environmental model GINFORS

The essential tool of our research is the econometric model $GINFORS_3$. GINFORS (Global INterindustry FORcasting System) is an empirically based global economic-environmental model. The economic part of GINFORS represents a dynamic Multi-Region Input-Output (MRIO)-model that endogenously explains (technological) developments in different industries as well as changes in final demand for different products in 38 countries and a region “Rest of World”. For an introductory overview on MRIO models see e.g. Wiedmann et al. 2007. A bilateral trade module endogenously explains the impacts of changes in competitiveness on the directions of international trade. In a third module, the evolution of income generation and distribution between the institutional sectors “corporations”, “government” and “private households” is projected. These three economic cores of GINFORS together with its feature of global coverage assure that GINFORS simulations map the whole range of direct, indirect and rebound effects. Basic methodological details of $GINFORS_3$ and related references are outlined by Meyer et al. (2013), a model evaluation against historical observations has been organised by Meyer and Meyer (2013), a more recent application focussing on German resource efficiency issues has been presented by Meyer (2015).

The global vegetation model LPJmL

The Lund-Potsdam-Jena dynamic global vegetation model with managed lands (LPJmL) uses process-based representations of major bio-geochemical, bio-geographical and bio-geophysical processes to simulate the role of vegetation and soils in the Earth system, in particular with respect to their influence on the global cycles of carbon and water, the effects of human land use on the global environment, and the impacts of climate change on natural ecosystems and agriculture. Carbon and water cycles are fully coupled. LPJmL is driven by monthly fields of temperature, precipitation, cloud cover, atmospheric CO_2 concentration, and land use (Sitch et al., 2003, Bondeau et al., 2007). The model has been successfully evaluated against various observational data, such as vegetation activity measured by leaf area index (Lucht et al., 2002), biosphere-atmosphere carbon exchange (Peylin et al., 2005), runoff (Gerten et al., 2004), and agricultural yields (Bondeau et al., 2007).

Modelling results

The discussion of modelling results starts with key findings of the reference scenario under business-as-usual conditions. We will look at expected growth patterns of different country groups and the evolution of selected environmental indicators. These results of the reference scenario then build the basis for the discussion of the policy impact assessment by means of a GINFORS/LPJmL application. Two core questions have to been answered in this regard:

(1) Does it seem feasible to reduce coincidently global resource use and CO_2 emissions, if a large-scale and diverse environmental policy mix is soon implemented around the world and continuously tightened?

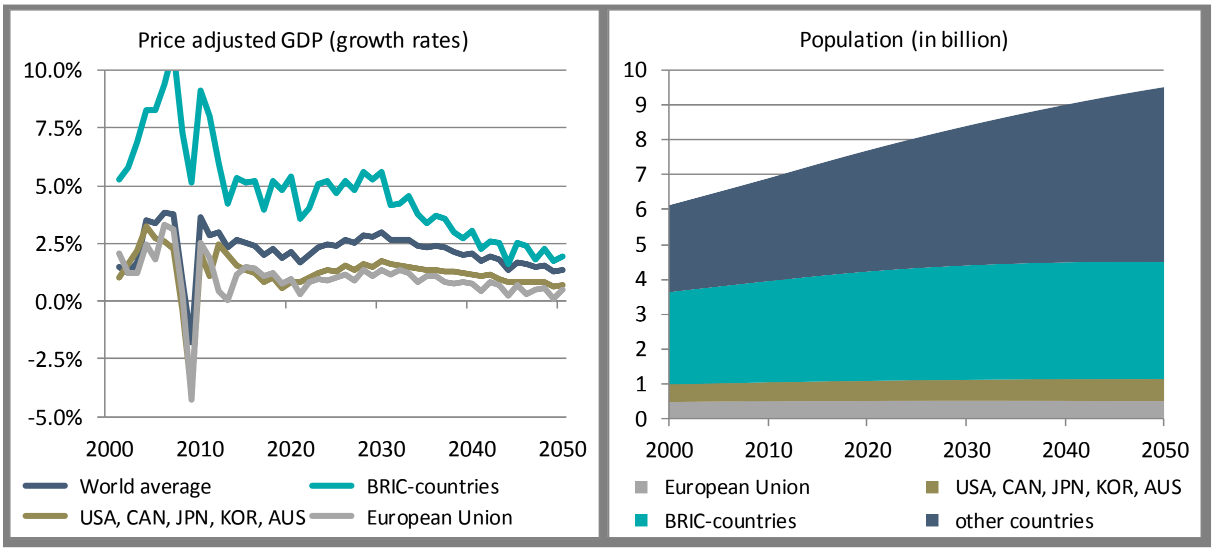
(2) Would such a radical policy shift be a pitfall for growth and jobs or would even the economy benefit from the paradigm shift?

More modelling results that cover additional details as well as results for the scenarios “EU Goes Ahead” and “Civil Society Leads” can be studied in Meyer et al. 2016a.

Development of selected economic and environmental indicators under business-as-usual conditions

Economic growth and the increasing world population are usually assigned as core drivers for accelerating global resource use and CO_2-emissions. Figure 2-1 shows in this regard right-hand side the exogenous specification for population development used in the model. Up to 2050 an increase of world population to 9.5 billion people is expected. Whilst in the past even the BRIC-countries (and here especially India) contributed notably to population growth, for the coming decades the other countries (and here mainly Africa and some Asian regions) are more or less the only group with ongoing population growth patterns.

The left hand-side of the figure documents the endogenously derived model results for GDP growth rates. In the long run the model projects a decline in economic growth for the world average as well as for the three distinguished country groups. Most evident is this observation for the BRIC-countries, where historical observations of 5 to 10 percent annual growth will come down, especially from around 2030 onwards, to “normal” growth rates of 2 to 3 percent. One of the core backgrounds for this result is changes in China. In the recent past, China’s economy has served as a core stimulus of economic growth around the world. But in the coming decades China will face an aging and declining population. Connected to this an ongoing acceleration of new megacities (and the respective investment needs) up to 2050 must not be expected. But if the construction sector does no longer serve as a key driver of prosperity in China, this will have substantial consequences for economic growth in China and around the world.



Sources: GINFORS$_3$, Reference Scenario 9/2015 (GWS) & UN World Population Prospects: The 2012 revision (medium fertility)

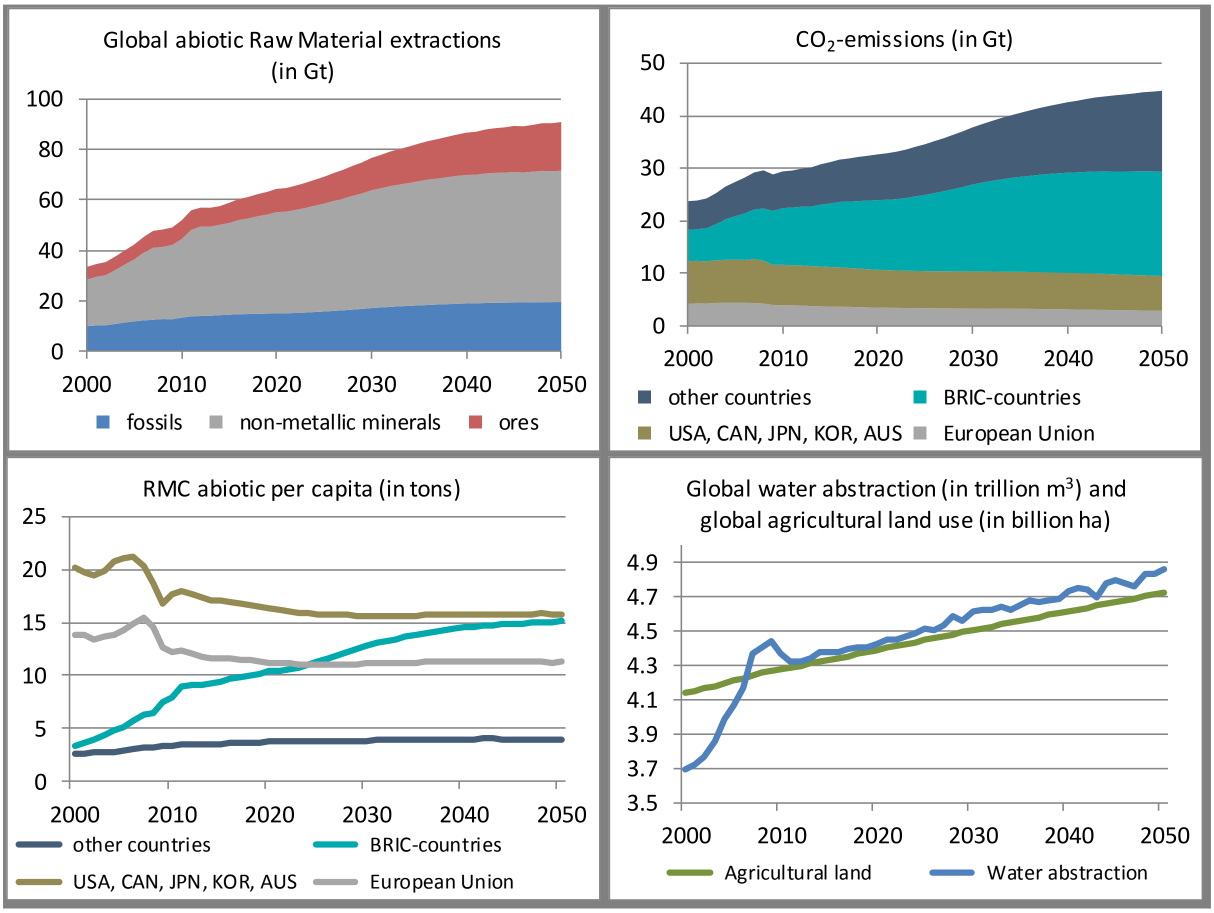
Country groups: BRIC = Brazil, Russia, India and China
USA, CAN, JPN, KOR, AUS = USA, Canada, Japan, Korea and Australia
European Union = EU28 without Croatia
other countries = mainly Africa, south and middle America (without Brazil) and low developed Asian countries

Figure 2-1: *Model results for GDP development of selected world regions in the reference scenario and exogenous specifications for population growth.*

The core implications of these developments (and the underlying structural changes) on global resource use and CO_2-emissions are summarized in the four graphs of Figure 2-2. With regard to the use of abiotic raw materials, the graphs on the left show that:

(1) Under business-as-usual conditions a further increase of global raw material extractions to 90 Gigatons in 2050 is to be expected, although this increase is much lower than in the recent past where we observed a doubling within less than 20 years.

(2) Ongoing increases in average per capita Raw Material Consumption (RMC) are expected for the 3 billion people living in the BRIC-countries, whilst in highly developed countries a slight decline is projected.



Sources for basic historic observations: WU Global Material Flows Database, WIOD, UN FAOSTAT & AQUASTAT
Sources for indicators and projections results: $GINFORS_3$, Reference Scenario 9/2015 (GWS)

Figure 2-2: *Model results for selected environmental indicators in the reference scenario.*

With regard to global CO_2-emissions, the figure shows that the business-as-usual efficiency gains and trajectories do not enable a stop of further increases. Neither highly industrialized countries nor developing countries are expected to contribute sufficiently to the needed regime shift.

The last graph of the figure shows the expected development of global agricultural land use and water abstraction. Although these results at first glance do not show dramatic increases they hint at ongoing or even accelerating unsustainable developments:

(1) The expected increase of agricultural land use by 0.4 billion ha is equivalent to half the size of Brazil. If this extension implies a further loss of natural forests in the same magnitude the implications for global ecosystems will be tremendous.

(2) A global water abstraction of more than 4 trillion m^3 already nowadays for many regions in the world implies severe water scarcity problems. The expected further increase in combination with implications of climate change on water resources stresses that these problems in some regions will accelerate.

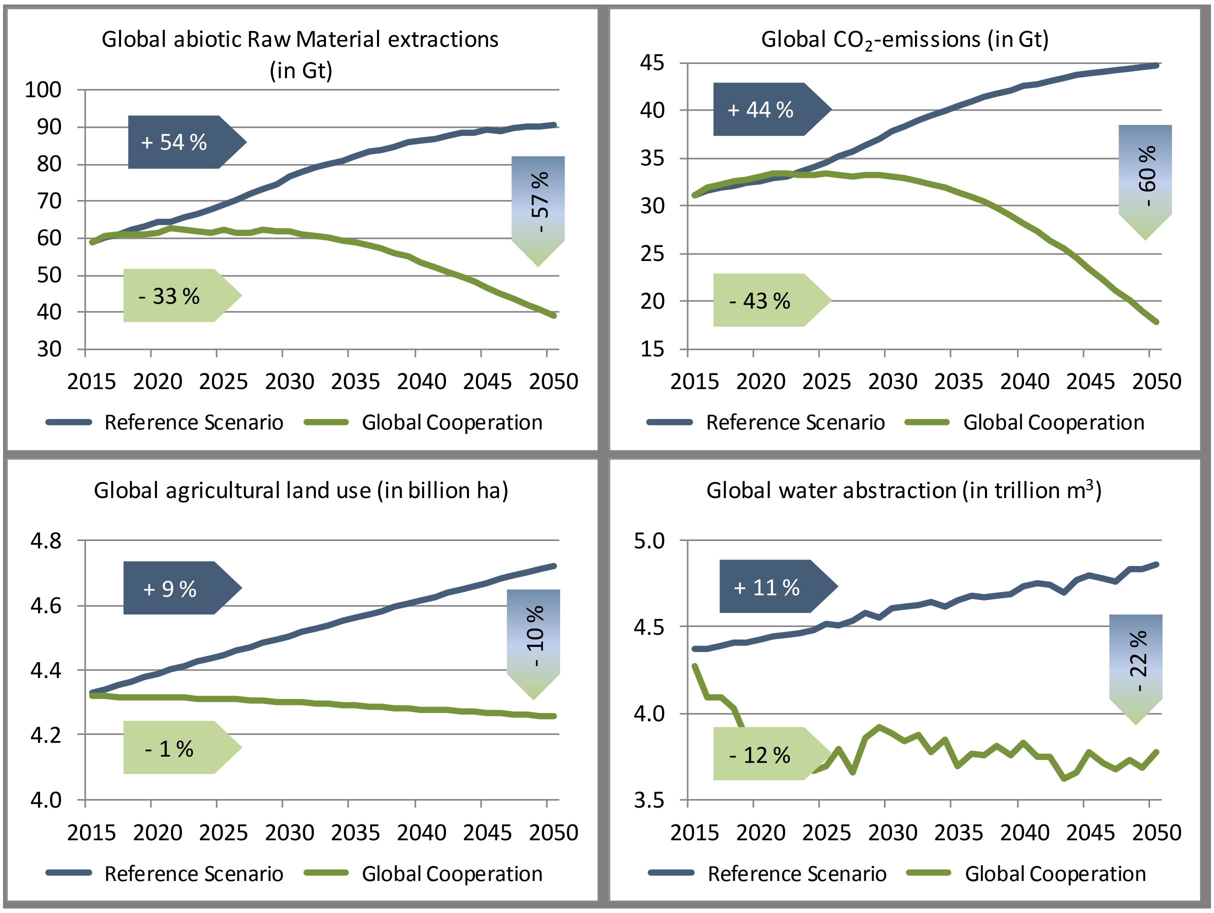
All in all, it can be summarized that the modelling results for the Reference scenario show a world with many unsustainable developments and increasing risks.

Implications of the Global Cooperation scenario on environment and economy

The main elements of the policy mix assessed in the Global Cooperation scenario already have been mentioned above. But before discussing the model results for implications of this assessment it has to be stressed, that the model results rely on the following basic narrative:

- the policy arena around the world is ambitious and encouraged enough, to implement and steadily enforce even those elements of the policy mix (like taxation) that might at least in the short run be opposed by many stakeholders.

- the entrepreneurs as well as civil society and consumers around the world at least accept or even support the policy guidance by technical and societal innovations that steadily replace short-term maximization by long-term sustainability.



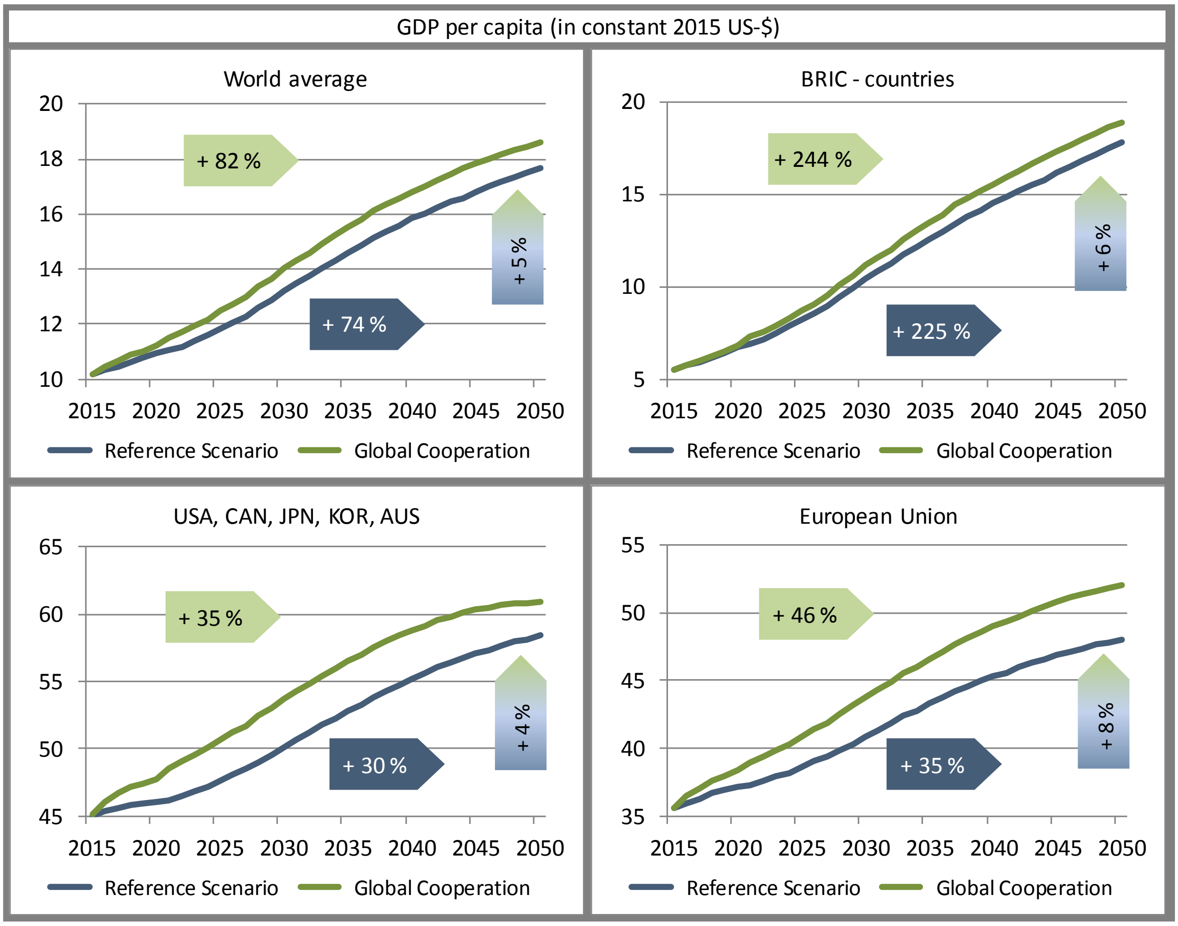
Sources: GINFORS$_3$, Reference Scenario & Global Cooperation Scenario 9/2015 (GWS)

***Figure 2-3:** Implications of the Global Cooperation Scenario on the global environment.*

Our first discussion of quantitative findings for the Global Cooperation scenario deals with the implications on global resource uses and CO_2-emissions. Figure 2-3 shows that due to implementation of the policy mix not only a relative decoupling but even absolute decreases will be achieved. But of course, this shift from increase to substantial decline especially with regard to abiotic resource uses and CO_2-emissions will not occur immediately but will need some time. The blue arrows in the graphs show the changes over time for the reference scenario, the green ones those for the Global Cooperation scenario. The arrows on the right hand of the graphs show the impact of the policy mix in the year 2050.

But what are the consequences for growth and jobs of such a shift towards a sustainable consideration of the planetary boundaries? Is a green growth possible, if we consider the complex interactions within the global economic systems as well as those between economy and environment? If we look at the following figure, the clear answer of the applied model assessment to the latter question is yes. Not only, that the decline in the global use of resources and in global CO_2-emissions is accompanied by persistent growth of per capita GDP around the world (green lines and arrows in the graphs). Moreover, the realization of the policy shift even enhances prosperity in terms of average per capita GDP compared to the reference scenario. Of course, this does not mean that the vast changes in the economic systems will originate winners only, but the benefits for the winning sectors will exceed the drawbacks for the losing sectors.

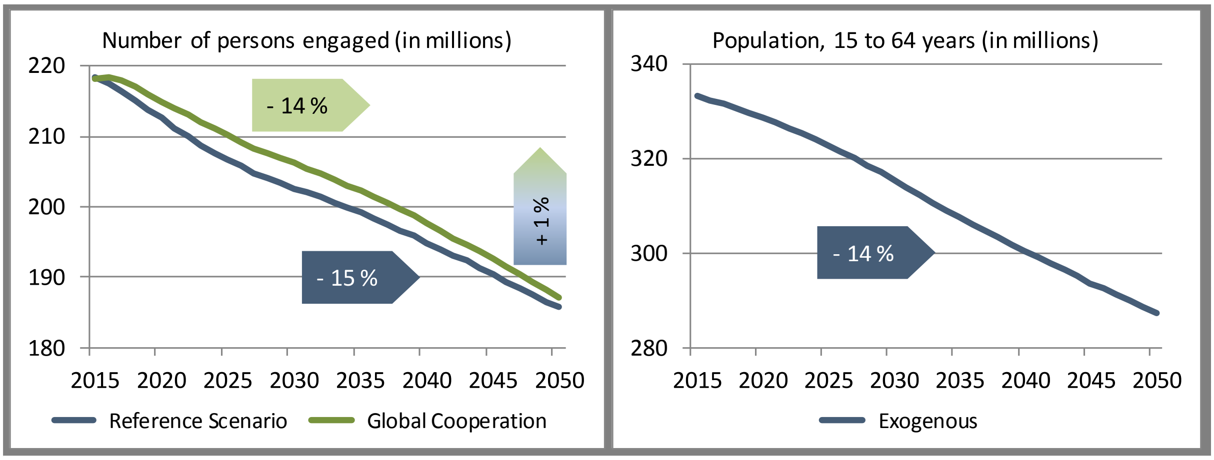
If we look at the differences among country groups for the induced shift in GDP growth, we can see that the European Union is expected to gain most. One background for this result is that the EU is a relatively strong demander but a relatively weak producer of basic resources and goods. As due to the reduced demand for these resources and goods the prices will fall (compared to the reference) the many demanders of resources and basic goods will benefit whilst the few producers will lose. A second background also is founded in the structure of EU's economy, the strong position on the world markets for investment goods. As the application of the policy mix leads to additional investment needs (e.g. for the conversion of power generation systems and for the implementation of more resource efficient production processes), the EU will benefit from the transition above average.



Sources: GINFORS$_3$, Reference Scenario & Global Cooperation Scenario 9/2015 (GWS)

Figure 2-4: *Implications of the Global Cooperation Scenario on economic growth.*

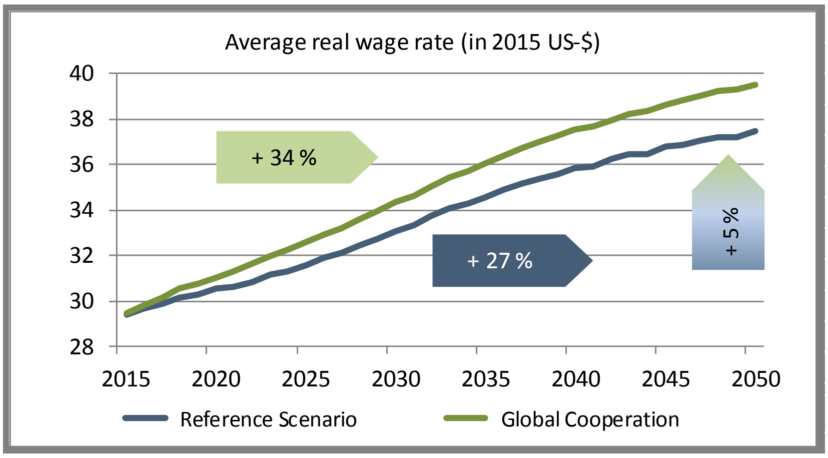
The last presentation of model results deals with question of implications of the Global Cooperation scenario for the labour market. This time (see Figures 2-5 and 2-6) we limit our presentation to the European Union to facilitate a representation of different labour market aspects. In a first step the graphs of Figure 2-5 show that in the reference scenario up to 2050 a reduction of the number of persons engaged by 15% is expected, whilst in the same time the 15 to 64 years old population declines by 14%. This means that at least for some EU countries unemployment is not expected to vanish. And also, the implementation of a policy mix for resource efficiency (as designed in the Global Cooperation scenario) cannot change this finding substantially. The overall positive impact on employment in the European Union in the year 2050 sums up to only 1% (which corresponds to about 1.4 million additional jobs), although at the same time an impact on GDP of +8% has been quantified.



Sources: $GINFORS_3$, Reference Scenario & Global Cooperation Scenario 9/2015 (GWS)

Figure 2-5: *Implications of the Global Cooperation Scenario on employment in the European Union.*

The main background for this result can be observed in the following last graph, where impacts on the average real wage rate are shown (+5% in 2050). This implies that the main beneficiaries on the EU labour market are those who have a job and not those who don't.



Sources: $GINFORS_3$, Reference Scenario & Global Cooperation Scenario 9/2015 (GWS)

Figure 2-6: *Implications of the Global Cooperation Scenario on wages in the European Union.*

Conclusions

Compared to previous own studies in the field of international resource efficiency projections (see, e.g., Meyer 2011), our simulation framework has been broadened significantly by latest model developments within the POLFREE project. In a linked simulation setup, which does also map feedbacks from a global vegetation model, we have implemented a “Global Cooperation” scenario which allows a limitation of global warming to 2 degrees as well as the achievement of ambitious targets concerning resource use until 2050. It could be shown that implementation of a wide-spread and powerful policy mix not only allows for transforming weak relative decoupling patterns to significant absolute decoupling patterns. Furthermore, the model results prove that such a shift would be accompanied by even more economic prosperity.

Besides these core results of the model application the authors are convinced that also from a methodological viewpoint the POLFREE project enhanced the respective knowledgebase (see Distelkamp et al. 2016 and Meyer, Ahlert forthcoming). Although impact assessment of resource and climate policies by means of models like GINFORS remains an important issue on the research agenda that should be steadily improved. Further model applications in combination with steady improvements of the underlying data availabilities as well as of modelling expertise are from the authors views essential ingredients for future research progress.

3. APPLICABILITY OF ENVIRONMENTAL IMPACT ASSESSMENT INDICATORS ON THE USE OF NATURAL RESOURCES IN THE BUILT ENVIRONMENT

Holger Wallbaum ✉, Alexander Passer, Stefan Bringezu,
Jun Kono, Marcella Ruschi Mendes Saade

Abstract

The paper addresses the outcomes of the analysis of state-of-the-art indicator-based approaches for the environmental impact assessment to quantify the impact of natural resources consumption. Life cycle based assessment methods are applied on the case of construction materials, construction products and entire buildings. The study has been conducted on behalf of the city of Zurich to support their strategy towards the 2000 Watt society with consideration of the potential trade-off situation between energy efficiency and renewable energies, greenhouse gas reduction potentials and the responsible use of (natural) resources.

Some environmental impact assessment methods claim to consider natural resources in their framework combining energetic and natural resources, which are detected or reported partly as separate parameters. A few methods use natural material resources as an input parameter, whereas other approaches consider mass flows in relation to suspected reserves or the willingness of the market to pay a price for a resource or a product. An expert survey among the project advisory group members has shown that the recyclability of a material resource and the avoidance of dissipative losses should be reflected within a reliable resource-specific environmental impact assessment framework.

To meet these requirements, the combination of different assessment methods to quantify the use of (natural) resources and their environmental impacts can be carried out without any further methodological development. The disadvantages are that the existing methods today do not meet all the requirements of a sustainable use of natural resources. Furthermore, the comprehensive results cannot be sensibly aggregated into a single number to support decision making processes.

Keywords: Life Cycle Assessment, resource indicator, natural resources, environmental impact

Introduction

After decades, which were characterized mainly from an environmental perspective by energy, pollution and climate discussions, the question of resources is gaining a greater interest of politics, economy and society. Especially the rapidly growing demand for energy and material resources by the younger economic powers China, India and Brazil led to rising resource prices, which put resource-intensive economies under severe economic pressure and even demonstrable results in shortages of various commodities in the markets. In a hitherto unprecedented clarity and speed, the mechanisms of a globalized and ever-growing economy become more obvious - with its advantages, but also challenges. Issues such as a long-term protected access to natural resources are central points of many national policies, since they also often have a remarkable national security dimension (Lovins, Amory, et al., 2005). Thus, it is not surprising that among other things, the EC (European Commission 2008) as well as individual EU Member States (Bundesministerium für Wirtschaft und Technologie 2010) and the United States have formulated a national resource strategy. Meanwhile, the sustainable use of natural resources, including increased resource efficiency, has become an explicit part of the Sustainable Development Goals (SDGs) in the Agenda 2030 (Bringezu et al. 2016).

A significant contribution to the debate on resources has already been made by the International Resource Panel (IRP) who published a report on 2012 about the hitherto significant findings (UNEP International Resource Panel 2012). In this report, a mass flow based assessment has been combined with an effect-related analysis. As characterization factors for mass fluxes the "mineral resources", "metals" and "organic resources" were used. Also, classical characterization factors for the effect parameters in the Life Cycle Assessment (LCA) such as "Greenhouse Gas" (GHG emissions), "acidification" (Acidification) and "CED-total" (Cumulative energy demand, total) were used. The study comes to the conclusion that especially on a global scale, the production of agricultural biomass and in particular the production of animal products has a huge environmental impact, followed by fossil fuels and metal production.

Regarding the latter, in spite of its growing significance in environmental evaluations, abiotic resource depletion calculation is one of the most debated issues in Life Cycle Assessments. Van oers and Guinée (2016) state the many reasons for such discussion are (i) abiotic depletion is a problem crossing the economy–environment system boundary, since reserves of resources depend on future extraction technologies; (2) there are different ways to define the depletion problem, and all can be justified from different perspectives; and finally (3) there are different ways of quantifying a depletion definition, and none of them can be empirically verified, since they all depend on the assumed availability and demand of resources in the future. Also, due to increasing focus on abiotic resource use modelling, bio-based resources have been typically left out of the equation, and lack an appropriate indicator that directly models their use.

Despite the large amount of resources used by the construction industry, several studies stated that the amount of mass of the various building materials and products are not a sufficient indicator to express the environmental effects. For example, the study by van der Voet et al. (van der Voet, et al. 2005) concluded that the environmental effects assessed by the “Environmentally Weighted Material consumption" methods of the mass-wise relevant materials are of minor importance. The IRP report came to the conclusion that both small material flows with very high environmental impacts as well as large material flows with low environmental impacts may be classified as minor challenge. However, the work of the IRP at the same time underlines the importance of buildings, in particular residential buildings, for a sustainable use of natural resources:

"*Buildings are the most important end-user of energy and many materials. They lead to substantial direct and indirect emissions of greenhouse gases, particulate matter and its precursor. Indoor air pollution from uncontrolled combustion is a major concern in health Developing Countries. For most impacts, the combustion of fuels or the use of fossil fuel-based electricity causes the largest contribution to the total impacts from housing. For wealthier countries, construction and the production of construction materials is the largest source of particulate matter.*"(Hertwich, Edgar G., et al. 2012, p 79)

Among others, the aforementioned studies lead to the conclusion that there are obviously uncertainties concerning the methodology, and the overriding importance of the building materials-related environmental effects. The environmental effects are explicitly understood by the resource extraction through the processing and finishing and the use phase right through to end-of-life. In recent years, several environmental assessment methods have been developed in the framework of LCA that claim to consider natural resources in their assessment and impact framework combining both energetic and natural resources (Klinglmaier et al. 2014, Rørbech et al. 2014), and some LCA databases also provide data on construction materials (Racamoa et al. 2016).

In a study on behalf of the Department of Sustainable Building, City of Zurich, Switzerland available methods have been applied on three levels: 1. building materials 2. construction element and 3. whole building. Software SimaPro 8.0 and database Ecoinvent version 3.1 supported the performed LCAs. In addition to LCA's assessment methods, the Wuppertal Institute's Material Input per Service unit (MIPS) (Schmidt-Bleek et al., 1998) was added to the evaluation.

This paper summarizes the results of the conducted LCAs, concluding on the strength and weaknesses of the currently available assessment methods and introducing the framework conditions for the development of such an assessment method based on expert interviews.

Methodological approach

In addition to the Swiss method of ecological scarcity, various international procedures which carry out an evaluation of the life cycle-wide environmental impacts are available. For this paper's purposes, the selection is based primarily on methods which are used in the established LCA software SimaPro. In particular, the following methods were examined in a first qualitative analysis regarding their suitability to answer the questions of this study: CML 2001, EPS 2000, Ecological Scarcity 2006 – 2011, Material Input per Service Unit (MIPS), Impact 2002+, Recipe 2008, Eco-indicator 99, Environmental Design of Industrial Products (EDIP), Ecological Footprint, Cumulative Energy Demand (CED), Cumulative Exergy Demand (CExD), Carbon Footprint (GWP). Although many of these methods perform a resource use assessment, they usually adopt energetic resources use as a measure, which fails to thoroughly cover natural resource use. Upon performing this preliminary analysis, authors then selected CML, EPS, Ecological scarcity 2006 and MIPS as the most appropriate methods to address the natural resource use topic.

In order to gain an initial insight onto how these methods model biogenic and mineral-based materials impacts, their appropriateness was first evaluated at the building material level, by applying them to two Ecoinvent data sets:

(1) "Concrete, normal, at plant / CH U" and

(2) "Sawn timber, softwood, raw, kiln dried, u = 20%, at plant / RER U".

Then, for a more detailed examination, the methods are assessed at the whole building level by applying them to two case studies extracted from John (2012): pp 67-69 (mfh10) and pp. 72-74 (mfh12). The mfh10 represents a typical massive construction of sand-lime brick masonry and reinforced concrete slabs in Minergie standard, whereas the mfh12 represents a mixed construction of wood frame and reinforced concrete slabs in Minergie-P-ECO standard.

At last, authors conducted informal interviews with advisory group members for this study, in order to elaborate a set of target questions that should be covered by a sound resource use indicator for the built environment. The experts' opinion fed an initial framework that lists conditions and possible preliminary indicators for an improved assessment method.

Results

Building material level

Figures 3-1, 3-2 and 3-3 show results for 1 m^3 of concrete and 1 m^3 of sawn wood using the respective resource use impact category of each evaluated life cycle based assessment method, while Figure 3-4 shows the MIPS results (in kg per kg) for concrete and sawn wood. Due to the different functional units and assessments' methodology, respectively, between Figures 3-1, 3-2 and 3-3 and Figure 3-4, results are not directly comparable, rather they show the contribution of the different construction materials in each method.

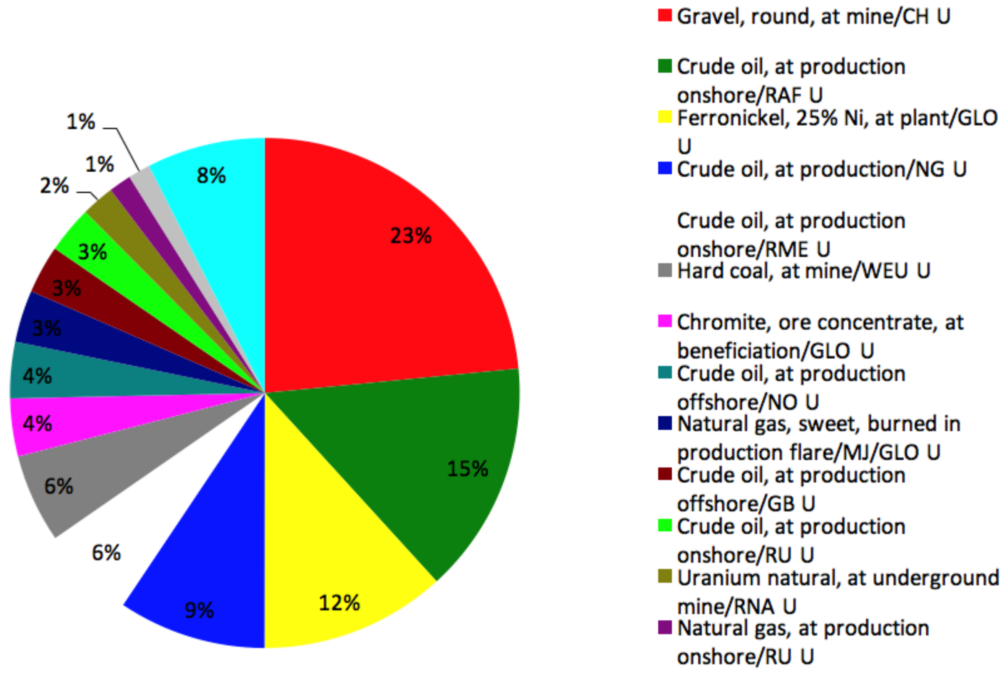


Figure 3-1a: *EPS 2000 abiotic stock results for concrete.*

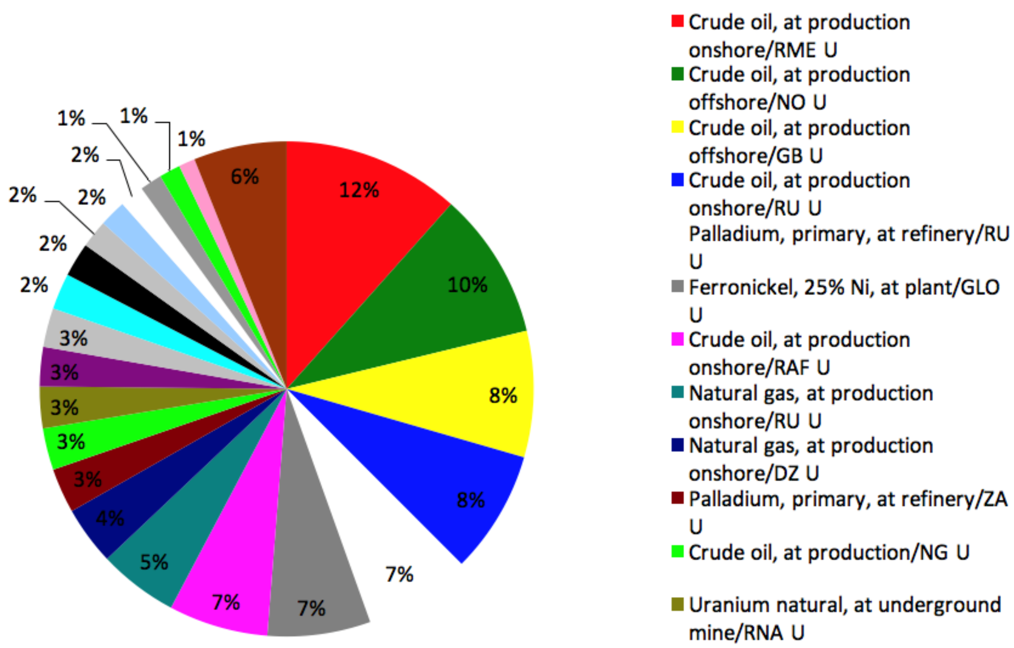


Figure 3-1b: *EPS 2000 abiotic stock results for sawn wood.*

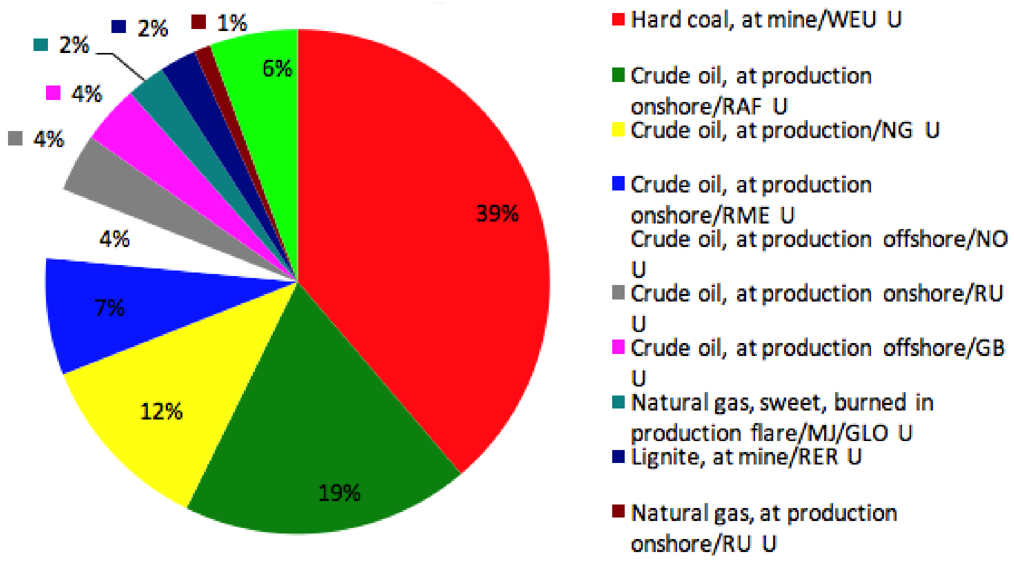


Figure 3-2a: *CML 2001 abiotic depletion results for concrete.*

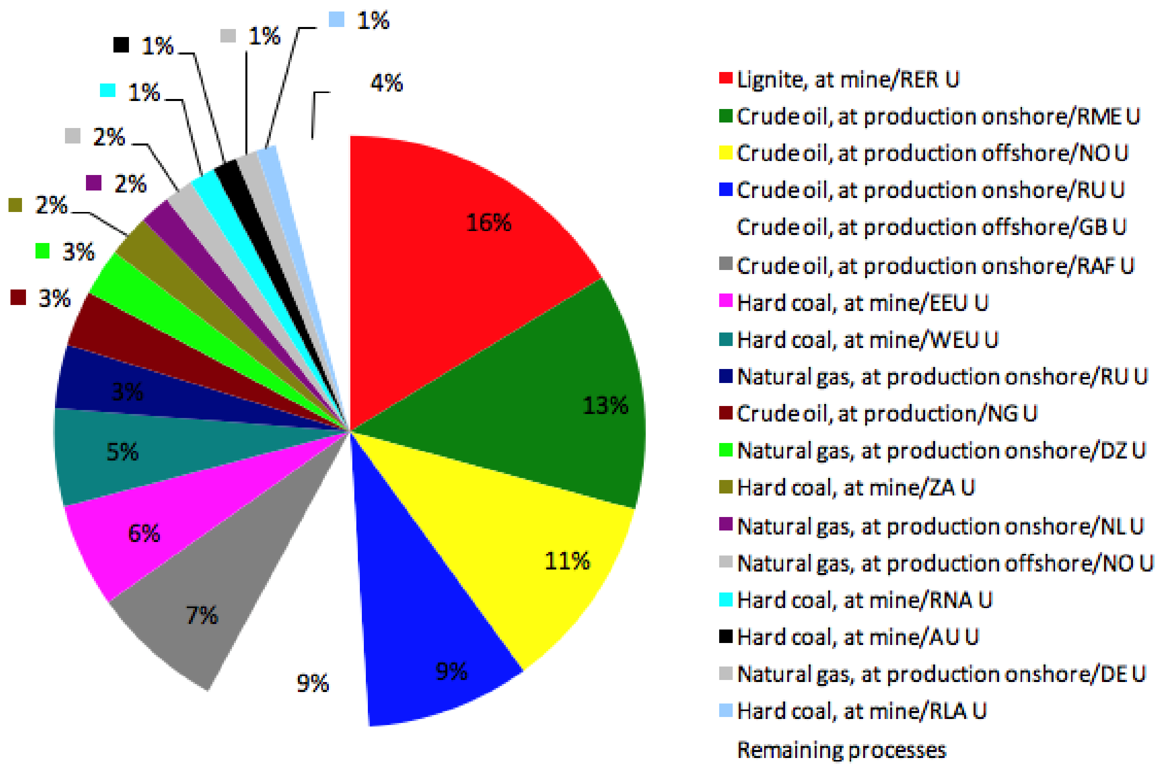


Figure 3-2b: *CML 2001 abiotic depletion results for sawn wood.*

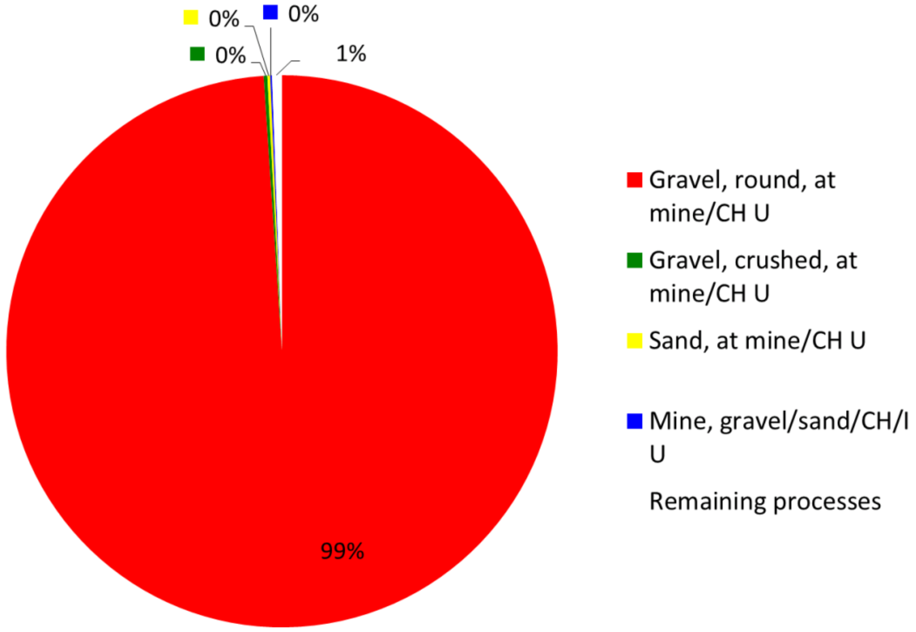


Figure 3-3a: *Ecological scarcity natural resources results for concrete.*

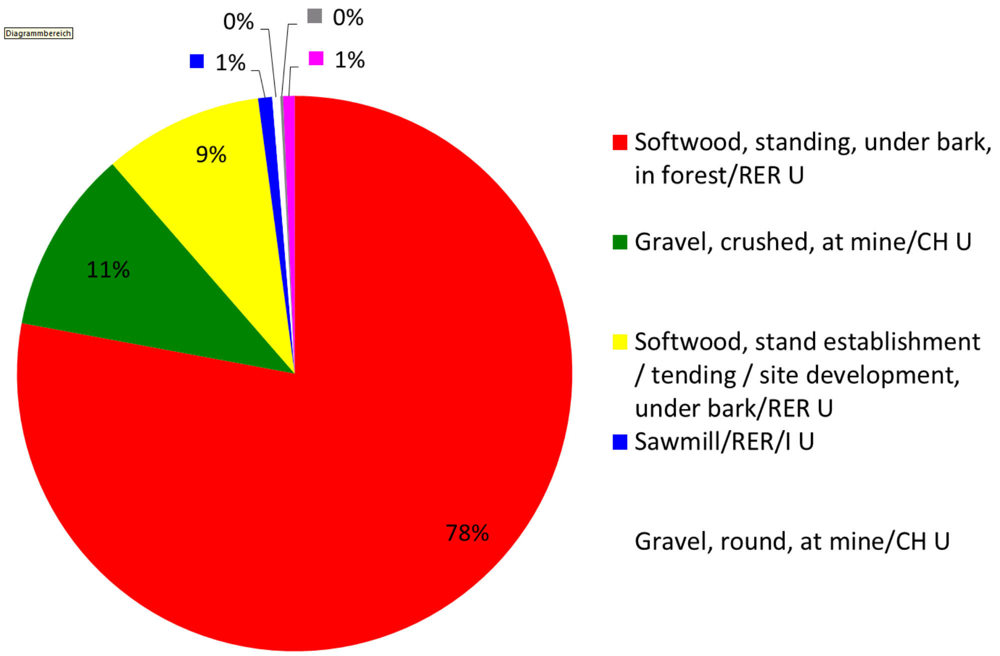


Figure 3-3b: *Ecological scarcity natural resources results for sawn wood.*

For concrete assessment, EPS2000's abiotic stock resource category is mainly composed of gravel and energetic resource use (Figure 3-1a). For sawn wood assessment, wood use itself is not contemplated (Figure 3-1b), because EPS 2000 captures bio-based products in the "biodiversity" and "ecosystem production capacity" categories, instead of in the abiotic stock resource category. Although this method does not fully compile resource use, it offers good starting points that could be considered when developing a new resource use indicator.

CML 2001, on its turn, prioritizes energetic resources effects, while non-energetic resource use plays a subordinate role in the assessment (Figure 3-2a and 3-2b). Renewable raw material usage (Figure 3-2b) has no effect in this category. CML, therefore, is not suitable for natural material use assessment in the built environment. The characterisation method used in the abiotic depletion category, however, can be tailored to produce LCI results for specific construction materials. This approach is used in other evaluation methods and it is still under development.

Figure 3-3a clearly indicates that gravel consumption for concrete manufacturing dominates the natural resources use category when adopting the Ecological Scarcity method, while for sawn wood (Figure 3-3b), wood production itself stands out, followed also by gravel consumption. This method offers an interesting approach to evaluate bio and mineral-based building materials and their impact. The latest Ecological Scarcity version, released in 2011, introduced a separate category that models only mineral resouces consumption. Upon performing a sensitivity analysis with both available versions, authors concluded that the newest version is not fit for biogenic building materials use modelling, since it does not directly assess their consumption.

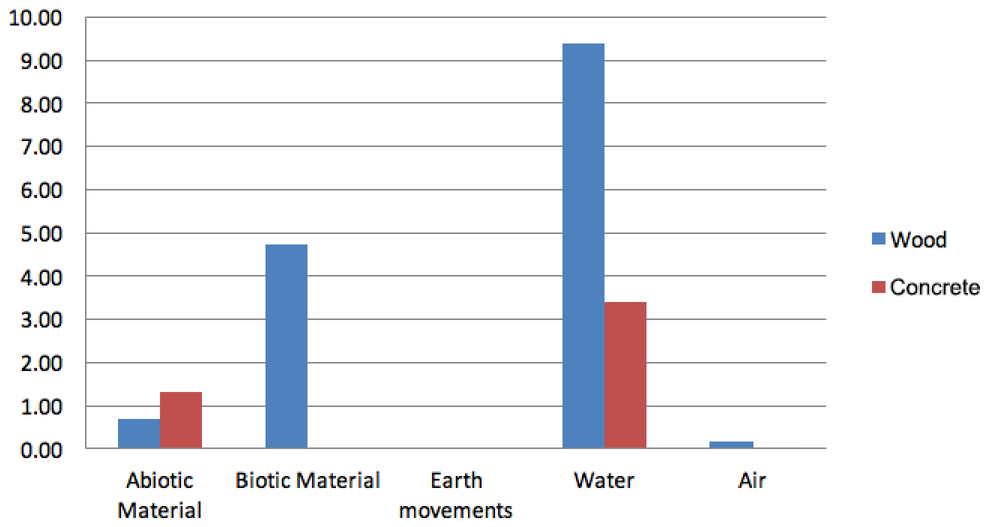


Figure 3-4: *MIPS results for concrete and sawn wood (kg/kg).*

The MIPS concept is characterized by considering resources used for a product or service, and although it does not show any specific environmental effect, the resouce input represents the "material footprint" as indicator of generic environmental pressure (see references in Bringezu et al. 2016). A basic rationale behind the indicator is that the resouce input determines the bundles of environmental impacts on the extraction and disposal and emission side and that a reduction of those input flows tend to reduce those impacts. One advantage of the input calculation is also that resource use is easier to quantify than the emissions. Figure 3-4 shows that the categories "abiotic material" and "biotic material" are particularly relevant for this paper's resource evaluation discussion. MIPS can also be calculated and recorded to show the relative proportions of the upstream process inputs as shown in Figure 3-3 (Saurat and Ritthoff 2013).

Whole building level

The previous building material level assessment indicated MIPS's adequacy to quantitatively model abiotic and biotic material consumption (Wallbaum 2002). From here on, focus will be given to the other life cycle based methods, to get an overview on how they handle resource use and consequent emissions on the whole building level. Figures 3-5, 3-6, and 3-7 present results for applying the three LCA methods to two multi-family houses (mfh10 and mfh12), built in Switzerland after 2006. Since CML 2001 does not support aggregation to the single score level, its results are presented separately for each impact category.

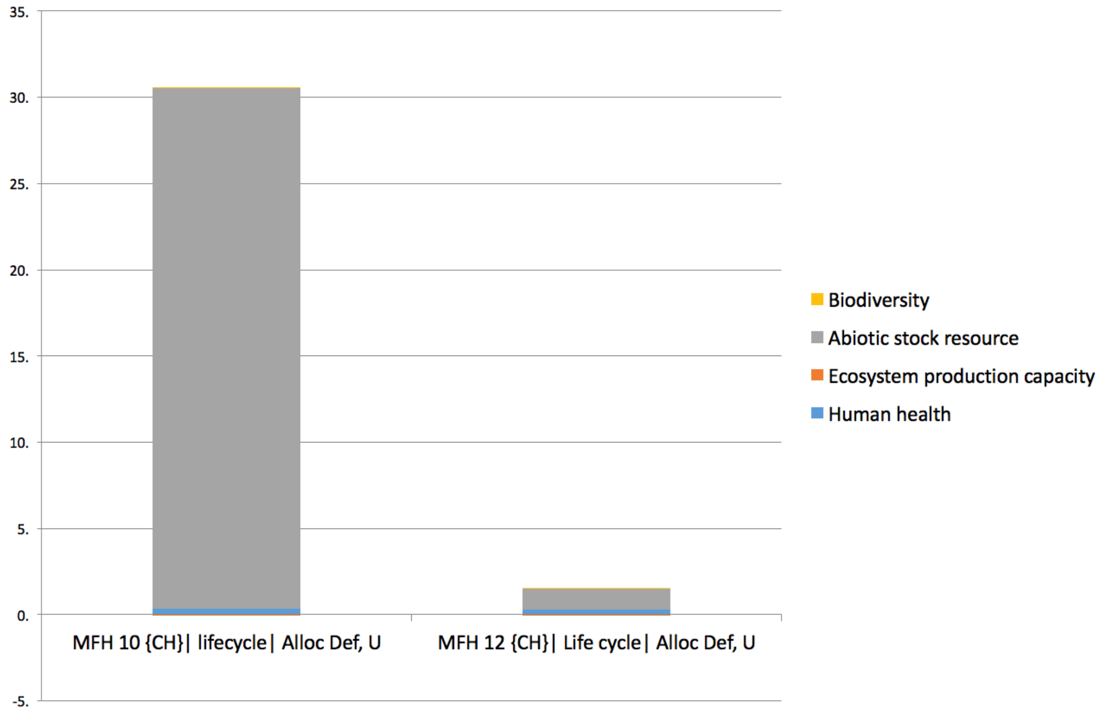


Figure 3-5: *Comparison between MFH10 and MFH12 using EPS2000.*

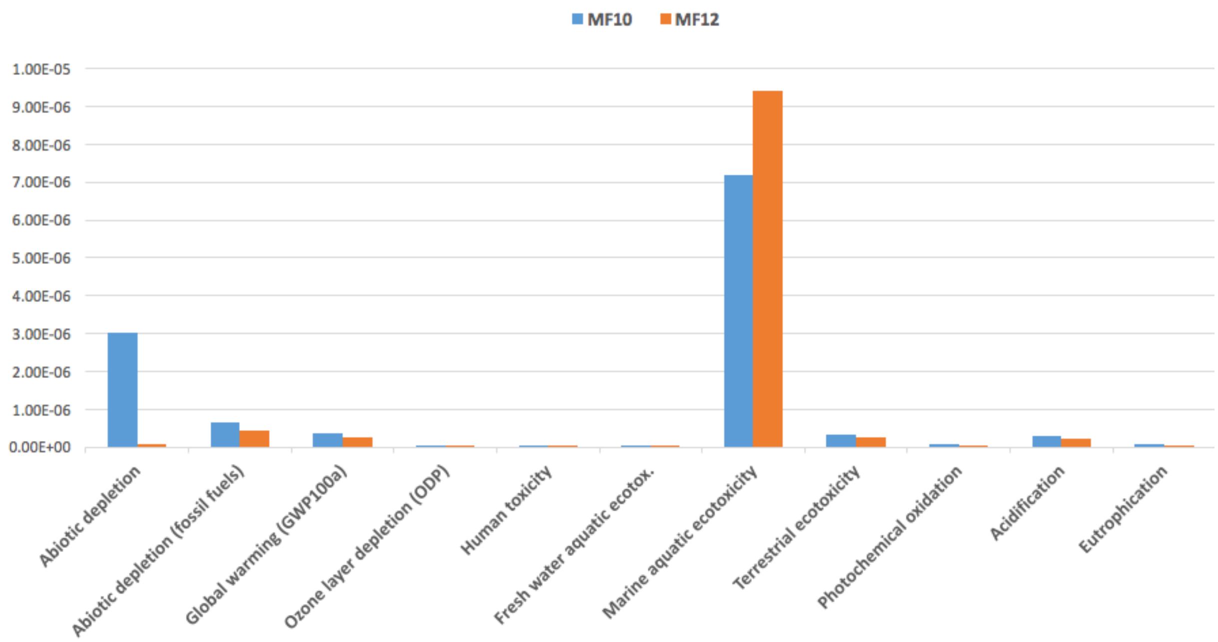


Figure 3-6: *Comparison between MFH10 and MFH12 using CML 2001.*

The three figures portray MFH12 as the building with the best environmental profile, with the exception of CML's category "marine aquatic ecotoxicity" (Figure 3-6). When focusing on the resource use results, the only method that showed MFH12 as a bit more intensive in resource consumption was Ecological Scarcity 2006 (green column, in Figure 3-7), due to the wood-frame used by that building. That method's "natural resource" category is the only one among the assessed life cycle based methods that takes bio-based materials use into account.

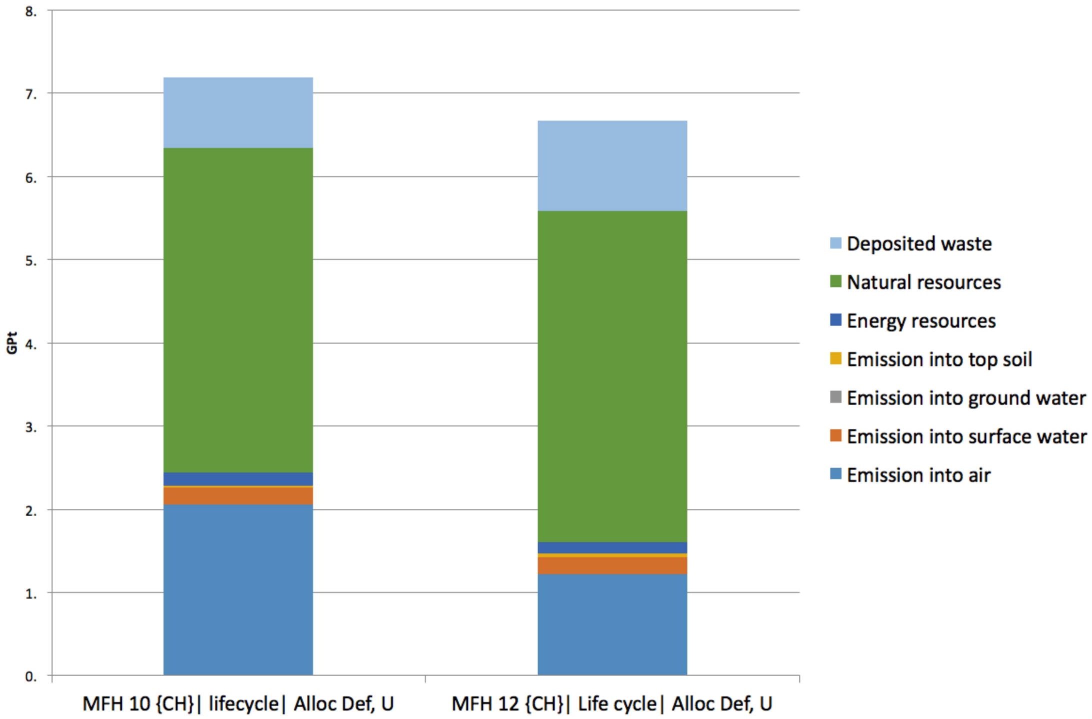


Figure 3-7: *Comparison between MFH10 and MFH12 using Ecological Scarcity 2006.*

Initial framework for developing a resource use assessment method

Members of the advisory group of this study were interviewed to indicate the most relevant target questions. Table 3-1 summarizes the experts' opinion, describes the objectives to be addressed in each case and lists possible preliminary indicators for each of them, if available.

Assessment criteria	What is covered?	Goal	Possible preliminary indicators
Resource availability/-scarcity	The available “reserves” and their utilization rate	Ensuring a sustainable/cross-generational availability of material resources	CML baseline “abiotic depletion potential” OR EPS “abiotic stock resource” category
Resource use related environmental impacts	Primary material resources used	The reduction of the mass related use of material resources with the same or even increased functionality that implies the reduction of the resource use related environmental impacts	MIPS
	The resource use related environmental impacts (emissions into soil, water and air)	Reduction or avoidance of eco- and human-toxic emissions	Ecological Scarcity 2006/2011 emissions-related categories, applied to the specific resource being used
Dilution potential	The loss or the recovery rate of the resource use	Reduction or avoidance of dissipative losses	CML 2001 Alternative 1 “abiotic depletion potential-elements”, considering van Oers et al (2002) proposed characterization model

Table 3-1: *Assessment criteria, indicators and goals used to assess the use of material resources over the entire life cycle.*

Preliminary indicators were chosen based on the assessed methods. Specifically for the dilution potential goal, authors draw attention to the recommendations made by van Oers et al (2002), that involve modifying CML 2001 Alternative 1 equation, by substituting the extraction rate with a leakage rate of elements, minerals and energy from the economy, and by assuring that the “reserve” parameter would refer to reserves in both the economy and the environment. This was further discussed and assessed in van Oers and Guinée (2016).

Jointly assessing each target issue is in line with Drielsma et al (2016) statements, regarding the importance of giving due consideration to fixed stock (such as target 1) and opportunity cost (such as target 3) concerns to ensure decisions drawn from both results actually contribute to a more sustainable future.

Discussion

The aim of the study was to examine current environmental assessment methods' ability to address the use of natural resources in construction sector, focusing on the "material resources" and not on the "energetic resources". For practical reasons methods used in environmental life cycle assessments were analyzed, together with the life-cycle-based MIPS concept and the ecological scarcity method, which are not classified as classical LCA evaluation systems and were not offered by default in the software. A total of 12 evaluation methods were investigated in the first step resulting with four methods suitable for the study's objectives. The main reason for the exclusion of the other eight rating systems is that these methods evaluate "only" energy resources use as a characterization factor for total resource use, which is not consistent with the aims of the study.

It is noteworthy that only two of the valuation methods commonly used in the LCA (e.g. CML 2001 and EPS 2000) evaluate the use of non-energy resources explicitly. This can probably be explained by the main history of LCA. Analogously to the history of environmental policy, which has been dominated for decades by a pollutant discussion, LCA has mainly focused on the emission-side evaluation of products and services.

Only the MIPS concept explicitly provides the use of resources classified by abiotic, biotic, water, soil and air. This procedure allows that both renewable as well as non-renewable materials can be displayed graphically with their resource requirements. According to the concept, the earth moving non-used resource extraction (like excavation of soil which is relevant for construction activities) is also covered. This valuation method does not cover specific environmental effects of resource use and/or scarcity.

The ecological scarcity method summarizes the input as well as the output side in one single assessment method. This method's charm is that it explicitly takes Switzerland's national circumstances (climate, resource availability, absorption capacity of possible lowering etc.) into consideration. Moreover, the results of an environmental impact assessment are expelled in a simple form for decision-makers, which are expressed in a single number, the so-called environmental impact points. High aggregation levels and assumptions made regarding resource availability etc. may also be questionable for methodological reasons. Because of these properties, the ecological scarcity method even until today is not compatible with the accepted life cycle assessment valuation methods according to ISO 14040. In the ecological scarcity method's current version, released in 2011, a division of resource assessment by separately presenting mineral raw material usages was introduced, which was not available in the 2006 version. Renewable resources are mapped through land occupancy size assessment. To understand this evaluation method, it is important to understand that it works with so-called "eco-factors", which are derived from the corresponding environmental legislation or policy objectives. The more the current resources consumption exceeds the pre-defined environmental objective, the greater the eco-factor is, which is then expressed as environmental impact points (EIP).

The analysis gave first indications that none of the environmental assessment methods explicitly discriminates a building material nor prefers a specific type of construction. Nevertheless, through the selection or non-consideration of evaluation parameters, i.e. building materials or construction techniques, especially in a comparative study, it is possible to induce a positive or negative appearance of the overall assessment. It also became clear that individual assessment methods differ in regard to their objectives and, to date, no common understanding exists on how the use of natural resources should be assessed.

According to this study's advisory group opinions, resource's (i) availability/scarcity, (ii) use-related environmental impacts and (iii) dilution potential are the most relevant issues that a resource use indicator should tackle. Table 3-1 lists preliminary indicators that could be used for each target issue, based on the results presented on section 3. Future research efforts should then encompass the improvement of currently available impact categories and the development of a scientifically sound metric combining available indicators to assess the risk of life-cycle-wide material losses.

It is noteworthy that Environmental Product Declarations (EPD) and Product Environmental Footprints (PEF), methods which are increasingly used as a reliable and verifiable source of LCA-based information (Passer et al, 2015), would greatly benefit from a solid resource use metric. PEF models resource depletion using either the Ecological Scarcity method (for water use) or CML (for fossil based resources use), while EPDs basically rely on CML to model fossil and non-fossil based resource use. Information obtained from this study's outcome (cf. Table 3-1) should enrich resource use modelling and better aid decision-makers.

Conclusion

This compilation highlighted the need for an appropriate scientific and transdisciplinary discourse on how to handle natural material resources use, in particular in the construction industry and it became obvious that today the benefits from a sustainable use of natural resources is not fully addressed in LCA (see also Wahlström et al. 2014), which is a rather "toothless" requirement for buildings when used to implement the EU Construction Products Regulation (CPR).

4. INTEGRATING ANTHROPOGENIC MATERIAL STOCKS AND FLOWS INTO MODERN RESOURCE CLASSIFICATION FRAMEWORKS

Andrea Winterstetter ⌧, David Laner, Helmut Rechberger, Johann Fellner

Abstract

This study investigates how anthropogenic resources could fit into the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009). Compared to geogenic resources, anthropogenic deposits are more heterogeneous and often more decentralized. Further, the human impact on production, consumption and disposal, combined with significantly shorter time spans of renewal are major differences. Factors influencing the classification of anthropogenic material deposits include various aspects such as technological developments, market prices, laws, and ecological and social considerations. They can be systemized according to their role during the individual phases of resource classification, namely prospection, exploration and evaluation. The prospection phase is determined by 1) the deposit's status of availability for mining, discriminating between "in-use stocks", "obsolete stocks" and "waste flows", 2) by the specific condition of handling and potential mining (push vs. pull situation), and 3) the system variables, which determine the potentially extractable amount of materials. System variables (e.g. technological options) also play a major role during the exploration phase and can potentially be varied in a scenario analysis. For the socioeconomic evaluation modifying factors with direct impact on the project's economics are investigated. The influencing factors of mining anthropogenic resources from 1) an old landfill, 2) waste electrical and electronic equipment (WEEE) and 3) wind turbines are analyzed. To map such different types of anthropogenic materials within the three UNFC-2009 axes "knowledge on composition", "field project status and technical feasibility" and "socioeconomic viability", specific guidelines are still to be defined and need to be demonstrated via case studies. Ultimately, this will allow for a meaningful comparison of anthropogenic with geogenic mineral resources, promoting efficient resource use.

Keywords: anthropogenic resources; urban mining; United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009); resource classification; resource policy

Introduction

To alleviate raw material criticality issues and, thus, the dependency on monopolistic supply structures, governments and institutions have been increasingly promoting improvements in resource efficiency as well as in the utilization of so-called anthropogenic (secondary) resources (e.g. recycling of waste) (e.g. EC, 2011). In this study anthropogenic resources are defined as "stocks and flows of materials created by humans or caused by human activity, which can be potentially drawn upon when needed" (Winterstetter et al., 2015b). While the exploration of geogenic deposits is a well-established discipline, the knowledge on anthropogenic resource deposits and their availability for reuse and recycling is still very limited. To obtain a comprehensive overview of existing and potentially extractable anthropogenic resource inventories, it is therefore vital to provide a methodological framework for the evaluation and classification of anthropogenic materials.

Conceptual background

Starting in the early 18th century in Europe, first reflections on a more sustainable use of natural resources were primarily motivated by the perception of dwindling key raw material deposits, such as wood and coal (Carlowitz, 1713, Jevons, 1906). Considered as the precursors to modern resource classification systems, their common feature is managing scarce commodities by making potential resource extraction projects comparable for involved stakeholders. After the Soviet Union's collapse the German Government proposed a new classification system to the UNECE Working Party on Coal to compare the vast resources in the formerly centrally planned economies to those in the market economies (UNECE, 2013).

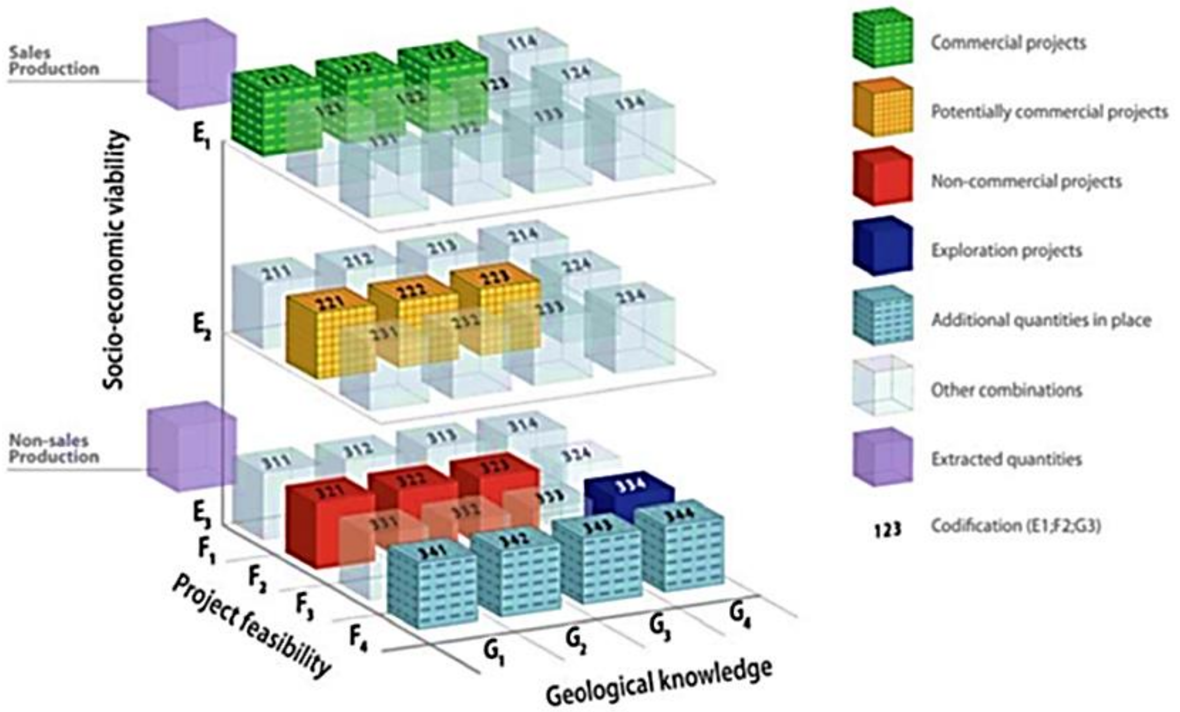


Figure 4-1: *United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009). Reproduced courtesy of the United Nations Economic Commission for Europe (UNECE, 2010).*

The United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources (UNFC) has been initiated by the UN Economic Commission for Europe, which was revised in 2009 and is today known as UNFC-2009. Under UNFC-2009 quantities are classified on the basis of the three fundamental criteria, namely "socioeconomic viability" (E1 – E3), "field project status and technical feasibility" (F1 – F4), and "knowledge on composition" (G1 – G4), with E1F1G1 being the best category (cf. Figure 4-1) (UNECE, 2013).

Objectives

This study investigates how anthropogenic resources could fit into UNFC-2009. The influencing factors of mining anthropogenic resources from 1) an old landfill, 2) waste electrical and electronic equipment (WEEE) and 3) wind turbines are analyzed.

Heterogeneity of anthropogenic resources: An attempted systemization

Evaluating anthropogenic resources requires a somewhat different approach compared to geogenic deposits. The human impact on production, consumption and disposal, combined with significantly shorter time spans of renewal were identified as major differences.

To facilitate the classification of mining specific materials from a range of radically different and decentralized human-made sources, which is often linked to big technical and legal uncertainties, influencing factors can be systemized according to their role during the individual phases of resource classification. The prospection phase is determined by 1) the deposit's status of availability for mining, discriminating between "in-use stocks" vs. "obsolete stocks" and "waste flows", 2) by the specific handling and mining condition and 3) the system variables. While the status of availability and the specific handling condition represent the preconditions for potential mining activities by defining the setting for the following classification, system variables determine the amount of technically extractable materials.

When prospecting anthropogenic resource deposits, there can be two types of conditions: In a push situation, like in the case of WEEE flows, anthropogenic materials have to be treated (this may include material recovery to reduce costs) due to legal requirements, whereas in a pull situation the materials are mined only if the initial socioeconomic evaluation is positive and otherwise left untouched, like in the case of mining a landfill for resource recovery, which comes close to mining geogenic resources. In a push situation optimal solutions within the given legal framework are sought (Winterstetter et al., 2015b).

System variables also play a major role during the exploration phase. In order to account for different (possible) sets of system variable values scenario analysis can be used. During the actual socioeconomic evaluation of resource extraction and valorization the modifying factors are investigated. Modifying factors, e.g. commodity prices, have an immediate impact on the project's socioeconomic viability and can potentially move the classification status of a given material deposit along the E-axis of UNFC-2009 from "non-commercial" to "potentially commercial" (resource) to "commercial" (reserve). They can hardly be influenced, but may change over time (Winterstetter et al., 2015b).

Phases & UNFC-2009 axes	**Influencing factors**	
Prospection	**Availability**	• **In-use stock:** Currently not available for mining (e.g. Nd in wind turbines), but at some point in the future • **Obsolete stock:** Potentially available for mining, sometimes even required (e.g. old landfill) • **Waste flows:** Treatment required (e.g. WEEE)
	Mining / handling condition	• **Pull**: Deposit can be mined • **Push**: Materials must be extracted from the deposit due to system constraints
Prospection (G-Axis) & Exploration (F-Axis)	**System variables**	System variables determine the amount of potentially extractable materials Different sets of system variables can be considered via **alternative scenarios**, but throughout a specific evaluation process, the system variables are **exogenously given** (e.g. composition, extraction technology, laws).
Socioeconomic evaluation (E-Axis)	**Modifying factors**	Modifying factors have a direct impact on the project's economics. They can hardly be influenced, but may change over time (e.g. commodity prices, treatment costs).
Classification	Combination of all criteria & classification under UNFC-2009	

Table 4-1: *Procedure for the classification of anthropogenic resources under UNFC-2009, based on Winterstetter et al. (2015b).*

Illustrating examples: Mining waste flows vs. obsolete stocks vs. in-use stocks

Waste Flow: WEEE

Treating waste flows, such as WEEE, typically represents a **push situation**. The management of WEEE flows in the European Union is mainly regulated and driven by laws, in particular by the EU directive 2012/19/EU, determining the annual collection, reuse and recycling targets. Under the extended producer responsibility (EPR) producers have to finance the take back of WEEE from consumers, guarantee their safe disposal and fulfill the set recycling targets (Directive, 2012). So here the question arises on how to treat WEEE in a socioeconomically optimal way within the given legal constraints. The amount of potentially extractable materials contained in a WEEE flow is influenced by **system variables,** such as the waste flow's volume, the product type and size, the share of usable materials and potential hazardous substances, as well as the recyclability of the specific product type. The technical and project feasibility of mining WEEE is chiefly determined by the set-up of the collection and recycling system. A considerable number of stakeholders is hereby involved with different responsibilities, such as legislators, producers, retailers, consumers, recyclers and municipalities (e.g. Huisman et al., 2008). Aside from collection, the recycling chain for WEEE consists of further succeeding steps, namely sorting, dismantling, pre-processing, and end-processing, which includes refining and disposal. A wide range of different treatment technologies are available, which can (potentially) address the specific needs of each product group (e.g. Dalrymple et al., 2007). Methods with higher recovery efficiencies are more likely to be selected if markets for the output fractions exist and if expected price levels are high enough to justify higher treatment costs or if alternative treatment and disposal costs can be avoided, i.e. if **modifying factors** with direct impact on the economics are positive. Under UNFC-2009 only confined projects can be classified. Therefore, spatial and temporal system boundaries have to be determined for waste flows (UNECE, 2010).

Obsolete stock: Old landfill

Mining stocks, such as old landfills, can either represent a **push or a pull situation**. In a **pull situation,** mining an old landfill requires positive socioeconomic prospects either for a private investor or a public entity, since the alternative of mining a landfill is regulated aftercare, where the closed landfill is simply left untouched. If the landfill represents an immanent threat to the environment, e.g. to groundwater, or if new landfill space is urgently needed, authorities will oblige the former landfill operator to act, i.e. the pull situation turns into a **push situation**, similar to mining a waste flow. When classifying a landfill-mining project in a pull situation, system variables, such as the landfill's location and size, its ash and water content, the share of valuables, combustibles, non-recyclables or even hazardous substances, and the contamination of the fine fraction, are considered as given for a certain scenario and the main focus is set on the modifying factors. Modifying factor with immediate impact on the economics differ, however, according to the chosen stakeholder perspective. A private investor is only interested in direct financial effects, while non-monetary effects tend to be ignored, if they are not internalized in form of subsidies (e.g. Bockreis and Knapp, 2011). A public entity, on the other hand, is more interested in long-term societal and environmental effects (Graedel et al., 2012), such as the elimination of a source of local soil and water pollution, the avoidance of long-term landfill emissions, or the creation of new jobs (e.g.Van Passel et al., 2013, Winterstetter et al., 2015a).

In-Use Stock: Nd in wind turbines

In-use stocks of NdFeB materials in wind turbines are currently not available for mining, but will become waste flows in the foreseeable future. Most probably the recycling of wind turbines will be regulated by laws soon, similar to the EU WEEE directive, based on the producer responsibility principle (Cherrington et al., 2012), meaning that permanent magnets and / or Nd materials will have to be extracted from wind turbines **(push situation)**. So, non-monetary effects, such as avoided environmental burden or positive societal externalities (e.g. supply security) can be internalized. To classify potential future mining projects of in-use stocks mainly **system variables** are considered. Generating in-depth knowledge on a deposit's resource potential has priority over the following socioeconomic evaluation, which is obviously linked to high uncertainties, due to not (yet) existing commercially proven technologies and thus precise knowledge on the share of potentially extractable and usable materials. The in-use stock's composition and its potentially extractable share of materials within the defined boundary conditions is determined by type, size, location and the total number of the wind turbines and the contained permanent magnets, as well as the ease of dismantling wind turbines (Gattringer, 2012). Uncertainties stem from producers' information and data, from the emergence of rare earth elements (REE) alternatives, from raw material and energy market dynamics as well as from governmental renewable energy policies (Schüler et al., 2011). Uncertainties arise also from the technical feasibility of recycling permanent magnets, since manufacturers typically do not publish reports or data on their individual recycling processes (Sonich-Mullin, 2012). Therefore, information on recovery efficiencies, investment and operating costs can practically not be found. The choice of specific methods and technologies for removing permanent magnets from wind turbines, and processing and separating REE from the magnets, influences the final amount of recovered materials, such as iron, boron and REE

(Nd, Dy, Pr etc) or entire permanent magnets, as well as investment and operating costs (Binnemans et al., 2013). Similar as in the case of WEEE costly technologies are more likely to be chosen if **modifying factors** are positive, e.g. if expected price levels for output materials justify higher treatment costs.

Conclusions & Outlook

This study investigated how anthropogenic resources could fit into UNFC-2009 and mapped within its three axes “knowledge on composition”, “field project status and technical feasibility” and “socioeconomic viability”. Factors influencing the classification of anthropogenic material deposits can be systemized according to their role during the individual phases of resource classification, namely prospection, exploration and evaluation. The prospection phase is determined by 1) the deposit’s status of availability for mining, discriminating between “in-use stocks”, “obsolete stocks” and “waste flows”, 2) by the specific condition of handling and potential mining (push vs. pull situation), and 3) the system variables, which determine the potentially extractable amount of materials. System variables also play a major role during the exploration phase and can potentially be varied in a scenario analysis, e.g. for different technological treatment options. For the socioeconomic evaluation modifying factors with direct impact on the project’s economics are investigated. Exemplarily, the influencing factors of mining anthropogenic resources from an old landfill (obsolete stock), from e-waste (waste flow) and wind turbines (in-use stock) were analyzed.

In order to obtain a comprehensive overview of existing and potentially extractable anthropogenic resource inventories and to allow the full integration into UNFC-2009, specific guidelines are still to be defined and need to be demonstrated via case studies, to account for the heterogeneous nature of anthropogenic resources. This will facilitate decision-making for political and private business stakeholders and allow for meaningful comparisons between anthropogenic and geogenic mineral resources, promoting efficient resource use.

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5. HOW THE ENERGY BUDGET SCHEME CONTRIBUTES TO DECOUPLING AND DEEP DECARBONISATION

Klára Hajdu ✉, Veronika Kiss

Abstract

Resource use is increasing globally, and four of nine planetary boundaries have now been crossed due human activities, out of which climate change and biosphere integrity are "core boundaries", implying a risk of driving the Earth system into a new state. While technological advances, policy changes and burden shifting from developed to developing countries have led to decoupling in many countries, this does not change the negative trends globally and address the main drivers behind. In the case of climate change deep decarbonisation of the global economy would be required resulting in radical emissions reductions.

The objective of this paper is to analyse the main reasons of the rift between what climate science requires and what current climate policies can deliver with the currently applied policies, and how an international energy budget scheme can tackle these problems. The energy budget scheme builds on initiatives like the energy entitlement scheme and the Tradable Energy Quotas (TEQs), which gained considerable political recognition in Hungary and in the UK respectively, building on substantial scientific research.

The energy budget scheme puts a hard cap on energy use, and links this with incentive schemes to deliver tightening national and international targets. The annual entitlements for energy use for households and all other public and private consumers ensure the needed reductions in greenhouse gas emissions, while the trade in entitlements among consumers on national level and countries on international level contributes to value change, global energy transition and puts Common but Differentiated Responsibilities (CBDR) into practice. The transition fund provides a financing scheme for driving investment and technological innovation, where the payback rate is linked to improvements in decarbonisation and made through unused entitlements. The dedicated market for environmental products and services operates with quota currency realised from entitlement savings, and boosts the green economy.

Keywords: quota, hard cap, decarbonisation, climate change, green economy.

Introduction

Mankind is using more and more resources, leading to an increase of total material extraction by a factor eight in the 20th century considering biomass, fossil energy carriers, ores and industrial minerals, and construction minerals (Krausmann *et al*., 2009). Even though population growth was a major driver behind the increase (Steinberger *et al*.,2010), the average per capita metabolic rate also doubled (Krausmann *et al*., 2009).

At the same time four of nine planetary boundaries have now been crossed out of which climate change and biosphere integrity are "core boundaries", implying a risk of driving the Earth system into a new state (Steffen *et al*, 2015). Crossing these core boundaries pose a serious threat on human wellbeing (MEA, 2005a; Stern, 2007), with numerous consequences already felt in all parts of world. Resource use is a major drive behind environmental degradation, and in particular the use of fossil fuels plays a leading role in climate change while climate change is a major pressure leading to biodiversity loss (MEA, 2005b). Thus, resource use has indirect impact on both of these planetary boundaries.

Analysing the trends of resource use and economic activity (UNEP, 2011), a resource decoupling can be observed in the last century, which was “spontaneous” rather than a result of policy intervention. While there seems a correlation between metabolic rates and income among countries, there are still substantial variations, implying that many countries benefit from higher incomes per capita at lower metabolic rates per capita. On one hand this can be related to population density of the countries, and on the other hand to trade, resulting from the relocation of primary and secondary sectors (and related resource use and impacts) from developed to developing countries (UNEP, 2011).

The International Report Panel outlines three scenarios for future resource use (UNEP, 2011). The tough contraction and convergence scenario, which would be more or less in line with the necessary efforts to prevent global warming beyond 2 degrees, would require unprecedented level of innovation. In addition, the report also stresses that this would imply not only technological innovation, but also institutional and relational innovations. Several researchers advocate for sustainability oriented innovation systems (SOIS), which “refers to the transition from one socio-technical system to another, qualitatively different one” (Geels & Elzen in Stamm *et al.,* 2009 p.26). The challenge that climate change poses in achieving deep decarbonisation of the global economy calls for such system level innovation.

Why current policies cannot deliver ambitious climate goals

Numerous policies to reduce greenhouse gas emissions have been introduced not only in developed, but also in emerging and developing countries. Climate policy measures include a wide range of measures from direct investments, fiscal incentives, market based instruments, through information provision and labelling, institutional creation, developing codes and standards and voluntary approaches (see an incomplete collection of policy measures in the climate policies and measures database of the IEA).

Targeted measures can increase investments, influence consumer choices or increase energy efficiency contributing to the lower carbon intensity of some economic sectors or individuals. However, considering the need for deep decarbonisation of the whole economy and a radical reduction of resource use that is substantiated above, two types of policies are more closely considered here, which could have the potential of a more transformative effect on the whole economy: the carbon tax and an emission trading scheme, both applied in several countries.

Various countries introduced carbon taxes together with tax reductions on labour costs in the last decades, realising a first step of environmental tax reform (ETR). Analysing European ETR examples with the Energy– Environment– Economy (E3) model for Europe, the results show that the ETRs caused just a modest reduction in fuel use and greenhouse gas emissions (with a maximum of 5.9% decrease attributed to ETR) in all the six examined countries and a very small increase in employment and GDP. The data show that higher taxes result in higher reductions of fuel consumption. In these examples, all the ETRs were assumed to be revenue-neutral (Andersen, 2010).

However, based on experiences of practical implementation, for instance the originally revenue neutral carbon tax in Switzerland was increased threefold in 2010 as the emission reductions were not on track, and one third of the revenue was channelled to the building refurbishment programme (submission to the IEA database). In another example the collected carbon tax in

Japan is used for several measures, such as subsidies and R&D support from the start. According to the estimates the emissions impact of the tax by 2020 is expected to be around 0.5–2.2 percent of CO_2 emissions in 1990, of which a minimal reduction results from a “price effect” (reduction in energy use through taxation) and the large majority comes from a “budget effect” (reduction through the use of tax revenue for emissions reduction measures) (submission to the IEA database). It is worth noting that even though Switzerland targets a 50% reduction of CO_2 emissions by 2030 compared to the 1990 level in its Intended Nationally Determined Contributions (INDC), this commitment is assessed medium by the Climate Action Tracker (Climate Action Tracker, 2015), falling below what would be necessary for preventing catastrophic climate change beyond 2 degrees. In addition, according to their analysis with the currently implemented policies and measures Switzerland will not be able to meet its INDC. Japan’s INDC is assessed as inadequate.

These analysis and examples suggest a trade-off between the possible objectives of a carbon tax. One objective could be to support the switching to renewables or increasing energy efficiency through channelling the revenues to measures, such as grants or subsidies or direct investments in R&D, in which case the tax is not revenue neutral. The other objective is capability to change consumer and investment behaviour while considering the needs of low income population and SMEs, i.e. reconciling policy efficiency with equity (making it revenue neutral). Additional concerns may arise with higher and thus more efficient tax rates on carbon in relation to the macroeconomic rebound effect of increased GDP (and employment), the decreased international competitiveness of energy intensive industries and the public acceptability. These concerns make it questionable if radical reductions of fossil fuel consumption can be achieved through the carbon tax as a main policy instrument.

Another relatively comprehensive market based instrument is the emission trading scheme (ETS) applied in Europe and several other countries. The EU ETS and the related flexibility mechanisms under the Kyoto agreement are heavily criticised for low efficiency in delivering decarbonisation, carbon leakage, as well as being open to fraud and speculation (Walter, 2013). What is more, the EU ETS only covers about 45% of emissions in the EU, and together with the Kyoto flexibility mechanisms it leaves the European economy without a hard cap on emissions.

As described below, many of the problems and challenges identified with these widely-applied measures can be more effectively addressed under a European energy budget scheme (Resource Cap Coalition, 2015), which is proposed by the Resource Cap Coalition.

The energy budget scheme as an effective means for decoupling and deep decarbonisation

The Core Scheme

As a central element of the energy budget scheme, energy consumption entitlements would be allocated among households and public and private organisations, covering high-carbon energy use. The total number of entitlements issued would equal Europe’s agreed energy budget, and decrease annually in line with the phase-out of fossil fuels. Consumers who use less than their allocated entitlements could sell them to the issuing body. Those, who need more could buy them from the issuing body if entitlements are available, thus effectively paying to the underconsumers.

The Transition Fund

The Transition Fund provides the opportunity for everyone, both energy producers and consumers, to realise future savings through energy efficiency and renewable energy investments. It also supports research and innovation in pursuit of close to commercial new technologies. The Transition Fund provides interest free loans in an alternative currency, so called 'quota money' with a payback period adjusted to the anticipated energy savings or income generation. The Transition Fund can also facilitate investments where beneficiaries are unable to contribute financially.

A Dedicated Market for Environmental Goods and Services

There is also the possibility of incorporating a dedicated market for environmental goods and services. This would be a market open only to those achieving certification on environmental and ethical criteria for goods or services, e.g. for outstandingly energy efficient appliances, organic food products produced with low-carbon energy input, electric vehicles or solar panels, or services offering insulation of buildings, installation of local renewable energy capacities or the building of passive houses. Income from the sale of energy entitlements could be given in the form of 'quota money' that could only be exchanged for products and services in this dedicated market.

Support Service

A supplementary Support Service on national level would provide advice to all energy consumers on lifestyle, planning, social and environmental issues, as well as information on the functioning of the scheme.

International application

The selling and purchasing of energy entitlements can also take place on international level among countries, based on national carbon budgets and how they compare to internationally agreed per capita carbon consumption. These predictable and objective international financial transfers can support developing countries in developing and modernising their energy sector through channelling the international transfers to the national Transition Fund or establishing the necessary institutional and physical infrastructure for introducing the energy budget scheme.

Feasibility of the scheme

The energy budget scheme is based on two national schemes, which were each assessed by a number studies. The UK government feasibility study (Defra, 2008) on the TEQs (which includes Tradable Energy Quotas, but no dedicated market and Transition Fund) in 2008 found that there were no technical obstacles to implementation. It also declared that personal carbon trading would be a progressive policy and that public acceptability was comparable with, or slightly better than, the presented alternatives of upstream trading and carbon taxation. However, the most influential report within the study assessed the "potential effectiveness and strategic fit" of the scheme (Elderkin, 2008). Unlike the other reports, this explicitly considered a personal carbon allowance scheme (i.e. applied only to individuals), thus removing several of the key benefits of TEQs. On this basis, the analysis concluded that the costs would outweigh the benefits, so the government withdrew from funding further research at that time, although expressing continued interest (Defra, 2008). Substantial research since, including

2011's high-profile cross-party parliamentary report (Fleming and Chamberlin, 2011), has challenged these negative conclusions.

The strategic environmental assessment of the Hungarian entitlement scheme (Tombácz, 2009) also analysed the impacts and several feasibility aspects, and found several positive environmental, economic and social impacts. Even though the concept attracted serious public and political support in 2008-2010, the governmental change prevented the parliamentary adoption of the proposed climate bill. However, Hungary's National Energy Strategy (Nemzeti Fejlesztési Minisztérium, 2012) includes a proposal for an energy cafeteria, which is based on personal energy quotas allocated for citizens, where savings can be exchanged for vouchers. These vouchers could be spent for low carbon intensity goods by certified producers.

Benefits of the energy budget scheme compared to other climate policy measures

The energy budget scheme is able to serve multiple objectives within a coherent framework.

It provides a **consistent and coherent European policy framework**, while allows for national flexibility in the details of implementation. The scheme links the guaranteed reduction of emissions with the financial incentives of switching to renewables and increasing energy efficiency, as well as boosting the green market through generating demand and supporting innovation. As the success of these separate measures depend on each other, this system level intervention can unlock huge potential for behavioural change, market transformation and innovation. This is a huge added value compared to other, narrower policy instruments.

It puts a hard cap on energy use (and consequently on emissions) in line with the global carbon budget that climate science determines. Thus, it is able to **guarantee the environmental outcomes** of the policy (Chamberlin *et al*., 2014, Tombácz, 2009), as opposed to taxing schemes and other cap and trade schemes with a soft cap. Thus, a radical reduction in emissions and a phase out of fossil fuels becomes a reality.

It can **reconcile policy efficiency and equity**. As underconsumers can sell their unused energy entitlements and overconsumers need to buy entitlements if they want to consume energy above their quota, this policy is effective in applying the polluter pay principle. On the contrary, carbon tax can put excessive burden on low income consumers, even though their responsibility might be relatively lower in the taxed pollution. In addition, state subsidies and grants are ultimately financed from taxes also from those, who less contribute to the problem of climate change through low carbon lifestyles (Tombácz, 2009). Going beyond the concept of equity these mainstream policy measures financed by the society at large divert financial resources from the necessary renewable and efficiency investments that should be realised by the consumers. The energy budget scheme, however, only diverts financial resources from the overconsumers, and only to the extent to reach behaviour change (Tombácz, 2009).

It uses limited **financial resources efficiently**, as state revenues are not used in the form grants and subsidies or tax incentives. Instead the Transition Fund provides zero interest loans in quota money to support the proliferation of low carbon technologies.

The scheme can **prevent carbon leakage** through the establishment of the Transition Fund, which can help companies switching to renewables or increasing energy efficiency, as a means to prevent increasing energy bills (Tombácz, 2009).

It increases **public acceptability** and thus the political feasibility of introduction. This is on one hand related to its ability to ensure equity, and on the other hand it generates intrinsic motivation for the public through the sense of a common objective and the opportunities of cross-sector cooperation, which can effectively drive behavioural change (Chamberlin *et al*., 2014).

It boosts deep decarbonisation and a transition to a circular economy through the **creation of a dedicated market** for environmental goods and services. Even though several other policy measures, such as performance labels, tax incentives, grants can also provide incentives for a green economy, their positive environmental impact can be easily lost due to the rebound effect on consumer or macroeconomic level without having a hard cap on energy use, while they could demand substantial state financing.

It creates an interest free **alternative currency** ("quota money") for the trade of energy entitlements, buying goods and services in the dedicated market and providing interest free loans from the Transition Fund. Even though the alternative currency can be exchanged to the national currency (with the payment of a commission fee), it boosts the dedicated market through generating demand for goods and services on the market through the accumulation of the quota money. The zero-interest nature of the quota money increases its velocity (i.e. how fast it changes hands through transactions) compared to the national currency, which further boosts the green economy (Tombácz, 2009).

As opposed to other price based mechanisms it **creates a predictable business environment** for the transformation of energy use, ensuring energy security and affordability. This is achieved through the determination of midterm and longterm targets of carbon intensive energy use reduction.

It effectively **promotes CBDR** in the international context through linking the application of national carbon budgets with international fiscal transfers from countries that overconsume on per capita basis to countries that underconsume. This framework also helps to move beyond the outdated differentiation of Annex I and Annex II countries under the UNFCCC based on objective criteria.

Conclusions

The energy budget scheme is a viable alternative of current climate policy measures, and deserves due attention among national and international policy makers. A European level sustainability impact assessment should be carried out to quantify the environmental, social and economic costs and benefits of the scheme within the European context, and its contribution to the global efforts to prevent global warming beyond 2 degrees.

6. CROSS-BORDER ELECTRICITY INFRASTRUCTURES AND EFFICIENT USE OF RENEWABLE ENERGY SOURCES

Karolis Gudas ✉

Abstract

Long-distance renewables integration projects emerge as feasible option for the decarbonization of the electricity sector and efficient use of resources. The paper provides an overview of the large-scale cross-border projects being implemented in the electricity sector, which among their objectives aim at integrating renewable energy sources. It reviews the role of multilateral regimes in the development of cross-border transmission links, outlines the challenges, and makes policy recommendations for regulatory developments in the international system.

Keywords: renewable electricity, cross-border electricity exchanges, world trade organization, energy charter treaty

Introduction

The integration of renewable energy-sourced electricity into the transmission systems on a wide geographical scale was introduced as early as 1930s by a famous systems theorist, Richard Buckminster Fuller. He modelled the use of abundant renewable energy sources to supply electricity to population centers around the world through an interconnected global electricity grid. Several decades later, in the 1950s, the United States (US) already planned hydroelectricity transportation from dams constructed in the Pacific Northwest to consumers in Southern California over the course of 1 000 km.

Now, more than ever the environmental aspect of electricity is driving both local and abundant renewables integration into electricity systems. Much of the infrastructure features cross-border element, as cost-efficient renewable electricity production often requires large-scale renewables integration (including wind, solar, hydropower and geothermal) into the high-voltage transmission lines, which often traverse territories of more than one state (IEA, 2013; IEC, 2013; Buchan, 2013).

However, the potential to exploit the benefits of interconnection of electricity systems in many parts of the world is still not harnessed. The nature of problems of interconnection and management of cross-border electricity systems range from the lack of coordination, strategic aspect of electricity, technological limitations, and security of supply to abuse of law, technical, fiscal, geopolitical and economic problems (Sovacool et al., 2013).

Based on the assumption that certain electricity transmission projects of cross-border nature have a potential to integrate large-scale' renewable energy sources and, therefore, substantially contribute to the climate change mitigation and rational resource use objectives, this paper focuses on the regulatory environment of the construction of cross-border electricity transmission links.

Section 1 reviews the wide-area electricity grid projects being implemented. Section 2 provides an overview of the investment regimes in the cross-border transmission links. Section 3 reviews the role of multilateral agreements. Section 4 finalizes with the policy recommendations.

Wide-area cross-border electricity transmission projects

The very first electricity systems began to interconnect after World War I in Europe and North America with the development of high-voltage transmission technologies which enabled the transportation of electricity over long distances. The distances of transmission links had, by then, reached beyond 600 km. Today, the operational high-voltage overhead transmission lines exceed lengths of 2 000 km, and high-voltage submarine transmission lines are planned for distances beyond 1 500 km (Gudas, 2016).

The developments in transmission technologies have triggered the assessment of feasibility and implementation of long-distance electricity transmission projects (Chatzivasileiadis et al., 2013).

The European Network of Transmission System Operators for Electricity (ENTSO-E), for instance, has developed the concept of a European Supergrid. It is projected to connect wind farms and other renewable energy sources across the Northern Seas of Europe to mainland Europe and regions around Europe's borders via a 10 000 km offshore cable supply chain, and a 27 000 km onshore cable supply chain (ENTSO-E, 2014; Corbett, 2013).

In 2012, the Southern African states established the Southern African Power Pool to enable trade in electricity between twelve Southern African states, and contribute to the renewables' integration in the region. Through the developments in the electricity generation and cross-border electricity transmission links, the share of renewable energy has the potential to increase by 36% in the member states of the Southern African Power Pool (IRENA, 2013)

In 2015, the Central American states have established the Central American Electrical Interconnection System, which connects through 1 800 km length transmission line the power grids of, and enables trade between six Central American states. The system contributes to the alleviation of periodic electricity shortages in the region, and optimizes shared use of hydroelectricity.

The Governments of Russia, China, Mongolia, Japan and South Korea aim to implement the Gobitec project. It is designed to transmit solar-based electricity produced in Gobi and Taklaman deserts over 2 000 km length transmission lines (Mano et al., 2014). The Gobitec project is based on the Desertec concept, which estimated that with a loss of 3% of electricity per 1 000 km, solar power would be sufficient to supply from deserts and arid regions to most parts of the world (Desertec, 2011).

The traditional benefits of interconnection required for renewable' electricity integration include lower overall costs of electricity supply, more efficient use of resources, increased access to renewable energy sources, prospect of locating power plants away from large population centers (Gönen, 2014), reduced balancing costs and greater access to more flexible power plants located in a wider geographical area (Sauvage et al., 2013).

However, performance of electricity systems may decrease with size, loading and complexity of the electricity grids (Kassakian et al., 2011). They may result in uncontrollable cascading effects leading to blackouts, such as the ones experienced in North America (2003), Indonesia (2005), Europe (2006), India (2012), which deprived millions of electricity consumers from the access to electricity for a limited period of time.

Investment in the transmission system options

Until the liberalization of the electricity markets in the 1980s, vertically-integrated undertakings typically controlled construction, use, and operation of the transmission and distribution systems, as well as the generation and supply side of electricity. Historically the transmission system operators had monopoly power over the decision of the investment into the transmission links. The investment options in the transmission system had been strictly limited to third-parties regardless of their potential contribution towards the objectives pursued by the state (renewables' integration, security of supply, etc.). Today the investment regimes differ from jurisdiction-to-jurisdiction largely depending on the market structures.

In Argentina, for instance, major new transmission investments take place only where users vote in favour for them, and are prepared to pay (Littlechild, 2003). Australian law allows third parties (Lévêque, 2006) to invest in the electricity network and become eligible for regulated revenues (Chatzivasileiadis, 2012). The law of Hawaii (US) allows a private developer to finance, build and operate the undersea cable, with the view of RES integration into the power production, after approval by the public utilities commission. EU law allows, under certain conditions, the construction of new interconnectors with state intervention, by a transmission system operator or by a merchant investor. Each and every investment option is subject to different eligibility and incentive regimes (Gudas, 2015).

However, many states in Latin America, Asia and Africa still restrict the participation of third-parties in the transmission market. They left the development and operation of the transmission links as a monopoly of the state or the undertaking owned or controlled by the state regardless of liberalization of electricity generation or other sectors.

International agreements and construction of the cross-border electricity transmission links

Historically the role of public international law in the facilitation of construction of the cross-border electricity transmission links has been symbolic. Each of the cross-border transmission links is subject to jurisdictional requirements, which may be conflicting in nature from procedural and substantive points of view. The conflicting jurisdictional requirements as well as restrictions imposed on the investment in the transmission links often deprive investors from commercial opportunities to plan the infrastructure projects, which are not only economically feasible, but also necessary in view of climate change mitigation objective. They often fall out of scope of any multilateral agreement.

The 1923 Convention Relating to the Transmission in Transit of Electric Power, adopted in Geneva (the 'Geneva Convention'), was the only one designed to regulate construction of the cross-border electricity transmission links. It was negotiated under the example of cooperation between Italian, Swiss and the French electricity systems. The electricity interconnections between Italy, Switzerland and France enabled in 1921-1922 to provide Italy electricity from France and Switzerland, when Italy suffered from a severe draught reducing hydroelectricity yields (Lagendijk, 2008). However, the Geneva Convention was of minor international significance. First, it did not entail any practical commitments. Second, very few states did ratify it (Roggenkamp, 1994).

All subsequent negotiations on the international agreements which were specifically designed to facilitate construction of cross-border energy infrastructures have been unsuccessful. The negotiations on the draft Transit Protocol of the Energy Charter Treaty have ended in 2011 without a conclusive result. The draft Convention on Ensuring International Energy Security, prepared by Russian experts, has hardly been discussed by the international community. However, both the draft Transit Protocol of the ECT and the draft Convention on Ensuring International Energy Security contained provisions on construction of cross-border energy infrastructures. The latter stipulated a requirement not to impede the creation of new transmission capacity without excessive delays. The former one required to have in place authorization procedures on legislation concerning the construction, expansion, extension, re-construction and operation of energy transport facilities used for transit.

WTO regime is not designed to facilitate the interconnection and exchange of electricity between cross-border electricity systems. First, it neither provides a legal basis to plan the construction of the cross-border electricity transmission links, nor contains the investment regimes in the transmission system. Second, the WTO system does not have the institutional setup to coordinate and, in later stages, police the activities in the cross-border exchange of electricity domain. Third, the activities of the transmission system operator largely fall out of scope of the WTO rules. They are regulated in the WTO only to the extent of the reach of Article XVII GATT and Article VIII GATS. Both these regimes are very limited, and in most of the cases do not cover the discretion of the transmission system operator's related to its right to construct the new transmission links, increase the capacity, connect the electricity generators and decide on the access of the transmission system operator's rules.

ECT obliges states to encourage relevant entities to cooperate in modernization, development and operation of energy transport facilities as well as facilitation of the interconnection of energy transport facilities. ECT regime (similarly to WTO) has no legally-enforceable mechanisms which could potentially provide guidance on the development of cross-border electricity transmission links. Though, ECT contains well-developed investment protection framework, which provides legal basis to protect the investments in the cross-border electricity infrastructures. Further, the Energy Charter Secretariat has developed non-legally binding model agreements, which provide detailed guidance on the development of cross-border electricity transmission projects.

The recent International Energy Charter of 2015, which is non-binding, but mirrors the intentions of the signatory states, contains several provisions on the construction of new cross-border energy infrastructures. In line with WTO principles and other international agreements, it has several important objectives aiming at facilitation of cross-border electricity infrastructures development. First, the objective to promote the realization of infrastructure projects important for providing global and regional energy security. Second, the objective to promote the development and interconnection of energy transport infrastructure. Notwithstanding, the International Energy Charter does not contain any guidance on the investment mechanisms and construction rules (substantive or procedural). If the intentions have a potential to translate into legally-enforceable commitments remain a question.

Conclusion

International agreements had little, if any, role in the facilitation of construction of cross-border electricity transmission links. The international framework should provide for rules on the investment, construction and operation of the cross-border electricity transmission links. These rules should make investment decisions subject to technical, environmental and economic considerations, as opposed to industrial policies. However, the existing policy frameworks focus mostly on the trade in electricity and subsidy policies, instead of governance of multinational electricity systems. Yet, a stable regulatory framework may facilitate investments in the large-scale' renewable integration in states having optimal climatic conditions.

7. RENEWABLE ENERGY FOR THE MINING INDUSTRY: TRENDS AND DEVELOPMENTS

Kateryna Zharan ✉

Abstract

Renewable energy (RE) for the mining industry has perspectives for an implementation and development confirms by the case studies from the mining countries. The European Union focuses on increasing of the capacity of RE generation and consumption according to the Directive on the promotion of the use of energy from RE sources. The specific objective of this paper is to explore a possibility for implementing of RE sources into the mining industry. Within this study the following aspects are dealt with, firstly, a comparative analysis of levelized costs of electricity from RE and fossil energy is presented. Secondly, the cost evaluation analysis of RE for transmission and distribution systems into the mining industry is considered. Thirdly, we investigate the technological possibilities for the RE integration into the mining industry. Finally, a guideline for the implementation of RE into the European mining industry is developed. Consequently, the conclusions are drawn about the main results of the paper.

Keyworlds: renewable energy, fossil energy, levelized costs of electricity (LCOE), biomass co-firing system.

Introduction

The main issue of this paper of RE integration into the mining industry has been raised in different studies paying attention to both scientific experts and industrial decision-makers. Mining and metal processing need a huge energy consumption. Since costs for traditional energy sources increase year by year, mining companies are looking for new solutions to substitute of fossil energy sources for renewables. The key point is that the costs for RE generation, grid connection, RE integration system and maintenance are comparable to fossil energy costs. However, integrating of RE to the mining needs still has a lot of constraints in the European mining industry.

Therefore, in the context of this paper, tree research questions are addressed:

(1) What is the criteria for costs evaluation of RE implementation, transmission, and distribution systems?

(2) What kind of technology may be used due to replace the RE with fossil into the mining industry?

(3) What is the guideline for integrating of RE into the mining industry?

First of all, we should correctly answer on the following question: Why do we need to substitute of fossil energy for renewables? Consider both environmental protection and economic benefit, RE can bring of “green” energy services to the mining industry where there is no access to the conventional energy sources.

The potential benefits for integrating of RE in the mining industry can be formulated as follows (Boyse, 2014):

- Decreasing in fuel and electricity costs, including transportation costs;
- Predictable energy costs, and thus reduced risk from intermittency and increasing diesel prices;

- Reduction in carbon emissions and comprehensive a less-polluting source of energy;
- A reliable and secure energy system for the mining industry;
- Reduced risk of power loss from supply disruptions;
- Enlarge economic competitiveness for the mining industry;
- Possibilities to repurpose land used by the mining industry;
- Growth in renewable energy market using it for the mining industry.

Indeed, evaluation of the LCOE for RE in comparison with fossil one makes implementing of RE in the European mining industry more real year by year. Figure 7-1 shows the continued persistent decline in the costs of a range of renewable power generation technologies.

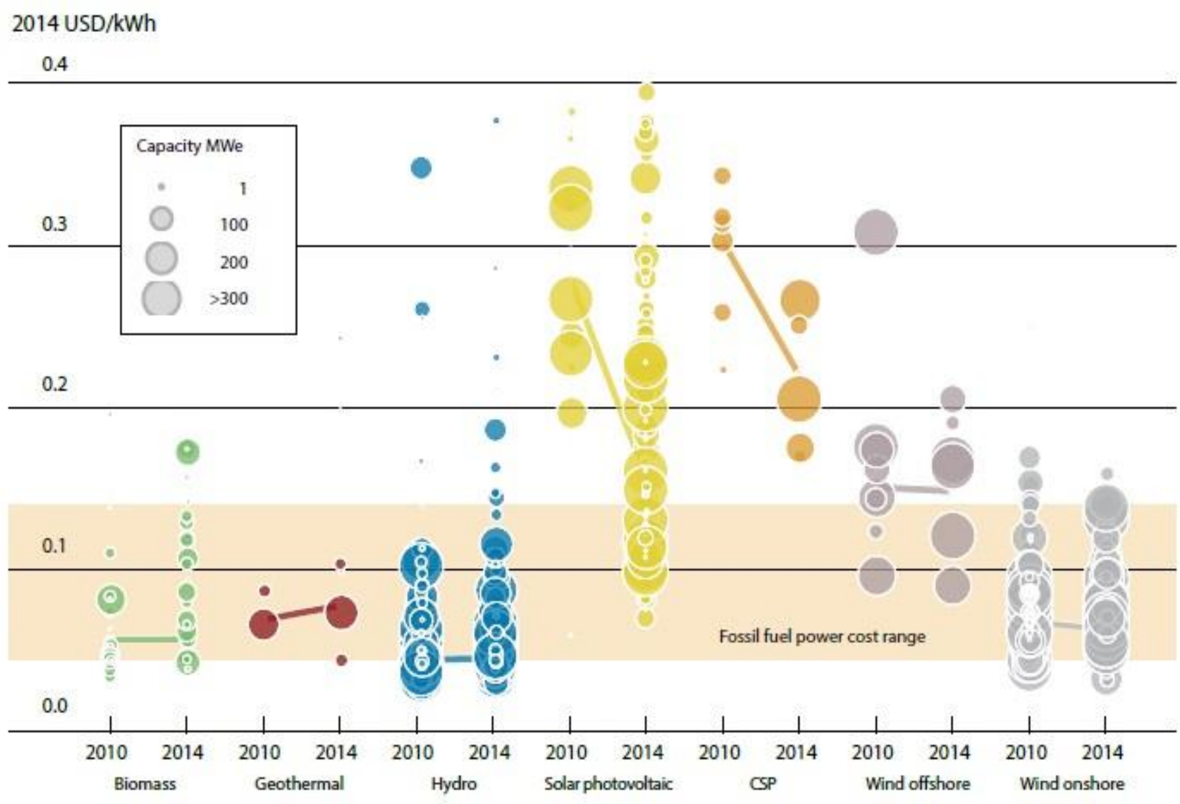

Figure 7-1: *The levelised costs of electricity from utility-scale renewable technologies, 2010 and 2014. Source: Taylor (2015).*

As shown in Figure 7-1 the most competitive solar PV plants are regularly delivering electricity for just USD 0.08 per kilowatt-hour (kWh) without financial support, compared to a range of USD 0.045 to USD 0.14/kWh for fossil fuel power plants. Even lower costs for solar PV, down to USD 0.06/kWh, are possible where excellent resources and low-cost finance are available (Taylor, 2015).

Onshore wind is one of the most available and competitive sources of electricity. Technology improvements, toward at the same time as installed costs have continued to decline, implying that the LCOE of onshore wind is within the same cost range, or even lower, than for fossil fuels. The best wind projects worldwide are consistently generating electricity for USD 0.05/kWh without any financial support (Taylor, 2015).

Costs evaluation of RE implementation, transmission, and distribution systems

Costs evaluating of RE implementation, transmission, and distribution systems also have to be clear highlighted before developing a business model for integrating of RE into the mining industry.

The costs evaluation depends on a range of factors, including:

- the specific electricity-system configuration;
- existing generation assets;
- share of variable renewable implementation;
- distribution of renewable resources and their covariance;
- existing mining market structures;
- finally, governmental support for RE development programs and projects.

In order to implement of RE in the mining industry a systems-based approach for calculation of costs should be done. Moreover, there is a necessity to evaluate all constituents of costs. Thereby, the system-based approach for costs evaluation consists of the multiple components such as technological costs, equipment costs and performance (including capacity factor), fuel costs, operation and maintenance costs, the economic lifespan of the equipment, and the costs of capital.

For instance, the renewable energy team in the Canadian engineering company Hatch has indicated that integrating hybrid power system – such as adding wind or solar to existing diesel systems – can cut mining companies' energy costs by around 10–20 % (Energy and mines, Canadian Clean Energy Conferences).

The diesel-PV hybrid facility may produce about 1.8 GWh of electricity per year, or about 60 % of the mine's annual daytime power needs. In comparison with the construction cost of $2.66 million with the annual fuel savings of 450 000 liters of diesel consumption, this PV project can achieve a payback period of the project of just 3.6 years. The project also took only six months to complete, from planning to construction (MD Cronimet Power Solutions GmbH, 2014).

Nevertheless, there are the constrains for integrating of RE into the mining industry, like following:

- geographical limit (RE sources do not exist in the European countries evenly);
- economic limit (the capital costs for penetration of RE for the mining are more than for fossil one);
- technological limit (there is no developed infrastructure in the European mining for using RE).

The capital costs involved in setting up of RE in the mining industry are still higher in a short term of mining exploration than costs for using diesel for mining needs. However, costs are expected to decrease in long term of mining exploitation. Thus, there is a necessity to take into account a lifespan of a mine before evaluating of payback period of investments for integrating of a RE infrastructure.

There is no single "true" LCOE value for a given power generation technology. Just as for non-renewable power generation technologies, the installed costs and capacity factors for RE are highly technology specific and site specific (Taylor, 2015). It makes evaluation for implementing of RE into the mining more challengeable.

Description of the biomass co-firing system as a possibility to meet the mining energy needs

There is a necessity to make a comparative analysis of the technological opportunity before developing a business model in purpose of avoiding unseen circumstances. Some main constraints and opportunities for mining companies and their energy needs can be defined as follows:

- POSITIVE: grid connection and transmission lines for mining industry move towards distributed RE systems, improve supply chain efficiency, energy-supply mix;
- NEGATIVE: need to operate in increasingly remote areas with proven mineral reserves which may be far from grid-connected power;
- POSITIVE: technological potentials for replacing fossil fuels with RE sources in existing plants may exist. This is illustrated for the case of biomass in a pulverized coal boiler (Figure 7-2).

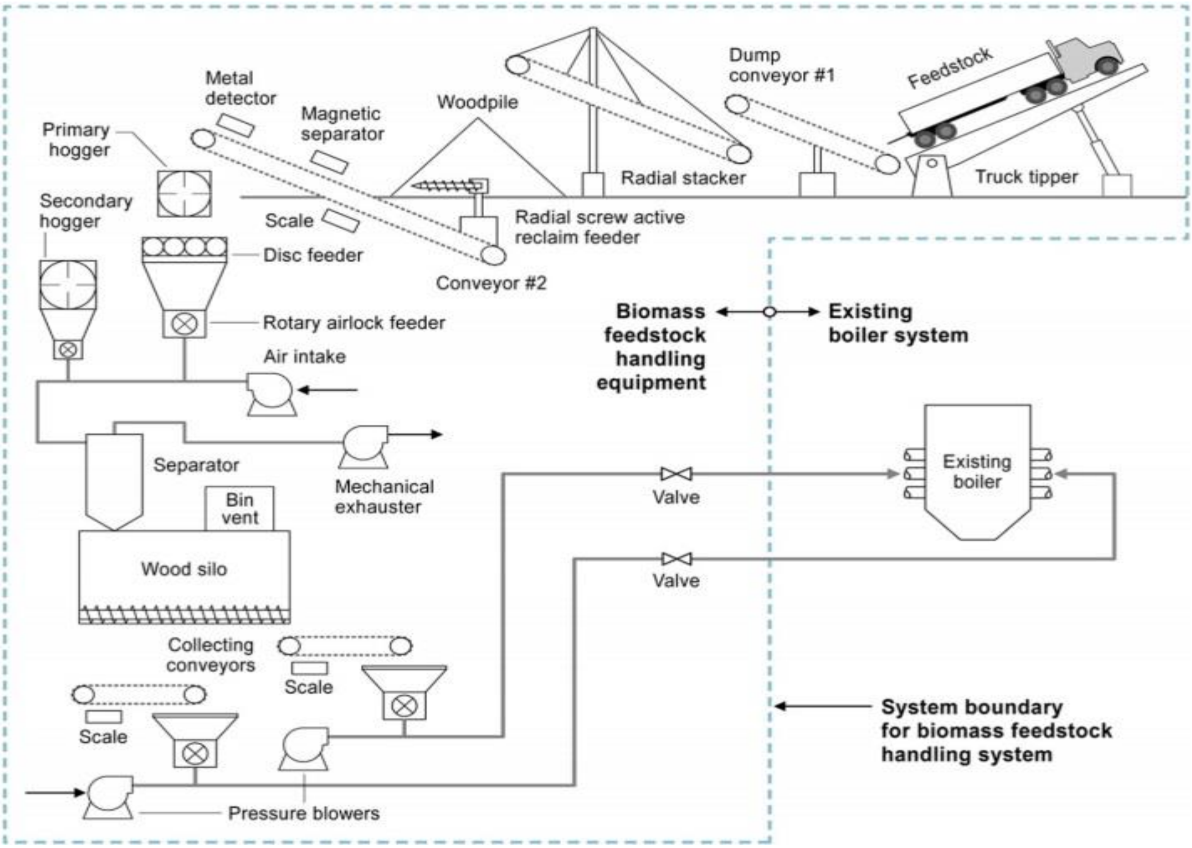

Figure 7.2: *Schematic of a separate injection biomass co-firing system retrofit for a pulverized coal boiler. Source: Hand (2012).*

Extensive demonstrations and commercial operations in the United States (EIA 2009b) and Europe (Cremers 2009) have shown that the substitution of biomass energy up to approximately 15 % of the total energy input (approximately 5 % for co-feed systems and 15 % for separate injection systems) (McGowin 2007) can be made with primarily burner and feed system modifications to existing stations (Hand, 2012). Therefore, such biomass as a fuel for a retro-fitted pulverized coal boiler is technologically feasible.

Regarding to this, the biomass co-firing system may be used like a hybrid-energy system in operational processing of a mine. Since the mining processing needs a stable energy supply, we suggest to use a biomass – fossil energy system. For instance, diesel fuel is used by trucks and excavators during mining, electricity is used to grind ore and refine copper and aluminum, and coal is required in order to smelt iron ore and make steel. The extraction of fossil fuels (coal, oil, and gas), and the construction of infrastructure required for energy generation have their own environmental impacts, including the production of greenhouse gas emission and increased risk of environmental contamination along the energy supply route. Reducing fossil energy consumption at mines can reduce greenhouse gas emissions and extend of the life of fossil fuel reserves in addition to reducing operating costs and therefore the cost of the commodity being mined (Miningfacts.org, 2012).

Guideline for the implementation of RE into the mining industry

The mining manufacturing processes are a complex system and completed within the technological requirements. The mining industry needs a reliable and affordable source of energy round-the-clock. Due to grasp into detail understanding how a RE can be integrated into the mining industry the guideline has been developed shown in Figure 7-3.

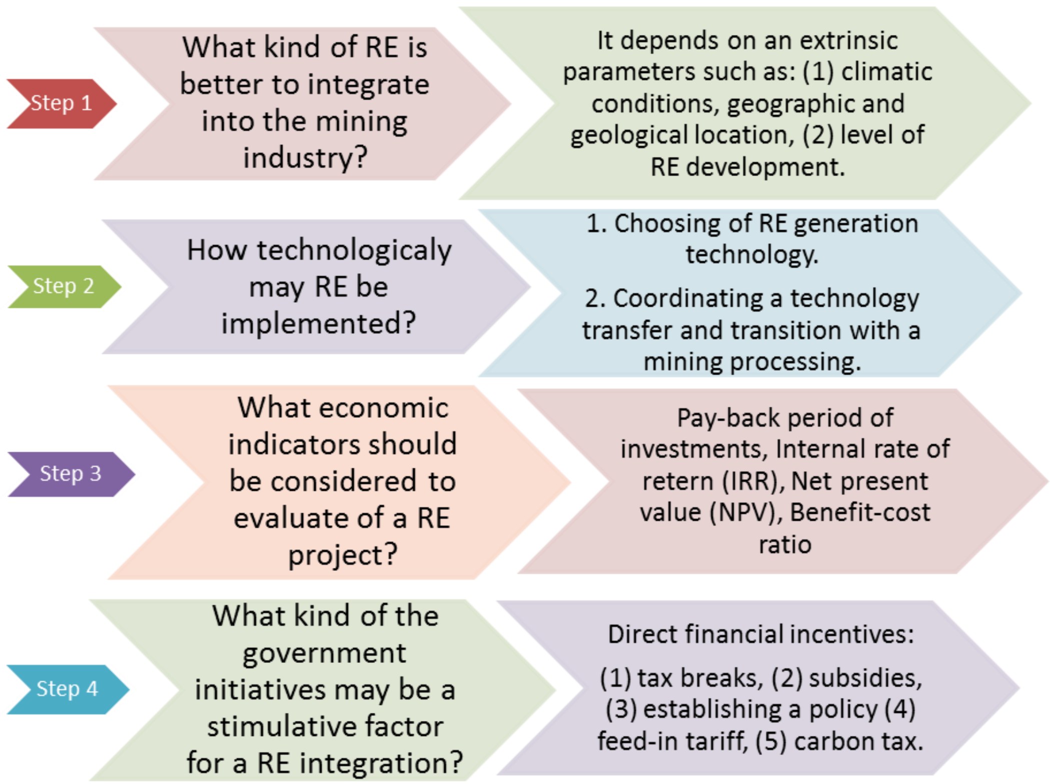

Figure 7-3: *Guideline for RE integration into the mining industry. Source: Self-prepared.*

The main idea for using of the guideline is to answer on each question together with an economic evaluation step by step in order to prepare of a business plan. The guideline will lead the mining companies to better forecasting, at first, what kind of RE sources should be integrated, what a technology for RE generation and delivery, what amount of RE can be generated in the following weather conditions – the technological evaluation (step 1 and step 2). Secondly, the economic evaluation of a RE integration may be done by using of the characteristics such as pay-back period of investments, IRR, NPV, and benefit cost ratio. Thirdly, the government can support of RE implementation by means of direct financial incentives such as tax breaks, subsidies, establishing a policy (allowing alternative energy companies to either sell energy independently or feed electricity back into the power grid will produce excess capacity and help to diversify the domestic energy supply), feed-in tariff, and carbon tax.

This guideline may help the mining companies to evaluate the existing possibilities for replacing RE with fossil one, evaluate an economic benefit of a project, and develop a business model for a European mining company.

Conclusions

Implementing of RE into the European mining industry has several challenges which have been emphasized in this study. Regarding very energy-intensive requiring a high reliability of energy source replacing of fossil energy with RE the mining industry still are challengeable. Furthermore, it needs a complete analysis in order to find a way to uptake of RE into the European mining industry. Nevertheless, the benefits evaluated in this paper show the future economic and environmental perspectives what may have a mine after a RE integration.

The main results of this study can be summarized as follows:

(1) According to comparative analysis of LCOE of RE and fossil energy there are economic perspectives for adapting of RE into the mining industry, and the benefits from a RE implementation have been emphasized in this study;

(2) Evaluation of costs for RE implementation and for transmission and distribution systems highlights a dependency of costs from different factors summarized under geographical, economic as well as technological limits.

(3) There is a necessity to make a comparative analysis of technological opportunity before developing a business model for RE integration into the mining industry. The technological possibility of RE implementation into co-firing retrofit for a pulverized coal boiler is demonstrated.

(4) This guideline for RE integration into the mining industry may help the mining companies to evaluate existing possibilities for replacing of RE with fossil one, calculate an economic effect of a project, and develop a business model for a European mining company.

The ongoing research will be consistent with the following issues:

- development of a questionnaire for mining and renewable experts in order to find possibilities, economic efficiency, and perspectives for RE integration into the European mining industry;
- dynamic linear and non-linear panel data analysis will be used due to data processing from experts and finding correlation between variables and developing of a forecast;
- development of a business model for RE integration into the European mining industry.

8. TOWARDS COMPANIES THAT PERFORM WITHIN THE EARTH'S REGENERATIVE CAPACITY

Annemarie Kerkhof ✉, Jeroen Scheepmaker, Gerben Meijer, Elmer de Boer, Kornelis Blok

Abstract

The latest Living Planet Report of WWF shows that we used the regenerative capacity of 1.5 planets in 2010 at present consumption levels. An increasing number of companies set targets to lower the impact of their activities on the environment, but such targets do not inform if the company performs within the limits of the earth's regenerative capacity. Inspired by the concept of planetary boundaries of Rockström et al. (2009), we aim to link corporate activities to global, regional and local boundaries. In this paper, we introduce a methodological framework in which we link midpoint indicators of Life Cycle Assessment (LCA) to scientifically established boundaries at global, regional and local level. The methodological framework consists of three steps: (1) quantify environmental impacts at product level, (2) define scientific boundaries at global, regional and local level and (3) set targets at sector and product level. The methodological framework has been applied to Eneco, an energy company in the Netherlands striving for sustainable energy for everyone, to set targets for climate change (within the 2 degrees' pathway) and particulate matter (below the WHO concentration target) in their power generation and supply. The methodological framework should be seen as a first step towards absolute boundary setting for companies.

Keywords: planetary boundaries, Life Cycle Assessment, companies, benchmark, climate change

Introduction

Human activities pose a severe threat to the resilience of the earth. The WWF *Living Planet Report 2014* (LPR, 2014a) shows that we used the regenerative capacity of 1.5 planets in 2010 at present consumption levels, and that biodiversity declined by 52 percent globally between 1970 and 2010. This demonstrates the urgent need to act within the earth's regenerative capacity in short term to avoid abrupt environmental change.

An increasing number of companies set targets to lower the impact of their activities on the environment, but such targets do not inform if the company performs within the limits of the earth's regenerative capacity. Inspired by the concept of planetary boundaries of Rockström et al. (2009), this paper introduces a methodological framework in which midpoint indicators of Life Cycle Assessment (LCA) are linked to scientifically established boundaries at global, regional and local level. The methodological framework should be seen as a first step towards absolute boundary setting for companies.

Challenges in linking planetary boundaries to business practice

The planetary boundaries concept of Rockström et al. (2009), updated by Steffen et al. (2015), introduces nine planetary boundaries, of which three with a global scale threshold (climate change, ocean acidification and stratospheric ozone depletion) and five with a strong regional operating scale (biosphere integrity, biogeochemical flows, land-system change, freshwater use, and atmospheric aerosol loading). The introduction of novel entities[2] can take place at the global scale, depending on the characteristics of the novel entity.

There are various challenges in linking the planetary boundaries to business practice:

(1) Level in the cause-effect chain: Bridging the gap between the planetary boundaries and business practice is challenging as the indicators of earth system processes (e.g. atmospheric CO_2 concentration in ppm, or Biodiversity Intactness Index) are defined at the end or near the end of the cause effect chain, while companies are located at the start of the cause-effect chain (see Figure 8-1). Therefore, planetary boundaries need to be translated to the company level, or the resource use and emissions from companies need to be translated to the indicators of the planetary boundaries.

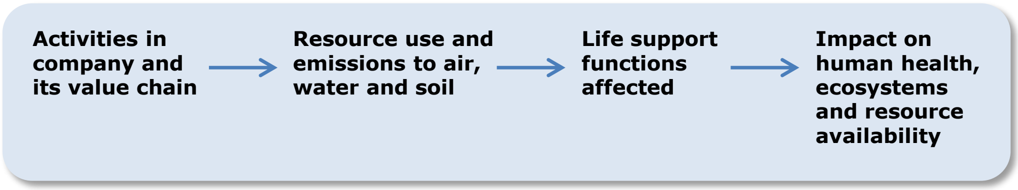

Figure 8-1: *Cause-effect chain.*

(2) Fair share: When translating planetary boundaries to the company level, there is the challenge of allocation. What is a fair allocation of efforts (e.g. emission reduction targets) among companies? There exist different allocation rules, e.g. based on historic emissions, reduction potential, etc.

(3) Local and regional boundaries: Companies act locally within local environmental conditions, e.g. certain background concentrations of particulate matter or in a country or region with a certain water scarcity. The background situation influences the distance to a certain boundary. Boundaries can therefore differ per country or region.

(4) Time-specific impacts: The time-related issue is of particular importance for climate change, where greenhouse gas emissions accumulate in the atmosphere over time, resulting in an increasing atmospheric CO_2e concentration. The time aspect influences the distance to a planetary boundary. Boundaries can therefore differ in time.

Methodology

A method that clearly links business activities to environmental impacts is Life Cycle Assessment (LCA). LCA is a widely accepted, used and standardised method for calculating the environmental impact along a product life cycle (ISO 14040 and ISO 14044). LCA could serve as the linking pin between the business activities and the planetary boundaries of Rockström et al. (2009). The link between planetary boundaries and LCA has been subject of research lately (Hoekstra and Wiedmann, 2014; Anders et al., 2014; Janeiro and Patel, 2015).

The planetary boundaries do not always fully match the inventory or impact categories of most environmental Life Cycle Assessment (LCA) frameworks currently in use. One way forward would be to develop transfer functions that translate the environmental impact categories

[2] Steffen et al. (2015) define novel entities as new substances, new forms of existing substances and modified life-forms that have the potential for unwanted geophysical and/or biological effects.

developed in LCA into the categories distinguished by Rockström et al. Another approach would be the development of boundaries for the impact categories that are commonly used in LCA (Janeiro and Patel, 2015). In this paper, we choose the latter approach for two reasons. First, LCA is a comprehensive method that includes environmental impacts at the global as well as regional and local level. In this way, trade-offs from impacts from the global to the regional or local level are taken into account. The paper of Steffen et al. (2015) which provides updated planetary boundaries also emphasises the importance and interaction of regional and local impacts on global earth system processes. Second, LCA makes use of a consistent midpoint and endpoint modelling which clarifies which impacts are taking place at the midpoint level (intermediate indicator halfway the cause-effect chain) or at the endpoint level (issue of concern). The planetary boundaries of Rockström et al. (2009) combine midpoint and endpoint indicators in one set of planetary boundaries. In the follow-up paper, it is acknowledged that there are many interactions among the planetary boundaries, and a two-level hierarchy of boundaries is suggested in which climate change and biosphere integrity should be recognized as core planetary boundaries through which the other boundaries operate (Steffen et al., 2015).

We propose the 3-step methodological framework as illustrated in Figure 8.2. It focuses on the environmental impacts of products (goods and services). Companies produce one or several products and in that way the environmental impact of products can be an indicator for the environmental impacts at company level. For companies with a diverse and large product portfolio this may not be feasible. There is not yet an approach developed for those companies. Instead those companies could set targets for certain product groups.

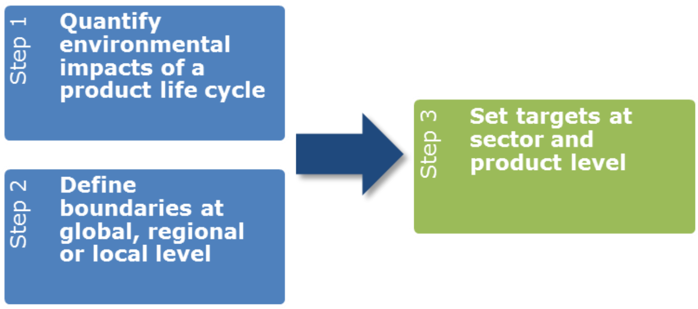

Figure 8-2: *Three steps of the methodological framework.*

Step 1: Quantify the environmental impacts of a product life cycle

For many companies, it is common practice to use Life Cycle Assessment (LCA) to quantify the environmental impact along the life cycle of their products. One of the steps in LCA, Life Cycle Impact Assessment (LCIA), translates emissions of substances to air, water and soil, and the use of resources to impacts on the environment by modelling the cause-effect chain. In this paper, we attempt to link the concept of planetary boundaries to the midpoint impact categories of LCA. The impact categories often included in midpoint LCIA methods are: climate change, ozone depletion, ecotoxicity, human toxicity, particulate matter, photochemical ozone formation, acidification, eutrophication, mineral deletion, fossil depletion, land use and water depletion.

Step 2: Define boundaries at global, regional or local level

We selected scientific boundaries at global, regional and local level that match the midpoint indicators of LCA (see Table 8-1). For this, we selected boundaries from scientific literature. The boundaries at global level are closely linked to the planetary boundaries of Rockström et al. (2009). Boundaries at the regional and local level deviate from the planetary boundaries. As most planetary boundaries do not match the midpoint indicators of LCA, we will use the term “environmental boundaries” in this paper.

Life Cycle Impact Categories of EU	**Boundary**	**Impact at global/regional/ local level**	**Source**
Climate Change	Atmospheric CO_2 concentration of 350 ppm and 1 W m^{-2} above the pre-industrial level	Global	Rockström et al. (2009)
Ozone Depletion	<5% decrease in column ozone levels for any particular latitude with respect to 1964–1980 values	Global	Rockström et al. (2009)
Particulate Matter/ Respiratory Inorganics	PM10: 20 µg/m^3 for the annual mean and 50 µg/m^3 for the 24-hour mean. $PM_{2.5}$: 10 µg/m^3 for the annual mean and 25 µg/m^3 for the 24-hour mean (not to be exceeded for more than 3 days/year).	Local	WHO (2006)
Photochemical Ozone Formation	Ozone target (maximum daily 8-hour mean): 100 µg/m^3.	Local	WHO (2006)
Acidification	Spatially-specific critical loads for acidification (sulphur and nitrogen) differ per ecosystem in Europe.	Regional	CCE (2008)
Eutrophication (terrestrial and aquatic)	Spatially-specific critical loads for eutrophication (nitrogen) differ per ecosystem in Europe.	Regional	CCE (2008)
Fossil depletion	Transition resource: Up to 2050, fossil fuel use should be limited by the increased percentage of fossil resources made available by technological improvement per year.	Global	
Mineral depletion	Limiting mineral use by the increased percentage of mineral resources made available by technological improvement per year.	Global	

Table 8-1: *Examples of boundaries per impact category.*

Step 3: Set targets at sector and product level

The boundaries at global, regional and local level are translated to the sector and product level in order to define targets at sector and product level. Combining LCA with absolute boundaries will provide companies with a method to define sustainability goals and pathways to act within the limits of the earth’s regenerative capacity. In practice, the translation of the environmental boundaries to sector and product level will have to be done per impact category.

Case study

The methodological framework has been applied to Eneco, an energy company in the Netherlands striving for sustainable energy for everyone, to set targets for climate change and particulate matter in power generation and usage.

Climate change

No scenarios for reaching an atmospheric CO_2 concentration of 350 ppm are included in the IPCC reports. The most stringent IPCC scenarios (stabilizing at 445–490 ppm CO_2 equivalent) could limit global mean temperature increases to 2–2.4°C above the pre-industrial level, requiring emissions to be around 50% of 2010 levels by 2050 (IPCC, 2007). Translation of this 50% GHG reduction target to regions, taking into account industrialized countries and developing countries (Annex I and non-Annex I) means that industrialized countries, e.g. US and EU, will have a target (2050) of 80-95% compared to 1990 levels (IPCC, 2007, Working Group III report, Chapter 13). A temperature goal of less than 2°C requires earlier reductions and greater participation compared to the most stringent IPCC scenario (IPCC, 2007, Chapter 13).

The EU has set up a roadmap for moving to a competitive low carbon economy in 2050 (EC, 2011), which describes how to reach the GHG reduction targets of 80-95%. Target for the power sector (electricity generation) is 27-36% in 2020 and 93-99% reduction in 2050 compared to 1990 levels. Based on the targets as defined in the EU Roadmap, the GHG emissions in 1990 of the power sector, and the projected electricity use in the period up to 2050 (EC, 2011), we have calculated the absolute emissions target for the European power sector in 2020 and 2050. We estimated the absolute CO_2 emissions target for the European power sector at 960 to 1095 Mton in 2020 and at 15 to 105 Mton in 2050 and an emission factor of approximately 282 g CO_2/kWh in 2020 and of approximately 11 g CO_2/kWh in 2050.

The direct CO_2 emission intensity of Eneco in 2012 (187 g CO_2/kWh) is within the set target of 2020 (282 g CO_2/kWh). Eneco has to work towards the target of 2050 to reach it in time. Renewable energy sources, like wind power, solar power and hydropower, are necessary for reaching the target of 2050.

The EU Roadmap only focuses on the reduction of direct CO_2 emissions. As a consequence, the defined target is also related to direct CO_2 emissions only. With the development of this methodological framework, we aim for linking life cycle GHG emissions to absolute boundaries, in that way avoiding burden shifting towards other life cycle stages or environmental impact categories. It needs further research to define targets that take into account the life cycle GHG emissions of electricity production.

Particulate matter

EEA (2012) provides information on the annual mean concentration of PM_{10} and $PM_{2.5}$ in different locations within Europe in 2010. Eneco is located in the Netherlands and activities there may influence the PM concentration of North-West Europe. PM concentrations in North-West Europe are higher than the WHO target and at some locations even double the concentration of the WHO target. Therefore, a reduction of 50% in PM emissions is needed to stay below the PM concentrations of the WHO Air Quality Guideline.

The average power sector in Europe produces electricity with 0.13 g $PM_{2.5}$e/kWh[3]. The particulate matter emitted per kWh of electricity produced by Eneco in 2012 (0.04 g $PM_{2.5}$e/kWh) is below the target of 0.065 g $PM_{2.5}$e/kWh (50% of EU27).

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3 Ecoinvent 2.2 data for the average European power sector in combination with the RiskPoll model of Rabl and Spadaro (2004).

Conclusion

The methodological framework introduced in this paper is a first attempt in linking global, regional and local boundaries to business practice. The analysis shows that the structural approach of life cycle assessment provides a good basis for linking boundaries to the products and activities of companies. The paper illustrates that global and local environmental boundaries for climate change and particulate matter can be linked to the power sector and company level. This enables companies to benchmark their products against global, regional and local environmental boundaries, and to design strategies that steer the company environmental impacts within the limits of the earth's regenerative capacity. In order to provide companies with a full suite of environmental boundaries at global, regional and local level, and with a consistent allocation of those boundaries among sectors and companies, further research is needed.

9. ESTIMATING CRITICAL EXTRACTION RATES FOR THE MAIN METALS FOR A SUSTAINABLE SOCIETY WITHIN THE PLANETARY LIMITS

Harald Ulrik Sverdrup ☒, Kristin Vala Ragnarsdottir ☒, Deniz Koca

Abstract

The critical rates of extraction of some metals was explored using a methodology based on the thinking behind critical loads for sulphur and nitrogen deposition developed in Europe 1990-2010. With a long-term sustainability view in mind, critical rates based on 5,000 and 10,000 years were estimated and found to widely exceed the present extraction rates. Huge advances in recycling, as well as a significant contraction of metal demand are required in order not to overstep the critical rates.

Introduction

Critical loads for sulphur and nitrogen was developed as a measure for how much acidifying and eutrophying pollution ecosystems can take without becoming damaged in structure, content or function for the future (Nilsson and Grennfelt 1988, Sverdrup and Warfvinge 1988, Sverdrup et al. 1990). Inspired by the development of critical loads for sulphur and nitrogen for the United Nations Economic commission for Europe under the Long Range Transboundary Air Pollution Convention (Nilsson and Grennfelt 1988, Sverdrup and Warfvinge 1998), we here attempt to do something similar for long-term metals use. We have in the past worked with a concept called critical loads for acidifying substances and their exceedances (Sverdrup and Warfvinge 1988), but also for use of phosphorus and limitations to population growth (Ragnarsdottir et al. 2011, Sverdrup and Ragnarsdottir 2011, 2012, 2013a, b, c) as well as using calculations to develop policy scenarios (Sverdrup et al. 1990, 1992,a,b), and we adapt this philosophy to finding the maximum metal use rate that is sustainable within the global boundaries.

Objectives and scope

The objective of this study is that if we assume we can define a sustainable metal use, a Critical Metal Extraction Rate by setting a time to civilization sunset, then we can by mass balance derive an estimate of a long term sustainable metal use within that time frame. We may define sustainable metal use as the use we can have for a very long time, alternatively forever, without causing damage, neither to the human ecosystem nor the natural ecosystem, and at the same time keeping a basic economy for society. Here we attempt first estimations of this concept.

Methods

The methods used are mass balances to calculate quantitative estimates, using know-how from earlier studies by the authors (Sverdrup and Warfvinge 1988, Sverdrup et al. 1990, Ragnarsdottir et al. 2011, Sverdrup and Ragnarsdottir 2011, 2012, 2013a, b, c).

Definition and theory

The critical rate (CR) is defined by one of the three following definitions:

1. Maximum net use in society of a metal, which for the time horizon adopted for sustainability, is translatable to a maximum annual mining rate.
2. Maximum allowable losses from the system, losses that are irreversible and that cannot be retrieved on an operational basis, depending on recycling efficiencies and average society life time of products.

The critical rate is equal to the maximum allowable loss rate society can tolerate and still be sustainable. The critical rate for a metal will be a multi-parameter estimation that will have to occur in several steps. Based on mass balance, we have the general equation of continuity for any metal:

$$\text{in + recycled = accumulated in system + produced + output} \quad (1)$$

There are three reinforcing loops driving the system, one involving metals and population, one involving oil and population, and one between oil and metals. The one involving oil and people has food and agriculture embedded in the arrows, representing causal links. Metals are very essential for food production as a main component of tools and machines. The system is driven by two reinforcing loops, one involving global population size – metal consumption – food, and another involving metal consumption – waste – recycling – metal available, and both work to make metal consumption and global population rise. The term accumulated in equation 1 is the amount of metal either in use or stored inside the system (dS/dt), produced is the amount mined, and this is rearranged to, produced from other sources than mining=0, waste=output, in= mined to the system. The bulk flux in society (F) is calculated from mining rate (M), recycling (R), change in the stock (S) and waste losses (W). This is captured the differential equation extracted in a re-shuffling of Equation 1:

$$\frac{dS}{dt} = F - W = M + R - W \quad (2)$$

The recycled fraction X_R is defined as:

$$X_R = \frac{R}{(M+R)} = \frac{R}{F} \quad (3)$$

The net flux needed to keep society going is depending on the gross flux and the recycling fraction:

$$\text{Net input} = F * (1 - X_R) \quad (4)$$

Where F is the flux into society from primary sources like mining. We have the mass balance estimating the sustainable mining rate as defined by the following Equations 1-4:

$$\text{Sustainable mining rate} = \frac{dS}{dt} + W - R \quad (5)$$

The net metal in is the sustainable metal use, and from this we may estimate the maximum amount we can mine from the mountains, if we can estimate the recycling amount. Output is the total output, but we subtract the amount of the output we recycle.

$$\text{Recycled} = F * X_R + r_A \quad (6)$$

Where F is the total flux through society, X_R is the fraction recycled, S is the stock in society of metal accumulated over the years and r_A is the rate of attrition of the infrastructure. At the critical rate, we assume we would like a steady state, that is that the net accumulation stops.

Metal	URR estimated using Hubbert's model or USGS 2013, ton	Dug up before 2010, ton	Presently remaining recoverable reserves, ton	Target recycling % of annual flux	Sustainable consumption, ton/year
Aluminium	20,000,000,000	880,000,000	19,200,000,000	80	19,200,000
Antimony	12,700,000	6,700,000	7,000,000	60	3,500
Bismuth	541,000	181,000	360,000	60	180
Chromium	904,000,000	470,000,000	437,000,000	80	437,000
Cobalt	13,700,000	2,100,000	11,600,000	80	11,600
Copper	1,260,000,000	702,000,000	558,000,000	80	558,000
Gallium	8,990	2,700	5,200	80	5.2
Germanium	18,600	6,100	12,500	80	12.5
Gold	320,000	185,000	135,000	95	67
Indium	58,100	11,000	47,100	60	24
Iron	339,000,000,000	100,000,000,000	229,000,000,000	60	114,500,000
Lead	1,283,000,000	590,000,000	693,000,000	90	1,286,000
Manganese	1,440,000,000	410,000,000	1,030,000,000	60	515,000
Molybdenum	33,000,000	10,500,000	22,500,000	80	22,500
Nickel	170,000,000	74,000,000	96,000,000	80	48,000
Niobium	5,452,000	1,470,000	3,972,000	80	3,972
Platinum	60,900	15,000	44,100	90	88
Rhenium	5,990	1,800	4,190	90	8
Selenium	280,000	102,000	171,000	60	85
Silver	3,200,000	1,892,000	1,308,000	80	1,308
Tantalum	159,500	109,000	58,500	80	59
Tellurium	19,520	7,600	11,080	60	5
Tin	96,600,000	20,400,000	76,200,000	80	76,200
Vanadium	21,000,000	1,600,000	19,400,000	80	19,400
Zinc	1,560,000,000	450,000,000	1,110,000,000	60	555,000

Table 9-1: *Estimation of sustainable consumption of different metals, based on a 5,000-years horizon and a high degree of recycling. Present recycling rates can be found in Sverdrup et al. (2013) for the year 2012.*

Stopped accumulation implies that short term accumulation can go on, but that all metal if used, will eventually be disassembled and the metal again returned to the market after a certain period of years. Then equation (5) is reduced to:

$$\text{Sustainable mining rate} = \text{W} - \text{R} \quad (7)$$

We need to address the issue of a far too large global consumption, where one root cause is the size of the global population. Consumption is governed by a very simple equation:

$$\text{Consumption rate} = \text{Net consumption per capita} * \text{number of consumers} * (1 - \text{X}_\text{R}) \quad (8)$$

The equation clearly states that there are three different parameters we can elaborate with in order to design the consumption rate at a sustainable level. Where R is the degree of recycling of the amount supplied to society. The system has its own internal feedbacks leading to population growth and increase in the use of metals. Metals are very essential for food production as a main component of tools and machines. By recycling and improving efficiencies and yields, we may reduce net consumption per capita, however if that is less than the increase in population, we are effectively losing the race.

Metal	Production now, ton/year	Sustainable metal consumption ton/year	Exceedence of metal use over sustainable ton/year	Consumption reduction to %	(Factor X)
Aluminium	40,000,000	19,200,000	20,800,000	-52.0	1.9
Antimony	180,000	3,500	176,500	-98.0	51.4
Bismuth	7,000	180	6,870	-98.1	38.9
Chromium	16,000,000	437,000	15,870,000	-97.3	37.9
Cobalt	110,000	11,600	99,400	-90.4	9.5
Copper	16,000,000	558,000	15,342,000	-95.9	28.7
Gallium	280	5.2	274.8	-98.1	53.8
Germanium	150	12.5	137.5	-91.7	12.0
Gold	2,600	67	2,533	-97.4	38.8
Indium	670	24	644	-96.1	27.9
Iron	1,200,000,000	114,500,000	1,085,500,000	-83.2	5.9
Lead	4,000,000	1,286,000	2,714,000	-67.9	3.1
Manganese	18,000,000	515,000	17,485,000	-97.1	32.4
Molybdenum	280,000	22,500	257,500	-91.8	12.4
Nickel	1,700,000	48,000	1,662,000	-97.7	34.6
Niobium	68,000	3,972	64,028	-94.1	17.1
Platinum	180	88	92	-51.1	2.0

Rhenium	50	8	42	-84.0	6.3
Selenium	2,200	85	2,115	-96.1	25.9
Silver	23,000	1,308	21,692	-94.3	17.7
Tantalum	600	59	541	-90.2	10.2
Tellurium	120	5	115	-95.8	24.0
Tin	300,000	76,200	223,800	-74.3	3.9
Vanadium	260,000	19,400	240,600	-92.5	13.4
Zinc	11,000,000	555,000	10,455,000	-95.0	19.8

Table 9-2: *Living within the planetary boundaries. Estimation of sustainable consumption of different metals and the present overshoot, based on a 5,000-years horizon.*

The improvements that can be made on recycling and efficiencies have clear limitations, where as so far the population has been steadily going up, to a point where the consumption volume is exceeding the planetary supply capacity. The maximum sustainable mining rate is given by the size of the mineable reserve and how long it must last:

$$\text{Sustainable mining rate } = \frac{\text{PRRR}}{\text{t}_{\text{DOOM}}} \tag{9}$$

Where PRRR is presently recoverable resources of any of the metals assessed, t_{DOOM} is the time to “doomsday” in years from now, implying after this point in time, the society do not have, do not want to or cannot get any metals, and thus will be in very deep trouble. Thus - the expression “doomsday”. This must necessarily be a very long time, we have based on our own value judgement set this to be 5,000 years, which we think is an absolute minimum. The sustainable consumption rate is determined by how efficient that mined amount can be used:

$$\text{Sustainable metal use} = \text{SMU} = \frac{\text{PRRR}}{\text{t}_{\text{DOOM}}*(1-\text{R})} \tag{10}$$

We most probably have an exceedence situation for many metals, where the present consumption is larger than the sustainable consumption.

Table 3. Living within the planetary boundaries. Estimation of sustainable consumption of different metals and the present overshoot. Assessment of the effect of choosing different time horizons.

Metal	Production now, ton/year	Time horizon applied, years							
		Sustainable metal consumption, ton/year				Exceedence of metal use over the sustainable use level, ton/year			
		10,000	5,000	2,500	500	10,000	5,000	2,500	500
Infrastructural metals									
Iron	1,200,000,000	57,500,000	114,500,000	229,000,000	1,145,000,000	1,142,000,000	1,085,500,000	971,000,000	58,000,000
Aluminium	40,000,000	8,100,000	19,200,000	38,400,000	192,000,000	41,900,000	20,800,000	1,600,000	none
Manganese	18,000,000	257,500	515,000	1,030,000	5,150,000	17,743,000	17,485,000	16,970,000	12,850,000
Chromium	16,000,000	218,500	437,000	874,000	4,370,000	15,782,000	15,563,000	15,126,000	11,630,000
Copper	16,000,000	279,000	558,000	1,116,000	5,580,000	15,721	15,342,000	14,884	10,420,000
Zinc	11,000,000	277,500	555,000	1,110,000	5,550,000	10,723,000	10,455,000	9,890,000	5,450,000
Lead	4,000,000	643,000	1,286,000	2,572,000	12,850,000	3,357,000	2,714,000	1,286,000	none
Nickel	1,700,000	24,000	48,000	96,000	480,000	1,676,000	1,652,000	1,601,000	1,220,000
Technological metals									
Molybdenum	280,000	11,250	22,500	45,000	225,000	268,750	257,500	235,000	53,000
Tin	300,000	38,100	76,200	152,400	762,000	261,900	223,800	147,600	none
Vanadium	260,000	9,700	19,400	38,800	194,000	250,300	240,600	221,200	146,000
Antimony	180,000	1,750	3,500	7,000	35,000	178,750	176,500	173,000	145,000
Cobalt	110,000	5,800	11,600	23,200	116,000	104,200	99,400	86,800	none
Niobium	68,000	1,986	3,972	7,994	39,970	66,014	64,028	60,006	28,030
Bismuth	7,000	90	180	360	900	6,910	6,870	6,640	6,100
Gallium	280	2.6	5.2	10.4	52	277.4	274.8	269.6	228
Germanium	150	6.2	12.5	25	125	143.8	137.5	125	25
Indium	670	12	24	48	240	658	644	622	436
Platinum	180	44	88	176	880	136	92	4	none
Rhenium	50	4	8	16	80	46	42	34	none
Selenium	2,200	43	85	170	850	2,157	2,115	2,030	1,350
Tantalum	600	30	59	118	590	570	541	482	10
Tellurium	120	2.5	5	10	50	118	115	110	80
Financial metals									
Gold	2,600	34	67	134	670	2,566	2,533	2,466	1,930
Silver	23,000	653	1,308	2,616	13,080	22,347	21,692	20,384	9,920

We have what some call an "overshoot":

$$\mathrm{EX} = \mathrm{PMU} - \mathrm{SMU} \qquad (11)$$

Where EX is the exceedence in use over sustainable use (SMU) and present metal use (PMU) is present metal use. We have calculated the reduction in % of the present extraction. Table 9-1 show estimation of sustainable consumption of different metals, based on a 5,000-years horizon and a high degree of recycling. Present recycling rates can be found in Sverdrup et al. (2013) for the year 2012. Table 9-2 shows an estimation of sustainable consumption of different metals and the present overshoot, based on a 5,000-years horizon. Alternatively, we may do the Factor x approach defined as the supply divided by the net primary extraction rate. For metals, recycling can be a very important tool where in a steady state situation, only the losses from the system needs to be replaced. We can increase efficiencies and recycling to a certain degree, but driving systems with out materials and energy is not possible. Some processes have absolute requirements, some materials are in no way substitutable and where substitution is not meaningful. Metals are in principle indefinitely recyclable, however never with 100% yield. Table 9-3 shows the estimation of sustainable consumption of different metals, based on a 5,000-year time horizon and a high degree of recycling regarded as a necessary efficiency target. We have elaborated with different consumption levels, population levels.

10. SUBSTITUTION OF METALS IN TIMES OF POTENTIAL SUPPLY LIMITATIONS: WHAT ARE THE MITIGATION OPTIONS AND LIMITATIONS?

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Abstract

Global production rates of metals vary from iron at 1.4 billion ton per year to platinum with 200 ton per year. Resource scarcity starts to manifest itself in rising prices and supply limitations, and metal substitution has been a major argument among economists when putting considerations of resource scarcity aside. Here we investigate the potential limits to metal substitution. Present consumption, recycling and irreversible loss rates, as well as the metal balances and properties are examined. Our findings suggest that the major limitations and issues to substitution are: (1) Physical limitations in terms of metal available; it can only take place by a more abundant metal taking partly the place of a metal produced in smaller amounts; (2) Functional limitations based of differences in physical and chemical properties; and (3) By considering substitution options often more energy is needed and larger CO_2 emissions occur. Substitution of metals is therefore not going to take the threat of scarcity away; it can only delay us in adapting to the level of sustainable use. The longer we wait, the more we risk squandering resources before we properly conserve our resources from becoming scarce.

Introduction

Resource scarcity as a logic continuation of finite reserves of resources on a limited Earth has been debated for a long time. Despite the fact that every miner knows perfectly well that every mine will some day run empty, it has been hard for many to realize that all mines may run empty. The assumption has been by many that discovery of new mines will neither decline nor stop. Substitution of materials and metals has been a major argument of economists in ignoring the possibility of scarcity. Substitution here means that we use a certain metal, say nickel for a certain function, but because of supply restrictions, we would like to replace it with another metal, doing as much as possible of the same function. The argument stresses that individual elements may run into supply restrictions, but we can always substitute it by something else. The mostly unaddressed, but underlying reason, has been the silent assumption that iron and aluminium production would never end, nor ever become restricted. We examine some of these assumptions here and use quantitative data to show how reality may look very different, if we are willing to examine the fact that the Earth is limited. Substitution of resources includes examination of alternatives driven by either better performance technically or for lowering costs (e.g. Anand 2012, Kooiman 2011, Ragnarsdottir et al., 2012, Sverdrup et al. 2013, UNEP 2011a, b, c, Wäger et al., 2011, Xiaouyie and Graedel 2013, Zuser and Rechberger 2011 and references therein). Lately, attention has been drawn to substitution as a potential way to mitigate resource scarcity (e.g. Ayres 2005, Deub and Griese 2005, Narayan 2015, Wäger et al., 2011 and references therein). However, Graedel et al. (2013) assess the possibility of substitution based on material function and property, and they conclude *"...for not 1 of the 62 metals are exemplary substitutes available for all major uses."* They go on to state that *"…for most, the substitutes proposed are either inadequate or do not exist at all."* Their analysis is excellent with respect to what functions the different elements can do, that their "service niches" do not overlap very well, so that substitution is normally incomplete. Hence it has already been suggested that the resource situation is serious, and that substitution as a mitigating tool may have been overrated.

Scope and objectives

The aim of this paper is to examine the limits to material substitution, with particular focus on metals. We investigate at present consumption rates, rates of recycling, rates of irreversible losses and the material balances. We also analyse the properties of some of the different metals, to determine to what degree another metal may fulfil the function of what it is supposed to substitute for.

The data we use for this study

Data was extracted by working through a number of databases and scientific literature (e.g. Bardi 2013, Elshakaki and Graedel 2013, Graedel et al. 2011, 2013, Graedel and Nuss 2014, Xiaoyue and Graedel 2013a,b, Ragnarsdottir et al., 2012, Sverdrup et al., 2013, Sverdrup and Ragnarsdottir 2014 and references therein). Table 10-1 shows a compilation of our best estimations of available reserves for metal extraction. The table gives ultimately recoverable reserves (URR), amount mined before 2010, remaining recoverable reserves (RRR), and points to the system dynamics sub-models that have been developed for the WORLD model of the authors. Analysis of Table 10-1 shows that substitution can only occur by using a metal in *rows above* in table to substitute for another metal in a row further down the table, if and only when they have matching properties and the function of the substituted metal matches for the purpose it is used for.

Metal properties are important and put limits on substitution

Many of the metals in Table 10-1 have interdependencies, and thus their production rate is not determined by their market price. Table 10-2 shows our estimates of sustainable mine extraction of different metals in ton per year. The assessment gives the effect of choosing different time horizons. By calculating burnoff rates we have assessed the amount that can be used every year, depending on how long we want the resource use to last. After this date, the resource will be gone for good, and the generations coming after that will simply have none. Here we consider timespans of 500, 1,000, 5,000 and 10,000 years (Table 10-2). Historically 5,000 years is the time we have had urban life with written documents. 10,000 years is roughly the time between two ice-ages. Our personal opinion is that the time horizon for a sustainability assessment should be longer than 2,500 years, and up to 10,000 years. The data in the table demonstrates that we have a problem with resource sustainability because even with only 500-years horizon our annual production is far above sustainable use (see columns 2 and 6).

Let us consider the possibility of substituting magnesium for aluminium (Table 10-2). Magnesium RRR is about 50 billion tons and that of aluminium 19 billion tons. While magnesium is physically abundant enough to substitute for up to 50% of the present aluminium, magnesium is reactive and therefore magnesium-aluminium alloys cannot have more magnesium than 50% due to fire hazard. Thus, there are limitations to what magnesium can be used for. Magnesium is also very energy demanding to produce, and thus, it will be more expensive to make than aluminium. The electric conductance of magnesium is poor compared to aluminium, and thus it is not useful in electronics the way aluminium is.

Similarly, we can compare the substitution of iron with aluminium. Iron annual production is 1450 million ton whereas aluminium production is 45 million ton. Alumina reduction to aluminium metal also needs much more energy than the reduction of iron oxide to iron metal. Therefore, aluminium can never fully replace iron as an infrastructure material.

In terms of substitution many of the important metals have some replacement or substitutability with respect to structural uses (e.g. substituting iron with aluminium), however when it comes to electrical and electronic uses, or chemical properties, these options are more limited; with respect to catalytic properties, the substitutability is virtually non-existent.

Metal interdependency

Of note is that many metals have no dedicated mines and no independent reserves (Sverdrup and Ragnarsdottir 2014) and are produced as a by-product of other metals. These include: bismuth, germanium, gallium, tellurium, selenium, indium, and cadmium. For other metals, there are independent reserves but also a significant amount of the supply may come from polymetallic ore reserves: gold, silver, platinum, palladium, rhodium, cobalt, antimony. Copper, zinc and lead often occur in such polymetallic ores and are to a significant degree extracted together from the same ores. To further our understanding of metal sustainability from burnoff calculations, we are developing the system dynamic WORLD model with polymetallic sub-modules mentioned in Table 10-1. They include IRON, STEEL, ALUMINIUM, COPPER, PGM, GOLD, SILVER and BRONZE models (Ragnarsdottir and Sverdrup 2014, Sverdrup et al. 2013, 2014 a, b, 2015, 2016). With the WORLD model, the integrated metal production of many of those metals listed in Tables 10-1 and 10-2 can be simulated with good accuracy, including recycling and prize (see Sverdrup and Ragnarsdottir 2014). We demonstrate that the WORLD dynamic model, and scenarios with lower population and higher recycling rates extends the time to resource scarcity into the future - but only by some decades to centuries.

Metal	URR, Ultimately Recoverable Reserves (ton)	Amount mined before 2010 (ton)	RRR, Remaining Recoverable Reserves (ton)	Sub-model modules developed by authors	Included in WORLD model
Iron	340,000,000,000	40,000,000,000	300,000,000,000	STEEL	yes
Magnesium	50,000,000,000	4,000,000	49,996,000,000	-	
Aluminium	20,000,000,000	880,000,000	19,200,000,000	ALUMINIUM	yes
Phosphorus	19,500,000,000	7,500,000,000	12,000,000,000	FoF	yes
Titanium	3,600,000,000	180,000,000	3,420,000,000	-	
Copper	2,722,000,000	760,000,000	1,962,000,000	BRONZE	yes
Manganese	1,440,000,000	410,000,000	1,030,000,000	STEEL	yes
Zinc	1,560,000,000	450,000,000	1,110,000,000	BRONZE	yes
Lead	1,283,000,000	590,000,000	693,000,000	BRONZE	yes
Chromium	904,000,000	470,000,000	437,000,000	STEEL	yes
Rare Earths	220,000,000	4,000,000	216,000,000	RareEarth	
Nickel	185,000,000	74,000,000	96,000,000	STEEL	yes

Molybdenum	33,000,000	10,500,000	22,500,000	-	
Tin	96,600,000	20,400,000	76,200,000	-	
Lithium	34,000,000	1,000,000	33,000,000	LITHIUM	yes
Vanadium	21,000,000	1,600,000	19,400,000	-	
Thorium	23,000,000	1,000,000	22,000,000	THOR	
Uranium	16,000,000	2,000,000	14,000,000	THOR	
Cobalt	13,700,000	2,100,000	11,600,000	BRONZE	yes
Antimony	12,700,000	6,700,000	7,000,000	BRONZE	yes
Niobium	5,452,000	1,470,000	3,972,000	-	
Silver	3,200,000	1,892,000	1,308,000	SILVER- BRONZE	yes
Bismuth	541,000	181,000	360,000	BRONZE	yes
Gold	320,000	185,000	135,000	GOLD	
Selenium	280,000	102,000	171,000	BRONZE	yes
Tantalum	159,500	109,000	58,500	BRONZE	
Indium	58,100	11,000	47,100	BRONZE	yes
Platinum	50,600	6,500	44,100	PGM	yes
Palladium	44,500	8,500	36,000	PGM	yes
Tellurium	19,520	7,600	11,080	BRONZE	yes
Germanium	18,600	6,100	12,500	BRONZE	yes
Gallium	8,990	2,700	5,200	BRONZE	yes
Rhenium	5,990	1,800	4,190	-	

Table 10-1: *Estimation of available reserves for metal extraction. Magnesium and titanium are mainly used for other purposes than producing metal. Substitution can occur by using a metal above on the list to substitute for a metal further down on the list, if and when they have matching properties, function and purpose of the metal substituted for.*

Metal properties

As outlined above metals have different properties, and these must be considered when substitution is considered. Graedel et al. (2013) did a through analysis based on many of their own earlier assessments of substitutability with regard to metal properties and functions they fulfil (atomic services). They conclude that from a perspective of properties and function, substitution is always incomplete. These researchers do not pull synthetic composite materials into the picture (polymers, ceramics, artificial designed compounds), but demonstrate that substitution is never going to deliver the same properties. We have attempted to consider function, service and the aspect of available amounts in our analysis. For structural purposes, strength, specific density and temperature tolerance plays a role. The conductive properties are variable, and substituting a poor conductor with a good one or vice versa may be difficult for many functions. When it comes to properties like corrosion resistance, catalytic properties or chemical reactions, the differences are larger and there is very little room for any substitution. The metals zinc, lead, indium and several of the rare earth metals have no good substitutes in their present functions and when they become scarce we may have to face technology losses.

Metal	Primary production 2012-2014 (ton per year)	Time horizon applied for sustainability estimate (years)			
		10,000	5,000	1,000	500
		Sustainable extraction (ton per year)			
Iron	1,450,000,000	22,900,000	43,800,000	219,000,000	438,000,000
Aluminium	45,000,000	1,920,000	3,840,000	19,200,000	38,400,000
Manganese	18,000,000	103,000	206,000	824,000	1,648,000
Chromium	16,000,000	43,700	87,400	437,000	874,000
Copper	16,000,000	55,800	111,600	582,500	1,165,000
Zinc	11,000,000	111,000	222,000	888,000	2,220,000
Lead	4,000,000	69,300	138,600	693,000	1,386,000
Nickel	1,700,000	9,600	19,200	96,000	192,000
Magnesium	1,000,000	20,000,000	40,000,000	240,000,000	480,000,000
Tin	300,000	7,620	15,300	76,200	153,000
Titanium	283,000	360,000	720,000	3,600,000	7,200,000
Molybdenum	280,000	2,250	4,500	22,500	45,000
Antimony	180,000	700	1,400	7,000	14,000
Rare Earths	120,000	21,600	43,200	216,000	432,000
Cobalt	110,000	1,160	2,320	11,600	23,200
Tungsten	80,000	750	1,500	7,500	15,000
Vanadium	70,000	1,940	3,880	19,400	38,800
Niobium	68,000	400	800	4,000	8,000
Lithium	37,000	3,500	7,000	35,000	70,000
Silver	23,000	131	262	1,310	2,620
Bismuth	7,000	36	72	360	720
Selenium	2,200	17	34	170	340
Gold	2,600	14	28	140	280
Indium	670	5	10	50	100
Tantalum	600	6	12	60	120
Gallium	280	0.5	1	5	10
Palladium	220	3.6	7	36	72
Platinum	190	4.4	9	44	88
Germanium	150	1.3	2.6	13	26
Tellurium	120	1.1	2.2	11	22
Rhenium	50	0.4	0.8	4	8

Table 10-2: *Estimation of sustainable mine extraction of different metals in ton per year. The method applied is a simple burn-off rate. The assessment gives the effect of choosing different time horizons.*

Whether substitution works depends on what the real problem is that is being addressed. Scarcity implies that there is too little material. So, if there is too little material, the main problem may not be with supply, but maybe rather demand, that too much is used compared to what is available at a sustainable level. And substitution cannot fix a mass balance that runs with a deficit. A different kind of mitigation is needed. In a world of limited resources factor X is the multiple by which we need to reduce our net consumption of a resource (Angrick et al. 2013, 2016). Discussions revolve around values of X from 5, 10 or even 100. There are some limitations to how many times we are able to reuse a material, because in every transaction or processing step there is some loss. For some metals this is very close to 100%. But most of the time 95% yield in a process is considered as quite good. If we involve 5 steps of processing at 95%, we get a total yield of 81.5%. Thus, there is always a loss.

Conclusions

Substitution is not a method for escaping the challenge of metal scarcity, except on a small scale. The limits to substitution are:

1. There are physical limitations in terms of material available
2. There are functional limitations based of differences in physical and chemical properties
3. There are issues with energy and CO_2 emission by changing to other materials in many cases

Substitution will only work for a metal where the production is large for a metal that is produced in smaller amounts. In addition to this come some other constraints. If the substitute metal has a tight market because of its scarcity and has no extra extraction capacity serving the market, then the capacity for substituting may be limited. Significant substitution may then drive up the price and make scarcity eventually become worse (Sverdrup and Ragnarsdottir 2014). The dependent metals from polymetallic mines have very little supply elasticity, in most cases none with respect to quantity, and the price will be correspondingly volatile.

Acknowledgements

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11. MODELLING THE GLOBAL PRIMARY EXTRACTION, SUPPLY, PRICE AND DEPLETION OF THE EXTRACTABLE GEOLOGICAL RESOURCES USING THE COBALT MODEL

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Abstract

The global supply of cobalt was simulated by combining 3 different system dynamics models; BRONZE, PGM and STEEL. The present use of cobalt shows a low degree of recycling and systemic losses are significant. The reserves of cobalt are not very large (20-25 million ton extractable) as compared to metals like copper, zinc or iron, and after 2170 cobalt will have run out under a business-as-usual scenario. The present business-as-usual for cobalt use in society is therefore not sustainable.

Introduction

The four most important strategic metals for human society are iron, aluminium, copper and zinc. The extraction of copper, zinc and lead is normally done from poly-metallic ores. We have earlier developed an integrated model (BRONZE) for copper, zinc and lead and some of the metals depending on them (Sverdrup et al. 2014b). Cobalt belongs to a series of technology metals, which are not large in volume, but are used for key components of important technologies that society depends on. Cobalt is very dependent on the production of other metals (Figure 11-1), and therefore there are complex dynamics in the market supply and demand system. Much of the cobalt originates from the copper-belt in central Africa (about 50%), and the volatility in the cobalt supply and price is a reflection of the troubled political situation in that region. Of the supply, about 55% is a by-product of nickel extraction, 35% is a by-product of copper production and 10% comes from other sources like platinum group metals extraction and chromium refining (Eckerstrand and Hulbert 2007, Mudd et al. 2013a,b).

Objectives and scope

Our goal was to use the BRONZE, STEEL and PGM system dynamics models and add a cobalt sub-module to the integrated structure to create the COBALT model. The objective is to use the validated systems dynamics model to investigate the system and explore what it would take to make the global cobalt supply system more sustainable.

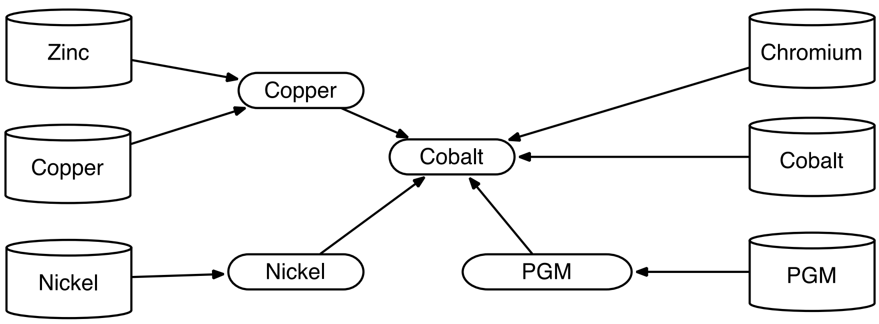


***Figure 11-1:** Cobalt flow-path in society. Connection between the production of many different metals and the parent metal ores is displayed here as a flowchart.*

Methods and theory used

The methods used in this study are several. The reserves estimates are based on classical geological estimates, and the allocation of extractable amounts is according to ore quality, stratified after extraction costs (Tilton 2009). The main modelling method uses systems analysis and systems dynamics (Sverdrup et al. 2014a, b, 2015). For the modelling we use the standard methods of system analysis and system dynamics, making up causal links and flow pathways in the systems. The model is based on mass balance expressed differential equations, and solved numerically. We use causal loop diagrams for reading out where the causalities are, to find intervention points in the system, and to propose policy interventions. Mudd et al. (2013a, b) made an important assessment of the available amounts extractable of cobalt. Harper et al. (2012) and Eckstrand and Hulbert (2007) mapped where these deposits are located and of what origin they are, providing important geological background material. There is consensus on the total extractable amount to be in the range of 17-20 million tons cobalt. The extractable amounts were set at the beginning of the model simulation in 1900, stratified with respect to ore metal content and relative extraction cost based on yield of extraction and energy requirements. Runs with the COBALT model were made for the time 1900-2400 in order to see how long cobalt would last.

Model description

The COBALT model is a model of models. Figure 11-1 shows the connection between the production of many different metals and the parent metal ores displayed as a flowchart. Only the part of the system relevant to cobalt is discussed in this study. Many metals are extracted from poly-metallic ores, some for new uses in new technologies. Cobalt from copper is generated in the BRONZE sub-module, supply from nickel in the STEEL sub-module and from platinum group metals in the PGM sub-module. The COBALT model consists of the following parts based on models published earlier and new system dynamics parts:

1. **BRONZE** model for copper, zinc, lead and many dependent metals (silver, antimony, bismuth, indium, gallium, germanium, tellurium, selenium, cadmium);
2. **STEEL** model for iron, manganese, chromium and nickel;
3. **PGM** model for platinum, palladium and rhodium;
4. **COBALT** is the newly developed sub-module for the cobalt market cycle.

Figure 11-2 shows the flow chart for the COBALT model, with the parent ores, the primary extraction and the dependent secondary extraction of many technology metals found in these parent metal ores. Table 11-1 gives the sources of cobalt. The full causal loop diagram for metal mining and copper in particular has been published earlier (Sverdrup et al., 2014b). The population estimates use the outputs of the fully integrated population model used in the **WORLD** model (Sverdrup and Ragnarsdottir 2011, 2014a, b, 2015a,b,c). The COBALT model is numerically integrated using a 0.05 year time-step in a 4-step Runge-Kutta numerical method of integration in the STELLA® modelling software. We assume the concentration in the refinery residuals used for cobalt extraction to remain constant, even when the ore grade of the mother metal ore grade goes down. Table 11-2 shows the input data for extractable amounts used to initiate the COBALT model.

BRONZE model simulation outputs

Figure 11-3 shows the primary extraction rate as reconstructed by the COBALT model for the past 115 years and predicted for the future from 2015 to 2400. The dots are observed values. Figure 11-4 shows the supply rate for cobalt as compared to mining rate and recycling rate. The primary extraction rate reaches a maximum at about 145,000 ton per year in 2015-2020, while the supply reaches a maximum of 210,000 ton per year in 2025. After 2100-2120 supply declines. The mining runs down to insignificant level by 2170. The supply is not kept up sufficiently by improvements in recycling as these are driven by market forces only, and cobalt supply declines sharply after 2100. The supply stays at sufficient levels until 2130, when it starts to decline. Figure 11-5 shows the stocks in use in society. Figure 11-6 shows the modelled recycling rates. The recycling rates are dynamic in the model and dependent on the market price.

Parent source	This study				USGS 2012 (million ton)	Mudd 2013 (million ton)
	Average parent metal content (%)	Average parent metal extractable (million ton)	Extractable amount (million ton cobalt)	Included in the COBALT model		
Copper production	0.23	3,767	8.5	yes	10	9
Nickel production	3.2	182-300	6-9.6	yes	5	5
Chromium production	0.006	1,905	1.0	yes	2	-
PGM production	2000	0.206	4.2	yes	2	1
Cobalt ores	0.5-3.0		1.0	no	1	0.5
Old mine dumps	0.2-0.7		0.5	yes	-	0.5
Sums			20-24.8		20	17

Table 11-1: *Sources of cobalt from secondary extraction and their concentration in the parent substrate, and estimate of total extractable amounts.*

Ore grade	Million ton copper			Ore grade (%)	Kg Cu per ton rock
	Known	Hidden	Sum		
Rich	15	5	20	40-5	400-50
High	10	20	30	5-1	50-10
Low	100	1,250	1,350	1-0.2	10-2
Ultralow	15	1,200	1,215	0.2-0.04	2-0.4
Extralow	15	1,100	1,115	0.04-0.01	0.4-0.1
Sums	155	3,575	3,730		
Ore grade	**Million ton nickel**			**Ore grade %**	**Kg Ni per ton rock**
	Known	**Hidden**	**Sum**		
High	29	1	30	5-1	50-10
Low	6	36	42	1-0.2	10-2
Ultralow	3	110	113	0.2-0.04	2-0.4
Sum	38	147	185		
Ore grade	**Ton platinum group metals**			**Ore grade %**	**g PGM per ton rock**
	Known	**Hidden**	**Sum**		
Extralow	1,400	36,000	37,400	0.01-0.005	10-5
Trace	0	38,000	38,000	0.005-0.002	5-2
Rare	0	61,000	61,000	0.002-0.0004	2-0.4
Nickel ore	0	22,400	22,400		
Sums			158,800		
Ore grade	**Million ton chromium**			**Ore grade %**	**Kg Cr per ton rock**
	Known	**Hidden**	**Sum**		
Rich	5	600	605	55-5	550-50
High	0	700	700	11-2	110-20
Low	0	595	595	2-0.5	20-5
Sums	5	1,895	1,900		

Table 11-2: *Input data to the COBALT model for extractable amounts.*

The recycling works reasonably well for metallic cobalt in super-alloys and other specific metallic uses since 1978-1980 when new and better technology was developed. In the other uses such as paints, chemicals or chemical catalysts, recycling is virtually non-existent. 2080-2120 the recycling rate increases as a market response to increased market prices. The recycling fails to match up to 100% because of losses. By market forces alone, recycling improves towards 2100, but by then far too much cobalt will have been wasted and lost diffusively. When compared to the recycling rates reported by the International Resource Panel, it becomes apparent that estimates of recycling rates at single point in time are very uncertain. Figure 11-7 shows the price in a longer perspective. After 2020, modest price increases start to modify the demand, and about 2070-2080 sharp price increases are predicted. After 2110, cobalt demand including price increase feedbacks cannot be met and the price rises further. This is the date for onset of physical shortage. The model gives price in value-adjusted prices in $ per kg cobalt.

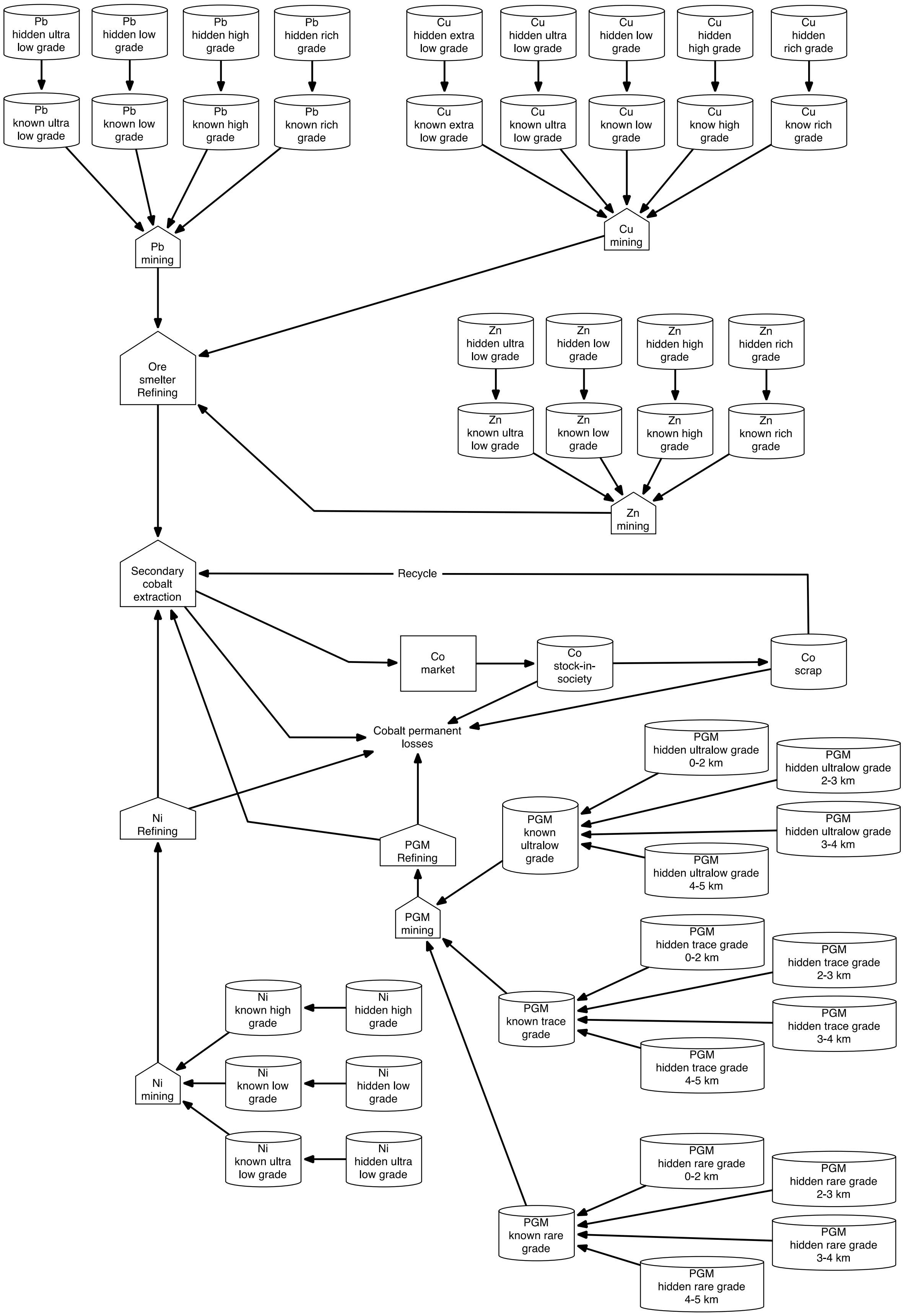


Figure 11-2: *Flowchart for the COBALT model, including independent and dependent metals relevant to cobalt. Other sub-modules in COBALT that have no use for cobalt, have been omitted.*

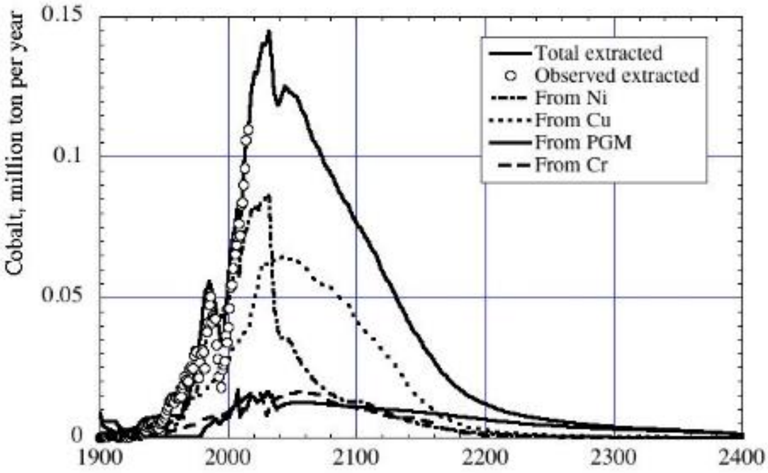


Figure 11-3: *Mining rate as reconstructed by the COBALT model, as well as from which mother lode it originates.*

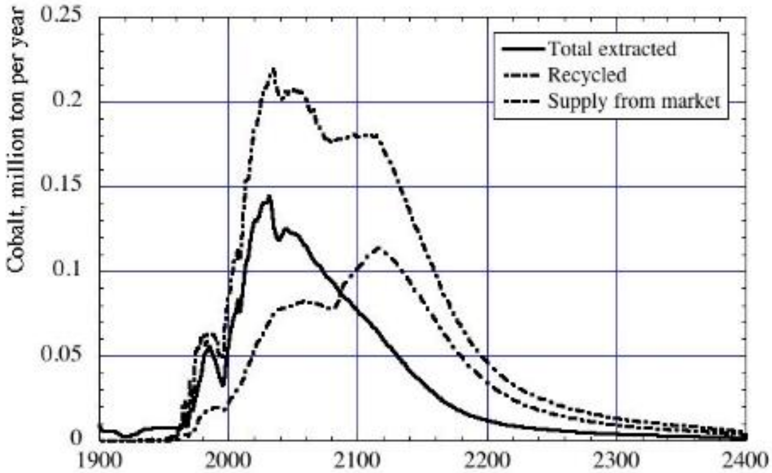


Figure 11-4: *Cobalt supply to different product segments.*

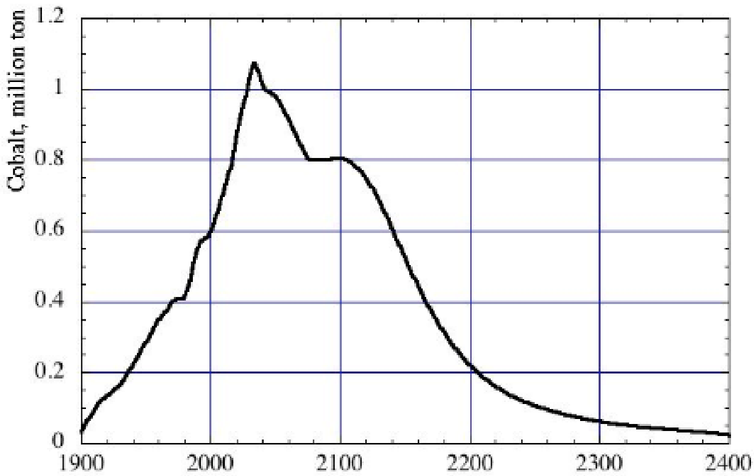


Figure 11-5: *Stocks in use in society.*

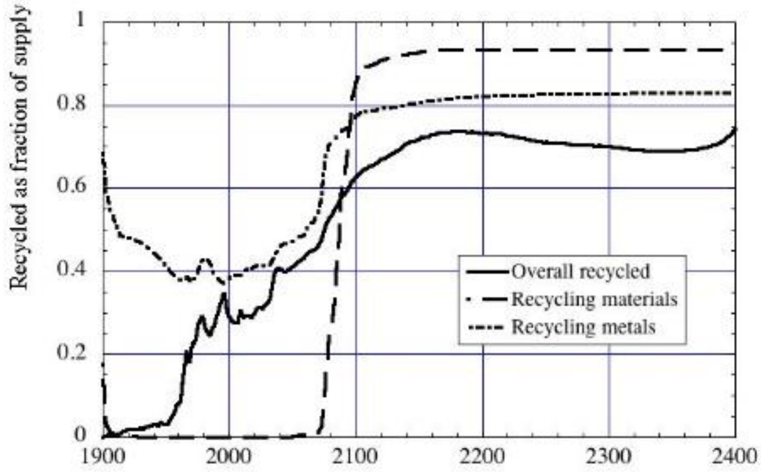


Figure 11-6: *Modelled recycling rates expressed as fraction of the total supply coming from recycled material.*

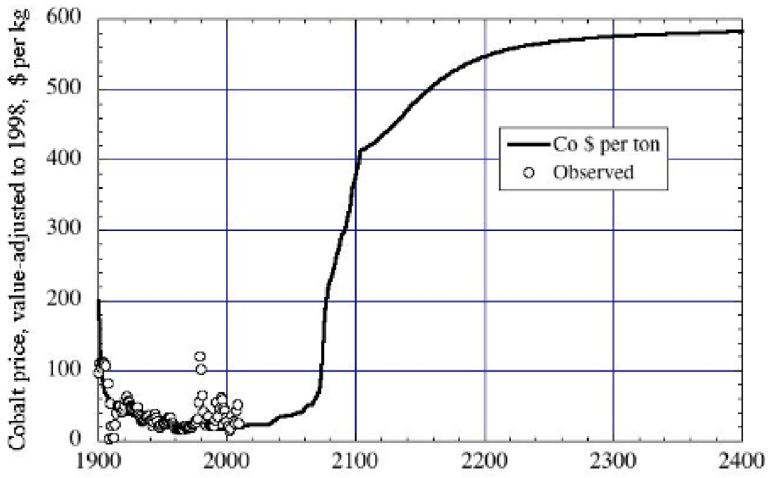


Figure 11-7: *Price in a longer perspective, 1998 value adjusted.*

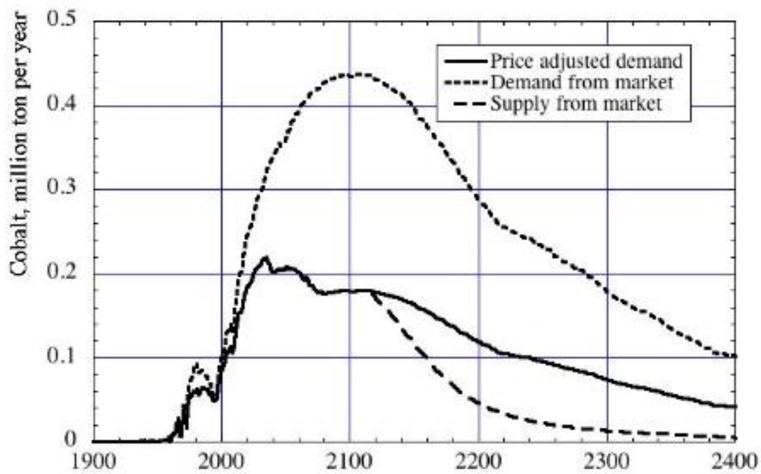
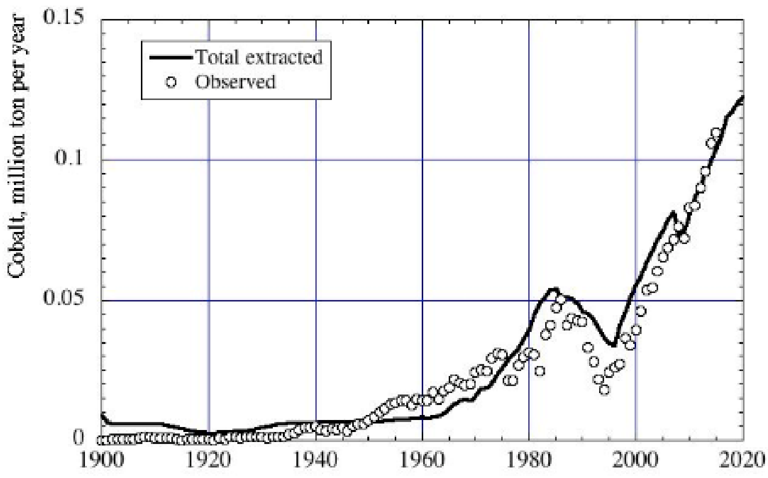
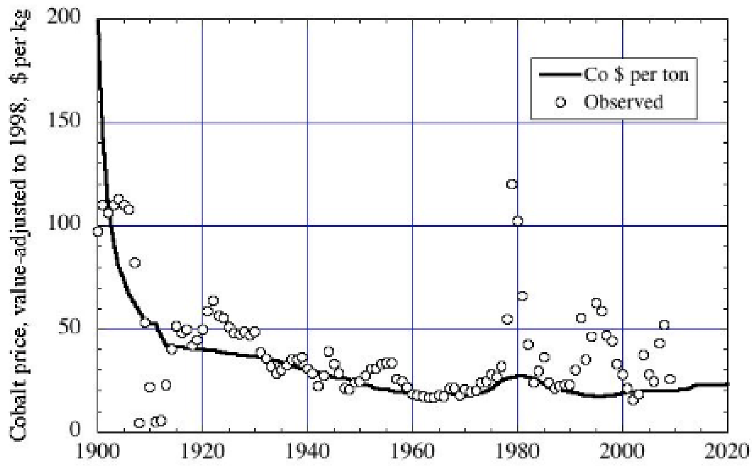


Figure 11-8: *Price-adjusted demand separates from supplied when demand can no longer be met in the market (2110).*



(a)



(b)

Figure 11-9: *A test of the model on the extraction rate to the observed cobalt extraction. r^2=0.94. The scale of the y-axis is amounts in million ton cobalt per year. (a) shows the modelled price as compared to the observed market price and the price in $ per kg (b), value-adjusted to 1998 $.*

The difference between unrestricted demand and the demand on the market after adjustment by the price feedback, shows the point when scarcity sets in and the price increase significantly. During 2015-2020, modest price increases starts to modify the demand, and about 2070-2080 sharp price increases are predicted (Figure 11-7). That is the point in time when demand can no longer be satisfied after price feedbacks on demand occurs about 2110. After 2120, cobalt demand, including price increase feedbacks, cannot be met and the price rises further.

Discussion

The general trends that we are able to check against seem to suggest that the COBALT model simulations give reasonable outputs. In Figure 11-5a show a test of the model on the cobalt extraction rate to the observed extraction rate. Figure 11-5b shows the modelled price as $ per kg value-adjusted to 1998 dollars for 1900-2020 as compared to the observed running current market price and the observed price in $ per kg value-adjusted to 1998 dollars and the observed price in the markets. For those metals we have assessed (copper, zinc, lead, silver, gold, platinum, palladium, cobalt, lithium, iron, aluminium, manganese, chromium and nickel), market mechanisms were inadequate for sustainable management of the materials.

Conclusion

The present use of cobalt shows a low degree of recycling and systemic losses are significant. The reserves of cobalt are not very large (20-25 million ton extractable) as compared to metals like copper, zinc or iron, and after 2170 cobalt will have run out under a business-as-usual scenario. The present business-as-usual for cobalt use in society is therefore not sustainable. Too much cobalt is lost if only market mechanisms are expected to improve recycling, and unnecessary cobalt is wasted if no policy actions are taken. We can conclude that the market mechanisms alone do not have the goal nor the competence to make cobalt use sustainable. Science-based solution-oriented policy is needed to correct the situation before it is too late and too much cobalt has been lost. Failure to take this message in will risk that society one day will be without cobalt. In order to conserve cobalt and allow it to be available for coming generations, present policies must be changed and the large losses mitigated within the next decades.

12. MODELLING THE GLOBAL COPPER, ZINC AND LEAD MINING RATES AND CO-EXTRACTION OF TECHNOLOGY METALS, MARKET SUPPLY, PRICE AND REMAINING EXTRACTABLE AMOUNTS

Harald Ulrik Sverdrup, Kristin Vala Ragnarsdottir ✉, Deniz Koca

Abstract

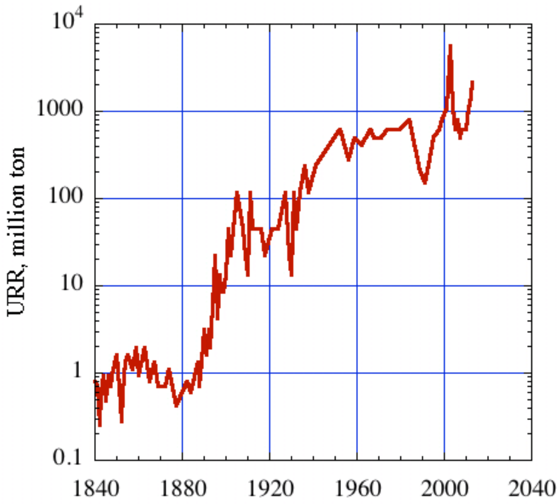
The total resources form copper, zinc and lead was estimated from a reworking of the literature. The data was used as input to the integrated systems dynamics model BRONZE, and used to estimate the global supply of these metals and the by-products antimony, indium, germanium, tellurium, cadmium, bismuth and selenium. The runs show that copper, zinc and lead go through peak production around 2050 and declines as the resources run out some time after 2100, and with them the metals produced as by products become unavailable.

Introduction

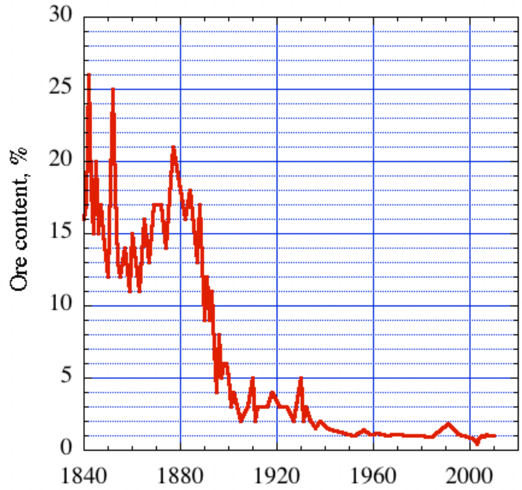
The BRONZE model is a model estimating the extraction rate of copper, zinc and lead and the metals that depend on this extraction for their production (selenium, germanium, gallium, indium, cadmium, silver, tellurium, bismuth and antimony). An integrated system dynamics model **BRONZE** was built for the purpose.

Model description

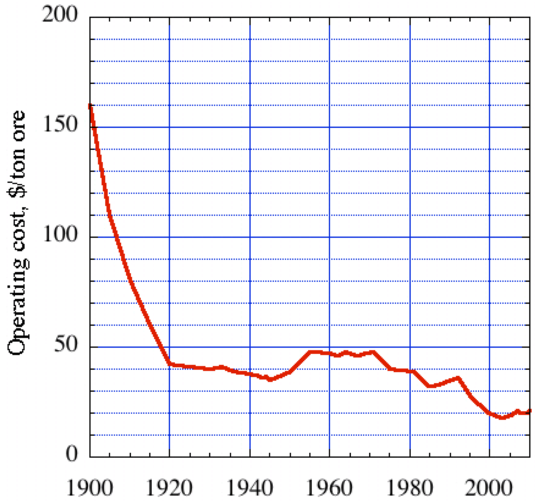
The BRONZE model is based on the earlier COPPER, SILVER and GOLD models and experiences learned from them (Sverdrup et al., 2013c, 2014a, b). Figure 12-1 shows the development of the copper resource, extraction costs and ore grade for copper. Figure 12-2 shows how URR increase as we include more and more lower grades of ore deposits in the estimate. The energy cost rise with declining ore grade and how the extraction yield declines with the ore grade. The degree of recycling is a function of metal price. Figure 12-3 shows copper and zinc production from mining and different supply fluxes. It also shows the simulated price as compared to the observed. Figure 12-4a shows lead mining rates, contribution from different ore grades and data on mining. Figure 12-4b shows mining, supply to the market and recycling. Supply to society is larger than mining because of recycling.



(a) URR



(b) Ore grade



(c) Extraction costs

Figure 12-1: *Diagram (a) shows the size of the extractable copper amounts as a function of time (House et al. 2011, Sverdrup et al. 2014b). (b) shows how the ore grade has gone down with time for copper. A similar development can be seen for zinc, silver, gold, nickel, uranium and several other metals. (c) shows how the extraction cost has gone down with time.*

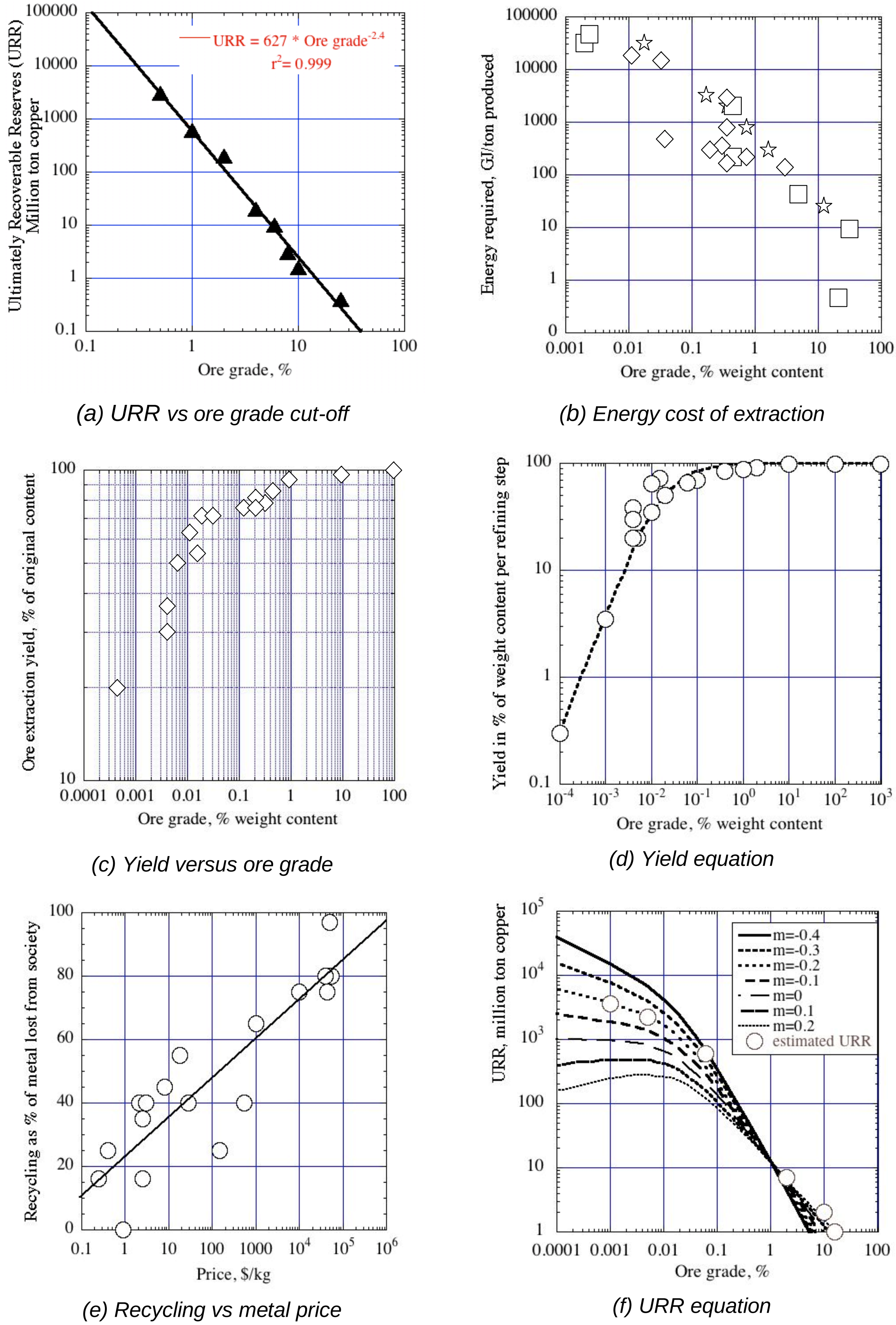
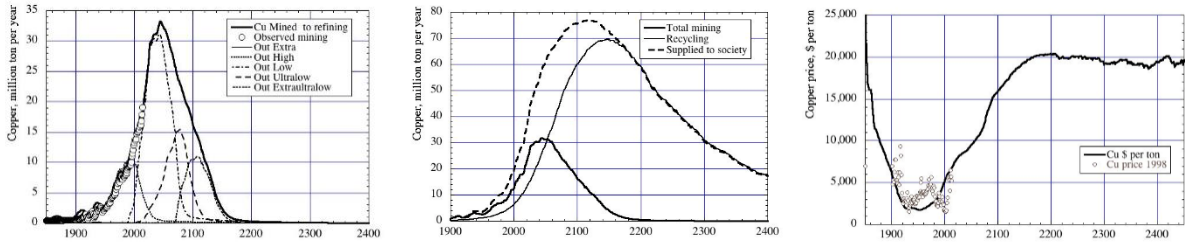
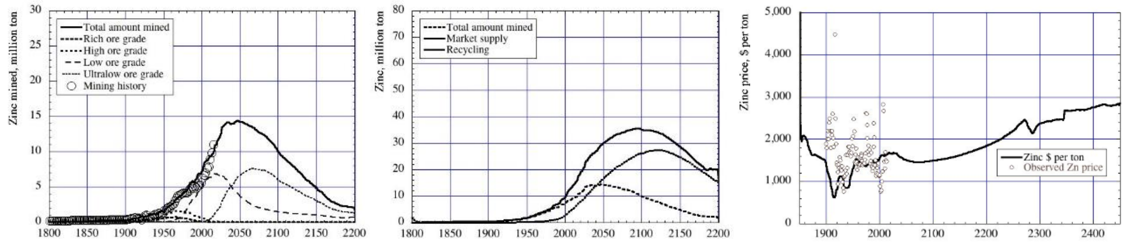


Figure 12-2: *Diagram (a) shows how URR increase as we include more and more lower grades of ore deposits in the estimate of URR. Diagram (b) shows how the energy cost rise with declining ore grade, equation (6) as compared to data. Diagram (c) shows how the extraction yield declines with the ore grade. Diagram (d) shows the degree of supply as recycled a function of metal price. Diagram (e) shows the fit of the resource equation.*



Copper



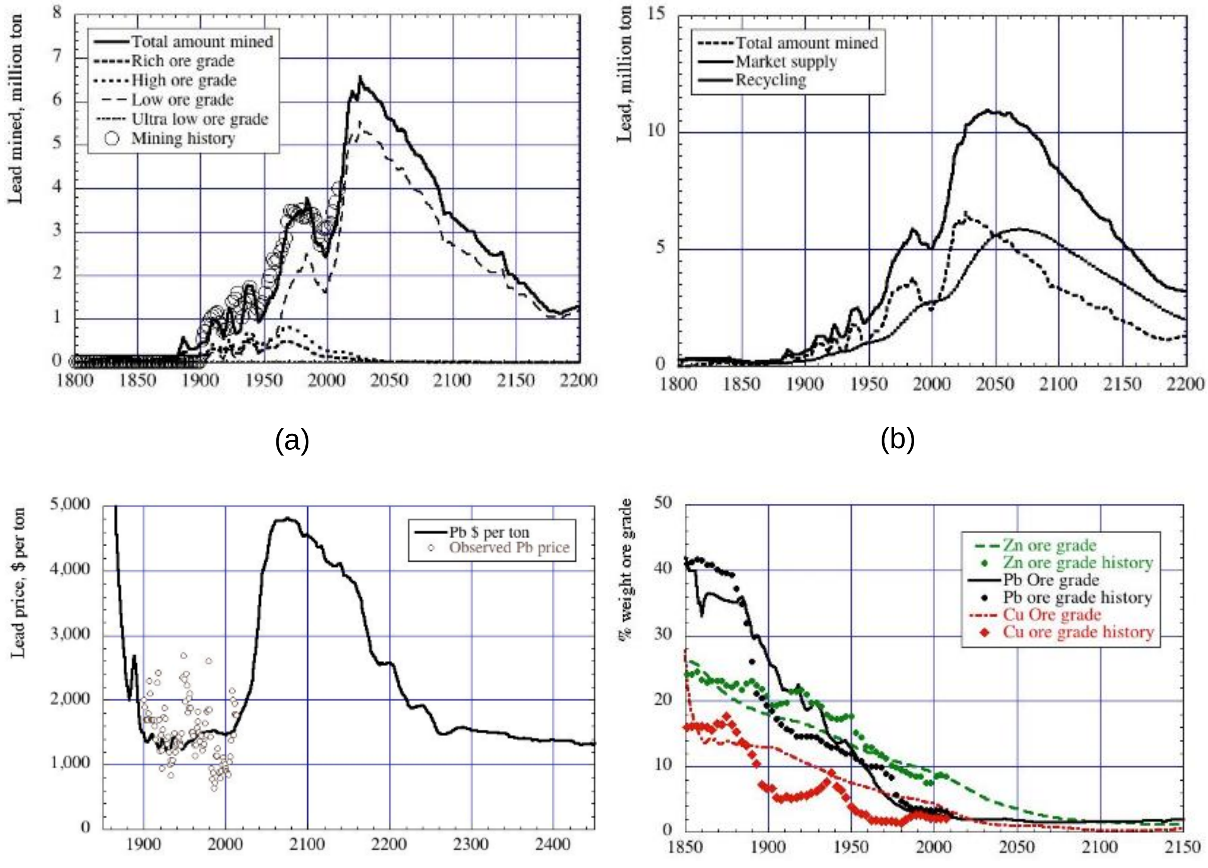
Zinc

Figure 12-3: *Copper and zinc production from mining and different supply fluxes. The circles represent observed mining rates. (b): mining, supply to society and recycling. (c) shows the simulated price as compared to the observed.*

COPPER							
		Copper; porphyric deposits (70%)					
Ore grade		**Million ton copper**				**Ore grade %**	**kg/ton content**
	Known	**Hidden**	**Sum**	**%**	**Cumulative**		
Rich	10	4	14	0.5	14	40-5	400-50
High	7	571	578	22	592	5-1	50-10
Low	70	1,313	1,383	53	1,975	1-0.2	10-2
Ultralow	10	403	418	16	2,393	0.2-0.04	2-0.4
Extralow	10	212	222	8.5	2,615	0.04-0.01	0.4-0.1
Copper; sulfide deposits (30%)							
Ore grade		**------------- Million ton copper -----------**				**Ore grade %**	**kg/ton content**
	Known	**Hidden**	**Sum**	**%**	**Cumulative**		
Rich	5	1	6	0.5	6	40-5	400-50
High	3	111	114	10	120	5-1	50-10
Low	30	270	300	27	420	1-0.2	10-2
Ultralow	5	359	364	33	784	0.2-0.04	2-0.4
Extralow	5	330	335	30	1,119	0.04-0.01	0.4-0.1

All COPPER deposits							
Ore grade		**------------ Million ton copper -----------**				**Ore grade %**	**kg/ton content**
	Known	**Hidden**	**Sum**	**%**	**Cumulative**		
Rich	15	5	20	0.5	20	40-5	400-50
High	10	670	692	19	845	5-1	50-10
Low	100	1,583	1,683	45	2,822	1-0.2	10-2
Ultralow	15	767	782	21	3,419	0.2-0.04	2-0.4
Extralow	15	540	555	15	3,736	0.04-0.01	0.4-0.1
ZINC							
Ore grade		**------------ Million ton zinc ------------**				**Ore grade %**	**kg/ton content**
	Known	**Hidden**	**Sum**	**%**	**Cumulative**		
Rich	1	28	29	1	29	40-5	400-50
High	5	310	315	12	344	5-1	50-10
Low	1	976	977	37	1,321	1-0.2	10-2
Ultralow	0	1,355	1,355	50	2,676	0.2-0.04	2-0.4
LEAD							
Ore grade		**------------ Million ton lead ------------**				**Ore grade %**	**kg/ton content**
	Known	**Hidden**	**Sum**	**%**	**Cumulative**		
Rich	20	10	30	1	40	40-5	400-50
High	5	40	45	1.5	75	5-1	50-10
Low	1	1,084	1,085	36	1,160	1-0.2	10-2
Ultralow	210	1,640	1,855	61.5	3,015	0.2-0.04	2-0.4

Table 12-1: *Input data to the BRONZE model. The extractable amounts were set at the beginning of the BRONZE model simulation in 1800, stratified with respect to ore metal content. The distribution of copper to ore grades is based on Figure 12-4b.*



(a) (b)

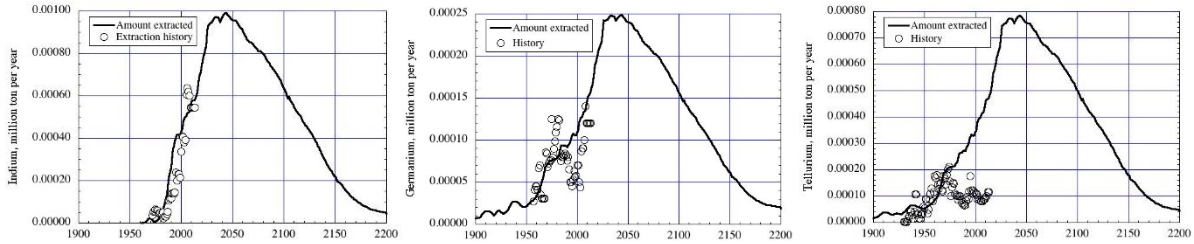
(c) (d)

Figure 12-4: *Lead (a): Lead mining rates, contribution from different ore grades and data on mining (o). (b) mining, supply to the market and recycling. (c) shows development of the extractable amounts over time. Diagram (d) known extractable amounts and stocks-in-use in society. (e) shows the simulated price for zinc (a) and lead as compared to the observed market price in 1998 value adjusted $ per ton.*

Figure 12-4c shows development of the extractable amounts and Figure 12-4d known extractable amounts and stocks-in-use in society over time. Figure 12-4e shows the simulated price for zinc and lead as compared to the observed market price in 1998 value adjusted $ per ton. Simulated and observed ore grades for copper, zinc and lead are r^2=0.86 for copper, 0.81 for zinc and 0.97 for lead. Figure 12-5 shows the production rate for the technology **indium**, **germanium**, and **tellurium** extraction compared to data. Figure 12-6 shows the connection between the production of many different metals as a flow diagram, showing parent reserves as barrels and rates of production as ovals. Many metals are extracted from poly-metallic ores, and they are all extracted out, many for new uses. The population data in the **BRONZE** model uses the outputs of the fully integrated population model used in the **WORLD** model system (Sverdrup et al., 2011, Sverdrup and Ragnarsdottir 2011, Sverdrup et al., 2012c). The population numbers are used to estimate copper demand and the oil price as an input to the **BRONZE** model. **COPPER**, **ALUMINIUM** and **SILVER** are sub-modules in BRONZE (Sverdrup et al. 2014a, b, 2015a). The whole system is on the way to become the new **WORLD** model (Sverdrup et al., 2012a, 2014a, b) where a considerable additional number of sub-modules are being integrated, **ALUMINIUM** (Sverdrup et al. 2015b) and **STEEL** which incorporates the model **IRON**.

Results

Figure 12-3a shows the simulated copper production, and the lines the supply from the different ore grades. For copper, the willingness to pay is good because of the importance of copper for many essential functionalities of society. The production is predicted to peak around 30 million ton per year (globally that corresponds to about 3.2-3.5 kg per person and year) and to decline after 2045. Figure 12-3b shows the supply to society, the mining rate and recycling. Long after the copper mines have run out, copper will be present in society and be supplied from recycling and urban mining. It can be seen that copper supply to society peaks at about 77 million ton copper per year in 2120 (7.5 kg copper per person and year).



Indium Germanium Tellurium

Figure 12-5*: The production rate for the technology* ***indium****,* ***germanium****, and* ***tellurium*** *extraction compared to data.*

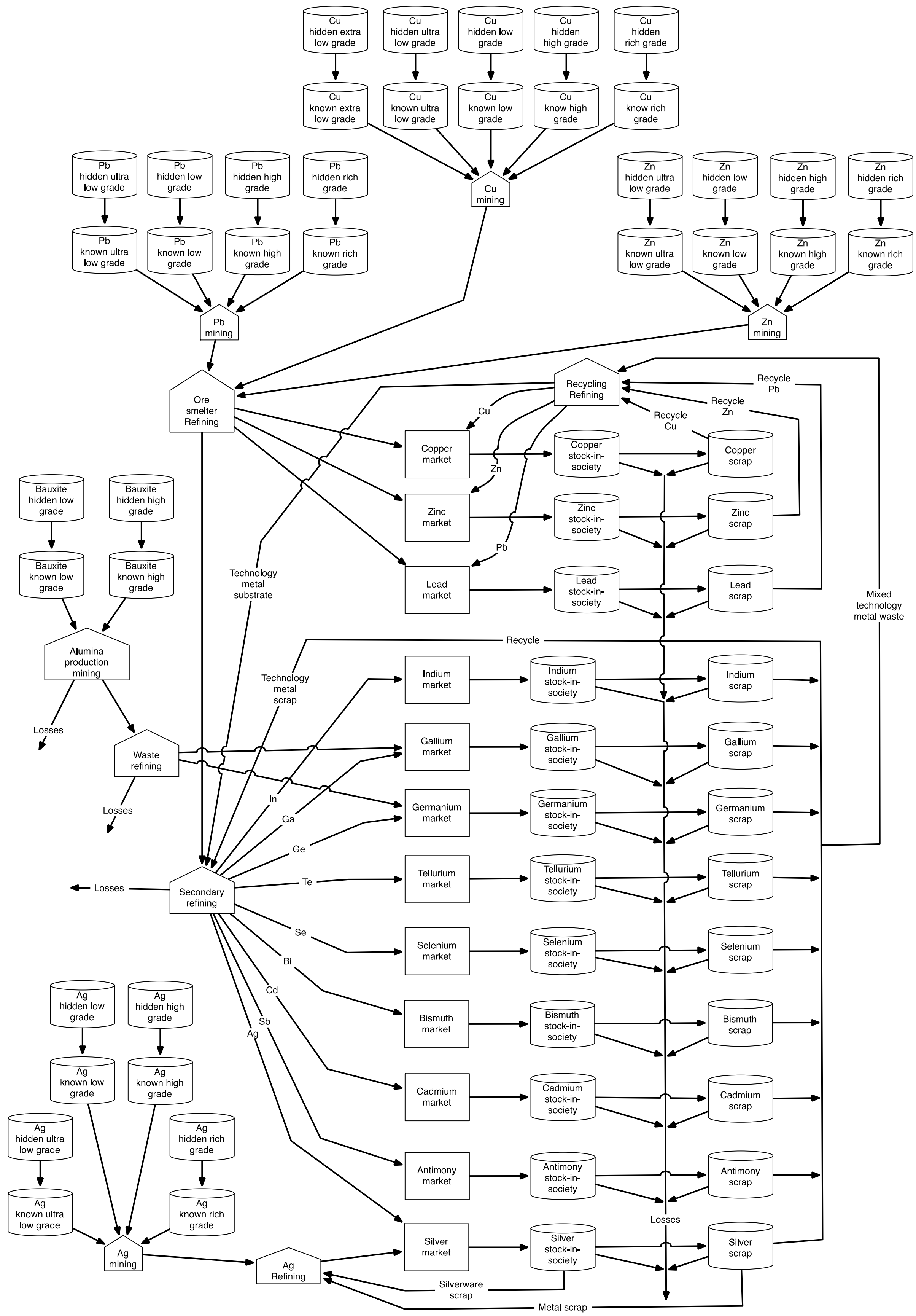


***Figure 12-6:** Flowchart for a part of the BRONZE model, including independent and dependent metals. The version with the STEEL and Cobalt model adjoined is not shown.*

Conclusion

The BRONZE model seems to be verified reasonably well against field data. The BRONZE model assessment and the Mass Flow Analysis by Northey et al. (2014) reach the same conclusions concerning need for future policies. However, the BRONZE model does give a richer picture, including more details and essential feedbacks. We are able to reconstruct the past history of mining rates, ore grade decline and approximate metal price levels. We get reasonable estimates of the production rates for the technology metals dependent on copper, zinc and lead for their production. We need to carefully distinguish between the primary production from mines and total supply to the market. Long after primary metal mining has been reduced to insignificant levels, supply may be kept up by efficient recycling.

The time after 2050 will be the age of urban mining, where more copper, zinc and lead metal is supplied from recycling that from primary extraction from mines. However, for the technology metals, many have at present low rates of recycling, and these are much more vulnerable due to decline in mining, unless the recycling efficiency can be significantly improved. The conclusion is the there is not an immediate risk for scarcity but that in the longer run (after 2030), scarcity manifested as rising metal prices should be expected and prepared for.

13. MODELLING THE FUTURE SECONDARY RESOURCE AVAILABILITY AND RECYCLING POTENTIAL OF ALUMINIUM IN AUSTRIA

Hanno Buchner ✉, David Laner, Helmut Rechberger, Johann Fellner

Abstract

Production of secondary aluminium (Al) currently represents about 70% of total European Al production with a still rising trend and about 50% European final Al demand. The utilization of anthropogenic Al resources as secondary raw materials is therefore a core aspect of moving towards a circular economy, from an ecological as well as from a raw material supply perspective. With respect to Al resource management, dynamic material flow models can be used to understand patterns of Al use, the evolution of Al stocks, and the future availability of Al scrap. In this study, a dynamic aluminium flow model is developed in order to investigate Austrian Al consumption, in-use stocks and post-consumer (old scrap) flows during the last five decades, from 1964 to 2012. It is found, that during the past 20 years Austrian Al in-use stocks have more than doubled up to the level of 360 kg/capita in 2012. Almost two thirds of the Al stock are contained in buildings and transport applications. In recent years, total old scrap generation amount to almost 50% of final Al consumption. Based on the historic Al model and projections of Al consumption until 2050, the future development of in-use stocks and old scrap generation is estimated. An increase of 130% in total old scrap generation is expected compared to the current levels. Modelled trends on scrap generation are finally contrasted with end-use Al demand as well as with industrial scrap demand in order to display the potential for future Al self-supply in Austria. Since improved recycling is a major aspect of European resource policy, opportunities and limits of increasing the domestic supply with domestic Al scrap, through increased collection rates, are shown.

Keywords: aluminium, Austria, future scrap availability

Introduction

During the last decades Al has become the most widely applied metal after iron (Recalde 2008). Due to unique material properties especially in terms of flexibility, corrosion resistance, conductivity and weight an increase in future demand is expected (EAA 2012). Simultaneously, available scrap amounts originating from existing in-use stocks are expected to increase, since even products with long average lifetimes (e.g. Al in buildings and infrastructure) will reach end of life during next decades. Even though global known primary Al reserves (bauxite) are expected to last for 200 years at current consumption rates (UNEP 2011), regions with limited access to primary resources (e.g. European Union (EU)) are considering secondary resources (like Al old scrap) as a complementary source of future raw material supply (European Commission 2008). Therefore enhanced recycling of old scrap is defined as one important pillar of the European Raw Material Initiative (European Commission 2014), which aims at securing future raw material supply as a prerequisite for strengthening European industry. In order to illustrate the quantitative limits and opportunities of Al recycling a dynamic material flow model of Austrian Al flows from 1964-2050 is shown in this study. Using historical production and trade data current in-use stocks are calculated and subsequently combined with estimates on future final Al demand in order to predict future stock development and Al scrap generation. By combining the latter with forecasts on future Al demand, the potential of future self-supply is calculated. A differentiated view of self-supply with respect to industry demand and final Al demand (=consumption at in-use) is finally given.

Materials and Methods

An input driven dynamic material flow model of Austrian Al flows has been developed (Buchner 2015a) based on top-down data (production and trade statistics). Ranging from production and processing of unwrought Al, over manufacturing and in-use to waste management, all stages of the Al life cycle are covered considering relevant foreign trade flows at each stage. Concerning final Al demand discrimination between six relevant sectors, namely, Transport, Building and Infrastructure, Mechanical Engineering, Electrical Engineering, Consumer and Packaging material has been made. Using sector specific life-time functions, the output (old scrap generation potential) of each sector is calculated by multiplying historical inputs with probability density functions of discard. In this study calculated in-use stocks from the historical model are combined with forecast on future Al consumption based on (Buchner 2015b). For the sectors Transport, Buildings and Infrastructure and Electrical Engineering, a stock driven approach is used for calculating the future development of in-use stocks. From the future development of in-use stocks, inputs (final Al demand) as well as old scrap flows can be derived. For the remaining sectors (Mechanical Engineering, Consumer and Packaging) where a stock-driven approach is not possible due to data limitations, an input-driven approach is used. Future inputs are determined based on the calculated inputs for 2012 and industry estimates about the development of future final Al demand in those sectors (EAA 2012).

Finally, current and future self-supply can be calculated by relating final Al demand and secondary production to modelled old scrap generation. In this study the self-supply of Al is defined as the (potential) share of old scrap in national secondary Al production and national final Al demand respectively.

Results

In-use stocks and old scrap flows

In-use and old scrap flows are derived from the model and shown in Figure 13-1. Starting at low levels of Al use and moderate built up of in-use stocks, Al demand increased significantly after 1980 leading to high growth rates of in-use stocks, due to long average life-times of most Al applications. Currently (2012) more than two thirds of all anthropogenic Al is stored in buildings and infrastructure (159 kg/cap) or the transport sector (109 kg/cap). Minor amounts of Al are found in engineering applications (66 kg/cap), consumer products and reusable packaging material (26 kg/cap). Even though growth rates have been decreasing in the last decade, in-use stocks are still on an increasing trend at rate of around 2 %/yr. In 2012 total Al in-use stocks in Austria are estimated to 360 kg/cap (Figure 13-1a).

Total old scrap generation is dominated by Al from transport application incl. vehicle exports (34%) and packaging material (20%). A total old scrap amount of around 13 kg/ yr cap is calculated, of which around 4 kg/yr cap are due to vehicle exports (Figure 13-1b). Exported vehicles are not available as scrap on the national market and should therefore not be considered as a raw material source in a national context. It should be further mentioned, that not all vehicles exported from national inventory are actually scrap vehicles, thus these estimates tend to be an overestimation in terms of scrap generation potential. However, looking at the trend of old scrap generation it is observed that old scrap amount quadruplicated since

1982. Finally, it should be noted that calculated in-use stocks and old scrap generation may be underestimated during the first 20-30 years of the model, due to the beginning of the model in 1964 (which implies an Al in-use stocks in 1964 of0 kg/cap). But these effects of initial stock assumption vanish over time and do not exhibit noteworthy influence on the in-use stocks and old scrap generation in 2012 (Buchner et al. 2015a).

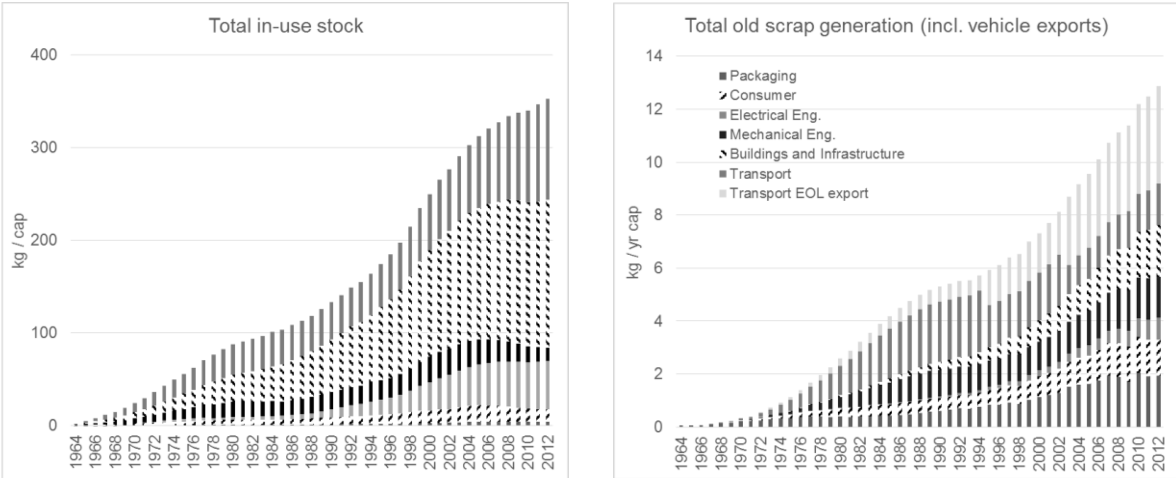


Figure 13-1: *Development of in-use stocks and old scrap flows (based on Buchner et al. (2015a)).*

Final Al demand

The trends of historical and future Al final demand for the six in-use sectors are shown in Figure 13-2. After 1980 a steep increase in national final Al demand is observed, mainly driven by Al consumed for buildings and infrastructure as well as transport applications. After 2010 a flattening (slightly decreasing trend) in final Al demand is observed finally leading to a sharp decline during the financial crisis in 2007-2009. Disruptions in consumption between 2009 and 2013 are mainly due to an increase in final Al demand after the financial crisis interacting with discontinuity originating from the transition from a fully input driven model (1964-2012) to a partly stock driven and partly input driven model (2013-2050). Based on the forecasts an increase of final Al demand for all sectors is expected. In 2030 final Al demand is expected to reach 28 kg/cap with a further increase to 35 kg/cap until 2050. Transport sector will by far be the dominant sector driving final Al demand, mainly because of optimistic assumptions on future Al use in vehicles due to light weighting. But also for the other stock driven sectors (buildings and infrastructure and electrical eng.) a slight increase in final Al demand is observed. Forecasts of the other (input driven) sectors are based on industry estimates, showing increasing trends of final Al demand for all sectors.

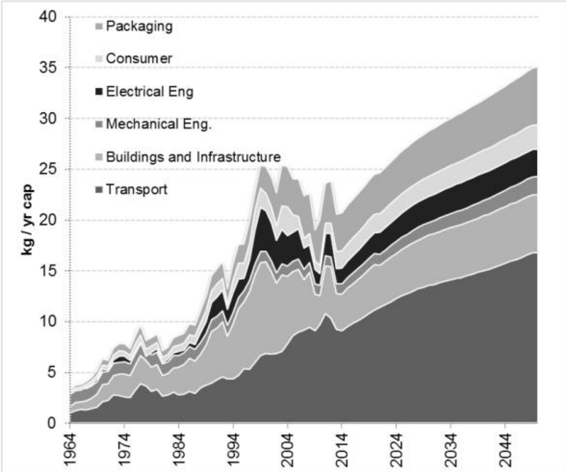


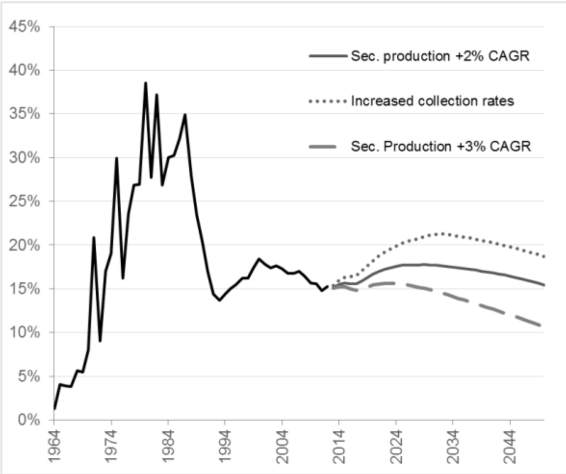
Figure 13-2: *Historical and forecasted final Al demand (Buchner et al. 2015b).*

Considering forecasted final Al demand and current in-stocks, trends of future in-use stock development and old scrap generation are calculated by the model. Total in-use stock is expected to increase from 360 kg/cap in 2012, to 440 kg/cap in 2030 and will finally reach 530 kg/cap in 2050. Increase in total old scrap generation will be even more pronounced, increasing from 13 kg/cap in 2012, to 24 kg/cap in 2030 and 31 kg/cap in 2050. In other words, old scrap generation is expected to increase by a factor of 2.5, mainly driven by high Al intensity in vehicles and increasing mobilisation of Al from current building and infrastructure stock.

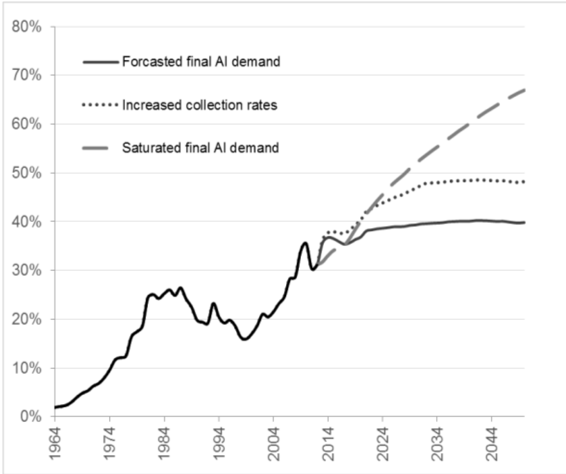
Current and future self-supply

From an historical point of view, an increasing trend in self-supply regarding production is observed, which is due to formerly low old scrap amounts and a marginal share of secondary production in total unwrought Al production until the 1980's. But with the close-down of primary production facilities in Austria in 1991 and a simultaneous increase of secondary Al production, self-supply suddenly falls to a still remaining level of around 15%. From an industry perspective, it becomes quite obvious that additional old scrap amounts originating from anthropogenic stocks will have a quite limited power to increase future self-supply, even though only a moderate growth of national production (2% CAGR) is assumed (Figure 13-3a). Increasing collection rates from nowadays levels to (theoretical) values of 95% for transport and buildings and the infrastructure sector and to 90% for all other sectors within the next 20 years could increase self-supply for production by around 5%. A 3% CAGR scenario is further modelled in order to illustrated the strong effect the of the assumed production scenario on self-supply in Figure 13-3a.

Comparing future old scrap generation with final Al demand, self-supply has been more or less increasing over time, with an exception in times of highly increasing Al demand between 1985 and 2005. Future self-supply is expected to slowly increase to a level of 40%, for the given assumptions of future final Al demand (Figure 13-3b). Increased collection (as described above) could further contribute about 10% to self-supply. If per capita Al demand would remain at today's levels an increase of self-supply up to nearly 70% could be expected. Even though calculating self-supply for final Al demand is a theoretical scenario, since a closed system (not trade flows, national production serves national final Al demand) is assumed, it clearly illustrates the limits of meeting final Al demand from old scrap sources.



(a)



(b)

Figure 13-3: *Historical and future self-supply with respect to (a) national secondary production and (b) national final Al demand.*

Conclusions

Addressing future resource policy, it is concluded that a more differentiated view regarding opportunities and limits of recycling measures is needed. From an industry perspective, additional old scrap amounts will be of quite limited power for easing primary raw material dependence and the potential self-supply from old scrap will stay between 15% and 20%, if growth visions of industry are set into action. Achieved growth in production quantities will be the dominating factor influencing self-supply. From a final demand perspective, a slightly increasing trend of self-supply is observed but for the given forecasts total scrap generation will be far too low for fully satisfying future Al demand. Issues of circular economy should therefore be discussed under the given limits of secondary raw material availability. Ecological and economic benefits from enhanced old scrap recycling have to be analysed in detail and policy action should further be undertaken in view of their limits regarding primary raw material substitution.

14. ASSESSING SUSTAINABLE LIMITS FOR MEALS - FIRST RESULTS FROM THE PROJECT NAHGAST: DEVELOPING, TESTING AND DISSEMINATION OF CONCEPTS FOR SUSTAINABLE PRODUCTION AND CONSUMPTION IN THE FOOD SERVICE SECTOR

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assisted by Diana Neundorf and Nils Seipel

Abstract

The food industry belongs to the most significant economic sectors worldwide. Regarding resource use, human nutrition is responsible for about 30 % of global resource consumption. In order to decrease resource consumption to a level in line with planetary boundaries, it is suggested to reduce the resource use of the nutrition sector by factor 2. In view of about 40 % market share in the total nutrition market in Germany, the restaurant and catering sector presents a large untapped potential to increase resource efficiency and improve consumers' health status.

In the light of the above, the current project NAHGAST aims at initiating, supporting and promoting transformation processes for sustainable business in the hospitality sector. Therefore, the project will promote the concept of a resource-efficient and socially inclusive economy through the development and testing of instruments for sustainable product innovations, which should be integrated in hospitality settings so actors will be able to measure and assess foodstuff and menus from the viewpoint of sustainability and health. By now, already existing indicators and assessment methods, e.g. Carbon and Material footprinting, or already targeted concepts such as the Nutritional Footprint or SusDISH have to be compared and analyzed. The aim is to provide a comparison of existing concepts and their adaption to reach the overall goal towards a deeper understanding of sustainable catering and food procurement. The paper may be seen as the conceptional and methodological part of the general framework of the NAHGAST project.

Keywords: nutrition, out-of-home catering, sustainability assessment, resource conservation, resource efficiency

Introduction and objective

Background

The pace of modern life is leading people to eat out more often – at cafeterias, canteens, fast food outlets, bars and restaurants. With so many food offers high in salt, saturated fat and/or sugar, eating habits do not always conform to current dietary guidelines and further do have a great ecological impact (Macdiarmid et al. 2012). Thus, Nutrition – meaning the consumption of meals – is responsible for a significant share of the resource consumption of a society and results in considerable material footprints (Mancini et al. 2012). In Europe, the food sector (agriculture, food manufacturing and hotels and restaurants) accounts for 17 % of greenhouse gas emissions and 26 % of natural resource use in final consumption. In order to reduce global resource use to a sustainable level, a sustainable level of resource use has to be defined for nutrition (see Foresight 2011; Jungbluth 2010; Koerber and Kretschmer 2006, Schmidt-Bleek

2009). In general, there is a notable lack of data differentiating dietary intake and ecological or social impact of meals eaten at out-of-home catering.

Objective

Following the idea of the nutrition ecology (Leitzmann 2003), the dimension of health has to be added to the typical three sustainability dimensions used to assess the sustainability impacts of food. Over the last years, different indicators and concepts have been established but most of them are lacking a definition of ecological targets or what is called sustainable levels in Lukas et al. 2015. To take the next step at this point, a comparison of several established methods seems to be necessary to develop a comprehensive concept which is useful for companies in the out-of-home sector and this is also fruitful to develop a deeper understanding about suitable sustainability assessment levels for nutrition, so far.

Methods

To provide a basis for the development of the new assessment method, a comprehensive desk research is needed. This here presented research offers a variety of economic, social, environmental and health indicators as well as relevant (multi-dimensional) concepts. To provide a satisfying number concepts and indicators, an expert workshop was hosted in July 2015 to rather evaluate the desk research.

The next steps may be the assessment of sustainable level for a distinct group of indicators. This has to be done in the near future.

Theoretical Background and indications

Obviously, more abstract and complex concepts tend to drawing up a greater number of indicators and potentially will have more dimensions. Indicators and concepts which are already applied to kitchens or food are of particular relevance for the NAHGAST project. Therefore, seven concepts, some based on only one, other based on several indicators, have been selected.

The **Carbon Footprint** represents a certain amount of greenhouse gas emissions (usually quantified in tonnes of CO_2 equivalents) that are relevant to climate change and associated with human production and consumption activities. The carbon footprint can be calculated e.g. for countries, regions and towns, for branches and enterprises, for demands (like nutrition) or for households (Wiedmann/Minx 2007). The Carbon Footprint can also be understood as the carbon component of the Ecological Footprint translating the tonnes of emissions into hectares of productive land and sea required to sequester carbon dioxide emissions (http://www.footprintnetwork.org/en/index.php/GFN/page/carbon_footprint/).

“The **material footprint** is a tool to measure and optimize the resource consumption of both products and their ingredients and the production processes along the whole value chain. It covers the whole life-cycle of the products, from the extraction of raw materials to the processing industry, distribution, consumption, recycling, and disposal.“ (Lettenmeier et al. 2012: 584). It is a practical measure for assessing the resource use of meals, because all resources and ingredients used in each process are summed up. The material footprint includes the direct and indirect use of abiotic and biotic resources plus soil erosion in agriculture. The concept is based on the MIPS concept (material input per unit of service) (Liedtke et al. 2014, Schmidt-Bleek 1994). It is a purely quantitative measure for natural resource use (Rohn et al. 2013).

The **Water Footprint** is a concept to measure the direct and indirect volume of water use or pollution by a defined group like a consumer (individual, society, nation) or producer (company). It is defined as the total volume of fresh water, which is going into the production of the consumed or produced good or service. Water use is measured in terms of water volumes consumed (evaporated) and/or polluted per unit of time. The water footprint is a geographically explicit indicator that does not only show volumes of water use and pollution but also the locations. The footprint breaks down into three components: the blue (surface and ground water), green (rainwater stored in the soil) and grey (water that is required to dilute pollutants to such an extent that the quality of the ambient water remains above agreed water quality standards) water footprint. It is an analytical tool to address policy issues of water security and sustainable water use (Hoekstra et al. 2011/ Hoekstra 2008).

The **MNI** (Menü-Nachhaltigkeits-Index, “Sustainability-Index of Menus”) is a concept developed in Switzerland to assess the sustainability of menus in the mass catering. The reason for developing this concept was that the consumer does not receive information about the health and environmental aspects of menus. To estimate the health dimension of the menu, the concept includes 8 indicators like the fat and carbohydrates content, based on the nutritional reference values for Germany, Austria and Switzerland (DEG et al. 2015). The health assessment is indicated by so-called “nutritional stress points” respectively “nutritional balance points”. To analyse the environmental dimension and to weight the environmental impacts, the methods of LCA (Life Cycle Assessment) and “ecological shortage” are used. The evaluation of different environmental effects like emissions, water use or loss of biodiversity is based on national ecological goals of Switzerland, where actual values are compared to the tolerance values (Distance-to-Target). The environmental evaluation is indicated by so-called “environmental impact points”. The aim is to provide a concept that helps the kitchen staff to create healthy and environmental-friendly menus and helps the consumers to select these menus (Müller 2015).

The **Nutritional Footprint** is a concept to evaluate the effects on health and environment because of nutrition. It includes four core-indicators each on health and environment. The dimension on health includes energy (kcal), content of salt, fibre and saturated fat (g). The indicators for the environmental dimension are Material Footprint (g), Carbon Footprint (g), water use (L) and land use (m^2). These eight indicators assemble to a new set of indicators where all phases of the value chain are examined. Next to that, a new ranking level was defined with regard to new limiting values of the effects of the indicators on environment and health, and was translated on a 3-steps-scale of small, medium and strong impact. The goal is to create a transparent and daily life oriented communication (Lukas et al. 2015, Goggins & Rau 2015).

susDish is subdivided in two accounting areas of health and environment (ecology) and has 31 indicators. The health value of the analyzed menus is assessed with 16 indicators, containing twelve reference-values of the DGE (German Society for Nutrition). With this approach, critical supply situations of single nourishments within the menu-line can be identified. To assess the ecological dimension, which includes 15 indicators, the life-cycle based concept of „ecological shortage“ is used (see MNI), including a carbon footprint. susDISH is software based. Each indicator can be evaluated individually but also be aggregated so that dishes can be compared with each other. After calculating the “eco-points” and “health points”, dishes can be placed in a traffic light coloured coordinate system so costumers can avoid eating “red” dishes – or kitchen managers can remove them from the offering (Meier et al. 2015).

FOODSCALE quantifies eleven sustainability categories (e.g. organic, seasonality, fairly traded food, meat, sustainable sourced seafood, eggs, water, food waste, origin of food, consumer engagement, engaging with smaller producers and local communities) that cover 36 food sustainability indicators. It incorporates social, economic and environmental issues, and considers the entire food system. It is based on a point scoring system, ranging from zero to 100. Each category and individual indicator is weighted to reflect its relative importance to food. This weighting was based on a number of factors including an extensive review of relevant literature, 25 qualitative interviews with food experts, as well as an iterative process of data collection adjusting during the development and pilot phases (Goggins & Rau 2015).

Conclusions

The field of nutrition represents an untapped (and, until now, even not systematically analysed) potential for reducing negative impacts on health and environment. Nevertheless, only very few concepts exist which enable actors of the out-of-home catering to measure and assess foodstuff and menus from the viewpoint of sustainability and health. The presented paper aims to demonstrate the status quo of established indicators and concepts which are already applied to kitchens/food. The knowledge gained from the analysis and comparison will be used to develop integrated methods for the assessment of sustainability and health impacts of out-of-home catering. Results of these reflections can be found in a project working paper (Speck et al. 2016).

To compare and analyze the existing concepts for assessing sustainability in out-of-home catering, categories have been formed and thus the results are concluded in Table 14-1). This table provides an overview and allows identifying correlations between the selected methods. Although, the table enables to evaluate the indicators and concepts by presenting their strengths and weaknesses. These evaluating items – as well as descriptive ones – in the very left column are checked for all seven analyzed concepts in the following columns; the more complex concepts are easily distinguished by different colour shades.

Classification	Water Footprint For Food	Carbon Footprinting For Menus	Material Footprint For Menus (Incl. Kalorie Intake)	Nutritional Footprint	Susdish	MNI (Menü-Nachhaltigkeits-Index)	FOODSCALE
Type Of Indicator (Resource/Mass-Based/Impact-Based Indicator)	Impact-Based	Impact-Based	Mass-Based	Mass-Based	Impact-Based	Impact-Based	Impact-Based
Subject	Whole Life Cycle	Whole Life Cycle	Whole Life Cycle	Whole Life Cycle	Whole Life Cycle	Whole Life Cycle	Whole Life Cycle
Number Of Indicators	1	1	2	8	31	>30	36
Addresses Dimension Of Sustainability	Ecological	Ecological	Ecological And Health	Ecological And Health	Ecological And Health	Ecological And Health	Ecological, Social And Economic
Link To Other Indicators (Direct Or Indirect)	No Link To Other Indicators	Strong Link To Energy-Related Indicators, Weak Link To Material Footprint	Weak Link To CO_{2aq} Emissions	Combination Of Different Indicators (Links E.G. Carbon Footprint And Material Footprint)	Several Indicators, Weak Link To LCA Categories: Links By CO_{2aq} Emissions And Soot Particles	Several Indicators, Weak Link To LCA Categories: Links By CO_{2aq} Emissions And Soot Particles	Several Indicators: Weak Links To Envir. Indicators (E.G. CO_{2aq} Emissions And Percentage Of Meat)
Practicability – Suitability To Companies And Understandability Of The Concept	Scientifically Based Calculation; Understandable And Illustrative	Scientifically Based Calculation, For The Calculation Is Specific Knowledge Necessary, But High Publicity And Good Data Availability	Based On MIPS Analysis, In Combination With General Nutrition Recommendations	Requires Data That Should Be Available In Daily Business- For A Calculation Specific Knowledge Is Necessary Or To Instruct Service Companies For The Calculation. The Concept Seems To Be Applicable For Companies.	Requires Data: Available In Daily Business - Scientifically Based Calculation, With A Great Variety Of Indicators. For Calculation, Instruction And Application Within Companies' Specific Knowledge Is Necessary. The Concept Seems To Be Applicable For Companies, But Several Software Has To Be Used	Requires Data: Available In Daily Business – Scientifically Based Calculation, With A Great Variety Of Indicators. For A Calculation Specific Knowledge Is Necessary Or To Instruct Service Companies For The Calculation. The Concept Seems To Be Applicable For Companies.	Requires Data: Available In Daily Business - Based On Scientifically Recognized Data, With A Variety Of Indicators. Reference Values Are Missing. The Concept Seems To Be Applicable For Companies, Missing Reference Values May Be Problematic

***Table 14-1 (part 1):** Analysis of selected concepts for assessing men.*

cont. Table 14-1

Classification	Water Footprint For Food	Carbon Footprinting For Menus	Material Footprint For Menus (Incl. Kalorie Intake)	Nutritional Footprint	Susdish	MNI (Menü-Nachhaltigkeits-Index)	FOODSCALE
Data Availability/ Origin And Effort Of Data Collection	Available International, National, Regional Databases (E.G. FAO Databases Like CLIMWAT Or GIEWS)- Data Availability On Freshwater Use Proves To Be A Limiting Factor For Establishing Meaningful Water Footprints Of Products	Scientific Publications, LCA Databases, Companies Data	Available International And National Databases (DGE Reference Values, WHO, Ecoinvent, GABI)	Available International And National Databases (DGE Reference Values, WHO, Ecoinvent, GABI)	Health Assessment Based On: DGE Reference Values Environmental Assessment Based On: ISO 14040/44, The Sustainability Guidelines (FAO), National Established Indicators And The Method Of Ecological Shortage	Health Assessment Based On: D-A-CH And The SGE Reference Values/ Environmental Assessment Based On: The Swiss Eco-Factors And The Method Of Ecological Shortage - Data Is Available Within The Company	Data will be Available Within a Company
Previous Application	Several Sustainability Assessments In The Food Sector	Several Sustainability Assessments In The Food Sector	Theoretical Application, First Pilot Testings	Theoretical Application	Within A Research Project With 20 Kitchen Settings	Within A Research Project With A Great Swiss Catering Company	No Application, Developed As Part Of A Multi-Method Research Project
Target Group	Governments, Companies, Communities, Individuals; Consumers And Producers	Governments, Companies, Communities, Individuals; Consumers And Producers	Out-Of-Home Catering Companies And Consumers	Out-Of-Home Catering Companies And Consumers, Also Benchmarking For Food Sector	Out-Of-Home Catering Companies And Consumers	Out-Of-Home Catering Companies And Consumers	Academic And Non-Academic Actors In The Food Sector
Main Reference	Hoekstra & Mekonnen (2011)	Macdiarmid et al. (2011)	Rohn et al. (2013) based Liedtke et al. (2014)	Lukas et al. (2015)	Meier et al. (2015)	Müller (2015)	Goggins & Rau (2015)

Table 14-1 (part 2): *Analysis of selected concepts for assessing men.*

15. CREATING A COMPETING DEMAND FOR WASTE RESOURCES: A STRATEGY FOR WASTE MINIMIZATION IN NIGERIA

Mynepalli K. C. Sridhar ✉

Abstract

Solid waste management in Nigeria is a social and public health concern. Waste problems are more serious in cities as the communities lead a non-indigenous lifestyle with respect to resource consumption and wastage. Nigerian municipal waste has organic biodegradables 50 to 70%, hard plastics/ plastic film 15 to 20%, metal scrap 10% and others mixed such as glass, ash, batteries, etc. depending on the culture, occupation, and other community activities. The waste generated (0.5 to 0.7 kg/capita), has a density of about 250kg/m^3, wet, and often mixed with non-biodegradables and hazardous components. Itinerary waste collectors parade the dumping yards for scavenging recyclable components in the waste which have a value. State and local governments tried various methods of disposal e.g. communal dustbins, house to house collection, curbside collection, private sector participation, open dumping and incineration. None of these methods yielded sustainable results, rather, cities became dirtier.

We introduced waste segregation, buy back and recycling activities in selected communities in Ibadan and Lagos and developed a “Competing Demand Model”. Here, when we add value to a particular component of the waste, that component will reduce or disappear from the waste stream. The generator will take adequate care to segregate such components and keep aside for economic gains. We introduced waste to wealth schemes, e.g. fertilizer from market and abattoir wastes, ferrous and non-ferrous metal recycling, paper, conversion of hard and film plastics and pet bottles into industrial feedstock. Communities started looking at these as a way of earning extra income. For this model to succeed, government, private entrepreneur or an individual may act as drivers and initiate community based small or medium scale entrepreneurship (e.g. recycling industry or collection kiosks) and pay some money in exchange for the resource, waste. This model yielded encouraging results with significant reduction of metals, paper and certain types of plastics from the waste stream with youth employment opportunities.

Keywords: competing demand, urban wastes, recycling, segregation, developing countries

Introduction

In Nigeria, solid wastes arising from urban areas have posed serious problems in causing poor environment, vector breeding, public health concerns and resource depletion. The waste disposal is through open duming, burning when dry, or throwing into drains or water bodies. These practices are mostly due to ignornce or negative attitude. In the northern Nigeria, organic wastes are heaped in a orner for severl months and finally take to the farms to fertilize the soils. Several attempts have been made to manage the wastes in a more hygienic and acceptable manner since independence. These include introduction of policies, penalties, improved collection methods, provision of transfer stations in larger cities, change of technologies, introduction of private sector participation, introduction of monthly sanitation exercises in all the States, and development of more landfill sites. None of these methods brought in any positive results (Adedipe et al 2005). On the other hand the volume of wastes has been increasing with changing composition and more and more itinerary waste collectors are found around dumpsites scavenging for recyclable components for monetary gains at the cost of occupational hazards (Sridhar et al 2002). This paper describes a new model tagged as `Competing Demand Model‘ we have developed which encourages creating a competing demand for a particular or specific waste component thereby reducing that component going into the waste stream.

Study Location and Methodology

The study was carried out in selected cities in Nigeria and in particular Ibadan, Lagos, Akure, Minna, Abeokuta, Owerri, and Makarfi in various parts of the country where the State Governments or private entrepreneurs initiated model recycling facilities for some of the waste components. The recycling concepts were initiated since mid 1980s from small scale to community scale and continued to date (Sridhar and Hammed 2014). These locations have three distinct socio-cultural features (Yorubas in south west, Igbos in south-east and Hausa-Fulanis in northern parts). Waste assessment was carried out for the composition and generation rates. The facilities introduce are: organic fertilizer from urban biodegradable waste, plastic (HDPE and LDPE) recycling into pellets or flakes which may serve as raw material for industry, biogas from livestock and food wastes, metal (ferrous and non-ferrous) recycling from scrap, tyre recycling into chips, bone recycling into bone meal.

The data were obtained through questionnaire survey in different locations, Focal Group Discussions (FGD), Key Informant Interviews (KII), and exploratory physical visits to see the state of the art and quantifying the waste components.

Results

Waste Components

Over the years, the waste composition did not change significantly. The major component has been organic matter in the range of 60 to over 80%. The recyclable components in the waste dump in a major city are shown in Table 15-1. In 1970s-and early 1980s, the major component in the waste was organic matter (culturally many Nigerians used leaves as food wrapping material which added to the bulkiness to waste), glass, metals, little plastics, rags, and others. In 1980s, the significant change has been introduction of plastics into households. Traditionally, Nigerians who were using metal in household items, slowly abandoned for attractive and colourful plastics which were also light in weight. Federal Ministry of Environment was established with several laws and regulations to prevent environmental pollution and resource conservtion. In 1990s the concept of recycling and reuse came into the minds of people who were hard hit by economic reforms and structural Adjustment programmes introduced through policy instruments. Many of the waste components disappeared from the waste streams in preference to reuse or recycling.

Serial Number	Component	Percent
1.	Glass	82.0
2.	Plastics (HDP)	46.5
3.	Plastics (LDP)	21.1
4.	Shoes	36.9.
5.	Rubber (Scrap tyres etc.)	21.9
6.	Metal scrap	31.6
7.	Textiles	9.6
8.	Batteries	7.9

Table 15-1: *The recyclable components found in a city municipal dump.*

The Competing Demand Model

The model is developed by taking into consideration, the following: nature of wastes, drivers, responses and tradeoffs, behaviours of the generators, governmental policy and regulatory instruments, economic instruments, private sector and SMEs, other Inputs and outputs. The model operates based on the fact that basically waste has no value. The drivers can add value to the waste through many ways. Once the waste component gets a value, peoples' behavior will change and try to conserve that component and thus the amount going into the waste bin reduces (Figure 15-1).

Thus, over a period of several years, we have evidence showing that some of the components in the wastes have added values. Typical examples may be drawn from the recyclables or dry waste. For example, glass, paper, aluminum, ferrous metal, batteries, used engine oil, bones and rubber have reduced from the waste stream. While some have totally disappeared (aluminum), many have reduced in the waste. More recently, with the establishment of organic recycling plants such as composting/organic fertilizer plants at state and private level (in 8 States) and biogas at 6 locations has brought awareness among the people who started doing business with waste (selling livestock and crop wastes, establishment of horticultural nurseries, etc.). The pricing structure varies from place to place depending on the distance from the source to the point of use and demand and supply. In the process, some additional ancillary SMEs came up particularly in the areas of procurement, fabrication and supplies from local sources. In our view, this is a tremendous impact on the changing ways of thinking among the populations.

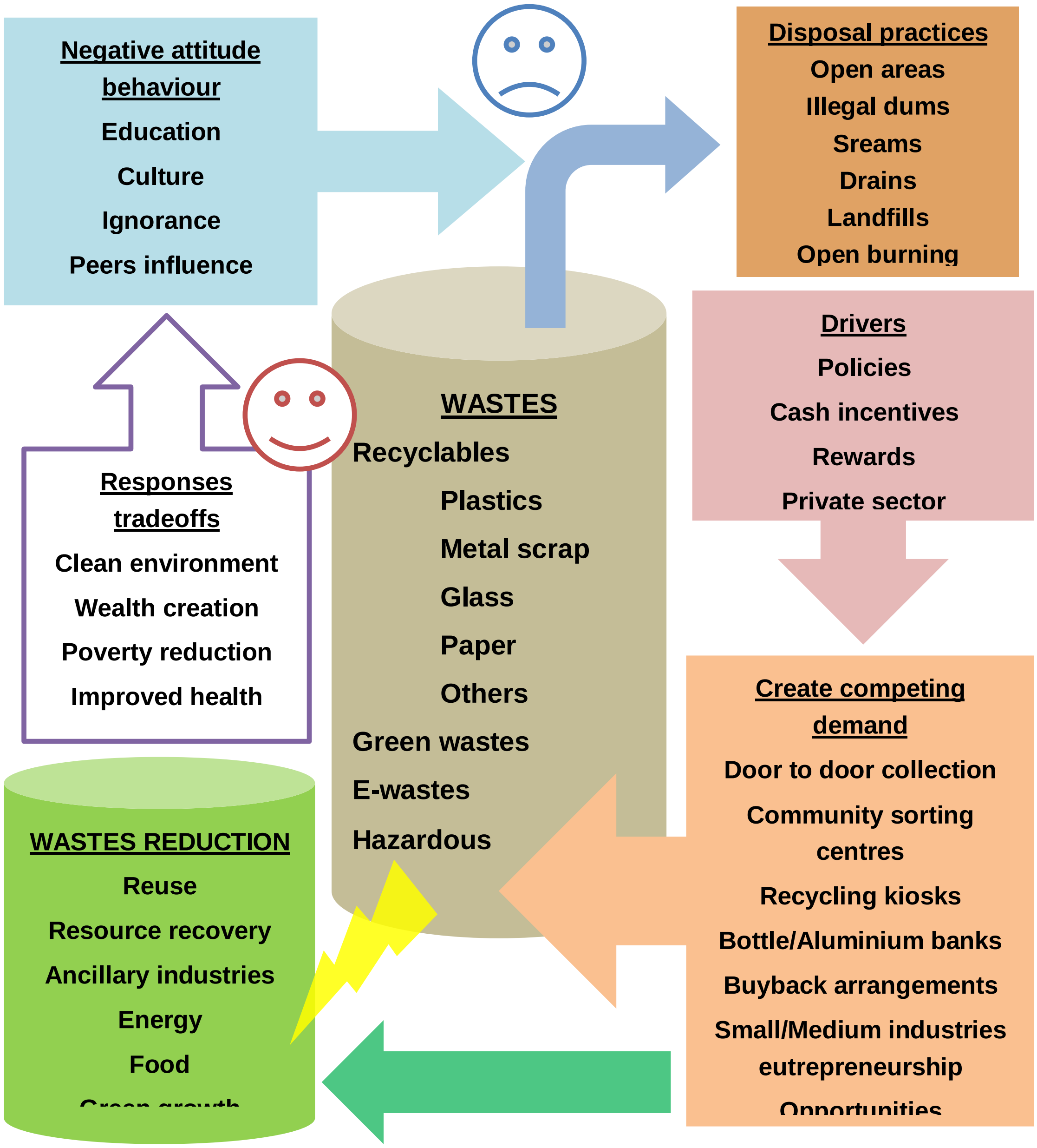

Figure 15.1: *A competing demand model showing the waste components, drivers, responses and tradeoffs and change in attitude and behaviour.*

How Does the Model Operate?

Application of the model is simple. If the government at State or Local level decides to minimize the waste generated, they have to mobilize creation of a competing demand for a waste component. The competing demand may be either government driven, private driven or individual driven. The demand can also be in the form of door to door collection with financial incentives, cash incentives, rewards, community sorting centres, recycling kiosks, bottle/ aluminum banks, entrepreneurship opportunities through soft loans or linking up with financial institutions. The model operates using the 3R principle through reuse, recycle or waste to energy. The role of government is limited to creating enabling environment.

Table 15-2 gives some examples of how the model has brought about significant changes in the waste composition in the waste stream and changes in behavior of the waste generators.

Serial Number	Waste Component	Management Strategy through competing demand	Outcome
1	Biodegradable Organic matter	Composting, biogas generation, animal feed supplements. Collection and isolation from waste bins.	Organic wastes attracted a price for procurement; difficult to get in some places.
2	Plastics (HDPE and LDPE)	Scavenging, direct supply to small and medium scale industries (SMEs).	PET bottles, broken hard plastics disappearing from waste stream; a price (NGN 10 to 20 per kg) is put depending on the quality.
3	Aluminum	Collection by private sector.	Rarely found in the waste stream; people get NGN 150 per kg weight.
4	Ferrous metal scrap	Export banned through policy; private sector collects from highways and other sources.	Metal content is reducing in waste stream; many medium.
5	Bones, animal blood and skin products	SMEs convert into animal feeds; obtain phosphorus source.	Export to outside countries has reduced; local demand increased.
6	Batteries	SMEs started extracting lead and plastic components.	Battery collectors increased and they pay a price to procure; SMEs have increased in the cities.
7	E-waste	Policy prohibits indiscriminate processing; Many people collect abandoned electronic goods at generating areas.	A price attached to waste; SMEs recycle for precious metals.
8	Used Engine Oil	SMEs started using for boilers; re-refining and selling as black oil.	Available at a price; used as secondary energy source.

Table 15-2: *Waste components, management strategy adopted, the Competing demand and the outcome.*

Conclusions

A Competing Demand Model was developed from the available information on the waste generation and management in Nigerian cities. The model is simple to operate, creates job opportunities and conserves the limited resources in the country. The model encourages adding value to the waste. To make the model work, the drivers play a very important role once the government provides enabling environment. For sustainability, the Private sector may be involved effectively. Some significant achievements are observed in the reduction of metal, plastics and batteries in the urban solid wastes in the country.

16. THE GUIDELINE SERIES VDI 4800 RESOURCE EFFICIENCY: AN APPROACH FOR INCREASING RESOURCE EFFICIENCY WITH THE AIM OF CONSERVATION OF NATURAL RESOURCES IN THE INDUSTRIAL SECTOR

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Christof Oberender, Wilfried Denz, Anke Niebaum

Abstract

In 2011, the Association of German Engineers (VDI) started working on a set of guidelines towards increased resource efficiency. These guidelines represent a framework that defines resource efficiency and outlines considerations for the producing industry. A special guideline for SMEs is included as well as guidelines on methodologies for evaluating resource use indicators, such as the cumulative raw material demand of products and production systems.

Resource efficiency, defined here as the relationship between a specific benefit or use and the natural resources that need to be spent or consumed to attain this benefit or use. It can be evaluated by defining a function which expresses the specific benefit and quantifies the resource requirements through a set of indicators (use of raw materials, energy, water, land and ecosystem services including sinks). The results from this also depend on the system boundary parameters and the allocation rules for by-products and waste treatment options. Optimising resource use is possible at all stages of a product's or production system's life cycle chain (raw material extraction, production and manufacturing, use and consumption, and the end-of-life stage).

VDI guidelines are widely accepted across Germany's industrial sector and therefore represent an important means of mainstreaming resource efficiency in this target area. As well as providing a methodological framework, the guidelines describe strategies and measures towards increasing resource efficiency, and they enable industrial producers and service providers to identify potential areas of improvement. The full article presents an overview of the methodology and contents of these guidelines and discusses their impact in achieving absolute reductions in the industrial use of natural resources.

Keywords: resource efficiency, life cycle thinking, guidelines, products and production systems, standardization

Introduction

Resource protection and the efficient use of natural resources are some of the biggest challenges of the 21st century. Therefore, Germany addressed the topic of natural resource efficiency and conservation in its 2002 sustainability strategy (Federal German Government, 2002). The topic of resource efficiency received further strategic grounding on a political level through the "ProgRess" German Resource Efficiency Programme (Federal German Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, 2012).

The motives to save resources or use them more efficiently are varied and depend crucially on the perspective of the actor. The main focus to significantly increase the efficiency of utilization of natural resources is on the private sector, as this is responsible for a very large share of exploiting and consuming natural resources (Baron et al., 2005). From a corporate perspective, primarily economic objectives are pursued in order to ensure competitiveness in the implementation of resource efficiency measures. Trigger for resource-efficient action are:

- Expected general cost savings (e.g. material and energy cost savings)
- Long-term hedge against rising commodity prices and reduction of dependence on raw materials
- Externally formulated demands and expectations on the company / product.

Research has shown that small and medium-sized enterprises (SMEs) in several sectors of the German economy could potentially achieve savings between EUR 5 billion and EUR 11 billion per year within a timespan of seven years (Baron et al., 2005). In the processing industries, which also carry very high material costs, the potential savings associated with natural resource efficiency are estimated at around 7 percent (Schröter et al., 2011). Nevertheless, the path towards improved resource efficiency in companies is frequently not followed as consistently as it could be (Schmidt and Schneider, 2010).

A fundamental problem with previous analyses of how businesses can increase their resource efficiency – and thereby achieve the cost savings outlined above – is that the methods and programmes deployed today are almost entirely focused on the operative material flows within a company ("gate-to-gate"). Significantly larger savings goals can be achieved when the entire life cycle of a company's products and services is taken into consideration ("cradle-to-grave") (Lang-Koetz et al., 2010; von Geibler et al., 2011; Rohn et al., 2013, 2014). Furthermore, in the context of resource efficiency, there has to date been a lack of unambiguous definitions and guidelines. Similarly, there are currently no nationally or internationally agreed evaluation and calculation methods and procedures to be found in this field. Only once provided with a strong definitional basis will companies be able to develop meaningful resource efficiency strategies to identify and implement specific measures.

With more than 154,000 members, VDI is Europe's biggest science and technology association, and, next to the German Institute for Standardization (DIN), one of the most important standard organisation in Germany. Given its wide-ranging base of technical expertise, VDI decided in 2009 to embrace resource efficiency as a cross-sectional topic. The objective was to close terminological and definitional gaps by streamlining both the terminology and the basic methods of calculating and evaluating the resource efficiency of products, processes, services and companies. Today, a framework of rules has been devised. To VDI, "resource efficiency" means that all natural resources such as raw materials, energy, air, water and land (soils) are exploited as responsibly and efficiently as possible, and that environmental impact is reduced to a minimum. Any evaluation of resource efficiency can therefore only take place if the deployment of all natural resources is quantified and viewed in context. Quantification is based on a set of indicators, each of which represents a resource category. The indicators are modular; when combined, they form a basis for evaluating the utilization of natural resources.

VDI 4800 Part 1 Resource Efficiency – Methodical Principles and Strategies defines general terms pertaining to resource efficiency. It also provides descriptions of the resource categories, general assessment principles and rules, and recommendations on how to conduct resource efficiency analyses and evaluations. The final version of this VDI standard was released in February 2016 (VDI 4800 Part 1: 2016-02). In-depth profiles of the individual resource categories and their associated indicators and assessment options will follow in further VDI Standards on Resource Efficiency (see Figure 16-1), which will be discussed briefly below.

VDI 4800 Part 2 Resource Efficiency – Evaluation of Raw Materials Demand was compiled for the "Raw Materials" resource group, including Water and Land as Input-materials. This standard describes an assessment model for raw materials including water and land/soil and was released as draft version in March 2016 (VDI 4800 Part 2: 2016-03). In VDI 4800 Part 2 the cumulative raw material consumption (German: kumulierter Rohstoffaufwand, KRA) is accounted in four categories: Construction materials and industry minerals, energy feedstock, metals and biotic raw materials. $KRA_{metallic}$ can be approximated by the inverse of the metal concentration in the respective ores. Other models are provided for assessing the scarcity of raw materials – their so-called criticality. This enables criticality evaluations for abiotic materials (metallic and non-metallic), fossil energy materials, biotic materials, and water and land/soil.

VDI 4800 Part 3 Resource Efficiency – Indicators for the Evaluation of Environmental Impact provides a model for assessing the environmental impact of products, processes and product-service systems as part of a resource efficiency analysis. A set of scientifically valid indicators is proposed that essentially references the sink properties displayed by different environmental media.

The third tier of resource efficiency analysis is VDI 4600 Cumulative Energy Demand, which was first introduced in 1997 and last updated in 2012. This provides guidelines on how to assess cumulative energy demand (KEA) and cumulative energy consumption (KEV). The cumulative energy demand represents the overall expenditure of primary energy (in energy units) arising from, or attributable to, the production, use or disposal of a product or service. This set of indicators forms the basis of evaluation.

In addition, VDI 4801 Resource Efficiency in Small and Medium-Sized Enterprises was released as draft version in February 2016 (VDI 4801: 2016-02).

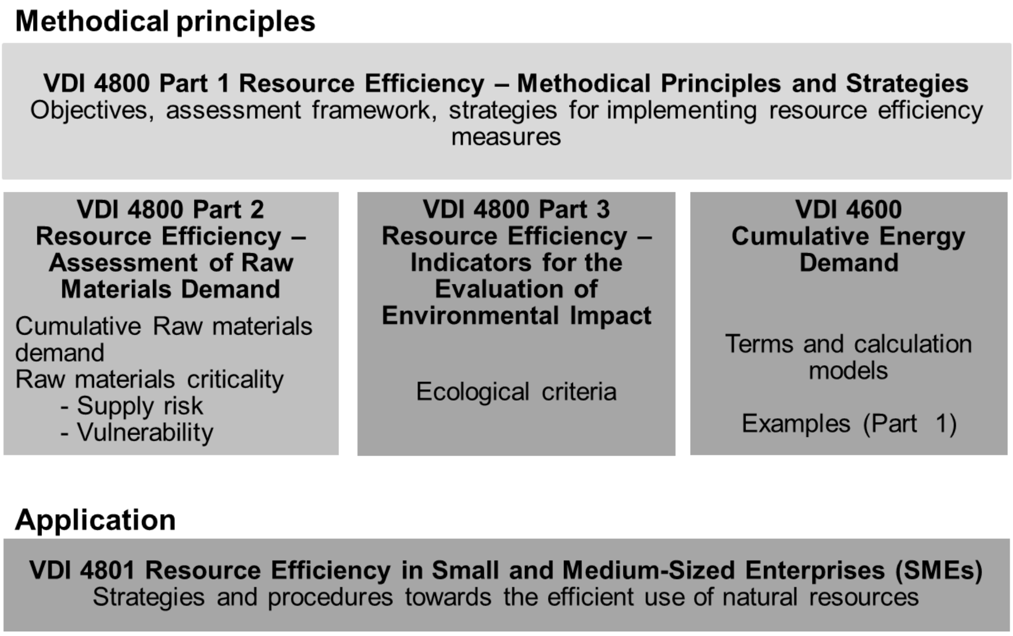

Figure 16-1: *Structure of VDI Standard series on resource efficiency analysis (acc. to VDI 4800 Part 1).*

Terminological definitions

One of the biggest challenges faced in compiling the VDI 4800 series of guidelines was that the concept of resource efficiency can be defined in many different ways. In a discursive process involving all the relevant stakeholders, a shared understanding of the term was negotiated and courses of action for day-to-day operations were outlined. The VDI committee was always guided by the overriding goal to conserve natural resources in order to protect the livelihoods of current and future generations. The sum of these objectives informed VDI's terminological definitions:

The VDI 4800 series of guidelines describe the term "efficiency", as the relationship between a specific use or benefit and the effort or expenditure required.

The VDI 4800 Part 1 provides a general definition for "resources", which is as the means that are used or deployed for a system or process, as well as a specific definition, which narrows the range of these means to the area of natural resources. In the VDI standard, "natural resources" are those resources that are part of nature, such as renewable and non-renewable primary raw materials, environmental media and ecosystem services. Implicitly excluded here is the commercial deployment of human resources and capital assets.

VDI 4800 Part 1 defines "resource efficiency" as the relationship between a specific benefit or use and the natural resources that need to be spent or consumed to attain this benefit or use. The definition of "benefit" was largely informed by the ISO Standard on Life Cycle Assessment (DIN EN ISO 14044:2006-10). For an analysis of resource efficiency according to VDI 4800 part 1, the benefit must be defined and quantified as the numerator of the equation. This is done as follows:

- Benefit and effort must refer to the same reference object and be determined completely by it. The reference object can be a product or service, a bundle of products and services, an organisation, e.g. an enterprise, or a process.
- The benefit is generated by the function of the reference object (e.g. the product or service), which usually can be described and quantified technically. Methods of life cycle assessment refer to this as a functional unit. Such a technical quantification is to be preferred over others because it is more reproducible.
- In case of multiple products or services or for organisations, the benefit results from the sum of the performance of these reference objects. It may happen that this performance cannot be aggregated and quantified with the help of technical parameters, or that it contains benefit components that are impossible to be described technically. In these cases, the benefit can be quantified in a different way, e.g. with the number of users of a service or with economical parameters such as an organisation's turnover. However, the benefit must still be quantifiable, and benefit and cost parameters must still be congruent. For example, turnovers achieved with financial operations must not be counted in if the cost relates only to production.

The life cycle concept

The use of natural resources can only be adequately assessed through a life cycle analysis. In this respect, the VDI standard at hand again complies with ISO Standard 14040 on Life Cycle Assessment. In most cases, this will require a company to account for the original extraction of the raw materials that end up being used in its manufacturing processes; this is commonly referred to as a "cradle-to-gate" analysis. In cases where the consumption and disposal stages of a product's life cycle also require resources (such as energy), a full-scale "cradle-to-grave" approach is necessary.

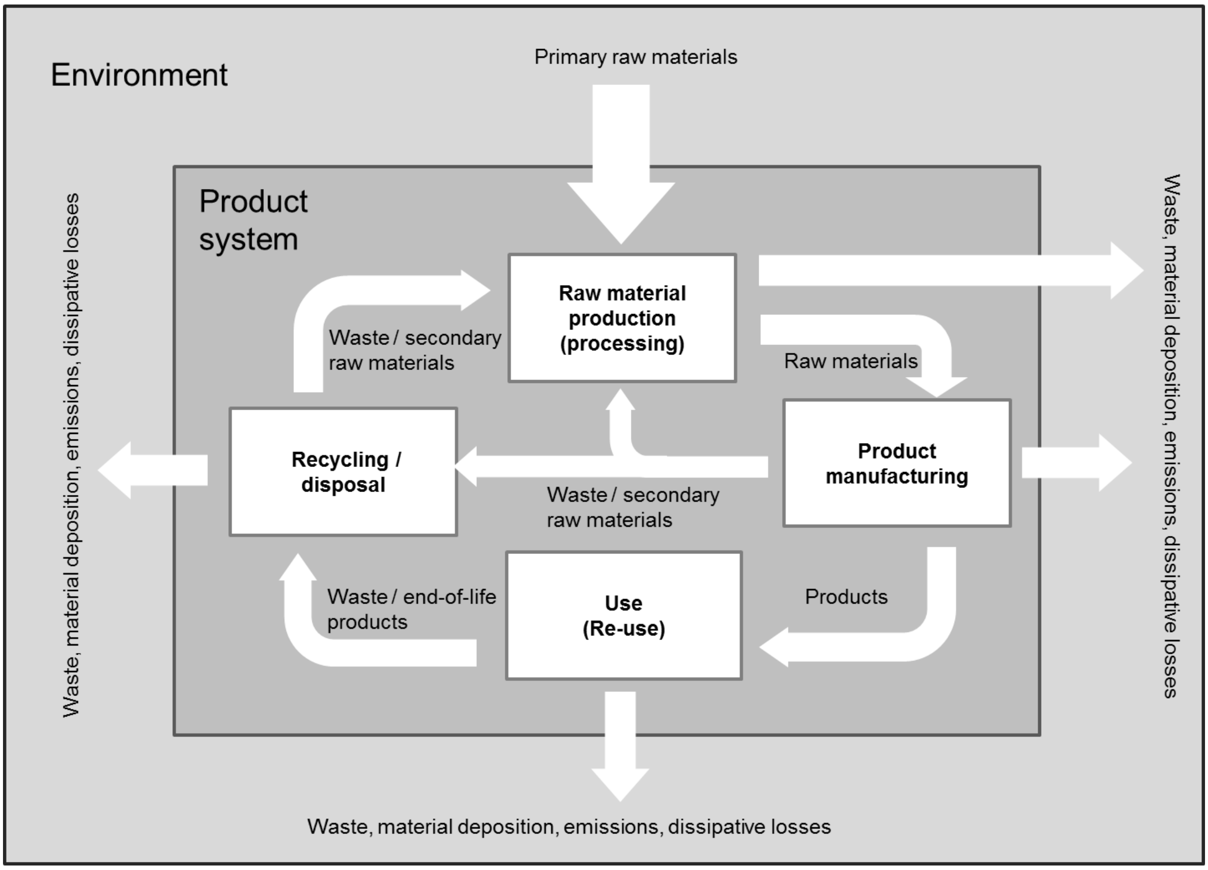

Figure 16-2: *Resource use across a product life cycle (from VDI 4800 Part 1).*

The life cycle concept becomes particularly relevant when the deployment of natural resources is understood to not only include the extraction of raw materials from their natural environment but also the role of environmental media as sinks. In this context, the storage of waste, the emission of harmful substances, and the use and transformation of land and soils can all be viewed as uses of natural resources. Factors such as these occur right throughout a product's life cycle, i.e., as part of the supply chain, during its use or consumption, and during its disposal. The only way to adequately address all of these stages is through a full cradle-to-grave life cycle assessment.

Implementation for products and processes

Targeted implementation of strategies and measures towards increased resource efficiency in companies requires that the involved parties receive suitable support in three main areas.

(1) A systematic approach that focuses on relevant operative aspects of the company as well as product life cycles requires methodical support.

(2) Due to the wide range of applicable strategies and measures, conceptual support may also be necessary.

(3) In addition, operationalisation requires systematic support for the involved parties' specific actions and processes. This applies particularly to small and medium-sized enterprises.

The first two of these areas are described in the VDI 4800 methodological series, in which also practical examples are included. The third area is described in VDI 4801 - Resource Efficiency in SMEs.

Product and process development

Methodical product and process development forms the basis for a comprehensive optimisation of products and processes across their life cycle. Figure 16-3 shows the connections between the Product development process chain and the Product Life Cycle process chain. These connections are elemental to the development of resource-efficient product systems.

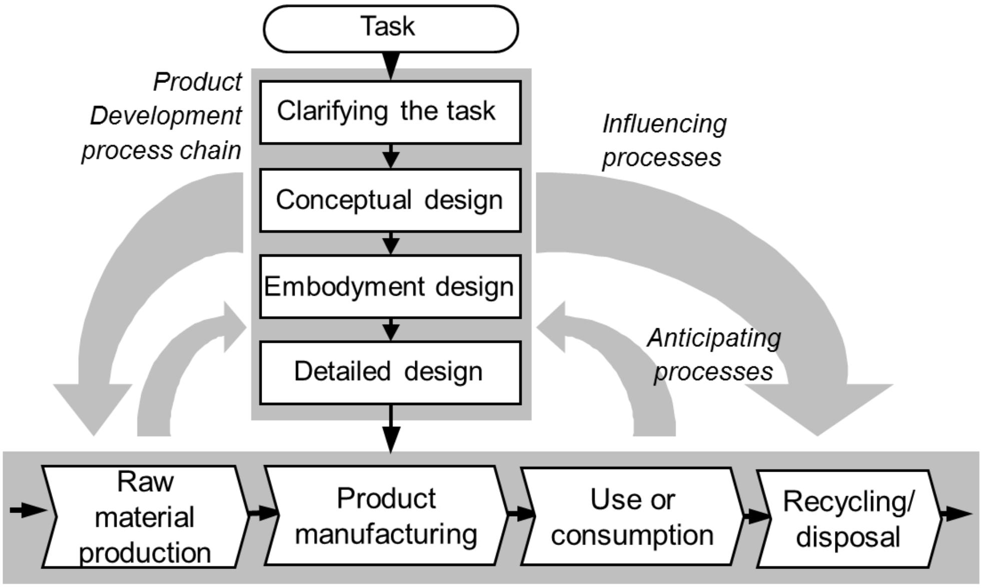

Figure 16-3: *Product development and product life cycle processes (adapted from Abele et al., 2005).*

The product development process defines functions, methods, types, physical contours and working materials. This is where decisions about technical, economical and ecological product properties are made, and with them decisions about production and recycling processes. Around 85 percent of the production costs are specified at this stage (Ehrlenspiel, 2007). In essence, the same parameters can be applied to resource deployment. Comprehensive measures towards increasing resource efficiency therefore need to address the product development process.

Product characteristics and processes and their associated resource use are defined across all stages of the product development process. As a general tendency, however, the initial stages of Clarifying the Task and the Conceptional design are more relevant in this regard than the later stages of Embodyment design and Detailed design. It should also be noted that the influence of product development could vary significantly across the individual life cycle stages. While the manufacturing processes are directly controlled by the company, use and disposal-related processes are much less controlled. This is due to the increasing timespan between product development and process implementation, but also due to the behaviour displayed by the product users and consumers.

Strategies towards increasing resource efficiency

As well as providing foundational principles for the development of resource-efficient products and processes, the VDI standard at hand is also intended to provide conceptual support in finding suitable solutions. For this, the relevant strategies are conveyed via descriptions, measures and examples. The strategies are structured according to their effect on the product or production process. The VDI standard outlines 14 product-related strategies that can lead to an increase in resource efficiency. These include substitution of materials, light-weight designs, fitness for purpose, miniaturisation, reparability and user/consumer behaviour. In addition, 23 strategies related to the production process are described. Examples include reduction of production volume, reduction of planned losses, efficient energy supply, cascaded use and product documentation.

Each strategy identifies those sections of the company that need to be addressed for it to be successful (e.g., product development, factory scheduling, process planning, purchasing/acquisition, production, sales). In addition, the affected life cycle stages are listed (raw material production, product manufacturing, use and/or recycling/disposal). Lastly, the strategy indicates if there is any need for exhaustive life cycle analyses.

Resource efficiency in small and medium-sized enterprises

The previous chapters discussed how companies can deploy the VDI 4800 to evaluate as well as optimise their products and processes according to the state of the art, thereby including the various life cycle aspects of these. The assessments required for this can be very elaborate and need to be carried out by trained experts. As experience has shown, such a level of expertise is generally not available to SMEs. At the same time, SMEs are generally not willing to finance the outsourcing of expert life cycle assessments. As SMEs are a significant target group, VDI developed a standard on the application level, VDI 4801 – Resource Efficiency in SMEs. Depending on their market position, operating conditions, production methods, product range and development structure companies can be provided with a range of different strategies and measures.

With VDI 4801 “Resource Efficiency in SMEs”, then, small and medium-sized enterprises can achieve a number of resource efficiency increases without having any in-house expertise in this area. The VDI 4801 guideline also represents a great starting point for companies to comprehensively optimise their products and processes in accordance with VDI 4800.

Conclusion and outlook

In conclusion, the creation of the VDI 4800 standard series represent the first published guideline set for companies and consultants to calculate, assess, evaluate and optimise the resource efficiency of processes, companies and products throughout their life cycles according to a standardized framework of principles. This serves as a basis for achieving the private sector resource efficiency and conservation targets outlined in the introduction of this article. Exactly to what extent and how soon the VDI standard will contribute to an absolute reduction in resource exploitation and consumption cannot be reliably predicted at this stage. This will require supplementary evaluations during the standard’s implementation. Implementation will require further supporting measures within Germany, i.e., suitable funding programmes and political frameworks – such as the current revision of the German Resource Efficiency Programme, ProgRess II (BMUB, 2015).

Looking beyond Germany, it will be very interesting to see how a series of guidelines such as this, and also the results projected here, may be able to be adapted across Europe and beyond, and how they may contribute to international regulations and standards. Certainly, the creation and publication of a nationally coordinated standard is an important first step towards further European and global dialogue on resource efficiency.

Part II

Technological Innovation, Business and Finance

17. PUBLIC POLICY FOR INNOVATION AND URBAN ENVIRONMENT

Antônio José Juliani ⌧, André Fábio de Souza

Abstract

Technological innovation has become central to the development of nations. The OECD countries and developing countries have created systems to encourage innovation and dissemination of technological innovation. In macroeconomic terms, companies already recognize the important role of innovative activities in the maintenance and increase of their participation in national and global markets. In discussions on the environment, the issue becomes important because these innovations create conditions as well, for improving the life quality of human beings in urban environments, but also involve risks and sometimes bring irreversible consequences to life on the planet. In this context, the objective of this paper is to explore the relationship between innovation and the urban environment and to indicate the need for public policies of technological innovation that converge to solve the problems and the environmental challenges of the cities in general. As stated Andrade (2003, p. 95), the innovation does not have its own ontology, but is open to contingency and indeterminacy of social practices. Thus, it is for public policy makers indicate the paths and possibilities, improving the levels and quality of production and also minimize environmental problems related to such improvement. Methodologically, this study begins with a discussion of the different approaches to eco-Innovation in the context of the sustainable cities and green buildings. It is followed by the technological innovation policies and their relationship to sustainability and concludes with a Brazilian case study that is on the application of eco-innovations to help the city of Rio de Janeiro to organize the Olympics Games in Brazil. Overall, it is concluded that environmental innovations are essential for the urban environment sustainability. However, it is necessary to enhance the governmental process that uses the environmental innovations as a public policy tool.

Keywords: eco-innovation, sustainable cities, green buildings, greenhouse gases.

Introduction

One of every two individuals are living in cities for the first time in history more than half the world's population is in cities. Developing countries, in turn, concentrate 80% of the urban population of the planet in the next two decades (Leite, 2010).

Whereas it is in the cities that are found the greatest changes and demands for public and private services, raw materials, housing, transport and employment, the challenge that arises is to reduce the negative impacts of such demands in the social, environmental and economic.

According to the UN, about 70% of the world population will live in cities by 2030, and this growth will occur mainly in urban less developed regions, whose population is expected to grow from 2.5 billion in 2009 to 5.2 billion in 2050. The challenges posed to the environment, social governance, quality of life and general urban sustainability are alarming.

In this context, given the challenges to mitigate the negative effects of urban growth and direct cities to sustainable development makes it imperative to develop environmental technology innovations to support environmental policies.

Thus, this article is part of the theme of environmental innovations and public policies that help urban environments to overcome the challenges in achieving sustainability. It will present some concepts of environmental innovation, public policy and sustainable cities to illustrate the analysis of environmental innovations and public policies that will be used for the city of Rio de Janeiro, Brazil, organize the next Olympic Games.

Innovation

As Schumpeter (1997), the reason for the economy out of a state of equilibrium and enter into a process of expansion is the emergence of some innovation, from the economic point of view, which considerably change the preconditions of balance, IE processes of economic development are fueled by innovation.

On the other hand, Schumpeter (1997) points out that the economic vision prevails over technological vision, because methods that are technologically inferior can still be the ones that best accommodate the given economic conditions. Thus, the economic development vision, from the point of view of innovation, conditions the technology as a means to an economic end.

Schumpeter (1997) highlights that should certainly be taken to satisfy the consumer's needs, but it is the producer who initiates economic change, and consumers are educated for him to want new things.

In this sense, Dosi (1982) points out that in the literature on innovation, there are two different approaches, the first relates to market forces as the main determinants of technical change (demand pull) and according to the definition of technology as an autonomous factor, regardless market needs, where the evolution of scientific knowledge, coupled with the entrepreneurial spirit of the business, this knowledge lead in the introduction of new products, services or processes (technology push).

Irrespective of the approach taken in that respect will invariably be some level of environmental impact, as if on one hand, innovation can generate products that satisfy the environmental remediation requirements or cut down the impact of existing technologies; on the other, it can also generate novel, more polluting products and much lower life (increasing the volume of technological waste).

From a broader perspective, comprising a wide range of possible innovations, the Organization for Economic Cooperation and Development - OECD (manual of Oslo, p 55, 2005) defines innovation as the implementation of a product (good or service) new or significantly improved, or a process, or a new marketing method, or a new organizational method in business practices, workplace organization or external relations.

Ansanelli (2003) states that environmental protection was not on the agenda in the history of economic development, being seen as opposed to economic growth, but emphasizes technological innovation as a way to alleviate the problem that economic development imposes on the environment.

The urgent demand for this change contributes to increased application of innovation as a puppet for a sustainable approach, with stress on its environmental dimension, defined by various authors as Eco innovation. The bibliography cites several definitions for environmental innovation.

Eco-Innovation

Eco-innovation is closely linked to a variety of related concepts. It is often used interchangeably with "environmental innovation", and is also often linked with environmental technology, eco-efficiency, eco-design, environmental design, sustainable design, or sustainable innovation.

While the term "environmental innovation" is used in similar contexts to "eco-innovation", the other terms are mostly used when referring to product or process design, and therefore focus more on the technological aspects of eco-innovation rather than the societal or political aspects.

The most common use of the term "eco-innovation" is to refer to innovative products and procedures that reduce environmental impacts. This is often used in conjunction with eco-efficiency and eco-design. Leaders in many industries have been developing innovative technologies in order to work towards sustainability. However, these are not always practical, or enforced by policy and legislation.

To UNEP, eco-innovation provides a win-win solution to improving economic competitiveness and sustainability as it originates at the company strategy level and extends influence beyond the company gates to the supply chain

Eco-innovation aims at reducing impacts on the environment, enhancing resilience to environmental pressures, or accomplishing a more efficient and responsible usage of innate resources. The growing market, reputational and regulatory pressures in response to growing resource scarcity and environmental degradation reinforce therefore the business case for eco-invention.

Operationally, it works through a new business strategy that incorporates sustainability throughout all business operations, based on life cycle thinking and involves partners across the value chain. By going through a lot of coordinated modifications to products (commodities / services), processes, market approaches and organizational social systems, eco-innovation enables the world of novel solutions leading to enhanced sustainability performance and competitiveness (http://www.unep.org/ecoinnovationproject/).

According to the OECD (2009a) environmental innovation is an innovation that results in reducing the environmental impact, whether this effect is intentional or not. The scope of environmental innovation can go beyond the conventional boundaries of companies to innovate and engage a broader social system, which causes changes in the socio-cultural and institutional structures standards.

According to Kemp and Foxon (2007) environmental innovation or eco-innovation, the production, assimilation and exploitation of novelty in products, production processes, services or business and management methods, which it aims along its life cycle, prevent or substantially reduce the environmental risk, pollution and other negative impacts on the use of resources (including energy use).

To (SETAC, 1993), Eco-innovation might be defined as any change in a production process, instigated by the firm, which reduces the impact of that production process on the natural environment or on society. The production process is a multi-stage operation from raw material extraction through to final waste disposal, i.e. “cradle to grave”.

Thus, eco-innovation under this definition is not restricted to that part of the production process that occurs at the production site, “Supplier challenges” i.e., sourcing the purchase of inputs to the firm's production process from suppliers that meet the firm's sustainability/environmental criteria, is therefore a form of eco-innovation under the definition applied.

According to Rennings (1998), the UN Conference on the environment, held in 1992 in Rio de Janeiro, the international community has pledged to seek ways to reconcile the socioeconomic development with the conservation and protection of the environment, making If clear that sustainability means long-term changes in technology, infrastructure, lifestyles and institutions.

These necessary changes can be prioritized and feasible; particularly the governments of the states, through the growth of public policy environment that hold into account the practical acceptance of environmental innovations. Thus, one of the policy instruments that can be used for environmental innovations can be effective and beneficial for the environment and society in general are public policies.

Public Policy

According to Bredariol and Vieira (1998) the first idea they have on public policy is a set of state actions to equate or solve collective problems. For Appio (2005), public policies are instruments of state intervention in society.

Public policies can be conceptualized as implementing instruments of political programs based on state interference in society to secure equal chances for citizens, with the design to guarantee the material conditions of a dignified existence to all citizens.

The OECD (2009a) points out that although regulations and government regulations have helped reduce the risk of environmental impacts, it is usually not the most efficient way and do not offer sufficient incentives to innovate beyond incremental solutions. Because of the potential environmental innovation will require action to ensure that the whole innovation cycle is efficient, with policies ranging from investment in research to support in your market.

It is needed a close coordination between environmental policy and environmental innovation policy. Rennings (1998, p. 14), adds that "a policy of promoting technological eco-innovation cannot be reduced to technological support programs or conventional measures of environmental policy, but have to find clever combinations of both."

The harmonization of environmental innovation policies with public policies contribute to the sustainability of urban environments and can contribute to the development of sustainable cities.

Sustainable Cities

Sustainable cities are those that take a series of effective practices aimed at improving the population's quality of life, economic growth and environmental conservation. They are usually very thoughtful and cities administered and practice sustainable actions in several areas.

According Spitzeck and Seixas (2014), some practices for sustainable urban centers are:

- Effective actions aimed at reducing the emission of greenhouse gases, aimed at combating global warming.
- Measures aimed at saving the natural common goods.
- Planning and quality in public transport services, mainly using clean energy sources.

- Actions to improve urban mobility, significantly reducing vehicle traffic.
- Advancement of social justice.
- The suitable destination for the waste, efficient systems creation aimed at recycling waste.
- Carrying out of educational programs for sustainable development.
- Efficient urban planning, especially taking into account the long-term.
- Adoption practices geared to conscious consumption by the population.
- Actions aimed at the rational use of water and its reuse.

Although there is a city that is 100% sustainable, several of them already practice sustainable actions in several areas and one of the ways to achieve urban sustainability is the use of environmental innovations to support public policies.

In this context, it will be analyzed using environmental innovations to seek sustainability of cities in a case study of the city of Rio de Janeiro in Brazil, which will host the next Summer Olympic Games in August.

Management Plan of Sustainability (Rio 2016)

To achieve sustainable transformation proposed in the application of the city of Rio de Janeiro to the Olympic headquarters and Paralympic commitments were made aimed at integrating sustainability criteria throughout the Games management cycle, from design and planning to implementation activities, review and post-event. The principles governing this integration are: responsibility, inclusion, integrity and transparency.

The organization of a size event and complexity of the Olympic and Paralympic Games in Rio de Janeiro hoping welcome 15,000 athletes from over 200 countries, implies concentrated mobilization of time (a few weeks), space (host city) and financial resources.

Games exert unprecedented pressure on the stock of accommodation, public cleaning system, power supply, water consumption, public security services and the host city's transport network.

The Games represent a singular chance to accelerate infrastructure investments necessary for the city and the population in the absence thereof only would solve out in a much longer term. Moreover, there are many opportunities for games function as a powerful example, leveraging the adoption of new patterns of production and consumption less harmful to the environment.

The main measures to be implemented in the city of Rio de Janeiro due to the realization of the Summer Olympic Games will be:

I. Providing public transport for spectators and workforce.

Installation of the Bus Rapid Transit (BRT), light Tracked Vehicles (VLT) and modernization of the Intelligent Transport System (ITS) - Expansion and modernization of the system of city traffic control in Rio de Janeiro (CTA) implemented from 1996, expansion and renovation of the subway and renovation of the railway system

II. Establish pollutant emissions reduction actions, including Greenhouse Gas - GHG in public transport systems.

Achieve, by 2020, reduce greenhouse gas (GHG) emissions by 2.3 million tons, equivalent to 20% of the municipality's emissions in 2005. The inventory of greenhouse gases, held in 2005 showed the road transport responsible for 37% of GHG emissions in the city.

The main measures are the expansion of the network of cycle paths, the expansion of the municipal bus fleet using cleaner fuels, operate Olympic and Paralympic fleet with less polluting fuels. Carbon emissions in transport operations are based on the internationally recognized hierarchy of reduce, replace and compensate.

Reduce: minimize emissions at the source, reducing fuel consumption with various measures, such as prioritization of low consumption vehicles using tires with adequate rolling resistance, and driver training in the techniques of economic conduct.

Replace: use low carbon fuels such as ethanol, biodiesel and electric vehicles.

Compensate: use carbon offset projects as a final step, after having exhausted the alternatives reduction and replacement.

III. Sustainable construction and urban improvements - Design guidelines and sustainable construction for permanent installations and temporary overlay (temporary facilities) were established with the aim of:

- Encourage more compact designs in order to facilitate better performance of energy consumption and materials;
- Extend the maximum useful life of materials and structures;
- Repurpose as possible of existing materials in the construction of spaces and use recycled materials or renewable sources;
- Replace deleterious materials;
- Reduce carbon emissions embedded in buildings;
- Adopt technologies that enable efficiency and rational use of water;
- Using bioclimatic passive systems, improving energy efficiency, providing greater thermal / acoustic / luminous comfort and creating healthier indoor environments and low emissions;
- Maximize the use of energy from renewable sources;
- Reduce the need for replacement and maintenance over the useful life of the facilities;

IV. Answer to international and national standards regarding the environment in the planning, development and construction of the entire infrastructure of the Games.

The main measures will be the redevelopment surrounding the Olympics stadium João Havelange, and the Maracanã surrounding urbanization.

V. Conservation and environmental recovery - Minimize the impacts on ecosystems in the Olympic and Paralympic facilities and their immediate surroundings.

The main measures will be - Environmental restoration of water bodies in the regions of the Games, a Program for Decontamination of Guanabara Bay, and environmental recovery of the Lagoon System Jacarepagua and environmental requalification of the Lagoa Rodrigo de Freitas.

VI. Expand monitoring of air and water quality in the regions of the Games

VII. Waste management. Turn off and start environmental remediation of landfills and implement integrated solid waste treatment, through legislation of the National Solid Waste Policy (Federal Law No. 12,305 of August 2010).

Conclusion

To develop cities on the principles of sustainability presupposes belief in human progress. In this sense, a strategic, proactive approach requires not only the adoption of measures and green parameters in virtually everything that is currently carried out, but, above all, the search and adoption of techniques and advanced technologies for streamlining projects and cities (Leite, 2010).

In this sense, make cities more sustainable means making use of environmental innovation through the development of public policies that reduce the negative impacts of the demands of housing, transportation, employment and economic activities on cities.

With regard to the Sustainability Plan of the Summer Olympic Games 2016 to be held in Rio de Janeiro, one can infer that there are several effective proposals of environmental innovations to be implemented in the city to make it more sustainable for visitors and their own population should enjoy the benefits after the games.

In general, the main proposals that have been made for the Games are being completed, but some will not be completed in time, such as the pollution of Guanabara Bay, a fact that shows that environmental, technological innovation processes need a great time to be applied or considered in the context of public policy.

18. RADICAL CROWD BASED OPEN INNOVATION AND DESIGN FOR SUSTAINABILITY

Ursula Tischner ✉

Abstract

Collaborative “crowd” based open innovation and design as well as funding activities, websites, platforms and projects are becoming increasingly popular. These combine the creativity of people with new enabling technologies like online platforms, rapid prototyping machines, simple Computer Aided Design (CAD) software to design and produce individualised products and services. However, very often these methods and tools are used to produce fun but unsustainable "stuff". How these new Internet and crowd based methods and tools can be used to create technological and social innovation and design that actually leads to more sustainable life styles has been explored and is demonstrated by the Sustainability Maker project, www.sustainabilitymaker.org, and its open innovation for sustainability platform www.innonatives.com, partly funded by the European Life+ Environment programme. The platform innonatives.com connects actors that have identified and/or suffer from sustainability related problems with actors who have found or would like to contribute to generating solutions for such problems. The platform systematically enables the creation of very divers open sustainability innovation and design solutions through crowd-sourcing, crowd-voting, crowd-testing, and helps to implement them through crowd-funding, an online marketplace for sustainable solutions, an expert system, and educational activities. Success and failure factors, other research findings, as well as the quality and type of solutions that can be generated by crowd based open innovation for sustainability platforms are discussed in this paper.

Keywords: open innovation for sustainability, crowd based innovation, crowd sourcing, crowd funding, radical innovation

The Need for Crowd based Open Innovation and Design for Sustainability

The world is facing a lot of severe Sustainability problems, which seem almost too complex to be solved: from Climate Change, diminishing Biodiversity, via Peak Oil and resource depletion, to water and food scarcity, poverty, health issues and social crises. Due to these problems Sustainability became a well-known notion as being the solution for these issues (Saarinen, 2006): it is a topic that is present and discussed around the globe. The willingness to go green is increasing and citizens are aware of problems such as global warming. About 75% of the German population is aware of climate change, a loss of biodiversity and the destruction of natural resources (Weber, 2008). Furthermore, 68% of Europeans consider climate change to be a serious problem (European Commission, 2011). Citizens want to act in a sustainable manner, but when it comes to picking between certain product attributes versus contributing to a better environment, they almost always decide for the attributes. Therefore, innovative ideas have to be generated to make sustainable products as appealing as usual ones (Ginsberg, 2004). Moreover, there is an expectation of customers for companies to act in a responsible manner, which includes sustainability. Out of 100% participants asked in a survey of the European Commission 35% agreed that businesses and the industry are responsible for dealing with the problem of climate change (European Commission, 2011). This clearly shows that not only being innovative, but also being sustainable can be used as a competitive advantage to outperform competitors (Ginsberg, 2004).

In the times of a globalized market it is increasingly difficult for an organization to stand out from competitors. To do so, a competitive advantage is needed, something that contrasts a company favorably from the others. Competitive advantages can be created internally or externally by a firm. Internal changes are often generated by innovation. They not only foster a competitive advantage, but can also be a basis to eliminate competitive advantages of other companies (Grant, 2008). To answer the need for innovation, the idea was to distribute knowledge from all around the globe via crowdsourcing or so called Open Innovation (OI). No one can possess all knowledge alone. Therefore, the quest of how to best access and distribute that knowledge led to the implementation of crowdsourcing (Chesbrough, 2011). "It taps into the knowledge, the creativity, the insight and skill of the world around you. It can help you predict next month's sales, or next season's fashion. It can improve the management of your supply chain. It can enhance your customer's experience of your product and services. It even outperforms the polls in predicting the winners of Presidential elections. And often these improved outcomes can be created with surprisingly modest investment." (Chesbrough, 2011).

The next question emerging is, can the quest for open innovation and crowdsourcing be combined with the search for sustainable solutions and create win-win situations for companies, citizens and the environment alike.

Emerging Tools for Crowd based Open Innovation and Design for Sustainability

As one person or one company alone can hardly solve the complex sustainability issues described above, it is important to establish open innovation processes and to involve a larger and diverse group of stakeholders and experts as well as users and customers in them. Various users may have similar problems and demands as well as very interesting ideas on how to solve them. To avoid inefficient use of resources and to serve the community, their information and innovations should be broadcasted, freely revealed and brought together (von Hippel, 2005). This is one of the most significant functions of Innovation Communities or so called Open Innovation Platforms (OIPs). OIPs have been introduced over the last years to facilitate and broaden the innovation process (Battistella, 2012). From the technical view, such online platforms serve as IT-based environments to find new innovators and act as a tool for users to interact (Komus, 2008). Based on Chesbrough, Komus and Wauch, and some further sources Hallerstede (Hallerstede, 2013) created the following definition for OIPs:

"An open innovation platform is defined as a virtual environment that offers digital services, with the aim to allow the creation of innovation by facilitating time- and location-independence, voluntary interaction of innovators."

A further reason for the necessity for OIPs is, that only through cooperating and multicultural knowledge changes can be made. Especially the needed social innovations towards sustainability cannot be designed and implemented without the integration of the relevant stakeholders. Having recognized the trend toward OIPs and the further need for sustainable solutions, the company 'econcept' developed and launched the open innovation platform 'innonatives.com' (from now on referred to as 'innonatives'), an online platform (OP) promoting the development of open innovation and design projects to solve sustainability related problems and implement sustainable solutions.

Tools that are used in the open innovation context and the innonatives platform are the following:

- ***Open Innovation***, a term originally coined by Prof. Henry Chesbrough meaning 'the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. [This paradigm] assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology.' (Chesbrough, 2006). It is important to notice that in the open innovation for Sustainability platform innonatives, the term ‘Open Innovation’ generally stands for innovation activities that involve diverse stakeholders, actors and experts. For instance, besides of companies, innovation projects can also be initiated by NGOs, municipalities, communities, citizens, networks etc.
- ***Crowdsourcing***, is a term composed by the words 'crowd' and 'outsourcing' that indicates the act of taking tasks usually performed by contractors (or employees) and outsourcing them to a specific community of people (the 'Crowd') in systems of mass-production. (Howe, 2006). This means in simple words that the general public (the crowd) is invited and enabled to generate contributions (ideas, innovations, concepts, services, products etc.) for a company or other organization.
- ***Crowdvoting***, the public or a specific community (the Crowd) votes for challenges, solutions, products, designs to select which of a number of solutions shall be selected. Crowdvoting is also a new form of target group research used by companies to get insight into the public opinion.
- ***Peer-to-Peer Production*** (p2p), Peer-production is a new form of production (of goods, contents or services) that involves members of communities in an organized way. It’s a 'coordinated, (chiefly) internet-based effort whereby volunteers contribute project components, and there exists some process to combine them to produce a unified intellectual work' (Benkler, 2006).
- ***Crowdfunding***, an approach for generating funds by asking the general public or a specific community (Crowd) to invest in or sponsor activities, such as implementation of new solutions or products, via online platforms, e.g. used by musicians and artists to fund their productions. Different forms of crowdfunding are distinguished such as, donation based or reward based crowdfunding, Crowdlending, Crowdinvestment.
- ***New business models,*** emerging via online platforms, e.g. grassroots economies that move the focus from mass production to individualization and production on demand, and on ethical, personal, political and sustainable values of the goods, mass customization, co-design and socio-preneurism (social and sustainable entrepreneurism). (See also: (Gassmann, 2010))

In addition to the new emerging methods and tools for open innovation and crowdsourcing, a growing group of well educated creative professionals is forming, who are not employed in traditional ways by companies, but are engaged in own creative projects or team up in temporary project groups to carry out divers projects. These professionals use crowdsourcing and crowdfunding sites more and more to realize and implement their ideas outside of the conventional marketplaces, or to be commissioned by traditional companies. More known examples are musicians and artists or designers producing their own pieces of art, music or designs without involving the mainstream industry and funding production as well as selling them via online platforms. Also, the maker and fablab activities (makezine.com) or craft oriented Do-It-Yourself sites like www.craftster.org or www.etsy.com support the very interesting new maker and participatory design movements.

To conclude, most of the individual elements that are used by the new innonatives.com platform are already applied by some actors and in some countries. But none of the previously existing platforms combined all elements and directed all its efforts towards solving Sustainability issues in the holistic triple bottom line approach of people, planet and profit. The specific innonatives approach is described in the next paragraph.

Create Innovation and Design for Sustainability via the Platform innonatives.com

The platform 'innonatives.com' specializes in innovation and design for sustainability. It is the world's first OIP that combines crowdsourcing, crowdvoting, crowdfunding and an online shop on a single platform to create radical innovation for sustainability. The platform encourages uploading sustainability related challenges, which are innovation and design projects seeking sustainable solutions that invite contributions by all (or specific) members of the 'innonatives' community. Anybody with an Internet connection and access to a device with Internet capabilities is able and encouraged to participate on 'innonatives'. Many of the sustainability solutions needed today exist already somewhere around the world. Often actors in one part of the world simply do not know of the great cases in other parts. That will change through innonatives by enabling a most diverse group of actors worldwide to team up for solutions development and exchange.

The innonatives platform has been generated by the European 'Sustainability Maker Project' (www.sustainabilitymaker.org), which is carried out by five core partners and a wider network of universities, companies and non-profit organizations. The core partners are 'econcept - Agency for Sustainable Design' (manager), 'ecosense media & communication', software company 'webclusive', 'Politecnico di Milano' and 'Forum soziale Technikgestaltung' (forum for social design of technology). The project is supported by the LIFE financial instrument of the European Union.

Innonatives offers Open Innovation, Crowdsourcing and Crowdvoting functions to carry out the innovation Challenges, a Crowdfunding module to generate budgets for implementation of sustainable solutions, an online shop to trade sustainable solutions, and an expert and educational system, as well as helpful tools for sustainability evaluation and development of Intellectual Property Rights concepts. All of the activities at innonatives.com are directed exclusively towards solving Sustainability related problems and implementing sustainable solutions.

The platform builds on the idea to carry out so called 'Challenges', sustainability innovation projects. To post a challenge, a challenge owner creates and describes his sustainability related problem. By proposing this challenge, he or she asks the so-called 'Solvers' (community of the platform) to develop solutions. Solvers post ideas and concepts. Crowdvoting and evaluation takes place via the platform. The users who suggested the most promising ideas and concepts will be asked to develop their ideas further and develop a more refined solution. At the end of the Challenge process all solutions are evaluated by the challenge owner, the experts (internal and/ or external experts of the platform) and the crowd (crowdvoting). By the use of crowdfunding and the online shop the winning solutions will then be implemented via the platform, or outside of the platform alternatively, whatever is best and most efficient. All modules can be used independently from each other: the Challenge Process, the Crowdfunding Module and the Online Shop. However, the platform will always guarantee that all contributions will have a high level of Sustainability.

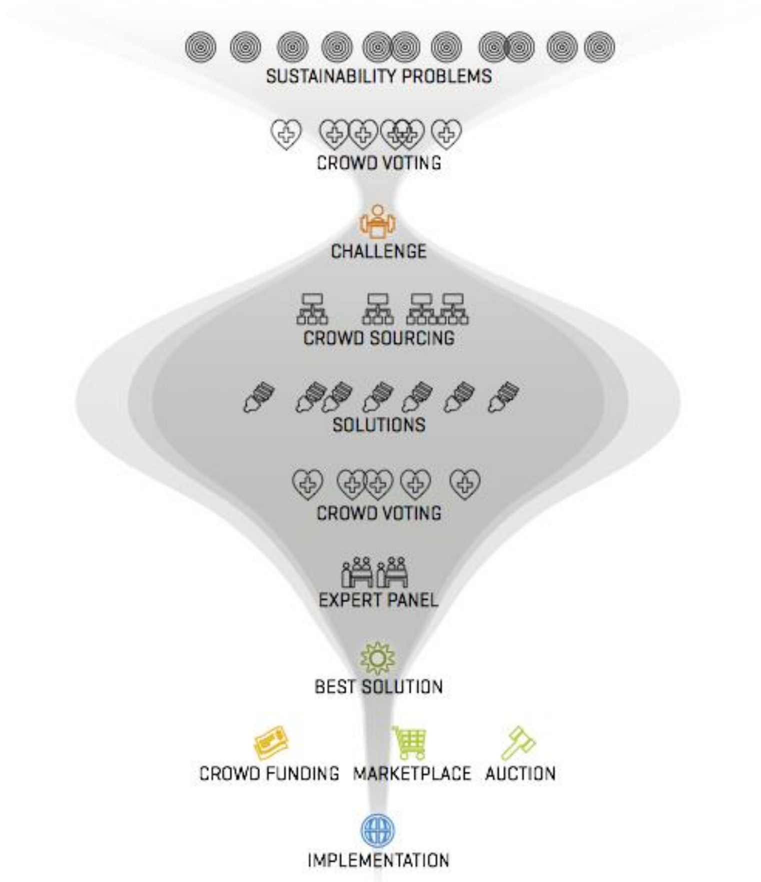

Figure 18-1: *The standard innonatives Process.*

The platform ‘innonatives’ defines sustainable innovation in line with the original UN Brundtland definition of Sustainable Development (Brundtland, 1987) and covers the three dimensions of Sustainability: environment, socio-cultural, economic prosperity. Sustainable innovations are defined as new products, services and production-consumption systems that fulfill customer needs and further drastically enhance the social and environmental performance along the whole lifecycle and service or production-consumption systems (see also (Belz, 2012)). Sustainable Innovation is not only about technological but also very much about social innovation, changing behavior and how citizens organize daily routines. Social innovation unlike technological innovation does not necessarily need expert knowledge but can be created by non-expert groups with a good knowledge of the actual situation and the needs and demands of the actors involved.

The innonatives platform itself will adopt an innovative sustainable business model and act more like a non-profit organization that invests all surplus gained, beyond the cost of running the platform, in sustainability solutions generated by the platform. It might establish the organizational form of a co-operative also involving ‘the Crowd’ in decision-making.

Why innonatives.com? About ‘Wicked Problems’ and possible Solutions

Sustainability related problems are big and complex, pose a real challenge for society, and require involvement of many different actors. That is why they are often referred to as ‘wicked problems’. ‘Wicked problems’ are defined by Rittel and Webber as follows (Rittel, 1973):

- They are difficult or impossible to solve because of incomplete, contradictory, changing requirements difficult to recognize and define.
- They are systemic problems with complex interdependencies and many actors and factors involved.
- It is difficult to analyze wicked problems and the solution of one aspect may reveal or create other problems.
- There is no ultimate true or false solution, a solution of a wicked problem can only be better or worse.
- Every solution to a wicked problem is a "one-shot operation"; there is no opportunity to learn by trial and error, every attempt counts significantly. Thus, planners are liable for the consequences of the actions they generate.
- Wicked problems cannot be solved by the application of traditional methods but demand creative solutions.

The assumption of the Sustainability Maker project is that by using the open innovation for Sustainability platform innonatives.com society is able to deal with wicked problems because:

- Online open innovation platforms involve a huge group of international diverse and multi-disciplinary actors and stakeholders (The Crowd).
- The platform searches for tangible problems within the large complex Sustainability issues that the crowd can handle, and then another and then another, moving in the right direction.
- Problems to be tackled are proposed, defined and voted for by the crowd, thus there will always be a local and specific problem that a majority of the participants find interesting and well defined.
- Only solutions will be implemented that a majority of participants and an expert panel find worth it and enough actors would like to use. Thus, it is very likely that the state of the art situation is improved.
- Solutions can be tested in niche markets, and then be up-scaled when successful.

The experiences of the platform innonatives.com so far were positive and lead to the assumption that indeed some of the effects above can be realized by some of the innovation projects. A more detailed analysis will be available at the end of the EU demonstration project Sustainability Maker in February 2016 (see www.sustainabilitymaker.org).

Success and Failure Factors for Crowd based Open Innovation and Design for Sustainability

This final paragraph discusses learning outcomes and state of the knowledge about what promotes and might hinder success of open innovation online platforms and more specifically www.innonatives.com.

Awareness and Accessibility

A website has to be found and people have to be aware of its existence and have to be able to access it (Antikainen, 2007). Anybody having access to the Internet has the opportunity to participate in 'innonatives' any time of the day. The team behind 'innonatives' conducts intensive social media activities and linking to other website, annual 'Sustainability Maker Conferences', 'innonatives' newsletters, distribution of flyers etc. As soon as there is a new challenge planned on 'innonatives', potential interest groups are contacted via social media platforms. Also the 'innonatives' users are encouraged to create their own communication campaigns. Keeping up intense media communication constantly is a demanding challenge. It is also necessary to connect local groups with the international community and to create exchange of offline and online communities and allow knowledge transfer. For this 'innonatives' involves local ambassadors, which can be design schools, where professors and students act as facilitators between local communities and the international online network.

User Acceptance and Satisfaction

According to Venkatesh et al. (2003), three factors are direct determinants of user acceptance and user behavior on the platform. These are: performance expectancy, effort expectancy and social influence. Performance expectancy is outlined to be "the degree to which an individual believes that using the system will help him or her to attain gains in job performance". Effort expectancy is defined as "the degree of ease associated with the use of the system". The social influence is termed as "the degree to which an individual perceives that important others believe he or she should use the new system". Users are not willing to spend more than about one minute of their valuable time to understand how a website works before they leave it and will most likely not return. Dickinger and Stangl (2013) identified as general success factors for the user acceptance of websites: Usefulness, Ease of Use, Enjoyment, Website Design, Trust, Content Quality, Navigational Challenges, System Availability, Satisfaction, Perceived Value. Thus the design of the website functions and user interface as well as the establishment of an interesting and positive community of users are essential for innonatives.com.

Language issues

In order for participants to be able to communicate with each other, a shared language is critical. At the moment, the majority of communication on the 'innonatives' platform is in English. Depending on the location of origin, people can feel overwhelmed by that. The current solution, which is temporary, is the integration of an 'Online Translator' tool. In the long run the platform shall be available in several languages. Already now it is possible to open a challenge in another language than English. Concomitant participation is then partly limited to people speaking the language featured in the proposed challenge, excluding all others.

Transparency and Trust issues

"Trust is important for information websites, but even more essential for transaction sites" (Dickinger, 2013). In an OIP such as 'innonatives', this refers for instance to issues such as payments for crowdfunding and to intellectual property rights distribution (IPR). IPR management is of outmost importance for the success of an OIP (Meige, 2011). Therefore 'innonatives' provides an IPR contracting module that helps Challenge proposers to define fair IPR models and contracts for the challenges. As the platform offers to run open or closed innovation challenges there are two types of IPR approaches: The open challenges (open to the public) normally adopt the Creative Commons License "Attribution- NonCommercial-

ShareAlike 3.0 Unported (CC BY-NC-SA 3.0)" which users accept upon registration. The principle of this Creative Commons License is that users broadcast their solutions publicly; every innonatives visitor can see them and also use and develop them further. However, only by referring to the originator of the solutions, who owns the IP rights. If somebody wants to use any open solution commercially, a (financial) agreement has to be made with the original inventor. In closed challenges specific rules for Copyrights and Intellectual Property Rights distribution have to be created, published and signed before entering into the closed challenge. This process is very transparent so that all innonatives users know right from the beginning what they are getting involved with by participating in the platform.

Motivation of Users

According to Antikainen (2007), several different factors influence the usage of an OP.

- Knowledge exchange and discussion with members to extract knowledge and gain new input or learn something, concerning giving information, advice and experience, professional or non-professional: Within 'innonatives' challenge an exchange of knowledge is possible. Discussions take place and a team can be formed to work together on a challenge.
- Commercial Activities: 'innonatives' offers financial rewards in challenges, creates funding opportunities through crowdfunding and the opportunity to trade in the online shop.
- Dating or meeting new people: At 'innonatives' it is possible to meet new likeminded people from different backgrounds and from all over the world. This enables users to benefit from networking professionally or finding interesting creative people, and creates knowledge transfer as well as encourages cross-cultural understanding.
- Playing and gaming: Making it more fun for people to participate: There are some gaming elements integrated in the innonatives platform such as the 'reputation management system'. Members are ranked according to their contribution level and receive higher levels of recognition the more active they are. This creates also a slight element of competition. Having an interesting avatar (user representation) at 'innonatives' can also add to the fun of the website. Users can choose their display name and picture freely.
- Similarity of users, which "refers to the extent to which potentially relational partners perceive or feel psychologically, morally or emotionally close or accustomed to each other" (Antikainen, 2007). This also counts for similarities in experience and background. 'innonatives' being an OIP for sustainability issues, brings together users that have at least one thing in common: the wish for creating sustainable solutions. They all work towards a similar goal. This is one of the most favorable success factors of the platform. It makes it very unique, uniting all users in the same important mission.

Picking the right crowd and providing guidance

This success factor presented by Hopkins (2011) reflects that only approximately 1% of a crowd will actively participate in crowdsourcing (although the 90-9-1 % rule is questioned now for social media participation). Considering this, it is crucial to start with a large number of participants, expert and non-expert audiences. The crowd should at best have a diversity in thinking which implies specialty knowledge. In 'innonatives' high value is placed on the diversity of the crowd and the experts on the platform. Focus is laid on creative people, sustainability crowd, those who care for sustainability and innovation, SMEs and NGOs. Big enterprises often do some open innovation by themselves, but the smaller firms normally are not able to run own innovation platforms and thus benefit from the opportunity to use 'innonatives' for their innovation projects.

Directing, guiding and valuing the crowd

Subsequently, also introduced by Hopkins (2011), is that "crowds require direction and guidance and someone to answer their questions". Making the participants feel a valued part of the community is crucial and can be seen as an incentive to participate. Guidance helps to keep the crowd focused on what the platform likes them to achieve.

How to formulate innovation challenges

Hopkins (2011) also suggests that challenges should be kept simple and be broken down in the smallest manageable components. As many of the users participate in their free time, the tasks should be small and simple enough, and fun enough, to be worked on in the spare time available. None of the challenges on 'innonatives' is too complex to be solved. Challenge owners should define clearly what they want, what they do not want and what they already know. An amount of meaningfulness is included in all innonatives challenges. As Carpenter (2011) specified, understanding the case for which a new innovation is needed is crucial to the potential participants. The challenge owner should call more upon the change that can be made by finding solutions for the given problem. Choosing interesting topics right from the beginning on is essential to encourage active participation. Most 'innonatives' challenges offer highly relevant topics like reducing food waste, banning plastic bags, upcycling waste materials, improving quality of life in poorer communities etc.

Incentives, Rewards and Achievement

Having analyzed twelve OIPs, Antikainen and Väätäjä (2010) found out that 62.6% of 100% of respondents state that monetary rewarding encourages their participation on OIPs. 57.2% state that non-monetary rewarding would also encourage their contribution. Furthermore, publicizing of rewarded users on the websites is crucial to many respondents, as well as a ranking list showing the quality of ideas. For some innovators, it is more important to have their name and innovation well distributed in a good light. They want to increase their public image (von Hippel, 2006). Besides of offering financial rewards, royalties, contracts, and other material benefits, the immaterial rewards such as being promoted and the factor of personal interest are very important in 'innonatives'. Sustainability is a matter of particular interest for the users. Participants prefer to engage in meaningful projects. Making a change by creating sustainable solutions and doing that together with interesting and creative people gives the participants a high satisfaction. Finally, efficacy and learning, pertaining to the "opportunity to exercise one's existing skills toward a goal, learn new ones, and receive feedback for improvement" (Carpenter, 2011) is also an element of 'innonatives', as the platform offers knowledge exchange with experts through the internal expert system, and educates on using specific tools such as for sustainability evaluation of challenges and solutions.

Conclusions

This manuscript presented the state of the art and connection of open innovation platforms and radical innovation for Sustainability. It used the platform www.innonatives.com as a case study to discuss success and failure factors for open innovation and design for Sustainability platforms. More conclusions and results of the European demonstration project Sustainability Maker which created and manages the innonatives platform will be published on the project website towards the end of the demonstration phase in March 2016 (see www.sustainabilitymaker.org).

19. MINING OF RARE EARTH METALS FROM HYDRO MINERAL RESOURCES IN SIBERIA: TRENDS AND PROSPECTS

Olga Ulanova ✉

Abstract

Siberian scientists showed by their scientific investigations that brines of Siberian Platform are a very important hydro mineral resource for economical development of the East Russia. Prospects for the integrated mining of the hydromineral resources in Russia remain low. This is caused by the absence of efficient and environmentally friendly processing technologies. The necessity of resolving these problems relates to the perspectives of developing a source of raw materials in Russia for extracting strategic rare earth metals and rather alkaline and alkaline-earth elements (lithium, rubidium, cesium, strontium etc.) from unconventional sources of mineral raw materials. The unique property of the brines is their industrially profitable concentrations: by 20-25 times on lithium, by 5-10 times on rubidium, by 3 times on cesium, by 10 times on strontium. Great resources of rare-earth metals and rather alkaline and alkaline-earth elements (in industrially profitable concentrations) are concentrated in Angaro-Lensky and Oleneksky artesian basin on all lithological horizons.

On the basis of theoretical studies and pilot researches revealed conditions of the selective extraction of strontium, lithium and rubidium from highly concentrated natural brines during the ion exchange. Technological schemes were developed to extraction of rare earth metals and rather alkaline and alkaline-earth elements from brines and various compositions of quarry waters of iron-ore and diamond deposits in Siberia.

Keywords: rare earth metals, rather alkaline and alkaline-earth elements, hydro mineral resources, Siberia

Introduction

Natural multicomponent brines are unique groundwater and promising sources of raw materials for the large-scale production of strategic rare earth metals (including alkaline earth elements). Brines are major hydro-mineral resources in Russia (Shvartsev S. L., 1996). Their production does not require expensive and dangerous mining operations, and their processing is energy-saving. As a rule, oil and gas reservoirs, iron ore mines, and diamond deposits have natural brines, and the brine exploration significantly increases the efficiency of investment into the mining districts (Ryabtsev A. D. et al., 2007).

Aim of study

To explore the issue, the Interagency Regional Educational, Scientific and Analytical Center on the Problems of Study and Rational Use of Hydro-mineral Resources of the East Siberia was founded on the basis of the Irkutsk National Research Technical University (INRTU) in 1998. Since then, research projects in the area have been carried out for more than 15 years.

The aim of the study is to evaluate the potential of hydro-mineral resources as innovative sources of rare earth elements in Siberia and to develop technological processes for selective extraction of rare alkali and alkaline earth metal metals from natural multicomponent brines.

Methodology

The methods used in the research projects are as follows: the atomic absorption analysis; the flame photometry; the flame mass spectroscopy; analytical-experimental, static, and dynamic methods for the ion exchange process; the mathematical modeling of the ion exchange kinetics; planning and processing of experiment results using the static methods and the Microsoft Excel software.

Discussion of Results

Characteristics of hydro-mineral resources on the territory of the Siberian platform

The resources referred to the hydro-mineral raw materials are the industrial groundwater, seawater, salted water, brines, mineralized lakes, etc. (Boiko T. F. et al., 2007, Kogan B. I., 1974).

Groundwater brines are a unique type of natural resources. They are promising as innovative mineral resources of the Eastern Siberia, which is proved by the studies of E. V. Pinneker, I. F. Shchepetunin, P. I. Trofimuk, A. A. Dzyuba, A. G. Vakhromeev, E. V. Zelinskaya, etc. (Trofimuk P. I. et al, 1969, Zelinskaya E. V. et al., 2001, Kotsupalo N. P., 1999).

The works by B. I. Kogan, V. A. Nazvanova, R. D. Gudenaukh, B. M. Devis, I. A. Klimenko, G. N. Nazarova, N. P. Kotsupalo, etc. laid the foundations of the technological processes for the isolation of metals from natural waters of high salinity. However, the real level of the cost-effective brine exploration of the Siberian platform as a complex mineral raw material still remains low. This is caused, first of all, by the complexity of the technology system due to high total mineralization of brines, a multicomponent composition, the difference in the concentrations of macro- and microcomponents, and the necessity of the selective extraction of metals having similar properties (Zelinskaya E. V. et al., 2001).

From the point of view of industrial brines, the lower aquifer system of the Angara-Lena basin is also interesting. Its brines of the mineralization of 320-440 g/l have calcium chloride, sodium chloride, calcium, and chloride-calcium-sodium compositions with high concentrations of rare elements. (Ulanova O. V., et al., 2001).

Besides, the brines of the Tunguska and Olenek basins are also considered promising. In the subpermafrost area, there is a distinctive aquifer of Ordovician deposits of the thickness of 5-7 m and higher. It is presented by sodium chloride brines, whose mineralization reaches 400 g/l. The most studied are the groundwater in the regions of explored deposits localized within the explosion pipes. (Table 19-1) (Zelinskaya E. V., 2003).

Element	**Concentration, mg/dm^3**		**Industrial condition, mg/dm^3**
	minimum	maximum	
K	210,00	37890,00	-
Na	10470,00	43033,00	-
Ca	591,00	80560,00	-
Mg	164,00	17290,00	1000,00
Li	7,00	346,00	10,00
Rb	1,22	17,13	3,00

Sr	36,00	2551,00	300,00
Zn	5,00	465,00	-
Cu	-	28,00	-
Mn	180,00	3500,00	-
B	202,00	408,00	200,00
Br	1,20	5320,00	150,00

Table 19-1: *The chemical composition of brines of the deposits within the Udachnaya explosion pipe.*

The analysis of the multicomponent composition of the studied brines showed that the brines of the Udachnaya pipe are very rich with microcomponents; their concentrations exceed the minimal commercial content: strontium 3.5–5 times; lithium 13-25 times; rubidium 2.9-4.3 times, thus, their deep processing is necessary to fully extract the valuable components such as Sr, Li, and Rb. (Ulanova O. V., 2001)

Processing technologies for hydro-mineral raw materials

A comprehensive long-term study of the unique Siberian hydro-mineral province was carried out by the Department of Mineral Processing and Environmental Engineering of the INRTU within a series of research projects. The ecological and economic feasibility was proved for the exploration of multicomponent brines of a number of deposits of the Siberian platform with the purpose of the deep and selective extraction of rare earth metals: lithium, rubidium, strontium, cesium, etc. from the sodium chloride brines of the Korshunovskii GOK (ore enrichment works) and from the calcium chloride brines of the Udachninskii GOK based on the following methods: the ion-exchange sorption, the eluent chromatography, the flotation, the crystallization, and the freezing. The technological schemes for metal extraction from free water and brines were developed. (Ulanova O. V., 2001, Ulanova O. V., 2015)

- The dependence of the degree of extraction of metal ions (Sr, Li, Rb, Ca, Mg, Na) on the concentration of hydrochloric acid in the range of 0.1 to 8 N HCl was established. It was shown that the efficient separation and extraction of metals is reached by the gradient elution, which allows to obtain products with the lowest content of impurities, particularly, to provide 92% extraction of strontium and 97.9% extraction of rubidium.
- Based on the height equivalent to a theoretical plate (HETP), the possibility of the chromatographic separation of Sr, Li, and Rb ions was shown using a KU-2x8 (Russia) and a Dawex-50x8 cation exchangers on the brines of the Udachninskii GOK at the 2 N HCL eluting.
- The technological scheme for the strontium and rubidium sorption extraction from the brines of the Udachninskii GOK was proposed.

Conclusions

The issues of the integrated production of groundwater brines in Siberia are not explored enough yet, despite the great prospects of this area. However, it is apparent that the key technology in the deep processing of groundwater brines is the extraction of industrially valuable rare and alkaline earth elements.

20. LI-ION BATTERIES FOR E-MOBILITY – ARE METAL RESOURCES UNDER PRESSURE?

Saskia Ziemann ✉, Daniel Müller, Armin Grunwald, Liselotte Schebek, Marcel Weil

Abstract

Electric vehicles (EV) as an alternative to fossil fuel based cars play an important role for a more sustainable development of the transport sector. Traction batteries such as Lithium-ion Batteries (LIB) represent the vital part of this technology and could face a significantly increasing demand bringing about also a growing need for the contained materials. Therefore it should be evaluated if a strong and fast increase in use of battery materials through EV might pose a threat for long-term availability of raw materials required for LIB production.

Starting with the example of lithium for EV-batteries we could show that the contribution of recycling to reduce the need for primary resources seems to be lower than often assumed, especially as long as demand is growing fast. Additional challenges for an effective recycling of EV-batteries are the low selectivity of battery recycling technologies complicating the recovery of certain valuable materials and also the dependency of the recycling rate on the efficiency of the whole recycling chain. Furthermore, supply risks could rise through high demand for primary raw materials as the dependency on reserves in critical countries increases when the smaller amount of reserves in stable countries is depleted.

Keywords: e-mobility, raw materials, resource availability, recycling, material flow analysis.

Introduction

The transport sector is responsible for approximately 25% of the energy-related CO_2-emissions and requires more than half the world's consumption of crude oil for gasoline production (Fulton 2009). To reduce greenhouse gas emissions as well as the dependency on fossil fuels there is a strong need for alternative drive concepts such as electric mobility.

Electric vehicles (EV) are predicted to gain considerable market share within the next twenty years (IEA 2010). Such a growing number of EV will most likely need large quantities of materials, especially for traction batteries as the vital part of this technology. Since lithium-ion batteries (LIB) are one of the most promising candidates for energy storage in EV a strong and fast increasing demand for traction batteries affects the need for the contained metals (e.g. lithium, manganese and cobalt) (Simon et al. 2015). Some of these metals can be regarded as critical materials which is why the impact of electric mobility on these materials should be assessed in greater detail. Thus, it will be evaluated if and how a growing number of EV might pose a threat for the long-term availability of the relevant raw materials in LIBs.

Assessing material demand for future EV-batteries

Methodological Approach

For assessing the extensive correlation between the possible development of raw material demand and supply we use material flow analysis (MFA). By means of MFA the substance flows across the whole life cycle of metals can be simulated, e.g. for the global lithium cycle (Ziemann 2012). Through further dynamic modelling the development of material flows and stocks over time can be analysed. Such a dynamic MFA model provides the basis for assessing different scenarios of EV market penetration and how this impacts the demand for raw materials. Further analysis can be directed to exploring options to meet this demand with primary and secondary resources. In this context different economic and geopolitical factors influencing future raw material availability are considered. The geographical distribution of lithium reserves as well as differences in the political stability of reserve countries account for a possible supply risk (Weil 2014). Therefore it is important to investigate the potential contribution of recycling to reduce the future demand for primary metal production and thus to increase resource savings.

Here we use the example of lithium to show how large scale implementation of EVs might influence the global flows of battery materials. On basis of such a dynamic MFA model strategies can be derived for improving the resource efficiency in raw material cycles.

Material Flow Analysis

To analyze the effects on lithium demand that would result from a growing use of traction batteries for E-mobility a lithium-demand model was developed. This dynamic MFA model uses given inflows and lifetime to calculate the stock, stock change, and outflow over time and thus represents an input-driven model. The evolution of lithium demand is then compared with available lithium reserves to identify not only the time span for sufficient lithium availability, but also the potential contribution of recycling and secondary material flows to save primary resources.

In this analysis a scenario, where LIB dominate the market for EV-batteries until the year 2110, is used aiming at understanding the effects of a more intensive use of lithium-based traction batteries. The basic assumptions underlying this scenario are applied in the lithium-demand model in the following way: the inflows are estimated from the potential development of the vehicle fleet within the next 100 years. The total number of car-like vehicles is growing to 1200 million in 2110, which is on a comparable level to present developments[4] (Stacy 2012). This assumption is based on the hypothesis that despite the anticipated population growth the car per capita ratio will be lower than today. Alternative power trains (electric, hydrogen, bio fuels) will successively replace traditional cars using fossil fuel-dependent power trains:

- 100 million vehicles will be driven solely by biofuels due to the strong competition between biofuel and food production,
- 50 million vehicles will be driven by pure hydrogen (without a traction battery) limited by high costs and restricted PGM availability,
- 1050 million vehicles will possess a traction battery: 900 million vehicles employing lithium-based traction batteries (see Figure 20-1, detailed numbers can be found in Table 20-1), 150 million vehicles using alternative battery technologies (e.g., NiMH).

[4] Some studies predict for the year 2020 already more than 2 billion vehicle worldwide (Sperling 2009).

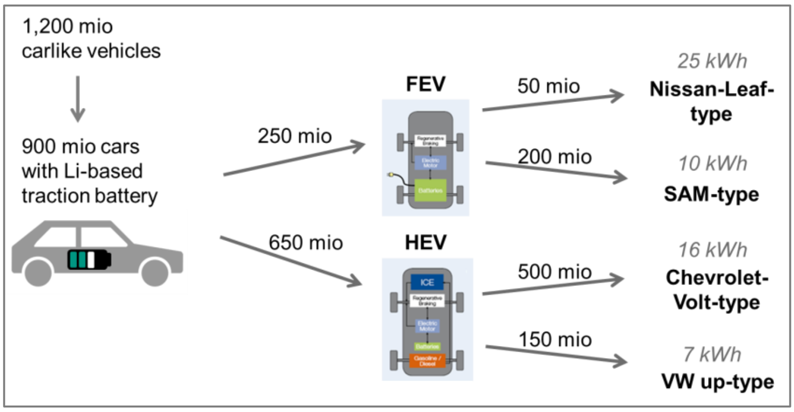

Figure 20-1: *Assumptions for MFA modelling of the future vehicle fleet.*

Type of EVs	Size of EVs	Battery size	Growth mode
250 million fully electric cars	50 million big to mid-sized cars, e.g. Nissan Leaf	25 KWh	exponential
	200 million small and light weight vehicles, e.g. Mercedes Benz Smart electric drive, Sam	10 kWh	linear
650 million hybrid vehicles (hydrogen, bio fuels, fossil fuels)	500 million big to mid-sized cars, e.g., Chevrolet Volt, Opel Ampera (growth, average battery size	16 kWh	exponential
	150 million small vehicles, e.g. Volkswagen Up	7 kWh	exponential

Table 20-1: *Assumptions of market penetration of the different EV types in the dominant lithium battery scenario (cf. Weil 2014).*

The specific lithium content depends strongly on the battery type and chemistry, which is why the net values found in the literature range from 0.114 kg/kWh (Gruber 2011) to 1.38 kg/kWh (Norris 2009). In the modelling average lithium content of 0.3 kg/kWh is applied as an approximation of currently used battery types in EVs, e.g. active materials containing Lithium Cobalt Oxide (LCO) or Lithium Nickel Cobalt Aluminium Oxide (NCA).

It is assumed that lithium-ion traction batteries have an average lifetime of 10 years even if the guarantied calendar lifetime of such a battery at present ranges only from 2 years (e.g., Sam) to 8 years (e.g., Ampera, Volt). The useful lifetime of batteries is generally expressed as the loss of a battery's ability to provide a specific amount of its original nominal capacity, usually 80%, but a battery can also be used below this capacity (Weil 2014).

In addition to the lithium demand for EV batteries the present use of lithium in other sectors such as the production of glass, ceramics, and lubricants and in batteries for electronics also has to be considered (Ziemann 2012). Based on the initial value of lithium production for these sectors of 28,000 t in 2010 (USGS 2012) we anticipate a growth of 3% per year, which is a rather conservative assumption in comparison to the yearly average increase in consumption of approximately 6% from 2000 through 2012 (USGS 2013).

Results and Discussion

The results of the modelling (cf. Figure 20-1) show that lithium demand is rising constantly and amounts to as much as 15 Mt in other sectors in the year 2110 (see basic demand) and it accounts for roughly 25 Mt for traction batteries (all other lines). Thus, the aggregated demand reaches values around 40 Mt, which represents approximately the twofold amount of the current worldwide reserves as estimated by Roskill (2009) or Yaksic (2009).

Comparing these results of future demand with the quantities of currently known lithium reserves allows for identifying time spans of sufficient raw material availability. Reserve figures of approximately 24.4 Mt for this comparison are chosen from Roskill (2009) and can be distinguished according to their occurrence in stable[5] or critical countries. It can be seen that the amount of reserves located in stable countries (R_{st} = 7.4 Mt) are depleted already in 2055 (cf. Figure 20-2). Considering the lithium deposits in critical countries (R_{cr} = 17 Mt) the total reserves would be sufficient until 2092. This means that the amount of lithium reserves could sustain a fast growing demand even beyond the year 2090, but the supply risk might increase significantly after 2055.

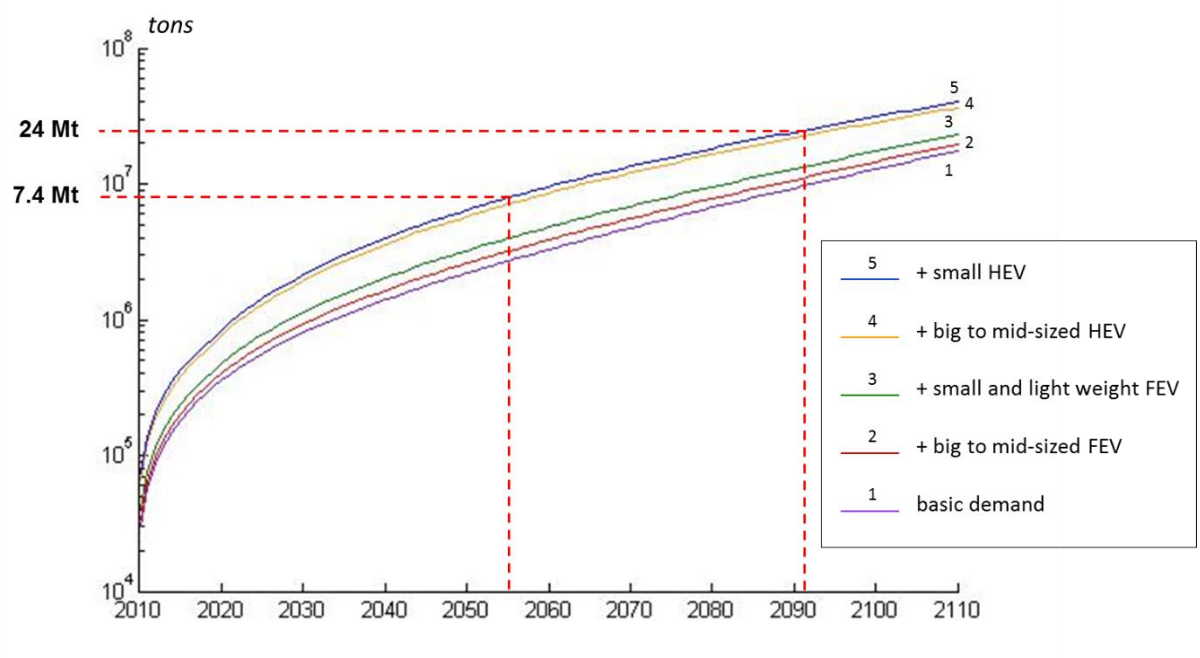

Figure 20-2: *Evolution of Lithium demand until 2110 (basic demand and EV-requirements) (based on Weil 2014).*

In this context, lithium recycling is predicted to play an important role for future raw material availability and to significantly reduce the depletion of current lithium reserves. Since the ability to recycle lithium products determines the possible amount of secondary raw material available, it is necessary to analyze how and to what extent recycling can affect the demand for primary lithium. The amount of a recovered raw material is determined by the efficiency of

[5] Political stability of countries can be described using the world governance indicators provided by the World Bank. The mean value of the six indicators representing the individual governance performance of each country is used to distinguish stable (WGI>0) and critical countries (WGI≤0). This distinction is applied as a measure of a country's risk for possible supply restriction of raw materials (DERA 2012).

the whole recycling chain that is why the recycling rate is depending on factors such as collection rate, dismantling efficiency, preprocessing efficiency and the recovery efficiency of the core recycling process (Hagelüken 2009). The effects of lithium recycling on reducing primary raw material demand are investigated employing two different recycling rates of 40% and 80% (see also Weil 2014 for details).

The reduced consumption of primary lithium due to the recycling of traction batteries and the supply of secondary lithium for battery production or for other sectors can prolong the availability of lithium reserves. In this respect the time span the reserves in stable countries would suffice with a recycling rate (RR) of 40% and 80% can be extended until 2058, and 2064 respectively. Taking into account the reserves in critical countries the exploitation of the total amount of available reserves of 24 million t can be prolonged until 2099 (RR 40%), and 2110 (RR 80%) respectively. This shows that even with optimistic recycling rates the contribution of recycling to extend the range of current reserves is lower than often assumed (cf. Figure 20-2).

These low recycling effects mainly result from the strong lithium demand of the fast (exponential) growing fleet of EVs. The effects of recycling would be much greater if the growth of vehicles slows down or reaches a saturation level. However, lithium recycling is challenged by limitations in recycling economics – in current recycling processes for LIBs lithium is not recovered at all (Tytgat 2013) – and by the fact that high recycling rates require high efficiencies in the whole recycling chain.

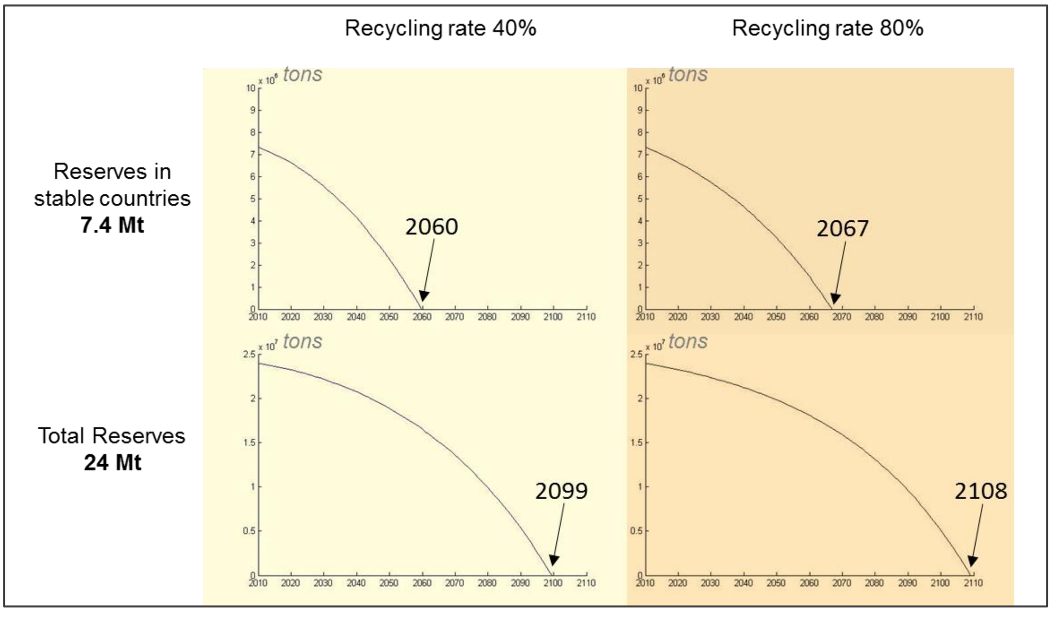

Figure 20-3: *Availability of lithium reserves with different recycling rates (based on Weil 2014).*

Conclusions

Since lithium-based secondary batteries are one of the most promising candidates for application in EVs there is great interest in lithium regarding its future availability. The developed model focuses in the chosen scenario on the reserves of lithium, because this part of the resources is economical exploitable with present technology, with an acceptable effort and to some extent bearable impacts to the environment. Furthermore the reserves are distinguished according to possible supply risks to consider differences in their accessibility.

The results of the modelling indicate that lithium availability should not be at risk in the close future, even if only reserves with comparatively low supply risks are taken into account. But, after the year 2050 the situation might change through the anticipated significant reduction of reserves in stable countries. Thus, in the medium- to long-term there is a certain risk for restricted accessibility of lithium reserves for key technologies.

This implies that lithium recycling needs to be enhanced in order to significantly increase the availability of secondary lithium. A higher contribution of recycling to future lithium supply could reduce the dependency on reserves in critical countries. Still, there are complex interactions between economic factors such as production costs of lithium deposits and geopolitical factors that have an impact on the economies of recycling as well as the development of potential supply risks. Therefore a more detailed assessment of changes in stocks and flows of lithium is required. However, the applied input-driven model relies on inflow data that are difficult to predict because of their strong dependency on economic and technical developments and is thus only suitable for certain issues. Instead the development of stocks has proven to not only be less affected by short-term changes, but also more relevant as they are becoming the most important resource providers for the future while primary resources face an increasing scarcity. In addition anthropogenic stocks are essential drivers for resource and energy consumption as well as waste and emission generation. Hence, a stock-driven model is needed to assess the evolution of flows and stocks and how they are influenced by stock development. This also allows for integrating more variable parameters in the modelling aiming at understanding their impacts and complex interdependencies to create a more comprehensive picture of supply risks for battery materials. Thus, it should be possible to evaluate further potential resource constraints for key technologies such as electric mobility and to develop strategies for reducing these limitations.

21. BUSINESS PLAN CALCULATION TOOL FOR MANUAL DISMANTLING FACILITIES

Markus Spitzbart ✉, Elisabeth Herbeck, Mathias Schluep

Abstract

Waste Electrical and Electronic Equipment (WEEE), or e-waste, is the fastest growing waste stream and can cause harm to human health and the environment when not treated properly. Especially in developing countries e-waste is often treated under critical health conditions and inadequate technologies are causing negative environmental impacts. Without proper legal framework conditions and control mechanisms specialized formal and informal recyclers are using rudimentary methods focusing mainly on reclaiming valuable recycling fractions, like ferrous and non-ferrous metals, while dumping the hazardous ones. To improve this situation effective e-waste management strategies are required.

The StEP-Business-Plan-Calculation-Tool supports entrepreneurs to set up an economic viable e-waste recycling business in an environmental sound manner. It can be further helpful for policy makers to understand the present economic framework conditions for e-waste recycling in their region. This paper gives an introduction into the design and structure of the calculation tool explaining its features. Further, possible use and benefits are illustrated.

Introduction

The generation of e-waste rapidly increased worldwide during the last decade. According to the ITU statistics the subscription to mobile phone providers raised from 87 Mio in 2005 to 582 Mio in 2013 [1]. It is expected that by 2030 a majority of obsolete computers will be generated in developing countries [2]. The current lack of e-waste management strategies and infrastructure in most developing countries bears a risk for the concerned countries and also contributes to the loss of important resources.

The Solving the e-waste problem (Step) Initiative with its members supports countries to establish the technological and institutional capacity to grasp the opportunity rather than suffer with the challenges. A well-established system to collect and treat used or obsolete electrical and electronic equipment on national level leads to an improved economic situation through the creation of green jobs and a decreasing impact on the environment and on human health. It also supports increased resource efficiency by substantially reusing material and not losing it through improper treatment by primitive recycling practices.

Dismantling of WEEE can be an opportunity for entrepreneurs to set up sustainable recycling businesses and creating green jobs. However a lot of challenges have to be faced when implementing a new dismantling facility, e.g.:

- An efficient strategy for collection of e-waste from different input streams (households, B2B-collection...) has to be identified and set up. Eventually purchase prices have to be paid for receiving the e-waste.
- Some of the collected appliances like desktop-PCs or notebooks have an intrinsic value where revenues from trading fractions coming out of the dismantling of these appliances can cover the treatment costs. This is different for quite a few other appliances like CRT-devices where dismantling expenses and disposal costs are higher than the achievable revenues.

- For each of the produced output fractions downstream partners have to be found. Some of the fractions, like copper, steel and aluminium can usually be commercialised locally. For other fractions like printed circuit boards a global market with quite volatile characteristics exists where prices offered for the same fraction can vary up to 40% within one year.
- Depending on the location of the facility transport costs for the output fractions to the different downstream partners (material recovery or disposal facilities) on national, regional and international level may significantly reduce the potential revenues.
- Depending on the local wage level and existing mechanical recycling plants in the region, it might be necessary to dismantle appliances into as many pure materials as possible or to apply a more superficial dismantling strategy focusing on depollution only and leaving material separation to mechanical recycling plants.

The presented Business-Plan-Calculation-Tool facilitates this complex planning process with a focus on manual dismantling facilities. Entrepreneurs can get a clearer picture about the achievable financial performance of a planned e-waste recycling business and support them to make the right strategic decisions based on the local market conditions.

A first version of the tool was developed by KERP[6], DRZ and EMPA[7] in 2012 within a project funded by StEP. It was further developed by DRZ and EMPA within an UNIDO-project aiming to implement an e-waste treatment facility in Kampala, Uganda [3].

Design, Structure and Features of the Calculation Tool

The Business-Plan--Calculation-Tool for manual dismantling facilities is excel based and exists in two versions:

- an open source version for the calculation on an annual basis
- a version distributed within workshops - mainly for entrepreneurs - containing features to calculate an entire 5 years' business plan

The core source of the tool is the result of a dismantling campaign conducted by the D.R.Z-Dismantling and Recycling Centre in 2013. Within this campaign the composition of output fractions after dismantling 13 relevant appliance groups (desktop PCs, notebooks, monitors, TV-sets, printers, mobile phones, etc.) has been analysed. The average times for dismantling these appliance groups have been collected for three different efficiency-scenarios (high, medium, low). This data has been collected for the following three different dismantling levels (see Figure 21-2):

- Hazardous components and high valuable components, like printed circuit boards are removed only and the remaining parts are destined to mechanical separation/ recycling.

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[6] KERP Competence Center is a global software and consulting partner for optimizing cross-enterprise business processes based in Vienna, Austria

[7] EMPA is an interdisciplinary research and services institution for material sciences and technology development

- Apart from removing hazardous components manual dismantling of components into more or less pure materials and recyclable fractions is conducted where viable with reasonable effort.
- Appliances are dismantled up to a point, at which further separation into pure materials is not possible without mechanical shredding.

The extended version of the tool, which is distributed through workshops, contains an additional feature, where further treatment steps like depollution of CRT-tubes, cable stripping, shredding of plastics and depollution of fluorescent tubes can be selected as part of the process flow.

The overall process flow mapped within the calculation tool (extended version) is pictured in Figure 21-1. Concerning collection, different input streams can be selected: Delivery of e-waste to the facility, B2B-collection and decentralised collection via collection points. For each output fraction the destination for further treatment (recycling or disposal) has to be chosen. It can be distinguished between local, regional or international market.

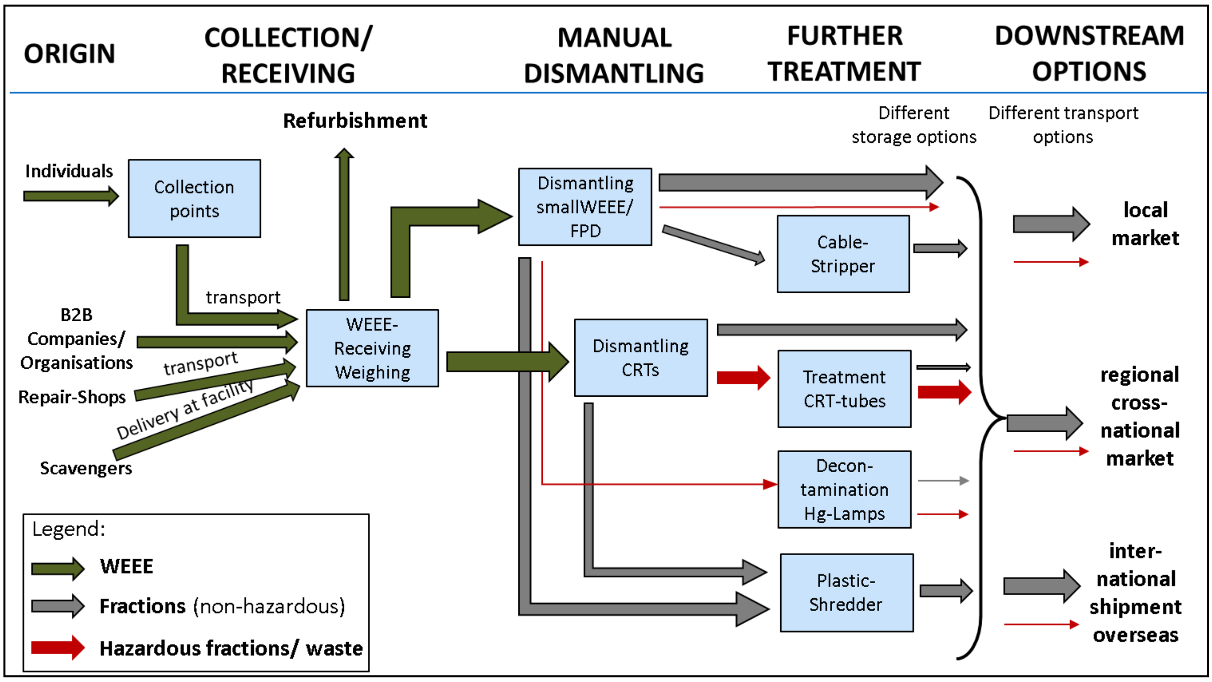


Figure 21-1: *Processes mapped within the calculation tool.*

To use the tool some essential data has to be provided. This data includes the following:

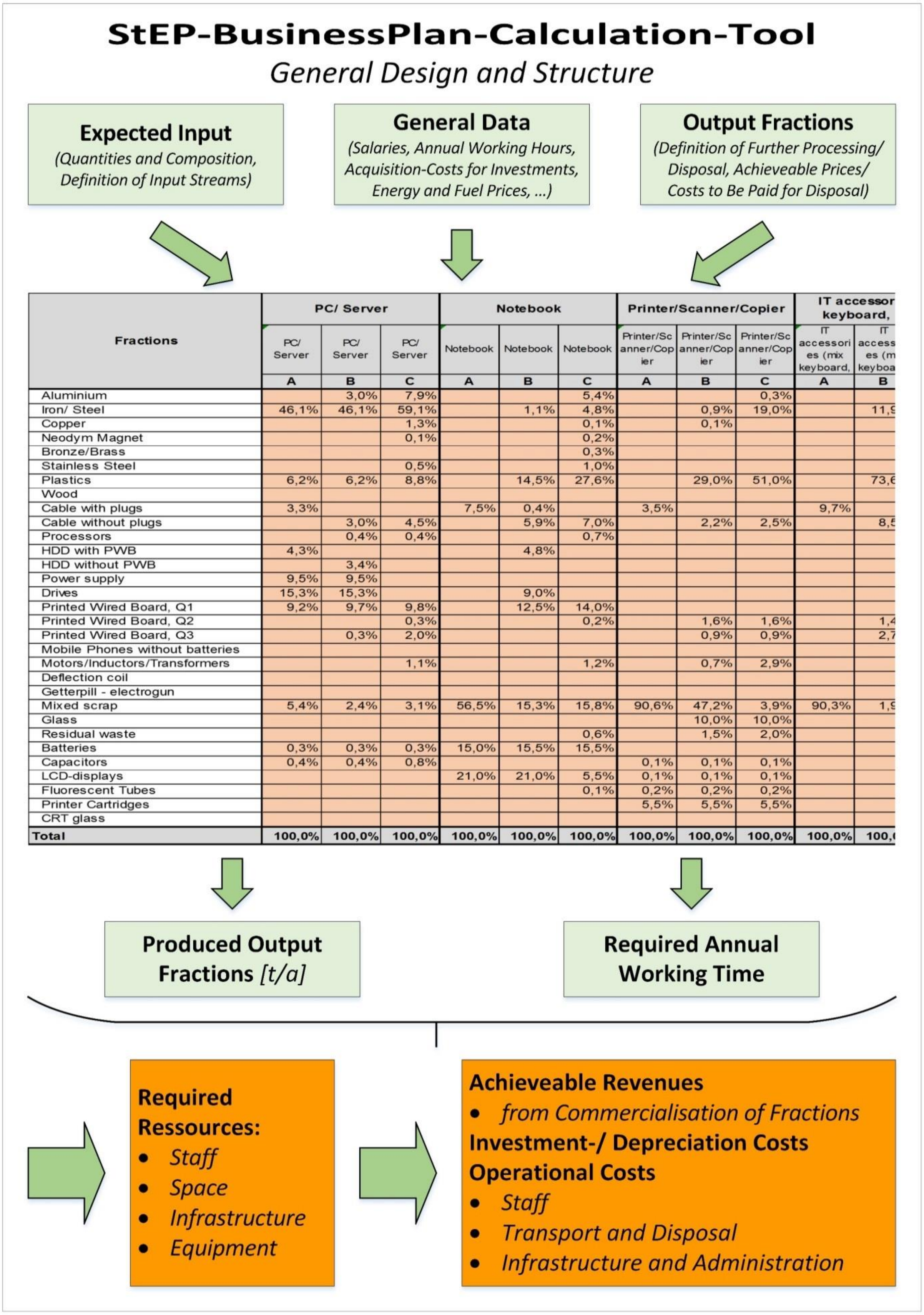
- Average salaries and annual working hours in the country
- Local price situation for energy and fuel
- Average rental and construction costs
- Purchase prices for investment of equipment and infrastructure
- Achievable revenues or disposal costs for each output fraction
- Average transport distances for each collection and downstream scenario
- Local interests for credits and savings,

- Taxes to be paid

Depending on the cost and price situation in the applicable region and the chosen scenarios concerning collection, dismantling and further recycling/ recovery, the entire business plan automatically calculates the following on an annual basis:

- Quantities of produced output fractions
- Required staff, investments and equipment
- Required space for administration, dismantling, storage, etc.
- Expected revenues and operational costs
- Entire profit and loss forecast
- Computed break-even

Figure 21-2 gives an overview about the general design and structure of the calculation tool.



Fractions	PC/ Server			Notebook			Printer/Scanner/Copier			IT accessor keyboard,	
	PC/ Server	PC/ Server	PC/ Server	Notebook	Notebook	Notebook	Printer/Scanner/Copier	Printer/Scanner/Copier	Printer/Scanner/Copier	IT accessories (mix keyboard,	IT accesses (m keyboa
	A	B	C	A	B	C	A	B	C	A	B
Aluminium		3,0%	7,9%			5,4%			0,3%		
Iron/ Steel	46,1%	46,1%	59,1%		1,1%	4,8%		0,9%	19,0%		11,9
Copper			1,3%			0,1%		0,1%			
Neodym Magnet			0,1%			0,2%					
Bronze/Brass						0,3%					
Stainless Steel			0,5%			1,0%					
Plastics	6,2%	6,2%	8,8%		14,5%	27,6%		29,0%	51,0%		73,6
Wood											
Cable with plugs	3,3%			7,5%	0,4%		3,5%			9,7%	
Cable without plugs		3,0%	4,5%		5,9%	7,0%		2,2%	2,5%		8,5
Processors		0,4%	0,4%			0,7%					
HDD with PWB	4,3%				4,8%						
HDD without PWB		3,4%									
Power supply	9,5%	9,5%									
Drives	15,3%	15,3%			9,0%						
Printed Wired Board, Q1	9,2%	9,7%	9,8%		12,5%	14,0%					
Printed Wired Board, Q2			0,3%			0,2%		1,6%	1,6%		1,4
Printed Wired Board, Q3		0,3%	2,0%					0,9%	0,9%		2,7
Mobile Phones without batteries											
Motors/Inductors/Transformers			1,1%			1,2%		0,7%	2,9%		
Deflection coil											
Getterpill - electrogun											
Mixed scrap	5,4%	2,4%	3,1%	56,5%	15,3%	15,8%	90,6%	47,2%	3,9%	90,3%	1,9
Glass								10,0%	10,0%		
Residual waste						0,6%		1,5%	2,0%		
Batteries	0,3%	0,3%	0,3%	15,0%	15,5%	15,5%					
Capacitors	0,4%	0,4%	0,8%				0,1%	0,1%	0,1%		
LCD-displays				21,0%	21,0%	5,5%	0,1%	0,1%	0,1%		
Fluorescent Tubes						0,1%	0,2%	0,2%	0,2%		
Printer Cartridges							5,5%	5,5%	5,5%		
CRT glass											
Total	**100,0%**	**100,0%**	**100,0%**	**100,0%**	**100,0%**	**100,0%**	**100,0%**	**100,0%**	**100,0%**	**100,0%**	**100,0**

Figure 21-2: *Business-Plan-Calculation-Tool: General design and structure.*

Use and Benefits

Sustainable e-waste management requires both environmental sound disposal of hazardous substances from e-waste appliances and state-of-the art recovery of materials destined to material recycling.

Using the Business-Plan-Calculation-Tool planning processes for e-waste dismantling facilities can be set up based on environmental and financial sustainability with consideration to local conditions in the different regions of the world.

The tool provides support to entrepreneurs planning to set-up an e-waste dismantling facility to get a good overview of the expected costs and revenues. For established facilities this tool is helpful to identify options for improvement in the current process to optimize their dismantling operations. In addition to the benefits for the business, the tool brings advantages to decision makers as it gives detailed background data which is useful when designing an e-waste policy framework.

22. COST-BENEFIT ANALYSIS OF WEEE RECYCLING IN GERMANY

Nicoleta Gurita ✉, Jan C. Bongaerts

Abstract

The paper analyzes the monetary value of precious and critical metals stocks in selected electronic equipment sold during 2004-2014 in Germany and at global level, as well as the value of the metals stock which is not being put to use. Initially a literature review on the definition of critical metals is being provided, followed by an analysis of the precious and critical metal stock content and monetary value for Electrical and Electronic Equipment (EEE). The stocks of precious and critical metals inside mobile phones and smartphones are assessed on the basis of sales volumes. Moreover, a cost benefit analysis of the end-of-life management of mobile phones and smartphones is being realized reaching the conclusion that the potential revenues from recycling these products can be quite significant. Furthermore, the issues and challenges in the German Waste Electrical and Electronic Equipment (WEEE) Management System are also being analyzed with a closer look at mobile phone and smartphone waste streams with the goal of identifying the potential of closing the resources loop.

Keywords: Waste Electrical and Electronic Equipment, recycling, Cost-Benefit Analysis

Introduction

Scarcity of natural resources and supply chain risks represent one of today's most vital topics. As Tiess wrote, "raw materials are the foundation of development and growth in every national economy" (Tiess, 2010).

The domestic raw minerals' production of the European Union is only about 3% of the global production, which makes the EU very much import and recycling dependent (European Commission, DG Enterprise and Industry, 2010). As such, ensuring opportunities for a secure supply of minerals is a very important task for the European Union, and in consequence, in 2008, the EU Raw Materials Initiative was set up as an integrated strategy to increase resource efficiency, reduce raw materials consumption, promote recycling and provide a framework for sustainable supply of minerals (European Commission, DG Enterprise, 2008b).

This issue very much applies to the electrical and electronic equipment (EEE) sector, as its production requires a mixture of various different kinds of raw materials, metals and precious metals, partly classified as critical by the European Commission. Since the beginning of the 1990's, the global market of EEE continuously grew at a high rate, and it is expected to continue to grow, while the lifetime of these products reduces as a result of rapid technological innovations and changes in consumers' interaction with the products they buy. According to Khurrum, M., Bhutta, S., et al., (2011), the United Nations University estimates that 20 to 50 tons of Waste from EEE (WEEE) are being generated each year globally (Khurrum, M., Bhutta, S., et al., 2011). In Europe, WEEE is the fastest growing solid waste stream and it continues to grow (Computer Aid International, 2010).

The paper analyses the monetary value of precious and critical metals in selected EEE sold from 2004 to 2014 in Germany and at global level as well as the value of the metals stock which is not being put to use. Initially, a literature review of the definition of critical metals by the US National Research Council and the European Commission is provided, followed by an analysis of the precious and critical metal stock content and monetary value for selected EEE such as mobile phones and smartphones. Overall, for the selected EEE, a total stock of 5.6 thousand tonnes of precious and critical metals can be estimated, with a total monetary value of more than € 558 million. However, the short life-cycle of these products combined with their inappropriate disposal when becoming waste leads to a major loss of these metals. Moreover, a cost benefit analysis of the end-of-life management of mobile phones and smartphones is being performed reaching the conclusion that the potential revenues from recycling these products can be quite significant. Furthermore, the issues and challenges in the German WEEE Management System are also being analyzed with a closer look at mobile phone and smartphone waste streams with the goal of identifying the potential of closing the resources loop.

Criticality

In general, metals are classified as „critical" based on their geological scarcity and supply risks. For example, in the USA, the term "critical metal" was first used in the Strategic and Critical Materials Stock Piling Act of 1939, and it defined "critical" materials as "materials that are needed to supply the military, industrial, and essential civilian needs of the United States during a national emergency that are not found or produced in the United States in enough quantities to meet such needs" (DeYoung et al., 2006). The National Research Council of the US defines critical metals as materials which perform an essential function in key applications for which substitutes are not easy to find, and which possess a high possibility of supply risks (National Research Council, 2008). Robinson describes critical metals as those on which the economy and security of a nation depend on (Robinson, 1986).

According to the European Union, metals can be classified as critical "when the risks of supply shortage and their impacts on the economy are higher compared with most of the other raw materials". The supply risk depends on the economic and political stability of the manufacturing countries, the production level, the possibility or substitution as well as recycling rates (European Commission, 2010). Table 22-1 contains the twenty critical materials identified by the European Commission.

Antimony	Cobalt
Gallium	Magnesium
PGMs	Silicon Metal
Beryllium	Coking Coal
Germanium	Natural Graphite
Phosphate Rock	Tungsten
REEs (heavy)	Niobium
REEs (light)	Fluorspar
Chromium	Magnesite
Borates	Indium

Table 22-1: *List of critical raw materials at EU level. Source: European Commission, 2014.*

According to the literature the term strategic is used for national security and military needs or requirements during national emergencies, while a critical material has a larger meaning. "*In accordance with these definitions, a critical material may or may not be strategic, while a strategic mineral will always be critical*" (National Research Council, 2008).

Whereas the definition of critical metals in the European Union is very new, the term “precious metal” has been in use for a longer time period and it is not based upon a precise definition. It seems that this term is used in a generic way to distinguish a particular metal with a so-called high value (as expressed by a particular market price) from another metal which does not have this high-value characteristic. For example, gold is seen as a precious metal and lead is not a precious metal. With the entrance of the definition of critical metals by the European Commission, confusion occurred since PGM are considered to be both critical and precious. Silver and gold, however, are considered to be precious but they are not critical. Since they are contained in the electronic products studies in this paper, a pragmatic approach towards the definition of precious metals had to be chosen. Hence, in this paper, precious metals include silver and gold whereas PGM are included in the category of critical metals. The wordings “critical and precious metals”, therefore, include all critical metals of the European Commission definition and silver and gold.

Methodology

Qualitative and quantitative data were employed to conduct the study. The qualitative data was fundamental to understand the subject matters; raw materials, electrical and electronic waste management and materials recycling. As a result, a comprehensive understanding of mobile phones and smartphones recycling can be obtained.

For the quantitative section, data such as the numerical values for the sales of mobile phones and smartphones in Germany, collection rates, reuse rates, recycling rates[8], and content of precious and critical metals in mobile phones and smartphones, as well as costs involved at each step of the recycling chain were obtained through an extensive literature research.

Subsequently, formulas have been developed to conduct the study based on the data found. The research method was descriptive quantitative.

To forecast the potential total value of precious and critical metals content in mobile phones and smartphones in Germany and to perform a cost-benefit analysis, several fundamental aspects are needed in order to establish the end results, including:

- Sales of mobile phones and smartphones. Sales values for 2004-2014 have been retrieved to estimate available stocks of mobile phones and smartphones (Bundesverband Technik des Einzelhandels e.V. (BVT), 2015).
- Reserves of mobile phones and smartphones have been calculated by assuming a 2 years life time of mobile phones and smartphones. The 'reserves' also include 'stocks', which are the non-collected mobile phones from previous years. The 'reserves' are available for recycling in a particular year.
- Identification of collection rates of mobile phones and smartphones (Öko-Institut e.V., 2012). The amount of collected mobile phones and smartphones is calculated by multiplying the collection rate with the amount of reserves.
- Identification of content of precious and critical metals in mobile phones and smartphones (Geyer & Blass, 2009; World-UN, 2009).

[8] Informal collection and treatment rates have not been considered in this study.

- Calculation of stocks of precious and critical metals in mobile phones and smartphones sold in Germany. To obtain the total stock of precious and critical metals contained in mobile phones and smartphones, the content of precious and critical metals (e.g. gold) contained in a mobile phone or a smartphone was multiplied with the amounts of mobile phones and smartphones sold. Similar calculations have been performed to identify the stocks of precious and critical metals contained in amounts of mobile phones and smartphones collected and amounts recycled.
- Calculation of potential monetary value of the precious and critical metals content in mobile phones and smartphones as well as monetary value not put to any use due to inefficiencies in the recycling process.
- Identification of recycling rates of precious and critical metals based on UNEP estimations (UNEP, 2013).
- Calculation of the potential monetary value of recycled materials (the prices for the precious and critical metals have been retrieved from: Die Recyclinghütte, 2014; Institut für Seltene Erden und Metalle, 2014; Infomine, 2014; Finanzen.net, 2014).
- Cost benefit analysis for mobile phones and smartphones recycling in Germany

Critical and precious metals stocks in mobile phones and smartphones sold in Germany

Based on the raw material composition of mobile phones (Geyer & Blass, 2009; World-UN, 2009) and smartphones (Öko-Institut, 2012), and according to the list of critical metals issued by the European Union (2014), the following twelve precious and critical metals have been selected for further analysis in this paper: *Gold, Silver, Palladium, Cobalt, Gallium, Indium, Chromium, Magnesium, Antimony, Beryllium, Praseodymium and Neodymium*. Copper is also taken into account due to its high content in the composition of both mobile phones and smartphones.

From 2004 to 2014, more than 159 million mobile phones have been sold in Germany (Bundesverband Technik des Einzelhandels e.V. (BVT), 2015), accounting in total for more than 5 thousand tonnes of precious and critical metals contained in them. Taking the average amounts of the selected critical and precious metals contained in a typical mobile phone and multiplying with the volume of sales, the following total stocks of these metals can be calculated (Table 22-1 – see at the end).

Highest metal potential content is represented by copper (2.394 t), followed by magnesium (1.860 t) and cobalt (607 t). Making use of average base metal prices, the monetary value of the metals in a typical mobile phone is estimated to be around € 2.7. Hence, the total monetary value of these metals in the entire stock of mobile phones sold in the same time period can be estimated at € 439 million. Since only around 5% of all mobile phones are recycled (Öko-Institut e.V., 2012), equivalent to 7,987,550 mobile phones, an estimated monetary value of approx. € 303 million is not put to use. It can be considered as a “hidden treasure”.

A similar analysis can be performed for smartphones which entered the market at a later date. From 2009 to 2014 around more than 90 million smartphones were sold. The critical and precious metals contained in this stock comprises more than 600 tonnes, with the highest amount represented by cobalt (approx. 567 tonnes), followed by silver (approx. 27 tonnes) and gold (approx. 2.7 tonnes). Similar to the case of mobile phones, the monetary value of critical and precious metals in a typical smartphone is estimated at € 1.32 and the total monetary value of these metals in all smartphones sold during the same time period can be set at around € 119 million. This value is three times less than that for mobile phones and it is due to the differences in the time periods and, eventually, also to advances in design resulting from technological developments. Assuming the same 5% collection and recycling rate (representing about 4,503,900 smartphones), an estimated monetary value of € 104 million is not put to any use. Since it is expected that the market for smartphones will continue to grow, and, if present low collection rates are kept, it can be assumed that the value of the total materials stock not put to use will continue to grow in the future.

At global level similar results can be calculated and they are shown in Table 22-.2. More than 7.5 thousand tonnes of silver, 1.3 thousand tonnes of palladium and 438 tonnes of gold are contained in more than 14 billion mobile phones (14,871,825,200) sold from 2004 to 2014. The estimated monetary value of these metals is calculated at almost € 41 billion (40,842,009,392).

Mobile phones				
Worldwide sold units between 2004-2014				14.871.825.200
Monetary value of sales between 2004-2014 (€)				40.842.009.392
Collection rate				5%
Unused material value				38.799.908.922
Metal		Metal price (€/g)	Mobile phone precious and critical metals composition (g)	Metals potential of mobile phones (t)
Gold	Au	29,5100	0,0295	438,72
Silver	Ag	0,4033	0,5050	7.510,27
Palladium	Pd	16,5000	0,0900	1.338,46
Cobalt	Co	0,0195	3,8000	56.512,94
Gallium	Ga	0,1995	0,0009	13,38
Indium	In	0,3251	0,0062	92,21
Copper	Cu	0,0051	14,9900	222.928,66
Chromium	Cr	0,0017	0,4600	6.841,04
Magnesium	Mg	0,0017	11,6450	173.182,40
Antimony	Sb	0,0081	0,0030	44,62
Beryllium	Be	6,5290	0,0020	29,74
Total				468.932,44

Table 22-2: *Monetary value of metals in global sales of mobile phones (2004-2014).*

Overall, for the selected products, a total stock of 5.6 thousand tonnes of critical and precious metals can be estimated, with a total monetary value of more than € 558 million. Given the considered collection rate, as shown above, it can be estimated that most of this monetary value is not put to any use (€ 408 million). The monetary value of the precious metals gold, silver and palladium account for 93 % to 89% of the total monetary value of the selected products.

In addition to this apparent neglect of a “hidden treasure”, it should also be noted that the concentration rates of gold and silver in the analyzed products are much higher than in deposits which are currently mined. Taking the example of gold, it is reported that the average concentration of gold in deposits which can mined is around 5 grams per tonne of ore (Gunn, 2014). In mobile phones and in smartphones, the gold concentrations are substantially higher (Table 22-3):

Electronic equipment	Gold content (g/unit)	Gold content (g/t)
Mobile phones	0,0295	261,06
Smartphones	0,03	177,51

Table 22-3: *Gold content of selected electronic equipment (g/unit).*

Assuming an average weight of a mobile phone of 113 g (Nokia, 2005), resulting in 8.849,55 units per tonne of mobile phones, a total amount of 261.06 g gold/tonne of mobile phones can be calculated. This is 52 times more than in a tonne of primary ore. Based on a similar computation, and assuming 169g (SpecTRAX, 2012) as the average weight of a smartphone (resulting in a number of 5.917,159 units), the current stock of smartphones contains about 177.51 g gold per tonne. If this gold is not being used, a substantial source of supply is neglected.

Recycling critical and precious metals

According to Chancerel (2010) 5% of amounts collected in Germany are reused. By discounting the amounts of mobile phones and smartphones being reused, the potential precious and critical metals available for final treatment can be calculated. Overall, for the selected products, a total stock of 2.1 thousand tonnes of critical and precious metals can be estimated, with a total monetary value of more than € 142 million. This would mean that only 37% of the precious and critical metals content makes it to final treatment.

Next, UNEP recycling rates have been considered in order to calculate the amounts of precious and critical metals which could potentially be recycled. Based on the calculations, only 931 tonnes of precious and critical metals, 44% of total amount of precious and critical metals contained in mobile phones and smartphones can potentially be recycled in final treatment, with an estimated monetary value of € 70 million, representing 12% of the total monetary value of precious and critical metals contained in the mobile phones and smartphones sold during 2004 - 2014 in Germany (Figure 22-1).

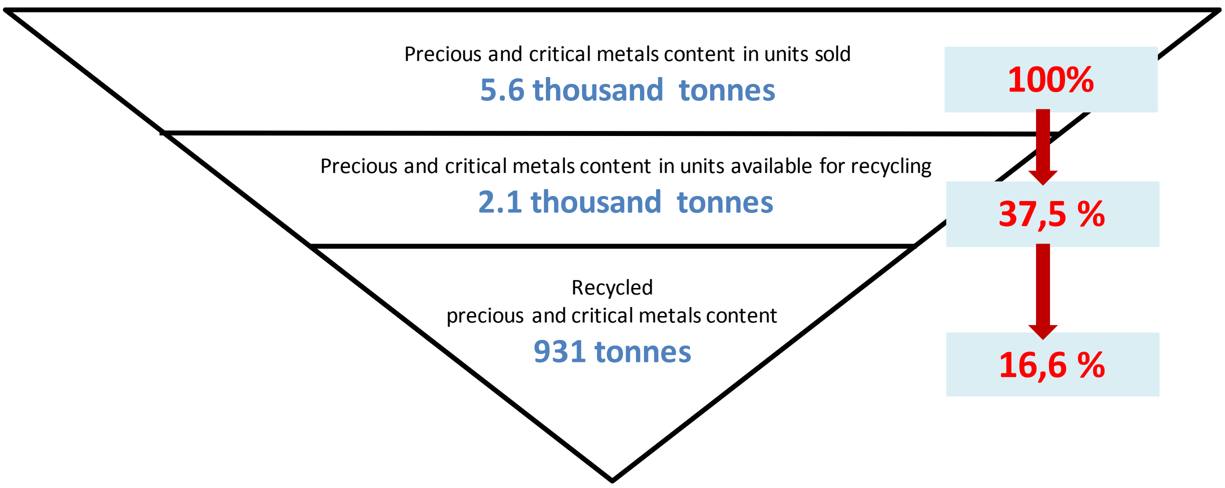


Figure 22-1: *Precious and critical metals stocks along the recycling chain.*

The major reason for the large "hidden treasury" monetary values which are not put to use clearly relates to the currently level of collection and recycling, in particular the very low collection rates at the end-of-life stage of mobile phones and smartphones. It seems that consumers do not have any substantial incentives to return these products at the end-of-life stage. Consumers are, however, vital for the creation of circular material supply chains since they are physically holders of these products. The creation of materials cycles also requires a receiving and processing industry, which currently is developed at a very small level.

Cost benefit analysis

A cost-benefit analysis allows for an evaluation of the actual situation of WEEE recycling in terms of costs and revenues. The economics of WEEE end-of-life treatment are shaped by several activities including collection, transportation, pre-processing and final treatment. First, data has been collected through literature research regarding the costs of each step in the end-of-life management of mobile phones and smartphones (Table 22-1 – see at the end).

Next, the costs of each activity of the end-of-life treatment for each year from 2006 to 2013 were collected and cumulatively added (Table 22-2 – see at the end). For the analyzed time frame a total cost of almost € 3.1 million can be estimated for all activities in the end-of-life management of the considered products. Compared with the potential revenues from secondary materials recovered after final treatment which account around € 70 million, it can be concluded that mobile phones and smartphones recycling represent an important source of precious and critical metals.

From Table 22-2 it can be observed that 46% of the costs (€ 1.4 million) arise from a financial guarantee which all producers and importers in Germany must provide for the end-of-life treatment of their products. The formula for calculating the financial guarantee has been developed by the Clearing House (EAR)9, as follows:

Financial Guarantee (in EUR) = Registration amount (in tons) x Expected return rate (as a percentage, as specified by EAR) x Estimated disposal costs (in EUR / tonne, as specified by EAR)

For the present study, for “Registration amount (in tons)”, the amounts sold per year have been considered. The “Expected return rate” assumed by EAR for mobile phones is 32% (the same has been assumed by the author for smartphones). If the collection rate of 5% considered in the present study would have been used, the total costs for guarantee would have been much smaller. It can be concluded that probably the expected return rate calculated by EAR is much higher than actual present reality, leading to increased costs for the producers for the end-of-life management of their products.

Final treatment accounts for more than 30% of the costs (€ 954.5 thousand). Considerable costs occur during pre-processing (€ 632.5 thousand), while lowest costs arise at the collection level (€ 527) (Figure 22-2).

[9] Clearing House (Stiftung Elektro-Altgeraete Register [EAR]) which is the designated authority carrying all functions and duties to ensure the proper implementation of the ElektroG (https://www.stiftung-ear.de/)

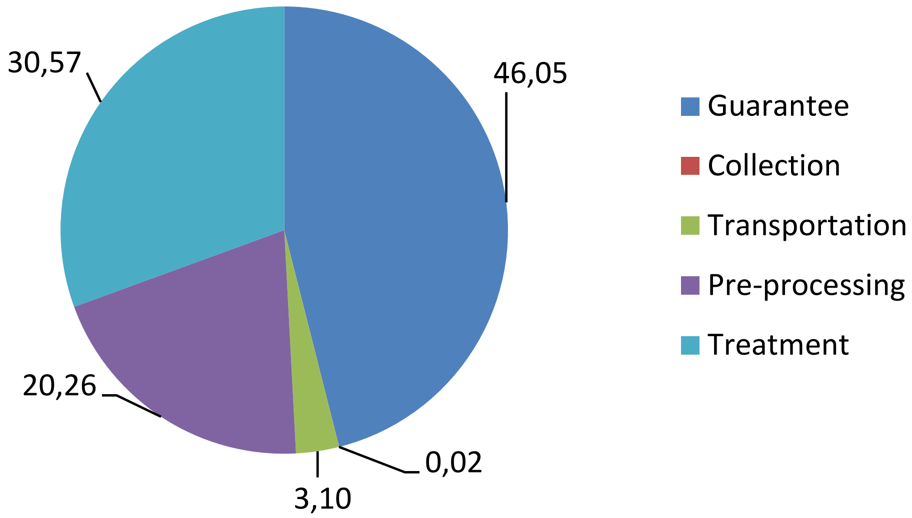


Figure 22-2: *Share of recycling costs per activity (%).*

Existing state-of-the-art metallurgical plants have the appropriate technology to achieve high recovery rates for valuable materials, as long as these materials reach the right material fraction. According to (Hagelüken & Corti, 2010), due to inefficiencies in collection, dismantling and pre-processing "less than 20% of the gold recycling potential from European WEEE is realized". According to the present study, just 0.02% of the precious and critical metals contained in mobile phones and smartphones can be recycled. As such, better and separate collection rates and specific focus that the precious and critical metals reach the right material fraction for an optimal recovering process can have a positive impact on recycling of WEEE.

Also, looking at the European WEEE II Directive10, it still contains mass-based instead of value-based recovery rates. Hence, WEEE recyclers have an incentive to achieve such mass-based recovery rates and they tend to collect materials which dominate in terms of weight. In this process, they neglect valuable materials which are lost along the recycling chain11 by ending up in materials fractions from which they cannot be recovered. A value-based recovery objective would, instead, set incentives to increase the collection of small WEEE and extract valuable materials in low concentrations, such as found in mobile phones and smartphones. Hence, the current mass-based recovery rates of the European WEEE II Directive have a prohibitive effect on the recovery and recycling of mobile phones and smartphones.

Conclusion

The outcomes of the study can be summarized as follows: (a) the precious and critical metals stocks in selected electronic equipment have been identified; (b) the monetary value of the

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[10] Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on Waste Electrical and Electronic Equipment (WEEE)

[11] A recycling chain is defined as "the sequence of operation leading to the recovery of materials from waste. These operations include (1) collection which is the beginning of any waste management process, (2) preparation for material recovery which covers manual and/or mechanical operations & sorting and (3) material recovery which consists in chemical, physical or metallurgical operations, but does not include incineration for energy recovery and the reprocessing into materials that are to be used as fuels" (European Association of Metals, 2013)

precious and critical metals in the selected products has been calculated; (c) the value of metals not put to any use due to the low collection rates and inefficient pre-processing has been estimated; (4) a cost benefit analysis of mobile phones and smartphones recycling has been realized; (5) major issues and challenges in the management of WEEE have been identified. Based on the case study of Germany on a limited number of types of electronic equipment it can be assumed that the urban mine potential of the planet is huge.

23. EXPERIENCES OF SMALL ELECTRONICS COMPANIES TO UNDERPIN CIRCULAR ECONOMY APPROACHES BY MEANS OF SIMPLIFIED LIFE CYCLE INDICATORS

Karsten Schischke ✉, Nils F. Nissen, Klaus-Dieter Lang

Abstract

The term “Circular Economy” gains ground currently not only among large companies but also among small and medium-sized enterprises (SMEs). Suitable metrics are required to address circular economy effects in the product design process or for communication purposes towards consumers and clients. Simplified Life Cycle Assessment (LCA) calculations can help to quantify environmental effects throughout a product’s life cycle, to educate consumers and clients and to communicate business strategies. More than 120 SMEs from a range of industrial sectors received mentoring on simplified LCAs. Experiences from this interaction with SMEs are an invaluable source of insights into the current status of implementing circular economy approaches among small European companies. The paper analyzes the LCA requirements among companies from the electronics sector, including the various perspectives of product manufacturers, suppliers, and information technology refurbishing companies, given the limitations among these companies regarding environmental know-how, influence on supply chains, and resources to engage in LCAs. The experiences of the SMEs are illustrated on the example of three case studies. Drivers and barriers for using Key Environmental Performance Indicators are analyzed.

Keywords: carbon footprint, refurbishment, lifetime, eco-design, electronics products.

Introduction

Business models rely on indicators. Under a circular economy such indicators have to reflect environmental impacts throughout the life cycle of a product or related service. Scientifically, Life Cycle Assessments (LCA) are considered state-of-the-art to deliver robust figures, but for small and medium-sized enterprises such a tool typically is too complex, time consuming and costly to be applied in daily business routines. The project “LCA to go - Boosting Life Cycle Assessment Use in European SMEs” was kicked off in 2011 with the vision to develop a methodology embedded in a free webtool, which lowers the entry barrier to life cycle thinking significantly (Schischke 2012). Customized tools and methods have been developed not only for electronics, but also for the sectors bio-based plastics (Dobon 2013), machine tools (Krautzer 2015), printed circuit boards (Sitek 2014), photovoltaics (Arranz 2013), smart textiles (Köhler 2013), and sensor systems in energy intensive industries (Saint-Mard 2013).

Assessment needs and approaches: Electronics sector

SME survey in 2011

A needs survey was performed in 2011 among companies on the European market (Pamminger 2011). The purpose of the needs assessment was to verify the status-quo regarding the application of environmental assessments and to understand their wishes for an assessment tool (Figure 23-1). Key findings are: Many SMEs are already communicating environmental information, usually related to material data, sometimes also energy data. Requests for LCA data, recyclability assessments, and total cost-of-ownership are rare, but they do occur. In general SMEs have limited knowledge about LCA. In future SMEs would use an environmental assessment tool if there is demand by customers or pressure from legislation, but companies also mentioned an interest in lifetime, reuse and service aspects.

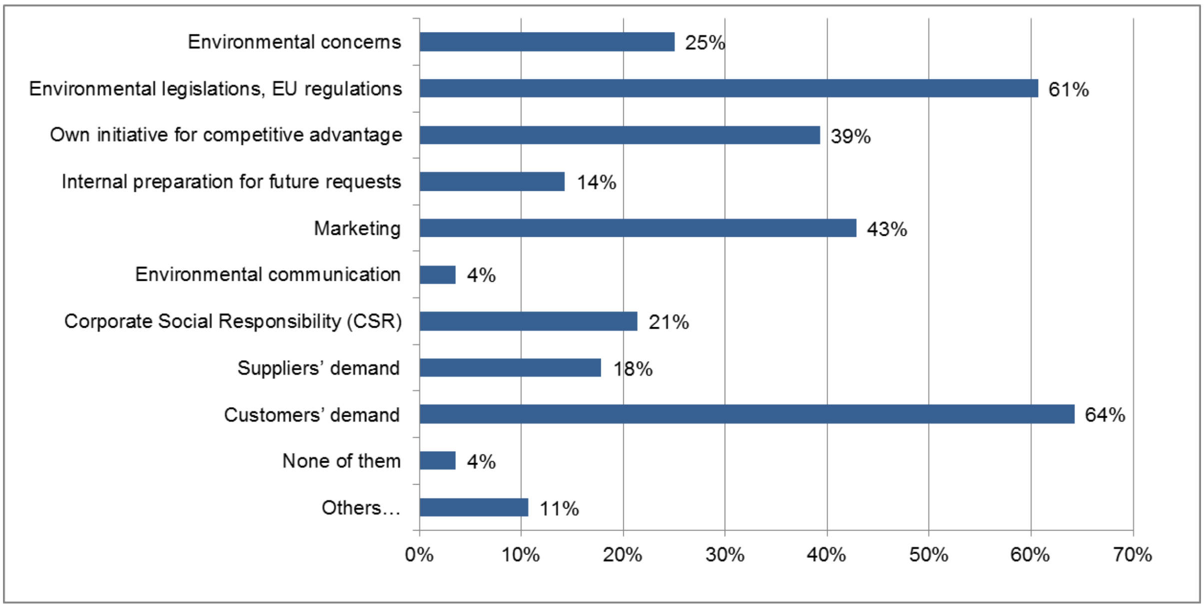

Figure 23-1: *Replies to the question "What are/will be your main drivers to undertake an environmental assessment?" (28 SMEs from the electronics sector answered this question).*

Assessment methodology and intended use cases

The LCA to go tool for electronics equipment provides a rough environmental assessment of the total product life cycle and in comparison to a pre-defined "standard" product. A rough environmental assessment of the major subassemblies helps to identify those sub-assemblies with the highest environmental impact at production. The user makes individual settings regarding computer configuration and likely use patterns. Recycling is reflected in the tool with a scenario, applying typical recycling quotas and related carbon credits. Based on these parameter settings the tool calculates Product Carbon Footprint, final energy consumption and resource efficiency (quantified as hypothetical savings of selected metals).

Manufacturing SMEs can decide, for which sub-assemblies' longevity, reparability and reusability are most important in terms of resource savings and carbon footprint reduction. The reuse and remanufacturing business is another target group with a clear interest to assess their business operations with environmental indicators. Repair is a similar market segment. Communicating environmental benefits of product refurbishment along with better separation for recycling is important for a larger share of these companies. Such businesses can particularly benefit from the predefined data models, which help to overcome the problem of not getting LCA data from the OEMs directly.

To illustrate a comparison with the LCA to go tool Figure 23-2 depicts the Carbon Footprint of three benchmark products for a typical life cycle (life time consumer products: 4 years, business laptop: 2,42 years). This comparison neglects the fact, that the functionality of the three products is different. According to this exemplary calculation the total carbon footprint of a typical netbook is 119 kg CO_2-eq, of a typical consumer laptop 155 kg CO_2-eq. and of a business laptop 144 kg CO_2-eq. (Schischke 2014).

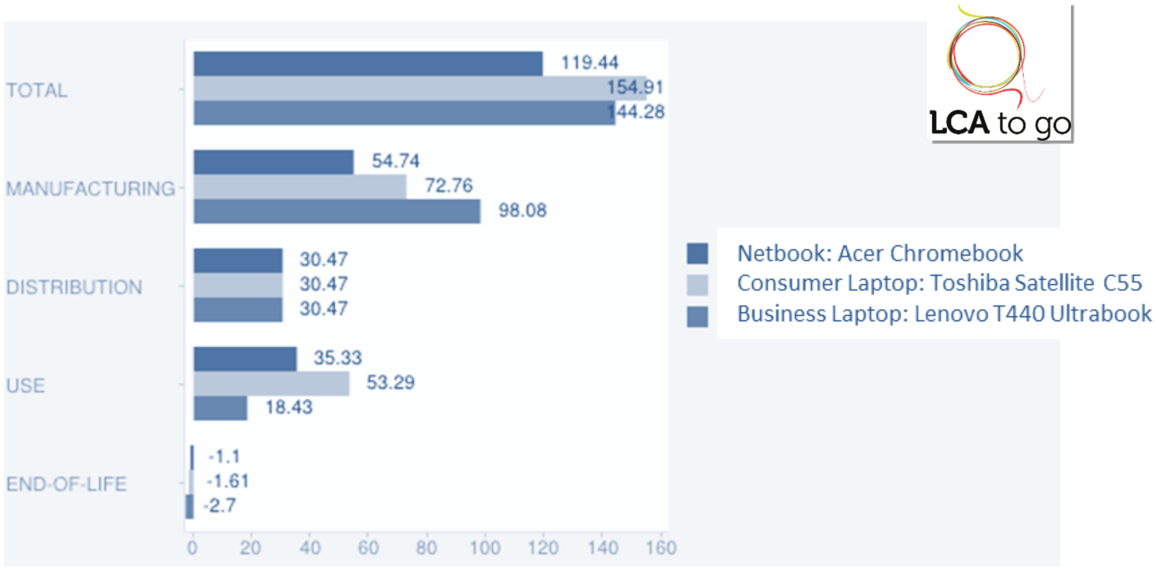

Figure 23-2: *Screenshot LCA to go – Carbon Footprint of 3 exemplary laptops (in kg CO_2-eq. / life cycle).*

A refurbishing company now can calculate for each of these models the positive environmental effects of a circular business model with collection of used devices, remanufacturing, refurbishment and parts replacement, resulting in a longer lifetime.

Findings of the Mentoring Programme

18 companies of the electronics sector joined the mentoring, ranging from companies in the lighting sector to IT companies, including engineering companies, small OEMs, and asset refurbishing enterprises, some working on business to business products, others on consumer products. Start-ups were among the mentored companies and well established mid-size enterprises. This broad spread of company profiles is also mirrored by the range of drivers, why the companies showed an interest in simplified LCAs and the related mentoring. Table 23-1 lists explicitly mentioned reasons, clustered by target uses of assessment results: Communication purposes regarding an already existing business model are dominating. For some, green arguments are obviously selling well. Cost issues are much less important.

Case studies

The following case studies are meant to illustrate the specifics of some of the mentored SMEs to facilitate a better understanding of their needs, markets and background.

Motivation for being interested in life cycle assessments (as reported by the mentors)	**Clustering of replies** external communication	costs	ecodesign	environmentalism	compliance
communicate environmental savings (customers are increasingly interested in environmental facts and figures from vaguely inquiring for any quantification on environmental benefits or the contribution to a circular economy to the Life Cycle Assessment evidence)	x				
support the stated mission to minimize the environmental impact of IT equipment	x				
improved communication with customers and administration	x				
set a ecodesign strategy for the manufacturer	x				
communicate the effect of resource savings GHG reduction through lifetime extension	x				
updated, verifiable and preferably auditable data are of great interest to put reliable figures to inquiries from clients	x				
improve marketing by providing the environmental information of their products to the customers	x				
familiarize clients with the LCA background	x				
more and more companies ask for LCA evidence	x				
include the eco-innovation concept in the design and production of their customers' products and the way to manage their business	x		x		
anticipate a kind of educational role	x			x	
optimize the economic and environmental results according to ecodesign standard ISO 14006		x			x
integrate environmental assessment into R&D			x		
find a tool to make a basic LCA in order to manage the design of IT system and being able to modify it in order to develop more sustainably designed products			x		
company is passionate about saving resources				x	
do something good for the environment				x	
new ways of looking at existing products by taking into account social and environmental values (lets 's make product that are fair for the people and the environment)				x	
develop more sustainable IT products				x	
promote the reflection and facilitate the decision making process of organizations and companies concerning environmental issues.				x	
develop an environmental management system certified by 14001					x
make a standardized way of quantifying carbon footprint credits part of the CENELEC standard on reuse.					x

Table 23-1: *Clustered motivating factors for electronics SMEs to engage in life cycle assessments.*

Packaging: Paxpring B.V.

Paxpring B.V. designs and delivers complete packaging solutions, frequently for customers from the information and communication technology sector. Besides costs and design, it is increasingly the environmental performance of a packaging solution, which matters for Paxpring's clients and more and more companies ask for LCA evidence, but have got only a limited understanding what Life Cycle Assessments actually are. Therefore, Paxpring also anticipates a kind of educational role to familiarise clients with the LCA background of packaging design. The mentoring included an extensive discussion about the background of a customized carbon footprint calculator: Including the end-of-life of packaging might change the whole carbon footprint as landfilling and decomposing of paper products might release methane, a greenhouse gas much worse than CO_2. Another finding, for paper products the carbon footprint of recycled paper is only slightly lower than that of primary material.

Assessing packaging options compared to the current design of a small plastic sleeve gave a clear indication that the option of a corrugated board alternative yields a similar carbon footprint, a mixed corrugated board / plastic foil option comes with a significantly higher carbon footprint and a folded cardboard package with a significantly lower one. Paxpring presented the design concepts and carbon footprint results to a client, and confirmed afterwards the usefulness of such indicators for a concept presentation and decision making.

Smartphone development: Circular Devices Oy

Since January 2013 a Finland-based team, which in the meantime acts as start-up Circular Devices Oy has been developing ideas and concepts to promote the approach of modular smartphones. "Reliable, repairable, upgradable" are the ultimate claims to be fulfilled by the so-called Puzzlephone (Santacreu 2015, Schischke 2015). The smartphone concept features a standard electronic interface as the linking component of three modules. Creating the Puzzlephone platform as an open standard will enable different manufacturers to contribute modules. This will increase customizability along with reparability and through an increased lifetime the smartphone will have a decreased environmental impact. A broken module easily can be replaced.

As the Puzzlephone platform is still in its early stages of development, ecodesign can be implemented with maximum beneficial impact. A generic smartphone eco-profile was chosen as a starting point to get the big picture right. Through a number of bilateral sessions and a comprehensive discussion paper some major design issues of the Puzzlephone concept where tackled, which will also guide the future process of actually translating the Puzzlephone idea into a real-world product. Keeping in mind robustness while at the same time optimizing recyclability and extending battery lifetime through improved thermal management yet without the extensive usage of metals for heat dissipation is a challenge the Puzzlephone platform will have to face on its way to the lowest possible environmental impact. Trade-offs between battery size and size of electronics is another issue. These are just some aspects, which have been addressed based on insights in environmental issues.

IT refurbishment: Metech Recycling (UK) Ltd

Metech Recycling (UK) Ltd. is one of the largest electronics recycling, refurbishment and resale enterprises in Wales. Disassembly of electronics devices at Metech is done manually and largely also non-destructive as component reuse is an important economic pillar.

For the mentoring the case of refurbishing a Fujitsu Esprimo P2540 was chosen. Most of the specification can be derived from Fujitsu's product documentation, including the annual power consumption of 137.8 kWh. The baseline scenario assumes a first life of 5 years. The total carbon footprint of this Fujitsu PC is roughly 430 kg CO_2-eq., thereof 110 kg CO_2-eq. from the initial material acquisition and manufacturing phase (see for comparison Fujitsu's own full-scale LCA assessment of another desktop PC: Böttner 2011). Recycling credits for material recovery is slightly more than 12% of the initial manufacturing carbon footprint, considering a default collection rate of 50% and moderate material recovery rates. At a company like Metech with a sound manual dismantling operation instead of shredder technology a much better separation of individual fractions for recycling can be achieved. The intended scenario however is refurbishing the computer, not material recycling at this point in time. For the refurbishment scenario a total lifetime of 8 years is anticipated, and as a worst case, that DRAM and hard disk drive have to be replaced. The assessment result unveiled, that Metech's transports logistics are less relevant for the total carbon footprint as long as larger batches are transported regionally. Under these assumptions computer reuse saves 8% of the carbon emissions on per-year-of-use-basis. When looking only at the manufacturing impacts and spare parts production (DRAM and HDD), the benefit of refurbishing is much more evident.

A numerical demonstration of the benefits of Metech's operations is considered useful by the company to feedback to customers, to inform internal decisions made concerning processes in order to maximise the environmental and resource conservation benefits of operations, and for use in efforts to educate the public about the global WEEE problem and demonstrate recycling and reuse as a solution (Charles 2014).

Conclusions

SMEs which potentially can benefit from a quantification of product life cycle impacts are those with a relevant impact on the supply chain, use phase and/or end-of-life and match one or several of the following categories: (1) specifying or even designing an end-product, and/or (2) making choices regarding material and component selection, and/or (3) having influence on process performance / efficiency with an impact on energy or material consumption elsewhere in the life cycle, and/or (4) being involved in activities (and decisions) influencing lifetime and reuse of products, and/or (5) being under market (legislative) pressure to provide relevant partial life cycle data to customers or where the perceived "green" features of a product / material require a solid knowledge in this domain. It is important to notice, that only a very limited number of European SMEs actually fall under one of the above categories. Many more SMEs are a minor player in large supply chains with very limited direct influence on the product life cycle and hence lack incentives to implement a circular economy approach, although they might be part of a larger cycle.

Acknowledgements

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Part III

Circular Economy and Decoupling

24. DEVELOPING A LOW-RESOURCE SOCIETY – FRAMEWORKS AND SCENARIOS TOWARDS A DECOUPLED FUTURE[12]

Holger Berg ✉, Christa Liedtke, Maria Schnurr, Holger Glockner, Michael Schipperges, Ullrich Lorenz, Katrin Bienge

Abstract

Resource-focused research on sustainability has revealed insights into the techno-economic aspects of living and working. Approaches that develop concrete pictures of societies in the future that are ready, able and willing to live and strive in a low-resource way are as a rule much scarcer or very abstract. However, without such approaches low-resource practices are not likely to be established on a broader scheme. On the other hand, a society that has made low resource-living a central institution will not only cater for less resource use, it will also make it a positive, socially accepted and beneficial experience for its members. Creating solutions for this challenge is thus mandatory for successful long-term policies towards new, low-resource systems. The question however remains what such a future society may look like.

Our contribution will address this issue by outlining a concept for a low-resource society and by introducing five explorative scenarios that delineate such a society. Firstly, the term low-resource society is presented in more detail. From this onset, five scenarios have been developed in workshops with experts and pioneers of low-resource living. These scenarios are distinct with respect to underlying assumptions on basic values and drivers, leading to very diverse narratives. They will be presented in brief and discussed in order to illustrate potential pathways and derive needs for further research.

Keywords: low resource society, scenarios, dematerialization

Introduction

Resource scarcity, resource depletion, harmful effects on ecosystems and the services they provide, detrimental effects on health, all these observations and more have led to calls for a reduction of resource use and extraction (e.g. UNEP 2015). However, with a view to contemporary resource use, such a reduction demands consequent changes of processes, customs and habits. Resource use and allocation is not just a technical issue but deeply rooted in culture, social practices, institutions and routines. Low resource use can therefore only be realized in a low-resource society, i.e. in a society that in its processes, institutions, organizations etc. supports, fosters and enables low resource use. It is obvious, that such a society will likely be much less dedicated to consumerism, existing material status symbols etc. and needs to develop new ways to satisfy individual, social and material needs.

But what may such a society look like? How will people actually behave, produce, live and work together? While some ideas exist, the questions surmount. Hence, calls for developing scenarios and providing visions of a low resource society have gone out (e.g. KRU 2014). In this contribution we want to shed a first light on this issue. In a scenario development process five distinct scenarios for such a society have been developed. This paper will illustrate basic

[12] The content of this contribution was produced in the project „Success factors for system leaps and normative scenarios for a low-resource society" (FKZ 371317103), supported by the Federal Ministry for Environment, Nature Conservation, Building and Nuclear Safety and the Umweltbundesamt. www.ressourcenleichte-gesellschaft.de

assumptions underlying these scenarios, the scenario process itself, and will sketch out what kind of approaches towards a low resource society emerged. It proceeds as follows: Chapter 2 will outline our approach towards a low resource society. It will also refer to some of the sources that contribute to such a conceptualization. Chapter 3 will outline the scenario process and explain how different scenarios may be arrived at. Chapter 4 then briefly introduces five scenarios that were developed with experts and pioneers of low resource living. In our description we will specifically relate to the dimensions that are being reflected in the scenarios and thereby line out the space of potential and the even contradictory paths that exist, from there we briefly discuss our findings and hint to needs for future work and research.

Towards a low resource society

To understand our approach it is necessary to refer to the connotation of a low-resource society in German ("ressourcenleichte Gesellschaft"). The term "leicht" has two separate meanings. It can be translated as "low" or "few" and hence refer to a society that has a relatively low level of resource demand and consumption. However, "leicht" also denotes the idea of easiness and convenience so that it also describes a society that is attractive and has a high quality of living. Our idea of a low-resource society is directly linked to both meanings and we will explain them briefly.

A normative basis for such a society is that it lives within its planetary boundaries and hence does not exceed or destroy the resource base it can sensibly draw from. This notion lies at the roots of our approach, which is related to the ideas of dematerialization and resource productivity (cf. e.g. Schmidt-Bleek 1994, UBA 2012).[13] More concretely, fulfilling these postulations may mean the reduction of resource use by a factor of 4 to 20 for Germany (KRU 2014). With regard to individual resource use this then hints to a resource consumption of about 8t per capita and year on average (Lettenmeier et al. 2014)[14]. Different ways of realizing such a reduction in resource use are conceivable and hence different shapes and images of a low-resource society can be discerned. To understand these different possibilities, we aim to create a number of diverse scenarios and therefore refrain from determining just one specific pathway that has to be followed on the way to a low-resource society.

The second meaning of "leicht", i.e. easy or convenient, refers to a society that creates a high quality of life for its members (Schmidt-Bleek 1994, Schneidewind et al. 2013). It hence needs to fulfil criteria relevant to an attractive societal constellation and indicates a society people actually want to live in (Liedtke et al. 2013). Societal scenarios created through such a perspective can be used to generate the public acceptance needed for actually achieving a low-resource future (KRU 2014). They can also be seen as a counterpart to scenarios that portray a future where low resource utilization is enforced through absolute scarcity or harmful events of any sort. In such scenarios societies are rather subject to enforcement, poverty and low quality of life due to shortages (see e.g. The National Intelligence Strategy of the US). Scenarios that refer to an attractive low-resource society may hence work as pre-emptive

[13] Dematerialization refers to the observation that a low-resource society would have to use and utilize less (material) resources for satisfying its needs and demand to function within the borders pointed to. In this regard raising resource productivity indicates the potential of performing more services with a given set of resources or performing the same amount with lower resource use (Umweltbundesamt 2012).

[14] Lettenmeier et al. (2014) also exemplify specific corridors of living for households that would be within the 8t target.

visions motivating for the realization of a "better" future. Again, at this point we refrain from making specific suggestions for the Gestalt of a low-resource society and aim for diverse scenarios that can provide a number of approaches towards a low-resource future.

Corresponding to the arguments laid out above, there are numerous approaches that may contribute to building scenarios for a low-resource society. Ideally, conflicting or opposing scenarios deliver a larger potential for drawing implications. So for instance, drawing from contradictory approaches like that of a "Green Economy" which is based on the concept of economic growth and onsets like "Degrowth" that specifically denounce this idea can help to arrive at such a broad room for possibilities.

The scenario process

Scenarios are a means of developing alternative answers (note the plural) to questions concerning the future of a chosen subject. Depending on the question, the resulting answers can be normative or descriptive, have a focus on actions or on external events, and reach into different time horizons. This scenario exercise was to answer the following question:

How can relevant players in society (individuals/consumers, business, politics, science) promote and achieve low-resource living in Germany by 2030?

Accordingly, the "answers" address actions and solutions only, and their style is descriptive rather than normative.

Based on the players relevant for low-resource living key solution areas where identified and ranked according to their impact strength, resulting in a short list of 13 „key factors" (Figure 24-1). Then for each factor alternative future developments (projections) were developed. These projections were designed so that they contained only alternatives deemed to contribute to low-resource living. To obtain a broad and reasonably realistic set of projections, pioneers of low-resource living from all over Germany were invited to develop these in a 2-day moderated workshop. The pioneers' broad backgrounds and extensive experiences in low-resource living allowed for a multi-facetted discussion and ensured compatibility with reality at the same time.

The 13 factors together with their projections generated the scenario space which can be presented in a "morphological box":

Individuals/Consumers					Business				Politics				Science
Consumption patterns	Digital technology usage	Community building	Opinion making	Social security and health care	Innovation paradigm	Value creation patterns	Employment models	Entrepreneurial motivation	Resource politics	Political decision making	Prosperity and growth concepts	Commercial policy and innovation support	Education and knowledge building
Collaborative consumption	Offline society	New order of families	News & knowledge as commons	Citizens' insurance scheme	Cooperative innovation	Regional economy	Cooperative labor division	Policy-based motivation	Broad non-fiscal support	Bottom-up & glocal	Green New Deal	Promotion of SMEs	Universal knowledge
Sustainable hedonism	IT-induced low-resource living	Global community	NGOs dominate opinion making	Lean social security	High-tech-induced low-resource living	Knowledge-based economy	New work models	High idealism	Focus on sanctioning	Bottom-up & local	Quality of life comes first	Top-runner approach	Top-down education
Voluntary simplicity	Digital regimen	New communes	Politics dominate opinion making	Cooperative models	Low-tech society	Circular economy	Basic income	Demand-based motivation	Real prices create new markets	Provident expertocracy	Commons and prosperity for all	Focus on tertiary sector	Bottom-up experience and learning
Rationed consumption			Media liberalisation	Basic security and care		Demand-based production	Low-resource living by rationalisation		Low-resource planned economy	Renaissance of the parliament			

Figure 24-1: *Morphological box with key factors (blue) and projections (grey).*

The next step was the creation of raw scenarios. Different projections had to be combined in a consistent manner. For this purpose, the consistency between all 46 projections was assessed on an ordinal scale, ranging from “completely inconsistent” to “completely consistent”. We then selected 5 scenarios along the MECE principle (mutually exclusive and collectively exhaustive) meaning that the scenario set represented a maximum variance and at the same time made use of each projection at least once.

The resulting raw scenarios, which by then consisted of a plausible combination of projections, now had to be brought to life by enriching them and casting them into a consistent narrative. Here, the low-resource pioneers were involved again: In a creative 2-day workshop setting, they discussed the following questions:

- Which steps/measures/events pave the way into this future?
- Who are the main players? How do they proceed?
- What are the main challenges?
- What are the main differences to the present? To the other scenarios?
- Compared to today, where are opportunities for lower resource use?

The pioneers created rich pictures of the future which the project team then transformed into distinct scenario narratives.[15] The focus of the narratives was on consumption, economy and world of work, policy making and civil society. This was followed by an exploration of the underlying value sets driving society, business, and politics.

Scenarios

In the following, we will outline the five scenario narratives and point out the conflicting dimensions around which they are clustered.[16]

Cooperatives Promote Regionalism

The first scenario is based on the ideals that govern cooperatives – orientation on the common good and fairness – but also has a focus on the (re-)regionalisation of many activities. The most obvious anchor of low-resource living here is regional sourcing which massively reduces transport energy and resource use. The strong, voluntary orientation on the common good – which is supported by legal measures – results in significant behavioural changes and fosters social innovations. A strong bottom-up decision- and opinion-making culture contributes to a high commitment of individuals to the idea of low-resource living.

Market-based Ecologism

This future is basically a continuation and intensification of the present high-tech strategy of the German government. The “Energiewende” is complemented by similar radical reform programs in raw material usage, transport and food/agriculture. Resource use reduction is

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[15] Though prepared and evaluated by the project team, scenarios and their content are therefore a direct outcome of the workshops and do not necessarily represent the opinion and ideas of the authors of this paper and their respective institutions.

[16] The design of the scenarios is deliberately broad and in parts ambitious. This strategy is taken as the authors allow for system leaps to occur: Sudden changes in the socio-economic configuration towards a low-resource society. Nature and Potential of such leaps are being explored in another part of the project.

achieved by implementing progressive technologies and fostering competition whereas consumer behaviour does not undergo massive changes. Consumers prefer long-lasting, high-quality products that adhere to strict environmental criteria, thus diminishing resource use and waste from consumer products. In conferring status, material symbols still play an important role. Coordination is managed by an interplay between political regulation as well as incentive setting and letting the market mechanisms work in this newly shaped environment.

Obligatory Moderation

This future is based on the idea that people would welcome more guidance in their lifestyle choices, especially in times where consumption and other decisions become more complex. Therefore, the government introduces an annual resource budget for every citizen. Interim regulations in a transitory phase and ample advice provided by public agencies help people to get used to live within their given budgets. As a result, sharing and reusing of products flourish and tighten community networks. The economy adapts by focusing on products that enable people to live within their budgetary means, which fosters competition and innovation. Citizens are grateful for the relief of burden that comes along with the high level of guidance. Accordingly, they put a lot of trust in the government and are only little involved in policy-making.

Voluntary Simplicity

In contrast to the “Obligatory Moderation” scenario, low-resource living in this scenario results from a voluntary moderation and simplification. People consume less, prefer less complex products, and focus on proximity and their local environment. The government responds to rising NGO pressure to simplify incomes and taxes by introducing a basic income that is funded by returns from higher taxes on resource usage. In response, the economy promotes simple products with high durability and performs salary adjustments. The latter become necessary with the introduction of the basic income which allows people to switch jobs more frequently, work more part-time, and demand higher salaries for less attractive jobs. Citizens and NGOs are pro-active players in policymaking and are increasingly recognized as such, resulting in a high level of civic involvement.

Enlightened Global Society

This scenario follows a radical post-modern agenda of dematerialisation. Most prominently, it involves the reduction of the industrial base and a radical focus on the tertiary sector. Strict resource efficiency standards for the growing amount of imports apply. This fosters global innovation and competition for resource use reduction. The driving values of this globally oriented society – solidarity, fairness, and individual responsibility – are reflected in both business/careers and policymaking. Individuals prefer self-empowering and meaningful career options; companies respond by significantly increasing flexibility and independence for employees. In politics, paternalistic policy making patterns are abandoned completely, and citizen engagement plays a more important role than ever.

This scenario set represents a broad range of approaches to low-resource living in Germany 2030, as illustrated in the following Figure:

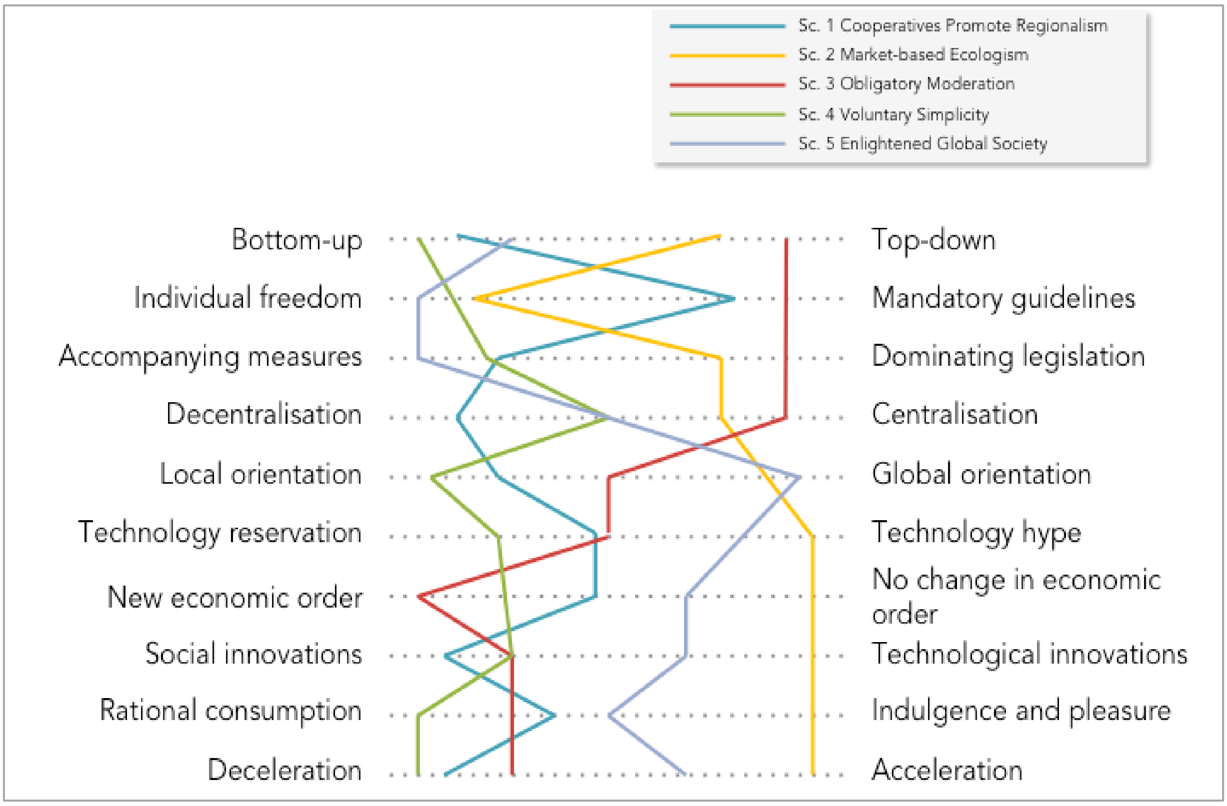


Figure 24-2: *Scenario characteristics – overview (preliminary assessment).*

It becomes clear that low-resource living will require different degrees of change. Scenario 2 requires a moderate level of change in daily life as well as consumption patterns whereas the other four scenarios will involve more or less strong disruptions, depending on the perspective. They range from massive changes in individual lifestyles (esp. consumption) all the way to systemic changes or even leaps, like the introduction of annual resource budgets (scenario 3), the introduction of a basic income (scenario 4), or the massive reduction of the industrial base (scenario 5). Besides these "technical" measures, the nature of the social dynamics and the setup of players vary greatly. While scenario 2 is based on an interplay between policy incentives and market mechanisms, scenario 3 involves a strong top-down approach. The other scenarios are initiated by a broad base of active civic and NGO engagement. Other differentiating categories include the geographical distribution of economic and political processes, the degree of technology use, and the nature and role of innovations.

The different options will determine the focus and range of resource conservation effects. Some scenarios are limited to new production patterns and certain industries while hardly affecting consumption, whereas others involve completely new lifestyles and will therefore result in comprehensive changes in value chains and infrastructures and public provision. Whether and to which extent these greatly different low-resource pathways are attractive for different parts of society is part of future work which will involve the discussion of the scenarios with stakeholders and with representatives of different social milieus. Moreover, it will be the task of future research to analyse the scenarios, examine their individual measures and potential more closely, and to carve out additional chances to achieve a low-resource society.

25. THE ZERO WASTE APPROACH TO RESOURCE MANAGEMENT

Richard Anthony ✉

Abstract

A Zero Waste system is a resource management system. The process of wasting resources is against nature. In a zero waste system everything has a place before, during and after use. There is no away. In the best-designed system, the dismantling or demanufacturing would be designed into the product. The system of extraction, manufacturing, use, and disposal to incinerators or landfill will be replaced with systems that capture the material and recycle them into a closed loop system of reuse, repair, recycle/compost and redesign. Raw materials will be used as reserves.

Introduction

The genesis of the Zero Waste movement comes from the realization that discarded materials are resources. These resources have been manufactured from a raw state with energy and labor. In the cases of metal and oil they are irreplaceable. The value of that energy and labor is still in the commodity, even after the user has discarded it.

This is called the “closed circle economy” and the analysis is called a “Cradle to Cradle” design. The recognition that, disposal by burning and landfill will leave a legacy of depletion and pollution for our children; will provide the basis for new analysis and new rules. These new rules will recognize the futures right to the planets’ resources and discourage wasteful and polluting practices.

Definition of Zero Waste

Toward the development of these new rules The Zero Waste International Alliance (www.zwia.org) have peer reviewed and approved of the following definition of Zero Waste.

“Zero Waste is a goal that is ethical, economical, efficient, and visionary, to guide people in changing their lifestyles and practices to emulate sustainable natural cycles, where all discarded materials are designed to become resources for others to use. “

“Zero Waste means designing and managing products and processes to systematically avoid and eliminate the volume and toxicity of waste and materials, conserve and recover all resources, and not burn or bury them. “

“Implementing Zero Waste will eliminate all discharges to land, water or air that are a threat to planetary, human, animal or plant health.”

Zero Waste & Global Warming

Landfills are one of the largest sources of Greenhouse Gases (GHG) in any community. Methane is 21-84 times more potent than Carbon Dioxide (CO_2). In most California city’s Climate Plans, the Landfill is among the top three (traffic, farms) emitting GHG’s. The California Air Resource Board (CARB) officials in 2014 recommended managing compostable organic materials to farms or facilities with aerobic and anaerobic digestion technologies.

Landfills and incinerators are in many ways an early end of life for first time used resources.

There is 71 tons "Upstream" of wasted materials and energy for every 1 ton Municipal Solid Waste discarded. If every discard in California (CA) was recycled or composted, the savings would be the equivalent of eliminating all auto exhaust in CA (EPA Waste Assessment Model). California has passed legislation (AB 341) calling for a 75% reduction goal and recommending to Cities that source separation be required.

Basic Principles

Different from the Integrated Waste Management approach, the zero waste approach considers all discarded resources as commodities. Unwanted discards can be separated at the source, stored separately, separately collected, processed, and sent to markets for reuse and recycling/composting. Ninety percent of our daily discards could be managed this way in a community collection program. The handling of the residual (less than 10%) can be discussed in the public forum on whether to require a product redesign or local ban.

There are five basic principles that are the pillars of the Zero Waste Approach.

- The first principle is that resources are finite.

  The process of wasting resources is against nature. Therefore the ultimate option is to control population and recycle resources to survive. Because the human species is driven to survive, the reasons and the answers can be seen in nature. Where there are limits in materials and space, contradictions to the flow of nature are obvious.

- The second principle is that there is no away.

  The notion of zero waste is as much as a principal of survival for the human species as it is a matter of fact in nature. A close examination of natural systems reveals that there is very little waste in nature. Everything is connected to each other. Every discard is an others feedstock. When the planet is seen as a finite sphere in space, there can be no away on planet earth. Everything that is sent away must go someplace.

- The third principle is that todays wasting and pollution rob the future of resources they will need.

  The recognition that even though disposal by burning and landfills of ash or landfill without burning may be cost effective under today's rules, the legacy of depletion and pollution for our children will provide the basis for new rules. These new rules will recognize the futures right to the planets' resources and discourage waste.

- The fourth principle is Highest and Best Use

  There is a hierarchy of use of materials that involves the highest and best use of materials in the areas of energy and resources. This includes: Reduce, Reuse, Recycling, includes repair and composting The "Three R's" are used to teach pollution prevention. The first R in the "Three R's" (reduce, reuse and recycler) refers to source reduction, or the area of discard management that addresses over packaging and single use products. The 3 "R's" are taught as a means to demonstrate how product design can lead to decreasing waste. Consumers are encouraged to consider buying products that can be reused, repaired, recycled and composted.

- The fifth principle is required source separation.

  Thus zero waste theory calls for disposal systems that place disposal costs responsibility on the manufacturers to redesign products for recycle ability. The discard management service provider whether government or private contractor, is mandated to collect source separated material from clearly labeled and conveniently located storage containers and deliver them to processing centers that will sort, process and reintroduce these materials back into the use system.

Resource Use

As the world population and living standard increases, world resources are used at increased rates as well. The impact of this increasing demand on the remaining of the planets finite resources like petroleum, metals, and its biodeversity of wild animals, birds,flowers, fish and trees is leading to their depletion and some cases, extinction.

Figure 25-1 from “The Limits to Growth” show poplulation growth from 1900 to 2100.

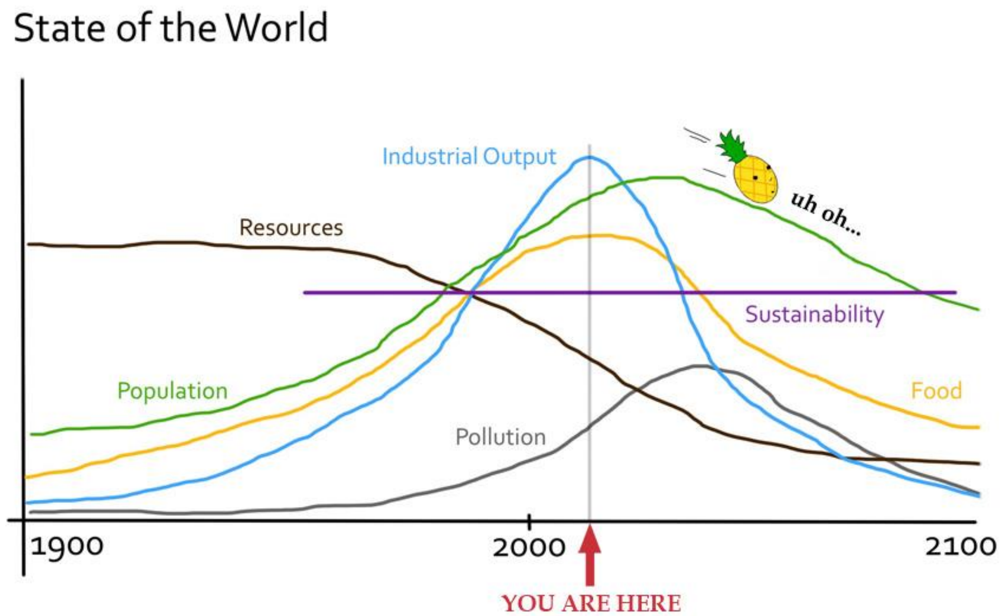


Figure 25-1: *Population growth from 1900 to 2100.*

As time reaches 2000 the lines cross, showing the population of the planet increasing while resources are depleted. This projection is reality today with the new recycling mills and factories in India and China and using western discards as material feedstock.

As the resources become depleted and the demand increases the value of these discards increase as well. Todays recycled material market is 100 times higher than what it was in 1970. This table demonstrates that recycling and/or composting is not a waste of money, but results in valuable resources with increasing demand.

Green House Gas and other Pollution Reduction

Table 25-1 shows the reductions in energy use, air pollution, water pollution, mining waste and water use when recycle resources are substituted for virgin materials. In the case of aluminum no new bauxite has to be mined and added to the aluminum melt to recycle it into another product. Steel today is the most recycled metal.

Reduction	Aluminum	Steel	Paper	Glass
Energy Use	90-97%	47-74%	23-74%	4-32%
Air Pollution	95%	85%	74%	20%
Water Pollution	97%	76%	35%	
Mining Wastes	99%	97%		80%
Water Use		40%	58%	50%

Table 25-1: *Pollution, Energy and Waste Reductions with Recycling.*

This table created by the USEPA is the basis of the Waste Assessment Model. For each commodity the reduction by recycling in energy use, air pollution, water pollution, mining waste and water use is given.

The Zero Waste Approach to managing resources considers the planets need and demand for these materials and the energy and greenhouse gas savings that occur when discards are managed as commodities.

Zero Waste Management

Today whether it's your home, your business or your community there are basic approaches to handling discards. The Zero Waste approach looks at discards both, upstream and downstream what some would call the waste stream. Efforts to reduce this stream of discarded materials can happen before purchase and use (upstream or prevention) or after use (downstream, end of pipe or recovery). In other words the Zero Waste Approach is about the prevention of wasting and recovery of discards.

Up Stream prevention programs include:

- Clean Production

  The goal of the final product is that the manufacturing of product will not hurt the product, the profit and the planet (triple bottom line). Factory managers are responsible for not incurring additional cost by creating and disposing of wasted and/or toxic materials.

- Product Redesign

  If any of the triple bottom line parameters (actions hurt product, planet, profit) are exceeded, the product needs to be redesigned. In our new economy the product must be repairable and/or recyclable/compostable and there will be no toxics used or created by the process that cannot be reused and recycled by the manufacturer.

- Product Stewardship

  A company takes pride in their products and create sustainable materials because is the right thing to do for the planet. In the past product stewardship was voluntary but today Companies are being required to take the lead in making their products and packages conform to international requirements.

Down Stream Recovery programs focus on capturing commodities at the point of discard.

- Reuse materials should be handled through box truck collection and drop off centers where materials can be looked at for reuse and repair. If not reusable and repairable they are dismantled into the basic recycling categories. All reusable and durable goods should be collected separately and processed as commodities.
- Composting compostable organics is the basic way of handling organic discards. These materials can be collected as yard trimmings and food scraps and composted in the back yard and/or collected separately and sent to farms and facilities that have composting and anaerobic digestion capabilities. The result will be healthy farms with less water and petro chemical demands and no local human created sources of leachate and methane emissions from the Landfill.
- Recycling all containers and paper products. These containers include metal, glass, paper and plastic.
- Resource Recovery Parks are the new transfer stations where commodity clusters can be collected separately and then transferred to the processing facilities. Special discards like rocks and wood have recovery areas at these parks.

Market Categories

All discards can be sorted in to twelve categories.

1. **Reusable** are materials that can be reused, repaired and /or dismantled for recycling
2. **Paper** includes cardboard, newspaper, writing paper, tissues and towels
3. **Plant Debris** include all yard trimmings
4. **Putrescible** are food scraps and organics that putrefy
5. **Wood** includes painted and unpainted although some painted wood is problematic
6. **Ceramics** are rocks, concrete, asphalt
7. **Glass** includes containers but not leaded glass
8. **Polymers** are plastic and can be sorted into resin codes for high resale value
9. **Soil** includes dirt
10. **Metal** includes ferrous magnetic metals like steel and iron and nonferrous metals like copper, aluminum, brass, gold etc.
11. **Textile** as reusable but in a class of their own and include cloth and woolen natural fiber as well as synthetic fibers
12. **Chemicals** are hazardous for disposal but they can be given out for further use.

Each of these materials in their categories has a positive monetary value. Credit for this system must be given to Dr. Dan Knapp of Urban Ore in Berkeley California.

Summary

The elements of a Zero Waste system include:

1. Producers taking responsibility for the impact of their product on the environment,
2. Producers designing products for the environment,

3. Clean production systems at factories that create neither wasted materials nor toxic discharges,
4. Retail stores take back products that are not recyclable or compostable,
5. Consumer purchase products that are environmentally friendly,
6. Resource recovery parks replace transfer stations and landfills,
7. Rules are changed to require separation, ban organics from landfill, no c and d without a plan and take back where no recycling system or composting system is in place,
8. Tax rules are changed to tax resources not labor,
9. Many new jobs in reuse, repair, recycling and composting care created.

26. CHALLENGES TO THE TRANSITION TO A CIRCULAR ECONOMY: UNDERSTANDING OF THE WEB OF CONSTRAINTS TO MORE EFFICIENT USE OF RESOURCES

Teresa Domenech ✉, Marc Dijk, Rene Kemp, Paul Ekins

Abstract

The concept of the circular economy has attracted the attention of policy makers and businesses in recent years. However, changing current patterns of resource use is a complex task. This paper aims to shed some light on the understanding of why resources are being used inefficiently and the factors that contribute to explain patterns of resource use. Based on the research undertaken under FP7 project on Policy Options for Resource Efficiency (POLFREE), the authors propose to move from the concept of barrier to resource efficiency, that seems to point to some concrete single factor that impedes more optimal use of resources, to the notion of 'web of constraints', that highlights the complex web of interlinked factors that interact with each other dynamically and simultaneously. To illustrate how different factors interact and feedback loops are generated leading to inefficient use of resources, the authors have selected two main areas from where to draw conclusions: buildings and mobility. In both cases, they represent areas of intensive use of resources and, where the feedback loops and interaction of supply and demand contribute to create conditions that drive and/or hamper resource efficient practices. Based on the analysis of the web of constraints, the paper draws some conclusions on the role of policy in tackling inefficient use of resources in these two sectors.

Keywords: circular economy, resource efficiency, web of constraints, building sector, resource efficient mobility.

Introduction: why are resources used inefficiently?

The concept of the circular economy has attracted the attention of policy makers and business in recent years. The circular economy is a system that is "restorative or regenerative by intention and design" (EMF, 2013) [i]and where waste is minimised through the cycling and cascading of resources through changes in the design of products, processes and industrial systems. The circular economy also promotes the transition to low carbon economy and the elimination of toxic chemicals that pollute resource streams impeding their full recovery. Resource efficiency is a key component of any strategy aiming for increasing the circularity of an economy and improving the way resources are used. Resource efficiency refers to the ability to use a reduced quantity or volume of resources to produce the same or an improved service or product. It is measured as the ratio between useful material output (Mo) and material input (Mi), both measured in physical terms (Dahlstrom and Ekins, 2005).

It is generally argued that resource efficiency and the circular economy are win-win approaches that align with environmental and economic rationale (Geng et al., 2014). Price increases in the commodity markets since 2000 have contributed to promote the idea that resources are scarce and its preservation may bring economic advantages that range from costs savings to issues of resource security. A number of studies have also pointed to the business opportunities of increasing resource efficiency and circularity. The resource revolution report by McKinsey (2011) estimated that opportunities for improving resource efficiency could be in the region of USD 2.9 trillion globally in 2030. Net benefits for a number of key sectors in Europe are expected to be in the region of €603 billion (AMEC&BIO IS, 2013).

If the prize for resource efficient behaviour is potentially high, one question that arises is why are these opportunities not being picked up by organisations and/or societies. The POLFREE project (www.polfree.eu) set to explore the type and scale of the obstacles preventing businesses, individuals and countries behave in a more resource efficient way. The first finding of the analysis is that there is a myriad of barriers that prevent more resource efficient behaviour of different actors. Moreover, these barriers seem to interact with each other and operate simultaneously, resulting in framework conditions that hinder efficient use of resources. Kemp and Dijk (2013) proposed the concept of "web of constraints" to better capture the complex interaction between individual and institutional behavioural patterns, inertia and direct and indirect linkages that result in inefficient use of resources. This web of constraints contributes to the understanding of why these opportunities are not being implemented and the decision-making and rationale behind actors' behaviour. The focus of this paper is precisely to explore the question of why resources are being used inefficiently and what are the challenges to increase better use of resources in two key sectors: the building sector and the mobility sector. Section 2 explores the web of constraint in the building sector and identified avenues for policy intervention to help overcome these constraints. Section 3 focuses on the mobility sector and provide examples of the web of constraints preventing the uptake of more resource efficient mobility systems. Section 4 draws some conclusions and lessons learnt and identifies future research needs.

The web of constraints in the building sector

The relevance of the building sector for resource efficiency

Construction is a sector of strategic importance for the EU, as main provider of buildings and infrastructures, key for the EU competitiveness of its industries and society wellbeing. The contribution of the sector to the EU economy is also of relevance, being the largest single economic activity (Ecorys, 2011) and a major employer. The total construction output for the EU in 2013 reached 1162 billion Euros, with 92.5 billion turnover, and created almost 4 million jobs. This represents 8.8% of total GDP for EU 28 and 6.4% of total employment and 29% of the industrial employment. The building sector is also the most energy and resource intensive sector of the EU economy. The sector consumes around 40% of the total energy and generates approximately 36% of the GHG emissions in Europe (EC, 2013). Moreover, energy consumption related to the production of construction products is around 5-10% of total energy consumption (EC, 2014). In terms of material use, it is estimated that it consumes between 30-50% (depending on the source) of the total materials in the EU27. This amounts to a figure of 1,200-1,800 million tonnes of construction materials used in the housing sector (new and refurbished buildings) (Ecorys, 2014). Aggregates (with approximately 721.6 million tonnes average 2006-2010) and concrete (662.2 million tonnes average 2006-2010) are the two biggest fractions of materials used in the building sector by weights, representing around 45% and 42% of total materials consumed respectively (Ecorys, 2014). Other construction materials include iron, aluminium, copper, sand, gravel, limestone, wood and building stone.

Given the material requirements of the sector, it is not surprising that construction and demolition (C&D) waste constitutes the single most relevant waste stream in the EU. The construction sector generated a total of around 859 million tonnes in 2010, of which around 95% corresponded to minerals and solidified waste (EUROSTAT, 2014). However, inconsistencies in the collection of the data and exact definition of C&D waste, explain considerable variation in data on the arising of C&D waste. A study commissioned by the Commission estimates waste generation to range between a total of 310 and 700 million tonnes per year (0.63 to 1.42 tonnes per capita, per year) and significantly more, between 1350 and 2900 million when including excavation waste (Ecologic, 2011). In terms of hazardousness, only less than 2% is hazardous, although small hazardous elements of the waste can contaminate large portions of inert waste under inadequate management procedures.

Although the material productivity of the construction sector, measured as GPD/DMC construction minerals, has increased substantially in the last decade (an increase of 45%), there are still untapped opportunities to further reduce primary raw materials consumption in the sector. Most of the policy focus has concentrated in reducing energy consumption and associated GHG emissions from the sector. Despite policy efforts, though, final energy consumed by households has just slightly reduced compared to 2000 (EUROSTAT, 2014).

Applying the concept of the web of constraints to the building sectors unveils a number of interesting interactions and feedback loops that contribute to explain limited uptake of resource efficiency measures. It is also important to note, that the web of constraints can turn into a web of drivers should the right incentives be in place to shift actor’s behaviour. The building sector is a complex sector, which involves a large number of stakeholders across its value chain. It can be divided between the design and construction phase and the occupation phase. In next section, the design and construction phase is briefly reviewed from the perspective of the web of constraints. The operational phase has been addressed in Dijk et al. (2015).

Web of constraints in the design and construction phase

The design and construction phase of a building or infrastructure defines the structural elements, building techniques and materials that give shape to the building and determine its potential performance. This phase requires close interaction between different actors across the value chain including clients, architects and designers, building contractors and building material providers. It is important to note that the design phase is disconnected from the end of life of buildings, giving the diversity of actors involved and the relative long life-span of buildings, which creates problems of split incentives that prevent approaches to minimise impacts occurred during the demolition phase.

The design phase is key in identifying potential of improving resource efficiency and minimising waste in latter stages. Changes in design to move towards a low carbon sector and “near zero energy buildings” have required important adaptations of building regulations in recent years to improve the energy efficiency during the occupancy phase. This has led to an increase in the use of insulation and composite materials, which may represent real challenges to reuse and recycle at the end of the use life of a building. A number of post-occupancy studies have also pointed at the existing gap between potential and actual performance, also referred to as “performance gap” (Bordass et al., 2001). A number of different factors have been identified as contributors to this performance gap, including lack of effective communication with occupants to ensure appropriate use of equipment and controls, behavioural issues and attitudes to heating and cooling (Majcen et al., 2015) or technical issues related to how materials are tested, generally in isolation rather than working in a system, and how techniques are specified (zero carbon hub, 2013).

The construction phase is to a great extent determined by the design phase. During the design phase large amounts of materials are required, including construction minerals but also energy intensive materials such as metals and concrete products. Improving resource efficiency during the construction phase requires alternative approaches to waste minimisation and waste management. Evidence suggests that policies that set incentives to landfill diversion, such as landfill taxes, may significantly contribute to increase resource efficiency and increase the viability of reuse and recycling alternatives for C&D waste (Martin and Scott, 2003). Landfill taxes may also contribute to promote the development of an advanced recycling sector specialised in C&D waste to increase recovery of valuable materials. The landfill tax illustrates how the web of constraints can become a web of drivers if certain conditions are in place. Other instruments that have been applied to incentivise resource efficiency in the building sector are aggregate taxes or levies. For example, the UK aggregates levy has contributed to increase recycling rate of aggregates to 25% and boost the market of recycled aggregates. It has also been estimated that a similar tax for the EU could lead to revenues in the order of €800,000 million, while reducing total material requirements for the sector (Bleischwitz, 2012).

While energy use in buildings is progressively decreasing, more attention is paid to embedded carbon of the housing stock. It has been estimated that while currently operational energy accounts between 40-80% of the whole life carbon for different types of building, advances on thermal performance of buildings are likely to offer quite a different picture in coming years, when about 95% of the whole life carbon of a building is expected to be embedded carbon (Sturgis Associates, 2010). This has led to increasing experimentation with a number of building forms and constructions techniques that focus on reducing embedded carbon of buildings through utilisation of novel materials and building techniques such as design for deconstruction and reuse of structural elements.

The reuse of structural steel illustrates well the complex web of constraints of improving resource efficiency in the building sector (see Figure below). Steel is an example of a 100% recyclable material. It is estimated that a tonne of steel scrap contributes to save over 1,400 kg of iron ore, 740 kg of coal, and 120 kg of limestone compared to new steel. Energy requirements are also significantly reduced in secondary steel production when compared to production from iron ore. Estimations range between 74% (EAP estimate) to 90% (US department of Energy) energy savings compared to primary production (EIA, 2014). While recycling of steel is a well-developed system, there are still untapped efficiency opportunities to substantially increase resource efficiency and reduce energy intensity by focusing on the ‘power of the inner circle’ of circular models. Re-use of steel has been estimated as having 98% reduced impact compared to new steel (BRE).

Moving towards business models based on selling the service rather the product in a sector such as structural steel could bring important benefits: 1) it can contribute to longer lasting relationships between customers/ suppliers; 2) it can contribute to close the loop of steel, ensuring that steel is reused or recycled at the end of the life of a building; 3) it can contribute to generate a more steady cash flow for suppliers while reducing the investment costs of customers. The re-use of structural steel has been explored in a number of pilot projects, but so far, unlike other construction materials which use have increased significantly such as low-carbon cements, leasing of structural steel still remains a rarity. Among the best-known examples of reuse of steel in the UK is the British Construction Steelwork Associate headquarters at Carrwood Park or BedZED development, which used 98 Tonnes of reclaimed steel. In general, the process of leasing of steel is in principle straightforward and it includes: a) provision of steel; 2) maintainance, if needed; 3) dismantling of the components; 4) cleaning, processing/ reconditioning, testing/ certifying and storing and 5) delivery to the new building. However, the fact that leasing of steel is not more widely adopted practice points to important interlinked obstacles that vary from the suppliers/ customer perceptions, resistance to change routines and standard way to do things, changes in business financial model, and costs associated with the recovery of the steel at the end of the leasing contract. The lack of standardised certification schemes for reused steel may detract some contractors from using it, but also the lack of demand proves it difficult and costly to develop such certification schemes. There are also issues related to the logistics of storing steel and being able to provide customers with the quantity of steel and strength required for specific projects, unless large stocks are kept. However, legislation pressure is likely to shift attention to embodied carbon, if operational energy is substantially reduced. The reuse of structural steel illustrates why economic incentives in themselves may be insufficient to lead to changes in practices unless accompanied with other measures, such as building inventories and reuse targets. Figure 26-1 below highlights the interlinked character of the obstacles to reuse steel.

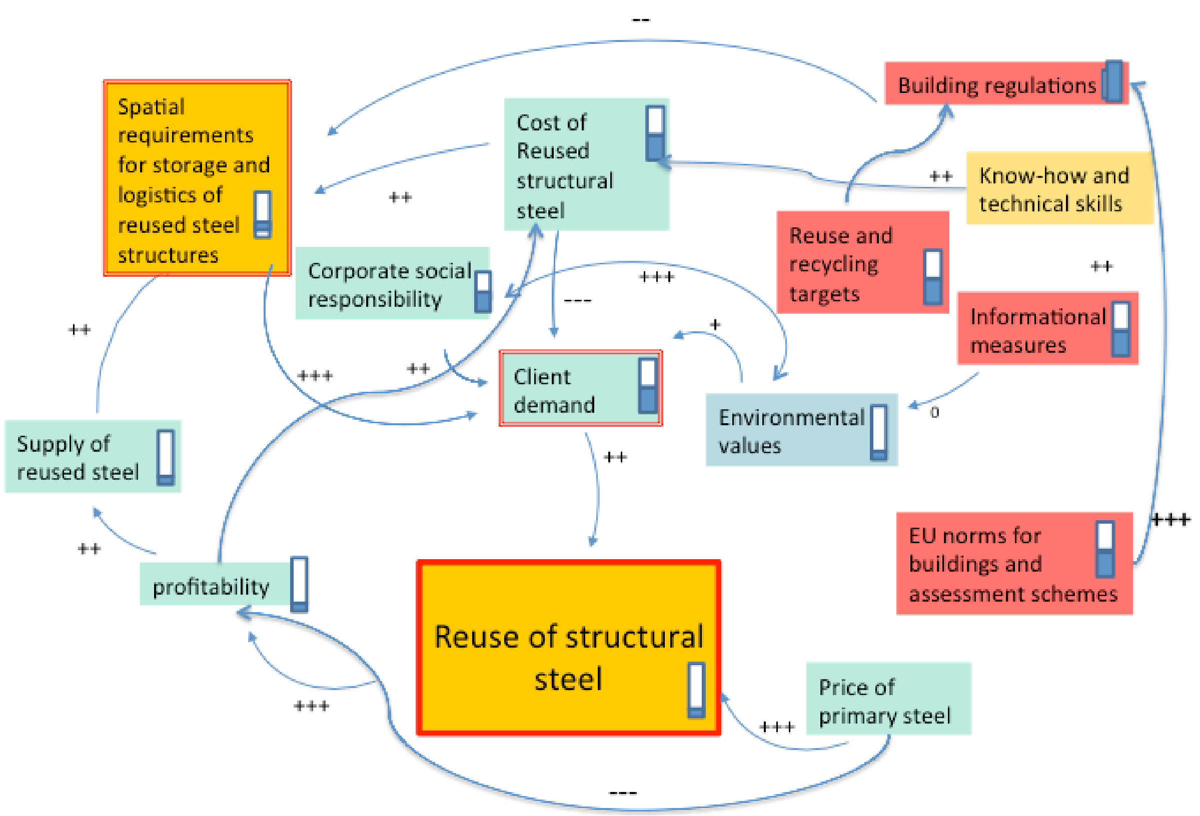


Figure 26-1:*The web of constraints for the reuse of structural steel. Legend: individual (blue), business (green), policy (red) and societal/infrastructural (orange) factors. The relationship between the factors is indicated (as positive or negative, varying from --- to +++). The level of the factor is scored as reflected in the thermometer icons.*

The web of constraints in the mobility sector

The mobility sector is the second biggest contributor to GHG emissions in the EU. About two-thirds of the transport-related emissions are associated with the road transport sector (EC, n.d.). POLFREE explored barriers to improving resource efficiency in the car-passenger sector. While EU transport policy is a key element of the efficient functioning of the internal market, transport systems are also the source of environmental impacts linked not only to GHG emissions and climate change but also local air pollution, land use and biodiversity, among others. Also, interestingly, while GHG emissions from other sectors have shown a decreasing trend from 1990, emissions from transport increased over 30% in the period 1990-2007. In 2008, transport-related emissions started to decrease, but in 2011 they were still above 20% higher compared to 1990 levels (EUROSTAT, 2015). A number of policies have been put in place to reduce emissions from the sector. The EU has set binding emissions targets for light-duty vehicles and has put in place regulation to ensure that consumers are provided with relevant information through CO_2 labelling. However, the policy framework for transport policies is a complex one with multi-layered interactions between different policy areas and stakeholders. Trade offs and opposite effects have been identified between for example measures to reduce GHG associated to road transport and development of infrastructures and roads to promote free movements of goods and people across the EU. Also, the EU has experienced an increase in its car fleet from 1995 levels, from 380 cars per 100 habitants in 1995 to 487 per 1000 habitants in 2012 (ACEA, n.d.). Although CO_2 standards have successfully reduced emissions of new cars, there is still lack of a coherent framework to provide incentives to consumers/ citizens to shift between transport modes and reduce car reliance or km travelled by passenger.

Based on a combination of a survey, focus-groups and individual in-depth interviews across three different MSs, POLFREE undertook an exploration of the factors influencing individual behaviour in relation to mobility and car use. Findings from the study pointed to the willingness of reduce the use of car, with 49% of the respondents said they would like to use the car less. However, motivations behind this were mainly associated to reduced costs and savings and to ‘do more exercise’, while protection of the environment and resource efficiency came only in third place (with 39% of the respondents considering as a factor to reduce the use of the car). Also, it is relevant to note that 28% of the respondents indicated that they have already reduced the use of the car to the minimum. Interestingly, the main reason why respondents said that is was difficult to reduce the use of the car is the fact that ‘public transport is not a good alternative’. This factor was especially relevant in countries such as Austria and The Netherlands, which have good public transport networks. Attitudes to what is acceptable and convenient may play a role in explaining this. Only a small proportion of the respondents did not own a car. Respondents reported that the main reason for not owning a car was to save money or because they do not have a driving license, while the percentage of respondents doing it for environmental reasons was around 15%. The study also revealed that there is a strong link between knowledge of existing energy labels for cars and the existence of tax-exemptions schemes associated with this, which seems to point to the relevant role of economic incentives in influencing consumer choice. Findings from the survey also indicated that just a small percentage of respondents were members of a car-sharing club (5% in the Netherlands, 4% in Austria or 7% in Hungary), indicating lack of a dense infrastructure of car-sharing stations as the key reason for the relatively low membership rate. The study also indicated that high-income households are more likely to own a car than lower-income households.

The web of constraints operating in car mobility is thus complex and builds on the interaction of regulations, economic incentives/disincentives, attitudes to transport, infrastructure and inertia. Some of these casual loops are shown in the figure below.

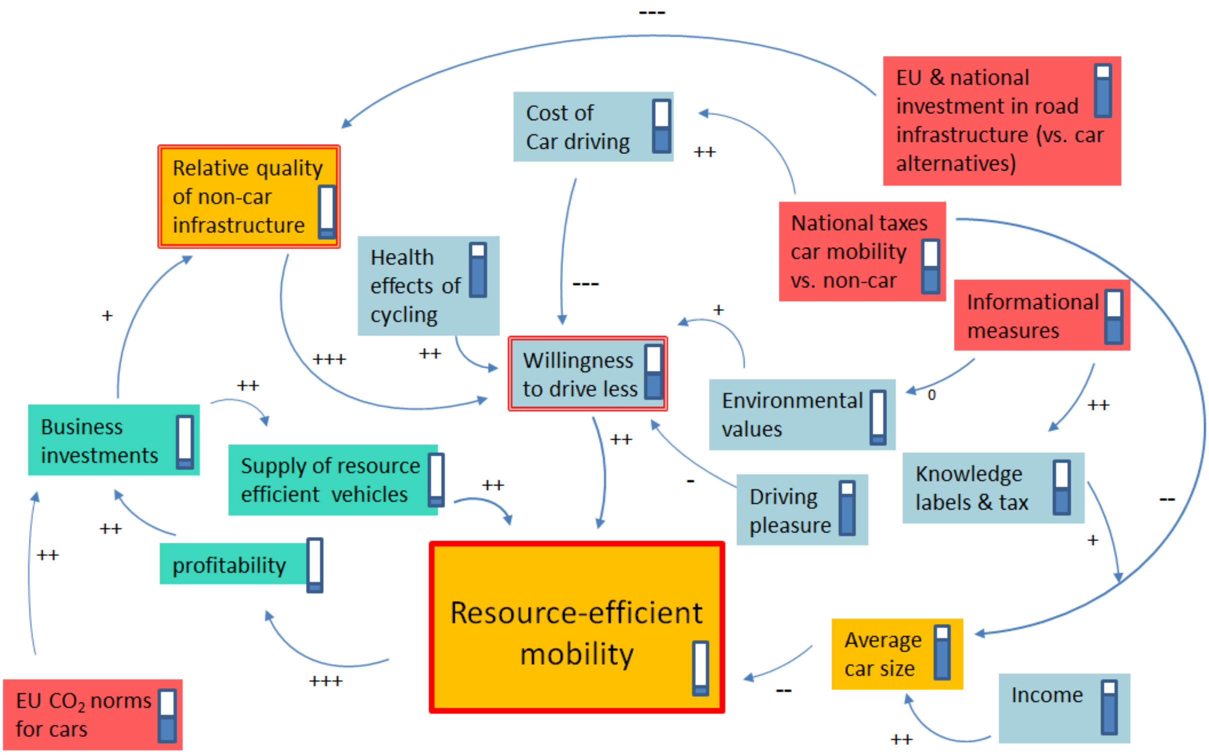


Figure 26-2: *Web of constraints in passenger mobility. Legend: individual (blue), business (green), policy (red) and societal/infrastructural (orange) factors. The relationship between the factors is indicated (as positive or negative, varying from --- to +++). The level of the factor is scored as reflected in the thermometer icons.*

From the analysis, some conclusions may be drawn. The decision to own a car is influenced by the economic status of the household, the infrastructure network and personal attitudes to convenience, health and to a lesser extent the environment. Regulation and policies seems to have an impact in influencing consumer choices by providing incentives to less polluting vehicles, however, the impact in impacting choice of transport is difficult to assess given the divergences between incentive structures in countries studied. Tackling the web of constraints thus require coordinated action in a number of policy areas that include technical standards, public transport networks and transport infrastructures. Changes in attitude and inertia may follow changes in framework conditions but are also influenced by other factors such as the role of cars as status goods and gratification of the experience of driving.

Conclusions

This paper has briefly explored the intricate web of factors preventing efficient use of resources, even when there seems to be opportunities to achieve win-win solutions. The concept of the web of constraints helps to understand the complexity of interlinked casual loops influencing consumer and business choices that explain a low uptake of resource efficient measures and life styles. The paper offered examples of the building and mobility sectors from the perspective of the web of constraints. Both sectors consume large amount the resources and generate significant environmental impacts but also hold large potential to increase resource efficiency. The analysis has illustrated the complex web of obstacles that interact dynamically preventing efficient use of resources. The notion of the web of constraints also helps to understand the complexity of designing policies that promote resource efficiency as several areas need to be addressed in an integrated and dynamical way to overcome the web-of-constraints and modulate the dynamics into a web of drivers. The analysis also points to important connections between different sector and areas. For example, different types of housing options and planning strategies could give rise to new systems of mobility. Co-housing and dense developments may favour the use of public transport and car-sharing platforms. The study has also noted that good public transport networks are not sufficient to guarantee reduced reliance on private cars and, that other factors such as attitudes to convenience and adequateness need to be considered. The analysis of the linkages across sectors and areas of policies are out of the scope of this paper but need to be addressed in future to set the basis for consistent and coherent policy mixes that help to overcome the web of constraints to resource efficiency.

27. A REGIONAL RESOURCE FLOW MODEL FOR PROMOTING A CIRCULAR ECONOMY AT THE REGIONAL LEVEL

Joonas Hokkanen ✉, Heikki Savikko, Riina Känkänen, Ari Sirkiä, Yrjö Virtanen, Juha-Matti Katajajuuri, Taija Sinkko

Abstract

A regional resource flow model is applicable for examining the resource efficiency at a regional level and at different scales varying from regions to urban areas and also smaller local development project areas. The Jyväskylä region has been the first in Finland to study the availability of regional resource information, to examine the use of natural resources and to develop a model to illustrate the actual material flows. A regional resource flow model was beneficial to the Jyväskylä region and now it has been expanded to also cover other regions in Finland. It also has clear potential uses globally.

The model gives a reliable representation about the interaction between industries in the region, the use of natural resources, the efficiency of regional economy, the employment impacts, the added value and the environmental impacts. The model provides new perspectives and application possibilities for promoting the bio- and circular economies as well as to the impact assessments of national, regional and local level plans, programs and projects. The model can be used to recognize the importance of companies to the regional economy, employment and the environment as well as the role of companies in promoting the circular economy.

Resource flows are built into the model based on a regional materials flow analysis and an environmentally expanded input-output method. Economic and other social benefits can be simulated and made measurable with the model. The life cycle-based environmental impact assessment included in the model provides a general view on regional and global impacts, direct point-source emissions and indirect impacts that actualize outside the region (life cycle emissions).

Keywords: circular economy, input-output modelling, resource efficiency, resource flows, environmental emissions, regional environmentally extended input-output model

Introduction

Natural resource depletion, population growth and climate change are all increasing rapidly and they require more regionally and globally resource-efficient and resource-wise activities. Hence, lifestyles which consume significant resources, resource strategy and resource flows must be improved and reviewed regionally in order to improve energy efficiency and regional economy, reduce emissions, and increase self-sufficiency.

The model was used to give an answer to the following questions:

- How are monetary and physical resource flows (€, ton, m3) directed to the study area, between industries, towards consumption and away from the study area?
- What value-added occurrences are identified in these flows?
- How large is the employment impact from production in the study area?
- What are the total emissions (direct and life cycle) from the flows? (incl. the production and consumption of the products made in the study area)

- How do changes in technology or demand affect e.g. interactions between industries, output, value added, employment or environmental impacts?
- How do other changes affect the area – and impact our goals
- What is the physical amount of unused waste and residual resources

This study describes a means to form a calculation and operating model for regional resource efficiency as well as developing the prototype for the Jyväskylä region. The model also takes into account the life cycle perspective, meaning that a life cycle assessment will be used for analyzing the material flows and their environmental impacts. However, resource efficiency can be viewed from the monetary, physical and environmental perspectives. Due to the several possible perspectives, the model does not provide one absolute result of resource efficiency on the regional level. In order to increase the accuracy of the model, companies should be more involved in the development of the model as well as share the data.

The model has been developed by Ramboll on commission from Sitra (The Finnish Innovation Fund). The Natural Resources Institute Finland (Luke) has been a cooperative partner in the pilot project in the Jyväskylä region. Investors in the project, accompanying Sitra, were The Ministry of Agriculture and Forestry, The Ministry of Employment and the Economy, and The Ministry of the Environment. Ramboll has continued the development of the modeling method.

Methods

The study is based on a constructive research method, in which a new model to describe and simulate the regional resource flows and environmental impacts of the flows was developed. In the model, the material flows of the industries were created by a method based on the regional material flow analysis and input/output model (Brand et al. 2000; Baumol 2000; Armstrong & Taylor 2000; Miller & Blair 2009; Kowalewski 2012). The most relevant industries were analyzed in more detailed based as much as possible on the real material flows collected from the earlier studies, environmental permissions and environmental databases and by interviewing participating companies (Tukker et al. 2006; Kowalewski 2012; Kitzes 2013). Other industries were derived in the model from a regional economic account and a national input/output model by using the FLQ-location quotient (Figure 27-1.) (Flegg & Webber 2000; Tohmo 2004; Flegg & Tohmo 2013). Life Cycle Assessment (LCA) methodology was used to assess environmental impacts of material flows (Jenssen et al. 1997; Finnveden et al. 2009; Guinee et al. 2011).

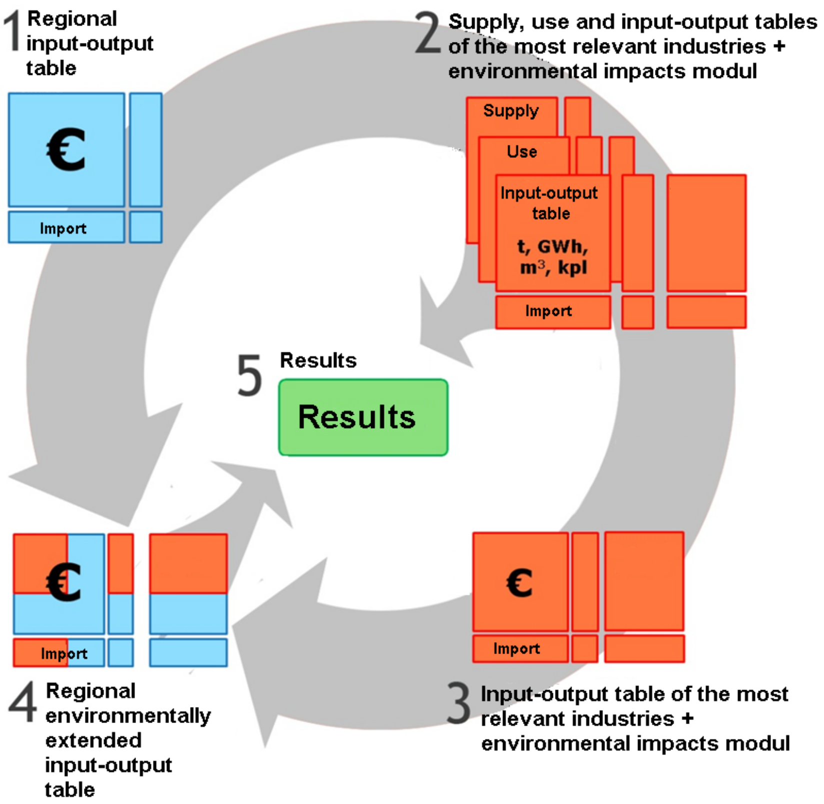


Figure 27-1: *The model to derive input-output data for other industries using the FLQ-location quotient.*

Results

The most essential resource flows in the Jyväskylä region are shown in the Figure 27-2.

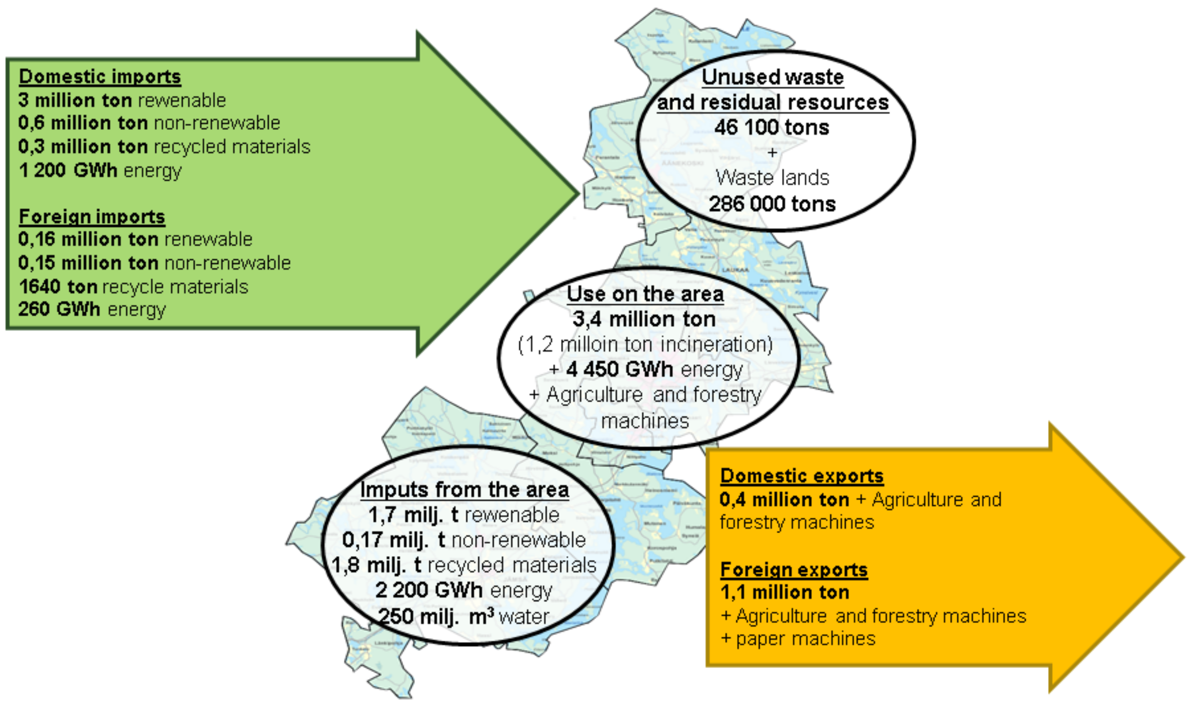


Figure 27-2: *The most essential resource flows in the Jyväskylä region.*

The most essential monetary flows in the Jyväskylä region in 2011 are shown in the Figure 27-3.

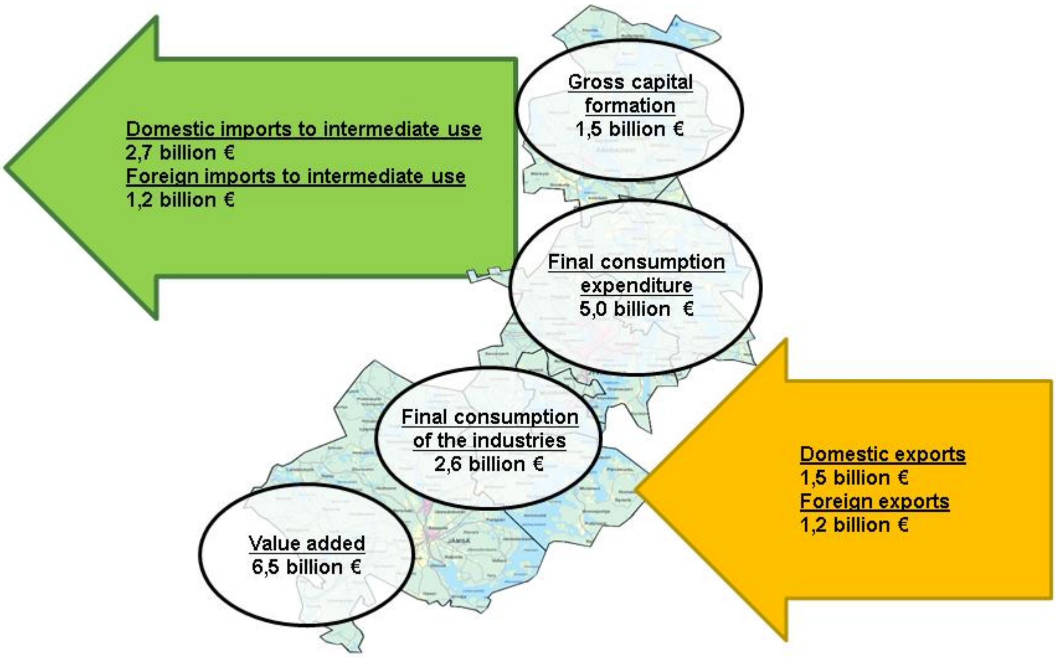


Figure 27-3: *The most essential monetary flows in the Jyväskylä region.*

By using the model, the most cost effective ways to reduce negative environmental impacts of material use can be identified. The modelling tool can help governance to promote attractiveness of a region from entrepreneurs' point of view and to support innovative business, which base on strengths of region and will promote resource efficient and carbon neutral economy.

The most cost-effective ways to improve regional resource efficiency are shown in the Figure 27-4 (arrows).

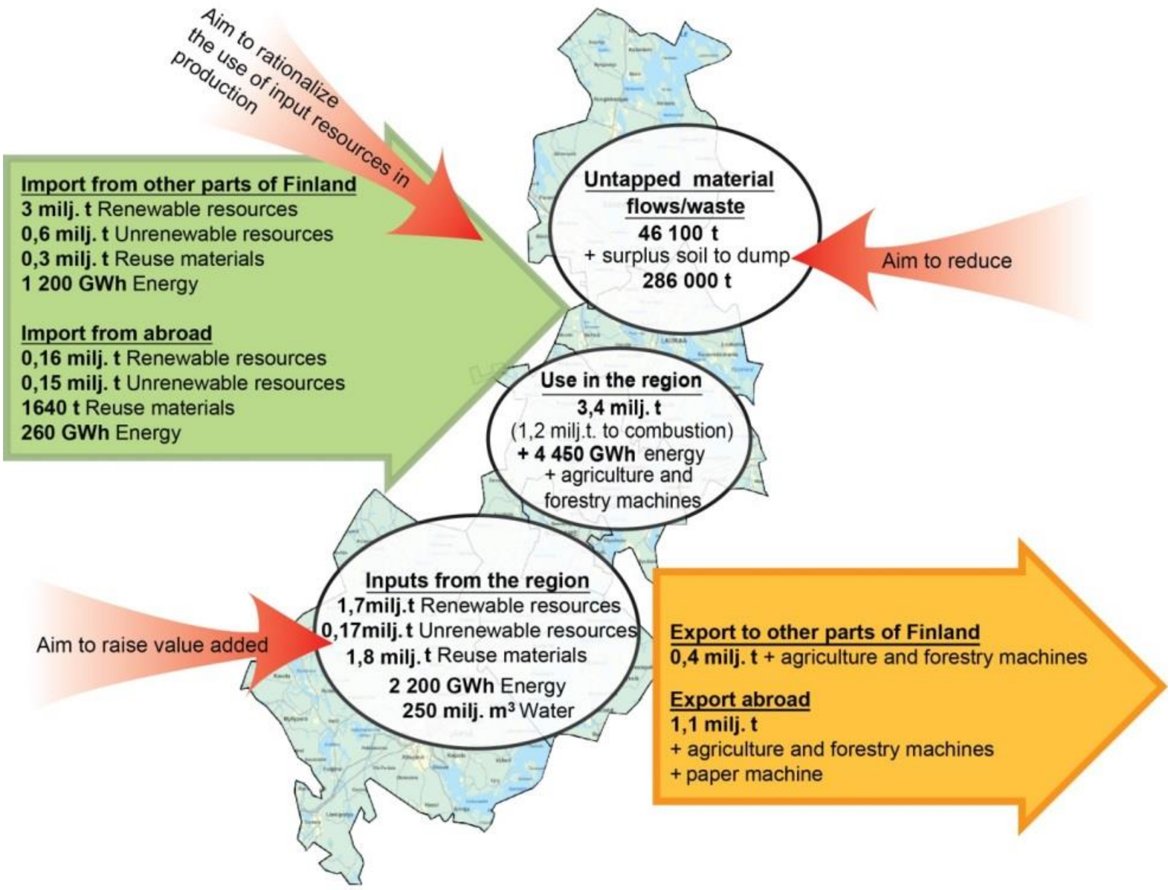


Figure 27-4:*The most cost-effective ways to improve regional resource efficiency.*

Conclusions

In this project, a clear method to create a regional resource model was developed wherein five different components were defined, allowing the final model to be formed and environmental impacts, resource flows and resource efficiency to be described. Also, the model can be copied to other areas. The required amount of work varies by the study area and its industrial structure. The prototype shows a clear general picture of the Jyväskylä region.

The regional resource model:

- Creates visibility to otherwise obscure regional material flows.
- Gives understanding on the industry structure and regional economy.
- Provides a reliable account of emissions due the production in the region at an appropriate order of magnitude.
- Estimates changes due to varying production levels, the regional economy, employment and environmental impacts caused by shifts in technology or demand.
- Offers more opportunities to interact with industry, government and residents.
- Presents a new type of application for the purposes of sustainable regional planning, the development of the bio- and circular-economies and to impact assessments of projects and plans.
- Includes the possibility to model f.ex. Nutrient circulation in the economy, and its leaking points, economical value, environmental impacts.

28. DYNAMIC INTERACTION OF MARKET AND BEHAVIOURAL BARRIERS IN THE TRANSITION TOWARDS A CIRCULAR ECONOMY: A HETEROGENEOUS-AGENT APPROACH

Boonman Hettie ✉, Husby Trond, Moghayer Saeed✉

Abstract

In this paper we analyse transition towards circular economy as a complex adaptive system focusing on the market and behavioural barriers. We investigate the conditions for successful introduction of a new production which is appropriate for a circular economy, 'circular' product with a focus on the contribution of underlying demand-side behavioural factors. To do that, we develop a heterogeneous agent model in which consumers are modelled to choose between two varieties of a consumer good/service in the market: a 'circular' product/service type and a 'non-circular' t type. The results and methods developed in this paper is applied to a use case of recycling of rubbers in the Netherlands.

Keywords: circular economy, heterogeneous agent models, bifurcation, complex systems

Introduction

In present, our society are confronted with many environmental challenges, some of them are generally conceived to be pressing. Resource efficiency is one of those challenges that despite its importance for reducing environmental impacts and maintaining the resource base for economic development, has been relatively slow to rise up the agenda of public policy. But, new concerns such as high rate of resource consumption in emerging economies and possible scarcities, and security of supply of raw materials has led to the inclusion of resource efficiency in Europe 2020. Moving towards a circular economy, i.e. an economy with more re-using, repairing, refurbishing and recycling existing materials and products, is seen as a key cross-cutting approach in resource efficiency agenda established under the Europe 2020 Strategy for smart, sustainable and inclusive growth.

Businesses are in the driver's seat in the transition to a circular economy, but they are facing barriers in their way. One of the most important barriers arise from market failures, which are the results of for instance weak price signals on some commodity markets17, heterogeneous beliefs and behavioural expectations of the actors, lack of information about financial risk or heterogeneity in the way that the existing information are perceived by the investors or consumers. Indeed, it is not evident that consumer, manufacturers or investors are willing to switch their pattern of (intermediate) consumption or investment. Yet, evidence from niche markets suggests that they under certain conditions may be willing to make such a switch. Next to the market and behavioural barriers, there are also other constrains such institutional and technological all interacting in a fully connected web of constraints (cf. Bastein et al, 2014).

In this paper we study the transition to a circular economy as a complex adaptive system. We investigate the conditions for successful introduction of a 'circular good/service', focusing on the contribution of underlying demand-side factors. To do this a heterogeneous agent model, HAMs (Brock and Hommes, 1997) is developed with a population of boundedly rational heterogeneous agents choosing between two varieties of a consumer goods or service – a

[17] Roadmap "Circular Economy Strategy", European Commission, 04 / 2015

'circular' and a 'non-circular' type. A boundedly rational world view with agents using simple strategies, perhaps not perfect but at least approximately right, seems more appropriate within a complex, nonlinear world (cf. Brock and Hommes 1997). HAMs are highly nonlinear, for instance due to evolutionary switching between strategies, and can exhibit a wide range of dynamical behaviour ranging from a unique stable steady state to complex, chaotic dynamics, and non-convex state dynamics with multiple equilibria (cf. Moghayer and Wagner, 2009). In the models with multiple equilibria there can be changes in the qualitative structure of the set of solutions with completely different economic outcomes if parameters are varied. Therefore, a classification of these outcomes based on different value of parameters is required. For this we use bifurcation analysis, which is the mathematics of classification. Using this analysis we seek to answer the following question: what are the necessary behavioural and market conditions for obtaining a stable market share of the 'circular' type?

In order to calculate the sustainability indicators as a proxy for the degree of the circularity of the economy/ businesses, we need environmental and economic data and most existing HAMs are not based on real-world data. In this paper we tackle this problem by designing a simple hybrid Environmentally Extended Input Output (EE-IO) model and HAM. The combination of the two methodological approaches opens possibilities to account for measuring environmental indicators in the circular market steady state.

Model

Heterogeneous Agent Model (HAM) of the circular economy

In this model we consider an industry with one firm that produces in a monopolistic market. The firm initially produces one product/service, the non-circular product. The firm explores the possibility to start producing a more sustainable product, i.e. a circular product. By circular product, we refer to a product or service that includes or eases the possibility of recycling, as part of the take-back scheme. The non-circular product is the conventional product, which is not being recycled. Consumers or other firms, for their intermediate consumption, make a choice between the circular and non-circular product. Two types of consumers/firms are distinguished, early adaptors and followers. The decision of consumers/firms is modelled as a discrete choice where differences in payoff associated with the (intermediate) consumption of different types gives rise to evolutionary switching behaviour. In addition to economic incentives, the choice is affected by: behavioural parameters (e.g. pro-environmental values, risk aversion); network externalities, where individual choices are affected by the choices of other agents in the population; the intensity of choice, reflecting the uncertainty associated with behavioural change or the convenience associated with the current choice. In each time period, consumers/firms face the same purchase choice, and can switch to the other product/service between each two time periods. The products pickup shares are then updated.

In the supply side, we apply a simple mechanism. The price of the non-circular product is assumed to be fixed. Under complete information, the inverse demand structure is derived. Profit optimization of the firms then result in expected optimal production with a quadratic cost function, which also depends on a total factor productivity parameter capturing the rate of the diffusion of the new technologies. This in turn leads to the expected optimal price. Under the current price function, the firm has a correct expectation of the price. The following diagram depict the structure of the HAM model.

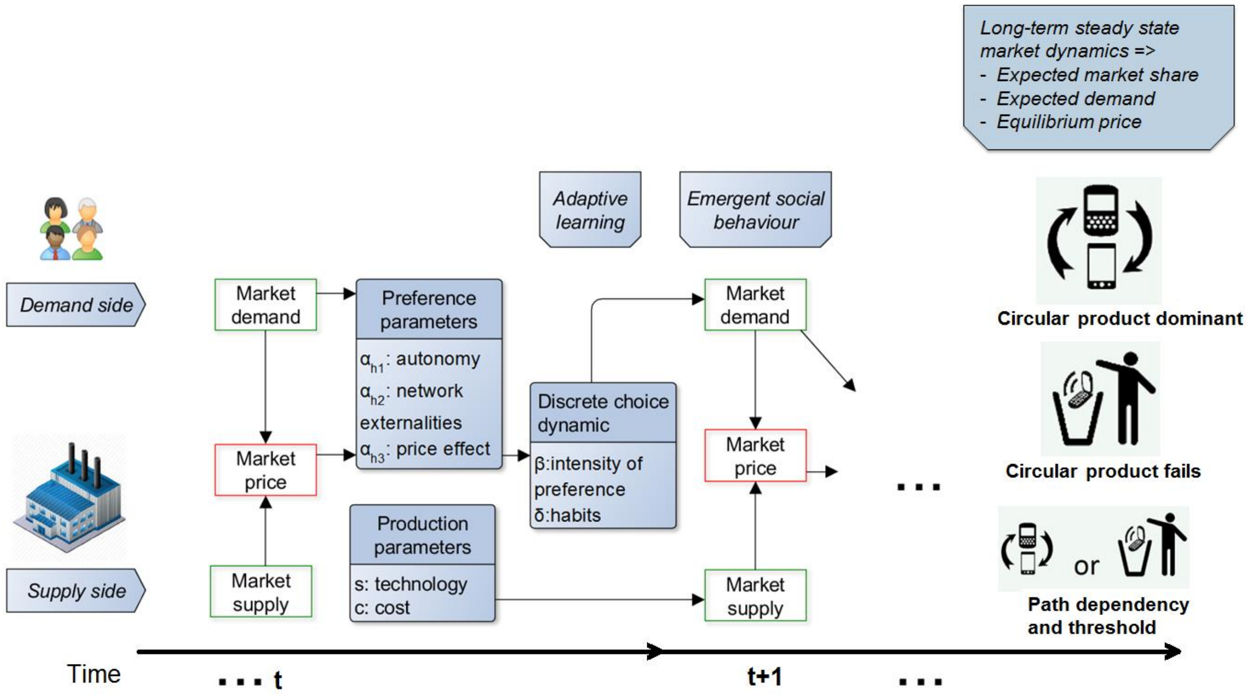


Figure 28-1:*The overall structure of the Heterogeneous Agent Model (HAM) of the transition towards circular economy.*

Environmentally Extended Input-Output (EE-IO) Model

In order to calculate changes in material inputs and waste flows from changes in the use of recycled tires, we use an EE-IO model based on the IO table of Netherlands of the year 2013, provided by Statistics Netherlands. This table shows the sale and purchase relationships between producers and consumers within an economy. It is produced by illustrating flows between the sales and purchases (final and intermediate) of industry outputs or by illustrating the sales and purchases (final and intermediate) of product outputs.

Furthermore, when changes in material inputs and waste flows from changing the recycled material content of tires we make the following assumptions: increasing recycled content in a tire to 7% leads to a 40% reduction in use of virgin rubber; increasing recycled content in a tire to 7% leads to a reduction of about 7 litres of oil per kg recycled content used; recycled rubber is currently not being used in tires (in the NL); the reduction in recycled rubber is equally spread over sectors.

Application: recycling of rubber in the Dutch tires industry

As a case study to illustrate the output of the modelling tools we analyse changes in input and waste flows due to an increase in the recycled material content of tires in the Netherlands. 70% of the world rubber consumption goes into the tire industry. Tires consist of natural and synthetic rubber. Virgin rubber and oil are most important raw materials. Tires are being reused and recycled, but high-value recycling remains low (Saiwari, 2013).

Around 9 million 4-wheel vehicles have Dutch owners. This means that close to 36 million tires roll down the Dutch road. We assume that a new tire should last for at least 80.000 km, thus around 6 years. Consequently, around 6 million tires need to be replaced in the Netherlands each year. However, only a very small share of new tires are recycled (reclaimed or containing recycled material). In our case study we focus on increasing the share of recycled material in tires through de-vulcanisation. Vulcanisation is a chemical process for converting Natural rubber or Synthetic rubber into durable materials via the addition of sulphur at high temperatures. When subjected to mechanical or thermal stress or ultrasound radiation, the structure of the vulcanized ELT rubber is modified. The resulting material can be re-vulcanised or transformed into useful products. Ideally, de-vulcanisation would yield a product that could serve as a substitute for virgin rubber, both in terms of properties and in terms of cost of manufacture. It could replace up to 40% of virgin rubber. However, current use remains low, mainly because of technical constraints.

Figure 28-2**:** shows a highly-simplified structure of the supply-chain of tires. From the figure it follows that an increase in high-value recycling (i.e., increase in the recycled content of tires) will reduce the material inputs needed for the production of tires and it will reduce the waste flow from end-of-life tires. Some of the traditional uses of recycled rubber will, however also be reduced as a consequence.

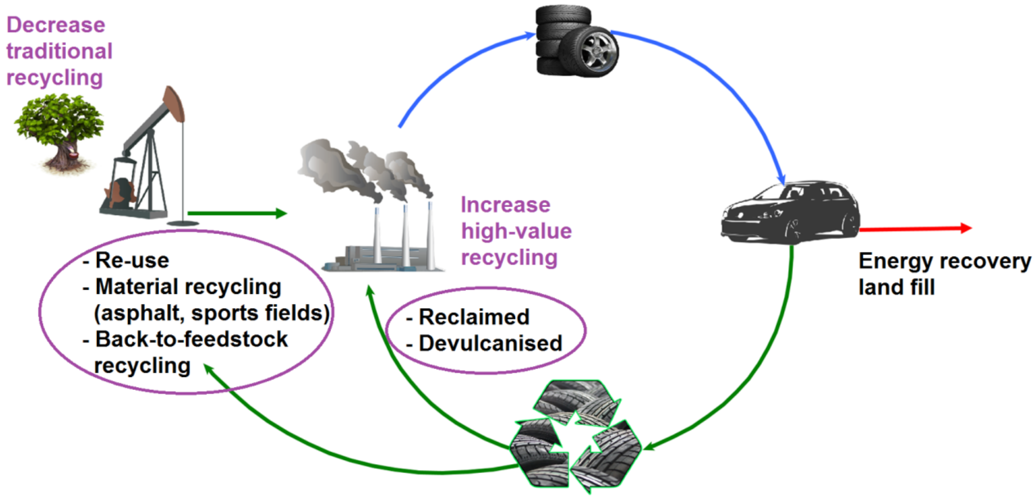


Figure 28-2: *A simplified structure of the supply-chain of tires.*

Circular economy within the tire business is not a new concept. For example, Michelin has been offering a tire-lease scheme for truck fleets for quite some time. Michelin also states that it is committed to increasing the recycled content in their tires. In our case-study we apply a broad definition of consumers, mainly referring to truck companies, and car-leasing companies.

Results

The “warm glow” effect or behavioural attributes in this case is interpreted as any product-specific factors which would lead a firm to systematically choose (or not choose) the circular product/service. For example, a possible “warm glow” effect could of course refer to a genuine concern for the environment or to a desire of the company’s side of being perceived as a sustainability champion within the industry. However, a positive “warm glow” effect could equally refer to worries about, for example, the impact of future regulation (e.g., mandatory standards for recycled content in tires) or, in the case of listed companies, to shareholder pressure over for example climate risks due to emissions from the transport sector.

Figure 28-3 illustrates the joint effect of a behavioural attribute, warm glow, and the intensity of preferences parameters. Varying the 'intensity of preference' parameter results in a 'fold bifurcation' and emergence of two alternative market long-term steady states: 'circular market dominance' and 'non-circular market dominance' which are separated by an indifference threshold (path dependency). This analysis provides a full portrait of the market phase and classify the long-term outcome based on the market instrument as well as consumer behavioral parameters. The diagram is partitioned into three parameter regions: unique steady state, ‘circular’ in which the ‘circular’ product dominates the market, ‘non-circular’ in which the diffusion of the ‘circular’ product fails, and dependent on the initial state. In the first region, there is a single equilibrium of the system that corresponds to a globally attracting steady state. In the other regions, the system has two stable steady states that can be distinguished as corresponding to a ‘circular ’or a ‘non circular’ steady state. The regions correspond to the situations that either the ‘circular’ steady state or the ‘non-circular’ steady state are globally attracting, or both are locally attracting.

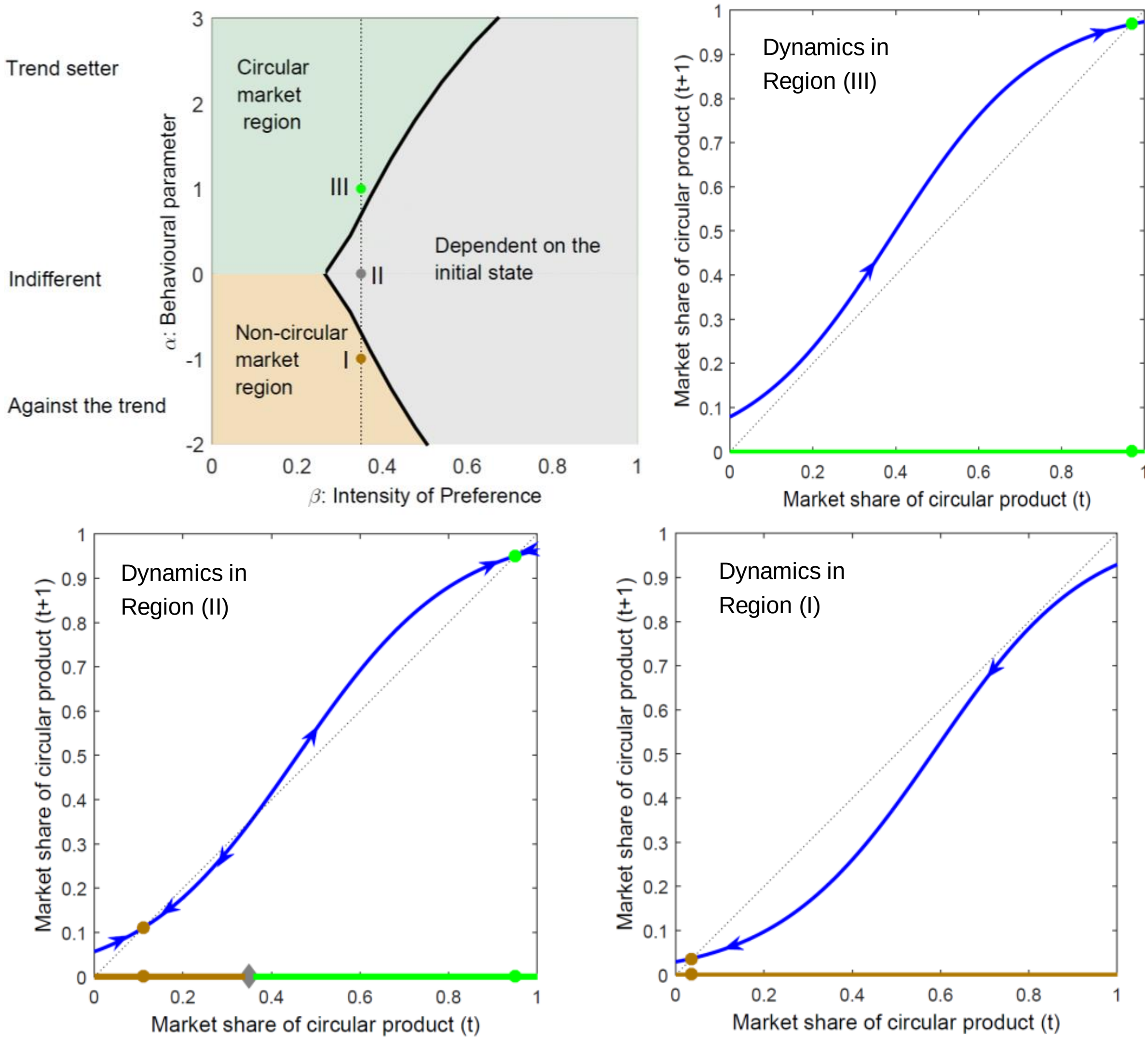
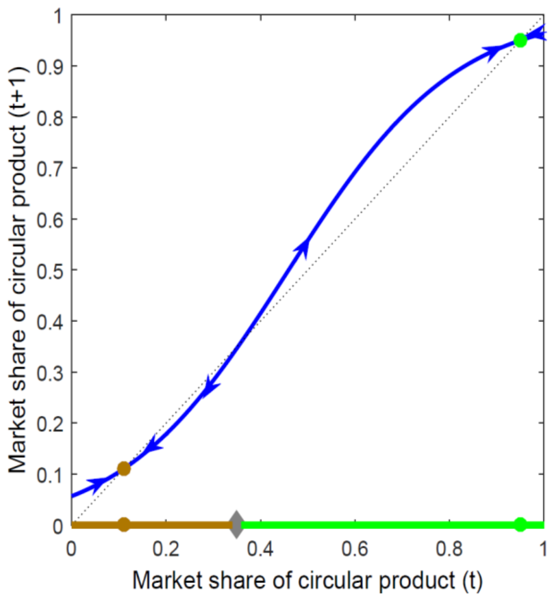


Figure 28-3: *Fold bifurcation curve (black) partitions the parameter space (α, β) into 3 regions with 3 different classes of transition dynamics.*

The Table next to Figure 28-4 illustrates the environmental and economic impacts of a change in preferences in line with Region II in Figure 28-3. In this case, both the 'circular' steady state and the 'non-circular' steady state are locally attracting, resulting in two alternative equilibrium market shares of recycled tires. All changes in material inputs and waste flows are measured as changes relative to actual material inputs and waste flows in the reference year (2013). In the 'circular' steady state, with a market share of recycled tires of 95%, use of raw material within the rubber- and plastic products sector are reduced by 38%, while the use of oil is reduced by 0.2%. Waste is reduced by 2.2%. The 'non-circular' steady state, with a market share of recycled tires of 11%, leads to a 4.4% reduction in the use of raw material and a 0.2% reduction in the use of oil. There is also a 0.2% reduction in the waste flow.



	Changes compared to the reference year %
Market share recycled tires	95.00%
Inputs (material used to produce tires)	-38.00%
Agricultural products (oil)	-0.20%
Destiny of end-of-life tires to	-2.22%

	Changes compared to the reference year %
Market share recycled tires	11.00%
Inputs (material used to produce tires)	-4.40%
Agricultural products (oil)	-0.02%
Destiny of end-of-life tires to	-0.26%

Figure 28-4: *Two alternative equilibria separated by indifference point: outcome depends on the initial level of adopters.*

Conclusions

In this paper transition towards a circular economy is modelled as a complex adaptive system using a heterogeneous agent modelling approach. The model is applied to the case of recycling of rubbers in the tire industries in the Netherlands for which a bifurcation analysis is performed. The resulting bifurcation diagram summarises the joint effect of the behavioural attributes of a consumer/firm and the intensity of preferences parameters. The diagram is partitioned into four parameter regions: unique steady state, market failure, high market uptake, and dependent on the initial state. In the ‘market failure’ region, characterised by low behavioural attribute and low intensity of preference transition dynamics steers the market to the ‘market failure’ state independently of the initial state. In the ‘high market uptake’ region – high intensity of preferences – the ‘circular product’ steady state is eventually reached, irrespective of the initial state. For markets in the dependent on the initial state region – market that are fragile and of medium to high ‘intensity of preference’ fall in this category – the outcome of transition dynamics is dependent on the initial state: if the number of initial adaptors it is sufficiently high, the ‘circular market dominant’ steady state is reached, otherwise the ‘market failure’ results. The two regions in state space are separated by an indifference point.

29. DESTROYING THE CIRCULAR ECONOMY IN ORDER TO SAVE IT - THREE CHALLENGES FOR ACCURATE INVESTMENT DECISIONS THAT HAVE EMERGED IN RECENT YEARS

Elmer Rietveld ✉, David Peck

Abstract

The circular economy concept, as presented by the Ellen MacArthur Foundation (EMF), together with many other organisations, could be threatened by opportunists and fantasists. In essence, anyone with an aversion to seek to scientifically clarify the present state of the planet, society and economy. Existing approaches might therefore be in need of destruction (and subsequent rebuild) or modification.

The eloquent promotion of the Circular Economy concept by the EMF has undoubtedly captured the attention and imagination of many business leaders, entrepreneurs, researchers, students and policy makers. Many organizations highlight and showcase their interest in a transition to a circular economy, which itself poses the risk of the concept being a victim of its own success. If everything is deemed important, then nothing is. What's worse: a scattered focus takes away the awareness of the 'wicked' 21st century challenges that are at the heart of the circular economy.

This paper aims to discuss three challenges to the circular economy framework that can be considered to be the most threatening to the survival of the circular economy going forwards.

Firstly, there are significant limitations concerning the available data in the public domain. Databases lack the level of detail, geographical coverage and accuracy needed. This means that in decision making, theoretical, conceptual thinking takes the place of verifiable fact-finding.

Secondly, there is an absence of an answer to the question: 'how should we define circularity, even if we did have the right data?'. Although propositions for indicator frameworks are available, (e.g. "measuring circularity" report of the EMF, 2015) there is no agreement for a framework amongst experts. The very term 'circular economy' is poorly defined in scientific literature and the range of interpretations from different stakeholders makes constructive debate and consensus building very difficult.

Thirdly, even if we could develop a clear definition of circularity, we have an inability to establish a framework of welfare optimization. We need to consider and account for corporate confidentiality, privacy needs, operationalise negative externalities and incorporate the nature and pace of disruptive innovations. The inability to do so has resulted in an unbalanced and suboptimal allocation of public resources, aiming for solutions that too often do not harmonise with the ideas based on a circular economy concept.

Manuscript

Over the past few years, the concept of the circular economy, as presented by the Ellen MacArthur Foundation (EMF), together with many other organisations, has proven to be an enticing and exciting prospect for governments and businesses to think about their material use and corresponding level of closed loop activity. The concept recognizes both the previous work of numerous people over many decades and it appreciates economic reality as perceived by various economic agents. This is the circular economy that needs to be preserved, even saved.

The rapid and sometimes overwhelming attention for the concept of circular economy has inevitably brought conflicting (and sometimes misguided) interpretations, numerous connotations and opportunists seeking advantage from an association with the circular economy concept. It is a normal tendency of people to question, dilute or evade any concept, particularly when trying to grasp the complexity and intricacy surrounding unsustainable resource use. Questioning is the cornerstone of scientific advancement. But allowing the unscientific discrediting of comprehensive concepts, consciously or unconsciously, like the circular economy, has the potential to be far more dangerous to society than, for example, international terrorism. Therefore, the unscientific circular economy is the concept that needs to be destroyed.

This paper will, due to the scope of the topic, refrain from an extensive analysis of the circular economy concept, which is so generally embraced as a perspective-to-act for businesses, governments and households. The planet needs to be able to provide a basis for meaningful human activity. The inconvenient facts and trends on resource use, pollution, depletion of natural capital, inequality, bio-diversity loss and consumption are part of virtually all introductions of work on the circular economy. At the same time these aspects can unfortunately currently only play a minor part in investment decisions. These decisions are measured in market prices and corresponding business-cases. It is not without irony that the appeal of the circular economy to many seems to be that it focusses on innovative business cases and corresponding investment decisions, not on goals based on environmental or societal externalities.

This paper claims that in order to be remain a significant analytical framework for sustainability, the circular economy approach has to address three main challenges.

The identified challenges are the result of completed projects from recent years that analyse circular opportunities all around Europe. Apart from the EU as a whole[18], countries like Denmark[19], the Netherlands[20], Sweden[21], Belgium[22], France[23] and the UK[24] have conducted macro-economic assessments. Germany already has a long standing track-record with many assessments[25] at a federal state level. Cities like Glasgow, Rotterdam and Hamburg, are examples that have conducted circular assessments, actively linking Material Flow Analyses (MFA) to opportunities for a more circular economy transition. After all, the scope of the classic

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[18] Cambridge Econometrics/Bio IS/European Commission, Study on modelling of the economic and environmental impacts of raw material consumption, 2014.

[19] Ellen MacArthur Foundation, Delivering the circular economy toolkit for policymakers, 2015.

[20] Ton Bastein, Elsbeth Roelofs, Elmer Rietveld, and Alwin Hoogendoorn, Opportunities for a circular economy in the Netherlands, 2013.

[21] Anders Wijkman and Kristian Skånberg, The Circular Economy and Benefits for Society, Interim Report, Club of Rome with support from MAVA Foundation and Swedish Association of Recycling Industries, 2015.

[22] Federale overheid (economie en VVVL), België als Voortrekker van de circulaire economie, 2014.

[23] Adrian Deboutière and Laurent Georgeault, Quel potentiel d'emplois pour une économie circulaire?, 2015.

[24] WRAP, Employment and the circular economy: Job creation in a more resource efficient Britain, 2015.

[25] Ministries of the Environment, Forests and Consumer Protection and Economy, Commerce, Agriculture and Viticulture. The Circular Economy State of Rhineland-Palatinate, 2008.

MFA is too narrow to identify a full range of circular opportunities[26]. Finally, enterprises ranging from SME's to multinational in size, have set out to base investment decisions on the quantified assessments of potential circular business cases.

A range of important questions therefore need to be addressed. How can we assess the level of circularity of companies or client portfolios? How should we account for external effects of economic activities? Is financial compensation, or delay of stringent legislation, acceptable to allow established enterprises to catch-up with Best Available Technologies (BAT)? How is Research and Development and Innovation (R&D&I) policy related to the growth of circular economy based approaches? How can we prioritize between different feedback loops in public investment decisions? Considering the three challenges discussed in the remainder of this paper, should prove useful in addressing these questions.

The first challenge: we don't know what goes on in the economy

"We want to build, but we don't have the bill of materials"

Publicly available data is not keeping up with the requirements for evolving theoretical concepts[27]. Databases designed for macro-economic analysis or environmental compliance lack a finer level of sectoral detail, product detail, geographical coverage and accuracy. Moreover, the databases are often made sub-optimal by regulations regarding privacy and commercial confidentiality. When it comes to decision support systems, concepts are usually referring to the need for verifiable facts, without addressing the need to overcome the limited resources and capabilities to gather these facts.

Much useful data is, however, already available. Initiatives such as the Ecoinvent database are a good example of a community gathering and filing knowledge over time in order to capture relevant information about production processes. Other examples are the Materials Data Management Consortium (MDMC, focused on energy, aerospace and defence) or the PEP eco-passport. (electrical, electronic and building installations products). The problem that these databases face is that they are bottom-up, user oriented. This means that they could easily overestimate certain impacts as they are not accurately balanced to match the size and activities of the global economy[28]. Furthermore, these systems still rely on voluntary contributions, and are sometimes not generally accessible or independently verifiable.

Arguably, circular research areas where the lack of data is most evident, relate to value chains. Whilst the development of data is to be encouraged, in practice it is often limited by a shortage of available data[29]. This moves the challenge to private sector organisations. Corporate purchasers often don't know where the materials in their purchases come from or what happens to their products and materials beyond the first tier. This is both an upstream supplier or downstream customer issue[30].

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[26] Leonardo Rosado, Samuel Niza, and Paulo Ferrao, A Material Flow Accounting Case Study of the Lisbon Metropolitan Area using the Urban Metabolism Analyst Model, 2014.

[27] Michel Moucharta, Jeroen V.K. Rombouts, Clustered panel data models: An efficient approach for nowcasting from poor data, 2005.

[28] Bo Weidema, the ecoinvent database - linking to the global market, 2010.

[29] Ellen MacArthur Foundation, Circularity indicators, 2015.

[30] Bruno S. Silvestre, Sustainable supply chain management in emerging economies: Environmental turbulence institutional voids and sustainability trajectories, 2015

The fact remains that many private investors seem to know what goes on in markets, and apparently do not suffer from lack of essential information. But they probably rely on either tacit knowledge or heuristic decision making that offers no solution to decisions to be made relating to public capital.

The second challenge: we don't know how to measure ourselves

"We want to build, but even if we would have the bill of materials, we wouldn't have the construction plan"

There are many ways to express a circular economy. Is circularity captured by waste prevention, recycling rates, avoiding depletion of social or natural capital, use of circular services, production without overall negative externalities, product lifetime extension, increase of functional units delivered by products or some other metric?

A part of the problem lies in acknowledging market value destruction as a result of a more circular economy. For example, original equipment sales (new product sales) could be cannibalised by the sale of a remanufactured product. At an extreme, if a company did not change their existing business model, a longer lasting product introduction could destroy the business. Only very recently, the problem of probable ambiguous attitudes of businesses that see their market share challenged, was addressed[31]. This relates to the commonly held view that one person's loss is the other person's gain. The global nature of circular means that the fact that a "loser" may be on the other side of the world. This receives little attention in assessing the benefits and challenges of a more circular economy. These elements can be captured by Computable General Equilibrium (CGE) models with ample geographic coverage (preferably a Multi Regional Input Output model (MRIO) on at least a national level). Outcomes of these applications receive mixed acceptancy responses[32], are costly, very complex and suffer from the previously mentioned challenge relating to data requirements.

Initiatives are emerging that try to create a benchmark on the circular economy, in order for companies to measure themselves against competition. Various self-assessment tools for businesses on resource efficiency exist. To carry authorized status, the tool that is under development by the EU, should be acknowledged by all stakeholders involved (users and developers). Among recent work supported by the EMF, is a method to measure the circular economy. The proposed method requires a Bill of Materials (BoM) statement (akin to a resource passport), an expression of standardized functional units ("what do I get out of a product") and expected lifetimes of products. Implicitly, this involves knowledge and information from the field of environmental economics / industrial ecology, the LCA perspective should offer the possibility to internalize any negative impacts on the planet. Just as with the CGE models, acceptancy and data availability often limits these possibilities.

The third challenge: we don't know what's good for us

"We want to build, but even if we would finish construction, we wouldn't know what to do with the result"

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[31] Ellen MacArthur Foundation, Growth Within: A Circular Economy vision for a competitive Europe, 2015

[32] F.J. Andre et al, Designing Public Policies, Lecture Notes in Economics and Mathematical Systems 642 Berlin Heidelberg, 2010

The list of potential investments that could drive forwards the transition to a more circular world is extensive. However, an independent overview of all possible circular economy transition actions still needs to be provided. Such circular investments can come in many forms, not only requiring economic or social capital. R&D&I spending, policy development costs, law enforcement costs, taxation reforms, insurance etc. can also be regarded as investments.

Furthermore, merging public investment up with private investment in joint programmes makes the determination even more difficult. The fact is that many innovations take place in the private sector where companies, for obvious commercial reasons, do not disclose details to the general public. This makes it difficult to create meaningful scenarios about ground-breaking (or even disruptive) innovations in, for example, the fields of material science or product design. The result is that recent studies on optimal circular investments have an unbalanced focus on mandates from public authorities, with a subsequent lop-sided allocation of money to the recycling feedback loop. Governments are, after all, usually responsible for waste treatment. Product design, shared use/reuse, repair and remanufacturing are elements of a Circular Economy mostly driven by responsibilities from businesses and desires from final consumers.

The never-ending race in the field of technological developments is an consistent aspect of human activity. This race has in turn led to the challenges discussed in this paper. One of the foundations of investment into new technological developments relates to the structure and mechanisms of intellectual property protection. The many legal disputes related to Intellectual Property (IP) demonstrate that a clear definition of ownership of ideas is difficult to achieve. Moreover, it is during periods of emerging economic (and technological) growth that IP rights are more consistently violated. Empirical evidence throughout recent centuries supports this view.[33]

Individuals active in established private enterprises are likely to proactively guard their business model and market share. It is often rooted in an individual's and organisational set of Key Performance Indicators (KPI's). This challenges the remarkably widespread assumption of the "homo economicus": the rational and informed economic agent i.e. human being. Creative destruction, risk aversion, shifting consumer surplus, path dependencies are relevant examples of aspects from the field of (behavioural) economics that challenge the ability of people to be "economicus". Recent findings demonstrate the confines of the "economic agent" which is supposed to be rational and fully informed.[34] This explains why innovation is obstructed on many levels in complex networks. A simple question is helpful (as counterbalance to the convolution presented in this paper): 'what would you do if you see market shares challenged, diminished, or even decimated?'. The aspects explored above explain at the same time the consistent inclination to ignore global geographical aspects. Westernized countries need to be able to take the view from emerging economies and regard reduced demand for their products as a valid cost of a circular economy transition for countries with a strong domestic export.

There is historical precedent for such holistic thinking around resource use, the role of the state, private sector and society. At times of conflict countries and even alliances of countries have rapidly moved to a high level of resource use understanding and action. The example of Britain in World War II provides a useful case study. The import supply of timber fell

[33] Ha Joon Chang. 23 things they don't tell you about capitalism, 2010.

[34] Rolf Wüstenhagen, Emanuela Menichetti. Strategic choices for renewable energy investment: Conceptual framework and opportunities for further research, 2012.

dramatically following the outbreak of hostilities. As a result of bombing, marriages and births the demand for furniture was high. The British government introduced tight material supply, furniture design, manufacture and distribution controls as well as demand controls through permits and rationing. Those who needed furniture were supplied. This case study shows what should be avoided (not least a world war!) but it also shows how in extreme circumstances ‘business as usual’ and the power of markets can be adjusted and the role of governments and society in a global supply system is creatively considered.[35]

Facing challenges by recommending solutions

The three challenges presented in this paper do not intend to severely simplify and limit the contribution of a transition to a Circular Economy. It tries to identify the greatest challenges faced by the whole of society after the successful the kick-start that the EMF and others have unleashed. Such a loss of drive could lead to cynicism that in turn would destroy the value that a circular economy can provide for society and the planet. By demanding attention towards such challenges and distractions we create room for real progress.

Tax reforms seem particularly appealing. A tax shift from labour to natural resource use and consumption is regarded by some as an inevitable development in fiscal policy. Indeed it presents a return to a historic form of taxation. It requires the need to express advantages and disadvantages both on a company level as well as on a national level. The Ex’tax Project[36], executed by the “big four” international accounting companies, is an example of an attempt to quantify the effects. Examples of measures evaluated are tax benefits to businesses that report transparently, introduce a pre-cycling premium, B2B compliance requirements, etc. The outcomes, using the current data, seem promising, but the results also hint that better, i.e. more detailed data, could reveal “rebound” effects that would limit possible outcomes. This research question is left unanswered, given the challenges one and two, as described above.

The removal of legal barriers (at least, those that are undesirable from a societal cost-benefit point of view) is an example of public scope-of-action. For instance, the reform of international waste legislation to make cross-border recycling possible and profitable is expected to have positive balance of effects. But legal constructs are not created without reason. The origin of the legislation needs to be assessed from a range of perspectives in order to gain support for changes in specific laws.

Although some options in changing taxation and legislation require further research, projects in recent years have resulted in clear aggregated recommendations.

Related to the 1st challenge, the mandate and resources of institutions that gather public data, should be revised, taking into account the needs of circular researchers, policy makers and entrepreneurs. An unoriginal recommendation perhaps, but a valid one all the same.

Relating to the 2nd challenge, business accounting practice needs to be revised in order to incorporate expressions of value that lie outside direct market prices. Such innovations should be done carefully and should have the involvement and consent of all relevant actors. After all, while a circular economy is about systems thinking, the combination of design and business models and the effective flows and feedback loops, the creation of an analytical methodology

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[35] Philip Pinch and Susanne Reimer, Nationalising local sustainability: Lessons from the British wartime Utility furniture scheme, Geoforum 65 (2015) 86–95.

[36] Deloitte, EY, KPMG Meijburg and PWC, New era new plan, 2014.

and tools requires a more narrowly defined scope[11]. Taking the monetary value "circular services"[37] as point of reference (design, leasing, specialised trade, repair, remanufacturing, recycling, etc.) could be a welcome addition to material oriented data.

Related to the 3rd challenge, major efforts should be invested to incorporate elements of welfare economics into societal cost-benefit assessment standards. A huge volume of work on shadow prices exist, and they will need to be made comparable and applicable. This could provide a strong basis for governmental intervention, which requires efficient, efficacious and legal grounds along with political engagement.

Synopsis

This paper attempts to identify important challenges in the long term circular economy transition and the analytical framework needed to do that.

Alas, facing or even meeting these three challenges will by no means guarantee a sustainable way to live on our planet. We could provide a list of hundreds of challenges and still not cover all obstacles in achieving a more sustainable society. Meeting these challenges will not even guarantee analyses on circularity to capture benefits of Research & Development & Innovation (R&D&I), development of (equally distributed) social capital and/or respecting the planetary boundaries. At the same time, economic theory, especially welfare economics, struggles to provide generally accepted frameworks to do this. If they do not, we cannot expect the circular economy concept and current actors to carry that weight for them. Individual utility of products expressed in market prices is hard to measure, let alone collective utility or effects that do not have a monetary market price.

Challenges plentiful or not, it would be not only frustrating but disastrous to see the circular economy concept being discarded in the future as just another hype. That would not in any way make life on this planet more sustainable.

On the upside, addressing the three challenges would compel private stakeholders to act. We would probably deem it irresponsible for decision makers within SME's and multinationals to act upon social responsibility factors alone, or a improved planet or unsubstantiated claims about market share or innovation. Investments that jeopardize the future of a business are, in themselves, unsustainable. If circular assessment frameworks are tailored to support economic sustainability, we are all on the right path.

If the wicked challenges of a transition to a circular economy in the modern world can be reduced to only these challenges, there would be much reason for optimism. Nevertheless, meeting these challenges would be a solid start in saving the circular economy as concept that will stand the test of time – long into the future.

[37] Ton Bastein, Elsbeth Roelofs, Elmer Rietveld, and Alwin Hoogendoorn, Opportunities for a circular economy in the Netherlands, 2013.

30. CAN A CIRCULAR ECONOMY PROVIDE A BACKBONE FOR A MORE SUSTAINABLE, FAIR AND SOCIAL MARKET ECONOMY IN EUROPE?

Ludwig Hermann ✉

Abstract

Most of us would readily subscribe the statement that our planet needs a transition towards a circular economy decoupling raw material use from economic growth. In a circular economy deserving this label, pressure on our earth's natural resources will definitely be reduced. But - what about the economic development? Will political and economic decision makers really manage to return to relevant economic growth rates or will the ecological footprint be reduced because of a constantly stagnating or even contracting economy? If a stagnating economy is the inevitable price for more sustainability, who will pay the salaries and pensions of those who already live in precarious conditions? According to the EU employment statistics, 35.5-53.8% of the population aged 15-24 was jobless in Portugal, Croatia, Italy, Greece and Spain in July 2014.

This paper raises many questions and has no real answer. In the economic areas overseen by the author, technologies for processing minerals and metals as well as energy conversion, is conceivable as a symbiosis of economic growth and circular economy: mining and processing of natural resources can be replaced by urban mining and processing; fossil energy carriers can be replaced by renewable resources. The market, however, will not be a driver due to mining and processing of renewable resources being currently more expensive than processing ores and consuming fossil fuels. This will not change, as long as the economy is not picking up. Without a strong demand, prices for commodities tend to go down and new approaches may be even less competitive in the foreseeable future than today.

The paper aims at fueling the discussion about the appropriate economic and societal framework and the research needed to come to a realistic and convincing judgment on the potential of the Circular Economy as a pillar for a fair and sustainable social market economy in Europe.

Keywords: circular economy, sustainability, growth, decoupling, raw materials

Introduction

In a world of finite resources, circular economy is not an option, it's a must. The big question is: can we adapt the European economy to circular principles without major disruptions, without sacrificing our welfare systems and without excluding ever more citizens from participation in the amenities of our society?

The recent study "Growth Within: A Circular Economy Vision for a Competitive Europe" authored by the Ellen MacArthur Foundation and the McKinsey Center for Business and Environment comes to the conclusion that exploiting all potentials under a Circular Economy approach could yield accumulated benefits of up to € 1.8 trillion per year triggering additional 7 percent points GDP growth compared to the business as usual scenario by 2030. The study investigated three systems covering the human needs of mobility, food and housing, representing 60% of expenses of European households and 80% of resource use.

The following pages contain a critical evaluation of selected findings and conclusions from the perspective of a mid-size European company with its main source of revenues coming from technologies and facilities for processing mineral and metals as well as converting energy.

Definitions

Circular Economy in the study is defined as an economy providing added value without consuming primary (finite) resources. It is based on the principles of i) preservation of natural capital, ii) optimization of resource yields by circulating materials and products as well as iii) avoiding externalities, i.e. negative impacts on air, soil and water as well as on animal and human life. From our point of view, a Circular Economy must equally address the principles of Sustainable Development, originally defined as "*the kind of development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (Brundtland Report, 1987). In a recent book, Jeffrey Sachs describes, Sustainable Development as "*recommending a holistic framework, in which society aims for environmentally sustainable and socially inclusive development, underpinned by good governance*" (Sachs, 2015).

Political and societal framework

Resource efficiency and sustainable growth has been stipulated as a strategic goal for Europe, evidenced by a number of Communications of the European Commission such as Europe 2020 [COM(2010) 2020 final] and Roadmap to a Resource Efficient Europe [COM(2011) 571 final]. The Roadmap outlines the pursued final state of the EU economy as follows:

The Vision: By 2050 the EU's economy has grown in a way that respects resource constraints and planetary boundaries, thus contributing to global economic transformation. Our economy is competitive, inclusive and provides a high standard of living with much lower environmental impacts. All resources are sustainably managed, from raw materials to energy, water, air, land and soil. Climate change milestones have been reached, while biodiversity and the ecosystem services it underpins have been protected, valued and substantially restored.

Most of us could agree with the targeted state and following the roadmap, EU member states should be on the pathway towards achievement of the objectives. In contrast, the state and directions of European policies and economies show only few indications for currently being on the right pathway, decisions and measures rather point to the opposite direction. Some examples:

- Whereas climate protection policies require phasing out fossil fuels, the IMF has recently estimated externalities (called direct and indirect subsidies) of fossil fuels in EU member states at € 330 billion per year. These include the non-functional CO_2 certificate market allowing free of charge, high risk and costly externalities such as global warming beyond the acceptable boundaries of 2°C (IMF Direct, 2015).
- Whereas policy-makers pretend penalizing pollution and providing incentives for sustainable use of resources, European environmental taxes (€ 300 billion per year) have dropped as a share of GDP and are - coincidently - just compensating the externalities from fossil fuel combustion. 18 member states have cut environmental taxes and only 5 have increased them from 2000 to 2012.

- Whereas the apparent objective is creating jobs and reducing unemployment, EU27 in 2012 collects 51% of tax revenues from labor and social contributions, 22% from consumption, 21% from capital and profits and only 6% from taxes on energy, transport, pollution and resource extraction.

Most studies on the Circular Economy point to the positive employment effect but so far no clear evidence has been produced with regard to the origin of this effect. If Europe is saving € 1.8 trillion of “material” expenses until 2030, a significant economic contraction may be the consequence. Big data and apps will not automatically compensate for the job losses in traditional, material processing industries. The promised land of job and value creation by new technologies facilitating information, the internet of things and cloud platforms for peer-to-peer sharing mobility and shelter may turn out as an illusion: think of companies like WhatsApp serving 450 million customers with a permanent staff of 55 when it was sold for USD 19 billion to Facebook (Reich, 2015). How many people will enjoy permanent jobs sustaining a decent standard of living if the Circular Economy does not involve real world growth and elevated social standards?

Despite the currently unsupportive political and societal framework, the transition towards a Circular Economy is the best option we have for getting our virgin material consumption, emissions at large and global warming, eutrophication, acidification and other impacts back on a sustainable track to tolerable values within the global system boundaries. Indeed, there are signs that policy-makers in a few EU member states and some policy officers in the European Commission have recognized the opportunities and challenges and adopted a set of favorable policy measures facilitating phosphate recycling. P-recycling could serve as a case study for similar transition activities once the recovery policies – currently subject to parliamentary and stakeholder proceedings in Switzerland and Germany – will be enforced in the course of 2016.

A world of opportunities and threats

In a Circular Economy, we have to get more value from existing and future stock. Getting more value means robust design for longer use, repairing, re-vamping and finally recovery of the value components/substances for recycling. Most of these steps will require more, better trained and skilled staff and certainly more working hours than replacing the original equipment – regardless of being a refrigerator, electronic device or a car.

We already have technologies for recycling nutrients, metals and minerals from waste material, even if not having fully exploited the value chain potential of – for instance – sewage sludge or municipal solid waste. We have processes to recover value materials from ash – nutrients as well as metals - and could close the value chains within Europe for a number of critical substances. If we adopt the circular pathway, the economy will be growing because recycled substances and products will be more expensive than virgin materials due to being more regional, smaller scale and more labor (process) intensive because of higher recycling material diversity, impurity and pollutant levels. Decreasing the taxes on labor and increasing taxes on primary materials could create a level playing field but nothing indicates that the European economy may take this direction: on the contrary, we have seen increased labor taxes to cut budget deficits but we have not seen new taxes on primary raw materials.

If we take the examples of phosphorus or zinc recycling, recovery processes use similar flow sheets and can even produce cleaner products with lower environmental impacts, albeit with more process steps including physical and chemical separation technologies. Consequently recycled concentrates tend to be more expensive than concentrates from mineral resources, even if their origin is waste and landfill costs are avoided. A transition to the Circular Economy route will require either subsidies or must become a legal obligation. Switzerland and Germany are obviously adopting the second option.

The author shares the main conclusion of the study – a smooth transition to a Circular Economy offers opportunities for growth and benefits for the environment. Eventually, it may become a backbone to the single market with higher environmental and social standards. However, if not firmly steered by the political decision makers, it may turn out as job killer and increase social inequality. In a non desirable scenario, Europe may achieve its sustainability objectives but large parts of its population may end up as a kind of urban subsistence farmers.

Circular Economy implications for a minerals and metals processing company

The Ellen MacArthur Foundation / McKinsey study translates the three principles of the Circular Economy into six business actions, the so-called ReSOLVE framework: Regenerate, Share, Optimize, Loop, Virtualise, and Exchange. It suggests a number of areas to be investigated by companies assessing the individual potential of the Circular Economy. For Outotec the implications could look as follows:

(1) Business opportunities. In a Circular Economy the engineering, assembling and commissioning business models would be transferred from ore bodies to urban mines, particularly during the development and implementation of a recycling infrastructure in Europe. If the structures should be in place by 2030, it could trigger a veritable boom. In turn, operating processing and manufacturing plants beyond the planned life cycles would create additional service and maintenance opportunities.

(2) Recoverably value from products sold for the last 5 years. Processing plants and equipment sold by Outotec usually are operational for decades, hence no recovery potential exist within 5 years from the date of selling.

(3) Increasing lifetime and utilization of products. Lifetime and utilization can be very long and can be even increased. Shutting-down a minerals & metals processing facility frequently follows the logic of cheaper energy or labor available in other global regions and only in second and third place come exhausted ore bodies as well as outdated processes and equipment. In a truly Circular Economy, shutting-down services would encompass recovery of building and steel construction materials and complete remediation of the construction site – another business opportunity.

(4) Products designed for take-back. For processing plants and equipment a take-back design and strategy is not easily conceivable. Value from steel and metals is recovered if a plant is shut-down. Brick and mortar construction material is frequently not recovered and has still potential – mainly for local use.

(5) Similar threats to our business as to power supply industry. If large processing plants located close to ore bodies were replaced by small processing facilities in an urban environment companies which do not adapt to the new scale and downscale their technologies and plants could be pushed out of business. The company strategy needs to be adapted to the scale of decentralized, urban recycling plants.

(6) Standardizing and sharing non-competitive material and infrastructure. This move is hardly conceivable due to the challenges involved in productization, i.e. the

standardization of components within the company departments and processing plants. Yet this process is underway and more standardization is expected in the years to come.

(7) Environmental footprint improvement if products circulated. Circulating products is likely to improve the environmental footprint of our plants for customers. We are designing and engineering our plants to recover and recycle as many products as technically and economically feasible. Still higher recycling rates could be achieved if supported by a legal framework demanding continuous improvement.

(8) Circularity reducing exposure to raw-material price fluctuations. Outotec is only exposed as far as steel and construction materials are concerned. In turn, customers are exposed to raw-material price fluctuations. The question is, however, if price fluctuations came to a halt in a Circular Economy?

Nutrient recovery as a test case for implementing the Circular Economy

The Circular Economy may indeed change the game for nutrient recovery technologies and much more, it may trigger substantial investments and economic growth. It may, if some remaining barriers are removed.

Currently, nutrient recovery is only implemented if recovery technologies involve accountable operating cost reductions. This condition is confined to struvite crystallization in Enhanced Biological Phosphorus Removal sewage plants which accomplish the cost reduction target regardless of selling the struvite crystals at market prices or giving them away for free.

- All other nutrient recovery processes that have reached technical maturity require the amendment of the current regulatory framework and possibly even a change of prevailing paradigms. In particular the following regulations deserve a review:
- A wider interpretation of official duties allowing or even encouraging public officers to undertake activities beyond the purification of wastewater. In some countries, for instance in Germany, recovering nutrients may be considered as a statutatory offense as long as not belonging to the official duties of a wastewater treatment plant (WWTP). The reviewed German Sewage Sludge Ordinance will, however, change the game due to including P-recovery as an integrated part of wastewater treatment.
- A paradigm change as far as system boundaries of a WWTP are concerned – the circular economy approach of treating waste water as a resource must include recovery and recycling of the valuable substances. This includes a review of commercial and in particular VAT related provisions – currently it is not clear how a Dutch public utility can undertake commercial activities and selling products without hampering its statutatory (VAT) tax privileges. In this area, however, modified business models seem possible which could bypass the difficulties.
- In case of public infrastructure investments, the focus must shift from (low) investment (CAPEX) costs to (low) life-cycle (OPEX) costs – a principle that so far has only scarcely been applied. If only CAPEX is considered, innovative circular solutions must frequently be sacrificed to stay competitive. Circulating energy and materials require more processes and – consequently – more equipment increasing the investment cost. In the long run, the higher CAPEX are usually compensated by lower OPEX due to lower energy and materials consumption, at least for plants with higher capacities.

Consequently, the implementation of the Circular Economy requires a fundamental, political, societal, ecological and economic review of statutory tasks assigned to utilities and their operating framework. A transdisciplinary process involving stakeholders from science, practice and regulatory bodies may be most appropriate for this task.

If the European society as a whole really introduces the Circular Economy and develops an adequate framework as outlined above, nutrient recovery by utilities can become an early mover and a success story. If, in turn, it's only a new headline for business as usual, nutrient recovery will remain a niche activity and only be implemented if it is improving the operating costs of the facility.

Conclusions

An evaluation of what has been achieved in the transition towards the desired state of the European economy – with rather precise short-term goals in *Europe 2020* - limited progress is actually noticeable for P-recovery and other recovery and recycling technologies. This is at least partly due to the lack financial incentives, supportive taxation or a binding regulatory framework.

If EU member states seriously implement the Circular Economy pathway, a number of underpinning measures have to be taken, in particular evaluating the environmental footprint of new vs. the traditional practices and the impact on countries outside Europe. If Europe wants to avoid negative repercussions on the economies of raw material supplying countries, compensatory policies need to be implemented in those economies.

At least two European countries have already decided to provide a binding regulatory framework for nutrient recovery: Switzerland and Germany. Indeed, publication of the corresponding acts has immediately triggered enquiries and discussions. Other countries like the Netherlands, Belgium and Denmark have more focused on farmyard waste abating its impact on soils and water bodies by limiting the volumes of manure allowed for spreading on cropland.

In Switzerland, Germany, the Netherlands, Belgium and Denmark we already see the economic impacts outlined above, albeit with a limited volume and due to covering only one, relatively small business sector. If the train continues moving in the right direction, if other critical materials will be addressed with a similar approach and if more countries and even all EU member states would join the initiatives – the EU has determined 20 critical raw materials which could be a first target for implementing the Circular Economy - we will see a real environmental and economic impact in terms of GDP growth and employment.

31. TOWARDS RESPONSIBLE PROSPERITY: PROGRESSING A CIRCULAR ECONOMY IN AUSTRALIA

Elsa Dominish ✉, Nick Florin, Damien Giurco

Abstract

In China, Japan and Europe circular economy concepts are being adopted as a mechanism for utilising resources to support long term economic, social and environmental benefit. Australia’s unique economic environment will affect the way circular economy concepts are implemented to build responsible prosperity. To date, the circular economy concept is yet to achieve a transformative effect and a new local narrative is needed to promote the benefits in the context of the current economic circumstances, as an extractive economy. Based on a review of international initiatives and discussion with stakeholders, the key enabling factors for progressing circular economy in Australia have been prioritised. Awareness raising and building networks were identified as most achievable to create change in the short-term and strong policies including regulations and targets, alongside innovation in business models, were identified as having the most impact. A coordinated and collaborative effort across all sectors and stakeholders will be required to successfully progress circular economy in Australia.

Keywords: circular economy, resource productivity, innovation, policy

Introduction

The concept of the circular economy is gaining major international traction as a framework for promoting an increase in resource productivity. This means using resources, including materials, energy, water, and knowledge more efficiently to capture new economic value and to avoid adverse impacts on the planet and people. It is important to be mindful that it is impossible to reach fully circular flows of resources in the economy, due to physical and technical constraints. At the same time, while current economic growth is linked to rising resource consumption, reusing resources can only meet part of current and future demand. In promoting a circular economy an emphasis on sufficiency and new modes of consumption that reduce demand is important for achieving sustainable outcomes and responsible prosperity (Florin, Madden, et al., 2015).

Diverse conceptualisations of the circular economy are emerging across different countries, driven by unique social, environmental and economic situations. Due to scarcity of land, resources and energy, as well as high capacity for innovation, Japan has been a frontrunner in implementing strategies for a sound material society. Europe has also been in leader in circular economy, driven by land scarcity for managing waste, resource security and promoting sustainable economic growth. China has adopted circular economy concepts as a sustainable development strategy, as the resource shortages and high levels of pollution resulting from rapid industrialisation began to limit future economic growth.

The ideas of circular economy have only entered the Australian discourse comparatively recently to the countries above. As Australia has an economy where exports are based heavily on resource extraction industries, it has a unique political and business environment that will influence the implementation of circular economy concepts. As these industries are reliant on international demand for resources and are highly emissions intensive, Australia’s economy is particularly vulnerable to changes in the global market and future carbon constraints. This is even more pronounced as Australia's key trade partners including Europe, China and Japan are actively promoting the idea of circular economy, so Australia risks being left behind.

In this paper we provide an analysis on how Australia could implement a circular economy. by looking at the actions taken by China, Japan and Europe, and comparing the political and business environments, key enabling factors are identified that are important for implementing circular economies. With refernece to the current policy and business environment in Australia, and the initiatives that are currently contributing towards a circular economy, we can see which of these enabling factors are emerging in Australia. Based on targeted discussions with key stakeholders in Australia, the paper concludes by offering a prioritised list of key factors that establishes the next steps towards promoting resource productivity within the circular economy as a theme of national importance.

Conceptualisations of circular economy

The implementation of circular economy concepts has been very different across Japan, China and Europe due to different political and business environments. All have a strong focus on regulation at a regional or national level. In China a top-down approach has focused on regulations, cleaner production, industrial ecology, waste management and developing new technologies, but with less emphasis on education or awareness raising. In Europe the implementation is a mix of top-down and bottom-up, as EU directives are implemented across countries either through policy (particularly regulations and economic incentives) or through business and NGO-led initiatives. In Japan, there has been an emphasis on coordinating and sharing the responsibility for implementation between national and local government, business, the public, NGOs and universities. A summary of the context, drivers, current implementations, and the factors that enabled this is given in Table 31-1.

CHINA
Overview and drivers
World's largest economy and centre of product manufacturing. Circular economy driven by pollution, resource and energy shortages that limit future economic growth.
Implementation
• Circular economy regarded as a new sustainable development model to help China leapfrog to a new economic structure, avoiding the adverse impacts of future economic growth • Initial focus on waste management and cleaner production, "Circular Economy Promotion Law" (2009) broadened focus to closing the loop on resources, energy efficiency, conservation and environmental management • Strong policy framework at Central Government level but there remains a significant gap between policy-making and practical action from businesses and the public • Focus on closing the loop on materials rather than reducing demand for resources
Enabling factors
• Policies are mainly regulations and there is limited focus on economic incentives, awareness raising activities and building networks for knowledge sharing. • Government is unwilling to use economic incentives as existing economic policies to promote infrastructure and manufacturing are closely linked with the price of resources • Implementation of circular economy programs is inconsistent across different provinces and there is often weak enforcement and low-levels of awareness from local government. • Awareness-raising is needed for public, who are generally positive about recycling but have low interest in sharing products

- Lack of network or system for information sharing has limited industry-led implementation

References

- Geng, Fu, Sarkis, & Xue, 2012; Liu, Li, Zuo, Zhang, & Wang, 2009; Su, Heshmati, Geng, & Yu, 2013; Wu, Shi, Xia, & Zhu, 2014; Xue et al., 2010; Yong, 2007

JAPAN

Overview and drivers

One of the world's most advanced economies and an early adopter of circular economic concepts. Circular economy driven by land, material and energy scarcity.

Implementation

- Established "Basic Act on Establishing a Sound Material-Cycle Society" in 2000, later the "Waste Management and Public Cleansing" and "Law for Promotion of Effective Utilization of Resources" acts introduced
- Responsibility for implementing circular economy shared between national and local government, business and citizens
- 2nd Fundamental Plan for Establishing Sound Material Cycle Society in 2008 also gives responsibility to NGOs and universities
- Laws focus on specific waste streams including packaging, home appliances, electronic appliances, food waste, construction materials and vehicles.

Enabling factors

- Coordination of policies and shared responsibility has led to high level of success. Regulations are developed at a national level, local government has responsibility of enforcement and business for implementation.
- Policies on public procurement promote the use of eco-friendly products by government and public institutions.
- Responsibility of NGOs and universities for sharing knowledge and coordinating between stakeholders. NGOs are expected conduct awareness-raising to promote actions for business and the public and set up community businesses. Universities responsible for advancing knowledge to inform policy-making.
- Economic incentives on products and waste encourage resource-efficient behaviour of business and the public.
- Regulation of vehicles has been highly successful, with less than 1% of end-of-life vehicles in landfill, due to strong enforcement and engagement with industry associations.

References

- Despeisse, Kishita, Nakano, & Barwood, 2015; Government of Japan, 2000, 2008; Schlegelmilch, Meyer, & Ludewig, 2010

EUROPE

Overview and drivers

Leading international voice for circular economy and world's largest regional economy. Circular economy driven by resource security and promoting sustainable economic growth.

Implementation

- Progress underpinned by EU Directives that provide minimum requirements for adaptation by countries.
- EU level directives mainly target responsibility of producers for collection and recycling of particular products including batteries, e-waste, vehicles and chemicals, or target cleaner manufacturing including restricting hazardous substances and industrial emissions.
- Limited policy focus on design of products, extending product life and reducing demand.

• Need for a more integrated approach rather than the current sector and product focused approach.
Enabling factors
• Most countries rely on national level regulations to meet EU obligations, while some including UK and Switzerland also rely on industry-led responses to market-based incentives. • Public investment in some countries has promoted innovation (e.g. UK Catapult Centres) and established infrastructure. • Implementation of regulations has been most effective when accompanied by economic incentives, public investment in infrastructure and awareness raising (e.g. German packaging policies). • Industry has led the focus on reuse, repair and remanufacture through new business models. • Stronger policies on public procurement and reduction of taxes on recycled and recyclable goods would promote the market. • Network building (e.g. WRAP in UK) has promoted voluntary agreements within sectors
References
• European Commission, 2011, 2014; FEAD, 2014; Swiss Academies of Arts and Sciences, 2014; Vanner et al., 2014

Table 31-1: *Circular economy implementation and enabling factors across China, Japan and Europe*

Enabling factors

Based on the review of circular economy implementation in China, Japan and Europe, a range of enabling factors have been identified that can be used to promote the concept of circular economy (see Table 31-2). These factors are ordered from those that are mostly government led (including regulatory instruments, economic incentives and public investment) to those that are mostly led by industry, either by industry associations or individual businesses. Several of these factors (including awareness raising, network building and voluntary agreements) may be led by either government, industry or other organisations including NGOs and academic institutions. While these factors have been characterised as government or industry led, successful implementation requires consistent and coordinated approaches across all levels of government, industry, NGOs, academic institutions and the public. This includes consistency across regions to avoid shifting practices to other areas.

	ENABLING FACTORS FOR IMPLEMENTING CIRCULAR ECONOMY
Government-led	**Regulatory instruments** including revisions to existing regulations that act as barriers to a circular economy or creating new regulations. Regulations can include product policy (e.g. extended producer responsibility, requirements on packaging and labelling, extended warranty periods), targets (e.g. on the percentage of resource recovery), selective bans (e.g. banning recyclable materials in landfill) and mandatory processes (e.g. mandatory resource recovery during production)
	Economic incentives including taxes, charges and levies. These could target primary resources (such as phosphorus), pollution (e.g. greenhouse gas emissions) and waste (e.g. landfill levies)
	Public investment can be useful for supporting R&D and innovation, upgrading or developing new infrastructure, funding training and new skills development and green procurement policies.
	Awareness raising e.g. providing information and advice to businesses, or campaigns targeted at consumers
	Network building within a sector, along the supply chain and between stakeholders to encourage knowledge sharing and collaboration e.g. connecting businesses to promote industrial ecology activities.
	Voluntary agreements within a sector or along the supply chain, which could be developed and managed by industry, government or a third party. These could include minimum industry standards (such as for responsible sourcing of products), product certification that influence business and consumer behaviour (such as a recyclability index) and industry led take-back and recycling initiatives.
Industry-led	**New business models** to encourage resource productivity and reduce demand, e.g. re-manufacturing of products, long term leasing agreements and sharing schemes.

Table 31-2: *Enabling factors for implementing circular economy*

The dominance of these factors across China, Japan and Europe has been displayed in Figure 31-1: A dark circle indicates that this factor has been implemented extensively or effectively. In the case of Europe all these factors are present in countries across the region, but those which are implemented most extensively have been highlighted.

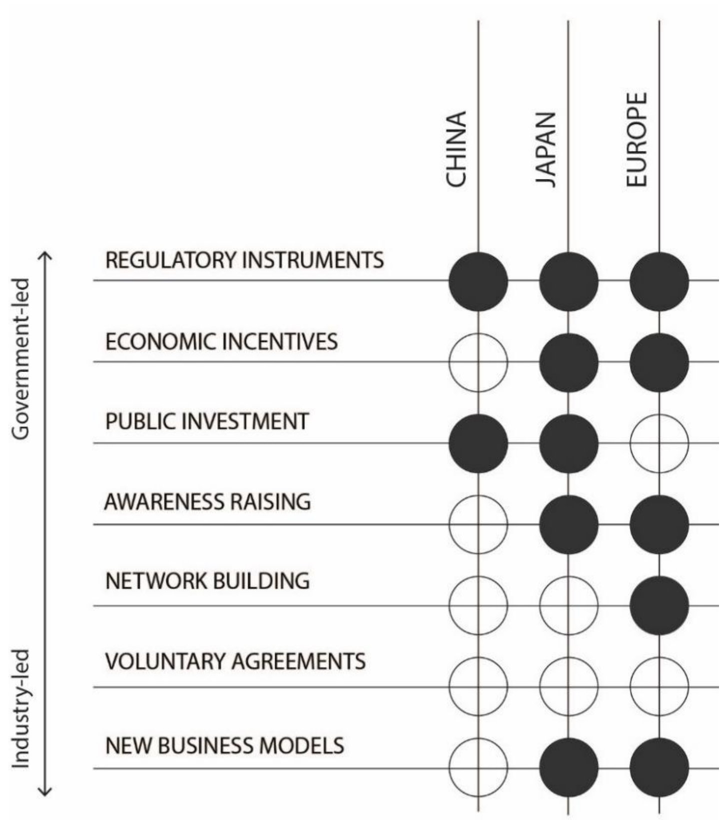

Figure 31-1: *Dominant enabling factors in China, Japan and Europe*

The emergence of Circular Economy in Australia

The implementation of circular economy in Australia so far has been fragmented and driven by niche sectors of the economy, and mainly focused on waste minimisation. There is not yet a clear and coordinated planning effort, and unlike the comparison countries, there is no national directive or strategy that focuses on circular economy or resource productivity.

This is in part due to the fact that compared to China and Japan, and to a lesser degree Europe, the drivers for a circular economy in Australia are less visible. A National Waste Policy has been developed in Australia, but remains to be comprehensively implemented and also requires more data. Waste generation is a growing problem, and is increasing at a significant rate compared to economic production. Australia's economic production (measured in gross value added) grew by around 70% in the period from 1996-97 to 2012-13, while at the same time waste grew by more than 150%, implying inefficient use of resources (ABS, 2015a)

Australia's quick economic recovery from the global financial crisis combined with the boom in commodity based exports has prevented a national focus on the need to seek a new economic direction focused on sustainable development (Effendi & Courvisanos, 2012). This can be seen in the lack of deployment of renewable energy despite abundant resources, and the lack of focus on resource efficiency or circular economy.

Driven by strong growth in China, Australia's key exports of iron-ore and coal grew by 100 percent in the period from 2005-2011 (Corden, 2012). The associated then-high Australian dollar, which grew by around 30% over this period, had an adverse affect on other exporting sectors of the economy, including agriculture, manufacturing, tourism and education. The high commodity prices also hid a national decline in economic productivity, distracting policy-makers away from focusing on growth in other areas of the economy (Green, 2015). As major contributors to government revenue these industries are hugely economically and politically powerful in Australia. However they are also highly emissions-intensive and trade-exposed to price fluctuations. With the recent exposure of the dependence of the Australian economy on natural resource exports the complacency is beginning to shift. An increase in the political pressure to create more sustainable economic strategies for Australia will likely be a strong driver for circular economy.

Social and environmental responsibility are becoming increasingly important as the public becomes more aware of the impacts of resource extraction, consumption and waste disposal, and environmental groups have successfully stalled the devleopment of new coal and coal-seam-gas mines (e.g., see: http://www.lockthegate.org.au/). Social drivers, including pressure on government and industry, are likely to be the main driver in the short term. However as the vulnerability of the trade-exposed economy becomes a larger political issue and the public demands longer-term thinking about the economy, economic drivers will likely emerge.

Government-led initiatives

Unlike in China and many countries in Europe there is no national focus on circular economy. In Australia the National Waste Policy provides the main framework for public policy relating to resource efficiency. The policy was orignially developed with environmental objectives, and aims to reduce waste, use waste as a resource, manage waste safely and reduce greenhouse gas emissions from waste (DEWHA, 2009).

Under this scheme there are a range of strategies, but legislation on product stewardship is the only nationally led strategy, and the remainder are implemented through individual states or industry groups. Televisions and computers were the first products to be regulated under the *Product Stewardship Act 2011*, with voluntary arrangements in place for tyres, packaging and mecury containing lamps. The National Television and Computer Product Stewardship Scheme (NTCRS) is government funded and requires large manufacturers to join an approved ‘co-regulatory’ arrangement responsible for collection and recycling of products. Most of this happens within existing recycling services, which export the waste for recycling offshore. This is in contrast to product stewardship schemes in Europe and Japan where manufacturers take responsibility for the collection and recycling of their products through their own infrastructure. The scheme has been criticised for being poorly implemented and communicated with the public. The current narrow focus of the scheme suggests there is great potential for expansion to include mandatory product stewardship for a larger range of products. To date, the focus on product stewardship activities has only been on waste management rather than on changing the design, manufacture and use of products, unlike in Japan and Europe. While Australia doesn’t manufacture many products there is activity in product design and the scheme could be expanded to influence the use of products.

At a state level there are limited regulations on products, with the exception of one state (South Australia) that has had a deposit-refund scheme on beverage containers since the 1970s. Due to pressure from industry groups this scheme has been slow to expand to other states, but will begin in NSW in 2017. This differs to Germany where their packaging scheme has strong industry support because of its economic value.

At a national level market based mechanisms focusing on extraction of resources (e.g. mining) and pollution (e.g. greenhouse gas emissions) have proven politically untenable due to the political power of mining industries. At a state level there are basic economic incentives, including a levy on sending waste to landfill in NSW. This levy is used to fund government programs that target reducing waste to landfill. Many programs have focussed on facilitating networks between businesses to undertake waste exchange and industrial ecology activities, for example the Industrial Ecology Business Support Network Grants Program. This program, along with the Sustainability Advantage scheme, have been successful in engaging a large network of businesses but further expansion and integration across states is needed to bring about large-scale changes to business practices. These schemes have now begun to also focus on success beyond the amount of waste sent to landfill, including the number of jobs created.

The fact that Australian policies have been developed with environmental rather than social or economic objectives has limited industry interest in innovating towards circular economy thinking. The need to revive Australia's manufacturing industry is another political issue, but the link with resource productivity is rarely drawn. Most funding for innovation in Australia is publicly funded, yet there is a piecemeal and inconsistent approach resulting in poor or underfunded policies to promote Australian innovation. Five industry "growth centres" were established to promote industry-university collaboration in Australia but have minimal funding, compared to similar initiatives in Europe on which they are based, such as the UK Catapult Centres (Laurenceson & Green, 2015). In Australia most support policy support for industry R&D comes from indirect support through tax incentives, rather than direct support (OECD, 2013).

Industry-led initiatives

A weaker policy environment than in China and Europe has led to an emphasis on industry-led innovation for implementing ciruclar economy activities in Australia. However it is necessary to look at the business environment to see whether this will eventuate, and whether business has strong enough drivers. Australia's economy has fared well in recent decades, but it can be argued that this is largely due to demand for resources from China and the region, rather than the strength of Australia's industry.

Many companies are at the front end of the supply chain (mining and agriculture), with some companies that target end-of-life and recycling. High wages compared to neighbours in the region and relatively inexpensive shipping costs means than low value recycling (such as aluminium) and low volume recycling (such as E-waste) tends to happen offshore. Unlike China, Japan and Europe that have an extensive manufacturing industry, and can therefore produce, repair or remanufacture products, and then recycle them, the majority of products in Australia are manufactured offshore.

Australia's capacity for innovation ranks poorly compared to similar economies according to the World Economic Forum report on global competitiveness (WEF, 2014). The quality of Australia's research institutions is ranked highly at 9 out of 144 countries, but Australia is found lacking in industry spending on R&D, government procurement of advanced products and university-industry collaboration in R&D. It is no coincidence that in a separate OECD report Australia is ranked last out of 33 countries for university-industry collaboration with large corporations and SMEs (OECD, 2013).

Australia's poor innovation environment can be partly attributed to the lack of policies discussed above, but also to the types of industry prominent in Australia. Australia is considered to have low economic complexity, a measure of a countries national economy based on the complexity of what it exports, as well as the number of different products. The

Australian economy is based predominantly on export of a few key resources and these are are usually not complex (raw materials from mining and agriculture with very limited value adding on shore). Countries such as Japan and most of western Europe tend to produce complex goods as well as a high number of different products. Australia is ranked 78 on economic complxity, compared to Japan at number one, and eight Euorpean countries in the top ten (CID, 2015). As another measure of this, Australia is ranked 95/144 countries for value chain breadth by the World Economic Forum, a measure of how broadly companies are present along the value chain (WEF, 2014).

Low levels of economic complexity mean that the Australian economy is vulnerable to trade fluctuations. But there is another aspect which is important when considering Australia's ability to innovate towards a circular economy. When a country produces complex goods in addition to a high number of products, such as Germany and Japan, they are more likely to innovate and develop new industries, as the knowledge and skills from existing industries can easily be transferred and developed into new ones. However in Australia the current knowledge and skills are focused around a small number of key industries which limits Australia's ability to add value to existing industries.

The decline in manufacturing in Australia has largely been attributed to geography and high wage costs, but countries like Germany and Switzerland have shown that being a high cost economy can still have internationally competitive manufacturing (Laurenceson & Green, 2015). Despite a decline in manufacturing there are around four times as many people employed in manufacturing as mining (ABS, 2015b). There are a number of globally competitive Australian manufacturing businesses that are often overlooked, these tend to be low volume, highly complex (for example a combination of products and services) and high value added (Roos, 2014).

Certain companies are taking advantage of Australia's manufacturing "sweet spot" to develop new business models that promote a circular economy, such as Fuji Xerox who leases products so they can be remanufactured at its eco-manufacturing centre. Industry groups have also taken the lead in developing voluntary agreements, focused around specific resources, products and sectors. Mobile Muster is a recycling program run as a not-for-profit initiative by mobile phone manufacturers, network carriers and service providers to promote the take back and recycling of mobile phones. The Australian Battery Recycling Initiative is also industry funded to promote the safe recycling of batteries. Industry groups such as the Steel Stewardship Forum are also looking at developing certification schemes to promote the purchase of products that promote the responsible and sustainable production of resources.

Discussion and conclusions

Through informal stakeholder interviews (including representatives from state government and industry bodies) the factors that are likely to progress circular economy concepts in Australia have been prioritised (see Figure 31-2). Harmonized policy frameworks, including strong regulations, long-term targets and economic incentives were identified as the most important policy led actions for to create change. As a first step, mandatory product stewardship legislation can be expanded to a wider range of resources and products. As has emerged in Europe, to redistribute the uneven costs and benefits that may arise, economic incentives are needed at the same time as regulations underpinned by ambitious resource recovery targets that are coordinated across states.

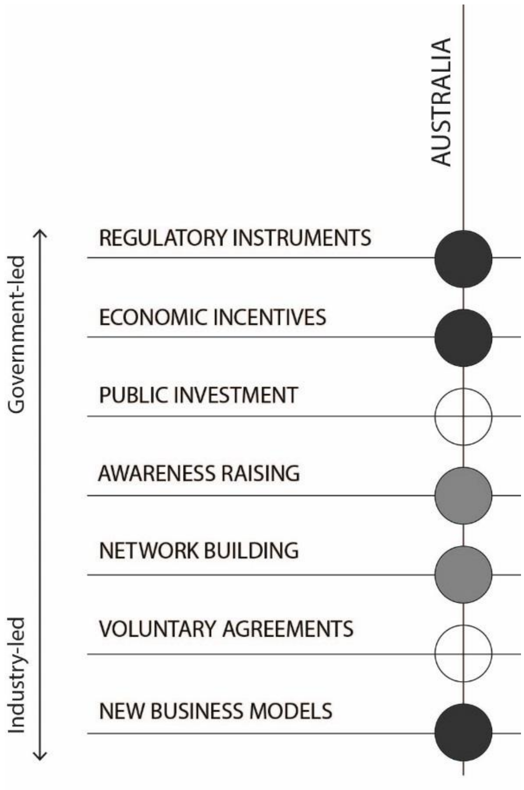

Figure 31-2: *Priority factors to enable a circular economy in Australia. Dark grey circles represent factors that have maximum impact, and light grey represent those most achievable in the short term.*

New business models that encourage resource productivity and reduce demand were considered equally important. These business models can work within the limitations of Australia's economy and take advantages of its uniqueness. Businesses can target the manufacturing "sweet spot" of high skill, high value manufacturing to focus on advanced and additive manufacturing, as well as local repair and remanufacturing. There is also business potential to tap into the abundant renewable energy resources to power manufacturing. As Australian businesses are mainly at the front end of the supply chain, these businesses can use this location to influence further down the supply chain, encouraging resource stewardship and responsible products in the global market (Florin, Giurco, & Dominish, 2015).

Government policy is largely developed due to public and industry pressure, so the most achievable actions to progress the implementation of circular economy in the short term were awareness raising and education initiatives. Greater awareness in the public and in industry would lead to pressure to increase regulations and other policies. This is in contrast to China where regulations have been put in place before extensive awareness raising and education, leading to implementation challenges. The example of Germany shows the importance of awareness raising for engaging consumers as well as industry in potential economic opportunities. Awareness raising initiatives can come from industry groups (such as Mobile Muster, Sustainable Business Australia and the Australian Council of Recycling who are already engaged in awareness raising), or can be government, academia or NGO led. Owing to the economy wide shift that needs to happen with coordination between and across different sectors and departments of government, as well as within the community; the stakeholders consistently reflected on the need for a shared message to promote circular economy concepts.

So far most messaging around the circular economy is yet to achieve a transformative effect in Australia because the narrative doesn't fit with the current economic environment, as an extractive economy. A unified voice from key stakeholders and local industry champions is needed to adapt the message to the Australian context so it can better resonate with government, industry and the public.

Alongside awareness raising, building networks across sectors and stakeholders was also considered important in the short term, for both knowledge sharing and exploring innovation opportunities. Public investment through procurement policies that promote a secondary market for resources and promoting R&D were also considered somewhat effective in the short and long term. Voluntary agreements, including standards and certification schemes, can be both positive and negative. So far this is an area in which Australia has made some progress, but there was concern that the development of a large number of standards can lead to market confusion and distrust, and that once standards are established in the market it can also limit innovation. At the same time these kinds of agreements can also push the competition within sectors, raise awareness and provoke government action.

There is a significant opportunity in Australia to stimulate circular economy concepts that can underpin responsible prosperity. Given Australia does not have the top-down approach, for example through a national strategy as in China and Japan, nor the regional directives of the EU, implementing circular economy requires new collaboration and cooperation across sectors and stakeholders. Towards this end, the emerging business-led innovation can be expanded with strong policy support that promotes circular economy as a theme of national importance.

32. DECOUPLING OF ECONOMIC GROWTH AND ENVIRONMENTAL IMPACTS IN GERMANY

Michael Lettenmeier ✉, Iina Heikkilä

Abstract

The paper highlights in which regard economic growth has been decoupled from environmental impacts in Germany. It is based on extensive desk research and six expert interviews.

The answer to the question if Germany can serve as an example for successful and absolute decoupling is not unambiguous. Germany has succeeded in stopping the growth of material and energy use. However, absolute decoupling is happening only when natural resource use and other environmental impacts are decreasing in absolute terms. This has, so far, not happened to natural resource use in general but only to specific emissions that can be regulated by technical means.

Total Material Requirement and Total Material Consumption (TMR and TMC), as well as carbon footprint and ecological footprint have not increased nor decreased during this century in Germany. Water footprint and land use for food production have increased, as well as domestic land use for infrastructure and settlements, and biodiversity decline.

Absolute decoupling, i.e. the constant decrease of environmental impacts while the economy is growing, could not be stated for any indicator that takes into account also the environmental impacts of imports. However, the development within Germany's borders cannot be considered sufficient while both economy and material flows are subject of constant globalisation.

As a conclusion, general absolute decoupling cannot yet been found in Germany. However, Germany has been politically active in decreasing natural resource use and other environmental impacts. This is visible, for instance, in strongly increasing activities of states and companies in the field of resource efficiency. However, so far we are not yet able to claim general evidence that economic growth generally could be decoupled from resource use and other environmental impacts when potential burden-shifting through imported goods is taken into account.

Keywords: decoupling, Germany, indicator, natural resource use

Introduction

Germany is well known as a forerunner in environmental protection and politics. However, environmental impacts of human activities are manifold (e.g. Steffen et al. 2015) so that statements on environmental impacts may depend on the indicator chosen. This paper summarizes a study (Lettenmeier & Heikkilä 2014) on the question to which extent economic growth has been decoupled from environmental impacts in Germany.

Starting point for the study was the German Resource Efficiency Programme ProgRess (BMUB 2012). According to the Programme German direct material use has declined in this century, even though the economy has grown. The purpose of the study was to find out whether Germany has succeeded in decoupling economic growth from environmental impacts in the basis of the following questions:

- Which indicators proof an absolute decoupling in Germany and which indicators do not?
- Are these indicators sufficient to assess the decoupling of German production and consumption from the environmental impacts?

Special focus was given to absolute decoupling because an absolute decrease in environmental impacts is necessary to improve the global state of the environment. In order to achieve absolute decoupling resource efficiency growth must be higher than economic growth. If the economy grows faster than resource efficiency, decoupling can only be relative. This may be related to the rebound effect where economies of scale in production outweigh increasing efficiency per unit produced so that consumption and environmental impacts start growing (Jorgenson & Clark 2013).

The study was performed by D-mat ltd. and commissioned and funded by the Finnish Innovation Fund SITRA. SITRA wanted to know to which extent Germany can serve as a successful example of decoupling economic growth from environmental impacts.

Methodology and data used

The study has been based on extended desk research and six interviews of central experts in the field. Desk research focused on time series of environmental indicators on a German level during the recent decades, especially after the reunification in 1990. We took into account existing research and statistical data provided by public sources and compared time series of different indicators.

A focus of the work was given to indicators related to Material Flow Analysis (MFA, see Bringezu et al. 2003) but we also looked at the development of other indicators in order to provide a broad picture of the situation. MFA is a concept for measuring environmental pressure from a natural resource use point of view (Bringezu et al. 2003). It is related to the notion that environmental impacts of human activities are finally based on the amount of natural resources input into human economy and therefore cannot be reduced effectively by just addressing the quality of output flows from technosphere back to nature (Ayres & Knees 1969, Schmidt-Bleek 1993).

Most of the data has been provided by the federal statistical office Destatis. We also used data provided by research institutions. In addition to the desk research, we interviewed six experts in the field in order to complement the statistical data used and to include all relevant aspects. Three of the experts represented governmental organisations and three of them research institutions. The semi-structured interviews covered the experts' experience and opinion on the question of decoupling as well as on the suitability of different indicators.

Results and discussion

Total Material Requirement and Total Material Consumption (TMR and TMC), as well as carbon footprint and ecological footprint have not increased nor decreased during this century. German domestic water use and traditional emissions into air have declined. However, water footprint and land use for food production have increased, as well as biodiversity decline and domestic land use for infrastructure and settlements.

Table 32-1 gives a summary of the indicators studied and their development. The development in the table represents especially the situation after 2000 because during the 1990ies decreases in impacts were observed due to the impacts of the reunification. Absolute decoupling could not be stated for any indicator that takes into account also the environmental impacts of imports. However, the development within a country's borders cannot be considered sufficient while both economy and material flows are subject of constant globalisation.

Indicator	Incl. impact of imports	Absolute decoupling	Reference
Absolute decoupling			
Abiotic DMI (Direct Material Input)	No	+	Destatis 2014
Greenhouse gas emissions	No	+	Destatis 2013b
Energy consuption	No	+	Destatis 2013b
Air pollutant index	No	+	Destatis 2013b
Domestic water consumption	No	+	Destatis 2013b
Development levelled out but no decrease of impact			
Total material requirement (TMR)	Yes	0	Dittrich et al. 2013
Total material consumption (TMC)	Yes	0	Dittrich et al. 2013
Abiotic RMI (Raw Material Input)	Partly	0	Destatis 2014
Carbon footprint	Yes	0	NTNU
Ecological footprint	Yes	0	Global Footprint Network
Not more than relative decoupling, if any			
Transport performance	No	–	Destatis 2013b
CO_2 emissions in transport	No	–	Destatis 2013b
Biodiversity index	No	–	Destatis 2014
Land use for settelm. and infrastr.	No	–	Destatis 2013b
Land use change	No	–	Destatis 2013b
Land use for food production	Yes	–	Destatis 2013a
Water footprint of nutrition	Yes	–	Destatis 2012

Table 32-1: *Indicators studied and their development.*

Most of the experts interviewed expressed the need for including unused extraction into the indicators on decoupling. However, there was also a view that TMR overemphasizes too much German lignite production. One solution in this respect could be indicating lignite-based material flows as a separate part of TMR while remembering that different countries can have "their own lignites" all having huge environmental impacts (e.g. copper in Chile). The continuous assessment of TMR still faces some methodological challenges (such as recycled materials and their coefficients) but these gaps could and should be systematically filled during the coming years.

Another point raised was that in Germany in the future is unlikely to see the same kind of economic growth than in the last millennium. This is due to the material base of economic growth, which is starts facing physical limits. Therefore, in the future debate more emphasis should be put on decoupling well-being and not just economic growth from environmental impacts. A strong “beyond GDP debate” has already started in Germany.

One point raised was that Germany probably is going to miss the decoupling-related targets of its sustainability strategy. One reason for this is that especially in the sector of mobility and transportation growth in consumption has offset the growth in resource efficiency, probably due to political reluctance to intervene in the area of car transport.

Conclusions

This paper reported on the question if Germany can serve as an example for successful and absolute decoupling of environmental impacts from economic growth. The answer is not unambiguous. Else than e.g. Finland, Germany has succeeded in stopping the growth of material and energy use. However, absolute decoupling is happening only when natural resource use and other environmental impacts are decreasing in absolute terms. This has, so far, happened to some domestic inputs and emissions but not to mass flows including imports, e.g. TMR, TMC or the carbon footprint.

UNEP distinguishes three types of decoupling (von Weizsäcker et al. 2014):

- Decoupling through maturation;
- Decoupling through burden-shifting;
- Intentional decoupling through productivity increase.

The first type refers to the "natural" process of replacing outdated technology and on the other hand moving towards a service economy. In Germany, this type of decoupling has been visible especially in the 1990ies. Burden-shifting refers to the transfer of production to third countries with lower costs and environmental standards so that the environmental impacts of production are happening elsewhere. If the statistics do not take into account the impact of imports, may decoupling appear to have occurred although it is just based on burden-shifting, which is to a certain extent visible in the German statistics studied. The third type, decoupling by intentional increase in resource productivity requires technological innovation, resource-efficiency-enabling infrastructure such as housing production, as well as appropriate consumption habits. In Germany, this is visible in strongly increasing activities of federal republic, states and companies in the field of resource efficiency.

Evidence of a broad absolute decoupling in Germany cannot yet been found. However, Germany has been politically active in decreasing natural resource use and other environmental impacts. Although Germany has set targets for increasing energy and resource efficiency there is way to go towards targets set by science (e.g. Bringezu 2015, Lettenmeier et al. 2014, Schmidt-Bleek 1993). Therefore, we are not yet able to claim general evidence that economic growth generally could be decoupled from resource use and other environmental impacts when potential burden-shifting is taken into account by considering also imported goods.

33. POLICY MIXES FOR RESOURCE EFFICIENCY – THEORETICAL AND PRACTICAL CHALLENGES

Henning Wilts ✉, Bettina Bahn-Walkowiak, and Nadja von Gries

Abstract

Based on an on-going research project called "Policy options for a resource efficient Europe" (POLFREE), this paper analyses potential policy instruments and their interdependencies in a policy mix for resource efficiency. It focuses on fundamental trade-offs in such a mix and identifies three generic challenges based on an empirical analysis of 27 specific instruments. The innovative aspect of the paper is to go beyond another long list of potential instruments or a mix of instruments, but to analyse them with regard to the theoretical requirements for coherence and consistency.

Keywords: resource management, waste management, resource efficiency, governance, policy mix, sustainable development

Introduction

Against the background of an often wasteful use of the natural resources, the European Union has named resource efficiency as one out of seven flagship projects to pursue its so-called Europe 2020 strategy, which means the EU considers resource efficiency a top policy priority. Policy formulation for resource efficiency however is at a very early stage. There is no lack of innovative ideas for instruments that could be introduced from an overall, rationale point of view – but the implementation is often weak and scattered.

Based on an on-going research project called "Policy options for a resource efficient Europe" (POLFREE), this paper analyses potential policy instruments and their interdependencies in a policy mix for resource efficiency. It focuses on fundamental trade-offs in such a mix and identifies three generic challenges based on an empirical analysis of 27 specific instruments. The innovative aspect of the paper is to go beyond another long list of potential instruments or a mix of instruments, but to analyse them with regard to the theoretical requirements for coherence and consistency.

The paper is structured as follows: Chapter 2 describes the necessity and theoretical background of resource efficiency policy mixes. Chapter 3 introduces the specific case studies analysed within the POLFREE project. The final chapter draws conclusions with regard to the process of policy formulation as well as further need for research.

The necessity of policy mixes for resource efficiency

The purpose of the FP 7 project POLFREE was to develop a policy mix that enables Europe to radically increase its resource efficiency. Such an approach of course raises the question of the necessity for policy interventions: Following Oates (1972), all environmental policies derive their legitimacy from existing market failures. As long as human activities directly and indirectly harm the environment with potentially disastrous outcomes, policies to counteract such failures are legitimate. Acknowledging the systemic character of many challenges, the more recent discussion has shifted towards system failures (OECD 2006) leading to more complex analyses on shared responsibilities between market participants and states.

In theory, free markets are able to deal with scarcities and to coordinate supply and demand in an efficient way. But especially in the case of raw materials these mechanisms show significant deficits when

- transforming geological or structural scarcity signals into anti-cyclic investments instead of following short term revenues,
- developing institutional arrangements for the reduction of price volatilities caused by supply bottlenecks and/ or social unrests,
- preventing price bubbles and the resulting risks for investments and planning procedures,
- internalizing environmental costs of access to and exploitation of natural resource deposits,
- considering the use of secondary resources from recycling/ urban mining as alternative to the extraction of primary resources in the development of new infrastructures, legislation or product design.

The need for a more ambitious resource efficiency policy that goes beyond the win-win rhetoric can clearly be derived from the need to counteract market and system failures by focusing on sustainable resource management. The sceptic economist however might raise the question about existing trends towards a decoupling, lowering energy- and resource-intensity, or about a ‘green Kuznets curve’, where a poorly designed policy could do more harm than good. Fact is that

- Global resource use is rising; however, the EU shows a mixed picture: while some EU-15 countries experience a decline in resource use, some EU-12 countries show sharp increases (EEA 2012);
- The trend towards any decoupling is neither strong enough to cope with environmental challenges nor evenly distributed. Some countries even show decreases in resource productivity rather than efficiency increases; comparing aggregated indicators (like GDP and DMC/RMC) shows that countries are very heterogeneous with respect to economic structures and power, endowment with natural resources, performances in resource extraction and use (SERI 2011);
- Material leakage and problem shifting to developing countries lower the global improvements significantly;
- After any establishment of resource-intensive patterns, the need for maintenance (e.g. of transport infrastructures) requires additional inputs. Thus, there is an issue of path dependency that makes linear progress more unlikely;
- Rebound effects are estimated to occur in the range of 10-50%, depending on the specific instruments and resources (Gjoski 2011).

Developing a policy mix to radically increase resource efficiency in Europe

Against this background, POLFREE identified elements of a new policy mix leading to an absolute decoupling of economic growth from unsustainable use of natural resources and environmental degradation.

Theoretical framework for policy mixes

A series of innovative instruments (or innovative adaptations of existing instruments) was described in detail and analysed with regard to their potential impacts. The innovative aspect of POLFREE is to go beyond another long list of potential instruments or a mix of instruments, but to analyse them with regard to the coherence and consistency of such a mix. Synergies and contradictory effects between specific instruments, but also the consistency with regard to specific policy targets were investigated.

Instrument specific design features

For the purpose of designing a policy mix, the single instruments have to be described by their essential characteristics. The policy mix concept developed by Rogge and Reichardt 2013 characterises the instruments by their ***goals, types and design features***. The instrument design features *stringency, profitability, predictability, flexibility, differentiation* and *depth* are not only an indication for the effectiveness and efficiency of the instrument and a requirement for the analysis of instruments' interactions (del Río González 2009, Rogge and Reichardt 2013) but they are also of particular relevance in order to analyse their innovation effects (Kemp and Pontoglio 2011, Vollebergh 2007).

Against this background we applied the analytical framework based on Rogge and Reichardt (2013) bringing together instrument specific design features and general characteristics of a policy mix. These policy mix characteristics can be applied both to the overarching policy mix, but also to distinct elements or processes. We will differentiate between consistency, coherence and credibility/ stability.

Identification of promising policy fields and instruments

Given the countless applications of resource usages and at the same time the variety of policy fields that influence the production, use and end-of-life phase of resources, a first step of a policy mix is the systematic identification of policy fields. Based on an intensive literature review on policy instruments applied in EU member states (EEA 2012) and described in the literature, the following nine policy fields have been selected as action areas with good prospects to reach a radical increase of resource efficiency in Europe: (1) Phasing out of environmentally harmful subsidies, (2) Internalisation of external costs, (3) Electricity production and distribution, (4) Fuel efficient mobility, (5) Zero Energy and material efficient buildings, (6) Minimization of food waste losses, (7) Product Service Systems, (8) Circular Economy, and (9) Industrial symbiosis network.

In order to describe the different policy instruments with their characteristic design features, a common analytical framework was developed to structure the analysis and allow to derive conclusions on their effectiveness in policy mix. This structure differentiates between the policy context, the design features of the specific instruments and their implementation.

- *Context of the policy field* – why are innovative instruments needed in this field? What do vision and pathways say about it? What are relevant studies, literature etc.?
- *Instruments* – which innovative instruments would allow to reach the targets described in the vision and to overcome the web of constraints?
- *Implementation* – what are relevant barriers for implementation? Who would win, who would lose? Who are veto players? What could be "flanking instruments" in order to distribute the expected welfare benefits between the different actors?

For all policy fields three specific instruments were described:

- The first instrument aims at the low hanging fruits of resource efficiency that could be described as win-win situation for all actors involved: increasing the efficiency of resource usage leads to cost savings (or quality improvements) so that very short amortisation periods can be achieved – sometimes even no additional investments are required at all. The basic rationale behind these instruments is often a reduction of transaction costs by improved framework conditions that make additional market activities economically viable without any additional external incentives (see OECD 2006).
- The second type of instruments requires severe market interventions by public actors that in particular force the supply side of raw materials and products to increase the resource efficiency of production processes. These instruments often follow the concept of technology forcing assuming the existence of technologies that are rationale to introduce from a social and long-term point of view, but not from the perspective of a single firm. In this specific case the regulator claims to be able assess their resource efficiency potentials: „Firms often have greater information about their own technological capabilities than regulators, and might be able to exploit this information asymmetry by hiding their true innovative capabilities, underinvesting in R&D, and claiming that the standards cannot be met. (Gerard and Lave 2003, p. 4).
- The third type of instrument aims at a systematic transformation of production and consumption patterns towards resource efficiency. In contrast to type 2, these instruments also aim to directly influence consumption or consumer preferences. From the viewpoint of politics these instruments assume a high level of awareness for the urgent need to increase resource efficiency within the population (and thus amongst voters).

The step from innovative instruments to strategy development and an efficient policy mix

The description of policy instruments clearly points out one of the key dilemmas of resource efficiency: There is no lack of innovative ideas for instruments that could be introduced from an overall rationale point of view. However, the implementation is often weak and scattered.

The results of the analysis of options to go beyond single instruments and integrate them into a consistent and coherent policy mix with relevant synergies between its single elements is presented in the following sections.

Consistency

A first step to design a policy mix is the assessment of the single instruments according to the instrument’s design features (Rogge and Reichardt. 2013). In order to provide direct comparability between the instruments, the assessment is structured by the six design criteria. Every section starts with a short description of each design feature followed by the assessment for each instrument.

Policy field	Instrument	Stringency	Profitability	Predictability	Flexibility	Differentiation	Depth
Phasing out environmental harmful subsidies	A comprehensive inventory of EHS in the EU	4	3	5	1	1	-
	Environmental Subsidy Controlling: The „Environmental Check“ for Subsidies	5	4	3	1	1	-
	Systematic phasing out of EHS	3	1	4	5	5	4
Internalisation of external costs	European-wide harmonization and introduction of construction minerals taxes (incl. border tax adjustment) _ Construction Minerals Directive	1	3	3	4	3	4
	TMR-based material input taxes	5	3	1	5	1	5
	LCA-based Value Added Taxes	4	1	1	5	1	5
From waste disposal towards a resource-efficient circular economy	Individual producer responsibility	1	3	5	5	1	5
	Mandatory eco-design standards for reuse and repair-ability	2	1	1	1	5	1
	Waste targets for resource efficiency	5	1	5	4	2	1

Figure 33-1: *Synopsis of the valuation of policy fields and instruments (3 in each policy field) with respect to 6 design features (extract of table in study); Source: Wilts et al. 2015, p. 166.*

A five-stage classification was developed: (5) marks instruments, if its properties fulfil the considered feature – namely stringency, profitability, predictability, flexibility, differentiation or depth. (1) stands for instruments which do not fulfil the feature. The further differentiation - (4), (3), (2) - allows a more detailed assessment, since a clear judgement is not always possible.

Coherency

The concept of policy coherency especially encompasses all policy processes across different governance levels – this specific aspect is of course of greatest relevance for the POLFREE policy mix which has to bring together and integrate in particular the different on-going activities on the EU and member state levels.

The following figure presents selected instruments and the relevant initiation levels. The stronger the colour, the more important is the initiation role of the respective level. The bold coloured marks have the same importance; the lilac marking is used in addition, if an instrument can be initiated at one or at an other level.

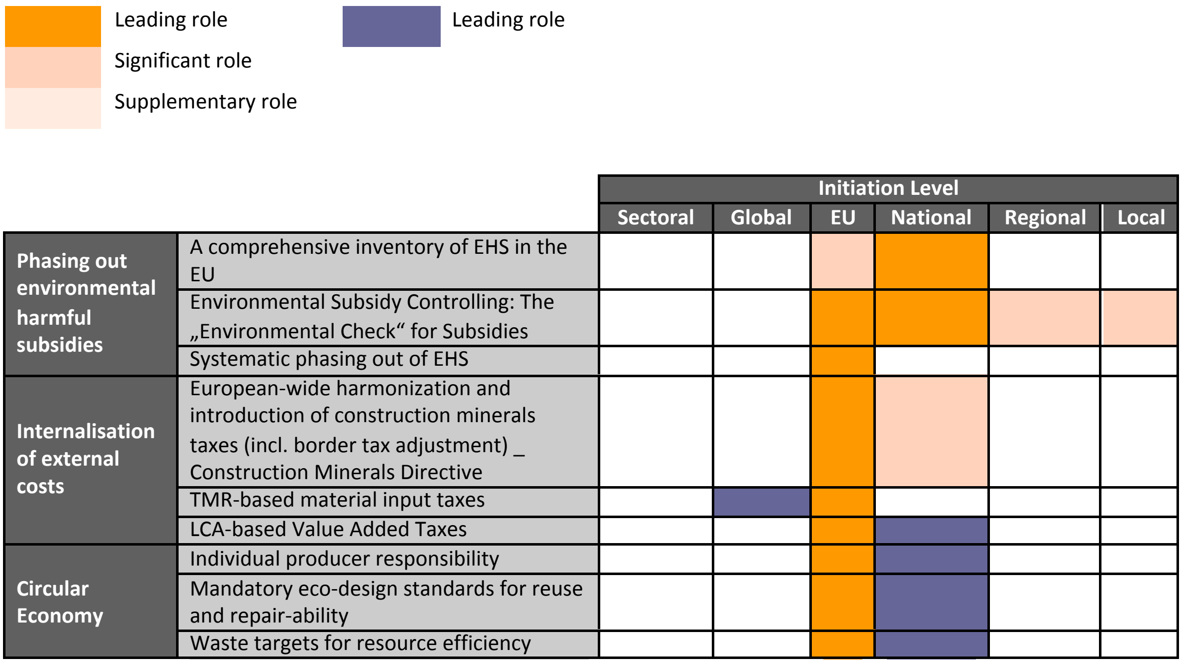

Figure 33-2: *Distribution of responsibilities for resource efficiency instruments; Wilts et al. 2015, p. 168.*

Conclusions

Taking into account the aspects of consistency and coherency clearly underlines the great challenges of establishing an integrated policy mix for resource efficiency – especially in contrast to traditional fields of environmental policy.

Firstly the character of resource efficiency as cross-cutting policy approach becomes evident: The more promising specific instruments seem, the more actors have to be involved in its development and implementation. This often requires complex coordination between different policy fields, e.g. in the field of food waste prevention between agriculture, industrial food processing, retailers and consumer policy. Despite the obvious potential environmental and economic benefits, high transaction costs of coordination are a powerful barrier. New platforms of coordination but also improved framework conditions for promising niche developments will be necessary in order to boost the uptake of existing technological and social innovations for resource efficiency alongside value chains – as addressed in several instruments of the POLFREE policy mix.

The need for cross cutting approaches also increases the potential number of veto players. The analysis of the instruments has shown that resource efficiency is often considered as a win-win strategy, but at the same time it produces a identifiable but powerful number of actors who currently generate income and influence from the wasteful patterns of resource consumption. For more or less all instruments the need for flanking instruments has been identified that aim to reallocate some of the cost savings or the revenues from new business models to those who potentially might hinder their diffusion. These elements can be seen as one of the key success factors for an effective policy mix.

The analysis has also clearly shown that despite the variety of existing long lists of instruments for resource efficiency, the actual implementation is often not really considered. This becomes especially obvious in terms of coordination between initiating actors on different spatial levels. Facing the complexity of resources and the complex web of constraints hindering their efficient use in production and consumption, there is definitely no common answer for who should be responsible. Several instruments (e.g. those focussing on the production phase like Eco design standards) seem to indicate the necessity of an European approach; on the other hand most instruments aiming at the consumption side highlighted the relevance of the regional or even local context. In addition, inconsistencies between national approaches are one of the major elements of resource efficiency policy failures. However, a process is needed that goes beyond eliminating inconsistencies but aims at a systematic reallocation of responsibilities between international, national and subnational institutions – taking into account the characteristics of specific resources and at the same time the “resource nexus”, the complex interdependencies between them.

34. POLICY PACKAGING IN SUPPORT OF ABSOLUTE DECOUPLING – A CONCEPTUAL MODEL

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Abstract

Global resource consumption has seen marked increases in the last century, in particular since the 1950s. In transforming these materials into products, food, infrastructure and energy functions for mobility and housing, significant environmental impacts are generated: ecosystems become ever more degraded, some 50 $GtCO_2e$ are emitted annually, and the global ecological footprint of human activities already requires more than 1.4 planet Earths.

Through systematic literature review, we identified a number of relevant drivers that lock unsustainable resource use in at European and global level, such as:

- consumption-based lifestyles (linked to social norms, increasing advertising efforts and rising aspirations)
- short-term product and consumption cycles fuelling a take-make-dispose mentality
- infrastructure design and planning locking in fossil fuel based structures and mobility decisions
- volatile resource prices, which are (still) mostly ignorant of the true external costs of the resources' use

We need to improve our understanding of the complex linkages between different trends and drivers in order to enable forward-looking decision-making. This requires thinking in terms of policy mixes, i.e. combining different policy measures, targeting different or the same trends and drivers. As knowledge on policy packaging is only starting to build up, we will develop a conceptualisation for resource policy packaging and roadmapping. This conceptualisation will have to take into account

a) the need to investigate and mitigate potential negative consequences of policy measures aiming at achieving main environmental objectives.
b) A time-dynamic roadmapping of policies, i.e. policy instruments packed in chronological order allowing for a transition pathway towards more ambitious resource policies.

We will present the conceptual model for policy mixing reflected on in the FP7-research project DYNAMIX (http://dynamix-project.eu/).

Keywords: policy mix, barriers and drivers, roadmapping

Introduction

Global climate change, increasing resource depletion and degradation of bio-physical systems as well as population growth and urbanisation rates set to raise the share of urban dwellers of total global population up to two thirds, or 6.5 billion, by 2050 (WBGU 2016): the number, the magnitude and scale and the complexity of interlinkages between environmental problems are on the rise (Balint et al. 2011). This not only puts strain on ecosystems, but also on socio-technical systems that are dependent on or coupled with these (Smith, Stirling, and Berkhout 2005).

In the wake of population growth and urbanisation there will be between 2 and 3 billion more middle-class consumers, predominantly in Asia and to a much lesser extent in Africa (WBGU

2016; EEA 2016). Linked to the diffusion of westernized consumption patterns, this rise in middle-class consumers and consumption aspiration will have tremendous implications on the use of resources (Hirschnitz-Garbers et al. 2015; Wiedmann et al. 2015) and the state of the world's ecosystems: resource consumption is expected to reach approximately 183 billion tons of minerals, ores, fossil energy carriers and biomass by 2050, more than 100 billion tons more than in 2015 (UNEP 2016). The use of resources, and in particular the production of bulk materials (e.g. steel, aluminium, cement and polymers), and their transformation into consumption goods, infrastructure, and housing is responsible for a significant share of human energy demand and greenhouse gas (GHG) emissions (International Energy Agency 2008; Brown et al. 2012; Duarte, Mainar, and Sánchez-Chóliz 2013). In transforming these materials into products, food, energy functions for mobility and housing and the necessary infrastructure (EEA 2012), also significant environmental impacts are generated: a large share of ecosystems becomes ever more degraded (MA 2005), some 50 Gt CO_2e are emitted annually (Montzka et al., 2011), and the global ecological footprint of human activities amounted to more than 1.4 planet Earths in 2005 (Galli et al., 2012). In this context, the planet's carrying capacities will be in significantly overshoot, with human activities expected to require two planet Earths around 2030 (Moore et al. 2012).

Furthermore, resource use across the entire value chain and the associated environmental impacts contribute to (further) transgressing existing planetary boundaries: for biodiversity loss and biosphere integrity; land system change; biogeochemical flows; and climate change scientific findings indicate that control variables are in or even beyond the zone of uncertainty (W. Steffen et al. 2015; Rockström et al. 2009). If these system states remain in or beyond the zones of uncertainty, there is high risk that the systems might tip (e.g. thawing permafrost in subarctic zones; changes in the Indian monsoon system; declines in boreal and tropical forests), which in turn might lead to complex cascades of adverse effects on human development; this even bears the danger to shift the system equilibrium of the Holocene towards new states, which are unknown in their implications on humanity (Lenton et al. 2008; Will Steffen et al. 2011).

Methods and approach

Against this background, research conducted in the context of the European FP7 research project DYNAMIX (DYNAmic policy MIXes for absolute decoupling of environmental impact of EU resource use from economic growth) and the German research project SimRess (Models, potential and long-term scenarios for resource efficiency, http://simress.de/en) investigated relevant drivers and trends for unsustainable resource use at European and German. This analysis forms the basis to enable the design of promising mixes of resource policies to change the drivers and counter the trends. Relevant drivers and trends encompass

- increasing adoption of consumption-based lifestyles linked to social norms, increasing advertising efforts and rising aspirations
- increasingly short-term product and consumption cycles fuelling a buy-discard mentality
- increasing pressure on the workforce in terms of less available time
- increasing number of city dwellers and spreading of urban sprawl
- infrastructure design and planning locking in fossil fuel based structures and mobility decisions

- volatile resource prices, which are (still) mostly ignorant of the true external costs of the resources' use
- further internationalisation of value chains and consumer demands leading to increasing complexity of trade patterns
- increasing digitisation of all spheres of society (private, commerce, work) and proliferation of personalized advertisement.

At the same time, many of these trends bear within them indications for change, for instance the yearning of (yet only smaller) parts of society (individuals, communities and innovative leaders) for a deceleration and simplification of lifestyles, or prevailing shifts from product to service-based business models, e.g. car sharing.

Conceptualising policy mixes

These drivers and trends affect resource use in multi-directional, dynamic processes with manifold interactions between different drivers in many directions – hence in complex webs much rather than in simple causal chains (Hirschnitz-Garbers et al., 2015). In this context, we need to improve our understanding of the complex linkages between different trends and drivers, which may be reinforcing, neutral or mitigating, to enable forward-looking decision-making focusing on breaking unsustainable trends and fostering drivers for change towards greater sustainable resource use. In order to retain the flexibility to respond to new findings while proactively supporting action, we propose that combining different policy measures, targeting different or the same trends and drivers, into policy mixes in a time-dynamic roadmapping process is needed.

This highlights that policy makers need to think in terms of policy mixes, i.e. packaging different policy objectives and instruments into policy mixes that are then able to target the different interrelated drivers and trends of unsustainable resource in a more comprehensible and adaptive way.

The concept of policy mixing may be an answer to this call. While policy mixes have been applied in environmental policy in various contexts in the sense of combinations of different instruments (see e.g. OECD 2007), the policy mixes seem to have been designed in the sense of adding new policy instruments when necessary without considering potential interactions and long-term consistency. This process has been called policy-layering and it may contribute to trade-offs and conflicts of objectives between the different instruments stacked upon each other, thus reducing the overall effectiveness of the policy mix (del Rio and Howlett 2013).

In this context, the concept of policy mixing seems promising because a policy mix combines several policy instruments aimed at achieving one or several interlinked policy objectives by (a) tackling the most important drivers underlying the need for policy support; (b) trying to maximise synergies and minimising conflicts between the instruments. Focusing on policy instrument mixes has emerged as a more nuanced model for analysing public policy in political sciences in the 1990ies. For instance, Gunningham and colleagues (Gunningham, Grabosky, and Sinclair 1998; Gunningham, Neil; Young, Mike D. 1997) investigated optimal policy intervention in the context of combining selective regulation with market-based approaches to design sophisticated instrument mixes. Further research found the design and implementation of policy mixes to be very much context dependent so that information deficiencies, existing actor constellations and strategic considerations, which enter decision-making processes in real-world situations and increase the risk of mismatch between policy instruments and outcomes, complicate policy mixing (Howlett 2004; Minogue 2002). A policy mix goes beyond combining loosely or rather unconnected policy instruments. It links long-term qualitative objectives and short- to mid-term quantitative targets to an instrument set in a time-dynamic sequential process – thus, it aims at enhancing the performance of the different instruments and exploiting synergies as much as possible to achieve the objectives and targets. Therefore, compiling and implementing a policy mix requires:

- A forward-looking roadmapping process, i.e., relating different policy instruments to each other in a time sequence that helps optimising synergetic effects and minimizing unintended negative side-effects; and
- Consideration of political processes in polycentric governance systems in order to be able to identify and secure long-term multi-actor support, to monitor processes and adapt the mix in feedback loops over time.

The following heuristic framework, adapted from Givoni et al. (2013), suggests a multi-step and iterative process to facilitate the design of policy mixes. This encompasses the following stages (see Figure 34-1 below):

1. Defining longer-term objectives and setting of short- to medium-term, more concrete targets for the respective policy areas;
2. Elaborating a theoretical causal model for problem solving in the policy areas (what is the problem situation? What are contributing drivers? What does impede changes?);
3. Selecting, based on heuristics and expert guessing, promising instruments from known potentially relevant policy instruments contributing to problem solving to form an initial policy mix;
4. Undertaking ex-ante assessments (literature based qualitative assessments, participatory scenario building and quantitative computer model simulations) of the initial policy mix as to its potential effectiveness and impacts. This usually entails comprehensive scientific analyses, which then enable substantiated decision-making as to whether or not to include the instrument analysed into the mix;
5. Adding, if the initial mix was found sub-optimal against the set objectives and targets, further instruments to the mix or revising existing instruments and re-running the assessment (repetition of steps (3) and (4)) to finalise the policy mix;
6. Preparing the final policy mix for implementation, enforcement and monitoring.

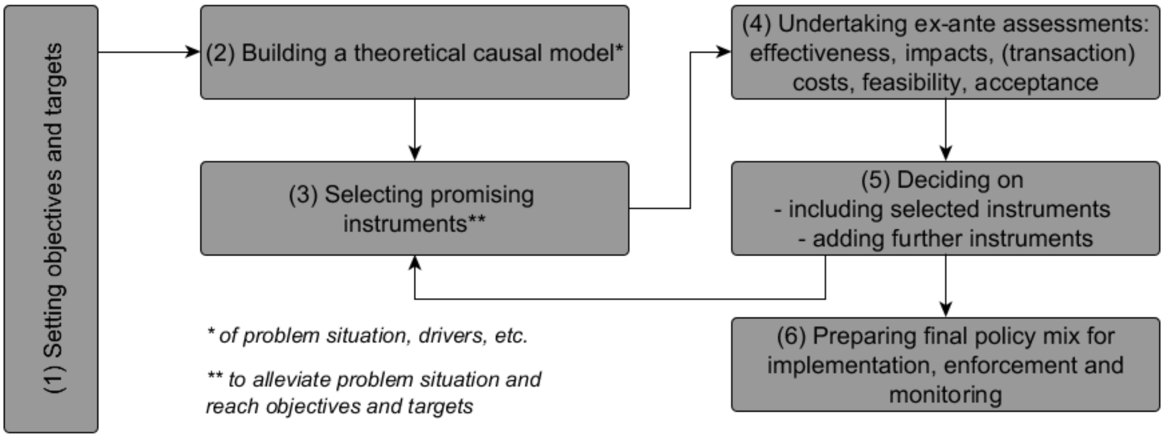

Figure 34-1: *Heuristic framework for policy mix design (Ekvall et al. 2016) (reproduction with permission of the authors).*

Outlook

The concept of policy mixing is promising because it requires identifying most important drivers and mechanisms to be tackled to achieve certain objectives. At the same time, by bundling together primary instruments, which mainly serve to achieve a set objective, with supportive instruments, which minimize or mitigate unintended negative side-effects of primary measures, acceptability and political feasibility of the policy mix can be strengthened.

However, in order for a policy mix to successfully respond to and be adapted to the specific context, it is important to consider: (i) The full range of policy instruments available and make use of different instrument mechanisms as appropriate (incentives, command and control, information and persuasion, infrastructure, enabling); (ii) The costs of policies for different actors (implementation costs for authorities, transaction costs and compliance costs for addressees); (iii) Potentially negative unintended side effects of the policy mix on target groups (e.g. issues of competitiveness for industry or regressive effects on lower-income households); (iv) Options to combine instruments to mitigate such side effects; (v) Political processes during design and implementation (Howlett and Rayner 2007; del Rio and Howlett 2013).

Thus, the concept of policy mixes will challenge political practices and experience. Resulting from political needs, such as existing alliances, election-based tactics, or lacking time or knowledge, policy formulation often leads to so-called policy layering instead of policy mixing in the above sense (Howlett and Rayner 2007). Therefore, political realities, as well as the dynamics and path dependencies of legislative periods, run counter to a strategic and more long-term implementation procedure of policy mixes. Hence, designing, implementing, and evaluating policy mixes is much more difficult than loosely bundled individual instruments.

35. THE CLIMATE IMPACTS OF FEEBATE ON CARS IN FUTURE SCENARIOS

Rafael Laurenti, David Palm, Tomas Ekvall ✉

Abstract

The ongoing EU FP7 project DYNAMIX aims to develop and assess dynamic policy mixes that achieve absolute decoupling between resource use and well-being. One of the policy instruments we assess is a feebate scheme for selected product categories. This instrument combines a fee for the environmentally worst products in the category and an economic incentive to choose the best products. France has such an instrument for cars.

We modelled the carbon footprint of the future European car fleet with and without an effective, EU-wide feebate scheme. The calculations were carried through in the context of the different background scenarios developed in the DYNAMIX project. These scenarios are based on different assumptions on the future rate of innovation and the degree of materialism in the economy. In a materialistic society with a high rate of innovation, the feebate system is likely to affect the share of electric cars rather than the size of the car. In a non-materialistic society with a low rate of innovation, the feebate system is likely to affect mainly the size of the car. In a non-materialistic society with a high rate of innovation, the feebate system is likely to affect both the size and the technology of the car.

Using different assumptions on the future European electricity system, the calculation results indicate that a shift to electric cars, or other technological improvements, is more important for the climate than a shift to smaller cars.

Keywords: feebate, cars, carbon footprint, scenarios.

Introduction

The DYNAMIX project

The acronym DYNAMIX stands for 'DYNAmic policy MIXes for absolute decoupling of environmental impacts of EU resource use from economic growth.' The DYNAMIX project is a collaborative project within the 7th EU Framework Program (FP7). The aim of the project is to identify and assess dynamic and robust policy mixes to shift the European Union (EU) onto a pathway to absolute decoupling of long-term economic growth from resource use and environmental impacts and to a sustainable future. To support this objective we established the following targets for the year 2050 related to the consumption of virgin metals, arable land, nutrients and water, and related to greenhouse gas (GHG) emissions (Umpfenbach 2013). The five DYNAMIX targets guided our selection of relevant policy areas:

- Metals: to reduce the use of virgin metals
- Land-use: to reduce the use of arable land, the input of nutrients, and the water stress
- Overarching policy: to reduce GHG emissions

For each of these three areas we developed a dynamic policy mix that included a set of interesting or promising policy instruments, based on an analysis of drivers and barriers, etc. (Ekvall et al. 2015a). The instruments and policy mixes are currently assessed using a combination of quantitative and qualitative methods for ex-ante assessment.

The feebate instrument

One of the policy instruments in the overarching policy mix is an EU-wide framework for feebate schemes for selected products. The feebate combines a fee for the environmentally worst products in the category and a rebate for the best products. The fee and rebate are balanced to make the system cost-neutral for each product category. This instrument is inspired by the French Bonus-Malus scheme for cars, which is designed to affect consumers (encourage the purchase of low-emitting cars and discourage the purchase of the high-emitting vehicles) and also to stimulate technological innovation in vehicles (Mission Ministérielle, 2013). The feebate framework would be expanded to include more products and a wider range of environmental impacts would be taken into account, such as emission of other harmful substances, small particles, and noise (Ekvall et al. 2015a).

The scope of the paper

This paper summarizes a quantitative study of the potential effects of a feebate system on the GHG emissions of the future European car fleet in a life cycle perspective. We modelled the emissions with and without an EU-wide feebate scheme, assuming that this feebate would greatly affect the composition of the car fleet. Besides this quantitative carbon footprint, we also include a qualitative discussion of how resource use could be affected.

A summary of the methods, assumptions, and results is presented below. Ekvall et al. (2015b) present more details on the study.

Modelling framework

Carbon footprint is a calculation of the GHG emissions of a product life cycle from cradle to gate, i.e., from raw materials extraction over production and use to management of the post-consumer waste. We developed a generic life cycle model of cars that allows for the calculation of carbon footprint of internal combustion engine vehicles (ICEV), electric vehicles (EV) and hybrid vehicles (HV) of three sizes: large, medium and small. The model was implemented in the GaBi software using input data mainly from Ecoinvent (2010) and Hawkins et al. (2013).

The model includes the material production, as well as the manufacturing, use and end-of-life of the vehicle. It also includes the extraction of energy resources and the production and distribution of the fuel and electricity used for propelling the car.

Background scenarios

To calculate the potential impact of a feebate system, we assumed the feebate to be effective. However, what effects can be expected depends on the context in which the feebate is implemented: the preferences of the consumers, the performance of available technology, etc. To manage the uncertainty inherent in the future, we calculated the GHG emissions in the context of the different background scenarios developed by Gustavsson et al. (2013) for use in the DYNAMIX project. These scenarios are based on different assumptions on the future rate of innovation and the degree of materialism in the values of the population (see Figure 35-1). These were the two key dimensions in the scenarios because they are important for the ex-ante assessment of environmental policy, highly uncertain, to a large extent influenced by factors beyond the control of policy-makers, and important in the public debate (Gustavsson et al. 2013). Each scenario includes a narrative explaining how the future evolves in that scenario and why. Each scenario is also described by a set of quantitative and qualitative parameters.

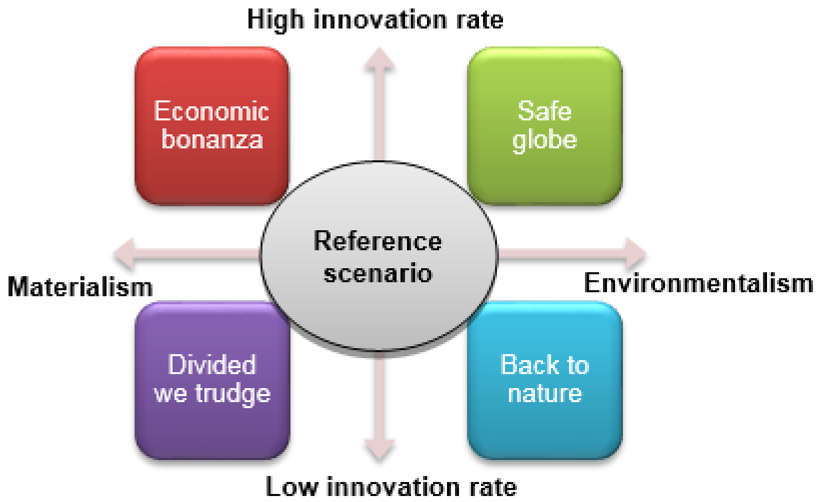

Figure 35-1:*The DYNAMIX background scenarios used for the carbon-footprint calculations of the future EU car fleet (Gustavsson et al. 2013).*

Based on the narratives, we draw conclusions on what can be affected by the feebate in each system:

- In the scenario "Economic Bonanza", a materialistic society with a high rate of innovation, consumers are likely to be more easily shifted towards advanced technology than towards smaller cars. This means the feebate system is likely to affect the share of electric and hybrid cars rather than the size of the car.
- In "Back to Nature", a non-materialistic society with a low rate of innovation, the feebate system is likely to affect mainly the size of the car. This is because the population in this scenario distrusts advanced technology and because good electric cars are not likely to be affordable even with a feebate.
- In "Safe Globe", a non-materialistic society with a high rate of innovation, the feebate system can affect both the size and the technology of the car. We assume this will be the case also in the Reference scenario, where technology evolves at a steady pace but without any major technological break-through.
- In "Divided we Trudge" we assume that the feebate cannot be really effective. The materialistic values will be a barrier to buying smaller cars. The low rate of innovation means the performance and price electric vehicles will remain unattractive.

We simplify the impacts by assuming that the feebate will have no impact at all on the size of cars in materialistic scenarios and no impact on the powertrain of the car in scenarios with low innovation rate, but be highly effective otherwise. This will exaggerate the importance of the scenarios, but it will make it easier to analyse the results (see next section).

For the purpose of the calculations we also added to each scenario assumptions on:

- The number of cars sold; this varies between scenarios but is not assumed to be affected by the cost-neutral feebate.

- The efficiency of the car; this is assumed to increase over time for all kinds of cars in the scenarios with average to high innovation rate; the efficiency is assumed to increase much more if the feebate is introduced.
- The GHG emissions of the future electricity production; this is important because part of the future car fleet is in the future electric or hybrid vehicles.

Quantitative results

The GHG emissions from each life cycle phase of passenger cars sold in the EU in the year 2013, 2030 and 2050 for all the five DYNAMIX background scenarios are presented in Figure 35-2. They have been normalized to the total life cycle emissions of the cars sold in the year 2013 (456 Mtonnes of CO_2-eq.). The emissions are divided into the different life-cycle phases of the car and the energy carrier, with indirect emissions denoting emissions from the production of the fuel and electricity for the car. Direct emissions from the car in use dominate the total GHG emissions in most cases.

The total GHG emissions are, of course, affected by the number of cars in use. The emissions are lower than 2013 in the scenarios Safe Globe and Back to Nature even without the feebate system. This is because the car sales are assumed to decrease in these scenarios, where environmentalist and non-materialistic values dominate.

The GHG emissions are also affected by the average size of the car. This is most clearly seen in the scenario Back to Nature, where the feebate is assumed only to affect the size of the cars sold. Note, however, that the car size has a moderate effect only on the GHG emissions.

A shift in technology towards more efficient cars and more electric and hybrid cars has a greater impact on the GHG emissions. This is most clearly seen in the scenario Economic Bonanza, where the feebate is assumed not to affect the car size but only the type of cars sold and the efficiency of the cars. A feebate system in this scenario drastically reduces the direct emissions because electric cars do not emit CO_2. However, the indirect emissions from electricity production increase because the feebate increases the total electricity demand of the car fleet.

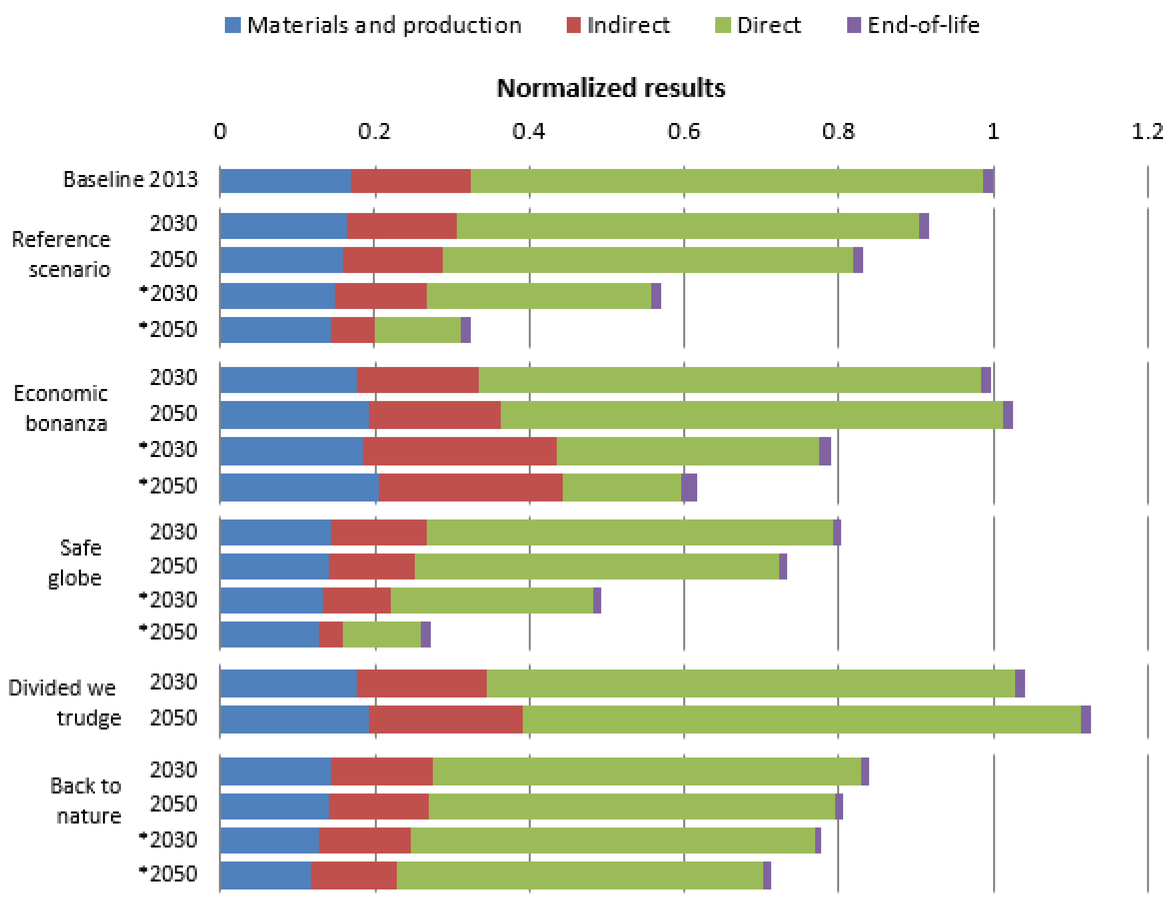

Figure 35-2:*Normalized GHG emissions of the EU passenger car fleet in 2013 and the five background scenarios of DYNAMIX. (* marks the emissions with an effective feebate scheme implemented).*

The lowest emissions are found in the Safe Globe scenario, where car sales decline and the feebate affects the car size, the type of cars sold, and the efficiency of all cars. In this scenario even the indirect emissions decline despite a higher share of electric vehicles. This is because indirect emissions are reduced from production of fuel to the cars, in particular, and because the feebate makes the cars more efficient in general. The increased use of electricity is less important in this scenario, compared to Economic Bonanza, because the electricity production relies less on fossil fuel.

Discussion and conclusions

It is clear from our results that impacts on technology is more important than impacts on the car size and that the development of background systems such as electricity production is important for how effective the feebate is to curb greenhouse gas emissions. The conclusion that technology is more important than size is difficult to generalize to other product categories. The size decides how much material needs to be produced, and reduced materials production typically means reduced greenhouse gas emissions. However, if this is more or less important than the technological choice will depend completely on the specifics of the available technological options.

Although our calculations have focussed on GHG emissions, we can also make some conclusions on the potential impacts of a feebate system on resource use. Almost all GHG emissions in our calculations stem from the use of fossil fuel. This means all conclusions made on GHG emissions can also be made on the use of fossil fuel. A feebate on cars can potentially greatly contribute to the reduction of fossil-fuel use for passenger transport, particularly if the feebate affects the use of electric vehicles. This is true even when the fossil fuel used for electricity production is taken into account.

A feebate can also have some impact on the use of metals and other resources, to the extent that it affects the size of the car.

36. EXPLORING THE POTENTIAL OF E-MOBILITY TO IMPROVE RESOURCE EFFICIENCY THROUGH SCENARIO-BASED LIFE CYCLE ANALYSIS

Teresa Domenech ✉, Marc Dijk, Sara Evangelisti, Carla Tagliaferri, Paul Ekins, Paola Lettieri

Abstract

The transport sector is the second largest emitter of GHG emissions in the EU and about two thirds of the emissions are generated from road transport. More importantly, while emissions from other sectors have shown a consistent decreasing trend, GHG emissions from transport have continued to rise and were 20.5% above 1990 levels in 2012, despite important improvements in vehicle efficiency. The electrification of the car float using vehicles running on plug-in electricity for their primary energy or e-mobility, has been considered a central option to improve the environmental efficiency of the transport sector and a key element to achieve the required Transport White Paper target of 60% decrease of GHG emissions by 2050. Although important innovations have been made in recent years, the requirements for e-mobility and also its implications are not always well understood. This papers uses a combination of Life Cycle Assessment (LCA) and scenario modeling to explore the energy and resource implications of e-mobility and helps to understand the contribution of e-mobility to the transport sector GHG reduction target but, more generally, to resource efficiency. Based on a comprehensive LCA, which covers e-cars from cradle to grave – i.e. manufacturing, use and disposal/recycling, the analysis builds three differentiated scenarios of e-mobility for 2050, based on different assumptions with regards to road transport use, e-car share and energy mix, as well as powertrain efficiency and recycling rate. Environmental impacts, energy savings and resource implications are analyzed for each of these scenarios. Based on these findings, the paper draws conclusions about policy mixes to promote resource efficiency in the transport sector and the role of e-mobility in a resource efficient economy.

Keywords: circular economy, resource efficiency, e-mobility, Life Cycle Assessment, scenarios.

Introduction: the transport sector and the potential of e-mobility to improve resource efficiency

The mobility sector is the second biggest contributor to GHG emissions in the EU. About two-thirds of the transport-related emissions are associated with the road transport sector (EC, n.d.). While EU transport policy is a key element of the efficient functioning of the internal market, transport systems are also the source of environmental impacts linked not only to GHG emissions and climate change but also local air pollution, land use and biodiversity, among others. Also, interestingly, while GHG emissions from other sectors have shown a decreasing trend from 1990, emissions from transport increased over 30% in the period 1990-2007. In 2008, transport-related emissions started to decrease, but in 2011 they were still above 20% higher compared to 1990 levels (EUROSTAT, 2015). The electrification of the car float using vehicles running on plug-in electricity for their primary energy or e-mobility, has been considered a central option to improve the environmental efficiency of the transport sector and a key element to achieve the required Transport White Paper target of 60% decrease of GHG emissions by 2050. The move to e-mobility as a way to reduce the environmental impacts linked to the sector and improve its resource efficiency also depends on the progress towards a low carbon economy and the decarbonisation of electricity generation. Important technological innovations have also been made in recent years to improve the performance and battery life of electric cars. In 2014, 75,333 new electrically chargeable vehicles were registered in Europe, which represented a 36.6% increase in one year (ACEA, n.d.), however, the number of electrical vehicles in Europe still only represents about 0.6% of overall new car registrations. The largest increase in new registrations (in absolute terms) was recorded in the UK, followed by Germany and France (ACEA, n.d.), countries that have incentive schemes and active policies to promote electric vehicles. In terms of market share, Norway is the frontrunner with 6% of the car sales being full electric cars in 2013.

Building a resource efficient Europe requires important improvements in the mobility sector with an absolute decrease of emissions and material requirements associated with it (i.e. infrastructure development). Although several Life Cycle Assessment studies on electric vehicles have been published in recent years (Hawkins et al., 2013; Hawkins et al., 2012; Kalhammer et al. 2007; Majeau-Bettez et al. 2011; Notter et. al, 2010; Shukla and Kumar 2008; Takahashi et al. 2005; Zackrisson et. al, 2010), there is still limited understanding of the role of electrification in a low carbon economy, taking into account future changes in the energy mix, car fleet and km per passenger and other changes that may influence the environmental efficiency of the sector, including improvement of mining practices, performance and powertrain of electrical vehicles, recovery of resources through recycling of batteries and other car components and changes in CO_2 standards for non-electric cars.

POLFREE[38] undertook a detailed analysis of e-cars using a combination of Life Cycle Assessment (LCA) and scenario modeling to explore the energy and resource implications of e-mobility and better understand the contribution of e-mobility to the transport sector GHG reduction target but, more generally, to resource efficiency. Based on a comprehensive LCA, which covers e-cars from cradle to grave – i.e. manufacturing, use and disposal/recycling, the analysis builds three differentiated scenarios of e-mobility for 2050, based on different assumptions with regards to road transport use, e-car share and energy mix, as well as powertrain efficiency and recycling rate. The following sections present the preliminary findings from this analysis[39].

Defining the boundaries of the LCA on e-cars

The first step in performing the LCA on electrical vehicles was to define the boundaries of the studies. Previous studies have generally omitted the end of life of vehicles and batteries given the limited information available on battery recycling processes and technologies. As one of the main aims of this study is to understand the electrification of cars for a resource efficient economy, the inclusion of the end of life stage was key in providing a full picture of the impacts associated with electric vehicles in comparison to conventional fuel powered cars. Figure 36-1 below shows the foreground and background elements considered in the analysis.

[38] POLFREE is a FP7 that explores policy mixes for a resource efficient economy in Europe (www.polfree.eu)

[39] Results from the scenario modeling will be completed by end of September (2015) and included in the oral presentation.

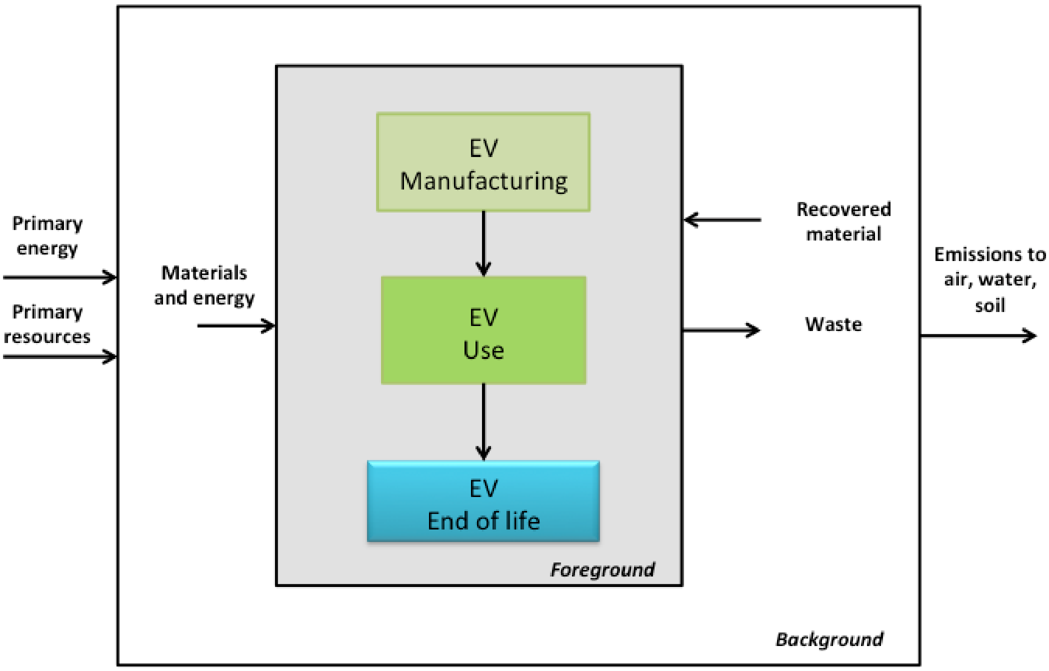

Figure 36-1: *LCA boundaries; Source: authors' elaboration.*

Another important preliminary step was to identify the type of e-car and battery on which the analysis would focus as well as the type of fuel powered car, which would be used for the comparison. The study chose to focus on li-ion batteries, as its use is becoming more widespread. The Nissan Leaf (100% electric) car is taken as the basis for the analysis. The Toyota Verso-S (0% electric) is selected for the comparison, given its similar characteristics in terms of size and model with the electric vehicle selected.

Although the LCA has taken into account all different car elements for both electric and conventional cars, key differences in the environmental impacts of both vehicles selected stem from the battery manufacturing of electric cars. Figure 36-2 below shows a simplified diagram flow with the key phases of the process of battery manufacturing.

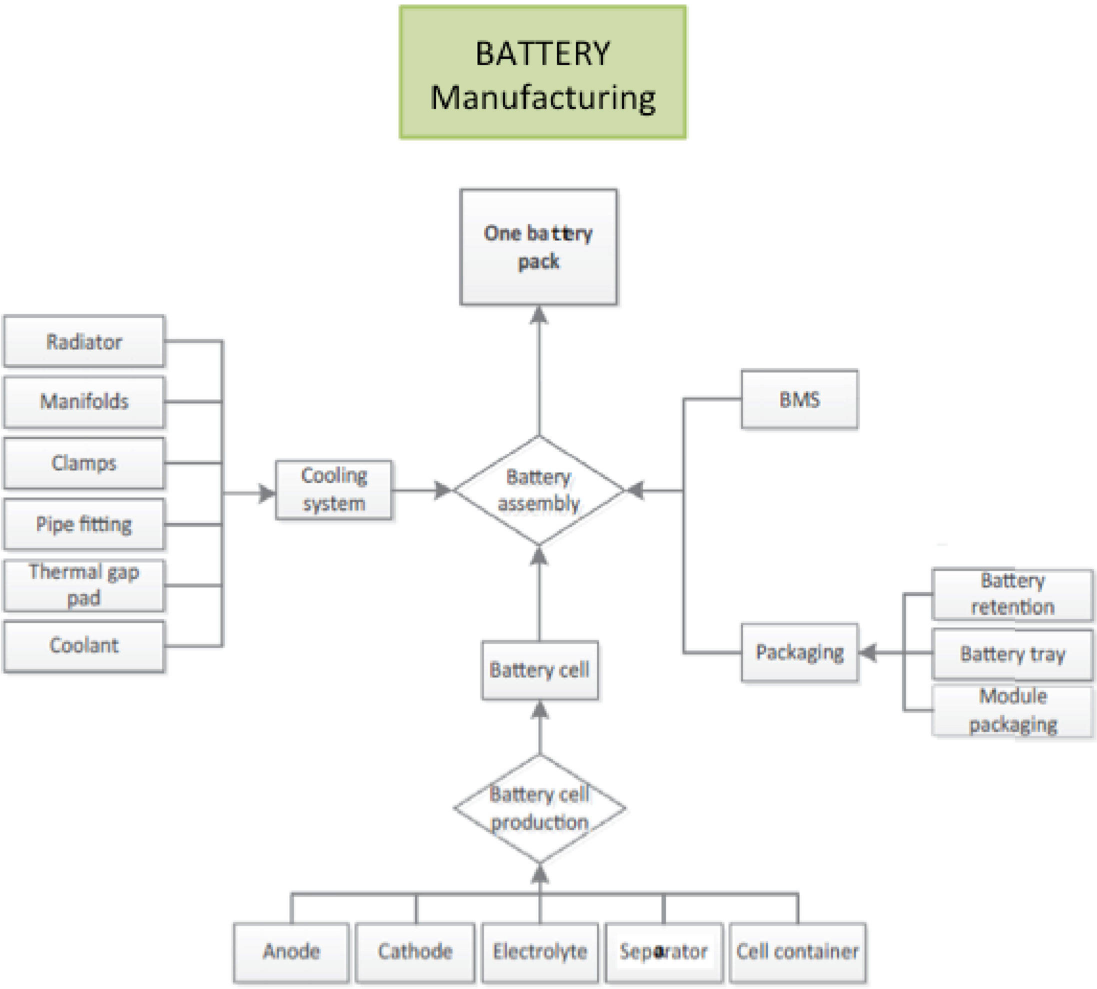

Figure 36-2: *Battery manufacturing process; Source: authors' elaboration.*

As noted above, the LCA study includes the end of life and recycling phase of the cars and batteries. Two key processes considered in the recycling of LI-Ion batteries are: pyrometallurgical processes and hydrometallurgical processes. These processes allow for the recovery of different metals contained in the battery. Key resources recovered through pyrometallurgical processes include steel, cobalt, non-ferrous metals, manganese oxide and plastics. Hydrometallurgical processes allow for the recovery of cobalt, aluminium lithium and other metals (such as steel and iron)[40].

Key assumptions

The study has selected the functional unit of 1km driven by car to allow for a straightforward comparison between both types of vehicles (electric vs. non-electric). The results obtained are based on an assumption of a vehicle lifetime of 150000km, that is an average figure of the duration of an electric Li-Ion battery. Two models have been created for the case of the electric car. One is based on literature data (EVI) (Majeau-Bettez et al., 2011), while the other one is based on more updated industrial data (EVII) (Ellingsen et al., 2014). For the calculation of the impacts associated to the use phase, the study used the average EU electricity mix for the

[40] This is based on state-of-the-art battery recycling plants in Europe.

electric car and diesel for the internal combustion engine vehicle. For the end of life phase, credits for metal recycling have been computed for both the conventional internal combustion engine vehicle and the electric car. The elaboration of the end of life phase needs to take into account the disparity between the number of cars put on the market and the number of cars that are disposed in Europe. Data seems to point to a huge leakage of car from Europe to other third countries where substantially less stringent regulations applied for the recycling and treatment of cars. To try to account for this unbalance the study has investigated two different scenarios for the disposal phase. One is based on a 100% vehicles disposal in Europe (closed loop scenario) and the other scenarios is based on the more realistic assumption that only 57% of the vehicles are disposed in Europe and therefore recycled and processed while 43% are exported to third countries (Oko institute, 2008). Given the lack of information about processing and disposing conditions in third countries, the study has assumed that 43% of the vehicles will be landfilled (open loop scenario). This, however, probably underestimates the impacts of vehicle end of life in third countries, where uncontrolled landfilled and informal recycling are common practices with associated increased environmental impacts. Gabi software has been used to support the LCA analysis. Gabi databases have been used to estimate environmental impacts of mining and extractives industries and energy mix in Europe.

Preliminary findings

This section summarises the key preliminary findings of the LCA for electric cars. Although a full LCA has been performed for both open loop and closed loop scenarios, only key results for the more realistic open loop scenario are presented here. A more detailed analysis of results by impact category is available at www.polfree.eu.

Open- loop scenario

The figure below (Figure 36-3) shows the normalised results for the open loop scenario. Impacts associated with water toxicity clearly stand out. These are mainly associated with the mining and extraction of primary raw materials and energy. These impacts are greater in the case of electric vehicles and are associated with the use of critical metals, such as lithium and copper, in the manufacturing of the battery.

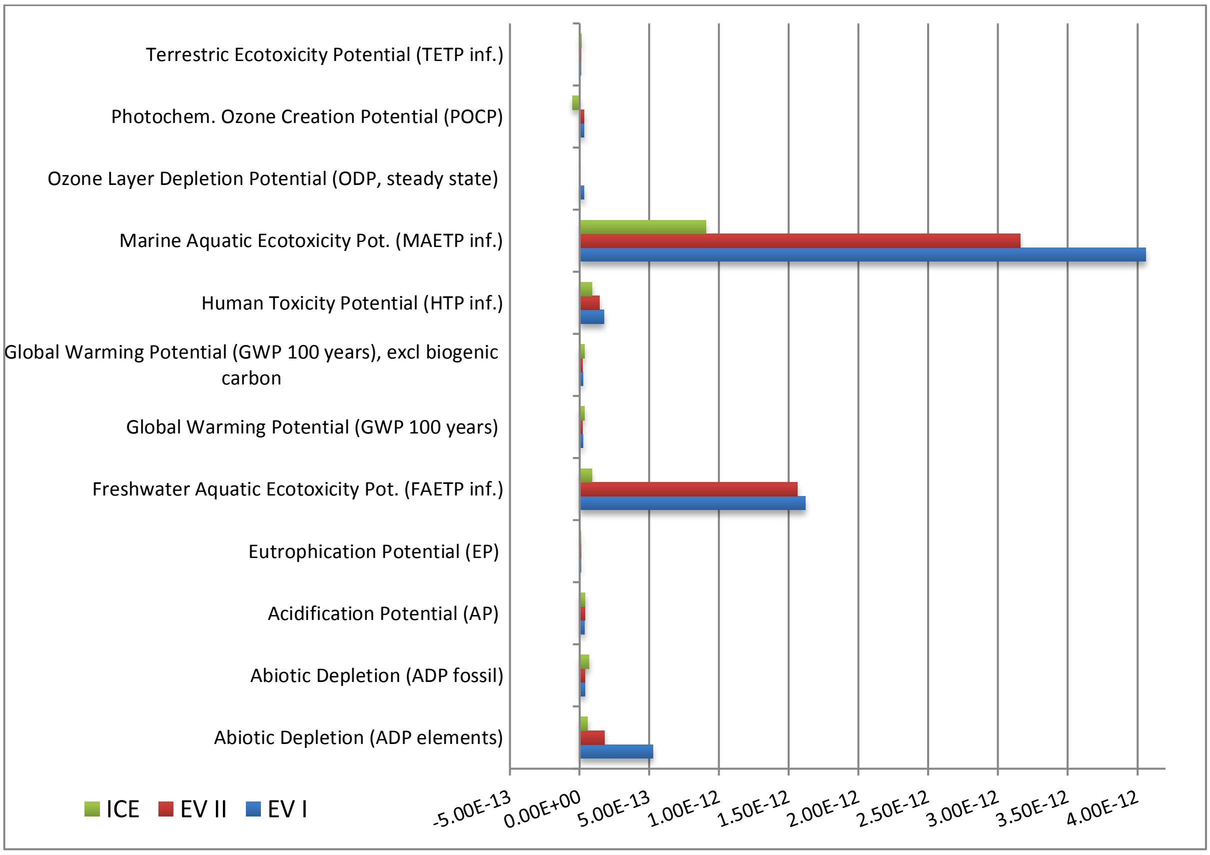

Figure 36-3: *Normalised impacts in open loop scenario; Source: authors' elaborated.*

As one would expect, in the impact category of global warming potential (GWP), overall impacts of internal combustion engine vehicles are higher than electrical vehicles. However, the manufacturing phase of electrical vehicles has a considerably higher impact than that of internal combustion engines.

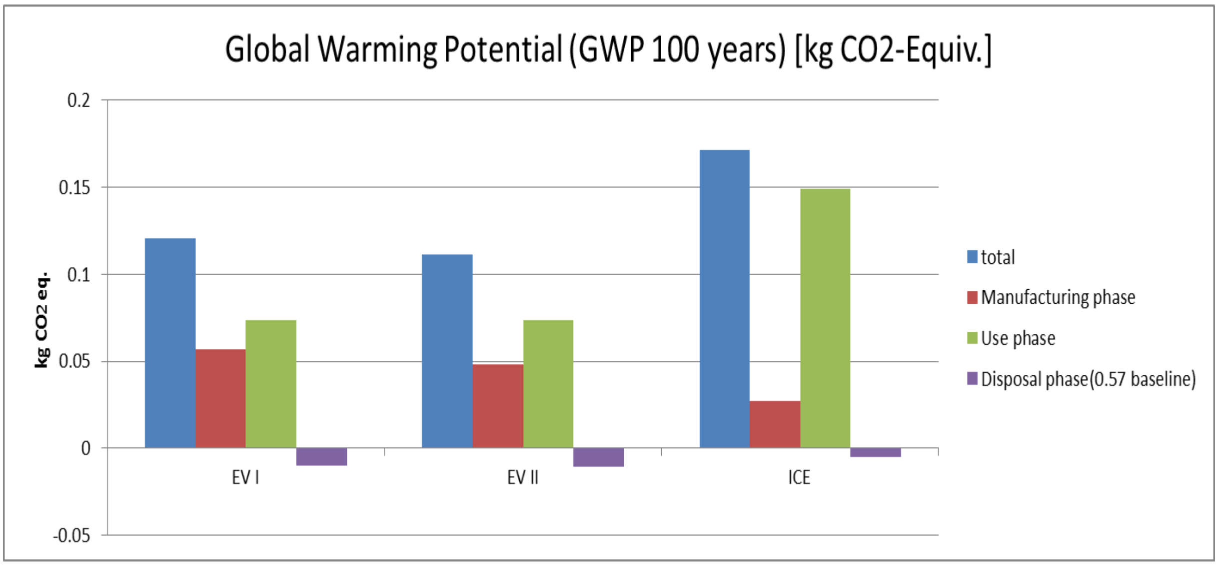

Figure 36-4: *GWP comparison; Source: authors' elaboration.*

Similarly, greater impacts are associated with internal combustion engine vehicles for the category of depletion of abiotic resources, due to their higher consumption of fossil fuels, as Figure 36-5 clearly reflects.

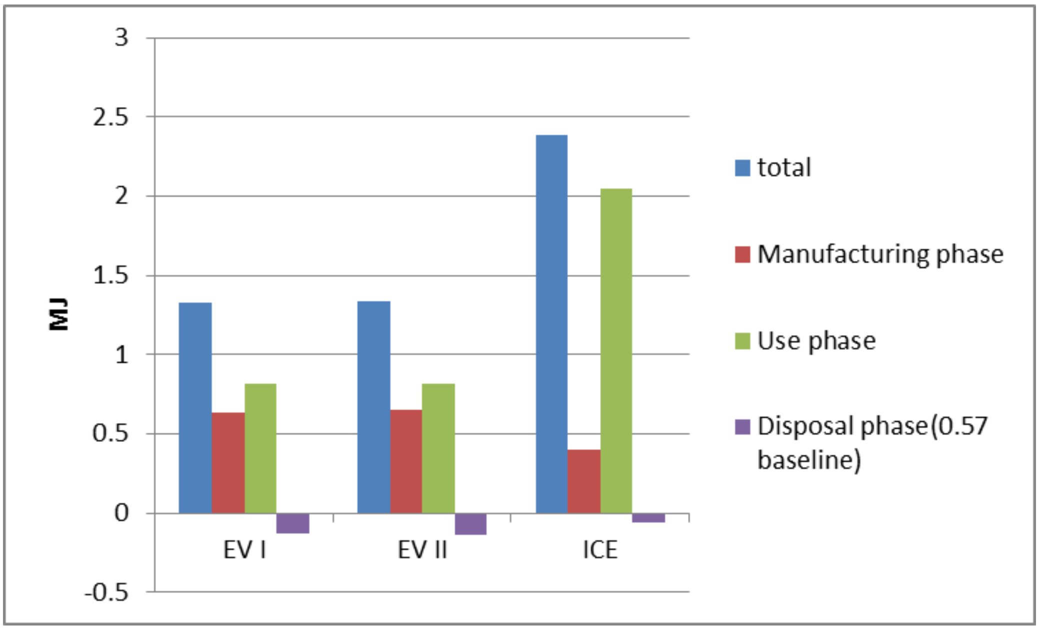

Figure 36-5: *Depletion of abiotic depletion (fossil) [MJ]. Source: authors' elaboration.*

The picture is quite different, however, if we look at the results of the analysis for different impact categories associated with toxicity (both eco-toxicity and human toxicity). In these cases, electric vehicles perform considerably worse than internal combustion engine vehicles given the impacts associated with extraction and mining of critical metals in the manufacturing of the battery as well as the chemical binders used in the battery. Figure 36-6 shows the comparative results for the impact category of human toxicity potential (HTP). In model EVI HTP impact is higher in manufacturing phase because of the presence of gold, nickel, copper and epoxy resin in the Integrated Circuit, which is allocated in the Battery Management System. In EVII HTP is higher in manufacturing phase because of the presence of copper in the anode and the active material in the cathode. Note that BMS modelled in EVI is different from the one modelled in EVII. The disposal phase has a negative impact given the credits assigned to the recycling of the vehicles. In this case, credits are higher for electric vehicles given the avoidance of impacts and recovery of critical metals used in the battery manufacturing.

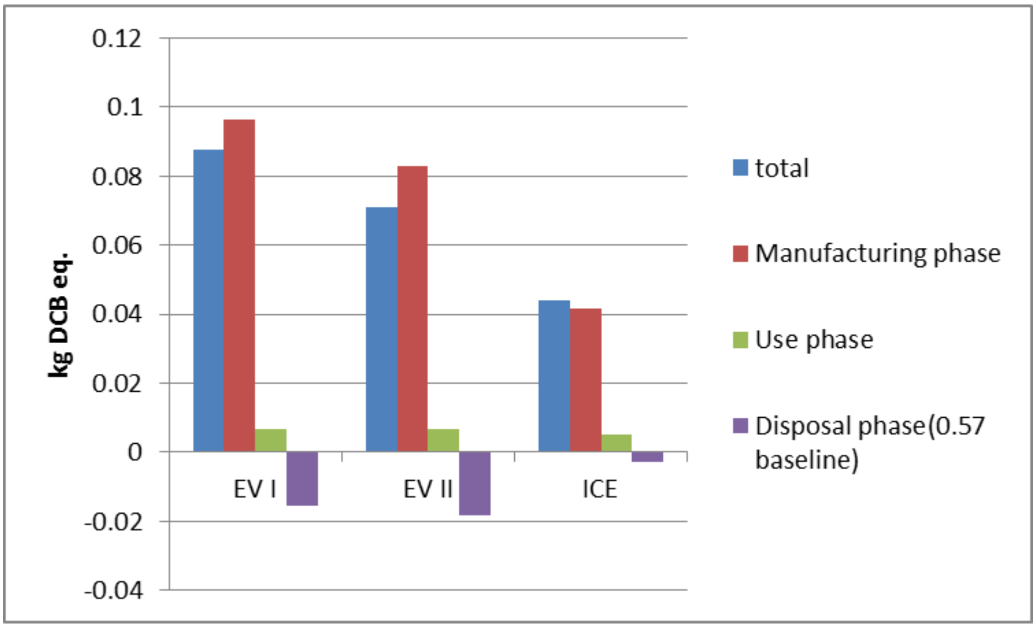

Figure 36-6: *Human Toxicity Potential Kg DCB eq. Source: authors' elaboration.*

Future steps: Modelling of scenarios

The electrification of the mobility sector has been at the core of policy interventions to reduce the environmental impact of the sector and increase its resource efficiency. Policy visions and future scenarios generally assume a move towards electric mobility (EC, 2011). However, there is limited understanding of what the implications of this may be. In POLFREE we have used a combination of LCA and scenario modelling to try to fill this gap and provide a detailed analysis of the implications of the electrification of the mobility sector. Departing from the results of the baseline scenario presented here, next phases of the study involve an exploration of what may the impacts be for 2020, 2030 and 2050 under different assumptions of changes in recycling efficiency and energy mix composition. It is expected that the move towards a low carbon energy system will decrease the impacts of e-cars compared to conventional combustion engine cars. The move to electricity though is unlikely to happen unless policy mixes and policy instruments are put into place. For each of the time horizons proposed, POLFREE has developed three different scenarios that reflect different institutional settings and global contexts. The three scenarios proposed are: “global cooperation”, “EU goes ahead” and “civil society leads”. Table 36-1 summaries main policy instruments applied in the mobility sector to promote e-mobility under each of the scenarios. At the same time, it is also important to note, that apart from the specific instruments designed for the mobility sector, the overall policy mix influences the environmental impacts associated with e-mobility through policies applied in the areas of energy and climate change, to promote adoption of low carbon technologies and increase energy efficiency, and recycling. GINFORS macro-model has been used to analyse the impacts of the policy mixes proposed to ensure that they are sufficient to reach the targets and sub-targets for a resource efficient economy in Europe, where emissions are reduced by 85% from 1990 levels and material consumption is within 5 tonnes per capita.

	Global cooperation			EU goes ahead			Civil society leads		
Policy instruments	2020	2030	2050	2020	2030	2050	2020	2030	2050
Economic instruments to promote e-mobility									
Subsidies on public land transport (% of basic price)				4	13	30			
Autonomous reduction of individual transport							4	13	50

Table 36-1: *Policy mix to promote e-mobility. Source: Meyer et al., 2015.*

Conclusions

The analysis presented here provides insights about the environmental implications of the shift towards e-mobility and its contribution to a resource efficiency economy. Although a number of LCA studies on electric cars have been performed in recent years, our study has extended existing models by considering: 1) the end of life of vehicles under two scenarios: a) high rate recycling (closed loop scenarios) and b) low rate recycling (open loop scenario) to better reflect current situation where the number of cars put on the market substantially surpasses the number of vehicles treated or disposed of in Europe; and (2) future scenarios for e-mobility that take into account changes in the energy mix and the transition to a low carbon economy.

Part IV

Lifestyle and Education

37. UNTYING THE GRIDLOCKS: CHANGING OUR HERMENEUTICS TO BIFURCATE FOR GOOD

Carlos Alvarez-Pereira ✉

Abstract

This contribution uses metaphors originated in the Dynamical Systems Theory to describe the potential pathways in the evolution of human societies and how, through the accumulation of tensions at critical points, bifurcations can emerge, for the good or the bad. Making the bifurcation go in the right way is no easy task, and it requires changing our framework of interpretation, by backcasting from desirable futures.

Keywords: gridlocks, bifurcation, hermeneutics, complexity, holism.

Early Signals

Concepts are important to build perceptions of reality, hence to build social reality itself, and even more if we intend to change it. About 50 years ago, Radovan Richta, a now forgotten philosopher from Prague, said that our civilization was at a crossroad (Richta 1966). Some years later, the Club of Rome proposed the concept of limits to growth in order to avoid collapse of civilization as we know it (Meadows 1972).

These and many other works published in the 1960s and 1970s had a real impact on the public debate and fueled important controversies with a potential to influence policy making, and in the last decades environmental concerns have certainly played an important role in the political agendas, both at national and international levels. But in terms of civilizational changes, it seems fair to say that the outcomes have been quite limited, or rather divergent as far as sustainability is concerned.

Actually, new studies are showing that the evolution of mankind in the last decades has followed a path which is surprisingly close to the predictions modelled for the "business as usual" scenario by Meadows and her team back in 1972 (Turner 2014).

Moreover, it makes no doubt that since Robert Malthus wrote "An Essay on the Principle of Population" back in 1798, dozens of thinkers and leaders have expressed deep concerns about the fate of humanity as a consequence of a socio-economic model based on the core assumption of unlimited growth. Also, in response to those concerns, many practitioners developed solutions which would be labelled today as "green", such as the solar machines created by Augustin Mouchot back in the 1860s, from which humanity could have profited to avoid in particular the dependence on fossil fuels (Bonneuil 2013).

All in all, Richta, Meadows and others were fundamentally right, but they have been unheard for decades. As a result, we are no longer at a crossroad, where we can easily choose between different directions, but trapped in a planetary high-speed gridlock, actually in a combination of intertwined gridlocks. We move faster and faster towards nowhere, and we are less and less able to think in perspective and to get out of the gridlocks.

The Gridlocks

First is the **gridlock of thinking** itself. Drowned as we are by an endless deluge of information and gossip, our mind goes up and down with the trending topics of "social networks" and thinking in perspective becomes extremely difficult: if we connect to everyday reality we are not able to think; if we disconnect from it, will our thinking be valuable or even heard by society? As anticipated by TS Eliot many decades ago, we can ask today where is the knowledge lost in so much information and, worse, where is the wisdom lost in so much knowledge.

It is not that real alternative thinking does not exist. It is probably stronger and has more potential than ever but we do not pay much attention to it. It can certainly be part of the show, in ways imagined by Guy Debord and described by Neil Postman, but in many dimensions of our indidivual and collective life we are not so interested in learning relevant knowledge when it is contrarian to the high-speed mainstream. Conversely, we are more and more able to unlearn some wise lessons acquired at a high cost in the past (f.i. that of a strong regulation of financial markets).

The gridlock in thinking makes us partially blind to the most determining one in the long term, the **gridlock of metabolism**. We know that our consumerist society of uneconomic growth and waste, driven by the materialistic lifestyles of the leisure class, is incompatible with the pace of renewal of natural resources brought to us by the magic alliance of Earth and Sun. Without solving that contradiction, sooner or later the collapse of human civilizations is inevitable, as it was for the people of Easter Island, a small-scale but significant precedent.

Of course, this metabolic gridlock is directly linked to the growing divergence between what is humanly desirable and feasible in harmony with the environment, and what is financially attractive. We also live in a **gridlock of purposes** when financial profitability has become the core obsession of our economy, while human and natural welfares are displaced to be only fourth or fifth derivatives of what we call success. That way, the economy produces unemployment, poverty and inequality except at very high rates of growth which are lethal for the depletion of resources, including climatic stability and, the least renewable of all, our own future.

Is all that new to us? Not at all, as said so many good diagnostics have been produced in the last decades, so many indicators are being monitored which say that we are still on the safest path to collapse. But we also live in a **gridlock of will** which prevents to act in a consistent way. This in turn is linked to a dramatic change in the distribution and effectiveness of power, and to the evolution of its nature itself.

On one side, a huge amount of power has been transferred from the western world to the rest, which by the way is where most of humans live, so this is nothing but justice. Unfortunately, we still think in very primitive terms of "us" and "them" and, worse, we take for granted that our power of the past, and still of today, gives us some kind of moral superiority. This makes very difficult to pursue the real opportunities to build together the tools of global governance, precisely when challenges are getting more and more global and complex.

Moreover, universal literacy, women emancipation and modern technologies are facilitating the emergence of a planetary interconnected citizenship which is redefining the nature of power. The paradox is that while traditional politics has committed suicide in the West by conceding much more power to market owners and self-proclaimed experts, reality is actually becoming more and more political, it is more and more determined by non-trivial interactions between a greater number of autonomous actors. Since the number of these and the connections between them grow dramatically, so does the complexity and unpredictability of our human society. This is not bad in itself, it may be instead the basement for the emergence of a new paradigm of civilization, but our tools of governance are not ready yet for that.

And this leads us to the most intriguing **gridlock of culture**, so difficult to apprehend. Consciously or not, when facing the contradictions of everyday life, we tend to pursue selfishly our individual interests, taking for granted the powerful but false idea that such a behavior is the recipe for individual and social progress. Powerful because it connects with many people adopting selfishness as an artificial relief for their fears, but false because it actually produces concentration of power and richness in the hands of a few, and therefore inhibits the potential of most and compromises the sustainability of our ecosystems. Still, what could make us choose freely generosity instead of sefishness?

Certainly, our culture praises innovation, a magic word constantly present in our era of mass media. But who can ignore that it often becomes a synonym for that high-speed consumerist stream of instantaneously obsolete artifacts which entertains our lives inasmuch it empties them of genuine humanity and spirituality? One may ask if modern art and creation are playing their proper role in solving the gridlock of our mass-media culture, or have become also part of the "société du spectacle" (Postman 2005).

Ultimately, we suffer from a **gridlock of vision**. Many concerned individuals around the world are already aware about what we describe here. Many books and reports are written to explore the complex challenges of our times, hopefully bringing a better understanding and capability to harness them. But a strong feeling exists that it is far from enough, that in the fundamental dimensions of our future, inertias are much stronger than innovation and that our high-speed pace of change is actually reinforcing the gridlocks. Why is that so?

For all what we say about change and innovation, we mentally live jailed in the imperialism of the present. We believe that human nature is essentially immutable and that the incredible and many times erratic accumulation of historic contingencies which has brought us to where we are today, has nonetheless given birth to the only world possible. In the name of realism, we censor ourselves, labelling as utopian so many alternative ideas of how to live, precisely when the only realistic option for the future, as Edgar Morin says, is to be an utopian.

Bifurcate for Good

How to untie the gridlocks? First by being aware that they exist, by describing them, whatever the effort it can take to leave our usual comfort zone. Most of the time, we abandon ourselves to the social high-speed stream leading to nowhere. While we know this is crazy, we practice the very human sin of procrastination and indulge ourselves by complaining about what we live and missing good old times.

But time has come to do the extra mile to wholly new concepts and actions. Their seeds are certainly there, dispersed but alive, some imagined maybe by poets, others by voluntary outsiders, but also many claimed by sensitive insiders. Time has come to assemble the seeds and give them the right soil and nutrients to make them grow into a new and beautiful embodiment of life on Earth.

The ultimate reason for those gridlocks to be so strong is that untying them is not possible in the same plane where they were created. We have to change our intellectual and emotional framework, i.e. the hermeneutics in which we express today our perceptions and concepts. In that plane, tensions will only accumulate in the gridlocks, up to a point of rupture where the sum of systemic instabilities will make a **bifurcation** happen towards a very different path.

But the bifurcation which starts at a social gridlock may either goes down, towards collapse, violence and misery, or up, towards a plane of higher complexity and richness. Unfortunately, in historical perspective, it tends first to go down before going up, because increasing complexity is typically not the easiest path to follow. It requires additional energy, consciousness and a sense of holism, as well as determination and generosity, all of them qualities which so many times do not win the game except when all simplistic options have been tried first, which is why human history has been built so often on tragedy.

For instance, the religious disputes which led to war and destruction in Europe from XV to XVII centuries were finally resolved, not by a one-sided victory or by a unification of doctrines into a single one, but rather by accepting a higher level of complexity, that of religious tolerance. Likewise, the complex and diverse European Union, that "unidentified political object" as Jacques Delors named it, did not emerge until the unprecedented catastrophe of two gigantic civil wars of planetary scale.

For sure, we will transit to a new bifurcation, this is guaranteed by the aspirations of nine tenths of humanity (including the women of everywhere) to break with the current statu quo. But how do we avoid the bifurcation heading first towards catastrophes, before eventually giving birth to a new planetary eco-civilization which is far from being granted?

Of course, we have much more questions than answers. As said, being aware of the gridlocks and understanding them is a step in the right direction. Imagining desirable futures may help: instead of so many exercises to forecast the future, which leave us trapped in the same hermeneutics of today, we could try to **backcast** from those desirable futures. For instance, we could envision dramatic changes in the purposes of human organizations; a cultural revolution built on more feminine values redefining the nature of power towards care and collaboration; an educational system transformed towards the true expression of human potential through the talents of all; and the promotion of generosity as the real driver of individual and societal progress.

We have more questions than answers. As advised by Antonio Machado, we know there is no way, one makes it by walking. But at least we know that **holism and complexity** are required. Ecosystems are holistic and complex per se. The bifurcation we need will not be less so. And when we say holistic, we mean different things. For one, we have to recognize that complexity is not wrong, it may be the testbed for the emergence of new synchronicities, of qualitatively new social artifacts to overcome the gridlocks we face today (Ostrom 1990).

For two, the center of the world is now everywhere. Time has come to conceive the world not from the West to impose our conception and values to the rest, but rather to build something new together. Maybe the shortest path to this will be coming back to Africa, where everything started long ago.

And for three, being holistic also means building with and from citizens of all over the world, through a combination of top-down, bottom-up and cross-generational approaches without which no new legitimacy will be possible. No doubt, new political and cultural processes will be necessary to transform our world. Who knows, maybe the right bifurcation will start in and from the cities, as the roots of active citizenship and as small-scale worlds where we could try to untie the gridlocks and open ways to a better future.

Conclusions

Achieving the humanly desirable in harmony with the environment will not be a spontaneous and smooth adaptation. The way out of the multiple high-speed gridlocks in which we are trapped will not be easy nor based on a "silver bullet" idea. Instead, it may come from the recognition that we need a different framework of interpretation to get rid of the current hermeneutics which is limiting our perceptions and concepts. Backcasting from visions of desirable futures will be useful to achieve this, but our way out will have to be built everyday in a process of processes to ensure that the bifurcation from the gridlocks goes in the right direction, while the potential to bifurcate first for bad is very high.

There is no recipe for this but complexity and holism are required. New synchronicities and social artifacts can emerge from complexity to overcome our gridlocks, and it is our responsibility to make them happen as the roots of a better future.

38. HOUSEHOLDS RESOURCE CONSUMPTION: IMPACT AND POTENTIALS OF SOCIAL PRACTICES

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Jens Teubler, Klaus Wiesen, Monika Wirges

Abstract

The transformation of society to sustainable consumption and production patterns is a future key challenge. Households play a major role in this transformation process.

This paper describes results of a resource consumption analysis at household level, conducted in Germany as part of the Living Lab research in the EU-project SuslabNWE (Sustainable Living Lab North West Europe, www.suslabnwe.eu). The project explores social and technological innovations in the field of heating and develops strategies for sustainable household consumption.

To analyse the resource consumption of households a methodology for assessing households' material consumption and consumption patterns was derived. The analysis intended to identify the impact of social practices on resource consumption. Therefore, households' (n=16) natural resource consumption was calculated in different fields of activity. The direct consumption of resources was taken into account as well as their life-cycle wide impact. Finally, it was possible to compile consumption roadmaps together with seven of the involved households. In the course of the road mapping process, the households developed different options in a short, medium or long term frame collaboratively with researchers to reduce resource consumption in the fields of actions.

Results show the applicability of the methodology, possibilities for further development, the transformational potential for changing behaviour as well as for product-service design (PSS). For example, it is possible to derive a less detailed questionnaire for assessing households' resource consumption that can be used and integrated in an online tool, developed for calculating individual resource consumption (www.ressourcen-rechner.de). The resulting resource profiles show that next to technical options there is a high potential for structural changes and social innovations materialized in low resource PSS. The road mapping process showed the high motivation of the households for changing social practices and the need for adapted PSS and infrastructures.

Keywords: household, social practices, consumption, natural resource use

Introduction

The transformation of society towards a sustainable development is an indispensable challenge in the twenty-first century. Economic actions already exceed ecosystem´s capabilities (Rockström et al. 2009). The global consumption of natural resources is still rising beyond the natural system's boundaries (Schmidt-Bleek 1994, Bringezu&Bleischwirtz 2009, Ward&Neumann 2012, Giljum et al. 2014). Thus, societal transformation towards sustainable consumption and production is a key challenge (Schmidt-Bleek 1994, Lettenmeier et al. 2014, 2012). Households play a major role in this transformation process. Within household consumption housing, nutrition and mobility are identified as key fields of activity responsible for high natural resource use (Acosta-Fernàndez 2011, Kotakopori et al. 2008). Due to the connection of social practises to all fields of activity in household´s consumption, an assessment of the whole household system is necessary to evaluate determinants, possible lifestyle changes and rebound effects (Brooks 1990, Kortkopori et al. 2008, Buhl 2014, Liedtke et al. 2015).

The goal of the project SuslabNWE was to implement a research and development network infrastructure, that serves the user integrated as well as the actor integrated development of sustainable product service systems in Europe. In North Rhine-Westphalia (SuslabNRW), a Sustainability Living Lab infrastructure has been built (based on the Three-Phase Model 1) Insight Research, 2) Prototyping and 3) Field testing). The main research question of this project was: "How can the energy and resource efficiency in buildings be increased through the integration of users as well as actors in the value chain "heating / room temperature" into the development of processes, products and services?" (Liedtke et al. 2015, Baedeker et al. 2014). For analysing a wider field of ecological sustainability as well as for analysing the whole consumption of households, an analysis of households' natural resource consumption has been included in this project. In this part of the Suslab project the natural resource use in form of the Material Footprint has been used as an indicator for sustainability (Huysman et al. 2015, Liedtke et al. 2014, Lettenmeier et al. 2009). Next to this input orientated indicator the Carbon Footprint has been used to compare the impact on resource use and greenhouse gas (GHG) emissions. This approach has been tested in a Finnish study in 2008 (Kotakorpi et al. 2008). This study was conducted according to the Finnish approach and performed in Germany for the first time.

Methods

16 households were typologised and questioned regarding their consumption patterns, ownership of items and daily habits in the fields: housing, nutrition[41], waste, mobility, recreation, tourism and household goods & appliances. By applying the Material and Carbon Footprint methods the households' resource consumption and GHG emissions were calculated. The identified hot spots were used to develop individual road maps towards lower resource consumption and GHG emissions for the participating households. The procedure was structured in three successive steps:

1. Household monitoring
    a. Recruitment and typologisation of volunteering households (typologisation)
    b. Survey of household consumption patterns and metrics (questionnaire)
2. Calculation and Evaluation
    a. Calculation of the Material and Carbon Footprints (calculation)
    b. Identification of resource and emission relevant activities (identification)

and for participating households in cooperation with scientists the

3. Roadmapping Process
    a. Compilation of road maps (road mapping)
    b. Evaluation of road maps after trial (evaluation).

41 To enable a better differentiation of households, pet food consumption was separated from nutrition later in the project.

First, the household monitoring (1) was conducted. After the recruitment of households in the study area (the City of Bottrop) by press release, all registered households were classified with a triangulative analysis of socio-economic characteristics (according to the given data on e.g. household size, family status, income, education and age of the head of household) – called household typologisation (sociodimensions 2015). After this, the consumption monitoring started in October 2014 and lasted for six weeks. The questionnaire was geared according to the Finnish study of households´ resource consumption (Kotakorpi et al. 2008), but tailored to the specific German situation.

Parallel to this step the calculation and evaluation of the Material and Carbon Footprint (2) started. The calculation of the resource consumption and greenhouse gas (GHG) emissions of the households are based on Life Cycle Assessment (LCA, ISO 14040/44 (2006) and IPCC (2007)) and Material Flow Accounting (MFA, Fischer-Kowalski et al. 2011) methods. The calculation of Material Footprints (MFs) (Schmidt-Bleek 1994, Lettenmeier et al. 2009, Liedtke et al. 2014) and Carbon Footprints (CFs) were based on a database for Life Cycle Inventories (Ecoinvent, version 2.2 Hedemann et al. 2007) which provides generic data for the production of basic materials, provision of food and feedstuff products as well as average data for transport and energy systems. These processes were modelled to the inputs of the household questionnaire and the scope of the study with the help of a software for Life Cycle Assessment (OpenLCA (Ciroth 2007). Its calculated impacts MF and CF were accumulated to provide cumulative yearly results per household, category and sub-categories. For both MF and CF calculations the inventory data was the same.

In a third step (3) a road mapping process was conducted. For this, the individual results were reflected with the participating households within a workshop and individual roadmaps for possible lifestyle changes were compiled in discussion with a scientist. The goal of these road maps was not to induce the highest possible resource or emission efficiency of one particular household. Rather, it was first discussed what behavioural changes could lead to a lower resource use and a decrease of emissions. In a second step it was discussed which of these behavioural changes the household would like to implement in the short, medium and long term.

Based on the same methodology used in SusLabNWE an online resource calculator with a less detailed questionnaire was developed. The calculator can be accessed via www.ressourcen-rechner.de. It offers the possibility to assess the personal resource consumption over the year in the fields of mobility, nutrition, leisure, holidays, private consumption, and living. Furthermore, the resource calculator provides a questionnaire for socioeconomic data. These data can be linked to the resource use establishing resource profiles on private consumption showing the relation of e.g. age, income and resource use.

Results & Discussion

The results of the Finnish household study with 27 volunteering households including all kinds of household types showed a range of factor 9. A large diversity of lifestyles of the participants was also identified by Groezinger et al. (2013) and their Material Footprints, ranged from 8.5 to 69 t per person per year (factor 8).

In the study at hand, households differed to a degree of factor 3.7 between the lowest and highest resource consumption, ranging from 16t to 60t per person and year (Figure 38-1). Although the results still show a high variability, the differences are lower than in Kotakorpi et al. (2008) and Groezinger (2013). One reason for this could be the similarity of the household types in the study, caused by the recruiting method (addressing volunteers via a press release of Innovation City in Bottrop (http://www.icruhr.de) and the small sample.

The different fields of activity have very different shares within the total consumption, but also between the households. For most housing - including heating - and mobility represent the highest resource demand but nutrition and goods&appliances are relevant as well. In general, individual consumption patterns could be identified that lead to individual and household resource consumption patterns.

Next to technical differences the individual resource consumption patterns can be explained with individual behaviour thus social practices. Especially, in the case of housing the share in the total Material Footprint even varies for households that show approximately the same total Material Footprint (see household no. 03, 04, 05, 09, 10 an 11). There is always a connection of different fields of activity among each other, e.g. nutrition and mobility. Thus, it is difficult to allocate precise social practices to one field.

Other influencing factors within the resource consumption (next to social practises) are the number of persons in a household, the living space and income. As expected, more persons living in one household reduces resource consumption per person compared to e.g. single households. In opposition, a larger living space induces a comparably higher resource consumption, due to the relevance of buildings and the heating of buildings (housing & energy). Within the 16 volunteers no statistical correlation with household types could be found. However, there is a tendency of higher resource consumption in empty nester households (senior citizens with children having already moved out) in comparison to young families belonging to the mainstream.

A correlation of total MF and total CF consumption shows a slight connection of these two indicators with a correlation factor of 0.48 that is based on major correlations on the fields of housing and mobility. In the field of goods&applications a negative correlation is found.

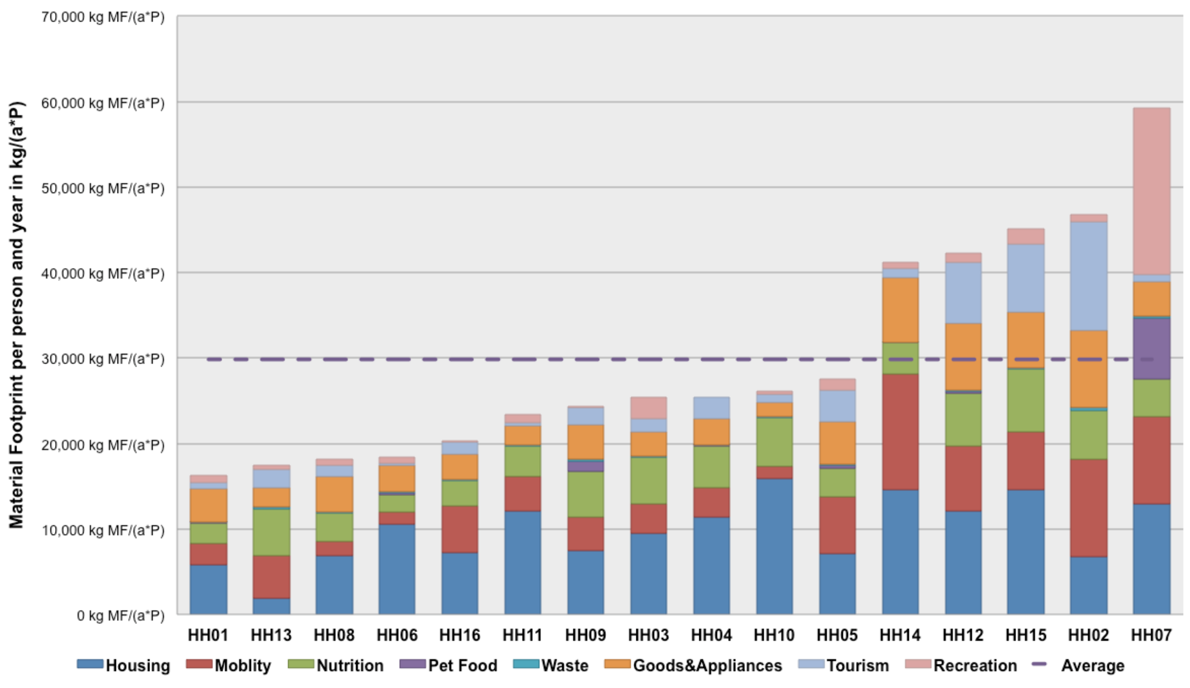

Figure 38-1: *Material Footprint of analysed households in increasing order.*

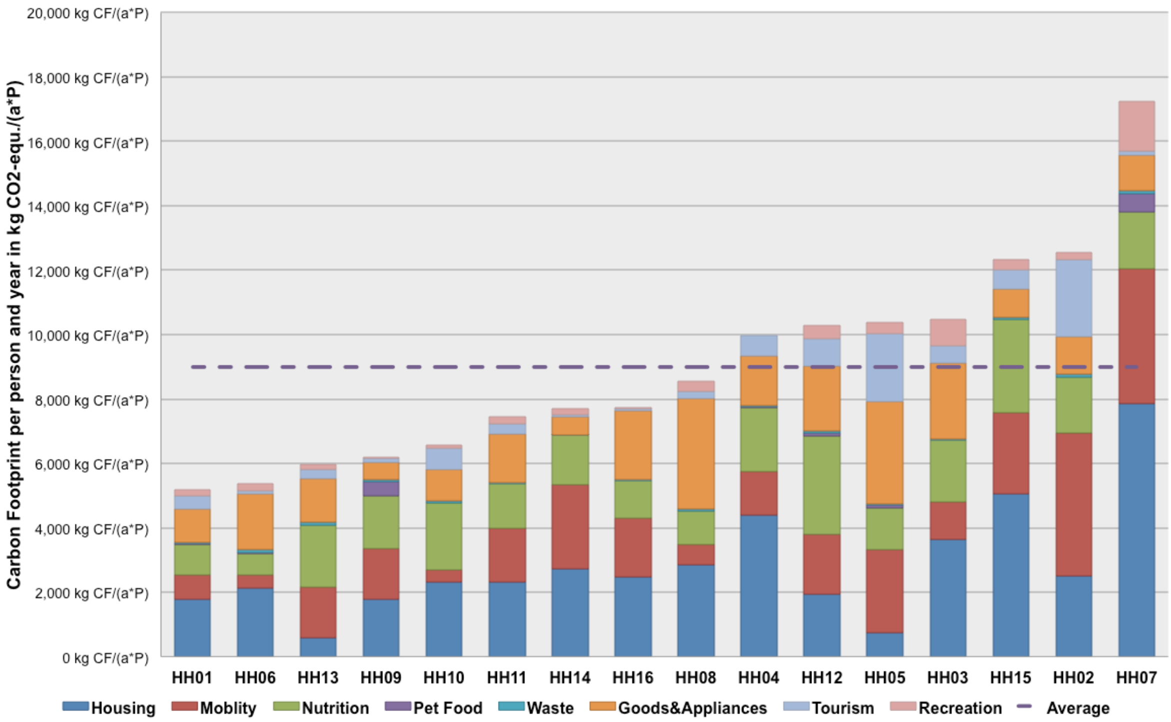

Figure 38-2: *Carbon Footprint of analysed households in increasing order.*

Results of the Road Mapping Process showed a high affinity of the volunteers for lifestyle changes. Some households told the scientist about changes they already conducted during the analysis period as e.g. going by bike instead of by car, combining trips by car and offering others a lift. In the case of mobility nearly all households wanted to try to use bicycles in the summer or public transport instead of a car and try to combine trips by car (like shopping and trip to work) in the short term. Two households wanted to try car-sharing. In the long term two households wanted to get along with just one car instead of two. In the case of housing most households wanted to change their airing behaviour in the short term. In the mid term three households wanted to change to renewable electricity. In the long term two households wanted to change their living space and two wanted to buy more energy efficient devices/appliances. In the case of nutrition nearly all households wanted to try to buy more organic, regional, seasonal or fair-trade food in the short term. Two households wanted to try a vegetarian and vegan lifestyle and three wanted to drink more tap water. Two households wanted to try the last two changes in the long term. In September 2015, a second workshop has been conducted for discussing the realisation changes. The conducted Focus group discussion with three participating households showed that first of all financial and infrastructural aspects lead to changes in the households. These findings are consistent with existing literature (e.g. Longhi 2015). These results show that there is always the need to investigate the external circumstances.

Conclusion & Outlook

Households' natural resource consumption (n=16) was calculated for seven fields of activity to analyse the impact of social practices'. Therefore, the direct consumption of resources was taken into account as well as their life cycle wide impact. Results of resource and GHG profiles show a high range of 3.7 (MF) and 3.3 (CF) within the volunteering households. It is assumed that these ranges would be higher if a representative sample of households in Germany was regarded. Further, results show that next to technical options, there is a high potential for structural changes and social innovations not only in the fields of housing, mobility and nutrition, but also in the field of goods&appliances. Regarding householdtypes no significant correlation with resource consumption could be found.

The road mapping process showed that the possibilities of households to change resource use is limited within the options of the urban environment. As described in different studies it is difficult for households to act alone. Next to the consumer level the political and business level must be integrated too.

With this holistic assessment of household consumption, it was tried to analyse the factors most influencing the resource consumption and GHG emissions of the households. It can be shown that individual social practices have a high impact. The individual data shows whether there is a greater impact e.g. in food consumption or mobility. For further evaluations it is necessary to question volunteers about the circumstances that lead to such social practices e.g. their time use and daily routines. This kind of questioning has not been conducted within this study. Within the road mapping process, it was tried to analyse these circumstances within the two workshops but not all households could be motivated to take part. Because the last workshop will be realised in September 2015 there are no results shown here. For further investigation such analysis should be integrated in the questionnaire. This is also tried within the resource calculator that has been developed on this resource analysis approach (www.ressourcen-rechner.de). Up to now over 4,000 data sets ("resource profiles") have been gathered. Currently the calculator is available in German only. An English version is in planning stage.

With this "resource analysis" a possible holistic approach has been tested to be included in the toolkit of sustainable Living Labs. It was possible to describe influencing factors in the different fields of activity. Due to this analysis the field of heating can be placed within the whole households´ resource consumption, it can be measured what impact reduced demand in one field might have on different fields of activity. It has been shown that for developing sustainable PSS solutions it is necessary to take the whole households consumption into account. Further, this investigation shows that future research also needs analysis of time use to analyse social practices in more detail. For this purpose, the online resource calculator will be further developed. With this, it will be possible to develop sustainable PSS supporting transformation.

39. ECOLOGICAL FOOTPRINTS AND LIFESTYLE ARCHETYPES: EXPLORING DIMENSIONS OF CONSUMPTION AND THE TRANSFORMATION NEEDED TO ACHIEVE URBAN SUSTAINABILITY

Jennie Moore ✉

Abstract

To achieve ecological sustainability, significant and absolute reductions are needed in demand on nature's services to yield resources and assimilate wastes. Estimates range from a factor of five to ten. This translates to an 80% to 90% reduction in energy and materials flows through the global economy. Urban sustainability literature tends to focus on the built environment as a solution space for reducing energy and material demands; however, equally important is the consumption characteristics of the people who occupy the city. While size of dwelling and motor vehicle ownership are partially influenced by urban form, they are also influenced by cultural and socio-economic characteristics. Dietary choices and purchases of consumable goods are almost entirely driven by the latter. An important question, therefore, is what dimensions of transformation are needed in various forms of urban consumption for cities to become sustainable? I use international field data that document urban ways of living to develop lifestyle archetypes. I then couple this data with ecological footprint analysis to establish consumption benchmarks in the domains of: food, buildings, consumables, transportation, and water that correspond to various levels of demand on nature's services. I also explore the dimensions of transformation that would be needed in each of these domains for the per capita consumption patterns of urban dwellers to achieve ecological sustainability. While there is tremendous variation across the international socio-economic spectrum, on average the dimensions of transformation needed in urban consumption commensurate with global per capita ecological sustainability include: a 73% reduction in household energy use, a 96% reduction in motor vehicle ownership, a 78% reduction in per capita vehicle kilometres travelled, and a 79% reduction in air kilometres travelled.

Keywords: sustainable consumption, ecological footprint, urban lifestyles.

Introduction

The global urban transition increasingly positions cities as important in determining sustainability outcomes because they serve as a nexus of consumption activity and related source of pollution (UNEP 2013, Folke et al. 1997). Global urbanization establishes infrastructures of provisioning that lock more than half the world's population in unsustainable patterns of production and consumption (Moore 2013, Kissinger and Rees 2010, Seyfang 2009). Cities are dissipative structures that rely on vast imports of energy and materials to retain internal coherence of form and function (Rees 2012, 2003, Downton 2009, Giradet 1999). At the same time, cities can offer highly efficient forms of living in terms of providing compact urban spaces where people can meet their daily needs with limited reliance on fossil fuels and efficient distribution of infrastructure services (UNEP 2013, Register 2006, 1987, Newman and Kenworthy 1999). This seeming paradox between the internal efficient distribution of resources within cities and the unsustainable inter-regional exchange of resources between cities and the hinterlands that support them points to the importance of considering cities within their bioregional and global ecological context.

The city and the dispersed hinterlands from where it draws resources comprise an inseparable urban ecosystem (Rees and Moore 2013, Rees 2012, 2003, 1992, Wackernagel and Rees 1996). The future of cities depends on urban development trajectories that take this whole urban ecosystem into account. To achieve ecological sustainability, significant and absolute reductions are needed in demand on nature's services to yield resources and assimilate wastes. Estimates range from a factor of five (Von Weizsäcker et al. 2009) to ten (Rees 1995). This translates to an 80% to 90% reduction in energy and materials flows through the global economy (Von Weizsäcker et al. 2009). An important question, therefore, is what dimensions of transformation are needed for cities to become sustainable, defined as existing within global ecological carrying capacity?

Research Approach and Methods

Building on Moore (2013), I use ecological footprint analysis (EFA) in combination with lifestyle archetypes of urban dwellers from around the world to probe how consumption in the domains of i) food, ii) buildings, iii) consumables, iv) transportation, and v) water play a role in determining urban sustainability outcomes. I chose these five areas because they capture the majority of directly measured household and personal consumption data for energy and materials. EFA estimates the area of biologically productive land and water required to continuously support the material and energy consumption and waste assimilation demands of a given population at prevailing levels of technology, money income, and socio-cultural values. It therefore orients the city within its global context by accounting for its ecological load, meaning the productive land and aquatic area required to support its biological and industrial metabolism (Wackernagel and Rees 1996). The word "lifestyle" means an approach to living that includes habitual behaviours and moral attitudes (Stein 1984) that are affected by the political, geo-physical, and socio-economic conditions in which a person finds themselves. The word "archetype" means an original pattern, model, or prototype (Stein 1984). In this research, the two words combined describe patterns of living that can be used as prototypes. Each lifestyle archetype represents the average pattern of consumption and household characteristics of urban dwellers according to a city's and/or country's average ecological footprint.

Differing consumption patterns and their corresponding ecological loads can be compared across cities or countries. They can also be used to inform equity issues when the footprint is assessed against the "fair Earthshare" estimated as the average amount of bio-productive capacity available on a global per capita basis (Wackernagel and Rees 1996). With 7.3 billion people on Earth and only 12 billion hectares of ecologically productive land and sea area, the Earthshare is estimated at approximately 1.7 hectares of land per person (WWF 2014), assuming average global ecological productivity across all hectares, referred to as a "global hectare" (gha) (Ewing et al. 2009). If everyone lived within the global ecological productivity of a fair and/or average Earthshare (1.7 gha/ca), humanity could live sustainability within the carrying capacity of Earth. This concept is also known as one-Earth or one-planet living (Moore 2013, Desai and Riddlestone 2002; Wackernagel and Rees 1996). Following the same logic, people who demand more than this amount of nature's services to support their lifestyles (i.e., demanding between 1.7 gha/ca and 3.4 gha/ca) are living a two planet lifestyle. This is because if everyone lived this way it would take more resources than our single Earth could supply. The assumption is that another Earthlike planet would be needed in order to supply the excess demand. People living at more than twice the average Earthshare (i.e., at more than 3.4 gha/ca) are said to be living a three-planet lifestyle and so on.

I used the WWF living-planet ecological footprint index to identify and group countries according to their average per capita ecological footprint at the one-planet, two-planet, and three-planet (or more) levels of consumption (WWF 2010). I chose to use the study year 2007 because this is the most recent year for which equivalence factors (used in ecological footprint analysis) have been made publicly available by the Global Footprint Network (www.footprintnetwork.org) (also see WWF 2010 and Ewing et al. 2009). I also reviewed ecological footprint analyses of cities within the countries indexed, making an effort to locate EFA studies within countries at the various levels corresponding to: one-planet, two-planet, three-planet or more levels of per capita demand on nature's services. I then undertook a literature search of field study data that qualitatively and quantitatively described patterns of living and average household consumption in various countries. I paid particular attention to any studies in cities for which an ecological footprint analysis had also been undertaken. The data from the field study literature included: caloric intake, food consumption by type and weight (FAO 2010), number of household members, size of dwelling space, dwelling type, motor vehicle ownership, vehicle kilometres travelled, ownership of personal appliances by type (Hoyer and Holden 2003, Holden 2004, Lenzen et al. 2004, Menzel and Mann 1994), and per capita municipal solid waste by type and weight (UN Habitat 2010). Additional information about the research methods and data sources is documented in Moore (2015).

Results and Discussion

Dimensions of Consumption across Lifestyle Archetypes

In order to short list a sample selection of case studies, I used triangulation of data that matched countries for which I had collected household and per capita urban consumption data to those in the WWF living-planet ecological footprint index (WWF 2010). I grouped the country data according to the one-planet, two-planet, three-planet, or more levels of demand on nature's services. A total of 34 countries were shortlisted (see Table 39-1). A total of 8 countries in the list are Latin American, split equally between the two-planet and one-planet levels of demand on nature's services.

Three plus Planets (> 6 gha/ca)	**Three Planets (4 < 6 gha/ca)**	**Two Planets (2 < 4 gha/ca)**	**One Planet (< 2 gha/ca)**
USA (7.99)	Sweden (5.88)	Chile (3.23)	Mali (1.93)
Canada (7.00)	Norway (5.55)	Mexico (2.99)	Ecuador (1.88)
Australia (6.83)	Mongolia (5.53)	Brazil (2.90)	Cuba (1.84)
Kuwait (6.33)	Spain (5.42)	Bosnia and Herzegovina (2.76)	Guatemala (1.78)
	Germany (5.09)	Argentina (2.60)	Uzbekistan (1.74)
	Italy (4.98)	Thailand (2.36)	Viet Nam (1.40)
	UK (4.90)	South Africa (2.30)	Iraq (1.35)
	New Zealand (4.89)	China (2.21)	Philippines (1.30)
	Israel (4.82)		Ethiopia (1.11)
	Japan (4.71)		India (0.91)
	Russia (4.44)		Haiti (0.67)

Table 39-1: *Countries in the research sample grouped by average per capita ecological footprint (adapted from Moore 2013, 2015).*

By correlating average household and per capita consumption and waste data with a city's (or its country's) corresponding average, per capita ecological footprint data, I was able to establish a range of consumption benchmarks in the domains of i) food, ii) buildings, iii) consumables, iv) transportation, and v) water that map to one-planet, two-planet, three-planet (or more) levels of demand on nature's services (see Table 39-2). I used the findings to build profiles that include a qualitative description of personal and household consumption patterns coupled with quantitative data pertaining to both consumption and ecological footprint. I then used these profiles, with their respective consumption benchmarks, to develop lifestyle archetypes for one-planet, two-planet, three-planet (or more) living. The three-plus-planet countries have the highest levels of consumption across virtually all domains. They also have the highest human development index rating, a metric comprising socio-economic indicators including education, health and income (UNDP 2011, 2013). In general, the progression from high to low consumption correlates with the archetype groupings, where the lowest levels of consumption and human development are associated with the one-planet archetype. Nevertheless, there are some exceptions within and between the archetypes that reveal important opportunities for further investigation. For example, many of the countries in the three-planet archetype, e.g., Germany and Japan, achieve commensurate levels of education and longevity with countries in the three-plus archetype. This implies that past a certain point, consumption is not directly correlated with human development outcomes. This finding is corroborated in the literature (Wilkinson and Pickett 2009, Victor 2008). Also, some countries in the one-planet archetype, e.g., Ecuador and Cuba, achieve a high human development index commensurate with that of the three-planet archetype indicating that consumption is not the only determinant of human development outcomes.

Component	Three plus Planets (> 6 gha/ca)	Three Planets (4 < 6 gha/ca)	Two Planets (2 < 4 gha/ca)	One Planet (< 2 gha/ca)	World Average
Ecological Footprint (gha/ca)	7.04	5.11	2.76	1.45	2.21
Food (t/ca/)	0.693	0.857	0.693	0.548	n/a
Daily Calories	3,525	3,240	2,893	2,424	2,809
Buildings Energy Use (kWh/ca)	14,381	8,850	2,545	692	2,596
Built Area (m2/ca)	51	29	13	8	10
Consumables Paper (t/ca)	0.2	0.2	0.1	0.01	0.1
Solid Waste (t/ca)	0.55	n/a	0.41	0.25	n/a
Transportation Vehicle ownership (no./ca)	0.5	0.5	0.28	0.004	0.1
Vehicle Travel (kmT/ca)	9,482	5,550	1,265	582	2,600
Air Travel (kmT/ca)	3,622	2,264	484	125	564
Transit Ridership (%)	10	20	24	19	n/a
Water (m3/ca)	1159	498	702	822	632
Domestic Use (%)	23	24	13	9	10
Human Development Life Expectancy (no. yrs.)	79	79	71	66	67
Education (no. yrs.)	16	16	14	11	12
Literacy (%)	98	99	94	72	n/a

Table 39-2:*Summary of Consumption Data by Lifestyle Archetype (adapted from Moore 2013, 2015).*

Transformation Needed to Achieve Urban Sustainability

Table 39-2 presents per capita consumption benchmarks associated with various lifestyle archetypes and the global average. Recall that one-planet living requires an average demand on nature's services no greater than 1.7 gha/ca. According to Table 39-2, the world average ecological footprint is 2.21 gha/ca. This means that the global average ecological footprint would need to be reduced 23% (down 0.51 gha/c from 2.21 gha/ca). If I were to use the one-planet archetype presented in Table 39-2 as the benchmark value then the reduction would be 34% (down 0.76 gha/ca from 2.21). This difference can be attributed to the characteristics of the limited sample size used to compile the consumption benchmarks in the one-planet lifestyle archetype. Future research encompassing a broader sample size is needed to narrow the discrepancy. Nevertheless, the findings point towards a reduction somewhere between one-third and one-quarter of current average ecological footprint that would be needed to bring the global population in alignment with global per capita ecological carrying capacity.

Following this same procedure, I can also estimate the dimensions of transformation needed in per capita household consumption to achieve urban sustainability in each consumption domain (see Table 39-3). The following reductions would be needed to close the gap between world average per capita household consumption and ecological carrying capacity: 63% reduction in the average per capita carbon footprint, a 14% reduction in average per capita caloric intake, a 73% reduction in household energy consumption, a 20% reduction in per capita dwelling space, a 96% reduction in per capita motor vehicle ownership, a 78% reduction in per capita vehicle kilometres travelled, and a 79% reduction in per capita air kilometres travelled. Although these only represent rough estimates, the magnitude of reduction begins to demonstrate a pattern somewhat reminiscent of the 80% to 90% reductions in energy and materials throughput previously identified (Von Weizsäcker et al. 2009, Rees 1995). Of course, the magnitude of reduction would be greater for that portion of the global population consuming at levels commensurate with the two-planet, three-planet and three-plus planet lifestyle archetypes respectively.

Component	Three plus Planets (> 6 gha/ca)	Three Planets (4 < 6 gha/ca)	Two Planets (2 < 4 gha/ca)	One Planet (< 2 gha/ca)	World Average
Ecological Footprint (gha/ca)	-79%	-72%	-47%	1.45	-34%
Food (t/ca/)	-21%	-36%	-21%	0.548	n/a
Daily Calories	-31%	-25%	-16%	2,424	-14%
Buildings Energy Use (kWh/ca)	-95%	-92%	-73%		-73%
Built Area (m2/ca)	-90%	-72%	-63%	8	-20%
Consumables Paper (t/ca)	-95%	-95%	-90%	0.01	-90%
Solid Waste (t/ca)	-55%	n/a	-39%	0.25	n/a
Transportation Vehicle ownership (no./ca)	-99%	-99%	-99%	0.004	-96%
Vehicle Travel (kmT/ca)	-94%	-90%	-54%	582	-78%
Air Travel (kmT/ca)	-97%	-94%	-74%	125	-79%
Transit Ridership (%)	+9%	-1%	-5%	19	n/a
Water (m3/ca)	-29%	+65%	+16%	822	+30%
Domestic Use (%)	-20%	-15%	-4%	9	-1%

Table 39-3:_Dimensions of Transformation Needed to Achieve Urban Sustainability (adapted from Moore 2013, 2015)._

While food often represents one of the most significant components in ecological footprint assessments of cities (Moore 2013, Scotti et al. 2009, Hoyer and Holden 2003); the research points to more traditional foci on buildings and transportation as areas where the greatest transformations would be needed, including in air travel which falls outside the influence of the built environment. Consumables and to a lesser extent the wastes associated with their use also represent important opportunities for transformation. However, with only one category for consumable products represented in this analysis, i.e., paper, it would be premature to speculate on whether it represents a significant opportunity for transformation. Further research to characterize a broader range of consumable products across the archetypes could benefit this line of inquiry.

Conclusions

The research uses lifestyle archetypes and ecological footprint analysis to profile urban per capita household consumption patterns in the domains of i) food, ii) buildings, iii) consumables, iv) transportation, and v) water and their demand on nature's services. Consumption benchmarks are established that align with global per capita ecological sustainability, called one-planet living. Unsustainable levels of consumption that exceed this amount by two or three times are also documented. While personal consumption choices play an important role in determining urban sustainability outcomes, the research points to more traditional foci on buildings and transportation as areas where the greatest transformations would be needed. The analysis reveals that to achieve urban sustainability, global average per capita consumption would need to be reduced by between one-quarter and one-third overall, with significant reductions approximating 80% to 90% in the domains of buildings and transportation. Specifically, a 73% reduction in household energy use, a 96% reduction in motor vehicle ownership, a 78% reduction in per capita vehicle kilometres travelled, and a 79% reduction in air kilometres travelled.

40. FUTURE HOUSEHOLDS: SMALLER FOOTPRINT, BETTER LIFE?

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Abstract

The paper presents a project on how to achieve future household consumption already today. The project calculated lifestyle material footprint, developed household-specific roadmaps for halving material footprints by 2030, tested relevant measures towards a one-planet material footprint of 8 tonnes per person in a year, and developed mainstreaming options in co-operation between service and infrastructure providers and households. We used the material footprint as an aggregated indicator for the overall use of material resources. Our approach was extended from just measuring household resource use to developing roadmaps, conducting experiments, as well as learning and upscaling, all of which contribute to the 'Transition-Enabling Cycle'. The results of the experiments were encouraging: Households decreased their material footprint already close to the 2030 targets in their roadmaps. They thus showed that it is possible to achieve dematerialisation of consumption by relatively few changes in everyday living even today. However, a part of the services used in the experiments had to be simulated because they were not yet available in the area where the project took place. Thus, achieving a one-planet level of resource use also requires systemic changes. While changing their lifestyles in the experimental phase of the project, some households noticed that their quality of life even increased on some areas. As a conclusion, we state that relevant and positive changes in household behaviour and activities can be achieved even soon. Thus there is no need for waiting until systemic changes have happened but households can make powerful improvements immediately, thus encouraging other actors to offer more sustainable solutions on the market.

Keywords: household, consumption, material footprint, Material Input Per unit of Service, sustainability transition

Introduction

The natural resource use of the human economy is on a higher level than ecologically sustainable (e.g. Bringezu 2015). The relevance of households for reducing resource use is crucial (Liedtke et al. 2015, Caeiro et al. 2012, Lorek and Spangenberg 2001). For a transition towards sustainable resource use by households, we must quantify and understand household consumption forms and its changes, as well as generate and evaluate alternative configurations (Doyle and Davies 2013, Liedtke et al. 2012, Schroeder 2010). Although most of human resource use can be related to household consumption, households cannot directly influence all features of their resource use (Kopsakangas-Savolainen & Juutinen 2013, Lettenmeier et al. 2014a). In a developed country like Finland, prevailing infrastructure and services determine a level of resource use that exceeds sustainability limits even with low-income receivers (Hirvilammi et al. 2013). Systemic change requires a reconfiguration of these systems, including technology, policy, markets, infrastructure, cultural meaning and scientific knowledge, in addition to consumer practices (Geels 2011, Schneidewind and Augenstein 2012).

This paper presents the pilot project Future Household the purpose of which was to promote sustainable resource use on the household level. Earlier approaches have mostly concentrated on assessing the resource use of household consumption (e.g. Kotakorpi et al. 2008, Lettenmeier et al. 2012). The Future Household project in Jyväskylä, Finland, didn't just assess resource use. We developed household-specific visions for sustainable resource use, experimented low-resource household consumption and included relevant stakeholders in a mainstreaming process.

Framework: material footprint calculation and sustainability transition

The MIPS (Material Input Per unit of Service, or MI/S) concept Schmidt-Bleek (1993) is a holistic approach for measuring the system-wide resource use of production and consumption. The amount of natural material input (MI) required over the life cycle of a good or activity is summed up and compared the specific benefit (called service, S) provided. MI is calculated separately for five categories of resources: abiotic and biotic raw materials, soil movement in agriculture and forestry, air, and water (Ritthoff et al. 2002) and expressed in mass units like kilograms or tonnes. MI contains both economically used resources and the unused extraction (see Bringezu et al. 2003) but makes no statements on the specific environmental impacts of different substances.

The material footprint is the sum of the categories of abiotic and biotic resources as well as topsoil erosion in the MIPS concept. It thus includes the same resources as the macroeconomic indicators TMC and TMR (Bringezu et al. 2003). Lettenmeier et al. (2009) use material footprint as a synonym for micro-level TMR (Ritthoff et al. 2002). Lettenmeier et al. (2014b) propose a sustainable material footprint level of 8 tonnes per person in a year on the basis of the sustainable resource use suggested by Bringezu (2009). They propose to allocate these eight tonnes to the consumption components of nutrition (3 tonnes per person per year), housing (1.6 tonnes), mobility (2 tonnes) and other purposes (1.4 tonnes, respectively). This proposal is based on plausibility of both consumption practices and technology on the basis of existing research results. Lettenmeier et al. (2014b) stress that they provide only one possible example of allocating the eight tonnes to different consumption components because individual allocation depends and the needs and demands of specific households.

The gap between the present material footprint of 40 tonnes per person in a year in Finland and the sustainable level of eight tonnes is huge. The material footprint of the average Indian, Brazilian and Chinese households has been reported 8.4, 11.4 and 15.2 tonnes, respectively (Hicks et al. 2015a, b, c). This huge difference tells the need for special efforts by the developed countries to develop solutions for sustainable production and consumption, as also stated by the United Nations (1992).

The sustainability transition approach derives from the conclusion that targets like the 8 tonnes material footprint can only be reached through transitions at different levels and in different technological, material, institutional, politic, economic, and socio-cultural dimensions (Rotmans and Loorbach 2009, Shove and Walker 2007). Overcoming the barriers to sustainability transition require both long-term strategies and processes of individual and societal learning, as well as experimenting ways towards these targets. Actors engaged in the process and social pressure they develop can lift up niches thus creating new social regimes. (Loorbach and Rotmans 2010.) The 'Transition-Enabling Cycle' by Schneidewind and Scheck (2012) structures transdisciplinary research. The cycle consists of four successive fields: problem assessment, vision development, experiments' implementation, and learning and upscaling. The methodology presented in section 3 follows the steps of that cycle in order to facilitate niche innovations that lead to socio-technical transitions.

Methodology and data used

The ‘Future Household’ project coordinated by the Finnish Innovation Fund Sitra started in April 2014 with a call for participating households. Only five of the 40 applying households were selected for participation because of the experimental and in-depth nature of the project. The households included one single person (household A), one household of two students (household B), two families with two and three children (households C and D), and one empty-nest couple (household E). Two of the households lived in the city centre, one in a suburb and two in surrounding villages. The households also greatly varied in terms of living space per person and car ownership.

A three-week period of consumption monitoring was the basis for calculating the material footprints in the different consumption components. Consumption monitoring followed and improved the methodology developed in earlier studies (Kotakorpi et al. 2008, Lettenmeier et al. 2012). On the basis of these results, participants created ideas for reducing the material footprints of their households in a co-creation workshop. The year 2030 served as a reference year in order to keep changes more imaginable (see Lähteenoja et al. 2013). Out of the households’ ideas, concerning both consumption and supply, household-specific roadmaps until 2030 were formed.

The households chose ideas of their roadmaps for implementation during a four-week experiment phase in October-November 2014. The experiments included considerable changes such as giving up a car, switching to vegan diet, or moving to a smaller apartment in the city centre. Some services such as car-sharing and demand-based public transportation were simulated. We calculated the effects of the experiments on the material footprints and made observations on how the experiments affected everyday practices. The households shared their experiences in social media and the regional newspaper. Right after the experiment period, households and project team discussed the experiences and results in a ‘future workshop’ together with infrastructure providers, service providers and city representatives. The workshop was linked to the planning of a new residential area next to the city centre that is developed by using the 'One Planet Living' principle.

The households were interviewed four times within one year in order to gather additional information on their consumption, practices and experiences. In addition, eight ‘gatekeepers’ (see Neuvonen et al. 2013) were interviewed after the ‘future workshop’. For more detailed information on the methodology developed and used in the project, we refer to Laakso and Lettenmeier (2016).

Results

The material footprints of the participating households ranged from 20 to 69 tonnes per person in a year. Figure 40-1 shows three material footprints for each household (A to E). On the left is the result of the consumption monitoring, in the middle the household’s roadmap target for 2030, and on the right the material footprint achieved during the experiment period. The material footprint of an average Finn is presented on the left and target level for 2050 on the right of the chart.

On the basis of the consumption monitoring, the highest variation was observed in everyday mobility, tourism and housing. The high share of mobility in households D and E is due to the use of two cars in both households. Household C did not own a car. The size of the house or apartment relates to the material footprint of housing. Household B had the highest material footprint for tourism, due to weekend trips to other Finnish cities. The material footprints of nutrition were close to the average in all but one household (A) who had low meat consumption. Household B had the highest material footprint for nutrition because of their relatively high consumption of meat and dairy products.

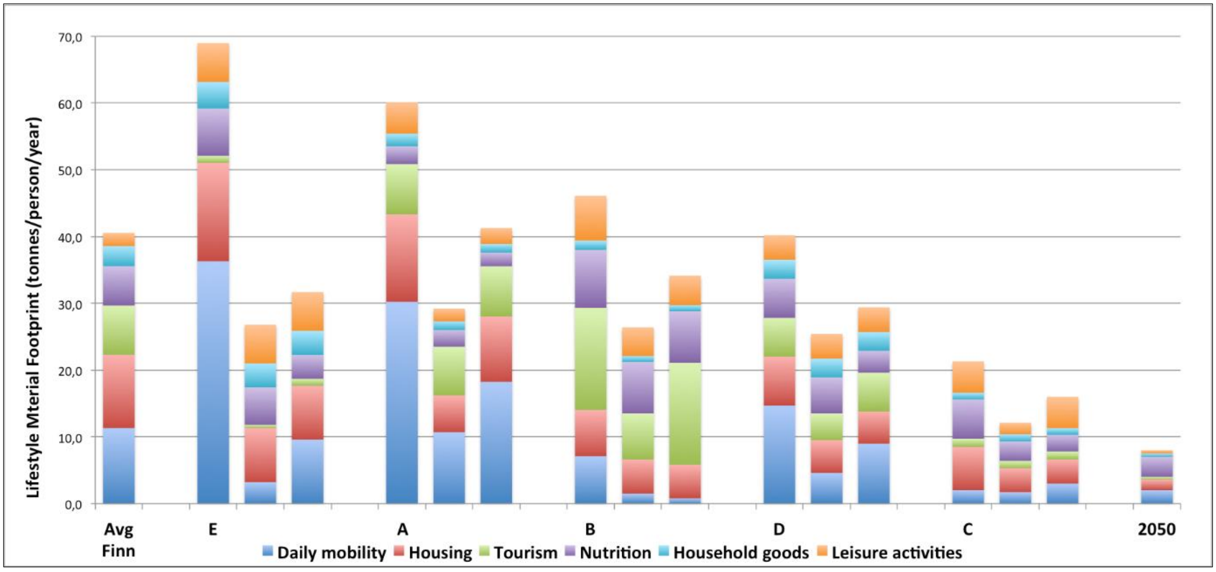

Table 40-1:*Material footprints of the household at the starting point, the target levels for 2030, and results of the experiment period.*

When the households received their material footprint results, most were surprised of the share of housing and mobility. Thus, it was useful to send the results before the roadmapping workshop so that households had the opportunity to consider reduction potentials when developing ideas for their roadmaps. The participants considered the material footprint an understandable way for illustrating the impacts of consumption, just as reported also by Kotakorpi et al. (2008).

All households succeeded in reducing their material footprints considerably towards their roadmap targets during the experiment period. Mobility contributed most to the reduction in most cases. From a households' point of view the experiments succeeded and households mostly felt they had managed to change their everyday routines to be more sustainable. The households also planned to continue some of the experiments, like local bus use, food home-delivery and vegetarian meals. Thus, some re-routinization happened at least in those areas where permanent behaviour changes were possible.

However, household also faced some difficulties especially in the area of mobility. This was due to re-organizing practices of everyday living and, for instance, deficient public transport connections. Also being a 'pioneer' of sustainable living felt hard occasionally (see Laakso, *forthcoming*). Despite these challenges, some household noticed and appreciated an increase in comfort and quality of life they would not have expected. For example, home delivery of food provided extra leisure time, as well as organizing the family's leisure activities with less car use. Living in a smaller apartment instead a big house offered a new kind of intimateness to the elder couple. Car sharing was felt easy-to-use after some stiffness in the beginning.

The participants shared their experiences with colleagues, friends, and relatives, and felt they were a positive example. The households found that their experiences made it easier for others to understand the importance of consumption behaviour and the need for new and more sustainable solutions. In a last interview round during spring 2015 households told that some new routines are still in use. Households A and B had started using ride-sharing services in order to minimize driving alone. Household D had sold their second car and household E was planning co-housing. All households were eating more vegetable-based food than earlier and considered in a new way the environmental impacts of their daily life. However, not all changes were positive: households B and C had to buy new cars due to changes in situations in life. This highlights the need for not only changes in individual behaviour by temporary experiments, but also in structures to enable sustainable choices in all stages of life.

Conclusions

This paper reported on a project facilitating the transition to low-resource household consumption. Besides monitoring consumption, households established own roadmaps towards sustainable resource use. During the one-month experiment period, they tested relevant options for reducing material footprints towards their roadmaps' target levels. The results show that reductions in lifestyle material footprint can be achieved by relatively few changes in consumption practices. However, households will not do it alone. In a field like nutrition households can start the change any time but assistance by experts during the project was felt helpful for adopting new behaviour. In other fields, a remarkable reduction in resource use requires more co-operation between users and suppliers. For instance, services like on-demand buses are not yet available everywhere and cannot be set up solely by households. Nevertheless, the encouraging result of the project is that we do not need to wait until 2030 for considerable reductions in lifestyle material footprint towards an 8 tonnes material footprint. The better and easier life households experienced during due to some experiments can be one important argument and driver in mainstreaming sustainable solutions.

Five households are far from mainstream. For addressing a broader public, new ways should be established to facilitate active and immediate change by households, but also by companies and public administration. Direct links between users and service or infrastructure providers should be established, e.g. in Living Labs (e.g. Liedtke et al. 2012) or other direct interaction between gatekeepers and consumers (e.g. Neuvonen et al. 2013). Also IT-based approaches for not only consumption monitoring and material footprint calculation but also roadmapping, testing and upscaling should be developed and utilized increasingly.

The material footprint can be used to measure large aspects of consumption, including production processes and infrastructure provision in the background. This helps keeping data understandable and manageable, which is strength when involving many kinds of actors in the transition process.

Households were able to decrease their material footprints in the experiment period and planned even further reductions according to their roadmaps. However, both the experiments' results and the roadmap targets of four of the five households are still above the average material footprints of households in emerging countries as reported by Hicks et al. (2015a, b, c). This shows, once again, the urgent need for developing and mainstreaming sustainable lifestyles in developed countries like Finland. We hope that our project will inspire researchers, households and other actors to join the effort in producing solutions towards a sustainable level of resource use in consumption, production and infrastructures.

41. SUPPORTING SUSTAINABLE LIFESTYLES BY COMMUNICATING BENCHMARKS FOR RESOURCE CONSUMPTION WITH HELP OF A NOVEL ENVIRONMENTAL ACCOUNTING SYSTEM

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Abstract

According to UNEP, household consumption is responsible for 60 % of the total life cycle impacts of final consumption in most countries. Therefore, the transition to a more sustainable society can only be achieved by changing current consumption and production patterns. There are two basic problems which need to be solved in order to reach this goal: The first problem is the lack of environmental information for products. The second problem is that even if information exists, it might be to abstract to incorporate and transform it into action. Based on results of environmental psychology and a model for individual change, we analyse this problem and postulate that by setting system knowledge and target knowledge in relation to each other meaningful benchmarks can be derived. Those benchmarks can help to create transformation knowledge, lead to a successful benchmarking process and therewith promote the transition to sustainable consumption. To develop such benchmarks, the following questions are addressed in this paper: (1) How is the current information base of target knowledge? (2) What information is interesting for specific target groups? (3) What are target group specific benchmarks and how should they be communicated? Even though businesses would also profit from improved information, the paper focuses on communicating information to consumers. The paper presents result of the project myEcoCost (www.myecococst.eu), funded by the European Commission. Within the project, a software system has been developed that automatically calculates resource consumption and emissions along a product value chain using company data from the companies' accounting systems. The results are shown as "ecoCosts" and can be provided via smartphone app to the consumer. Therewith the system can help solving the problem of missing system knowledge of economic actors and serve as basis for benchmarking.

Keywords: resource use, environmental accounting, ecoCosts, material footprint, carbon footprint

Introduction

In our society, it is widely accepted that a transition towards a more sustainable economy is required (UNEP 2015, EC 2014, UN 1987) leading to a reduction of material use (Weizsäcker et al. 2014, European Environment Agency 2014, EC 2011, Schmidt-Bleek 1994) and carbon emissions (IPCC 2014) in production and consumption patterns. The main barriers for such a transition are the complexity of global production systems, limited availability, and quality of life cycle data (UNEP 2012, Liedtke et al. 2014, Seiler-Hausmann et al. 2004) which are challenging to improve (Miyamoto / Fujimoto 1999).

The myEcoCost system, developed within a research project funded by the European Commission, addresses this issue. Based on recent developments in information and communication technology, it offers a methodology to account for the environmental impacts of individual products and services but also businesses, supply chains and consumption patterns of individuals. By aiming at establishing a global collaborative network of resource accounting nodes and generating (close to) real time life cycle data the system would overcome many of the problems that current practices of measuring resource consumption and environmental impacts suffer from. Businesses joining the network can use it to account for their resource inputs and outputs as well as emissions, and calculate the ecoCosts of their products and services. These ecoCost are aggregated along specific supply chains, from primary production through to the point of sale, and result in reliable and comparable product-specific data that can support better, more environmentally oriented decision-making in private or public procurement, in design processes and in private households.

Relevance of specific data for a sustainability transition

Already today, a huge amount of data is collected on consumer behaviour but instead of informing us about our behaviour, they are mainly used for market research to better address and create consumer demand. Since most products in the past have been designed and produced with a focus on generating economic growth and wealth neglecting environmental implications, the system´s impact crossed planetary boundaries and therewith risks the wellbeing of current and future generations (Meadows et al. 1972, Schmidt-Bleek 1994, Bleischwitz / Bringezu 2011, Rockström et al. 2009, Steffen et al. 2015). To promote more sustainable decisions in the future, environmental criteria e.g. on the challenges of climate change and resource scarcity, should be considered within decision processes.

To address the demand for consumer guidance, a lot of different product labels were developed. Due to their number, they are perceived to drown the consumer with too much, too varied and too unsubstantiated information. Thus, a new form of guidance and information on life cycle impacts and costs of resource use are required to support more sustainable consumption decisions.

ecoCost values could provide a solution for this. With ecoCost values widely available, the view on products and services could change! The system would allow to track purchases and their environmental effects over time. Therewith not only individual consumption decisions but also overall lifestyles could be assessed and compared to ecological limits. This could lead to a new era of eco-awareness in everyday life, but also in business, with myEcoCost providing a vital infrastructure prompting designer, producer and consumer decisions toward more sustainable lifestyles and an ecologically based economy. Different to current labeling, the ecoCost of a product could be displayed on the price tag on a retailer's shelf and/or through scanning a product barcode via a smartphone app at the shop or at home. Just as a generation of people became aware of their personal calorie intake and changed their consumption patterns accordingly, this could empower consumers to align their decisions with the recommended personal eco-impact level (Lukas et al. 2015).

In order to provide EcoCosts to consumers, the system needs to be in place in many companies. To achieve this, the system also offers an added value to businesses and is easy to implement without inducing too many efforts. ecoCost are calculated on the basis of existing data for procured products and the specific processes inside a company. myEcoCost is not limited to single industries but can be implemented across all types of businesses since it works based on a configurable model for production processes or services working with company specific data. The calculation is kept on the IT infrastructure of the business itself – which can be as simple as a laptop for a small business or a server in the case of a large business – to guarantee the privacy of company data. Based on this data and the data received from their suppliers, the company calculates the ecoCost. The ecoCosts are then communicated along the supply chain until they reach the point of sale and are communicated to the consumer. Today´s availability of digital technologies at lowering costs can facilitate the uptake of such a highly connected system (see Figure 41-1).

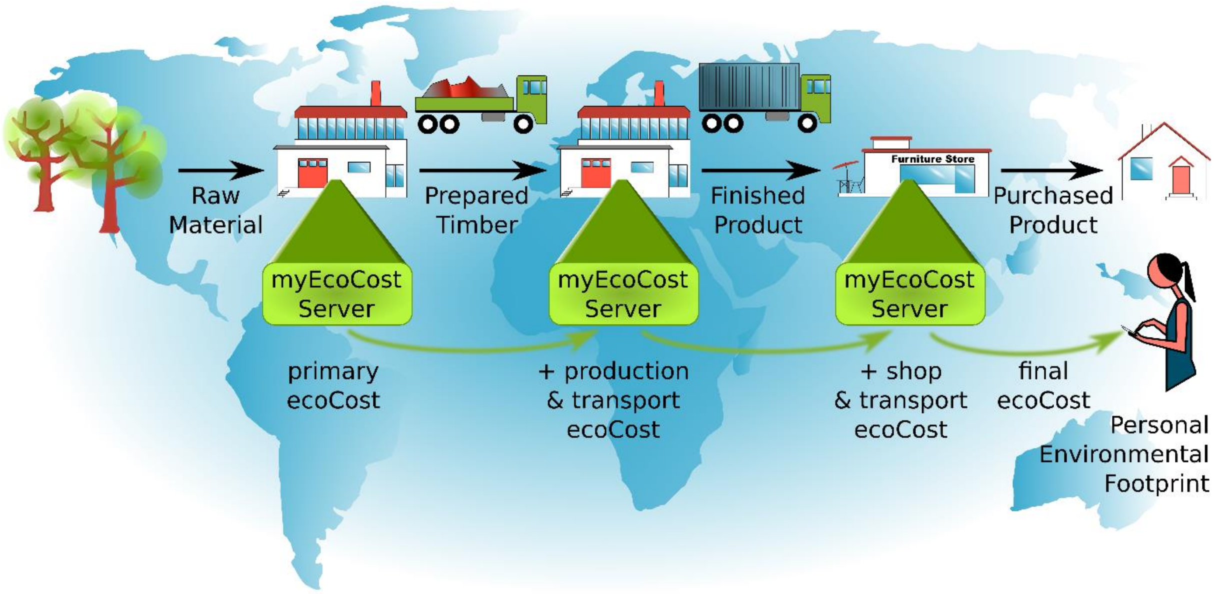

Figure 41-1: *Flow of ecoCost through various steps of a supply chain.*

In the prototype developed, the ecoCosts are represented by the two indicators material footprint and carbon footprint as examples for mass-based and impact-based indicators. The Material Footprint indicator considers all abiotic and biotic raw materials extracted from nature, including not only economically used extraction, but also the share of unused extraction (Liedtke et al. 2014). The indicator concept is based on the idea that every resource extracted from nature will at some point be released back to nature. Hence lowering the resource extraction automatically leads to lower emissions.

As greenhouse gas emissions play an important role in the public discourse, the Carbon Footprint based on the Global Warming Potential (GWP) of the IPCC 2007 report (Bernstein et al. 2008) was also included in the calculation of ecoCosts.

With myEcoCost system widely in place, end consumer can access the ecoCosts by scanning the product's barcode and/or by checking the values on the shelf labels when buying products. Using the myEcoCost consumer app, the consumer can store and access statistics on their own personal record. The app offers a personal "ecoAccount", where all purchases with their related ecoCosts are listed. This consumption is the sum of all ecoCosts related to the products purchased over time, incurred during the use phase and from discarding them as waste. Figure 41-2 summarizes all input and output flows relevant for accounting household consumption.

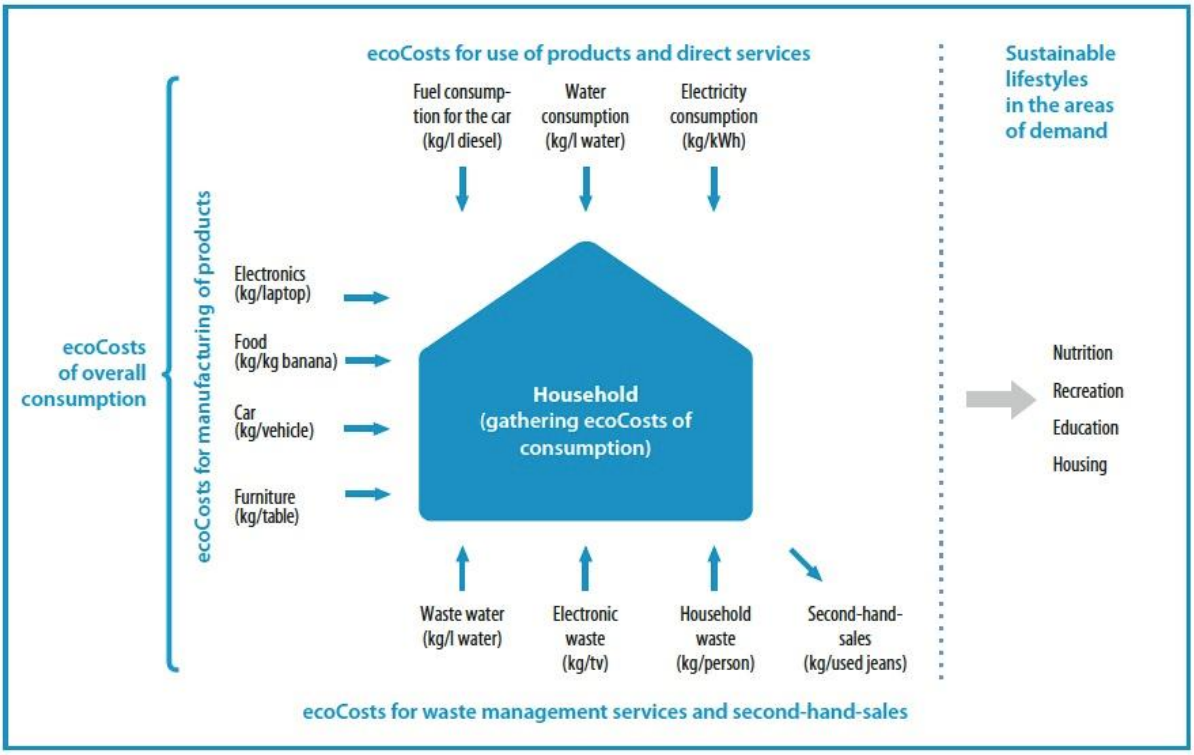

Figure 41-2: *Different life cycle stages of consumer products.*

Communicating ecoCosts – the consumer interface

Most people may have difficulties to judge the magnitude of environmental effects when just showing a product's Material or Carbon Footprint without a reference point. It also will be difficult to compare products with a different functional unit (e.g. kg/per Product or kg/l). A benchmark partner is needed against whom a product can be measured in a meaningful way.

Literature on business benchmarking shows several hints where benchmarking partners can be detected depending on the aim of the process. Andersen & Pettersen (1996) present the four categories internal, competitive, functional and generic benchmarking. – according to their different foci, the benchmarking partners differ. For the benchmarking process in myEcoCost, the benchmarking partners are already predefined. By defining ecoCost levels (e.g. average vs. best in class) for products, lifestyles or industry sectors, users of myEcoCost get a reference point against which they can measure their own or a product's performance. This allows them to identify and understand the impacts of their behaviour; they can then adapt their practices towards more environment friendly ones, in order to minimise the ecoCosts induced by their consumption. It is expected that this will result in two effects: environmental preferences become operational, and the exposure to information about current performance will most probably raise consumer awareness and encourage them to act.

One benchmark illustratively implemented in the consumer interface of the prototype is the product benchmark. It enables the consumer to evaluate information based on the Material Footprint and Carbon Footprint for specific products. The indicators can further be split into the sections transportation, packaging and overheads. The system can also offer information on the material intensity (kg material use/ kg product) of a product based on its current price (e.g. €/kg). Once implemented, the consumer can scan several products at the point of sale, and then perform the above mentioned comparisons on their mobile device.

In the consumer interface, we anticipate increased flexibility to extend the accounting system to include more indicators. Therewith, it will be possible in future to integrate extensive additional product information – not only ecoCosts, but also recommendations for use, information on vital characteristics of the product, and even the opportunity to give feedback to the producer of the product.

By aggregating consumption data and making it available for personal evaluation, the myEcoCost system allows the consumer to assess his or her consumption. Total personal ecoCost consumption could be recorded via a myEcoCost Customer Card, which is already implemented in the prototype. For personal evaluation, several benchmarks are provided. Consumers can set individual targets, compare their material consumption to the European average (44 tonnes per capita and year) (Bringezu 2015, Bringezu et al. 2009) or to the sustainable limit of 19 tonnes per year, which corresponds to 53 kilograms per day by 2030 (Wiesen et al. 2015, Lettenmeier et al. 2014).[42] For future applications, gamification aspects such as benchmarks of personal peer groups or introducing eco-performance competition using social media and platforms can be an interesting option. In a similar way, this also applies to sharing products. This is of great importance in order to keep the system attractive for consumers and thus to allow them to continuously evaluate and improve their environmental performance. To have a significant impact, the system has to be attractive for a broad target group.

Currently, the prototype version of the consumer tools covers presentation and comparison abilities based on ecoCosts. Since the consumer tools are developed in a modular manner, further functionalities can be added depending on future demands. These could include, for example, more detailed product information on contents, allergens, product labeling as well as traceability information. The overall design of the consumer tool can be updated for complete storage of consumers' own consumption data over time without the necessity to store it on external servers. Updated versions of the consumer tool could also allow consumers to estimate their current material footprint, their carbon footprint and their consumption of vital resources such as fresh water.

Based on these estimates of their current environmental performance, consumers can use tools to evaluate different scenarios for adapting their lifestyle and making sustainable decisions on how to consume in the future. Updated versions of the consumer tools can also support effective interaction between consumers and producers. Furthermore, they may form the basis for communication among consumers of a given product (e.g. direct rating systems, tips for efficient use, or ways to place pressure on the producer to reduce the ecoCosts of their products). As a result of the decentralised data management and network structure and based on the latest data security standards, consumers could use the data in IT-based environmental management systems at consumer or household level. They could further be linked to smart home systems or personal health software.

myEcoCost proof of concept and way forward

Several activities have been performed in order to evaluate the final achievements of myEcoCost with a broader audience consisting of different stakeholders. The main proof of

[42] A personal resource footprint calculator has recently been developed: see www.ressourcen-rechner.de (in German).

concept of the myEcoCost core was a live demonstration of the complete system for a heterogeneous external audience. All components of the project results were demonstrated and explained in detail. During the live demonstration, partners of the myEcoCost consortium entered real data from their businesses. Based on this data the transfer and aggregation of ecoCost data up to the consumer at the point of sale was simulated. All components have been displayed individually and in a fully integrated way. This live demonstration proved that the myEcoCost system runs as a complete, integrated system that can include all partners of a supply chain and is ready to be taken to the next stage.

However, until this system is ready for market launch and can be widely distributed, there are still important steps to take such lowering complexity of data entry, improving the life cycle database to close data gaps and end of life calculations. Once the system is fully established, it will offer new business opportunities for resource efficiency and environmental improvements, provide better data for LCA practitioners, and improve consumer decision-making. It also provides the chance helping society to better observe planetary boundaries, e.g. as demanded by the new UN Sustainable Development Goals (UN 2015, Steffen et al. 2015). To be meaningful for consumers, the fully developed system aims at providing ecoCosts for as many products as possible. One benefit that consumers gain from using the system will then be their access to reliable environmental information and benchmarks which can be the foundation for their consumption decisions. Since only people with a high awareness about sustainability issues will benefit from this, the system will eventually include further features such as additional information on allergens, other food sensitivities or social aspects (e.g. Fair Trade labels). As an overall impact for consumers, the myEcoCost system will make their shopping more convenient, healthier and more sustainable.

Concerns for data privacy and security are a major barrier for the implementation of myEcoCosts. In the past, hacked government and company servers and the spying of governments have alarmed many consumers. These issues could severely weaken the acceptance in society as well as by businesses. Therefore data security has been constantly addressed in the system development process and will also be comprehensively considered in the future, integrating state-of-the-art data security and privacy standards. An important step in the general setup of the network structure, which has already been taken, is storing consumer or business-specific data in a decentralised way, mainly on the user’s own devices or servers. In future development processes, as well as in communication strategies, the best available data security standards will continue to be applied, including continuous updates when new challenges arise or superior solutions become available.

42. ECOLOGICAL LIFESTYLES: BENEFITS OF SECOND-HAND PRODUCTS SOLD THROUGH INTERNET PLATFORMS

Martin Lehmann ✉, Conrad Leuthold

Abstract

Environment-friendly lifestyles are becoming more and more popular throughout society. Part of this trend is also connected to the second-hand articles being resold over various Internet platforms. In order to figure out what this could mean in terms of reductions in CO_2e-emissions, tutti.ch asked myclimate to perform a study on the environmental benefits of purchasing second-hand products compared to the production of new goods.

On the basis of the assessment of 41 products in the 8 product categories furniture, toys, sport articles, small household appliances, large household appliances, electronics, baby/child and clothes/accessories, the total CO_2e-emissions saved by the reuse of all the sold products over one year are calculated.

The data inventory includes the raw materials, the production processes, as well as the packaging and transport of new products. The Swiss database ecoinvent was applied for background data. In most cases, producer information, end-of-life studies and Environmental Product Declarations (EPDs) served as primary data source. The received total GHG-emissions for the 5 most sold products in each category were extrapolated to the overall emissions of each category, with a safety margin of 33%. In order to cover the rest of the product categories of the tutti platform (like game consoles, gardening equipment or books), an average of all the assessed categories was extrapolated to the total GHG-emissions of all the re-sold products by tutti over the period of one year – again with a safety margin of 33%.

The results show that more than 50% of the CO_2e-emissions are caused by the category furniture, followed by electronics. The entire GHG-emissions saved by the tutti platform in a year add up to approximately 47’600 t CO_2e.

The study concludes that the saved CO_2e-emissions by the tutti Internet platform are remarkable. The avoided purchase of new products not only helps climate protection, but also resource and energy efficiency, as less natural resources and energy carriers are being consumed for the production and transport. A lifestyle that fosters the use of a product up to its functional end-of-life therefore makes a lot of sense and does not affect the standard of living.

Keywords: lifestyles, second-hand articles, CO_2-emissions, climate protection, resource efficiency.

Introduction

Tutti.ch consulted myclimate to determine the CO_2e-emissions of second-hand products compared to newly produced articles. The assessed articles contain the five most sold products of each of the main product categories on the tutti.ch platform. On the basis of this analysis, the CO_2e-emissions are extrapolated to all the sold products on the tutti.ch website over the period of 1 year. The category “vehicles” is not a primary focus of tutti and has therefore been left out in this study.

Framework and Methodology

Goal and scope of the study

The goal of the study is to calculate the CO_2e-emissions saved by buying second-hand articles compared to newly fabricated products. The report is written by myclimate for tutti.ch and is used to promote the environmental benefits of second-hand products sold on their platform.

Products overview

The 41 assessed products of 8 categories are listed in Table 42-1 below.

Product Category	Products
A. Furniture	Sofa, Bed, Table, Cupboard, Bureau, Chair
B. Toys	Lego, Playmobil, Training bike, Toy tractor, Football table
C. Sport Articles	Bicycle, Home trainer, Trailer (Bicycle), Snowboard, Skis
D. Small Household Appl. Appliances	Coffee machine, Sewing machine, Vacuum cleaner, Microwave, Ironing board
E. Large Household Appl. Appliances	Washing machine, Fridge, Dishwasher, Tumbler, Baking oven
F. Electronics	Smartphone, TV, Tablet, Laptop, Digital camera
G. Baby & Child	Pram, Maxicosi, Child car seat, Playpen, Cot
H. Clothes & Accessories	Handbag, Watch, Shoe, Jacket, Evening dress

Table 42-1: *Most sold products per product category on tutti.ch web platform.*

Functional unit and system boundary

For this carbon footprint study, the functional unit relates to 1 specific product of each category, e.g. 1 sofa, 1 bicycle, 1 furniture or 1 jacket.

The products are assessed from cradle-to-gate, including the transport to Switzerland. Due to a lack of data and the small relevance on the overall result of most of the products, the use-phase has not been considered in this study. It is assumed that the end-of-life phase of second-hand products is identical to the one of new products; therefore the end-of-life phase is also excluded from the investigations. For the packaging of the new articles, a product-specific assessment has been carried out.

The data traffic of the Internet platform is deducted from the emitted CO_2, as it is assumed that this energy consumption for the trade of second-hand products has been caused additionally compared to new products.

The time frame of the study encompasses 1 year (September 2013 – August 2014).

Database and methods

Primary data for the traded products have been provided by tutti.ch statistics. The ecoinvent database (2.2) is used for the GHG-assessment of the different products, complemented by published LCA-studies and producer information.

The internationally recognised impact assessment method IPCC 2007 (GWP 100a) is applied to evaluate the CO_2e-emissions of the different products. This method accounts for the Global Warming Potential related to a time-span of 100 years.

The study assumes that the trading of second-hand products replaces the purchase of newly produced articles of the same kind. With the purchase of second-hand products, the manufacturing of new products, including the packaging and transport to Switzerland, can be avoided.

Manufacturing – Packaging – Transport

The various articles are modelled by the weight of the products' input materials, combined with a manufacturing process like extrusion or injection moulding. The packaging for the different products consists – where required – of corrugated board, styrofoam, plastic film and a Euro pallet. For articles produced in China or India, the transport is modelled by a transoceanic freight ship, followed by a barge from Rotterdam to Basel and a final average 100 km truck delivery (16 – 32 t, Euro 4) within Switzerland.

Energy Consumption of the tutti.ch platform

The data traffic - generated by the users of the tutti.ch website - sums up to 21'900 kWh power consumption over the period of one year. This creates CO_2e-emissions of 2'742kg CO_2e.

Extrapolation of Emissions

The five most sold products of each category are assessed for their CO_2e-emissions and are extrapolated to the totally sold volumes per category. Due to rather large uncertainties in this study, an uncertainty margin of 33% is applied. The same approach (safety margin 33%) is used to extrapolate the emissions of the studied categories to all the product categories on the tutti.ch platform in order to assess the overall CO_2e-emissions of the total product volume.

Data inventory

For obvious reasons, it is impossible to determine THE typical representative of a product category. As a consequence, a generic product for each subcategory has been created. Table 42-2 shows the specification of each assessed product.

Products	Weight (kg)	Products	Weight (kg)	Products	Weight (kg)
A1 Sofa	71.0	C4 Snowboard	3.6	F3 Tablet	0.45
A2 Bed	68.4	C5 Skis	4.3	F4 Laptop	3.15
A3 Table	49.3	D1 Coffee machine	3.2	F5 Digital camera	0.50
A4 Cupboard	99.7	D2 Sewing machine	9.5	G1 Pram	16.5

A5 Bureau	60.7	D3 Vacuum cleaner	10.1	G2 Maxicosi	5.0
A6 Chair	16.4	D4 Microwave	17.5	G3 Child car seat	9.4
B1 Lego	1.51	D5 Ironing board	5.8	G4 Playpen	14.9
B2 Playmobil	0.58	E1 Washing machine	37.8	G5 Cot	24.4
B3 Training bike	3.50	E2 Fridge	85.0	H1 Handbag	1.00
B4 Toy tractor	10.2	E3 Dishwasher	39.1	H2 Watch	0.15
B5 Football table	40.4	E4 Tumbler	40.0	H3 Shoe	0.82
C1 Bicycle	15.0	E5 Baking oven	40.1	H4 Jacket	0.90
C2 Home trainer	41.3	F1 Smartphone	0.15	H5 Evening dress	0.85
C3 Trailer (bicycle)	15.0	F2 TV	22.0		

Table 42-2: *Weight of the different most popular articles on the tutti.ch platform.*

Additionally to the weight of the products, the weight of the packaging is identified, and the distances for the different modes of transport are calculated based on the country of production.

Impact assessment

Within the framework of this study, the impact of the various products on climate change is assessed. The chosen indicator, the GHG potential (IPCC 2007, GWP 100a), describes the potential of greenhouse gases on the climate within a time frame of 100 years. GWPs are based on the heat-absorbing ability of each gas relative to that of carbon dioxide (CO_2), as well as the decay rate of each gas (the amount removed from the atmosphere over a given number of years) (GGW 2015). ecoinvent 2.2 serves as background database.

Results

CO_2e-emissions per product and product category

In a first step, the CO_2e-emissions for each product under investigation are calculated. The top-5 articles are TV (approx. 640 kg CO_2e), fridge (~435 kg CO_2e), baking oven (~410 kg CO_2e), sofa (~380 kg CO_2e) and washing machine (~315 kg CO_2e), whereas the bottom-5 are represented by shoes (~16 kg CO_2e), training bike (~13 kg CO_2e), an average Lego set (~12 kg CO_2e), watch (~11 kg CO_2e) and an average playmobil set (~4 kg CO_2e).

Apart from the total CO_2e-emissions per product, a comparison on the basis of 1 kg of product is meaningful. In this ranking, the list is headed by the smartphone (~330 kg CO_2e/kg), the tablet (~200 kg CO_2e/kg), the digital camera (~150 kg CO_2e/kg), the jacket (~80 kg CO_2e/kg) and the watch (~70 kg CO_2e/kg). The products with least GHG-impact per kg are the table (~1.6 kg CO_2e/kg), the playpen (~1.4 kg CO_2e/kg), the football table (~0.9 kg CO_2e/kg) and the bureau (~0.8 kg CO_2e/kg).

CO_2e-reductions of all the investigated products

Based on the CO_2e-emissions of each product and their corresponding sold volumes on the tutti.ch platform, the total CO_2e-emissions can be determined. The total of all the investigated sold products adds up to approximately 14'000 t CO_2e per year. Sofas make up the biggest share (25.5% of the total), followed by TVs (12.0% of the total), bicycles (9.7% of the total), tables (8.9% of the total) and beds (7.9% of the total).

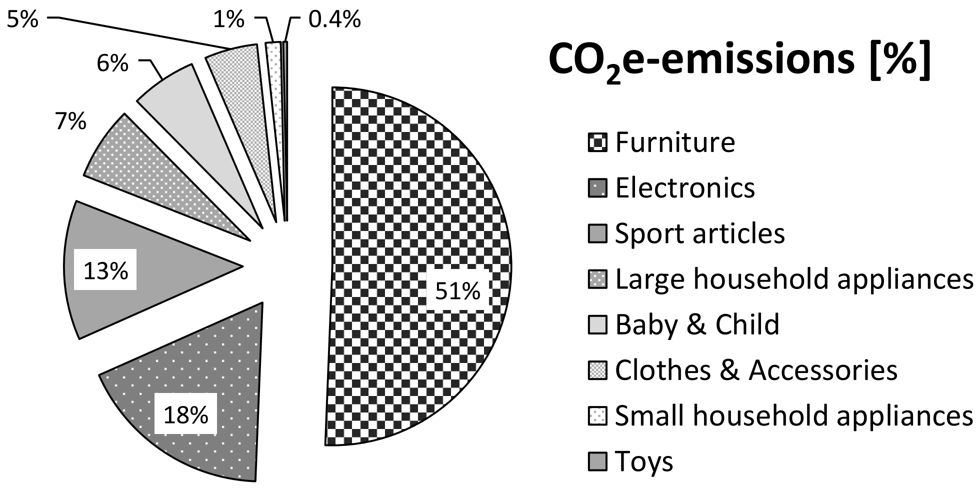

Figure 42-1: *CO_2e-shares (%) of the investigated product categories on tutti.ch*

Figure 42-1 shows the CO_2e-shares of all the different product categories looked at. The category furniture causes the highest GHG-impact, followed by the electronics and the sport articles.

Extrapolation of CO_2e-reductions to all tutti.ch products

According to the methodological approach described in Chapter 2.4, the total emissions of all the sold tutti.ch products of all categories are calculated. All the purchased products in the investigated categories account for over 31'000 t CO_2e (conservative extrapolation with a safety margin of 33%).

The estimated emissions for the so far not assessed categories like gardening equipment, game consoles, books etc. make up another 16'000 t CO_2e. As a result, it can be concluded that the total amount of all the sold products from September 1, 2013 to August 31, 2014 add up to 47'600 t CO_2e (see Figure 42-2).

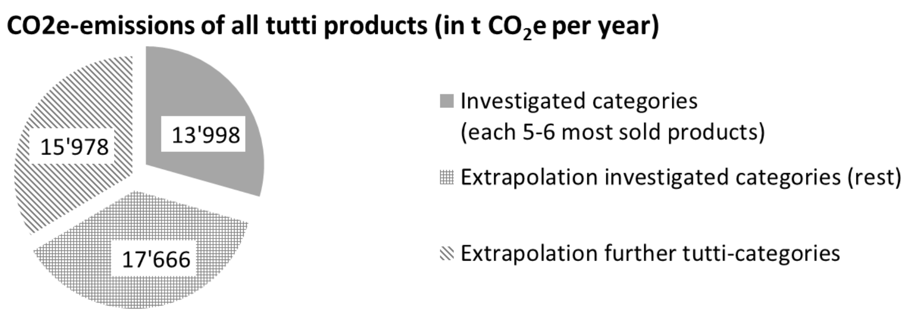

Figure 42-2:*Total CO_2e-emissions of all the investigated 8 product categories and extrapolation to all the tutti.ch articles for the period of 1 year.*

Conclusions

The entire GHG-emissions saved by the tutti platform in one year add up to approximately 47'600 t CO_2e. This is equivalent to 20'000 return flights Zurich – New York (economy class) or the electricity consumption of 85'000 households in Switzerland (average of 4'500 kWh/a, 4 persons).

The study concludes that the saved CO_2e-emissions by the tutti.ch Internet platform are remarkable. The avoided purchase of new products not only helps climate protection, but also resource and energy efficiency, as less natural resources and energy carriers are being consumed for the production and transport. A lifestyle that fosters the use of a product up to its functional end-of-life therefore makes a lot of sense and does not affect the standard of living.

It could be argued that neglecting the use-phase of products would not describe the real-life situation, as especially new electronic products consume much less power than second-hand products. However, this is only the case, if the use-phase is dominant compared to the manufacturing of the product. New smartphones actually have to be recharged as often as 2-3 year old second-hand smartphones, due to heavier use for data traffic and applications. Furthermore, with the power mix in Switzerland, the break-even point that justifies the purchase of e.g. a new fridge compared to an “old” average fridge is approximately 34 years. This life-span is longer than the life-expectancy of a new fridge.

Considerations and investigations of rebound-effects (is the purchase of a second-hand product really replacing the purchase of new good?) are key questions for further research. At the same time, it would be interesting to make a link to the social profile (lifestyles) of consumers visiting the tutti.ch platform.

43. CHANGE AGENTS ENGAGED IN SUSTAINABLE TRANSFORMATION IN THE FINNISH FOOD SYSTEM

Katariina Koistinen ✉, Satu Teerikangas, Mirja Mikkilä, Lassi Linnanen

Abstract

Food security is a crucial topic in sustainability science. Agricultural land occupies approximately 37–38% of the Earth's land surface, and about one third of the EU's environmental impact is caused by the current food system. Further, feeding the world's rapidly growing population is a mounting challenge. To achieve a sustainable food system, a holistic system transition is required. Whereas past research has primarily focused on macro-level sustainable system transformation, this paper responds to calls to look at change at a micro level, by focusing on sustainable system transformation that is initiated by individuals. Inspired by system intelligence, this paper presents the hypothesis that change agents are needed across the current food system to enable sustainable system transition. This agency is studied throughout the agricultural value chain – from the agricultural production phase, through the distribution and retailing phases to the consumption phase. The paper explores how individuals become involved with, and stay engaged in, sustainable transformation. The findings are based on a qualitative study in which 26 individuals involved in the Finnish agricultural value chain were interviewed. The findings show that individuals' intrinsic motivation and ethical stances explain their engagement with sustainable transformation. Further, the study identifies the fact that change agency can be either active or passive. To our knowledge, this paper is among the first to bring a micro-level perspective to sustainable transformation in the context of food systems. Our findings carry important implications for the emerging study of sustainable transformation that is initiated at the micro level. When our understanding of micro-level change increases, sustainable systemic change is more likely to become institutionalised.

Keywords: food, agriculture, micro-level change, change agency, sustainable transformation

Introduction

Ensuring food security is one of the critical topics in the field of sustainability science (Gregory and George, 2011). Agricultural land takes up about 37–38% of the world's land surface and we are in the phase where the challenge is not solved simply by adding crop fields (Smith et al., 2008; Simons, 2015). Recent studies imply that about one third of the environmental impact in the EU is caused by the current food system (Tukker et al., 2006; Tukker et al., 2009). Creating a more sustainable food system and feeding future generations seem to be crucial goals for the upcoming years.

In order to achieve a more sustainable food system, large-scale changes are needed (Simons, 2015). The current literature and research about sustainable transformation is mainly dominated by a macro-perspective (Abell et al., 2008; Markman and Waldron, 2014). There is a lack of focus and appreciation of the micro-perspective; creating transformation is seen as reliant on macro-level societal forces. Whilst macro-led change is necessary for system transformation, there is a certain place for change initiated at the micro level as well. Our two fundamental arguments are that individual agents are part of the system and that they are capable of changing the system. We argue that understanding individuals is a critical element that is lacking in the present research on system transformation. By ignoring one piece of the puzzle, the dynamics of sustainable transformation cannot be fully understood. Therefore, our unit of analysis is change agency and how agents enable sustainable transformation. We hypothesize that individuals are the missing link in system transformation.

In this study we start addressing this large gap by exploring the dynamics of agency. This paper seeks understanding from social sciences and from management research. In it, we take the step of embedding change agency and micro-level change from organizational research within the issue of sustainable systemic transformation in response to calls to create synergy between the technical and social sciences. At the heart of the concept of micro-level change is the assumption that change starts with individuals and the decision to accept and adopt something new depends on individuals and their reactions to the new style of practice. Furthermore, internal change agents are argued to play an important role in implementing change (Van der Heijden et al., 2012). The term ‘change agents’ refers to individuals who act as catalysts, embracing the responsibility for managing change activities (Robbins et al., 2010). It is acknowledged that micro-level change can create society-level outcomes, and even causally produces strategic phenomena, but it is still unclear how these phenomena emerge from individual actions (Abell et al., 2008). To strengthen our argument, we are inspired by a recent research stream called System Intelligence (SI), which seeks to understand human behaviour in complex interactive settings, and in tangible efforts to generate change (Hämäläinen and Saarinen, 2004). Therefore, the role of change agents implementing sustainable systemic change is the focus of our keen interest.

The paper aims to understand why some individuals change their behaviour towards sustainability and why they stay engaged in sustainable change. We are striving for a better understanding of sustainable micro-level change within the framework of the Finnish food system. Individuals’ change behaviour and engagement in change is more important than the actual practice of change, as long as the change is related to food and sustainability. The change can be, for instance, an individual’s shift to vegetarianism or the decision to start to farm only organic products. The research questions driving our inquiry are: (1) what motivations underlie the pro-ecological behaviour of change agents in the food system? and (2) what forms does change agency take in the Finnish food system? Given the lack of previous research, we selected a qualitative research design with 26 interviews.

The paper contributes to extant research as follows. The first contribution is to offer exploratory findings on pro-ecological change agency in the food context. The focus of the paper was on change agency since the individual level has often been lacking in the current system literature and in the sustainable transformation literature. Our second contribution suggests that in addition to system perspectives, research on sustainable consumption needs to consider the role of individuals as change agents within systems. Our third contribution is to utilise theorising from organizational research in the context of sustainable transformation. In so doing, we respond to recent calls to break the division between technical and social sciences in the study of sustainability.

The paper is structured by presenting first a theoretical overview where we address the system literature and system intelligence to illustrate the connection between systems and individuals. After system literature we discuss the literature from change agency and micro-level change from management research, which we utilize in the sustainability context. Next, we present a more precise methodology and follow this with our empirical study and its results regarding individuals’ motivations in sustainable change. We then proceed to the discussion and our concluding remarks.

Theoretical Framework and literature review

We bring up a combination from system thinking and managerial thinking since at the present these two different fields of study do not complement one other. The aim of the literature review is to give a general view on how systems are related to the individual level, and furthermore, to provide an impression of where the current literature stands. The main contribution is to strengthen the micro-level perspective within the field of sustainable systemic transformation. After exploring the literature, the research proceeds to a study of the dynamics of agency in the Finnish food system.

System literature

If human actions are to be brought back within planetary boundaries, it is essential to transform current socio-technological systems (Meadowcroft, 2009). 'Transition management' often refers to the government of sustainable development, and it combines life course, environmental, and political-economic forms of transition (Loorbach and Rotmans, 2010; Brown et al., 2012). Transition management focuses on governing the development of sustainable regimes out of green niches, which includes favouring the selection environment for green niches by putting incumbent regimes under strong sustainability pressure (Smith and Stirling, 2010). Still, we argue that the research that falls under the label 'transition management' has been steered by the top-down approach and that the current literature is too static; it does not pay enough attention to the influence or potential of the individual. This results in the stagnation of system transformation. We aim to bring more dynamism to the debate, and we move the focus from the top-down to the bottom-up approach.

Despite the dominance of the literature on macro-level change in recent years, the phenomenon of System Intelligence, for example, where the main argument is that human agents are able to influence the whole system, has acknowledged the art played by individuals (Hämäläinen and Saarinen, 2004). The reason why system intelligence is so prominent and inspiring for this study, is the great potential for change that it offers; system intelligence refers to the phenomenon whereby an individual successfully combines system thinking and emotional instincts.

It is crucial to realise that the current system in which we are living is defective and the system is not everlasting. We have created the system boundaries ourselves. System intelligence highlights the possibility to redraw these socially constructed system boundaries (Jones and Corner, 2011). The unsustainable system that we are now living in also displays characteristics of a 'system of holding back'; a space in which everyone involved pictures a common desire in his mind, but nobody behaves so as to achieve it (Sasaki et al., 2014). As a consequence, people become entangled in systems that serve nobody's interest and which can make people act in undesirable ways. As people act in such ways, they maintain the system and its influence upon others, partly causing the system of undesirable behaviours to regenerate itself (Hämäläinen and Saarinen, 2004). This carries significant potential for individuals to create change in the system. Even a minor change in the system can result in a radical change (Sasaki et al., 2014). The clear message is that change agents can transform the system and the focus on the macro level is not enough.

Change agents and micro-level change

In this section, we look at the existing thinking in management studies on general change agency and micro-level change, since the literature lacks research on change agency at the individual level in the field of sustainability. However, being inspired by the above presented emphasis on individuals' capabilities, we highlight change agency as a crucial link in generating sustainable change. Individuals who act and manage change activities are called 'change agents' (Robbins et al., 2010). Change agents often play an important role by articulating and presenting ideas in ways that influence people and result in change (Caldwell, 2003; Lawrence et al., 2006). Many writers also argue that the more complex the change process is, the more difficult it is to achieve, and the greater the need to utilize the skills and experience of a special change agent (Buchanan and Boddy, 1992; Schuyt and Schuijt, 1998; Lichtenstein, 1997).

The term 'micro-level change' refers to the change that takes place when an individual changes his/her previous behaviour. Micro-level change plays a key role, since the beginning of the change usually lies in the minds of individuals and, given the right conditions, individuals can change the whole presenting system with their actions. Millar et al. (2012) indicated that, at the micro level, individuals need to adopt and internalize new practices profoundly to make them effective. The individuals and their thoughts should not be ignored any longer, if the goal is to reach systemic transformation.

The macro level dominates the presenting literature on sustainable transformation (Abell et al., 2008; Markman and Waldron, 2014). However, the focus needs to change; it is time to turn our attention to the micro level. Individuals cannot be disregarded any more (Abell et al., 2008). Langley et al. (2013) state that individuals play a crucial role as key actors in many recent studies, but still there is a certain lack of analysis focusing on the individual level itself. Felin and Foss (2005) argue that new routines emerge from or are created and changed by individual actions. These arguments strengthen the statement that sustainable changes and developments can emerge from individuals and can also be made to flow into the mainstream by them. This suggests that there is a need for a better understanding of the individual level in order to create sustainable systemic transformation.

The human brain is capable of adapting rapidly to new visions, new circumstances. Because of this flexibility, sustainable transformation, initiated by individuals, can emerge quickly from the micro level in suitable conditions. It is striking that individuals' visions can be collective (Mintzberg and Waters, 1985). This collective behaviour may play a key role in sustainable transformation, since collective visions often take the form of the pursuit of a cause in which individuals are willing to sacrifice short-term personal gain for longer-term, generally beneficial collective aims (Hernandez, 2012; Donaldson and Davis, 1991; Donaldson and Preston, 1995). Still, individuals' intrinsic motivation is often the single most compelling reason why individuals embark on an activity and why they stay engaged in it. By 'intrinsic motivation' we mean the motivation of engaging in an activity purely for the sake of the activity itself (Lepper et al., 1973). When individuals are intrinsically motivated, they pursue activities for the interest and enjoyment those activities provide (Csíkszentmihályi, 1975), and they often perform them at fairly high levels (Amabile, 1996; Grolnick and Ryan, 1987). People, who are intrinsically motivated to sustainable transformation, are likely capable to enable change.

Even though understanding micro-level change is the core of this study, individuals live in the world and they are surrounded by interaction. Individuals are part of a system. In fact, the most straightforward way to move from the micro level to the macro level is built on the assumption that the whole, macro, is the sum of its parts, micros (Alexander et al., 1987). The macro level is a large institutional level including the whole of society, and on this level there are also other ruling factors than just the micros. Still, when the macro level is examined and divided into small enough parts, behind every institution we eventually find individuals. Generalized, it does not matter how large the entity under consideration, the macro level is only the repeated experiences of large numbers of people in time and space (Alexander et al., 1987). In addition, if the members of an organization share a vision, in this case about a sustainable food system, and identify so strongly with it that they pursue it as an ideology, they are bound to exhibit patterns in their behaviour, so that clear realized strategies can be identified (Mintzberg and Waters, 1985). It is crucial to understand that the output of a successful micro-level change can be significant.

Research design

It is clear that activities at the micro level are able to create system-level outcomes, and even causally produce strategic phenomena, but how these phenomena emerge from individual actions is still beyond current understanding (Abell et al., 2008; Hämäläinen and Saarinen, 2004). In this paper, we stated earlier that a sustainable food system is needed, and this requires systemic transformation. Systemic transformation has mainly focused on top-down policies, and we have argued that this is not enough, and that we need a stronger focus on the micro level. We are now aiming to make that micro-focus apparent through change agency in an empirical study.

We have discussed the reasons why the micro level is crucial, how individuals possess a significant potential, and how they are capable of creating change. It was necessary to demonstrate how systemic transformation and micro-level change are bundled together in order to create a synergy between technical systems and people-oriented social sciences. Still, the current research lacks knowledge about change agency in the food context, and even in the sustainability context. We argue that without enhancing change agency in systemic change, the potential of individuals is lost, and therefore we aim to understand micro-level change through our qualitative study, which includes 26 change agents.

To our knowledge, this paper is among the first papers to focus on change that is led from the micro level in sustainable transformation. In addition, there is very little to be found on micro-level change in the existing research in sustainable food science. Since it is limited or even absent in the existing literature, we have taken an abductive perspective to our study.

Methodology

The empirical part of this paper covers our qualitative research, which was implemented by semi-structured interviews, the aim being to find answers to the research questions. The core of the empirical part was constructed by interviewing individuals who are related to the food system in Finland, and who act differently compared to the mainstream. Change agency was studied throughout the Finnish agricultural value chain. Respondents were chosen from the agricultural production phase, the distribution and retailing phase, and from the consumption phase. Respondents' age, gender and education varied; the only combining factors were that they had all changed their behaviour towards sustainability in Finland's food system. Respondents were, for example vegans, organic farmers, or retailers of locally-grown food. In total, 26 change agents who participated the interviews and the interviews were carried out between September 2014 and May 2015. The interviewees were gathered in two phases. First, we carried out an internet-based search, from which the first change agents were selected. During the first interviews, we asked interviewees to suggest further change agents. This created a snowball-effect, which led to finding new interviewees from our first interviewees.

During the later interviews, the responses started to repeat each other. It was clear that, with our sample of 26 change agents, the saturation point had been reached and we had achieved the desired effect. Details about the interviewees are presented in the Table 42-1.

Interviewee	Food system phase	Field	Duration
1	Distribution and Retailing	Local food	30min–1h
2	Distribution and Retailing	Local food	30min–1h
3	Agricultural production, distribution and retailing	Organic food	1h–2h
4	Agricultural production, distribution and retailing	Organic food	1h–2h
5	Distribution and retailing	Local food	1h–2h
6	Agricultural production	Urban farming	30min–1h
7	Agricultural production	Local food	30min–1h
8	Distribution and retailing	Veganism	30min–1h
9	Consumer	Vegetarian diet	30min–1h
10	Consumer	Reducing food waste	30min–1h
11	Agricultural production, distribution and retailing	Organic food	1h–2h
12	Agricultural production, distribution and retailing	Organic food	1h–2h
13	Agricultural production, distribution and retailing	Organic food	1h–2h
14	Specialist	Whole food system	30min–1h
15	Distribution and retailing	Veganism	30min–1h
16	Consumer	Vegetarian diet	30min–1h
17	Consumer	Veganism	30min–1h
18	Agricultural production, distribution and retailing	Organic food	30min–1h
19	Consumer	Veganism	30min–1h
20	Consumer	Vegetarian diet	30min–1h
21	Distribution and retailing	Whole food system	30min–1h
22	Distribution and retailing	Whole food system	30min–1h
23	Consumer	Veganism	30min–1h
24	Agricultural production	Organic food	1h–2h
25	Consumer	Organic, local and vegetarian food	30min–1h
26	Agricultural production	Organic food	30min–1h

Table 43-1: *Interviewees.*

Because of the study's qualitative nature, the main focus is on data analysis and creating interpretations from the received data. First, we carried out the interviews and recorded them.

After the interview sessions the recordings were transcribed. Later, the data analysis was conducted using Word and Nvivo. The open quotes were chosen from the Word files. The quantifiable data was analysed using Nvivo. It is a characteristic of Nvivo that the data analysis can be conducted repeatedly to ensure the validity of the study. In Nvivo, coding is also easy to categorize in order to ensure reliability. In the study, the interviews were tested beforehand and all the interviews were recorded to achieve good reliability.

The semi-structured interview format was a suitable choice for the empirical part of the study since we were carrying out qualitative research. Interviews moved around the central theme, but they were conducted in a conversational tone, in order to get data that was as representative as possible. The interview questions revolved around a similar core in every interview, but respondents were given the opportunity to freely articulate their thoughts and feelings during the interviews. It is noteworthy that even though there was no strict structure in the interview, the questions needed to remain around the theme (Tuomi and Sarajärvi, 2002). The interview questions centred on individuals' reasons for change-promoting behaviour and change engagement. The core of the interview questions, and the theme to which they are linked is shown in Figure 43-1. The questions were strictly chosen to ensure validity and support finding the answer to our research question.

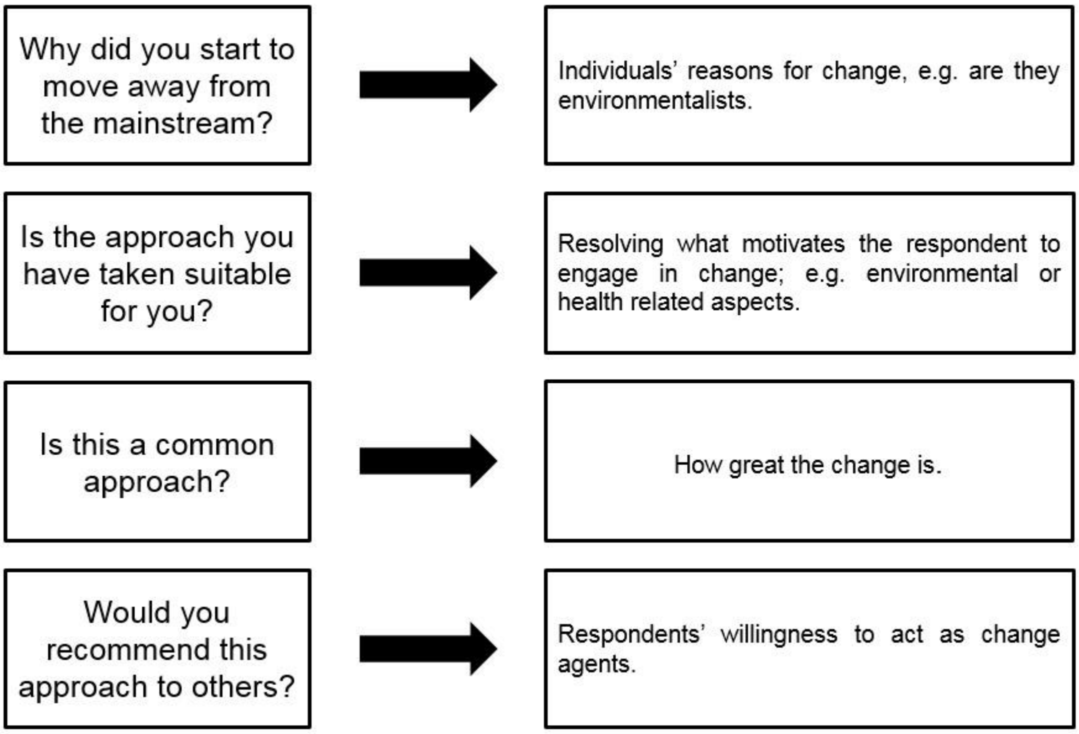

Figure 43-1: *Core of the interview questions and what the questions were aimed at.*

Dynamics of Agency in the Finnish food system

Why do agents act?

The reasons why individuals change their behaviour and stay engaged in change were the main interests of this paper, since the underlying assumption was that when we have an understanding at the individual level, systemic change can also be understood holistically. The responses of the interviewees varied somewhat, but certain similarities could be identified.

Table 43-2 summarizes the inducements to action most frequently mentioned by the individuals we interviewed in categories of significance.

Reason why individuals changed their behaviour or maintained new behaviour	Category of significance
Environmental concerns	High
Social environment	Medium
Animal rights	Medium
Contact with the countryside	Medium
Health	Medium
Affected by consumer behaviour	Low
General ethical concerns	Low

Table 43-2: *Main reasons why individuals changed their behaviour.*

Given from the responses, the most significant motivation for change behaviour was environmental reasons. Environmental reasons varied from concerns about carbon emissions and overuse of water to wanting to reduce the distribution phase of the food system. One respondent spoke about environmental concerns as follows: "*I have thought about the environment, and thought about how much fodder production consumes water. When I saw the figures, it was shocking*." Another respondent described a personal connection to the environment as follows: "*We have always lived very strongly from the earth. An environmentally-friendly lifestyle has always been present*." Even though 20 out of 26 respondents told us that environmental reasons motivated them to act, only eight of them said that caring for the environment was the dominant reason.

After the environmental reasons four medium motivations were found: individual's social environment, animal rights, individuals' deep connection to the countryside, and health related concerns. During the interviews, animal rights were given as a medium/high motivation for behavioural change as often as health-related concerns, contact with the countryside, or the effect of one's social environment. However respondents named animal rights as the dominant motivation more frequently than the other reasons: "*The most important inducement, for me, is animal rights*"; "*I think the well-being of animals has been the motivation for me*"; and "*The biggest influence on my decision was animal rights.*"

Health was also a strong motivation for change for the respondents. It was seen as a desirable goal either for the respondent or the respondent's family. Organic food, locally produced food or a vegetarian diet were seen as healthier than the mainstream diet. In addition, a food's purity or authenticity was also described as a health-related aspect in the interviews. Respondents said that food purity promotes their health. They expressed concerns about the purity of 'regular' food, and mentioned issues such as, for example, antibiotic residues, or how well nutrients survive during long periods in handling and distribution. Four interviewees said that health concerns were dominant or self-evident reasons for acting differently, and one interviewee told us that her choice was affected by health-related aspects: *"My purpose was* *to find authentic food, which includes as little as possible food additives and has the shortest distribution as possible.*"

Even though the answers gave an indication of each individual's deep intrinsic motivation, we also saw demonstrated the fact that individuals are not isolated. Their social environment had an effect on their behaviour. Several respondents told us that their interest in food was shaped at home during childhood. For example, one of the respondents described childhood memories: "*My mother, for example, made very traditional foods, and sustained food traditions. I have always been very interested in how traditional foods are made. Those were very nice childhood memories*." Other interviewees mentioned that the social connections that influenced their decisions were spouses, friends, and in general the surrounding community, for instance: "*My eyes were opened when I met my wife, who was born in the country*." Many of the interviewees also told us that they either grew up or had spent a great deal of time in rural areas during their childhood, for example, with their grandparents. They described positive memories of rural life: *"I grew up in the countryside, so I have respect for nature*"; "*As a child, I watched how my grandfather farmed cabbage and I saw how he kept the potatoes in the cellar, so it (interest in food) came from my childhood*."

In contrast to these four motivations, which appeared at the significance level of medium/strong, we found that 'consumer behaviour' and 'general ethical concerns' were given a lower significance as motivations for change behaviour and continued engagement in change. For example, one respondent described her consumer behaviour as follows: "*It is just very a reasonable idea that food does not need to come from far away. We could be using local products, and if we did, the need for packaging would decrease, and the money would stay in the local area. Maintaining the local economy and the vitality of rural areas is important to me.*" The general ethical concerns were characterised as a moral obligation for change behaviour. Respondents appealed, for example, to the rightness of the chosen behaviour: "*My decision makes me feel good, because I think it is just the right thing to do*".

The findings suggest that intrinsic motivation is individuals' main driving force in changing to sustainable behaviour, or in maintaining this behaviour. In this paper, intrinsic motivation appears mainly as concern about environmental threats, concern about animal rights and interest in health benefits. As an addition to individuals' intrinsic behaviour, the results showed that people who are affiliated to an individual can have an impact on the individual's behaviour. The findings show that individuals whose actions promote sustainability are typically very environmentally conscious and their change behaviour and engagement in change are mainly affected by ethical standpoints. The findings also endorse the assumption that individuals may have a significant influence on others, since the importance of the social environment was so apparent in the data.

How do agents act?

In terms of our second research question, we discovered that the form of change agency depends on the agent involved. First, it was apparent that agency can be either active or passive. Most of the individuals we interviewed were very active and passionate in promoting their chosen behaviour and sustainable change. For instance, one respondent described the choice to become a vegan as follows: "*I would definitely recommend veganism for others. But only recommending it just feels so insufficient. Actually we should ask others (who eat meat or dairy products) to justify their actions. I just don't get it why the norm is upside-down*." However, some of the respondents described the change as a very self-evident part of their life. They acted in a more sustainable way, but they did not feel any need to advocate their choices. Some respondents even indicated that their sustainable actions are very personal, and that they feel it is more or less unnecessary to talk about their sustainable actions to others. Even though they did not actively promote their actions or behaviour, many of them had an effect on others. For example, one of the agents had a farm from which products were distributed mainly to the local area. The agent did not show any interest in promoting local food, but the products were still widely known and were given the quality label for local produce. The agent described his behaviour as follows: "*I grew up with this. I have been doing this since I was a kid,"* and "*I could be doing something more stupid. Food produced here simply tastes better than some foods produced further away.*" Based on these findings, we conclude that agency can be active or passive, but regardless of which it is, it can influence others.

We also found that change agents' capabilities can vary; they can be specialists or marketeers. Most of the respondents were typically deeply engaged in change and their knowledge about the phenomenon was great. They appeared to be specialists in their chosen behaviour. For these change agents, it was also typical that their original sustainable change often occurred without influence from their social environment or any other social contact. The following quote describes very well the knowledge-level of many of the specialist change agents: "*The main reason why organic food is in a stage of stagnation is the absence of knowledge. Farmers don't know how to farm naturally and productively at the same time. There are so many ways to be organic but also have productive crops. The problem is also that counselling is so poor, and counselling is often affected by the agricultural business, and that creates conflicts of interest. Organic farming also suffers from negative images but that is because of ignorance. If we teach the farmers, they will realise their possibilities and understand how organic farming makes sense in agriculture. In addition, organic food costs too much; it should be cheaper to the customer. There should be higher taxes on those agricultural methods that harm the environment.*"

However, there were also a few respondents who may have lacked up-to-date knowledge about their chosen sustainable phenomenon, but they clearly knew how to inspire others. Typically, their original change behaviour was influenced by their social surroundings or rural affiliation. They had not concretely created anything new in the food system by themselves, but they were able to market pre-existing actions further on. They were looking for ways to improve the current system and their marketing capabilities were visible during the interviews: "*The timing was very important (for the spread of organic food), since people were ready for organic food. But you cannot change individuals' values. It is important to appeal to the green consumers, because they are likely to buy organic food if they know what organic food is and how other types of food work.*" "*I think that examples in the media are too distant. Preaching doesn't work either; we should show that a vegetarian diet is easy. And the change doesn't need to be definitive, even small changes create stimulus for bigger changes. People hunger for a sense of community*."

We found out that change agents who had more specialist tendencies were often capable of creating change and successful grassroots movements. Their deep knowledge helped them to discover flaws in the existing system and they were able to think beyond existing system boundaries. They also had a sense of how to change the existing system and find more sustainable alternatives to the status quo. Change agents with marketing capabilities were also able to look beyond the current system boundaries, but their thoughts were more human-centred. They sought and discovered ways to influence others in order to disseminate more sustainable approaches in ever-wider circles.

We argue that when systemic change takes place, the form of agency should be taken into consideration. The form of agency can dramatically influence the change for better or for worse. Figure 43-2 presents an example of how a change agent's capabilities can ease systemic change.

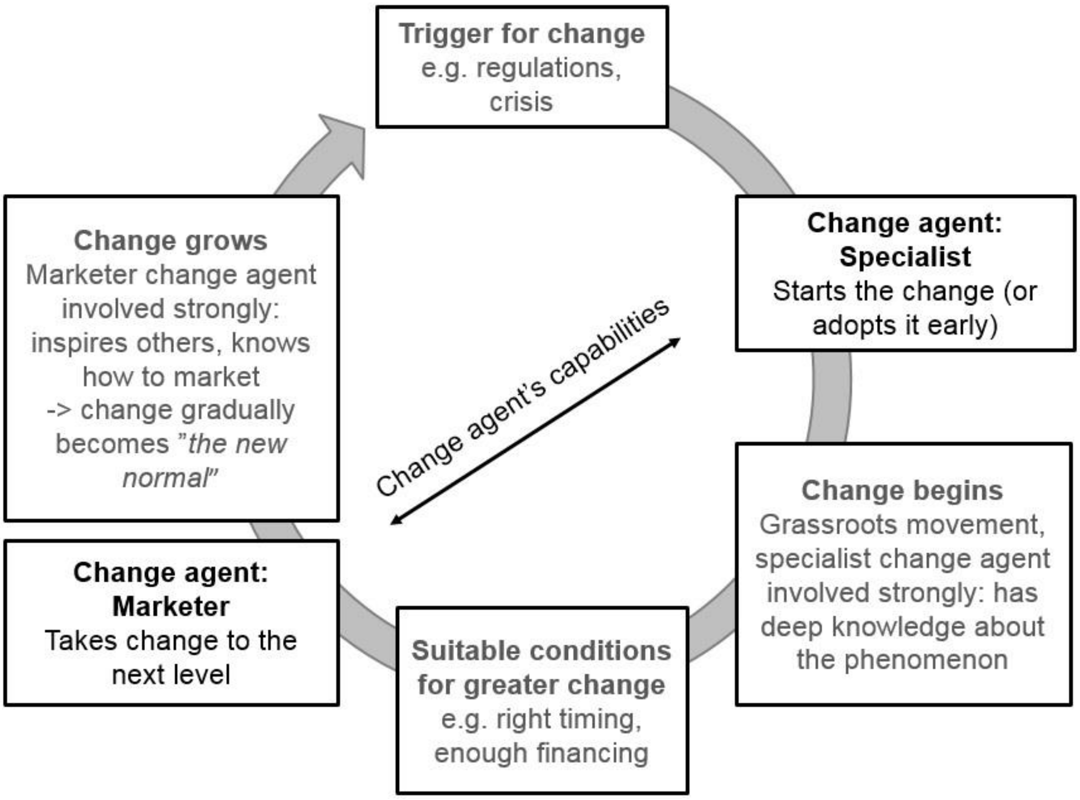

Figure 43-2: *Cycle of change and how change agents can affect change*

We maintain that different phases of the system need different forms of agency. When the change agents are in the system phase that is most natural to them, they can exploit their capabilities optimally. 'Marketer change agents' may not discover opportunities to create change, but on the other hand, when the aim is to inspire greater change, the 'specialist change agent' might not give the best possible output. In order to create a holistic systemic change, every individual's greatest positive potential should be exploited.

Discussion

The aim of this research was to achieve a better understanding of change agency and micro-level change as a crucial part of systemic sustainable transformation. We studied the dynamics of the agency in the Finnish food system. Our paper makes three contribution to extant theorizing.

First, the current system literature and sustainable transformation literature are primarily focussed on the macro level and the systematic utilization of the micro perspective is lacking. In addition, the literature in the field of agricultural innovation is largely using the systems approach, whereas our understanding of the effect of the parts of the system is scant (Lamprinopoulou et al., 2014). It is into this context that our first contribution needs to be set. We provide early, explorative findings on the role of micro-level factors in enabling sustainable system transformation, through the study of change agents in the Finnish food system. Our findings were two-fold, focused on the motivations of change agents on the one hand, and the nature of change agency on the other hand.

Our theoretical framework identified intrinsic motivation as an engaging factor in individuals' activities. Our research results also revealed that individuals change their behaviour and stay engaged in change based on their intrinsic motivation and ethical standpoints. Intrinsic motivation engages change agents in change even if sustainable change is not always easy. The results make clear that individuals appear to be very environmentally and ethically consciousness. These change agents often have very deep knowledge about their chosen sustainable actions and they possess valuable knowledge about sustainable practices. Many of the interviewed agents can be described as specialists in their chosen sustainable movement. However, one significant problem seems to be that these agents are able to create or sustain successful sustainable grassroots movements, but these often remain locked into very small niches. Actually, we might not even know the real extent of different sustainable movements. This finding implies that large systemic transformations are stagnant at the micro level. A holistic systemic change needs new ways to move the transformation beyond their niches.

Further, the research results reveal that in the food context change agency activities are visible and therefore change agency can be utilized in the sustainable transformation. The results showed that agency can be either active or passive, and change agents can possess different kinds of capabilities. We identified 'specialist' capabilities and 'marketer' capabilities. This finding raises a question; what other kinds of capabilities can be found? This finding also draws attention to system structures and how to exploit change agents' capabilities in the different phases of the system.

Second, we argue that current systems are governed by the macro perspective, and that sustainable transformation is often structured by exploiting sustainable consumption policies. However, we state that leaning on policies and macro-level forces is not enough. Inspired by system intelligence, we wanted to learn more about the micro level and about individuals' motivations in the sustainability field. We argue that systemic change needs a micro perspective too. As an attempt to bring more recognition to the individual level, we studied systemic transformation through the lens of change agency. We hypothesize that when the agency is holistically understood in system transformation, implementing sustainable consumption policies will become simpler. Consequently, sustainable consumption will increase.

Third, in this paper we are responding to calls to bring the social sciences into the fields of sustainable transformation and system transformation, where the discussion is mainly dominated by hard technical sciences. We wanted to break this monopoly and we utilized findings from organizational theories. We have made an attempt to merge the ecological view into change agency theories from social and management sciences. Our unit of analysis was change agents since our argument is that people do not change their behaviour based on top-down policies, and we conclude that there is a need for a greater emphasis and understanding on the micro level. Our aim was not to solve major philosophical problems according to micro and macro oppositions, but we wanted to study agency, to start the journey of understanding individuals in the systems, and how to strengthen the connection between sustainable systemic change and individuals. We wanted to understand the process by which agents move the change from A to B. We brought up new insights about what triggers individual change in Finland's agricultural value chain. However, we still call for more research with a greater emphasis on the micro. We are calling for new bridges for sustainable systemic transformation and change agency.

This paper is only a beginning of the attempt to understand the whole of sustainable systemic transformation. Our study is just starting to grasp the phenomenon and therefore our view is limited. The research was conducted in Finland with a limited group of respondents and the nature of the study was qualitative. Because of the qualitative nature of the study, the data is always subjective and based on interpretations. Hence, the generalization of the findings is challenging, and our aim was merely to open new paradigms.

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44. A ROADMAP OF RESOURCE EDUCATION AS A KEY FACTOR FOR IMPLEMENTATION OF RESOURCE PRESERVATION AND EFFICIENCY

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Abstract

Natural resources, especially raw materials, are key production factors and therefore fundamental for our prosperity. A conserving and efficient treatment of natural resources will have to be a key competence of future societies. An important step to more resource efficiency is fostering public awareness and establishing a corresponding culture to protect resources. Under the basic idea of "Education for Resource Preservation and Efficiency ", a large research project in Germany called "BilRess" aims to contribute to the goals of resource policy through an educational strategy. The main objective is to develop an "Educational Roadmap for Resource Conservation and Resource Efficiency (R&R)" in interaction with relevant actors in the educational system, describing steps to integrate the topic in all important educational contexts in the future. Therefore, an inventory of educational materials, interviews and focus groups with several actors were conducted and the BilRess-Network was established in 2014 (by now including 130 members). Results show that resource education is not yet established in the educational system in Germany. The paper will present intermediary results of the roadmap for the different areas of education (school, apprenticeship, further education, university/college) – including specific comprehensive requirements. Important factors include: Raising public awareness for sensible resource handling through campaigns, carving out practical relevance of R&R within all educational areas, strengthen networks between relevant actors, increasing awareness of institutions through further training sessions, establishing the idea of material resources in framework curricula, examination regulations, syllabi and teaching modules, further developing educational materials, media and teaching concepts for all educational areas, establishing learning platforms as well as extending qualification of teachers. In order to put these ideas into practice and foster resource preservation in education, including communication and education activities through political measures (e.g. ProgRess, German national resource efficiency programme), a political promotion scheme for the idea itself is required.

Keywords: education for sustainable development, competencies, resource preservation, resource efficiency, roadmap resource education

Introduction

The resource transition – next to the energy transition – is an indispensable step towards sustainable development. Just like it was recognised that we use too much energy from not renewable fossil resources we have to substantially decrease our material consumption of substances (metals, minerals, salts) and environmental media (soil, air, water) in order to reach more sustainable levels (Die Bundesregierung 2012; BMU 2012). Currently resource use in Germany is at approx. 70 tons per capita and year, while in the long run it has to be decreased to 8 tons per capita and year (Lettenmeier et al. 2014; Liedtke et al. 2015). Even more so as their functionality can hardly be substituted by renewable resources. Furthermore, specific resources cannot be used for different ends at a time. Farmland cannot be used during one growing season for energy crops, cereals, plants or bio-plastics at the same time. The resource transition therefore has to rest on two pillars: resource conservation and resource efficiency (Schmidt-Bleek 2007).

Resource efficiency means to deliver the same use through less input of materials or substances, which requires technological innovations. Examples are mining and smelting technologies which deliver a maximal output in resource extraction or steel sheets in the automobile industry which deliver higher stability at less material input through change of forms (ISI and IZT 2009:27).

Resource conservation means to entirely forgo the use of a resource. Resource conservation roots in social innovations and circular economy. Social innovations can reduce consumption e.g. when tools are not individually bought but shared. Recycling of specific substances e.g. in mobile phones is another important step to, once extracted, keep resources in use for the longest possible period (UBA 2014, Patalong 2010, Informationszentrum Mobilfunk o.J.).

The key to resource transition is awareness of the necessity to consciously handle resources and develop adequate competencies to act accordingly in practice. Both awareness and competencies root in resource education in all areas of education (Baedeker et al. 2014).

Raising public awareness means to promote and establish consciousness for an efficient and preservative use of resources. This has to be accompanied by establishing a corresponding culture to protect resources. The German resource efficiency programme “ProgRess” (BMU 2012) and its continuation ProgRess II emphazise this necessity and asks for educational changes which affect all areas in the educational system. Under the basic idea of “Education for Resource Conservation and Efficiency“, a large research project in Germany called “BilRess” aims to contribute to the goals of resource policy through an educational strategy. The main objective of the project is to integrate the topic in all important educational contexts in the future, based on the development of an "Educational Roadmap for Resource Preservation and Resource Efficiency" in interaction with relevant actors in educational systems. Therefore the Roadmap serves as an orienting concept and comprises an inventory of existing educational opportunities (determination of contents, structures, competencies and actors). Accompanying to the Roadmap, the second objective was to establish the BilRess-network as a communication platform as well as a portal for events, meetings and conferences to link stakeholders and to promote professional exchange of knowledge.

The framework of analysis in relation to resources is based on the definition of the “ProgRess” - Guidelines. In this context the project concentrates on material utilization, which comprises abiotic raw materials like ores, industrial minerals and construction minerals. Biotic raw materials will also be considered if they are used for material processing. Raw materials that are used for energy purposes, are not taken into consideration. Natural resources such as water, soil/land and air will be involved in case of system related issues.

Status quo of Resource Education: The example of general education/schools

The BilRess-Project contributes to increase awareness for resource preservation and efficiency and helps to establish the topic in the German educational system. Starting point was an extensive inventory of existing educational opportunities in the topic area. The status quo encompasses the collection of existing educational opportunities, projects, media and materials as well as online offerings in four educational areas: general education/school, apprenticeship, university/college, and advanced vocational training.

After this data collection, an analysis of documents (framework curricula, examination regulations, syllabi etc.) was conducted in order to determine in how far resource preservation and efficiency is already established in the different areas of education. Building on this, approx. 60 interviews and 10 focus groups with approx. 105 participants were conducted to identify needs for action and suggest proposals for action for the different areas of education. Finally, a „roadmap resource education“ is currently being developed interactively with key actors from the educational system to show ways towards a future integration of resource preservation and efficiency in all areas of education.

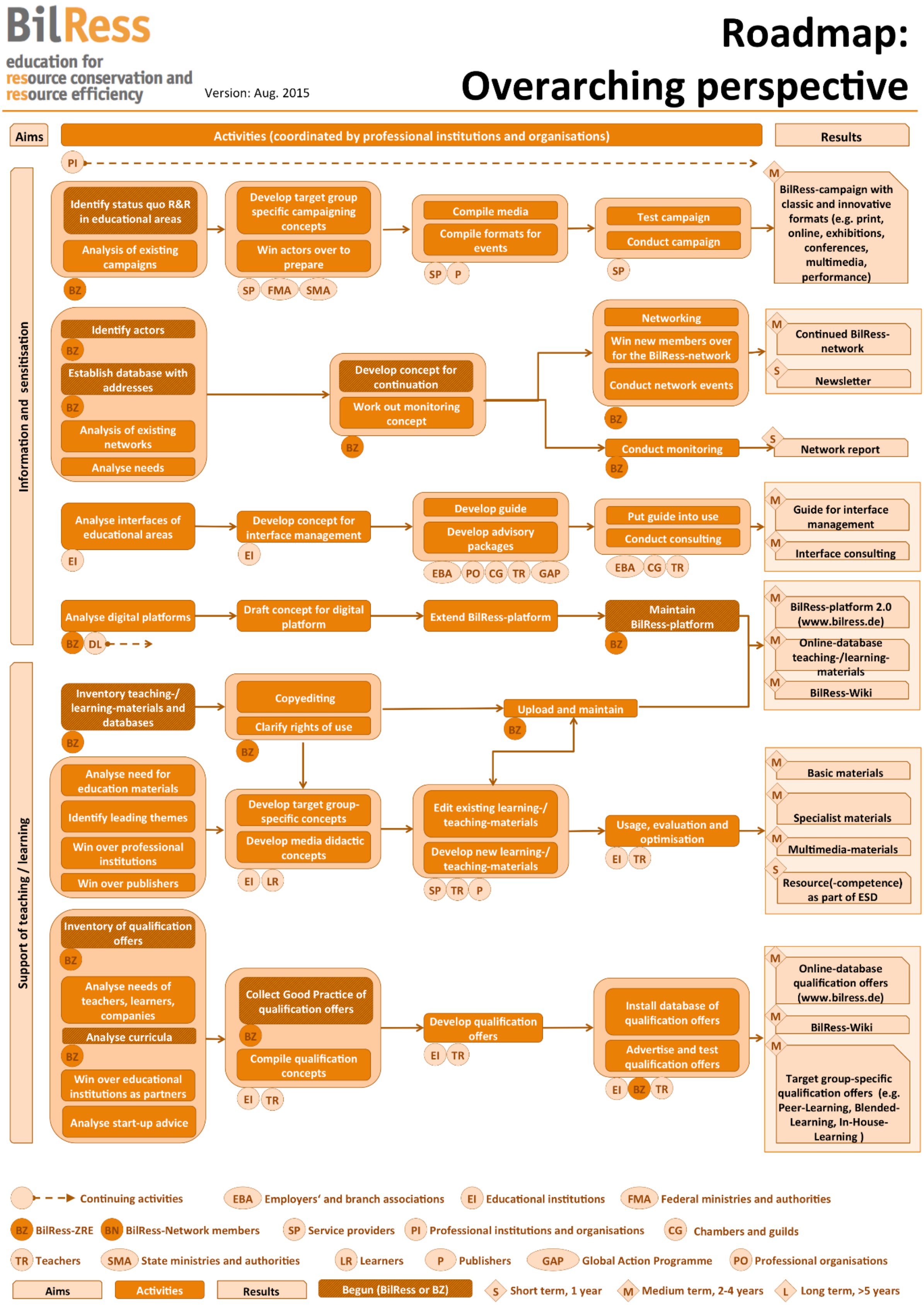
The foundation of general school education is laid by curricula, which are enacted by the German federal states individually. Meanwhile, however, Education for Sustainable Development (ESD) has reached almost all curricula, types of schools and grades nationwide. Furthermore, the update of the orienting framework for the learning area of global development (BMZ 2015) draws back on several aspects of sustainable development for lessons. The understanding behind the word ’resources’ however is primarily connected to energetic use (fossil resources) and environmental media (air, soil, water) in the teaching materials. Resource conservation and efficiency are seldom or not at all named directly in school curricula. Consequently, this topic is also not mentioned in school books. With sustainability being anchored in curricula, however the foundation for a resource education is laid. Teachers just will have to be animated to make material resource use a topic in lessons more often through a range of supporting tools. The following figure shows an example, taken from BilRess-Wiki, of a project which aims at resource preservation and efficiency as a topic for 6th to 8th grade school education.

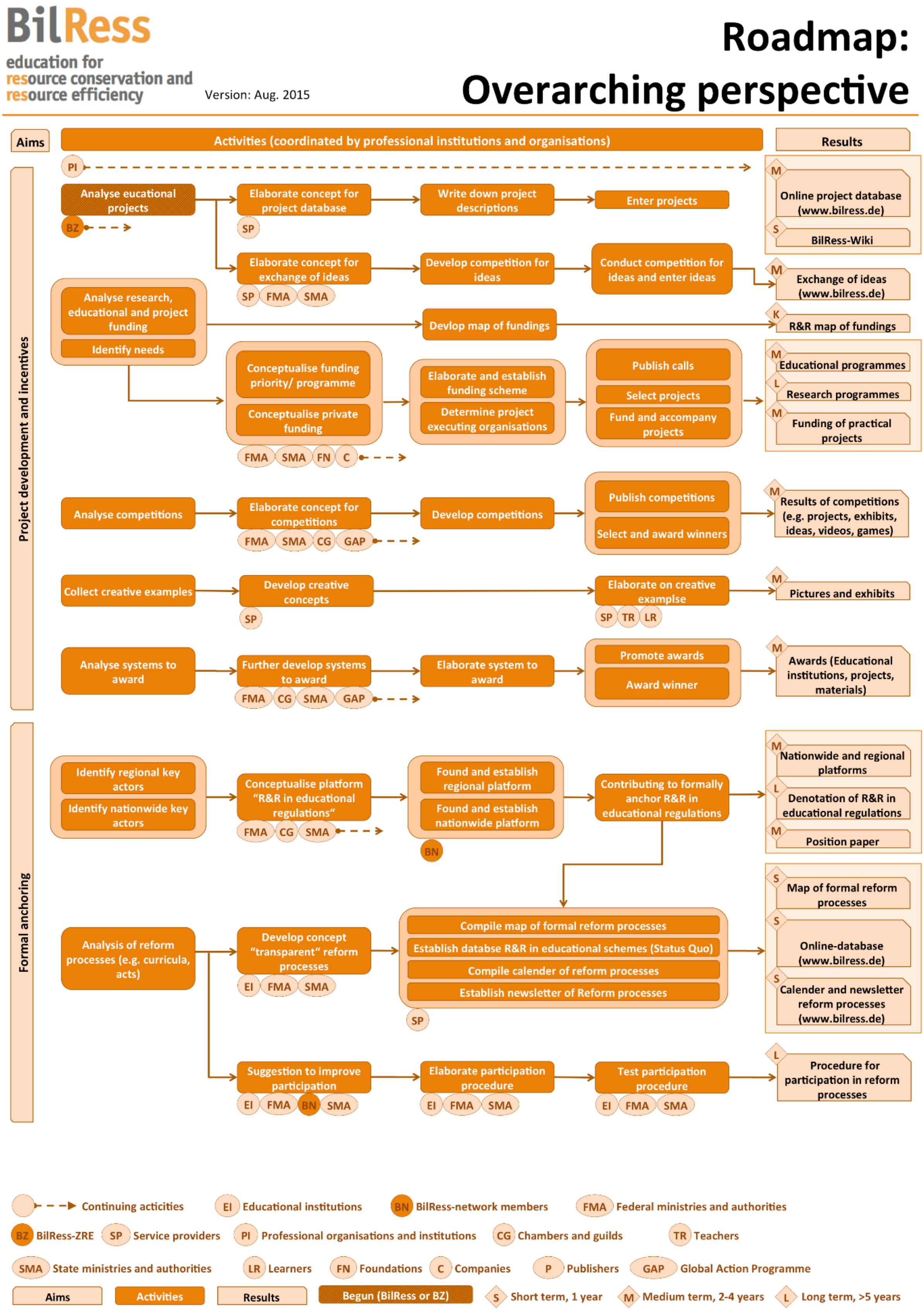
The BilRess-roadmap: overarching perspective over the different areas of education

As the resource efficiency programme is still young so is education for resource conservation and efficiency: it is only at the beginning. In all areas of education starting points can be found in the form of pilot projects. Some education materials can be found as well as websites which integrate the topic or present very subject-specific examples. To systematically promote education for resource conservation and efficiency activities so far need to be extended and stabilised much more (Baedeker et al. 2014).

The status quo analysis in the four areas of education (see section 1) provided specific results for each of these areas, which were graphically translated into roadmaps and discussed with experts and adjusted accordingly, e.g. at the second BilRess-network conference in March 2015 in Frankfurt/Main, Germany.

The several common aspects which could be identified in terms of barriers and needs for action formed the basis to elaborate on a roadmap in an overarching perspective. A first draft of results was discussed in depth in the course of an expert workshop and possible ways of solutions to anchor education for resource conservation and efficiency were developed. Through intensive dialogue within the project team, the roadmaps specific to an educational area and the overarching roadmap were advanced and mutually adjusted. The following figures present the overarching roadmap.


BilRess
education for
resource conservation and
resource efficiency
Version: Aug. 2015
Roadmap:
Overarching perspective
Aims
Activities (coordinated by professional institutions and organisations)
Results
Information and sensitisation
Support of teaching / learning
PI
Identify status quo R&R in educational areas
Analysis of existing campaigns
BZ
Develop target group specific campaigning concepts
Win actors over to prepare
SP
FMA
SMA
Compile media
Compile formats for events
SP
P
Test campaign
Conduct campaign
SP
M
BilRess-campaign with classic and innovative formats (e.g. print, online, exhibitions, conferences, multimedia, performance)
Identify actors
BZ
Establish database with addresses
BZ
Analysis of existing networks
Analyse needs
Develop concept for continuation
Work out monitoring concept
BZ
Networking
Win new members over for the BilRess-network
Conduct network events
BZ
M
Continued BilRess-network
S
Newsletter
Conduct monitoring
BZ
S
Network report
Analyse interfaces of educational areas
EI
Develop concept for interface management
EI
Develop guide
Develop advisory packages
EBA
PO
CG
TR
GAP
Put guide into use
Conduct consulting
EBA
CG
TR
M
Guide for interface management
M
Interface consulting
Analyse digital platforms
BZ
DL
Draft concept for digital platform
Extend BilRess-platform
Maintain BilRess-platform
BZ
M
BilRess-platform 2.0 (www.bilress.de)
M
Online-database teaching-/learning-materials
M
BilRess-Wiki
Inventory teaching-/learning-materials and databases
BZ
Copyediting
Clarify rights of use
BZ
Upload and maintain
BZ
Analyse need for education materials
Identify leading themes
Win over professional institutions
Win over publishers
Develop target group-specific concepts
Develop media didactic concepts
EI
LR
Edit existing learning-/teaching-materials
Develop new learning-/teaching-materials
SP
TR
P
Usage, evaluation and optimisation
EI
TR
M
Basic materials
M
Specialist materials
M
Multimedia-materials
S
Resource(-competence) as part of ESD
Inventory of qualification offers
BZ
Analyse needs of teachers, learners, companies
Analyse curricula
BZ
Win over educational institutions as partners
Analyse start-up advice
Collect Good Practice of qualification offers
BZ
Compile qualification concepts
EI
TR
Develop qualification offers
EI
TR
Install database of qualification offers
Advertise and test qualification offers
EI
BZ
TR
M
Online-database qualification offers (www.bilress.de)
M
BilRess-Wiki
M
Target group-specific qualification offers (e.g. Peer-Learning, Blended-Learning, In-House-Learning)
Continuing activities
EBA Employers' and branch associations
EI Educational institutions
FMA Federal ministries and authorities
BZ BilRess-ZRE
BN BilRess-Network members
SP Service providers
PI Professional institutions and organisations
CG Chambers and guilds
TR Teachers
SMA State ministries and authorities
LR Learners
P Publishers
GAP Global Action Programme
PO Professional organisations
Aims
Activities
Results
Begun (BilRess or BZ)
S Short term, 1 year
M Medium term, 2-4 years
L Long term, >5 years



In the following we conclude key results from the roadmap process and present some suggested next steps from this roadmap in greater detail.

Conclusions: key roadmap results showing further steps (Baedeker et. al. 2016a, 2016b)

Establish BilRess-competence center in existing structures: Without coordination and continous promotion resource education and thus increased resource competence will remain in marginal existence. A competence centre can help to break through by conducting and coordinating different activities like organisation of information campaigns, network actors or initiating projects for resource education.

BilRess-campaign: Both society wide as well as specifically for educational areas there is a lack of consciousness and knowledge about the relevance of the topics of resource conservation and resource efficiency. A public campaign, which comprises ample target group specific information materials and types of events, is key to sensitisation for the topic. Only through broad public discourse and addressing multipliers the topic will permanently be on the agenda of educational actors, institutions, social partners and politics and will create incentives to broadly anchor resource education.

Promote networking: For continuous resource education networking of key actors is very important, which should be promoted at different levels from local to national, as well as both specific for branches and overarching. Actors need a forum to exchange their activities and experiences, new members might be sensitised for the topic and become multipliers themselves. Status of networking should regularly be reported. The continuation and further development of the BilRess-network is made possible by the integration into the "Competence Center Resource Efficiency 2015-2019" fostered/funded by the BMUB under the coordination of the VDI Center for Resource Efficiency (ZRE). This is considered as an important success and it supports a continuity-oriented resource education.

Interface management: So far a “strategy“ for resource education is missing since the topic is only marginally established in the educational areas. For an integration in all areas concertation is required, e.g. on how this can be conducted in apprenticeship between vocational schools, learning environments between firms and enterprises. For such an interface management learning goals need to be explicated and how these can be concerted between educational areas.

BilRess-Platform 2.0: Specific platforms can be used for information, communication and networking. As resource education is a specific topic, it can be offered on a specific platform BilRess 2.0, indicating that users can communicate with each other. The platform should be linked to others like search engines for vocational trainings or highly frequented platforms for teaching-/learning- materials. The platform BilRess 2.0 should contain all materials as well as a calendar on activities of educational policy or events of relevance for resource education.

Developing teaching-/learning- materials: many educational actors would use the resource topic if materials and units or seminars simply to use were available that can directly be integrated into existing educational work. These materials should on the one hand offer the possibility to broadly use them to increase awareness and show opportunities for action (basic materials). Specialist materials should be used additionally in order to show the concrete links to different professions. Teachers furthermore are interested in multimedia and high quality materials for conducting lessons (multimedia materials).

Offer qualifications: These should be directed towards teachers (multipliers) so they can increase their resource competence and integrate it into conveying knowledge in their educational area. Offers should be tailored to the respective need for knowledge and reach from easily assessable topics for general education to specialist topics to deepen knowledge. An important element is on-site advice in schools, vocational schools, higher education institutions, organisations offering vocational trainings, companies and different bodies. These can trigger processes which affect the direct environment of multipliers and thus lay the ground for resource related projects.

Conduct and promote resource projects: Many educational areas offer open spaces for individual project work. This can be promoted by specific incentives. Resource related projects are possible to conduct e.g. in schools or vocational schools in „project weeks" or excursions. Universities and colleges can conduct resource related projects in seminars or student seminar papers. Project promotion in the form of educational programmes, research programmes of practical projects (e.g. in companies) resource education can considerably be extended.

Competitions and Awards: Both types of incentives have proven relevant in education. Competitions can be conducted in the form of awarding a „best project" or acknowledgement of accomplished or planned activities. Since there is a high effort for announcement, such competitions should at least be conducted continuously in medium term. Awards are especially appreciated by institutions. Several examples exist for the are of schools (e.g. awards for schools active in climate protection or in the course of the German ESD-Decade) which however are mostly related to energy or waste. The development of a „resource-scout-system" in relation to the established „energy-scout" also seems promising.

Integrating R&R into formal educational regulations: The key to an encompassing resource education are regulations, syllabi and curricula. When natural resource are anchored in these or only mentioned explicitly as part of ESD according teaching-/learning- materials will be developed and used in lessons. However this change process is very demanding, which is why the topic of resources should best be integrated into current ongoing reform processes. In school education it can be linked to ESD if it is made sufficiently explicit that natural resources are part of resource education. In vocational education the topic can be anchored along the topic of environmental protection in companies.

45. DIRECT AND INDIRECT USES OF URBAN FOREST RESOURCES: CASE IN NAGOYA CITY, JAPAN

Kiichiro Hayashi ✉

Abstract

Urban forest has an important role in a city. Also citizen utilizes urban forest resources directly and indirectly in many ways. In this study, the direct and indirect uses of forest resources were studied based on a simple multipoint on-site field survey to grasp the role of urban forest for human society as a case in Nagoya City, Japan. The survey topics include not only ecological research items but also cultural aspects of citizen's use of urban forest. As a result, deciduous broadleaf forest was dominant followed by evergreen broadleaf forest in Nagoya forest area. Per hectare carbon stock was high especially in some of historical shrines. Some cultural ESs had frequently used in Nagoya City.

Keywords: urban forest, forest use, ecosystem service, cultural ecosystem service

Introduction

Urban forest has an important role in a city. Also citizen utilizes urban forest resources directly and indirectly in many ways. For example, citizen's visits to urban park for recreational purposes mean that they utilize it directly. On the other, people can get benefits from urban forest such as carbon stock, air regulation services indirectly. These services are called ecosystem services (Millennium Ecosystem Assessment, 2005). The loss of forest area means the loss of the direct and indirect uses of forest. Nagoya City, Japan is one of the cities facing this issue, which has over 2 million in population. According to Nagoya City (2015b), the green coverage ratio of the city has been decreasing because of the expansion of urban area by development activities. For example, the green coverage, including forest, grassland, agricultural land and water area in Nagoya City, was decreased from 29.8% in 1990 to 22.0% in 2015 (Nagoya City, 2015b). The loss of green area is one of the serious issues in the city.

In this study, the direct and indirect uses of forest resources were studied based on a simple on-site field survey to grasp the role of urban forest for human society as a case in Nagoya City. The survey topics include not only ecological research items but also cultural aspects of citizen's use of urban forests.

Method and Results

Method

By an ecological filed survey, detailed results could be obtained for limited number of forests. Also by GIS (Geographical Information System), the wide coverage of forest can be analysed but it was difficult to study the quality of each forest, and the citizen's use of forest by, for example, recreational purposes. To overcome those issues, a simple multipoint on-site filed survey was selected for this study combining with GIS analysis. The simple field survey method similar to Yonekura et al. (2014) was employed for this study.

According to the Nagoya green coverage GIS data (Nagoya City, 2010), there were approximately 240 forests (≥ 1 ha) in the city. In this study, a forest was defined as a continuous tree crown area which has ≥ 1 ha size. Among them, around 171 forests were surveyed for a 100-m2 and/or 400-m2 (Table 45-1) from 2013 to 2015. For the carbon stock survey, the diameter of breast height (DBH≧5cm) and the height of trees were measured to calculate above ground biomass in each 100-m2 site (also 300-m3 site surveys are now on going) based on the equation of Tadaki et al. (2004). For underground biomass the quarter of the above ground biomass was added same as like Tadaki et al. (2004). Carbon content of the biomass was used 50% in this case. The statistical analysis was conducted using Excel ver. 2010 (Microsoft corp.), SPSS statistics ver.22 (IBM corp.). The ArcGIS 10.2.2 (ESRI Japan Inc.) was used for the spatial analysis.

	In 100-m² area	**In 400-m² area**	**Entire forest area**	**Outside of forest**
Basic survey items	Longitude, Latitude, Elevation, Slope, Topography, Temperature+, Relative humidity, Whole-sky photography++, etc.			Temperature, Relative humidity
Biomass surveys	Tree species, Tree height, DBH Crown area of each tree, Vegetation cover (tall trees, medium trees, short trees, very short trees, etc.), Recruitment (seedling growth) Mass of dead wood, etc.	Number of large trees (DBH ≧ 40 cm) and Number of oak trees (e.g., *Quercus serrata, Quercus variabilis, Quercus glauca, and Quercus myrsinifolia*)	Number of large trees (DBH ≧ 80 cm)	
Cultural aspects of citizen' use			Aesthetic value, Recreation, etc.	
Habitat survey	Human intervention, Human accessibility, Human and vehicular traffic, etc.			
Other	Non-native species, Number of hollow trees Soil survey(Water content+++, Soil hardness++++, Surface soil and litter thickness, etc.)	Number of gingko trees (*Ginkgo biloba*)		

+: illumination meter (LM-8000, MK Scientific, Inc., Japan); ++: fish-eye lens(IDF-3, Izawaopt, Japan);
+++:soil water content meter (ProCheck, Decagon Devices Inc., U.S.A.);
++++: soil hardness meter (Daiki Rika Kogyo Co., Ltd., Japan); DBH means Diameter at Breast Height.

Table 45-1: *Simple multipoint on-site field survey. Source: Hayashi and Ooba (2015) revised.*

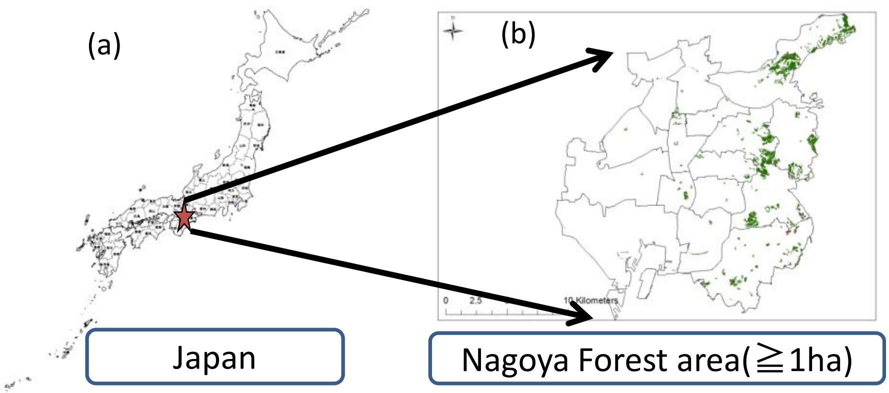


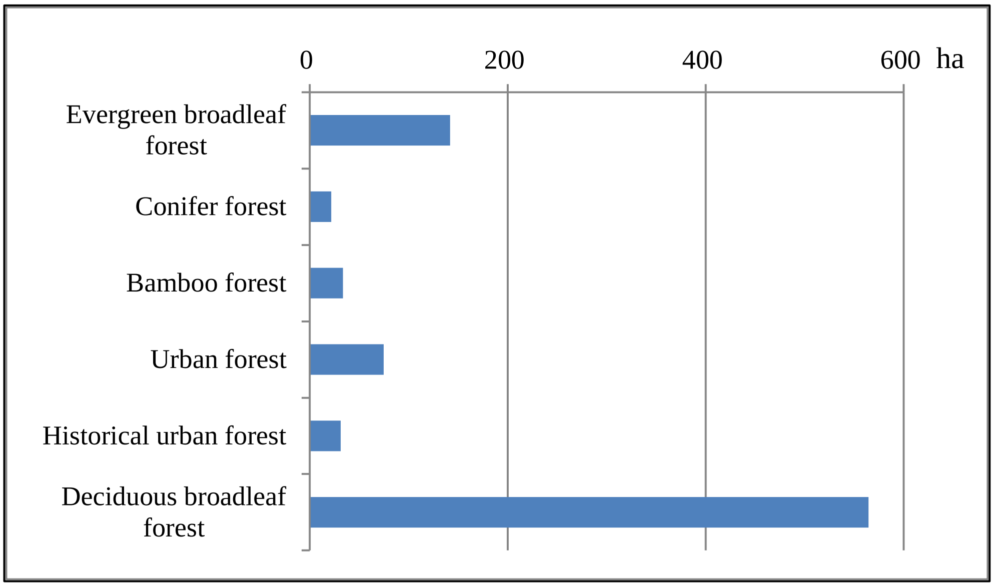
Figure 45-1: *Maps of the study area, (a) Japan with Nagoya City in the star symbol, (b) Forest area in Nagoya City. Source: (b) Forest area in green colour by Nagoya green coverage GIS data (Nagoya City, 2010).*

For cultural aspects of forest use, a subjective assessment by the author was conducted based on the facility and equipment for citizen's use (e.g. walking trail) in each forest.

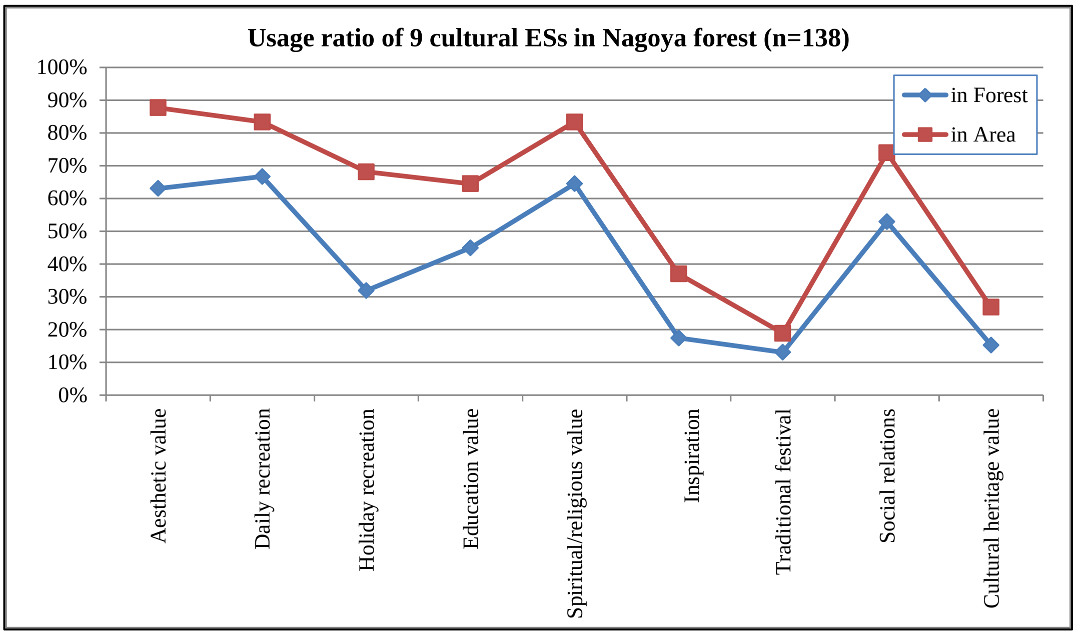
Nagoya City is located in Aichi Prefecture (Figure 45-1), and the city hall is located at 35.181°N, 136.906°E. The average annual temperature for the city in 2014 was 16.1°C and the average precipitation was 1505.5 mm (Japan Meteorological Agency, 2015). The area of the city is approximately 326.4 km^2 and the population was 2.27 million as of April 1, 2014, making Nagoya City the third largest city in Japan (Nagoya City, 2015a).

Results

Deciduous broadleaf forest is dominant followed by evergreen broadleaf forest in the city (Figure 45-2 (a)). Per hectare carbon stock is high especially in historical shrines. Some of cultural ESs, such as, aesthetic value, daily recreation, spiritual/ religious value and social relations had relatively high percentage of usage in Nagoya City (Figure 45-2 (b)). In the future, forest should be categorized based on urban forest resources and then the conservation and/or management policy should be considered for each category. The remaining forest surveys are still on going.



(a)



(b)

Figure 45-2: *(a) Total area by type of forest in Nagoya City (n=171) and (b) Usage ratio by each nine cultural ES in Nagoya forest. Note: These were calculated based on the survey data until 2015.*

Conclusions

The direct and indirect uses of forest resources were studied based on a simple multipoint on-site field survey by utilizing ecological research items and cultural aspects of citizen's use of urban forest. Deciduous broadleaf forest is dominant followed by evergreen broadleaf forest in total area. Per hectare carbon stock is high especially in historical shrines. Some of cultural ESs had highly used in Nagoya City.

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Part V

Contributions and Views of Private Organizations

46. INFRASTRUCTURE – A CRUCIAL KEY FOR RESOURCE EFFICIENCY, SUSTAINABILITY AND RESILIENCE

Hans-Peter Egler ✉, Raul Frazao, Silvio Leonardi

Abstract

Due to its significant contribution to socioeconomic development, its huge environmental impacts and its key role in a functioning economy, adequate infrastructure development is vital for our sustainable future. The way infrastructure such as roads, sewage systems, power plants and hospitals are developed is central to tackling today's most pressing challenges: improving resource efficiency; advancing sustainability; and improving society's resilience against stresses.

However, several obstacles hamper their adequate implementation: the low level of know-how regarding environmental, social and governance (ESG) requirements; the weak capacities of project sponsors, designers and developers; the lack of well-structured, bankable projects; and the lack of a standardised approach.

To overcome these obstacles, Global Infrastructure Basel (GIB), a Swiss not-for-profit foundation, envisions through its activities a world where sustainable and resilient infrastructure is the norm rather than the exception. To achieve this vision, GIB launched SuRe® - The Standard for Sustainable and Resilient Infrastructure - at COP21 in Paris. Applying this certification standard will allow procuring authorities, investors and project developers to include state-of-the-art sustainable and resilient criteria into their project. The first field-test has provided important insights into the potential of sustainable and resilient infrastructure, and revealed further improvements regarding the development of the standard.

GIB has also started a global capacity building initiative to enhance the capacity of the public sector, financiers and project developers. In this regard, GIB focuses in particular on the role to the public sector due to its potential to positively influence the process at large. Developing the capacities sets the right impulses to overcome the obstacles to sustainable and resilient infrastructure. With the envisaged common understanding between key stakeholders, infrastructure can be planned, built and operated whilst also respecting the planetary boundaries.

Keywords: infrastructure, sustainability, resilience, resource efficiency, sustainable and resilient infrastructure, green infrastructure; Sustainable Development Goals, Sustainable Development Goals.

The importance of infrastructure

Infrastructure such as roads, bridges, tunnels, water supply systems, sewers, electrical grids and telecommunications are essential ingredients for the development of our societies. Research has shown that well-designed infrastructure projects have long-term economic benefits by increasing economic growth, productivity and land values, while also providing significant positive spill over effects. Standard & Poor's (2015) evaluated that an increase in infrastructure spending equivalent to 1.0% of gross domestic product (GDP) has a multiplier effect of between 1.0 and 2.5% over a three-year period. Moreover, infrastructure inherently impact on and interact with our environment and the natural processes that occur within it (Pollalis and Schodek 2012) and thus leads to large environmental burdens.

Why sustainability and resilience are key for infrastructure

Depending on the choice of infrastructure and how it is planned, constructed, operated and maintained, infrastructure can have positive and/or negative impacts on our environment, in addition to its effects on society and the economy. Due to its long lifespan, infrastructure result in lasting impacts during operation and beyond. Therefore, building the thousands of fossil-fuel power stations that are currently planned throughout the world will have negative impacts and consequences over the next 30-50 years at the very least. Not to mention the bounded capital, which is committed to a service that makes the achievement of the two-degree target impossible.

Infrastructure is equally vulnerable to a range of shocks and stresses, including natural hazards like earthquakes, storms and sea level rise, but also man-made changes like economic transformation and rapid urbanisation. Such shocks and stresses have the potential to weaken infrastructure and possibly threaten its very functioning and critical service provision. This in turn is likely to lead to the reversal of previous socio-economic development gains. The resilience of infrastructure, an often-underestimated factor, is key for its ability to adapt to these types of changing conditions and withstand shocks and stresses while still providing essential services and functions to society, the economy and the environment.

Infrastructure which does not embed sustainability and resilience criteria could result in devastating impacts on our environment and may open a Pandora's box of sustainability issues: destruction and degradation of natural habitats, loss of biodiversity, poaching, illegal mining, wildfires and land speculations (Laurance et al., 2015), as well as threatened health and safety of both employees and affected society.

Outlining the problems

Rising infrastructure needs

Increased urbanisation, population growth and economic growth are the main drivers for the rising infrastructure needs. Cities, their development and thus their infrastructure play a central role in this regard. The OECD estimates that global investment needs will be US$57 trillion till 2030, while the New Climate Economy (NCE) estimates the need to be approximately US$90 trillion for the same period (NCE, 2014). The infrastructure needs in Latin America are estimated to be US$320 billion a year or, in other words, 6.2% of the regional GDP (Perrotti and Sánchez, 2011).

The investment gap

Governments have historically funded infrastructure. They are unlikely to continue to do so and fund the required infrastructure developments given rising budgetary deficits and significant levels of debt. According to the B20, the global infrastructure investment gap will amount to US$15-20 trillion between 2015 and 2030 – equivalent to US$1.0-1.33 trillion a year. Indeed, public infrastructure investment in Latin America has dropped significantly from an average of 3% in the 1980s to an average of 1% in the 1990s, and slightly increased to 1.6% of GDP in the last decade (FAL Bulletin 2014). At the same time, private investment increased, but not to the point of compensating for reduced public spending. Thus, an infrastructure-financing gap is currently widening at a rapid pace throughout Latin America and the Caribbean. An appropriate and timely response to rising infrastructure development and financing needs will be a key success factor to the region's linkages with the world economy and may – if adequate infrastructure is chosen – lead to improved resource efficiency, cost savings and sound economic returns, while reducing risks and negative externalities and increasing the overall quality of life.

Lack of know-how

Low capacity to identify and prepare infrastructure projects is widely regarded as the key limitation factor at the local level. This is mainly because developing complex infrastructure projects requires expert knowledge and interactions between projects developers and other key stakeholders like the public sector and financial institutions. Adding resilience and sustainability criteria into such endeavours does not simplify the development process. Since the earliest definition of "sustainability" in the Brundtland Report of 1987, definitions have varied widely. The range of ambiguous definitions of sustainability has increased the difficulty to systematically assess sustainability and its achievement within a project, which leads us to the key question: *What do sustainability and resilience mean in the context of infrastructure?*

Lack of project pipelines

A major reason for the mismatch between the demand and supply of infrastructure finance is the lack of investable projects in the pipeline. Beside projects' financial viability, there is a political component to this issue whereby a predictable pipeline of well-structured projects often does not exist due to the lack of know-how, governmental commitment and frameworks, which in turn further hampers infrastructure development. Thus, facilitating project development and binding regional commitments to long-term infrastructure development plans are necessary to stabilise project pipelines beyond political cycles.

Delivering solutions

After defining the importance and the problems facing sustainable and resilient infrastructure development, the main question shifts to how sustainability and resilience criteria can be implemented, measured and evaluated in infrastructure projects. Having a clear overview of these aspects is invariably a key component of any attempt to improve the quality of infrastructure projects and maximise their benefits while minimising adverse effects.

SuRe® – The Standard for Sustainable and Resilient Infrastructure

Both the long lifespan of infrastructure, often across several decades, and the fact that approximately 75% of the infrastructure that will be in place in 2050 does not exist today (Wiener, 2014) represents a huge opportunity. Getting such scale of infrastructure development right will be critical to whether or not the world locks into a high- or low- carbon growth path. With the development of SuRe® – The Standard for Sustainable and Resilient Infrastructure the Global Infrastructure Basel Foundation (GIB) wants to support such developments in a way that meets the needs of present and future generation. SuRe® is a global voluntary standard which helps to integrate state-of-the-art sustainability and resilience aspects into infrastructure development and upgrade. SuRe® consists of 76 criteria divided into 14 themes spanning environmental, social and governance (ESG) aspects and relies on the independent verification and certification of infrastructure projects. SuRe® aims to drive the integration of sustainability and resilient aspects into infrastructure through:

- establishing a common language and understanding of sustainable and resilient infrastructure projects between project developers, financiers, local authorities and end-users;
- providing guidance on how to manage sustainability and resilience aspects of infrastructure projects, both from a risk management and a benefit creation perspective, and starting from as early as possible in the projects' life cycles.

SuRe® is fundamentally different from other standards because of the multistakeholder process that drives its development. The SuRe® Standard engages important players from the infrastructure and construction industry, financial services, the public sector as well as civil society and academia from all around the world (including Latin America).

Applying SuRe®

SuRe® provides general benefits in terms of advancing sustainability and resilience best practice in infrastructure. It is user-friendly and facilitates the clear communication of a project's tangible contribution to addressing some of the contemporary macro-challenges society faces while enabling project comparability. SuRe® also provides a tool that is compatible with international guidelines and safeguards used by international financial institutions (including Multilateral Development Banks (MDBs)). Different levels of certification are awarded depending on the score achieved across all 76 criteria. The SuRe® certification is open to infrastructure projects globally and across different types of infrastructure, including both greenfield and brownfield projects. The certification is based on an independent audit and verification carried out by accredited third parties.

Lessons learned

A preliminary version of the SuRe® Standard was used to evaluate its suitability and applicability with regard to validation and verification of infrastructure projects. Three different projects, all of which had previously successfully registered with the United Nations Framework Convention on Climate Change (UNFCCC) and had been audited on-site as part of that registration process, were used for this purpose: 1) “Bus rapid transport system Bogotá, TransMilenio Phase II to IV” in Colombia (CDM-project 0672) 2) “DAKFOCAM” wastewater project in Vietnam – Methane recovery and biogas utilisation (CDM-project 5290) 3) “Activité de déshydratationde luzerne et de pulpe de betterave” in France – Energy efficient dehydration of agricultural products (JI-project FR1000215).

This first SuRe® desk assessment, carried out by an independent third party auditor, led to a set of major findings concerning the suitability and applicability of the SuRe® Standard as well as its usability and accuracy – all of which were taken into account in the further development of the standard:

- Scope of the standard: both management system and project-specific issues need to be addressed;
- Eligibility criteria: project eligibility criteria need to be defined e.g. notably in relation to minimum scale and documents required;

- Project boundaries: responsibilities and sphere of influence of the project regarding the area, the fully owned, controlled or equity shared operations as well as up- and down-stream impacts need to be defined;
- Sufficient data provided by the infrastructure project: need for coherent templates as well as relevant project design documents and monitoring reports to support independent auditing processes;
- Quality, extent and details of project information: a distinction between limited and reasonable level of assurance (to be provided) could be introduced;
- Project/location specific materiality: different projects at different locations may face incomparable threats and opportunities, i.e. the project-specific material issues need not only to be elaborated by the project proponent but to be taken into consideration by the evaluator, too;
- Project phases (design, construction, operation): different approaches may be needed to evaluate a project's performance at different stages and that might have implications for the type of certification.
- Modalities of communication between project components and GIB: need for clear and traceable guidance;
- Transparency regarding project information and performance against the standard: this is crucial for the credibility of the standard; therefore, public disclosure requirements need to be defined.
- Beneficial impacts: once the assessment criteria have been assigned to different impact areas (i.e. water, air, soil, biodiversity, social responsibility, etc.), the assessment results may reveal rated impacts on these areas.

Tools for capacity building

GIB offers a range of capacity building services such as workshops, presentations or longer-term capacity building packages to enable infrastructure developers, financiers and public sector actors to develop the skills and knowledge necessary to create sustainable and resilient infrastructure. Capacity building services are directly based on the principles of the SuRe® Standard and aim to generate a consistent and coherent understanding of what sustainability and resilience mean for infrastructure and how they can be implemented in the planning, design, procurement, construction and operation of infrastructure assets. GIB focuses its capacity building activities to the public sector due to the potential to positively shape the infrastructure development process at large by e.g. properly planning infrastructure development, improving project selection and optimising fund allocation, and designing adequate procurement processes.

Mobilising investors for sustainable infrastructure

Infrastructure investments possibly offer stable and predictable returns over the long term, returns that are resilient to variations in the economic cycle and potentially offer protection against inflation and possess a relatively low correlation to other asset classes. However, the complex nature of infrastructure investments and their long lifespan also entails specific challenges e.g. for cash flow calculations due to:

- Funding streams: The sources of revenue, such as taxation revenues or user charges, collected often over years to repay for the cost of infrastructure development - are not always clearly identified or capitalised upon;
- Changing prices of factors of production and consumer needs: Financial planning must take into consideration a multitude of scenarios respecting different level of prices. The scenarios also need to anticipate regulatory changes that may affect prices e.g. new taxations such as social security taxes or carbon taxes. Analysis of price elasticity of supply (PES) is required to know project's break-even point;
- Difficulties in net present value calculation: In developing countries different discounting factors require different time periods. The valuation approaches typically base on long-time continuous development, clarity as well as stability of risks – both assumptions are questionable in developing countries.

In light of the required scale up of investments, the interplay of various measurements is required to create the right conditions for infrastructure development and to attract more private-sector investments. A critical first step is required to strengthen and enable consistent policy frameworks, including on public procurement, to improve infrastructure development in general. Second, it is necessary to focus on improving project quality through the implementation of sustainability and resilience aspects. Applying SuRe® and using GIB's capacity building services can therefore play a vital role in helping project sponsors and developers to implement and measure sustainability and resilience aspects; communicate sustainability and resilience benefits; boost project quality and support the development of a pipeline of bankable projects. The quality of sustainable and resilient infrastructure is likely to be better on the grounds of less delays or showstoppers to construction and operation, the implementation of appropriate measures to mitigate environmental and social risks, possibly lower operating costs; as well as the generation of further tangible benefits for the environment, society and the economy.

Conclusion

Given the pivotal role of infrastructure for the economy, society and the environment, the development of sustainable and resilient infrastructure is essential to achieving the United Nations Sustainable Development Goals (SDGs) and supporting a shared sustainable future. SuRe®'s independent third-party certification and GIB's associated capacity building programme pave the way towards building infrastructure which not only delivers efficient and needed services but also in a way which helps towards tackling the world's largest sustainability challenges stemming from population growth, rapid urbanisation, social inequalities, excessive use of finite resources and carbon-intensive lifestyles.

47. THE GOOD GROWTH PLAN FARM NETWORK – MONITORING RESOURCE EFFICIENCY OF CROP PRODUCTION SYSTEMS

Elisabeth Fischer ⌧, Juan Gonzalez-Valerob, An Segersc

Abstract

The FAO estimates that food supplies need to increase by 70% to feed a growing population of 9 billion people by 2050. The changes in agricultural practices required to grow more tend to exert higher demand on resources and put eco-system services at risk of degradation. Syngenta, a global company selling agrochemicals and seeds, invests in research and development of agricultural innovations that help farmers produce more with less. In 2013, Syngenta launched The Good Growth Plan and set global targets to be met by 2020 with regard to resource efficiency and other indicators. A global monitoring and evaluation system was set up to track progress on these targets. To measure improvements of farm resource efficiency, a global network of over 3500 farms in 41 countries was established. The network covers 23 different crops in different market segments, including smallholder farms in developing countries. The sample includes reference and benchmark farms. While reference farms are real customers selected by Syngenta, benchmark farms were randomly selected within the same market segments. In 2014, the baseline farm surveys were carried out by Market Probe, an independent agricultural market research company. Data on resource efficiency will be collected annually until 2020. With more years of data available, panel techniques and time series analysis will be used to assess trends and determinants of resource efficiency.

Keywords: agriculture, crop productivity, resource efficiency, total factor productivity growth

Introduction

The global challenge of food security

In the year 2050, the world's farmers will have to sustainably produce more food to feed a larger, more urbanized and prosperous population of 9.6 billion people. Resource degradation, climate change and recent decreases in yield growth of major crops and rises in international food prices have led to renewed concerns over agriculture's ability to meet this global challenge.[43]

Conflicting public opinions exist about how to best address this challenge and the role of the private sector is not recognized. The Agricultural Disconnect, a 2013 survey conducted by Syngenta to investigate people's perceptions on food security, revealed sharply divided views.[44] Acknowledging the urgency of food security, farming is not perceived to be conducted responsibly today. Respondent's openness towards leveraging improved technology excludes innovations in crop protection, fertilizers and genetically modified seeds. Survey respondents endorse using more land, water, and labor to grow more food, but at the same time wish to preserve biodiversity and watersheds and improve rural livelihoods through increased

[43] FAO (2015)

[44] Syngenta (2013)

incomes. The results reveal that agricultural systems are complex and that inherent trade-offs are not well understood.

Strategies to increase agricultural production are better understood in the scientific debate. Agricultural production can be raised through a) expansion - converting arable land into farm land to plant more crops; b) intensification – intensifying the use of inputs, such as irrigation, fertilizer and pesticides, which leads to increases in crop output per hectare; and c) efficiency - adopting more efficient technologies, such as improved seeds, modern inputs and improved cultivation practices, which leads to increases in total factor productivity (TFP).

Looking at trends and drivers, methods, and available data, Fuglie et al. (2012) present a comprehensive assessment of productivity growth in agriculture since 1961. Measured globally, efficiency-led growth has overtaken input intensification as the main source of growth. Over the past five decades, global agricultural output grew on average by 2.24 percent per year.[45] From 1960 to 1990, input intensification has been the main driver of agricultural output growth. Since then, productivity increases have been largely achieved through technological and institutional improvements that use agricultural inputs and resources more efficiently. At the same time, the rate of growth in input intensification and resource expansion declined. For example, the availability and adoption of GM soybean, maize and cotton lead to a 37% decline in chemical pesticide use while yields increased by 22%, translating into an increase in farmer profits by 68%, as found in a recent meta-study funded by the German government and the European Union.[46] But despite these successes, regional differences in productivity and food insecurity continue to persist. This is particularly apparent in Sub-Saharan Africa, the region with the lowest levels of agricultural productivity and highest rates of food insecurity. Moreover, TFP is estimated to grow insufficiently to meet future estimated food demand by 2050, as findings from the 2014 GAP Report by the Global Harvest Initiative indicate.[47]

To close the gap, there is a call to increase public investment in agricultural research and development (R&D) and extension services.[48] Strong empirical evidence exists regarding the positive impact of such investments on efficiency-led productivity growth.[49] R&D is a major source of more efficient agricultural technology, while extension and advisory services drive its adoption on the farm. As such, agricultural R&D significantly contributed to agricultural development and poverty reduction in developing countries. For example in China, nine people were lifted out of poverty for every 1000 USD spent on agricultural R&D in China, second only to the effect of education.[50]

While there is strong empirical evidence for the contribution of public R&D, there is no systematic and quantitative evidence on the role of private R&D in agriculture for efficiency-

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[45] Fuglie & Rada (2013)

[46] Klümper & Qaim (2014)

[47] Global Harvest Initiative (2014)

[48] FAO (2014)

[49] Fuglie et al (2012)

[50] Fan et al. (2004)

led growth and food security.[51] The rate of growth in public spending on agricultural R&D has fallen since the 1990.[52] At the same time, private spending is gaining importance. The Agricultural Science and Technology Indicators (ASTI) published by IFPRI show that the amount of private spending has increased from 2000 to 2008 by 11% to 8.3 billion USD, increasing the share of private investments to 21% globally.[53] Other sources report even higher rates of 35 to 41%.[54] The trend is driven by several large multinational companies, such as Syngenta, that undertake R&D activities mainly in OECD countries and maintain experiment stations in less developed countries for technology transfer. Syngenta's global R&D expenditure grew by 50% to 1.4 billion USD from 2009 to 2014. While the company operates in 90 countries across the globe and maintains breeding stations locally, its R&D is organized as a global function with investment attributed to global and regional level. Hence, data on private R&D spending at country level is not as comprehensive and accessible as data on public spending.

Population growth, climate change and increased weather variability, decline in biodiversity and soil quality, water scarcity and volatility of food prices present enormous challenges for feeding the world equitably and sustainably. Future productivity improvements need to save a wider set of resources and eco-system services to minimize negative impacts to the environment and should better serve the needs of vulnerable populations.[55] Given the increasing importance of private R&D in agriculture, a better understanding of the private sector's role to raising productivity, agricultural development and food security is required.

Syngenta's commitment to productivity

As a response to rising concerns on the prospects of achieving global food security, Syngenta launched the "Grow More From Less" campaign in 2011.[56] By providing access to agricultural innovation, Syngenta helps to ensure that farmers can produce enough to meet the world's needs for food, fuel and fibre. This however requires a system-wide approach that links technology, land and people, which builds the foundation for a sustainable production system in which empowered rural economies and resource efficiency are fundamental to achieving food security. Syngenta's agricultural innovations have beneficial impacts on water, land, and biodiversity by allowing more efficient and responsible use of these basic natural resources, even in the face of climate change. The company offers a range of products that help plants to better tolerate stress and enable farmers to produce high yields even in unfavourable conditions. The areas for Syngenta's agricultural innovations include:

- Seeds – for example, seed varieties with bred-in pest resistance or improved capacity to deal with environmental stress developed through marker-assisted breeding, biotechnology, hybridization or conventional breeding.

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[51] Fuglie et al. (2012)

[52] Fuglie et al. (2012)

[53] IFPRI (2015)

[54] Pardey & Beddow (2013)

[55] Fuglie et al. (2012)

[56] Syngenta (2011)

- Crop protection – herbicides, fungicides, and insecticides to help farmers reduce crop yield losses from weeds, pests and diseases;
- Crop enhancement – for example, growth regulators for better management against stresses in the form of products that help crops better tolerate abiotic stresses such as drought, reduced nutrients or increasingly irregular weather conditions;
- Seed care – chemical or biological substances that are applied as seed care directly to seeds and seedlings to protect against biotic and abiotic stress;
- Farming practices – data and analytics on weather, soil, field topography developed into integrated and actionable grower advice, such as product recommendations and application instructions

Extension, advisory service and training is key for successful technology transfer to the farm. Farmers must be able to choose the right technology and inputs suitable for their local conditions, and apply them at the right time and in the right way. Syngenta invests into educating farmers to ensure they use agro-chemical products effectively, profitably and safely. In 2014, Syngenta trained 4.7 million people worldwide, of which 74% were smallholders in developing countries.[57]

Moreover, Syngenta has taken deliberate steps to measure the contribution of its technology and solutions to the global challenge of food security. In September 2013, the company announced the Good Growth Plan with six measureable targets to be achieved by 2020 and will report on progress annually.[58] The company committed to increase the average productivity of the world's major crops by 20% without using more inputs or resources. A comprehensive global monitoring system was implemented based on principles of participation, independency, auditability and transparency.

The Good Growth Plan reference farm network

To track progress towards its commitment to increase crop productivity and resource efficiency, Syngenta created a global network of 3600 farms covering 23 crops in 41 countries. It includes farmers of all sizes and all types: from highly professional agricultural companies in the USA, cooperatives in Spain, commercial small-scale farmers in China, and to smallholders in Latin America North. Farm data collection, consolidation, and analysis are conducted independently by Market Probe, a Belgium-based market research institute. These efforts present a unique farm-level data set for crop-specific output- input ratios linked to Syngenta's technology and solutions.

Objective

The main objective is to annually assess progress on the company's commitment to increase crop productivity and resource efficiency, by measuring performance in output-input ratios against set targets on real customer farms for selected crops and market segments relevant for Syngenta's commercial strategy. With that, Syngenta considers a real world situation that takes into account preferences and decisions made by its customer farmers. An improved

[57] Syngenta (2015)

[58] Syngenta (2013)

understanding of what works locally to increase productivity sustainably will help the company improve its solutions that are tailored to the geography and needs of the rural communities. The data contributes to close an important research gap to create a better understanding of the role of the private sector in efficiency-led agricultural productivity growth.

Survey scope and design

The survey is designed as a longitudinal study that involves repeated observations of output-input ratios over 7 years on the same farms. Farms are grouped into clusters, which include similar farm types and represent a specific crop grown in an area with similar agro-ecological conditions. The reporting scope (countries, crops, customer segments) was determined by Syngenta bottom-up at the country level in line with the strategic agenda.

A cluster includes both reference and benchmark farms:

- Reference farms – farms that are managed by farmers with a direct link to Syngenta or value chain partner. They were selected by Syngenta.
- Benchmark farms – farms that are managed by farmers who are independently and randomly selected by Market Probe using defined screening criteria matching the characteristics of the cluster.

Sample design and selection

Sample sizes for each cluster were determined in order to measure significant increases in crop efficiency over time. These were determined by Market Probe based on target productivity increases and assumptions regarding the variation of yields in each cluster. The smaller the expected increase, the larger the sample size needed to measure significant differences over time. Variations within clusters are based on previous research from the countries. Additionally, growers were also organized into clusters as a means of keeping variances under control, as well as distinguish between growers in terms of crop size, region and technological level.

- A minimum sample size of 20 interviews per cluster is needed. The minimum number of reference farms is 5 of 20. The optimal number of reference farms is 10 of 20 (balanced sample).
- For results to be statistically significant when assessed over time, the minimum and optimum sample sizes need to be determined based on target increase and yield variation in each cluster.

Reference farm sign-up was organized through Syngenta's commercial organization in the countries. Reference grower characters were used to describe a cluster-specific profile based on which Market Probe independently and randomly selected comparable benchmark growers to provide a control group within each cluster.

Metrics and measurement

Syngenta measures productivity performance of crop production by relating the crop yield to a set of inputs and resources used in its production. The key performance indicators (KPIs) represent partial measures of agricultural productivity and efficiency:

- Land productivity (tonnes crop output per hectare land)
- Labor efficiency (man hours per kg crop output)

- Nitrogen efficiency (kg of Nitrogen per kg crop output)
- Pesticide application efficiency (number of applications per kg crop output)
- Pesticide efficiency (kg of active ingredients per kg crop output)
- Irrigation water efficiency (liters of irrigation water per kg crop output)
- Energy efficiency (machine hours per kg crop output)

The respective productivity targets were determined at the cluster level. The priorities and potential to increase productivity and efficiency varies between different regions and market segments. Hence, for each cluster a specific target was set for focus KPIs.

The farm questionnaire has been developed jointly by Syngenta and Market Probe. As each crop requires different practices and has different indicators, the final questionnaire was therefore split into crop modules. The master questionnaire was translated into 29 local languages, which were reviewed and approved locally. The questionnaire covers: Farm activities (e.g. crops grown), soil management and safe-use practices, detailed use of chemical fertilizer, pesticide quantity by application and pest pressure, seed variety and seeding rates, labor and machinery hours, irrigation water use, abiotic stresses (such as heavy rain, cold or lack of rainfall), crop yield, harvest time, and post-harvest losses, crop sales and prices.[59]

Data collection and sources

The data were generated by the respondent reference and benchmark farmers who measure and report on their input use and crop outputs over the respective crop season. Data collection started in June 2014 and was completed in January 2015. It took place according to the planting and harvesting times in each cluster. The first section of the questionnaire was administered during the crop season. The second section was administered after the harvest. Per respondent, information for up to two cultivation areas (e.g. plots, fields) is collected. These are defined in the data as growing areas (GA). The farmer interviews were conducted face-to-face in the local language by Market Probe interviewers using structured questionnaires. Respondents were introduced to objectives of The Good Growth Plan and, if necessary, trained on recording input use and crop outputs. The Local help desk support was provided by Market Probe throughout the season in case of questions.

Data quality controls

Market Probe uses SPSS (Statistical Package for the Social Sciences) for data entry, cleaning, analysis, and reporting. After collection, the farm data is entered into a local database, reviewed, and quality-checked by the local Market Probe agency. In case of missing values or inconsistencies, farmers are re-contacted. In some cases, grower data was verified with local experts (e.g. retailers) to ensure data accuracy and validity. After country-level cleaning, the farm-level data is submitted to the global Market Probe headquarters for processing. In case of missing values or inconsistences, the local Market Probe office was re-contacted to clarify and solve issues.

[59] To download the questionnaire, please check:
http://www.syngenta.com/global/corporate/en/GoodGrowthPlanData/Pages/progress.aspx

Measurement and reporting on agricultural productivity within the Good Growth Plan Reference farm network falls within the scope of Syngenta's non-financial reporting, which refers to all non-financial information on quantitative and qualitative information on the company's strategies, policies or activities pursued towards the business, environmental or social goals.[60] The company's non-financial reporting is guided by the Global Reporting Initiative principles and externally assured by the audit company PricewaterhouseCoopers (PwC). Starting in 2014, Syngenta began to raise its non-financial reporting processes from a limited to a reasonable level of assurance utilizing financial reporting concepts to design, implement and document reporting process and controls for all performance indicators associated with The Good Growth Plan.

Analytical tools

The basis for performance management is the productivity and efficiency percentage increases measured on reference farms. The overall trend will be measured against the 20% target to be achieved by 2020. The baseline year for all clusters is 2014, the starting year of the data collection. When sufficient data is available, Market Probe will use panel and time series tools to derive more precise estimates once sufficient data is available. The survey is set up as a longitudinal survey, which allows using panel and time series analysis to describe the change in productivity and efficiency over time. These regression models can be used with two and more years of observations and control for time-invariant unobserved differences that may affect the metrics.

More specifically, an assessment of TFP growth will be conducted. Partial measures like crop yield trends consider output relative to only one input. This limitation ignores the potential for new technology to raise productivity by saving other resources and fails to distinguish between impacts of intensification and technological change. As assessment of TFP growth involves observing trends in agricultural productivity by comparing an index of agricultural inputs to an index of outputs. Changes in TFP can be attributed to two components: technical change and improvement in technical efficiency. The former represents improvements in best production practices, while the latter occurs when actual production practices move closer to the existing best practice.

Research progress and outputs

The focus of the first year of data collection was to establish the farm network and set the baseline. The achieved number of clusters, reference and benchmark farms for the KPIs "Land Productivity Index", "Nutrient Efficiency Index", and "Pesticide Application Efficiency Index" are published in the Annual Review 2014 as part of the Good Growth Plan section (Figure 47-1). The KPIs are expressed as a percentage increase. Clusters are categorized in a frequency chart separately for reference and benchmark farms according to their cluster-specific KPI increase. In the Annual Review 2014, all clusters start at 0% with the baseline year 2014.

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[60] Syngenta (2015)

Non-financial performance summary

The Good Growth Plan

	2014	2013	2012
Make crops more efficient[1]			
Total number of reference farms	860	–	–
Total number of benchmark farms	2,738	–	–
Total number of clusters[2]	205	–	–

	Reference farms' performance compared to baseline 2014[3]			Benchmark farms' performance compared to baseline 2014[3]		
	2014	2013	2012	2014	2013	2012
Land productivity index:						
≤0%	183	–	–	183	–	–
>0–<5%	–	–	–	–	–	–
5–<10%	–	–	–	–	–	–
10–<15%	–	–	–	–	–	–
15–<20%	–	–	–	–	–	–
≥20%	–	–	–	–	–	–
Nutrient efficiency index:						
≤0%	183	–	–	183	–	–
>0–<5%	–	–	–	–	–	–
5–<10%	–	–	–	–	–	–
10–<15%	–	–	–	–	–	–
15–<20%	–	–	–	–	–	–
≥20%	–	–	–	–	–	–
Pesticide efficiency index:						
≤0%	183	–	–	183	–	–
>0–<5%	–	–	–	–	–	–
5–<10%	–	–	–	–	–	–
10–<15%	–	–	–	–	–	–
15–<20%	–	–	–	–	–	–
≥20%	–	–	–	–	–	–

1 2014 first year of reporting
2 Number of clusters with either reference or benchmark farms
3 Number of clusters with both reference and benchmark farms per range of percentage increase in land productivity, nutrient efficiency and pesticide efficiency since the 2014 baseline. US Department of Agriculture data are used as baseline for both reference and benchmark farms in clusters located in the USA

Table 47-1: *Non-financial performance summary, the good growth plan.*

In addition, baseline crop efficiency data for all efficiency indicators for each cluster were published on The Good Growth Plan website (www.goodgrowthplan.com).[61] The data were aggregated at cluster level using a weighted average of results from reference and benchmark farms. The data are anonymized. The data is free to download. It is published on the web, accessible to anyone and licensed to be re-used using creative commons licenses. The company collaborated with the Open Data Institute to publish the data.

The baseline results were also shared with reference and benchmark respondents in the farm network. Farmers were able to compare their individual performance to the respective cluster average, which builds an important starting point for future productivity increases.

Conclusion and next steps

In 2014, Syngenta set up a global farm network with a unique scope to monitor resource efficiency and the effect of its products and solutions in real-life conditions. Baseline farm data on productivity has been collected. The data collection for the second wage, cropping seasons 2015/2016, is ongoing and will be made available in March 2016.

[61] Syngenta (2015)

Syngenta is publishing and sharing the farm network data with the ambition to unlock shared value to rural communities and society. The data is collected to assess the performance of agronomic practices and technologies in real-life conditions. This generates realistic insights into and evidence of their effectiveness and prospects for contributing to efficiency-led productivity growth and global food security. The insights have tangible business impact if they help to improve Syngenta's delivery of products and services to farmers.

48. PUTTING CIRCULAR ECONOMY PRINCIPLES INTO PRACTICE

Jonathan Perry ✉, Markus Stutz

Abstract

Circular economies produce virtually no waste, as materials are re-used and recycled continuously. It's a dramatic shift from the current linear economy in which we take, make, consume and dispose – drawing regularly on natural resources to create products that eventually end up as waste. Dell supports the principles and practice of the circular economy model and over the past two years has been transforming its approach to the supply chain and business models to become more circular in nature.

Dell has created a closed loop supply of plastics where obsolete IT products are collected, disassembled and sorted. After a shredding and purification process it is compounded to produce plastic pellets. This plastic is then moulded into plastic parts such as the back panel or stand of an All-in-One computer, a display or a front bezel of a desktop. Closed loop plastics are now being used in 35 Dell products at a volume of 1,800 tons with the aim of further growth in the near future.

Dell has incorporated the use of wheat straw from rural China in its packaging. Instead of being burned on the field it is purchased and broken down before being mixed with recycled content cardboard to be used as corrugate or pulped cushion material. This process views another's waste as a resource, reduces air pollution, and uses less energy and water.

Smart sourcing and recycling are only a part of the circular economy. We need to continue to incubate innovation to unlock the economic potential that can bring increased value and new jobs with it. To transition to a true circular economy, collaboration within and across industries and borders is essential, it is not something anyone can do alone.

Keywords: circular economy, Dell, closed loop, plastic, packaging.

Introduction

The last 150 years of industrial evolution have been dominated by a one-way or linear model of production and consumption, in which goods are manufactured from raw materials, sold, used, and then discarded as waste. Yet recent sharp price rises, increased volatility and growing pressure on resources have alerted business leaders and policy makers to the necessity of rethinking materials and energy use - the time is right, many argue, to take advantage of the potential benefits of a circular economy. Such a model offers the opportunity to move away from our "take - make - dispose" production and consumption patterns, by ensuring, through careful design and innovative business models, that technical and biological materials continuously flow, safeguarding valuable resources and restoring natural capital. As demonstrated in the Ellen MacArthur Foundation's "Towards the circular economy" reports featuring analysis by McKinsey and Co, the economic potential of the model is considerable, with possible net material savings in excess of 1 USD trillion for the global economy [1].

Closing the Loop for Plastics in Electronic Products

Plastics in Computers

Plastic is one of the most useful and important materials in modern society. Plastics are produced from petrochemicals via polymerisation and polycondensation and engineered for computer applications. Engineered plastics in computers are used for its durability, ease of fabrication into complex shapes and their electrical insulation qualities. High flowability, stiffness, good cosmetic, easy processing, flame retardance, dimensional stability are important properties for electronics products which are met with plastics. Plastics use in electronics has led to advances in weight reduction and miniaturization in many electronic products, so less material is used in production. Besides recycling challenges, upstream manufacturing of plastics from fuel is resource intensive, requires large amounts of energy and releases relatively high levels of CO_2 emissions in the process. Globally, between 22% and 43% of plastic waste is disposed of in landfills. According to Consultic study done by PlasticsEurope in 2013, only 26.3% of all plastics was recycled in the entire European Union [2]. To make matter worse an estimated 10 to 20 million tons of plastic is finding its way into the world's oceans each year according to the UNEP.

Using recycled-content plastics and other sustainable materials is one key opportunity to curb our resource use. Since early 2008, Dell gradually started increasing the use of post-consumer recycled content. In fact by end of year 2013, we have used over 18'000 tons of post-consumer plastics in our products. One of our environmental goals is to use 22'000 tons of post-consumer recycled-content plastics and other sustainable materials in our products by 2020.

Closed Loop Plastic in Dell

We started researching on application of closed loop systems in electronics. A closed loop system is defined as "a system in which materials are reclaimed, returned to and reused for the production of the same type of product in which the material was first used" e.g. from a plastics used in electronics to another plastic in electronics or from water bottle to a plastic bottle.

Our first step was to get all the stakeholders engaged both internally and externally. External stakeholders included Dell's recycling service partners (environmental partner) who provide collection and recovery of old electronic equipment. Internal stakeholders included leads from various function critical for this project's success. We built a cross functional team from environmental compliance, services, procurement, marketing, engineering and supply chain. This team was critical to understanding the business challenges from the entire product lifecycle perspective and help driving the necessary action within their business.

Figure 48-1: *Dell's closed loop plastics supply chain.*

Dell has a decade long partnership with Goodwill Industries in United States [8]. Under this program, consumers have easy drop off access to recycle any brand of computer equipment for free at over 2000 participating Goodwill locations in North America. Since 2004 this effort has kept over 100’000 tons of e-waste from potentially getting into landfill by responsibly recycling it. Dell opened up this channel for diverting old electronics to our certified environmental partner Wistron Green Tech. Old systems destined for recycling are treated per the Dell Disposition Policy and our takeback agreements with environmental partners. They are disassembled and sorted into various recyclable streams.

The incoming material received by WAM is baled mixed plastic. This material is primarily from dismantled end of life consumer electronics that contain "engineered plastic resins" such as ABS, PC/ABS, PC and HIPS. It is not easy to separate and sort this material manually or by machine. The “traditional” practice is to sort the plastic manually, by visual inspection or by burning the plastic to identify the resin by flame colour and smell. Unlike this traditional method, at WAM this plastic undergoes a through a state-of-the-art optical sorting technology and a hydro-purification process to sort and separate plastic automatically. WAM consolidates the multiple steps of bale-breaking, shredding, sorting, purification, modification, colour matching, compounding and pelletizing under one roof. The QA/QC lab is equipped with advanced instrumentation and testing machines to ensure that the PCR plastic produced by WAM meets the stringent characteristics and tolerances required for being used in new Dell products. The compounded PCR pellets produced by WAM are used as raw material by moulders who manufacture them into new parts for computer cover, housing etc.

Dell has launched this innovative closed loop recycled plastics program and has realized that there is tremendous opportunity to divert plastics from electronic waste into new electronic products. Also, when products are designed for reuse/recycling and with a high a percentage of recycled resin, suppliers will build capacity to meet the growing demand. More work should be done to improve the customer education about benefits of recycling, improve collection rate and sortation techniques by recyclers so that the plastics can be more readily recycled into new electronic products. We also feel that more work is needed in understanding the carbon footprint and other life cycle impact differences between traditional and closed loop recycled plastics. By reusing plastics already in circulation, Dell is cutting down on e-waste, reducing carbon emissions and helping drive a circular economy for IT.

Circular and Sustainable Approaches to Packaging

Typically, packaging has played a linear role in the delivery of most goods. It exists to protect the products until they arrive at their destination, and afterwards – in most cases – the packaging was thrown away. Efforts have certainly increased across industries to improve the recyclability of packaging, but more circular approaches are needed. While Dell has looked at some opportunities for reusable packaging and delivery, our attention has focused on using innovative materials to drive more circular, sustainable approaches. In this case, nature has provided models for materials design and Dell's packaging engineers have used biomimicry as a way to make packaging more sustainable.

Bamboo Packaging

The efforts began in earnest in 2009 when Dell developed bamboo-based cushions. The plant grows back at up to 2.5 cm per hour, making it a rapidly renewable resource, and the end design was also recyclable and compostable (per ASTM standards). The bamboo packaging led to looking at how other source materials could be used to reduce the carbon footprint across the packaging's lifecycle.

Mushroom Packaging

In 2011, Dell began working with Ecovative to use agricultural waste and mushroom spores to grow cushions for heavier products. This took the sourcing a step further than the bamboo efforts, going from an abundant and rapidly renewable plant to something that was identified as waste (cottonseed hulls). That waste provided the sugars for the mushroom spores to grow. The resulting cushions could also be composted, helping return those nutrients to soil after they'd served their purpose as packaging.

Dell continues to use mushrooms for cushioning in select product shipments, but the biggest challenge faced was scaling the effort to meet Dell's global needs.

Wheat Straw Packaging

The idea of using by-products as a source material inspired other work. Dell supported a project with partner YFYJupiter to develop a new process for refining the stalks from grains into a pulp usable for both corrugated cardboard and moulded cushions. In 2013, this led to using wheat straw as an input.

The source material for the boxes and cushions is the straw left over after the wheat harvest, which is typically burned in the fields by farmers, creating downwind air pollution. Dell and YFY are purchasing this straw from farmers outside Shanghai and using an enzymatic process to break down the straw. This process reduces the energy and water needed for creating the corrugate, too. The end result is packaging that looks, performs and even recycles just like traditional corrugate, but incorporates this waste material to reduce the energy/water inputs and minimize the need for virgin material.

For boxes, the wheat straw is used as part of the wavy medium between the flat liner sheets and is a blend of 30% wheat straw, 70% recycled old corrugate. The percentages are reversed when the wheat straw is used as a moulded cushion.

In addition to relieving some of the environmental burden and using waste materials from one industry as an input for another, the wheat straw packaging also demonstrates one of the economic benefits of a more circular approach. In this case, the farmers are getting additional income from their wheat harvest by selling the leftover straw.

Using Technology to Make the Circular Economy Work

While efficiently using and reusing materials is the backbone of the circular economy, it is imperative also to look at other ways of delivering value. This includes selling access rather than ownership and finding ways to design waste out of the system. Technology has an important role to play in both of these approaches.

Access and efficient delivery

Technology is enabling the scale and ease-of-access to a wide range of products and services that could not have been imagined in years past. There are a multitude of examples from what is known as the "sharing economy," few of which would be more than a bulletin board on a dormitory wall without the computational power and software that can coordinate activities like auctions of used items (eBay), connecting riders and drivers (Uber) or rental of extra space (Airbnb).

As it relates to the physical hardware itself, leasing models ensure a significant increase in the percent of material recovered and responsibly recycled. According to the organization Step – or Solving the E-Waste Problem, each year, 45.6 million metric tons of damaged, obsolete or otherwise unwanted electronics go un-recycled. Those resources are lost – buried or otherwise removed from the economy.[3] Dell Financial Services, for example, ensures those leased assets get recycled or reused.

Transitioning processes to the cloud is a different way to reduce resource utilization while scalably increasing productivity. By hosting various applications at a data centre and tapping into them on-demand it can reduce the need for individuals to have the programs on their own machines. This has contributed to smaller end-user devices as the data centre takes over the main job of processing. It also has brought that computing power to more users who do not need to have their own data centres but instead can tap into existing on-demand providers or shared platforms.

Virtualization is another way Dell customers can extend their technology without taking on new resources. Creating virtual (rather than actual) versions of servers, enables the physical server to run multiple operating systems in parallel, increasing utilization. Migrating physical servers to virtual ones and consolidating also means needing less space, less power and less cooling, all of which carry their own environmental costs. Because virtualization can greatly expand capacity without adding physical resources, it can delay or even eliminate the need for customers to build out a new facility when they need to expand their capabilities. Similar to the way Airbnb takes the spare capacity of someone's home and makes it "productive," virtualization gets more from existing resources.

Understanding the system

Looking at the whole system – rather than products or programs in isolation – is critical to successfully transition to a more circular approach to the economy. Technology provides powerful tools for understanding and measuring those systems, helping drive more efficient processes and identifying new opportunities.

While machine-to-machine communication has been available for some time, the growth of the Internet of Things and the ability to have real-time ecosystem data in a format that can be easily analysed has the potential to identify inefficiencies in the system. Within the realm of smart building technologies, the ability to have sensors that can detect systems that are not performing efficiently or correctly can greatly reduce resource or energy waste. The same is true of other smart systems – where smart transportation can better coordinate multiple resources to reduce idling and traffic congestion.

Central to this is the analytics. The use of high performance computing clusters to analyse Big Data (large, complex data sets) is critical. This data can be used to improve yields from manufacturing or even agricultural activities, used as part of modelling and simulations to predict outcomes, or otherwise applied in ways that allow the user to understand how the system works. And with that systems-level knowledge, the user is better equipped to improve efficiency and transition to a more circular approach.

Conclusions

As a company, Dell supports the circular economy both in principle and in practice. The consumption of natural resources has increased over the past few decades and as people in emerging markets become wealthier, resources will become scarcer and more expensive. Therefore efforts need to be made to find alternative business models that consume fewer resources and prevent them from prematurely exiting the economy.

Dell finds itself in two main elements to the circular economy. Firstly, we must implement circular principles into our business and supply chain. Transitioning ourselves to a more circular approach is a business decision and will help Dell remain competitive. Secondly, technology is a critical tool in enabling the Circular Economy itself and is Dell’s core business.

Given the increasing use of resources globally, Dell has to expand its growing efforts to develop circular business models that preserve natural resources through reuse and recycling. Dell has put this into action in its own supply-chain through sustainable packaging and closed loop plastics use.

Technology is a key driver and will reduce resource use through technologies such as cloud that allows companies to harness computing power and not have to buy the actual hardware

The circular economy is a global issue. There is a need for collaboration through the supply chain, across sectors and with Governments around the globe to make the circular economy happen.

49. CRADLE TO CRADLE® - PARQUET FOR GENERATIONS RESPECT FOR RESOURCES AND PRESERVATION FOR FUTURE

Reinhold Herkströter ✉, Albin Kälin

Abstract

Working with wood means assuming a responsibility. Wood is the most important naturally re-growing raw material and it is considered to be the construction material of the future. However, treated with chemicals (adhesives, lacquers) the resource wood becomes waste.

Having adopted a new technology under the name of "Silente", Bauwerk Parquet, based in Switzerland, is breaking new grounds. Silente products follow the Cradle to Cradle® design principle. Cradle to Cradle® stands for a closed raw material cycle and a respective quality assurance process. Bauwerk parquet is designed to last. It should never become a waste product or consume unnecessary or environmentally harmful energy. Raw materials are preserved and the resourcewater is treated with consideration. Bauwerk acts in a fair and socially responsible manner, both within the company and in public. EPEA Switzerland is assisting Bauwerk in its implementation of the Cradle to Cradle® vision. Raw materials and ingredients from up to 36 suppliers are assessed on material health, reutilization, environmental impact and traced back to their origins. The "Silente" Bauwerk Parquet products are Cradle to Cradle Certified™ at GOLD level.

Bauwerk floors that incorporate the new Silente technology can easily be dismantled and returned to the company. Thanks to the new "Silente-Mat", the parquet can be taken up without being destroyed. All components can be either reconditioned or recycled for new products.

Bauwerk products that incorporate the Silente technology are made exclusively from materials that are safe for both humans and the environment. Thanks to this closed cycle, Bauwerk conserves the valuable resource wood and acts in the interest of future generations.

- The use of healthy, non-hazardous materials
- The subsequent use of all materials in a closed cycle
- The validation of renewable energy
- Environmentally compatible water management
- Social responsibility

Keywords: parquet, wood, cradle to cradle, circular economy, innovation, generations

Introduction

Wood is the most important naturally re-growing raw material and it is considered to be the construction material of the future. However treated with chemicals (adhesives, lacquers) the resource wood becomes waste.

Cradle to Cradle Design opens the perspective of an industrial society where processes of production and use are designed by transfer of principles of Nature. Nature knows material flows, but Nature does not know waste, avoidance, constriction and restriction. Nature is simply involving right materials at the right place and at the right time.

In the case of wood treated with chemicals innovation is needed to develop only chemicals which are safe for biological cycles.

Cradle to Cradle® Design

The Idea - Cradle to Cradle® Design defines and develops cycleable products.

In regard to differentiation to conventional recycling the quality level of the raw materials remains throughout multiple product lifecycles and only purely "assessed safe chemicals" are used.

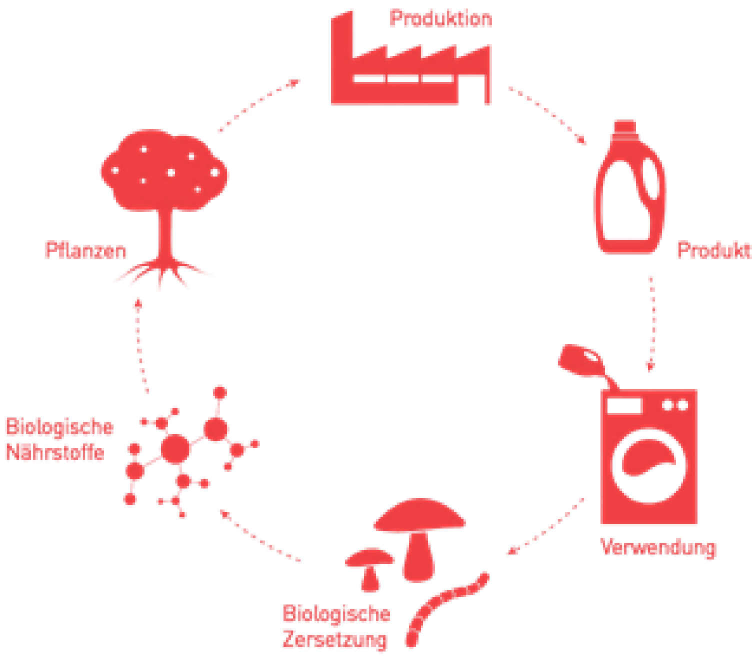
The products are developed according the model to maintain the quality of raw materials over multiple life cycles taking the production processes, the use and the reutilization into account. This means: No waste, all ingredients are considered as nutrients. The right materials are integrated in defined cycles (metabolism) at the right time and place.

The 3 Cradle to Cradle® Design Principles:

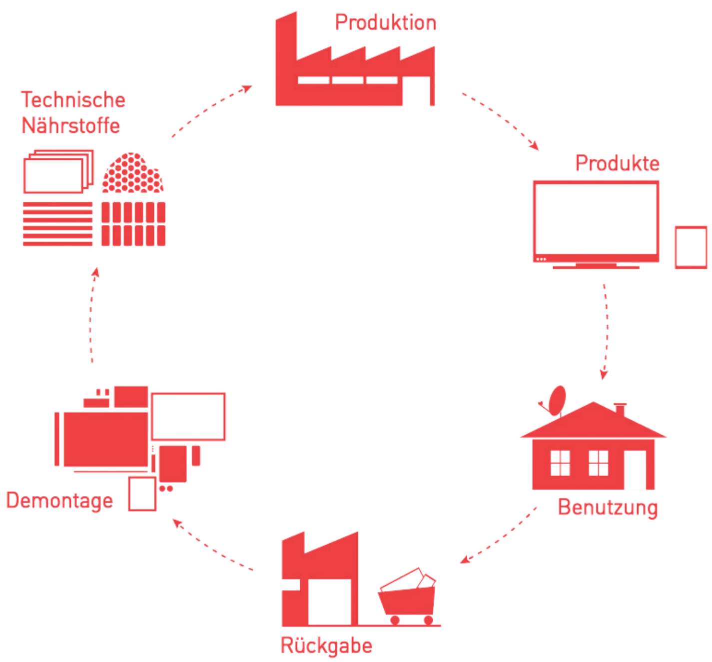
- Waste = Food
- Energy: use of renewable resources
- Diversity

Nature as a model reflects ongoing developments in a Cradle to Cradle® product: Flourishing trees in spring are only apparently redundant. From a few blossoms new trees are growing. All blossoms not used for growth, fall to the ground and become nutrients.

Cradle to Cradle® Products reach a new quality dimension and distinguish themselves through high economic value as well as modest, ideally with no environmental damage. They achieve high consumer friendliness and are credentials of a paradigm change towards consumer behavior and in the industrial production. Cradle to Cradle® Design defines not only form, functionality and ingredients of a product. The goal is to strive for a new dimension in quality and safety in endless cycles.



Consumer Goods (natural fibers, cosmetics, detergents, etc.) are designed so that they can be used in biological cycles over and over again. They decompose to organic nutrients and promote biological nutrients and systems such as plant growth. The renewable raw materials are in turn the basis for new products.



Service Products (TV sets, cars, synthetic fibers, etc.), the so-called technical nutrients, are separated to enable the production of new commodities after fulfilling their initial function. The users / consumers purchase only the relevant services, e.g. Television. The materials remain the property of the manufacturer, which retains them through collection and reenters them into the technical cycle.

Differentiation: Quality equal Quantity

Cradle to Cradle® Design transmits the principle “Quality equal Quantity” to industrial systems. Materials together with material flows are designed to be beneficial and useful for the regeneration and conservation of biological and technical resources. This approach liberates from the present obligation to diminish, reduce or slow down the need to negative environmental impacts.

“Silente” Bauwerk Parquet

Working with wood means assuming a responsibility. Wood is the most important naturally re-growing raw material and it is considered to be the construction material of the future. Depletion and illegal deforestation eliminate this basis for future generations. For the wood industry, it is fundamental to take responsibility for sustainable forestry which is fundamental and vital from an ecological standpoint. Purchasing raw wood from sustainable sources (e.g. FSC, PEFC certified) has been very important to Bauwerk for years. Bauwerk has guaranteed the use of innovative solvent-free industrial lacquers and adhesives, the extensive practice of recycling throughout the production process, the most advanced techniques aimed at lowering harmful emission and a high level of safety for its employees and the environment through its ISO 14001 safety certification.

The implementation of strict regulations when purchasing raw wood and commercial products is an important part of the company’s approach. All Bauwerk parquet comes from sustainable forestry

Having adopted a new technology under the name of “Silente”, Bauwerk is breaking new ground. Silente products follow the Cradle to Cradle® design principle. Cradle to Cradle® stands for a closed raw material cycle and a respective quality assurance process.

PARQUET FOR GENERATIONS

Bauwerk parquet is designed to last. It should never become a waste product or consume unnecessary or environmentally harmful energy. Raw materials are preserved and the resource water is treated with consideration. Bauwerk acts in a fair and socially responsible manner, both within the company and in public. EPEA Switzerland is assisting Bauwerk in its implementation of the Cradle to Cradle® vision and as general assessor for the Cradle to Cradle Certified™ certification.

Raw materials and ingredients from up to 20(36) suppliers are assessed on material health, reutilization, environmental impact and traced back to their origin. During the certification process for Bauwerk’s new silente technology, both the suppliers and Bauwerk’s manufacturing facilities were subjected to close scrutiny.

Bauwerk floors that incorporate the new silente technology can easily be dismantled and returned to the company. Thanks to the new “Silente-Matte”, the parquet can be taken up without any effort. All components can be either reconditioned or recycled for new products.

Bauwerk products that incorporate the silente technology are made exclusively from materials that are safe for both humans and the environment. Thanks to this closed cycle, Bauwerk conserves the valuable resource wood and acts in the interest of future generations.

THE CRADLE TO CRADLE CERTIFIED™ GOLD AWARD FOR SILENTE PRODUCTS CONFIRMS:

- The use of healthy, non-hazardous materials
- The subsequent use of all materials in a closed cycle
- The validation of renewable energy
- Environmentally compatible water management
- Social responsibility

ISO 9001+14001 certificate and the Bauwerk company's strategy.

Innovation Story

Bauwerk parquet is glued always completely with the subfloor. This has the advantage that aconnection is made to the entire floor structure which also prevents noise. Skilled workersare trained for a perfect installment of the wooden parquet.

Task and implementation:

The dismantling of a glued floor after its useful life has many difficulties. On the one hand the work is noisy, dirty and tiring and, secondly, time-consuming and expensive. In addition, the floor is destroyed during removal and must be discarded. Due to the different material components, a recycling of the waste is not possible. The problematic expansion of the soil structure inspired to search for a suitable separation layer between Parquet belts and subsoil, which should bring a relief.

In addition, a growing interest on the customer side for solutions with regard to walking and impact sound emissions was perceptible. These trends led to the project launch in 2011. Together with the German manufacturer, WPT, a walking and impact noise reducing mat was developed. The mat should be to a high degree technically effective and environmentally friendly. This was achieved with the raw material consisting of 80% natural chalk and the linking polyurethene glue is also very ecologically. Above and below the mat feels like a natural felt. The surface is additionally provided with a grid of yarn as desired separation layer, on which the parquet should solve from subfloor during disassembly.

The mat was called "Silente mat" and the method has been patented by the manufacturer. It is produced exclusively for Bauwerk. The standard version is manufactured in rolls of 7.5x1m. Assembly is done by sticking the mat to the subfloor. On the mat every Bauwerk parquet can be glued.

Parallel to this development Bauwerk got into contact with the EPEA Switzerland, the company supports the implementation of Cradle to Cradle® and to obtain the certificate Cradle to Cradle Certified™. The Cradle to Cradle concept is the development of products for material health, their use, recovering and reuse, by maintaining its high value over its entire lifetime and multiple lifecycles. After some project discussions, the idea came up, to develop the parquet floor nondestructively. In this way, the floor can be used repeatedly in a closed loop and multiple product cycles.

Applying the tailored mat strip directly to the finished parquet and then to the floor, two innovative approaches could be combined in one product. On the one hand, the desired separation mat layer represents 80% non-destructive expansion and secondly the Silente system enables improvements in walking and impact sound emissions.

Parquet Cleverpark is available in the size 1250x100mm. The product was subjected to standard tests for walking and impact sound determination at the EMPA in Duebendorf scored in system design (building Glue MS 40 for bonding to the subfloor + Cleverpark Silente) with very good values.

A major project in Chur, Switzerland, where around 1,500 m² Cleverpark Silente were laid, represented the first Silente project and offered the possibility to check the building acoustic values of a qualified architectural acoustics expert. This confirmed the values indicated in the certificates. Clever Park Silente is the only system manufactured with demonstrable results for walking and impact sound.

In 2013 the scientific institute EPEA assessed the product for Cradle to Cradle Certified™ Silver certification. The company and the product have been evaluated in 5 main categories:

- Material Health
- Material reutilization
- Renewable Energy and Carbon Management
- Water Stewardship
- Social Fairness

Result

As a result, the Cleverpark Silente received in the categories material reutilization, Renewable Energy + Carbon Management, Water Stewardship, Social Fairness the Cradle to Cradle Certified™ gold level, for the criterion of material health silver status. The assessment of materials, chemicals > 100 ppm in regard to their environmental and health relevance criteria such as acute and chronic toxicity, irritation potential for eye and skin sensitization potential, mutagenicity, carcinogenicity, teratogenicity, reproductive toxicity, endocrine disrupting activity, biodegradability / persistence and aquatic toxicity. The raw materials for the floor were also tested for the level of organ halogens (chlorine, bromine, fluorine) and the content of toxic heavy metals (e.g. antimony, arsenic, lead, cadmium, nickel, mercury).

The cost of the core team of five employees and external consulting was high, especially since all the component suppliers (tier 1: six suppliers) and their upstream suppliers had to disclose their entire product specific data (tier 2: 36 suppliers). The chemical components were assessed at EPEA Int. Umweltforschung in Hamburg.

The certificate has been awarded Silver in October 2013 a total of five systems Parquet (parquet plus new Silente mat).

In January 2015, the project Cradle to Cradle Certified ™ Gold started. Since only the area material health had silver status and all other areas were already on the Gold Level, the suppliers were asked for solutions to replace the "gold-critical" components due to optimized materials.

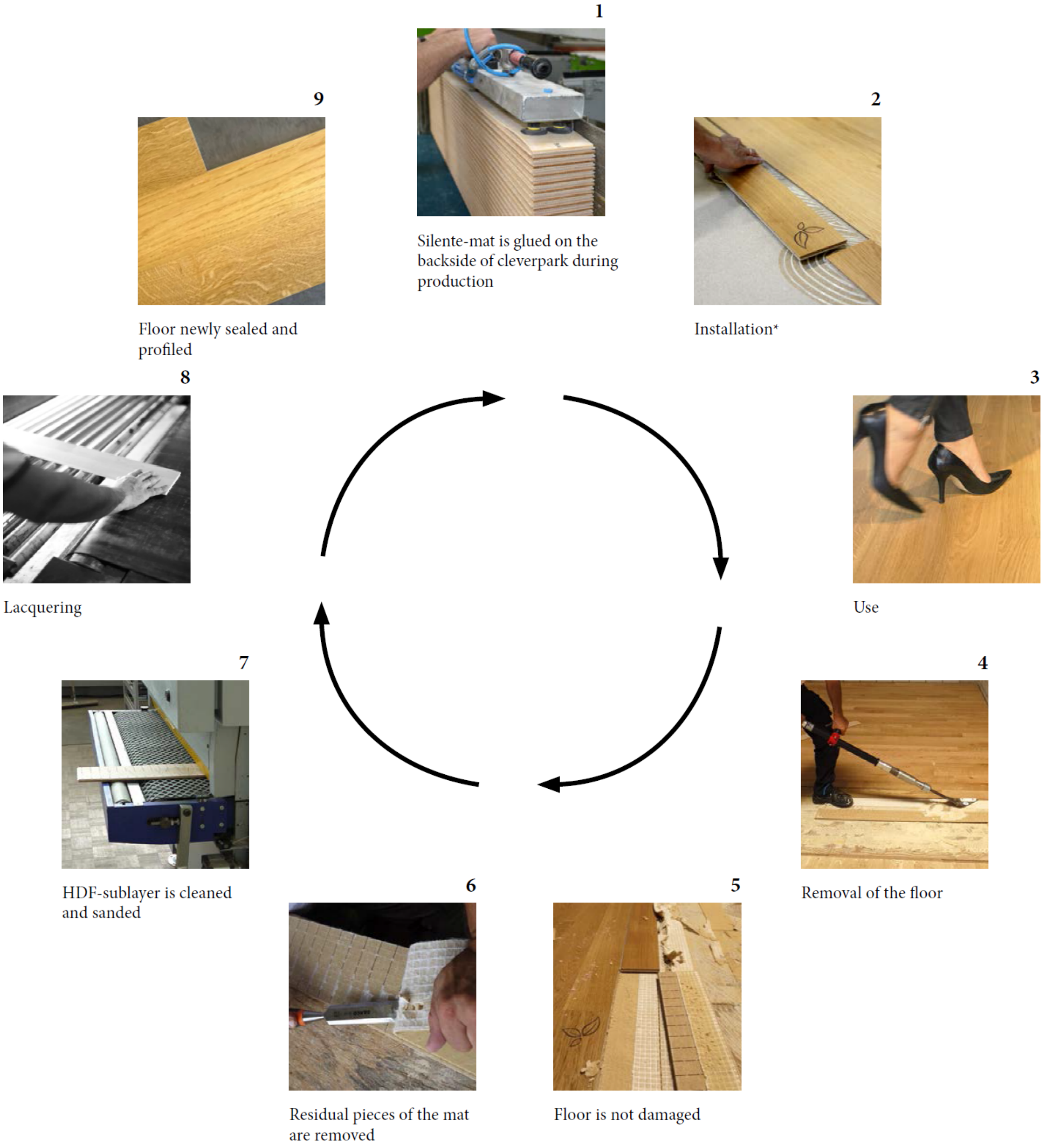
In active collaboration this could be achieved and, since June 2015, the Bauwerk assortments Clever Park and Multi-Park Silente got awarded with the Cradle to Cradle Certified ™ Gold certification. Bauwerk is the world's only company in wood parquet achieving gold level.

Healthy living of Bauwerk products is a pillar of the activities, now all results from the C2C® project will be transferred to the entire Bauwerk Swiss Parquet production.

Bauwerk is convinced to have done a significant step forward. Both within the company as well as great progress for the customers has been made as well as for the environment, as in the future less valuable timber is required. Through the multiple use of the products an important contribution to sustainability is made.

SILENTE TECHNOLOGY

closed loop



* *this closed loop has been awarded with the "healthy living" label*

BAUWERK®
Parquet

Conclusions

The Cradle to Cradle® concept improves the economy in the entire value cycle of a product. Related risks within the supply chain and the production achieve higher transparency. The cost of the economy, the environment and the social aspects become predictable and profitable.

All substances and materials along the entire supply chain are being considered from raw materials to products within the Cradle to Cradle® Design Concept. This results in a product of unmatched quality. Therefore, a continuous raw material use is practiced without restrictions.

Bauwerk-Boen Group

Founded in 1944, Bauwerk Parkett AG is the leading Swiss parquet manufacturer and the leading European supplier of two-layer parquet. The roots of Boen go far back into the 17th century when two sawmills near the Norwegian city of Kristiansand laid the foundation for today's leading supplier of 3-layer parquet. By the merger of the two companies in June 2013 the new Bauwerk Boen AG becomes one of the worlds leading high end parquet manufacturer and Europe's No. 2. The Group employs approx. 1700 employees and produces over 9 Million m2 per year. The whole range of different parquets is offered by the two brands Bauwerk and Boen and is distributed through different sales channels in over 50 countries worldwide. The key markets are Switzerland, Germany, Austria and Scandinavia. Bauwerk Boen operates factories in Lithuania and Switzerland.

EPEA Switzerland GmbH

EPEA Switzerland GmbH supports companies in different areas of activities in the development and implementation of Cradle to Cradle ® design concepts.

With an experienced, internationally oriented and interdisciplinary working management team, Cradle to Cradle ® projects are implemented in all industries in the Alpine region (mainly Switzerland and Austria) – and in the textile industry worldwide. Scientific reviews for all projects are created in close cooperation with EPEA Internationale Umweltforschung GmbH.

EPEA Switzerland is an accredited general assessor for the Cradle to Cradle Certification™.

50. RECOVERY OF PRECIOUS METALS FROM INCINERATION BOTTOM ASH

Roland Weippert ✉

Abstract

Incineration bottom ash (IBA), the final solid residues from Energy of Waste Facilities (EfW), holds a huge potential for recovery of valuable metals and a complete reuse of the residual mineral matter. Modern treatment technologies allow for a recovery of lumpy metals to the greatest possible extend and the production of a homogeneous secondary construction material.

Over the last two years, LAB Geodur has developed a new approach for IBA treatment: Based on its existing dry treatment process for wet-discharged and matured IBA, known under the name of RecuLAB® NF, a wet processing for fresh IBA has been developed, which allows to directly treat wet-discharged IBA. This process, called RecuLAB® AU, is designed to treat IBA without any upfront storage or maturation. RecuLAB® AU is a modular concept, which can be installed on the premises of an EfW plant or at an existing IBA treatment site.

Given the wet processing, both the metal recovery yield as well as the metal qualities are importantly improved. Besides further value creation from additionally recovered metals down to 0.03 mm, a sand-like secondary aggregate is produced, opening up new application possibilities. The mineral fraction additionally benefits from an improved visual appearance and from further reduced contamination. Process water is kept in a closed loop, enabling a residue-free treatment technology. Due to the wet processing, typical dust issues from IBA treatment can be completely solved. With this, not only the mode of operation is simplified, the environmental and working conditions are massively improved, too.

Keywords: incineration bottom ash, recycling of precious metals, wet processing.

Introduction

In modern EfW facilities, municipal solid waste is converted into energy (e.g. electricity and/or steam) and an inert fraction called IBA is created. Typically, 20-25% of the waste input (by weight) is converted to IBA which predominantly consists of Silicon, Calcium, Sodium, Iron, Aluminium, Copper and other metals. IBA is therefore a blend of fine inert mineral compounds (rock, glass, ceramics) and metals. On average, about 80-85% of IBA is of such mineral character, whereas 10-15% are ferrous and 2-5% are non-ferrous (NF) metals. The grading of IBA typically shows the following scheme: 20-25% is smaller < 2 mm, 50-65% is smaller than 25 mm, 90-95% are smaller than 65 mm.

Over the last 25 years, the removal of ferrous components has been implemented as a standard for IBA recycling, whereas over the last 15 years an additional focus was given to the recovery of NF metals. Over the last 5 years technological development has seen important acceleration for the recovery of NF metals as recovery grading was improved from 8 mm down to 1 mm. Key drivers for these technology developments came from both ecological and economical boundaries:

- Additional potential to divert IBA minerals from landfills

- Need for better preparation of IBA minerals for re-use as high-quality secondary construction material
- Increasing raw material (metal) prices
- Further incentives to reduce CO_2 footprint.

Re-use of IBA minerals is regulated within an European framework, albeit each individual country has its own regulations regarding a potential re-use (e.g. quite complete re-use in Denmark or the Netherlands, partial re-use in Germany, France or Italy, complete mono-fill in Switzerland). Key drivers for IBA re-use are the leachate potential, i.e. the inherent risk for groundwater contamination, as well as physical-chemical parameters for construction materials.

Metals in IBA

Despite there have been very sophisticated separate collection systems been installed in many places, there is still an important amount of metals which are difficult and/or demanding to be pre-sorted before incineration. These metals can especially be found in composite products, as smaller debris or in WEEE residues. In some countries, car shredding residues are also co-incinerated in EfW plants. Together with WEEE residues, they add important amounts of precious metals as well as rare earth metals to the IBA mix.

A large portion of the metals leave the incineration process in their metallic form whereas especially small/thin particles or metals with lower melting temperatures will be oxidized (e.g. base metals), burned (e.g. metals with low melting point) or evaporated (e.g. metals with low boiling point).

Additional metal losses are created using the traditional wet-discharge system for IBA: When the inert fractions leaves the incineration zone, it is quenched in a water basin which also serves as air control instrument. Eventually burning residues are extinguished and the IBA is cooled and wetted for later handling and storage. Given the alkaline and puzzolanic character of IBA, the drying of wet-discharged IBA will harden to create concrete-like structures, while corroding and encapsulating metals in a mineral matrix.

Over the last years, dry IBA discharge systems have been developed and installed (e.g. at KEZO Hinwil or Satom Monthey). Using this system, the IBA is discharged without water, not wetting the IBA. With this, the corrosion on metals is completely omitted, encapsulating of metals does not take place as it is typical for wet-discharged and matured IBA, consequently metal recovery rates and metal qualities are higher in a dry process. As a down-side, the necessary dust protection is significant as IBA processing requires full enclosure.

Recovery of Metals from IBA

Metal recovery in IBA recycling respects the following sequence

- Grading:
    - An optimum use of metal recovery equipment can only be performed in well-graded material.

  - Different types of sieves can be used for IBA grading. Material size and moisture content of the IBA to be treated predominantly determines the sieve type to be preferred.
- Crushing:
  - Mechanical impact helps to free encapsulated or coated metals from their mineral matrix and makes them accessible for metal recovery equipment.
  - Given the brittle and hard characteristic of IBA, and recognizing the risk of dust building in crushers, only selected IBA particles should be crushed (e.g. in clear defined grading, focussing on encapsulated metals).
  - For most secondary construction material applications, the given grading of IBA should not be changed.
- Ferrous metal recovery:
  - Ferrous metals can be recovered relatively easy and therefore enable quick wins, but also support a smooth further processing if bulky ferrous items are eliminated at the beginning of the recycling process.
  - Drum magnets and/or overhead magnets are the typical ferrous metal recovery equipment.
  - Depending on the magnetic characteristics of certain stainless steel fractions, it is also possible to recover alloyed steels with such magnets.
  - It is important to use magnets in all prepared IBA fractions – not only for the recovery of all ferrous metal particles, but also to protect the eddy-current equipment and to support their recovery efficiency.
- NF metal recovery:
  - It is important to not only recover ferrous metals - for increased value contribution and for further reduction of heavy metal contamination (leachate potential).
  - Modern eddy-current systems are capable to recover NF metal particles below 1 mm.
  - Generally, the higher the electrical conductivity of a metal, the high the recovery grade of such metal particles. And again, the narrower the grading band of the material, the higher the efficiency of an eddy-current machine.
  - For the recovery of stainless steel metals, inductive sorting and x-ray sorting systems have proven to be very effective over the last years.

Recovery of very Fine and Precious Metals from Wet IBA

Recovery equipment for metal recycling from IBA has importantly improved over the last decade. BAT allow today to recover metals pieces down to about 1 mm. As a further development of the metal recycling strategy, it was obvious to directly recover metals after the wet quenching of the IBA, omitting the typical maturation step before IBA treatment. LAB Geodur has developed such a new approach for IBA treatment. Based on its existing dry treatment process for matured IBA, known under the name of RecuLAB® NF, a wet processing for IBA has been developed, which allows to directly treat wet-discharged IBA. This process, called RecuLAB® AU, is designed to treat IBA without any upfront storage or maturation.

The IBA is wet sifted at 2 mm, the fraction > 2 mm can directly be processed on available/traditional IBA processing technologies. Due to the wet processing, both the metal recovery yield as well as the metal qualities are importantly improved. The mineral fraction additionally benefits from an improved visual appearance and from further reduced contamination.

In the fraction < 2 mm, it is now possible to recover metals, among them the group of precious metals, down to a size of 30 µm. Besides further value creation from additionally recovered metals, a sand-like secondary aggregate is produced, opening up new application possibilities. Process water is kept in a closed loop, enabling a residue-free treatment technology.

RecuLAB® AU is a modular concept, which can be installed on the premises of an EfW plant or at an existing IBA treatment site. Due to the wet processing, typical dust issues from IBA treatment can be completely solved. With this, not only the mode of operation is simplified, the environmental and working conditions are massively improved, too.

The pilot, industrial-scale RecuLAB® AU plant will be commissioned beginning of 2016 at the KVA Linthgebiet in Switzerland.

Figure 50-1: *RecuLAB® Au module.*

Conclusions

Incineration Bottom Ash (IBA), the final solid residues from Energy of Waste Facilities (EfW), holds a huge potential for recovery of valuable metals and a complete reuse of the residual mineral matter. Modern treatment technologies allow for a recovery of lumpy metals to the greatest possible extend and the production of a homogeneous secondary construction material. With this, EfW plants and the complete re-use of IBA are very important pillars for the circular economy.

51. ENTREPRENEURIAL SUPPORT FOR E-WASTE RECYCLERS

Elisabeth Herbeck ✉, Markus Spitzbart, Mathias Schluep

Abstract

Sustainable recycling of e-waste bares opportunities as well as obstacles - mainly for small and medium size enterprises. Especially the current challenging market situation for second-hand raw materials makes it difficult for small e-waste recyclers to operate in a sustainable manner. Numerous studies have been conducted to define the required framework conditions in order to operate an e-waste recycling plant in an economically and environmentally sound manner. Besides policy measurements, enforcement of legislation and financing schemes, sustainable business models are key factors.

In order to support entrepreneurs to set-up sustainable e-waste recycling plants, the Dismantling- and Recycling-Centre in cooperation with the World Resources Forum and other international organizations, developed various tools. The Business Plan Calculation Tool supports entrepreneurs to set-up an economic viable e-waste recycling business. The Dismantling Guide provides guidance for technicians to dismantle appliances in an effective and efficient manner. The Recyclers Information Centre is a platform under development that will provide business operators with information to improve their ongoing practices in terms of dismantling, component harvesting, reuse operations and downstream options.

Introduction

The generation of e-waste rapidly increased worldwide during the last decade. According to the ITU statistics the subscription to mobile phone providers raised from 87 Mio in 2005 to 582 Mio in 2013 [1]. It is expected that by 2030 a majority of obsolete computers will be generated in developing countries [2]. The current lack of e-waste management strategies and infrastructure in most developing countries bears a risk for the concerned countries and also contributes to the loss of important resources.

A well-established system to collect and treat used or obsolete electrical and electronic equipment on national level leads to an improved economic situation through the creation of green jobs and a decreasing impact on the environment and on human health. It also supports increased resource efficiency by substantially reusing material and not losing it through improper treatment by primitive recycling practices.

Dismantling of WEEE can be an opportunity for entrepreneurs to set up sustainable recycling businesses and creating green jobs. However a lot of challenges have to be faced when establishing a new dismantling facility, e.g.:

- An efficient strategy for collection of e-waste from different input streams (households, B2B-collection...) has to be identified and set up. Eventually purchase prices have to be paid for receiving e-waste.
- Some of the collected appliances like desktop-PCs or notebooks have an intrinsic value. The value of the output fractions can cover the treatment costs. This is different for many other appliances like CRT-devices where dismantling expenses and disposal costs are higher than the achievable revenues.

- For each of the produced output fractions downstream partners have to be identified. Some of the fractions, like copper, steel and aluminium can usually be commercialised locally. For other fractions like printed circuit boards a global market with quite volatile characteristics exists where prices offered for the same fraction can vary up to 40% within one year.
- Depending on the location of the facility transport costs for output fractions to different downstream partners (material recovery or disposal facilities) on national, regional and international level may significantly impact the potential revenues.
- Depending on the local wage level and existing mechanical recycling plants in the region, an best applicable dismantling technique should be chosen. It might be necessary to dismantle appliances into as many pure materials as possible or to apply a more superficial dismantling strategy focusing on depollution only and leaving material separation to mechanical recycling plants.

In order to support entrepreneurs mainly in newly industrialized countries, the below tools have been developed. The Business Plan Calculation Tool supports entrepreneurs on a financial and planning level, the Dismantling Guide provides technical guidance to most efficiently dismantle appliances and the RIC provides a platform to constantly improve the ongoing operations and keep up to date with new developments in the field of e-waste treatment, including component harvesting and repair activities.

Business Plan Calculation Tool

A first version of the tool has been developed by KERP[62], DRZ and EMPA[63] in 2012 within a project funded by the Solving the e-waste problem (Step) Initiative. Step with its members supports countries to establish the technological and institutional capacity to grasp the opportunity rather than suffer with the challenges.

It was further developed by DRZ and EMPA within an UNIDO-project aiming to implement an e-waste treatment facility in Kampala, Uganda [3].

Design, structure and features of the tool

The core source of the tool is the result of a dismantling campaign conducted by the DRZ-Dismantling and Recycling Centre in 2013. Within this campaign the composition of output fractions after dismantling 13 relevant appliance groups (desktop PCs, notebooks, monitors, TV-sets, printers, mobile phones, etc.) has been analysed. The average time for dismantling these appliance groups has been collected for three different efficiency-scenarios (high, medium, low). This data has been collected for the following three different dismantling levels (seeFigure 51-2):

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[62] KERP Competence Center is a global software and consulting partner for optimizing cross-enterprise business processes based in Vienna, Austria

[63] EMPA is an interdisciplinary research and services institution for material sciences and technology development

a) Hazardous components and high valuable components, like printed circuit boards are removed only and the remaining parts are destined to mechanical separation/ recycling.

b) Apart from removing hazardous components manual dismantling of components into more or less pure materials and recyclable fractions is conducted where viable with reasonable effort.

c) Appliances are dismantled up to a point, at which further separation into pure materials is not possible without mechanical shredding.

The extended version of the tool, which is distributed through workshops, contains an additional feature, where further treatment steps like depollution of CRT-tubes, cable stripping, shredding of plastics and depollution of fluorescent tubes can be selected as part of the process flow.

The overall process flow mapped within the calculation tool (extended version) is pictured in Figure 51-1**Figure 21-1:**. Concerning collection, different input streams can be selected: Delivery of e-waste to the facility, B2B-collection and decentralised collection via collection points. For each output fraction the destination for further treatment (recycling or disposal) has to be chosen. It can be distinguished between local, regional or international market.

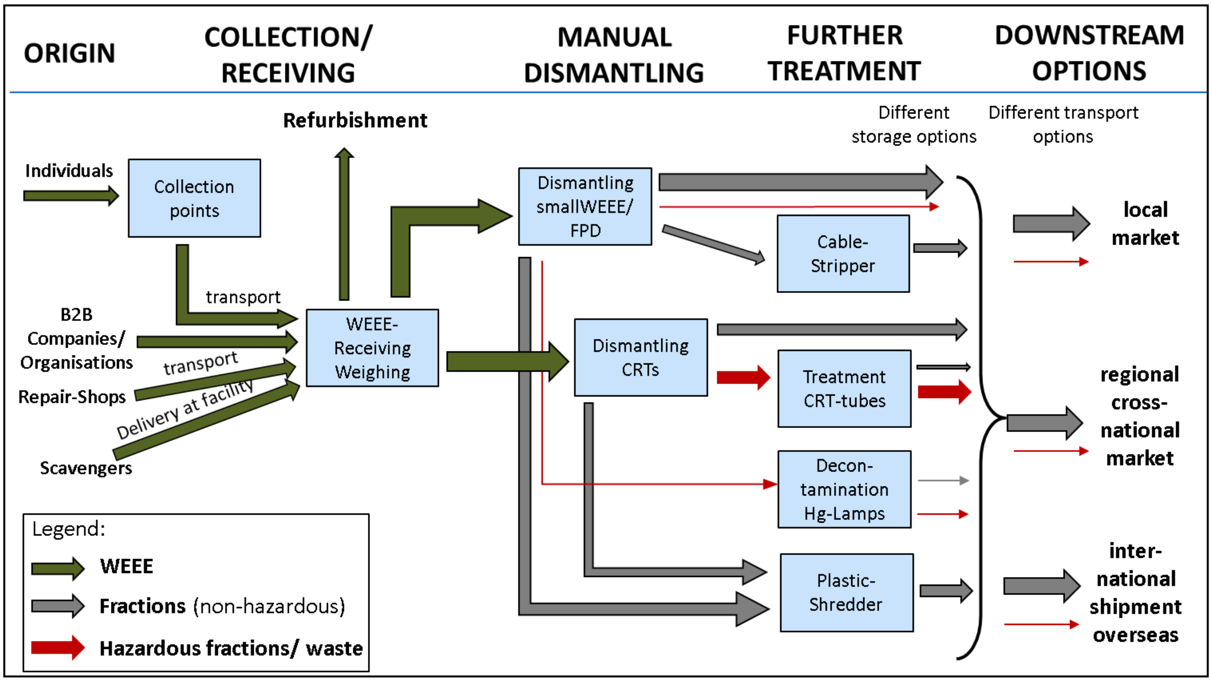

Figure 51-1: *Processes mapped within the calculation tool.*

To use the tool some essential data has to be provided. This data includes the following:

- Average salaries and annual working hours in the country
- Local price situation for energy and fuel
- Average rental and construction costs
- Purchase prices for investment of equipment and infrastructure

- Achievable revenues or disposal costs for each output fraction
- Average transport distances for each collection and downstream scenario
- Local interests for credits and savings,
- Taxes to be paid

Depending on the cost and price situation in the applicable region and the chosen scenarios concerning collection, dismantling and further recycling/ recovery, the entire business plan automatically calculates the following data on an annual basis:

- Quantities of produced output fractions
- Required staff, investments and equipment
- Required space for administration, dismantling, storage, etc.
- Expected revenues and operational costs
- Entire profit and loss forecast
- Presumable point of break-even

Use and benefits

Using the Business-Plan-Calculation-Tool planning processes for e-waste dismantling facilities can be set up based on environmental and financial sustainability with consideration of local conditions in the different regions of the world.

Dismantling Guide

The dismantling guide provides step-by-step guidance for manual disassembly procedures of electrical and electronic equipment. Information regarding hazardous components and required caution during the dismantling process is provided as well as some basic storage requirements and downstream options.

The guidebook was originally prepared for the e-waste programmes of the State Secretariat of Economic Affairs SECO (Sustainable Recycling Industries), which are implemented by the Institute for Materials Science & Technology Empa and the World Resources Forum WRF. The guidebook was further adapted together with the DRZ for the UNIDO project “Creating Employment Opportunities and Ensuring Effective E-waste Management in Cambodia”, which was jointly initiated together with the Republic of Korea, through Korea International Cooperation Agency (KOICA) and Samsung Electronics.

Design, structure and features of the tool

The dismantling guide describes and illustrates how IT appliances can be recycled through manual dismantling. It contains of three main parts:

- Basics: Required tools and equipment for the dismantling process are introduced.
- Dismantling: Required steps for dismantling of the selected IT-appliances are described and illustrated through photos and step-by-step guidance. Necessary health & safety precautions are highlighted.

- Downstream processes: Output fractions produced by dismantling are specified. Necessary precautions for storage and adequate destinations for recovery versus environmental disposal are headed.

Manual Dismantling is the recycling technique, which leads to the highest recovery rates in the subsequent recycling and recovery steps. Dismantling of WEEE normally comprises the following main dismantling steps:

1. Opening of the appliance (separation of the housing from the rest of the appliance)
2. Localization, identification and removal of hazardous components
3. Dismantling and separation of the remaining components into marketable fractions

However, some appliances require special caution during dismantling. For example, during the dismantling of CRTs, aeration of the CRT-tube has to be included as an additional dismantling step to avoid implosion.

Flowcharts of the appliances provide a good overview of the components and the treatment steps to be applied. The figure below shows the flowchart of a laptop. Components like the keyboard and the HDD can be further dismantled and others like plastics should be destined to end-processing.

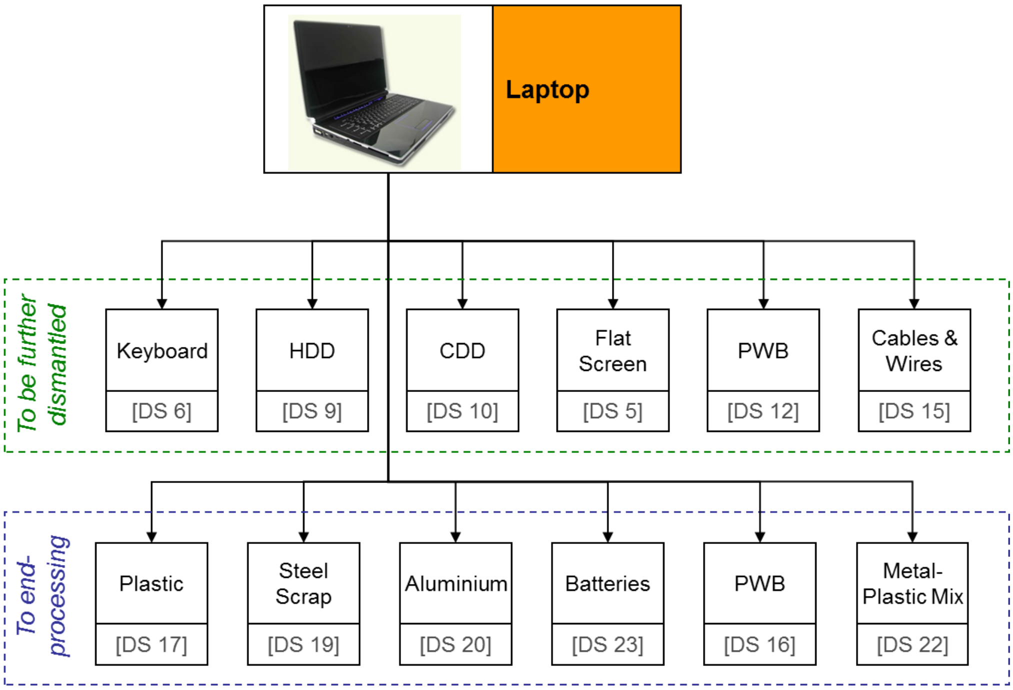

Figure 51-2: *Flowchart Laptop.*

For each component detailed step-by-step dismantling procedures are included in order to ensure that the dismantling process is conducted in an efficient and effective manner. Besides the dismantling procedures, the guide also covers further treatment options of fractions and highlights requirements for transport and storage mainly of hazardous fractions.

Use and benefits

The main purpose for the dismantling guide is to provide training material training material for technicians working at a manual e-waste dismantling facility. The provided information is valuable for technicians as well as mangers of e-waste treatment facilities.

Recyclers Information Centre (RIC)

The Recyclers Information Centre (RIC) is currently being developed by iFixit GmbH in collaboration with Fraunhofer IZM and DRZ within the CloseWEEE project which aims at improving technology and procedures for end-of-life treatment of WEEE.

Design, structure and features of the tool

The RIC a web-based platform providing support to e-waste recyclers in order to improve and optimize their operations. It focuses on material recovery as well as on preparation for reuse and component harvesting.

This will constitute a centralized source of visually illustrated, multilingual information regarding safe, fast and efficient procedures for treating WEEE, including information on the presence of hazardous substances as well as disassembly procedures. The main features of the RIC are:

Feature	Description
Generic disassembly guides (based on dismantling guide)	– General description of equipment – Dismantling steps – Resulting output fractions – Required tools & equipment for dismantling – Health & Safety Aspects
Product specific disassembly guides	– Description of product – Specific dismantling steps – Resulting output fractions – Required tools & equipment for dismantling – Health & Safety Aspects – Components to be harvested
Preparation for reuse	– General potential for re-use – Required steps for testing/ refurbishment – Frequent defects/ components to be replaced – Required tools & equipment for repair – Health & Safety Aspects
Fraction specific information	– Average material composition of fraction – Characteristics of fraction – Indications how to store & transport – Indications about the economic value of the fraction – General guidance for shipment
Downstream options	– General description of the downstream market – Possible fraction to be treated with the recycling process (accepted impurities/required composition) – Effectiveness – Indications about recovery rates

By providing this information in a centralized manner, the project aims to improve the efficiency of manual disassembly and/or pre-separation both in the case of repair/reuse and recycling. In the first case, this would allow for more cost-effective repair/harvesting of components; in the second case, better pre-processing is expected to lead to higher quality of recycled fractions.

The development of the platform is an iterative process during which both the content and form will be developed in consultation with manufacturers, recyclers and reuse centres in order to ensure that it meets the needs of all parties concerned.

Use and benefits

The RIC platform will serve as a central platform for sharing information between manufacturers and recyclers/reuse parties in a standardized format. It will provide guidance to perform working steps in a sound manner as well as options to improve existing workflows and processes. Further, based on the information that is Included in the RIC, recyclers will be supported to comply with legal requirements. In addition the detailed background information will support strategic decision processes as well as government authorities to develop effective policies.

The product specific disassembly guides as well as the guides for preparation for reuse will open new business opportunities to recycling facilities.

52. MUNICIPAL WATER/WASTEWATER AGENCY SERVICES: SHIFTING FROM LINEAR TO CIRCULAR

Steven Sherman ✉

Abstract

Municipal water/wastewater agencies play an essential role in community well-being. Traditionally, municipal water/wastewater agencies have followed a linear (“take, make, dispose“) mode of thinking based on resource extraction. Often, the model follows this form: a public agency transports water (frequently over great distances) and delivers it inexpensively and without restrictions to customers, who use it liberally once and then discharge it to the wastewater treatment facility, where the public agency treats and discharges it (often without further economic use). Among other issues, water/wastewater agencies use enormous amounts of energy. Drinking water and wastewater systems account for nearly 4% of U.S. energy usage, and emit 45 million tons of greenhouse gases annually.

These core service providers must transition to circular economy modes of thinking and programming in order to meet emerging 21st century needs. Some leading municipal water/wastewater agencies in the U.S., notably the East Bay Municipal Utility District (EBMUD) in California have begun the long shift toward a more circular approach.

EBMUD’s wastewater operation has gone from being a major purchaser of electricity to becoming North America’s first publicly-owned wastewater treatment facility that is a net producer of renewable energy, using anaerobic digestion of food waste and conversion of biogas to electricity. In addition, it produces soil products, nine million gallons per day of recycled water, and offers a way (through acceptance of brine wastewater) for California’s key agricultural production area (the Central Valley) to begin to manage the harmful build-up of salt in the region’s soil.

Traditional key service providers, such as water/wastewater agencies, can better address 21st century needs by extensively incorporating circular approaches to the definition of issues, articulation of goals, identification of opportunities, and development of feedback loop-based programs that support environmental and economic sustainability.

Keywords: wastewater, food waste, renewable energy, anaerobic digestion, water conservation, soil products, recycled water, circular economy.

Introduction

Municipal water/wastewater agencies play an essential role in community well-being. Traditionally, municipal water/wastewater agencies have followed a linear (“take, make, dispose“) mode of thinking based on resource extraction. Often, the model follows this form: a public agency transports water (frequently over great distances) and delivers it inexpensively and without restrictions to customers, who use it liberally once and then discharge it to the wastewater treatment facility, where the public agency treats and discharges it (often without further economic use). Among other issues, water/wastewater agencies use enormous amounts of energy. Drinking water and wastewater systems account for nearly 4% of U.S. energy usage overall, and emit 45 million tons of greenhouse gases annually (U.S. EPA, Reference #1). Water and wastewater utilities are typically the largest energy consumers in municipalities, often accounting for 30-40% of total energy consumed by municipal governments (U.S. EPA 2012).

These core service providers must transition to circular economy modes of thinking and programming in order to meet emerging 21st century needs. Some leading municipal water/wastewater agencies in the U.S., notably the East Bay Municipal Utility District (EBMUD) in California have begun the long shift toward a more circular approach, embracing the themes of greenhouse gas reduction, resource conservation, public health protection, and environmental protection.

This paper highlights these aspects of resource conservation and circular economy at EBMUD, with focus on production of renewable energy and soil products using anaerobic digestion of otherwise wasted solids and liquids.

Shifting from Linear to Circular

20th Century Outcomes

The widespread adoption in the 20th century of indoor plumbing, centralized water storage, treatment and delivery, and wastewater treatment helped to propel significant changes throughout society. Within a relatively short span of time, the following effects and after-effects came to become so commonplace that earlier times became almost unimaginable:

- Abundant, clean, safe drinking water and flush toilets became available via indoor plumbing in most dwellings and buildings.
- Major attention began to be paid to cleaning up rivers, lakes, and coastal waterways, and preventing pollution, starting in 1970s.
- The public health benefits of general access to clean water and wastewater treatment accelerated population growth and urbanization.

Public water and wastewater treatment agencies tended to follow a model that typified linear aspects:

- Resource method: extractive; single use, then disposal
- Approach: mechanistic; non-market
- Cultural style: bureaucratic paternalism
- Values: compliance; certainty; hierarchy.

The following description is a broad brush, somewhat simplistic look at their activities. They gained exclusive rights to extract water from mountainous areas, rivers and lakes; built large-scale systems for storage, treatment and delivery of potable water, and developed centralized, linear treatment systems for wastewater. In the process, they:

- used considerable non-renewable energy in conveying and treating water and wastewater;
- focused on increasing water supply (for one-time use) over conservation and recycling;
- did not effectively reuse soil nutrients present in wastewater;

- focused on complying with environmental regulations instead of on achieving higher standards of excellence;
- did not actively partner with businesses and the public to stimulate a circular economy.

21st Century Needs

To meet the challenges of global warming, conflict over natural resource and energy access and use, soil conservation and agricultural productivity, and creating sustainable economic activity that is circular in nature, water/wastewater agencies must re-examine their mission and function, and shift and expand their approaches to the delivery of essential community services. In brief, within the context of a systems approach, the following areas need more concerted attention:

- Energy: conservation; renewable energy production, use and sale
- Water: conservation; recycling
- Soil: soil amendment production; protecting agricultural productivity (salt management)
- Community Engagement: interactive identification of issues and opportunities
- Market-driven Solutions: pursuit of excellence and circular economic activities (supported by effective public policy)

Public water/wastewater agencies can develop circular economic services to meet emerging challenges and opportunities.

Circular Economy Services

The following water/wastewater agency services, among others, mesh well with a circular economic framework:

- Renewable Energy Production: Anaerobic digestion of liquid and solid residuals, including domestic sewage and food and beverage processing byproducts, to generate renewable energy (biogas converted to electricity), captured heat, and renewable transportation fuel.
- Water Conservation: Water agencies can structure their services, partnerships, and rates so that they become their community's leading champion of water conservation and cascading use of water for multiple purposes (beyond dams for hydro-electricity, water storage and recreation).
- Soil Products Production: Wastewater agencies can generate soil products for agricultural use, whether through co-digestion with domestic sewage (subject to debate) or through dedicated digestion of food/beverage processing residuals.
- Recycled Water Production: Wastewater agencies can use sophisticated systems to develop and deliver non-potable, recycled wastewater to industrial customers and for landscaping purposes.
- Salt Management: Wastewater agencies along coasts can be an outlet for the growing concentration of environmentally damaging salts in agriculturally fertile valleys (e.g., California's Central Valley) that do not drain well.

Case Study: East Bay Municipal Utility District

The East Bay Municipal Utility District (EBMUD) is a publicly-owned, publicly-operated water and wastewater agency centered in Oakland, California. It conveys water from distant mountains to approximately 1,300,000 customers and provides wastewater treatment service to approximately 650,000 people. The wastewater treatment facility abuts San Francisco Bay.

EBMUD is located in an area of the U.S. that has a high concentration of leading environmentally-minded educators, researchers, activists, policy makers, and entrepreneurs. As a result, EBMUD has started to engage in activities that support a broader circular economy. Below are some examples:

Renewable Energy Production and Production of Soil Amendments: EBMUD began co-digesting piped sewage with trucked septage and liquid food waste (initially, fats, oils, and grease) approximately 10 years ago, in order to derive monetary value from otherwise stranded or underused assets (excess digestion capacity). In 2012, EBMUD became the first wastewater treatment plant in North America to produce more renewable energy onsite than is needed to run its facility. Baseline usage is approximately 5 megawatts, and average generation now exceeds 6 megawatts. The facility has about 11 megawatts of installed electrical generation capacity, and recovers and re-uses waste heat from the digestion process (combined heat and power). In a short period of time, EBMUD's wastewater operation has gone from being a major purchaser of electricity to becoming a net supplier of renewable electricity.

Anaerobic digestion of food waste reduces the volume of materials that might otherwise create methane pollution when buried in landfills, and repurposes these materials for use as renewable energy and soil products.

EBMUD accepts various otherwise wasted materials for anaerobic digestion, including:

- Fats, oil, grease
- Septage
- Beverage industry process waste (notably, wineries, breweries, soft drinks, dairies)
- Industrial food processing waste
- Animal processing waste
- Commercial food waste (restaurants, hotels, coffee shops, bars, grocers, etc.)




In addition, EBMUD accepts trucked wastes that do not contain, or are low in, organic matter, such as brines, industrial process water, and construction site water.

Combined, annual revenue from this program topped $10 million in fiscal year 2014-2015, consisting predominantly of tip fees. A secondary source of revenue comes from the sale of surplus electricity to EBMUD's public neighbor, the Port of Oakland, which has growing needs for renewable energy to power ships that, in response to environmental concerns about diesel emissions, must switch diesel power off ("cold-ironing") and use local power while in port. (San Francisco Chronicle 2011) Residual digestate is used (at a negative price) as alternative daily landfill cover or as a soil amendment on non-food-crop land.

Going forward, EBMUD seeks to process up to 200 tons per day of commercial food waste, which has net energy value of well over one megawatt, generated mostly from within one hour's drive of the facility. The vision is grand, but local, with local sourcing, local production, and local end use. Additional end products are under consideration, especially compressed natural gas (CNG) for vehicle fuel. Renewable CNG, the only negative carbon-intensity fuel made in California, potentially could be used for powering vehicles that deliver food waste to EBMUD. Dedicated digestion of food waste (without sewage) may allow for broader uses of the residual digestate, such as a component of compost that is certified for use in organic farming.

Challenges in expanding this program abound. For example, from a sourcing perspective, low landfill tip fees and surcharges, weak enforcement of existing source separation policies, and lack of bans on landfilling of food waste means that food waste continues to be, at approximately 15%, the highest single source of waste in landfills in California. (California Integrated Waste Management Board 2009) Not more than 5% of food waste in the U.S. is composted or digested; almost all is disposed. (U.S. Environmental Protection Agency 2015) In addition, few wastewater treatment plants in the U.S. have large-scale operating experience with the anaerobic digestion of food waste, which means that the industry remains in a nascent stage in the U.S., although interest and activity is growing. (U.S. Environmental Protection Agency 2014) Technical challenges include the removal of contaminants and grit, management of gas production, and stability of digester chemistry. Other challenges include the requirement by key feedstock suppliers that their food waste not be used as alternative daily landfill cover or co-digested with sewage sludge, such that the resulting digestate does not contain wastewater biosolids, which can limit its use and marketability; developing dedicated digestion and de-watering is expensive. Finally, low prices for natural gas and electricity dampen demand for renewable energy.

An overarching key lesson about EBMUD's renewable energy production efforts is that it needed to adopt a market-oriented feedback loop mentality, with price flexibility, tolerance for unknowns, willingness to experiment and to make mistakes, and ingenuity in sourcing materials, in order to achieve success.

EBMUD has embarked on expanded programs in water conservation, recycled water production and acceptance of salt-laden wastewater from key agricultural areas. These programs are described briefly below:

<u>Water Conservation</u>: EBMUD is in an geographic area that is prone to periodic severe drought, including today. In 2015, EBMUD achieved a 23% reduction in water usage, through a combination of tiered pricing, penalties for overuse, education, technical assistance, lawn conversion and appliance rebates, and discounts on water-saving devices.

<u>Recycled Water Production</u>: EBMUD produced about 9 million gallons per day of recycled water in 2013. It is used primarily for industrial cooling towers and landscaping. Demand is growing for recycled water, which helps to stabilize potable water supply during droughts. EBMUD's goal is to recycle 14 million gallons per day by 2020, saving enough of EBMUD's potable water to supply nearly 100,000 customers per day.

Salt Management: Excessive water usage without available drainage of deposited salt that is present in the water means that key agricultural areas in California's Central Valley face long-term environmental, economic, and public health risks of considerable magnitude. EBMUD annually receives over 10 million gallons of this briny wastewater, which it discharges to brackish San Francisco Bay, and is engaged in evaluations to determine how much more it can receive using current methods. This is an example of the steward of one ecosystem helping to mitigate environmental problems in another ecosystem.

Conclusions

Traditional key service providers, such as water/wastewater agencies, can better address 21st century needs by extensively incorporating circular approaches to the definition of issues, articulation of goals, identification of opportunities, and development of feedback loop-based programs that support environmental and economic sustainability. The East Bay Municipal Utility District (EBMUD) is one example of how water/water agencies can begin to shift from linear to more circular approaches and services. EBMUD's wastewater operation has gone from being a major purchaser of electricity to becoming North America's first publicly-owned wastewater treatment facility that is a net producer of renewable electricity. In addition, it produces soil products, nine million gallons per day of recycled water, and offers a way (through acceptance of brine wastewater) for California's key agricultural production area (the Central Valley) to begin to manage the harmful build-up of salt in the region's soil.

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