WORLD RESOURCES FORUM

NATURAL RESOURCES

Sustainable Targets, Technologies, Lifestyles and Governance

Christian Ludwig | Cecilia Matasci | Xaver Edelmann | Editors

2015

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Foreword

The sustainable management of Natural Resources is a key factor for the further prosperous development of mankind. Conservation as well as intelligent use of the available resources will be required. Innovative approaches are needed. Indicators are necessary to measure the status and set reasonable targets to protect the environment. Decoupling economic growth from an ever increasing demand of natural resources will be essential to be successful on the long-term. Clean technologies have to be resource and energy efficient. Materials cycles should be controlled and closed if appropriate, i.e. if technically and economically feasible, and if the environmental impact can be reduced. Circular economy thinking is an important step towards a sustainable governance of natural resources.

The World Resources Forum (WRF) is the science-based platform for sharing knowledge about the economic, political, social and environmental implications of global resource use. WRF promotes innovation for resource productivity by building bridges among researchers, policymakers, business, SMEs, NGOs and the public. Like this WRF helps to come up with innovative approaches and new solutions to tackle the many challenges. According to above needs and tasks, the WRF 2015 conference has put the focus on the following four topics:

1) Circular economy and decoupling
2) Technological innovation, business and finance
3) Targets, indicators, and benchmarks for resource use
4) Lifestyles and education

This book presents the best papers of WRF 2013, held in Davos, Switzerland (October 6-9), and WRF 2014, held in Arequipa, Peru (October 19-22). In both conferences many high standard scientific presentations have contributed to the interesting discussions. After an evaluation, the best papers have been selected and authors were invited in spring 2015 to update and resubmit a revised version to be considered in this book. The book is now arranged to make an additional contribution to the topics which are in the program of WRF 2015, Davos (October 11-14) and is accordingly structured in four parts (I-IV).

Before any actions can take place, reasonable targets need to be set. In this context new and important methods, indicators and benchmarks are presented in Part I. The sub-chapters focus, but not exclusively, on resources efficiency for different materials and goods, energy efficiency, climate change, and food footprint.

Often no or little incentives are needed for taking action if the development can be justified with economic benefits. Technological innovations will be implemented, if money can be earned or current costs can be reduced. Therefore, in this book, Part II is dedicated to technological innovations, as well as to business and finance. Reducing the impact on climate change, implementing renewable energy, preserving land resources, and valorizing wastes and byproducts are discussed.

Of course our society is a relevant factor in increasing resource efficiency. Changing lifestyles and strengthening education are corner stones in making the necessary change towards a sustainable resource management system. In Part III we discuss social transition, innovation, responsibility, as well as building up awareness for an efficient and conservative use of resources through education.

Last but not least, if the market does not solve the problems, if the individual goodwill and responsibility is not sufficient to reach the targets, then new approaches and planning have to be developed, and if necessary the rules have to be changed to achieve a sustainable circular economy. With this perspective Part IV is dedicated to circular economy and decoupling. Political decision making and successful governance towards a sustainable resources management have to include all interdisciplinary aspects discussed in this book.

I am pleased to see that the content of this book contains many valuable information that contributes to the important discussion for the development of a worldwide sustainable resource management system.

I thank the Managing Director of WRF**, Bas de Leeuw**, for his collaboration and the Editorial Manager **Géraldine Mercier** for her technical assistance during the realization of this book.

In the name, also of my co-editors **Dr. Cecilia Matasci** and **Dr. Xaver Edelmann**, I wish you a pleasant reading.

Prof. Dr. Christian Ludwig
WRF Scientific Chair

Villigen PSI, September 2015

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Part I

Targets, Indicators and Benchmarks for Resource Use

1. From scarcity to security: a rationale for resources in LCA

Lucia Mancini, Serenella Sala and David Pennington

Abstract

In order to tackle the challenges related to natural resources, the European Union has launched the flagship initiative "Resource Efficient Europe", which aims at reducing use of resources and improving the efficiency of their use. Other policy initiatives have been started to ensure the access to resources over time. Environmental impacts associated with resource extraction and use should be evaluated through integrated assessment. Life Cycle Assessment (LCA) is a well-established methodology for assessing the impacts of goods along the supply chains. In the context of LCA, however, there are several impact assessment methods, so far limited to assessing the depletion potential. Based on the results of an expert workshop and other research activities carried out in the Joint Research Centre of the European Commission, this paper provides a theoretical rationale for the development of a comprehensive impact assessment of resources.

Keywords: natural resources, life cycle assessment, critical raw materials, impact assessment, resource depletion

Introduction: EU policy background on natural resources

Availability of natural resources and access to them are two fundamental conditions for the well-being of human societies. In the last decades global resource extraction and consumption has drastically increased, as well as prices of many commodities and raw materials.

In order to tackle the challenges related to natural resources the European policy has included in its growth strategy for the coming decade the Flagship Initiative "Resource Efficient Europe" (EC - European Commission, 2011a). It addresses all the types of natural resources (minerals and metals, water, air, land and soil, marine resources) and aims at reducing use of resources and improving the efficiency of their use in all the key economic sectors.

The access to resources and the security of supply of raw materials has also become a high-priority theme in the political agenda of EU. The Raw Material Initiative (EC - European Commission, 2008) and the more recent communication "Tackling the challenges in commodity markets and on raw materials" (EC - European Commission, 2011b) have been launched in order to ensure the access to resources and avoid supply shortages, which would reflect on loss of competitiveness.

In order to prioritize the policy initiatives in the field of resource security, the EC identified the materials facing the highest supply risk with respect to the whole economy. 14 Critical Raw Materials (CRM) deserving better monitoring and further potential policy actions (EC - European Commission, 2010a) have been listed.

Fig. 1 provides an overview of the EU policies on natural resources, depicting the resource types that are addressed. The Resource Efficiency Initiative takes into account all kinds of resources, and includes a specific communication on Bioeconomy (EC - European Commission, 2012), thus focusing on renewable biological resources. the Flagship Initiative on Industrial Policy (EC - European Commission, 2010b) and the Raw Materials Initiative focus on minerals, metals, fossil fuels and secondary materials. However, biotic raw materials will be also taken into account in future updates and development of the methodology for the identification of CRM.

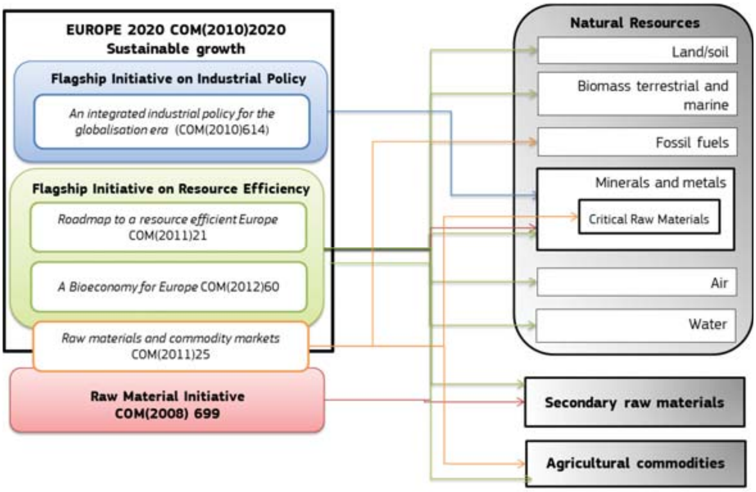

Figure 1: *Framework of EU policy addressing different resource categories*

In order to ensure sustainability, environmental impacts associated with resource extraction and use should be evaluated through integrated assessment.

Both the Flagship Initiatives “Resource Efficient Europe” and “An Integrated Industrial Policy for the Globalization Era” mention the necessity of considering “the whole life-cycle of the way we use resources, including the value chain” in order to appropriately address trade-offs.

Life Cycle Assessment (LCA) is an internationally standardised methodology for assessing the impacts of goods (both products and services) along their supply chains. Resources consumed and emissions that are associated with the supply, use, and end-of-life of products are compiled in the inventory phase. These are then further assessed in terms of environmental, health, and resource related burdens through the use of indicators in an impact assessment (LCIA).

LCA essentially aims at making better informed decisions related to products and services in both business and policy.

Natural resources in Life Cycle Assessment

Natural resources are usually accounted for in LCA in the impact category “resource depletion” under the area of protection “natural resources”, which takes into account the issue of present resource use on future availability (EC - European Commission, 2011c). Resource scarcity is therefore the rationale on which this category is commonly based in current practice, while different methodologies are used in this context.

Several impact assessment methods exist for resources, having different theoretical approaches and different comprehensiveness in terms of number of resources modelled.

This variety of methods depends on the different problem definitions underpinning the resource impact category. Some methods consider the decrease of resource itself as the main problem to be addressed and therefore are based on reserves and/or extraction rates (e.g. Guinee, 2002); others measure the decrease of useful world reserve of energy/exergy (e.g. Dewulf et al., 2007) or the potential changes in costs/energy requirements for extracting resources with lower quality (e.g. Goedkoop & Spriensma, 2001; Müller-Wenk, 1998; Steen, 1999) ((EC - European Commission, 2011c; Klinglmair, Sala, & Brandão, 2013).

In the context of the European Commission recommendation for life cycle impact assessment (EC - European Commission 2011a), an impact assessment method for resources has been selected after having analysed the existing methods against a set of criteria related to model’s scientific robustness and comprehensiveness. These recommendations have been produced in order to foster reproducibility and comparability of results especially in those application contexts where it is vital to ensure the same level playing field among participants (e.g. organizations engaged in environmental communication; consultants providing advice to policy makers).

The CML-IA method (e.g. Guinee, 2002), measuring the resource depletion as the ratio between resource extracted and reserves, was considered as the most appropriate for minerals and fossils resources. However, there is still need of increase capability of methods to address a number of elements still barely considered by existing models. A recent review and models’ comparison (Klinglmair et al., 2013) underscores that LCIA methods consider resource depletion in a relatively limited way, focusing mainly on the extraction of a resource from the natural environment and the consequential decrease in its future availability for human use.

Furthermore, the relative ranking of resource resulting from different models is very variable, even if the modelling has in general a narrow focus.

Schematically, the area of improvements in current models entails: a. the need of widening the number of resources modelled (e.g. many CRM are not included yet); b. developing a common framework that allow resource comparison when fundamental properties and use are different (e.g. fossil, water, biotic etc); c. addressing biotic resources and the associated carrying capacity; d. assessing the effects of recycling and anthropogenic stocks in the overall evaluation of availability; e: addressing more socio-economic and strategic issues such as security of supply and criticality; f; introducing the assessment of the effect of scarcity in natural environment, which can vary extensively from a resource to another.

The debate on resource depletion indicators: workshop results

The workshop “Security of supply and scarcity of raw materials: a methodological framework for sustainability assessment” was organized in November 2012 by EC- JRC, Sustainability Assessment unit (Mancini, De Camillis, & Pennington, 2013). It aimed at discussing the potential of supply chain analysis in supporting a resource policy. In particular, it questioned if and how the consideration of resource criticality in LCA would provide policy makers and industry with more relevant information on how to manage CRM more efficiently, and how to combine resource security strategies within sustainability assessments. The workshop gathered together different stakeholders (from academia, industry, consultancy and government) and two different scientific communities, from sustainability assessment and from criticality assessments. Between others, the following research questions have been posed to the experts:

- Which should be the scope of a LC impact assessment method for resources?
- Should resource security of supply be part or be considered in supply chain sustainability assessment?

A broad consensus was expressed within the workshop participants in recognizing that current indicators for resources in LCA have strong limitations and that different aspects related to resources should be taken into account, in addition to scarcity. It was therefore concluded that a re-design of the impact assessment methods for resources in LCA is needed, and that it should not be limited to depletion aspects.

Two different positions emerged concerning the issue of integrating aspects like security of supply in LCA; this position are based on different perspectives about the elements that should be gathered in the impact assessment of resources, and therefore to the scope of LCA itself:

- Some participants advocated that LCA is a strictly environmental assessment methodology, and therefore all economic aspects connected with resources should be left outside the LCA; according to this view, aspects like security of supply could be assessed in, e.g., Social LCA.
- Other participants supported the idea that LCA is a tool for assessing impacts of different nature and it shouldn't limited to environmental aspects; the consideration of the real resource availability (including, e.g, supply risk, anthropogenic reserves, trade barriers, etc.) would provide decision makers with more reliable information. The inclusion of resources in LCA was strongly supported due to the fact that it includes the compilation of physical input flows (while, e.g., Social LCA do not).

During the discussion was generally recognized that scarcity based indicators have already an economic nature and that resource depletion is not properly an environmental issue, since it would affects mainly human societies. It was acknowledged, however, that depending on the type of resource some impacts on ecosystems can also occurs (e.g. in case of resources that support habitats or are part of biogeochemical cycle). However, current impact assessment methods do not take into account these aspects.

Outlook: aspects to take into account in a comprehensive impact assessment of resources

Resource use is a core issue in sustainability assessment which involves either the social, economic and environmental spheres. Restricting the impact assessment to a single aspect (e.g. depletion) provides a partial picture of the problems linked to resource use and the related indicators have strong limitations when are used to support decision making.

After reviewing the existing methods for impact assessment, and gathering the conclusions of the "Security of Supply and Scarcity of Raw Materials" Workshop, a list of aspects that should be taken into account in a comprehensive impact assessment of resources can be compiled (fig.2). These aspects can be clustered into five groups:

1. Aspects related to resource properties:
    - Thermodynamic loss due to the resource extraction
    - Renewability
    - Involvement in biogeochemical cycles
    - Role as natural habitat (e.g. freshwater/forest) and in natural habitats (as part of overall landscape)

2. Aspects related to resource availability
   - Biophysical availability
   - Resource scarcity (which relates availability with extraction rates)
   - Resource criticality (which includes also the geo-political constrains)
3. Technological constrains/opportunities
   - Recyclability
   - Substitutability
4. Environmental impacts
   - E.g. damages on habitats, landscape, etc.
5. Socio-economic impacts
   - E.g. impacts derived by increased competition for resources and resource conflicts

In this rationale aspects linked to resource properties and availability are prior to the resource use, while the technological aspects and the impacts regard the post-use phases. However, technological aspects can influence the prior aspects, e.g. recycling can affect resource availability.

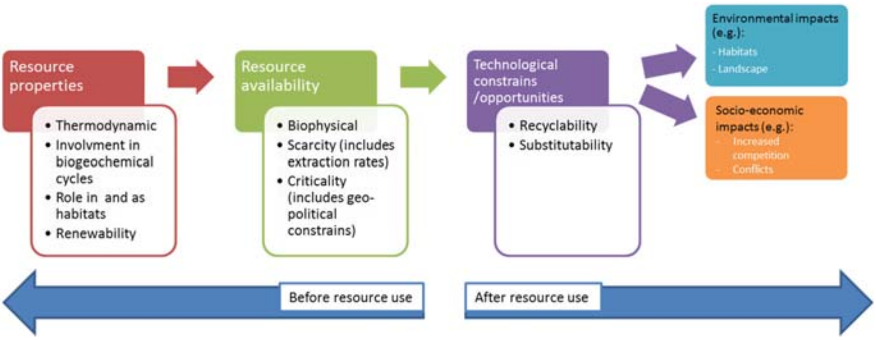

Figure 2: *A rational for a comprehensive impact assessment of resources: aspects to be considered*

Conclusions

While LCA a well-established methodology for assessing environmental impacts along the life-cycle of goods, the assessment of resources has still rooms for methodological improvement, beyond the assessment of the depletion. A consensus on the impact assessment methods is still lacking. Indicators assessing resource properties, resource availability, technological constraints and opportunities as well as environmental and socio-economic impacts should be developed. Indeed, the inclusion of social and economic aspects is debated, even if – as emerged during the Workshop discussion – most of the current methods already have an economic base.

In this paper we argued that the assessment of natural resources should be comprehensive, and should gather different aspects, from scarcity to criticality and also environmental impacts due to extraction. We illustrated a rational including the relevant aspects for the sustainability assessment of resources and that could be used for future development of an impact assessment method for resources.

2. A global collaborative accounting network to calculate the resource use of products and services

Klaus Wiesen, Justus von Geibler, Stephan Wallaschkowski,
Marie-Sophie Wilde, and Robert Mostyn

Abstract

To promote sustainable buying decisions there is the need to better inform consumers about the environmental burden of products. Today, environmental product assessment is mostly conducted by the producer itself or external consultants using life-cycle inventory data from databases. These assessments are time consuming and, due to inconsistent system boundaries, scopes and time references, results are difficult to compare. Despite the progressive developments of information and communication systems, reliable, accurate, and up-to-date data for assessing the resource use of products and services is still lacking.

Within the European project myEcoCost (runtime 2012 - 2015) a novel methodology will be introduced that defines a global collaborative network of resource accounting nodes. It will provide a means of accounting for and expressing usage of natural resources at the micro level for products, services and technologies to inform economic actors on environmentally relevant information with dynamically calculated, near real-time figures. Relevant and timely data is linked to the financial accounting and passed from supplier to customer recursively through the whole value chain to produce ecological costs for each product or service. Output of the project will be a sound and straightforward resource accounting system and accompanying ICT and software elements to demonstrate the myEcoCost approach in a proof-of-concept prototype.

This paper outlines the myEcoCost vision and presents interim results with respect to the resource accounting methodology.

Keywords: resource efficiency, eco-accounting, material footprint, llife cycle assessment, ecological costs

Introduction

Promoting green products and resource efficiency have become two major policy objectives in Europe. In this regard, the European Commission's "Roadmap to a resource efficient Europe" (European Commission 2011, p. 3) proposes the following milestone for the business sector: "All companies […] can measure and benchmark their lifecycle resource efficiency. Economic growth and wellbeing is decoupled from resource inputs and come primarily from increases in the value of products and associated services." Today, however, measuring resource use at product level suffers from data quality and consistency. There are several measurements, and data are often out of date or estimated using different assumptions.

The myEcoCost project (www.myecocost.eu), funded by the EC, addresses this data quality issue by developing an integrated and automated bottom-up eco-accounting system to inform economic actors on environmentally relevant information with dynamically calculated, near real time figures. Besides designing a straightforward and comprehensive resource accounting methodology in line with international environment policy objectives, the project aims at developing key Information and Communication Technology and software elements to demonstrate the myEcoCost-infrastructure in a proof-of-concept prototype. In conjunction these components form the nucleus of the myEcoCost system, promoting consumer decision-making moving towards more sustainable lifestyles and a resource based economy.

The work in the myEcoCost project is organised into seven work packages (WPs), as illustrated in the Figure 1 below.

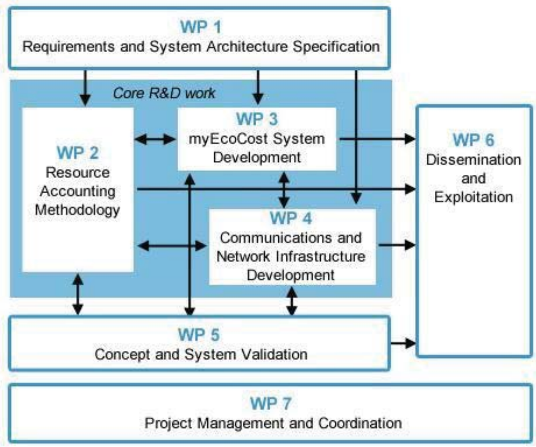

Figure 1: *Illustration of the myEcoCost project structure*

WP 2, 3 and 4 form the core research and development work. They deal with the resource accounting methodology definition in the environmental and economic domain and with a complete software and communication technology development and integration process. These WPs were preceded by the specification of the myEcoCost system and architecture in WP 1 started from application scenarios. A comprehensive crosscutting set of validation and demonstration activities in WP 5 will complete them. Supported by reliable project coordination (WP 7), these key thematic and development activities feed into a strategic and ambitious dissemination and exploitation programme (WP 6).

This paper focuses on interim results of WP 2. Firstly, the myEcoCost system will be described and its envisaged functions will be illustrated. Based on the functional requirements we secondly argue for the Material Footprint as a core indicator for resource use with large-scale applicability in the global economy. Finally, conclusions on further steps and outstanding research challenges are drawn.

The myEcoCost approach

The myEcoCost approach involves embedding an eco-accounting module alongside existing financial accounting systems. It will deal with the receipt of all goods and services accepted by the business, the aggregation and allocation of overheads, the calculation of ecoCost of freshly produced products, and the transmission of ecoCost information to the customer. Each ecoCost accounting module will represent a node in an Internet-based global collaborative network of resource accounting nodes whereby each one communicates through the myEcoCost servers with the next node in the value chain. This way, a data flow of ecoCosts will be introduced, accompanying the money flow which is currently the dominating unit of Information in most accounting systems. Timely and relevant data is passed from supplier to customer recursively through the whole value chain, running in parallel to the existing flow of goods and services, until it reaches its final destination, the end consumer (Figure 2). Here, the data can be used amongst other things for assessing personal environmental footprints. With the myEcoCost approach regular and consistent eco-accounting can be implemented into businesses of all sizes and thus sow the seed for a new era of eco-awareness in everyday life regarding resource consumption.

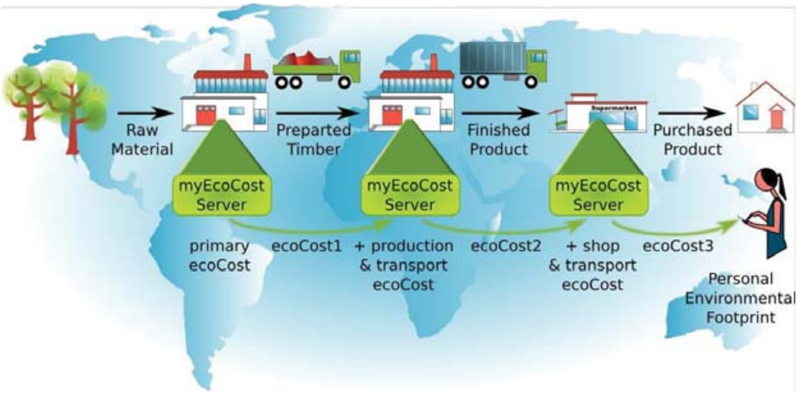

Figure 2: *Environmental data flow in the myEcoCost resource accounting system (Geibler et al. 2013)*

With respect to the natural resource accounting, a specific accounting framework will be developed based on a review of existing eco-accounting methodologies, e.g. from ISO 14040 (International Standard Organization 2006), JRC (Joint Research Centre 2010) and other scientific sources (Schmidt-Bleek et al. 1998), aiming at pragmatic and highly automated data gathering. Since financial accounting is obligatory, regardless of country or company size, and as many companies have not yet implemented an environmental accounting system, events and data from the well standardized bookkeeping and cost accounting systems may be employed as a driver for ecoCost calculation. Together, they can provide linked yet distinct monetary and physical (resource) data sets. The registered data can include:

- Quantities of raw materials and pre-productions by means of incoming invoices
- Amounts of energy/water consumption and waste disposal
- Primary material consumption of processes/machines/cost centres
- Overhead material consumption of cost centres (e.g. administration, staff)

Being connected to and driven by the existing financial bookkeeping and cost accounting system, the ecoCost accounting module benefits from all the checks, balances, procedural safeguards and regulatory frameworks (best practice) provided by that system, thereby fitting into an existing and well known quality control infrastructure.

Functional requirements and indicator selection

As a key step in the myEcoCost project, requirements for the myEcoCost system have been identified for the purpose of illustrating its breadth, depth, accuracy, and applicability (myEcoCost Consortium 2013). The requirements gathering process included a series of business scenarios that spanned the natural course of product flows, from primary production on a farm through the chemical supply chain and manufacturing of household cleaning products, a service based company, to retailer and to consumer over the logistics chain.

Based on the insights provided by the scenario exploration, a number of indicator sets have been screened for their suitability concerning the myEcoCost system requirements: The indicators must be comprehensible, easy to communicate and allow for an estimation of resource efficiency and environmental impacts. Furthermore there is a need for good data availability and low complexity in indicator assessment to ensure long term and broad applicability of the myEcoCost system. Additionally the used indicators should be highly aggregated and politically relevant to be compatible with the macro level link to sustainable limits.

As the myEcoCost approach is designed to focus on resources, it was decided to choose one resource indicator as core indicator (which can be supported by other supplemental indicators, particularly the carbon footprint). The indicator screening[1] resulted in the choice of the Material Footprint, covering the use of abiotic and biotic resources as well as soil erosion (Lettenmeier et al. 2009). Compared to Life Cycle Assessment methods (usually requiring a combination of several midpoint and endpoint impact assessments), the Material Footprint is much easier to monitor as it uses simple and robust allocation rules close to material flow analysis. Moreover, it is the only measurement covering all abiotic and biotic resources including unused extractions.[2] As resource use also allows drawing conclusions on the emerging outputs, this indicator covers major environmental impacts as well; a detailed and complex analysis of emissions becomes disposable. Finally, the Material Footprint allows for good comparability by illustrating all categories in a single indicator, thus promoting quick buying decisions based on one overall value. Through its transparency and the use of the image of the "ecological backpack" it is intuitive and understandable, which supports credibility among non-experts and end-users. However, the myEoCost structure will be flexible and in future further indicators may be calculated as well. To show linkages with output indicators, the prototype for instance will allow ascertaining the carbon footprint.

MIPS as accounting framework for calculating the Material Footprint

Description

The Material Footprint as an input oriented indicator is part of the MIPS-concept (material input per service unit) developed by the Wuppertal Institute for Climate, Environment and Energy (Schmidt-Bleek et al. 1998). As a tool MIPS is able to measure the overall material and energy consumption of a certain product or service throughout its entire lifecycle. It can be described by the formula:

$$MIPS = \frac{MI\ [kg]}{service\ unit}$$

The material input (MI) sums up the quantity of materials (in kg or t) needed for performing a particular function. They are related to the service unit. The service unit is a measure for a

[1] This screening examined 17 different indicators and was based on a RACER-analysis, which is a tool recommended by the European Commission that defines "relevant", "accepted", "credible", "easy to monitor" and "robust" as important characteristics an indicator has to fulfill (Best et al. 2008).

[2] These categories also provide a strong link with costs for material consumption. Thus, an increase of resource efficiency within these categories may lead to a decrease of material costs (ADL, ISI, Wuppertal Institute 2005).

specific value of output, which has to be suitably defined in each individual case (e.g. kg of product, miles of transportation per person).

The calculation of MIPS is divided into biotic material, abiotic material, air, water and soil erosion. The MIPS concept requires no impact assessment phase as such, which is compared to LCA (ISO 14040/44) also a big reduction of complexity. As all emissions and related impacts result from the extraction of natural resources one can say that a reduction of the in-puts can also lead to a decrease of all emissions and environmental impacts. Hence MIPS allows a rough approximation of the overall environmental burden.

The Material Footprint as a subordinate indicator is defined as the sum of biotic, abiotic and erosion parameters (Lettenmeier et al. 2009). For a valid Material Footprint assessment it is essential to have reliable data on the whole product or service value chain. That’s why generating a collaborative network of resource accounting nodes is a central subject of the myEcoCost project to address the data quality issue. Nevertheless, to bridge gaps during the inventory phase, LCA databases and resource data from Wuppertal Institute will be used additionally.

Calculation example

To demonstrate the Material Footprint calculation within the myEcoCost project we apply as an example a typical end-consumer supermarket product: potato pancakes, with the value-added-steps farming, packaging, transport and processing.

	Farming	**Packaging**	**Transport**	**Processing**
Example processes	Soil treatment (fertilising, irrigating, planting), agricultural machinery, sheds, chemicals (fertilizer, pesticides, inorganics)	Raw materials (Polyethylene), process energy	Fuel, lorry	Raw materials (like oil, flour, onions), process energy, packaging
Abiotic	0.10 kg/kg	0.344 kg/kg	0.007 kg/kg	2.46 kg/kg
Biotic	1.06 kg/kg	0.004 kg/kg	-	1.06 kg/kg
Soil erosion	0.22 kg/kg	-	-	1.46 kg/kg
Material Footprint	**1.38 kg/kg**	**0.348 kg/kg**	**0.007 kg/kg**	**4.99 kg/kg**
		6.725 kg/kg		

Tableau 1: *Material Footprint calculation of 1kg of potato pancake production (based on assumptions).*

Tableau 1 shows the biotic, abiotic and soil erosion parameters for the production of one kg pan-cake potato of a leading German potato pancake supplier, estimated from the resource in-puts of its main production steps. Each step represents a company, which gathers the prod-uct specific inventory data. Based on that data, the Material Footprint for each value-added step will be calculated separately and then attached to the resulting product receipt. Sum-ming these values up along the value chain yields the overall Material Footprint (Fig. 3). A comparison with the Material Footprint of alternative offers (e.g. regional or organic productions) allows consumers to make profound buying-decisions regarding ecological aspects.

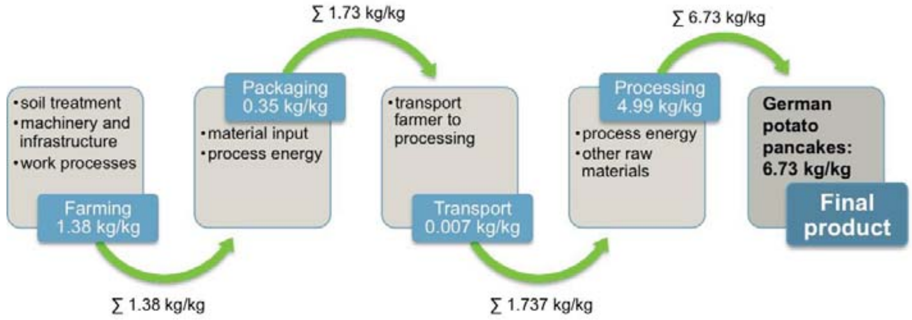

Figure 3: *Value chain in potato pancake production*

Conclusions

The myEcoCost approach gives a means to an automated and cost effective accounting system for natural resources with timely, relevant and highly reliable information on the environmental burden of products and services. Due to its large-scale applicability in the global economy, the myEcoCost system could build the nucleus of a new era of eco-awareness in everyday life. It would enable consumers and producers to make more informed choices and promote the transition towards more sustainable lifestyles in a resource constrained economy.

Within this system, the Material Footprint has been selected as a sound and straightforward indicator for measuring resource consumption. It can be easily calculated by coupling the existing financial bookkeeping and cost accounting systems with a physical resource accounting system (myEcoCost) and thus can be employed by companies, regardless of country or size. Optionally it can be linked with output indicators such as the product carbon footprint.

As the full implementation of the complete system is out of scope of the project, a series of demonstration scenarios have been identified for the purpose of illustrating the different aspects of the system. These are planned to be implemented for the pilot demonstration at the end of this project, namely:

- Farm production demonstration: to involve a business at the beginning of the supply chain with very specific characteristics with respect to ecological accounting and direct usage of natural resources;
- Industry production demonstration: to involve a business in the middle of the supply chain having an indirect usage of natural resources;
- Retail and consumer demonstration: to involve a business at the end of the supply chain and the consumer, whose acceptance and usage is key to the success of the whole system.

Acknowledgements

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3. Resource efficiency in industrial SMEs: Drivers and effects on productivity

Lourdes Fernández Felipe-Morales, Marcos Alegre Chang, Denisse Cotrina Escalante and María del Pilar Céspedes Dávalos

Abstract

In many developing countries, SMEs are the backbone of economic and industrial activity, contributing to approximately 75% to industrial activity. With increasing resource prices, social awareness and environmental regulations, it is becoming difficult for SMEs to keep the same pattern in the use of energy, water, and material resources for production while remaining competitive in the market. However, some of them have implemented resource efficiency in cleaner production measures. A research project supported by IDRC was developed to explore drivers and relevant effects on resource efficiency in SMEs which are adapting the transition to a greener economy in two cities: Lima and Buenos Aires. As part of this study, we aim to explore industrial SMEs in Lima City. A survey of 307 SMEs was applied to stratified random samples which represent Lima industrial zones. Important factors were identified using Logit dichotomous model, it was applied to find out which are statistically significant. We concluded that some categories of good practices, efficiency energy and waste management are identified statistically significant to explain the decrease cost of production due to implementing environmental actions in industrial SMEs in Lima. These results and the Map of Resource efficiency SMEs will provide inputs for policy makers.

Keywords: SMEs (Small and Medium Sized Enterprises), RECP (Resource Efficient and Cleaner Production), green industry, environmental sound technologies, green economy

Introduction

In the new global context of climate change impacts, humanity is facing an economic growth with natural resource-intensive use. In many developing countries, small and medium enterprises (SMEs) are the backbone of economic and industrial activity, contributing to approximately 75% to industrial activity. With increasing resource prices, social awareness and environmental regulations, it is becoming difficult for SMEs to keep the same pattern in the use of energy, water, and material resources for production while remaining competitive in the market (UNEP). SMEs are often high polluters due to obsolete technology in their small-scale operations and/or the lack of efficient end-of-pipe pollution control systems. However, some of them have implemented resource efficiency in cleaner production measures. In this context, there is a need to research drivers and effect on productivity in SMEs that have implemented RECP practices.

A research project supported by International Development Research Centre (IDRC) was developed to explore drivers and relevant effects on resource efficiency in SMEs which are adapting the transition to a greener economy in two cities: Lima (Centro de Ecoeficiencia y Responsabilidad Social - CER/Grupo GEA) and Buenos Aires (CENIT) in 2013-2014. As part of this study, we aim to explore drivers and effects on resource efficiency in industrial SMEs in Lima City capital of Peru.

Peru is a country with an economic growth characterized by the intensive use of natural resources. SMEs account for 99.5% of all enterprises in the country, which are responsible for 49% of national GDP (INEI, 2013). However, in addition to the positive aspects, these companies cause environmental damage and risks to human health from the environmental pollution they generate. The highest concentration of manufacturing companies is located in Lima City, representing 54.1% (74,513) of the total sector in the country. Lima has a large industrial manufacturing sector with high environmental pollution and territorial conflicts in which SME's coexist with residential areas (CER- Grupo GEA, 2010).

In Lima City, urban growth has generated degradation in the quality of water, soil and air (Grupo GEA, 2010). The main contaminant found in Lima City remains the particulate matter PM10 and PM2.5 (SENAMHI).These pollutants are dispersed from south to north-east wind action, which could be contributing to increased respiratory disease in the exposed population districts in those areas (DIGESA, 2011). The rate of presence of atmospheric dust in Lima City was 14.1 tk2 / month, which is alarming because the World Health Organization (WHO) recommends a limit of 5 tk2 / month.

Industrial environmental critical areas in Lima

Areas with the highest incidence attributable to industrial pollution have been generated mainly by a lack of urban planning and zoning in Lima City. This has led to an emerging city like Lima, with more than 9 million people, which have grown leaving several industrial areas inside. Within this context, industrial environmental critical areas are those that identify the risks to the environment that exist in a given geographic area because the environmental risk is directly proportional to the areas where the highest concentration of industries is shown. In these areas, from an industrial approach, should be considered the activities performed by firms through managing resources, processes, raw materials used, both its quantity and its environmental characteristics and discharges, emissions and waste produced (Blas, 2013).

Resource efficiency and productivity

Resource Efficiency is about doing more with less - creating more value with less impact. In business terms, focusing on resource efficiency means process optimization (Tasmania) through the reduction of energy or water consumption, as well as through a reduced amount of waste generated in the production processes, companies can: reduce costs of production and improve resource efficiency (SMEToolkit). For most industries, increasing resource efficiency in production is not simply a response to environmental objectives. It has become a core determinant of economic competitiveness and sustainable growth (SERI, 2009). Further, Resource productivity is a measure of how productively resources are being used to produce the desired products and/or services. It improves as less water, energy, and materials are used per unit of product output of the company (UNIDO, 2010).

Exist different productivity definitions that can be used for different purposes and each have its own advantages and disadvantages. For UNIDO, productivity is a measurement that shows how much product it produces per unit of resource used. It is important to note that increases in production do not necessarily result in increased productivity. If an increase in production is brought about with an increase in resource use (materials, water and energy), production will have increased, but productivity will have remained constant or may even have decreased (UNIDO, 2010). For this study we consider productivity defined as decrease production cost with improves environmental quality.

Hypotheses of the study

From the above literatures and experience of CER the proposed hypotheses of this specific study are:

H1: There is a significant relationship between good practices and costs of production due to implementing environmental actions in industrial SMEs.

H2: There is a significant relationship between clean technologies (accessories) and costs of production due to implementing environmental actions in industrial SMEs.

H3: There is a significant relationship between energy efficiency and costs of production due to implementing environmental actions in industrial SMEs.

H4: There is a significant relationship between water efficiency and costs of production due to implementing environmental actions in industrial SMEs.

H5: There is a significant relationship between waste management and costs of production due to implementing environmental actions in industrial SMEs.

H6: There is a significant relationship between creation new product lines and costs of production due to implementing environmental actions in industrial SMEs.

Research Methodology

A survey type of research “Greening SMEs in Lima-2014” was designed by CER/Grupo GEA in order to investigate several drivers and factors such as clean technology, employment, gender, competitiveness, productivity and public policy to affect manufacturing SMEs. The questions were adopted from previous literature and experience of Peruvian Cleaner Production Centre (CER). Cross-sectional qualitative information was collected through the survey corresponding to the year 2014. For this specific study, we used the data available of this survey to test the hypotheses mentioned before. Also we used the definition of SMEs according Peruvian Low that relates the category of SMEs to amounts of annual sales.

The study population was determined on the basis of data of the enterprises registered 2012 in Lima City by SUNAT. Also, SMEs have been considered according to Peruvian law and the belonging to one category of non-primary manufacturing (15-37) as the International Standard Industrial Classification (ISIC) (INEI, 2010). The selected SMEs were 5,946 which 5,731 (96.4%) were small and 215 (3.6%) medium. Other criteria considered in the study were that SMEs operate and have their facilities (plants) in Lima City, also have production processes of transformation, not services. These criteria only have filtered when the data was collected and validated.

Stratified and proportion random sampling (Bernal, 2006) was used, because it ensures the reduction of selection bias and sampling random subgroups or strata of a given population. The manufacturing sector analyzed comprising 22 sub-sectors. The sample size was defined as five stratums. These stratums are composed by 38 districts according to (existing and potential) industrial areas of Lima (MarketView, 2012). The sample size type was by proportion (Bernal, 2006). According to the results of the pilot survey to 30 companies, the event occurs that SMEs perform some environmental practice related to water and / or energy is 70% while 30% do not make any (Bohorquez, 2011). The sample size obtained is 307 divided in five stratums. The data was collected from 320 Manufacturing SMEs. A random sample of 2,032 SMEs was invited to participate in a face to face interview survey, generating a 15% response rate. However, only 307 questionnaires were used for analysis as determination sample size. Direct interviews were used to collect information from the owner/manager in the company. The implementation of the surveys was conducted with support from the Ministry of Industry.

Empirical analysis

We considered for this specific study only SMEs that had implemented some environmental action related to energy and / or water. The result was 229 valid observations that is representing 75% of the total sample. We test our hypotheses with binomial regresion analyses. The unit of analysis is the individual firm. Dependent Variable: Cost of production. For cost of production we construct a variable with increase cost of production (0) and decrease cost of production (1). Independent Variables: Implement resource effiency: Perception of favorability of implementing environmental actions in terms of factor conditions and the presence of manufacturing industries (Porter, 1998) is assessed by asking respondents for their perceptions of industrial SMEs in Lima City. We ask SMEs managers to assess the implementing environmental actions for their firms of following items: good practices, clean technology (accessories), energy efficiency, water efficiency, waste management and creation of new product lines. Each category mentioned has several options. For each option, we construct a variable with implemented (1) and not implemented (0). See Table 1.

Results

We used descriptive statistics (graphics) to describe the basic features of our data in this study. Based on the data of 229 SMEs that implemented RECP, we used a pie chart to see the manufacturing sectors distribution of them: Metalmechanics 22.3%, textile 22.3%, food 9.2%, furniture making 7% and plastic 5.2% (See Figure 1). Also, we can see in Figure 2 the manufacturing sectors distribution of SMEs that implemented resource efficiency and decrease the cost of production (20% of the SMEs that implement resource efficiency).

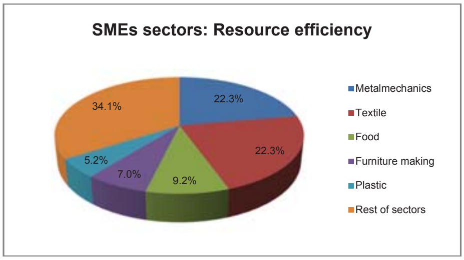


***Figure 1**. SMEs sectors: Resource Efficiency*

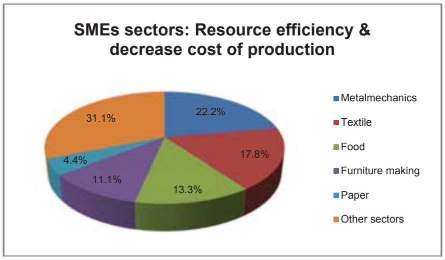


***Figure 2**. SMEs sectors: Resource Efficiency and decrease cost of production*

Econometric estimations were made with qualitative information and developing a binary choice model that fits with the data available from the survey “Greening SMEs in Lima-2014”. The dichotomous choice model Logit is used to analyze problems associated with decision making when SMEs face a binary process lesson. In order to see the significance of the variables in each category for implementation of clean technologies, good practices and waste management, a model Logit is estimated grouping the variables according their categories. After making the estimations for each category, seven variables were selected for the final estimation and evaluate the impact in the cost of production due to implementing environmental actions in industrial SMEs in Lima City. (See Table 1).

The Logit model is estimated, as can be seen in the Table 2, with the seven variables selected, four of them achieve a 90% of significance. The variables that can explain some effects in the costs of operations after their implementation are: GEP3, EE2, WM2 and WM3. The variables GEP3 and WM3 present a positive effect in decreasing the costs of production; however, the variables EE2 and WM2 present an opposite effect.

Three tests were made for choose a model that better adjust with the variables proposed, Likelihood Rate Index (LRI), Akaike's Information Criterion (ACI) and Bayesian Information Criterion (BCI). Because the information is designed as a binary choice mode, the models evaluated were the Probit and Logit models. According to the Table 3, comparing the Logit model with the Probit model, for the first case, the ACI and BCI are lower, and also the LRI is closer to 1, wich means that the model that adjust better with the information is the Logit model.

Category	Variables	Description
Good Environmental Practices	GEP 3	Turn off the light and / or PC to non-working hours
Clean Technologies (Accessories)	ACC 1	Change to energy saving light bulbs
Energy Efficiency	EE 2	Compressors
Water Efficiency	WE 1	Industrial effluent treatment
Waste Management	WM 2	Not implemented waste
	WM 3	Material reuse in production
	WM 4	Material reuse in new product

***Table 1**: Description of variables*

Variables	β	Sig. Z
GEP 3	0.6141805	0.082
ACC 1	0.5184237	0.227
EE 2	-1.033186	0.051
WE 1	0.6806702	0.110
WM 2	-0.9130962	0.087
WM 3	0.8165462	0.059
WM 4	-0.6349	0.248
Pseudo R2 = 0.0779 Sig. X = 0.0135		

***Table 2**: Results of Logit model according significance*

Tests	Logit Model	Probit Model
Log-Likelihood	-104.63406	-104.64002
Akaike's Information Criterion	225.2681	225.28
Bayesian Information Criterion	252.7379	252.7498

***Table 3:** Tests for model adjustment*

Map of Resource efficiency SMEs in Lima City

Based on the "Map of industrial environmental critical areas in Lima City" developed in the main study which shows the air pollution, three basin rivers an industrial areas, we have developed the “Map of Resource efficiency SMEs in Lima City”. We plotted the location of SMEs that have implemented resource efficiency and SMEs that have implemented resource efficiency and decreased their cost of production due to implementing environmental actions. SMEs have a relative concentration in Lima Cercado industrial zone and surroundings. In this area, metalmechanics and textile sectors are more representative (see Figure 3).

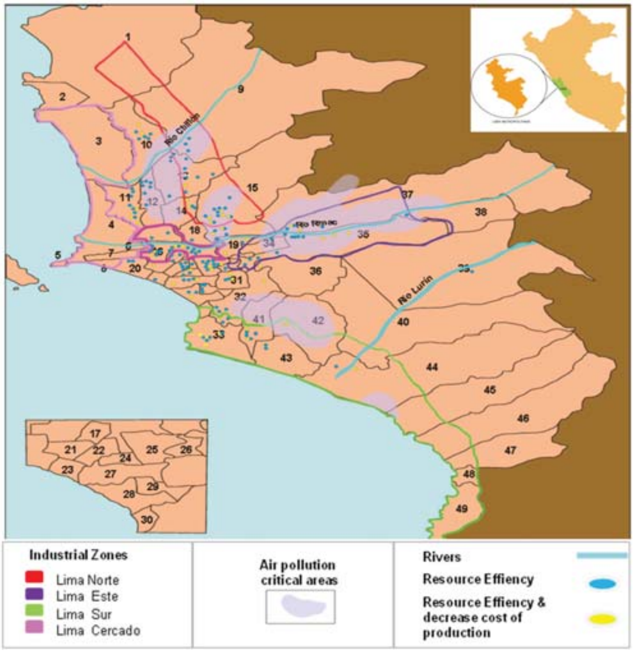


***Figure 3**. Map of Resource efficiency SMEs in Lima*

Discussion

This outcome reveals an interesting reading as far as the drivers and relevant effects on resource efficiency in SMEs of Lima City is concern. The results from the estimation of the Logit model, as can be seen in the Table 2, have positive and negative effects in the costs of production. The positive effects reflect a decrease in cost of production. The positive effect of GEP3 variable explains that the perception of the implementation of good environmental practices in SMEs have a direct effect in the reduction of their costs. The turn off the light and / or PC to non-working hours in short time can explain the reduction of energy cost in short term. Further, the WM3 variable shows a positive sign, which means that there is a perception that a reuse of material/waste brings more efficiency in the production process, so the costs can decrease due to a better utilization of resources in short term.

On the other hand, the negative effects reflect an increase in the cost of production. The effect negative of the EE2 variable explain the perception that the implementation of compressors in the production process implies an increase in the costs of production since is an expense that is made in a short term. It is worth mentioning that depending on the kind of manufacturing sectors, compressors could be the main machine in the production process. Also, the WM2 variable has a negative effect; this means that not implementing any type of waste management increases the costs of production due to the SMEs are not being efficient with the waste in production process.

A closer look deep into the context exposes the basic reasons behind the results shown before. Manufacturing SMEs of Lima City normally have implemented measures that reduce energy cost in short term. If SMEs implement measures (clean technologies) that require changing machines or equipment which means a significant cost of inversion, they perceive it as an increase in their cost of production regardless the cost reduction in the long term.

Waste management is a RECP practice that the SMEs do not usually implement. Despite of this, SMEs consider that not implementing waste management measure increase their production cost. The most of SMEs sell their waste and perceive that this type of action reduces their cost of production. However, SMEs that use material reuse in their production, perceive a decrease in their costs. It has a direct effect on the quantity of resources used in their production. In the case of water efficiency, is not a significant RECP measure to explain a decrease cost of production. Nevertheless, it is worth mentioning that some of SMEs not use water in their production process, and the water cost is significant inferior than the cost of energy in Lima.

Conclusion

Metalmechanic and textile sectors are those which SMEs have implemented RECP and perceive the decrease their cost of production. Some categories of good practices, efficiency energy and waste management are identified statistical significant to explain its impact on the productivity and in the improvement of the business were drawn. These effects in the productivity have been perceived as short term. SMEs have a relative concentration in Lima Cercado industrial zone and surroundings. In this area, metalmechanics and textile sectors are more representative. These results and the Map of Resource efficiency SMEs will provide inputs for policy makers to design programs to improve the productivity and the perception of it among the SMEs.

4. Cascading as a suitable strategy to improve the resource efficiency of wood consumption?

Karin Höglmeier, Gabriele Weber-Blaschke, Klaus Richter

Abstract

Increasing the efficiency of resource use has become a major strategy in the pursuit to limit the impacts of resource utilization on the environment. A cascading utilization of resources is generally regarded as a suitable means to achieve such a limitation. The goal of the presented study was to determine whether a cascading utilization of wood is beneficial for the environment compared to the use of primary wood. Additionally we examined the change in efficiency of wood consumption by cascading.

We conducted life cycle assessments (LCA) of two scenarios of wood cascading and of reference systems using primary wood resources. The “basket of benefit” method was applied to compare the systems. The efficiency of resource use could be compared by accounting for the necessary wood inputs into the systems.

We found that the environmental impacts assessed by LCA were slightly smaller in both cascading scenarios compared to the use of primary wood. Wood was used more efficiently in both cascading scenarios with savings of more than 10 % in one case.

Further studies are necessary to arrive at generalized conclusions regarding a cascading utilization of wood. However, our findings indicate positive effects on environmental impacts and efficiency of resource use.

Keywords: cascading, waste wood, life cycle assessment, system expansion.

Introduction

The European Commission states increasing resource efficiency as a major strategy for generating economic growth, to fight against climate change and limit the adverse environmental impacts of resource use. In addition, the finite nature and instability of fossil resources supply has led to a heightened awareness concerning the importance of renewable resources such as biomass for an additional and a more sustainable supply for both energy-related and material use.

However, also wood as a renewable resource is not unlimited with respect to volumes and regional availability. To ensure a stable supply for multiple purposes and to meet the growing demands, the efficiency of the use of wood as a resource has to be enhanced and additional strategies for the management of the wood have to be identified.

A suitable means suggested both by science and legislative bodies to achieve a more efficient resource use is the concept of cascading, meant as the sequential use of a certain resource for different purposes.

The aim of our study was to analyze, whether using wood in cascades creates ecological benefits and is more efficient compared to using only primary wood resources.

Material and Methods

Life cycle assessment (LCA) of wood cascade chains by application of the “basket of benefit” methodology

In order to assess and compare the ecological performance of different options of producing both products and energy out of wood, full life cycle assessments according to the standards ISO 14040 and ISO 14044 were conducted.

The basis for the calculation was the database ecoinvent in version 2.2 (*Frischknecht & Jungbluth 2007*) for all background data, data concerning wood production in the forest, transportation and consumption of electricity and other fossil fuels. Modeling of the wood based panels (particleboard and oriented strand board (OSB)) was based on *Rüter & Diederichs (2012)*.

Sorting and processing of the waste wood was modeled by using data provided by several waste wood facilities in southern Germany.

The production processes of particleboard and OSB out of 100 % waste wood were modeled based on literature data as these processes are currently not state of the art in Germany.

Incineration in a 6.4 MW Combined Heat and Power (CHP) plant with effective flue gas cleaning was assumed for the production of energy out of primary wood and for the end-of-life of all wood products (waste wood).

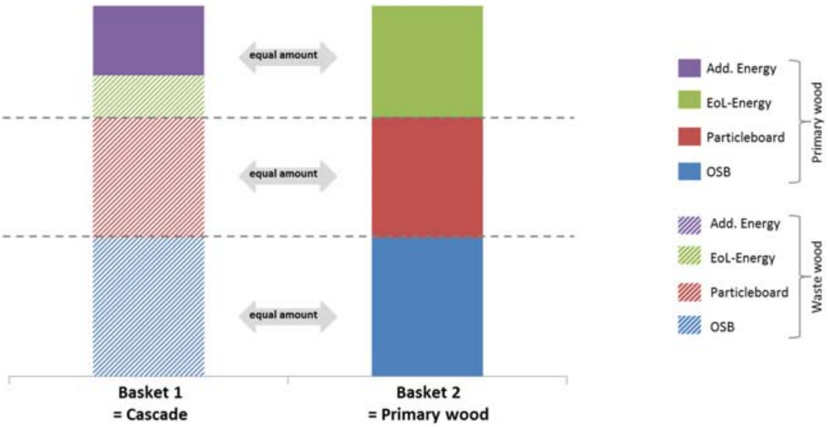


Figure 1: *Scheme of a possible basket of benefit composition.*

A precondition for comparing two systems by LCA is the equality of goods and services produced by the systems under study. Especially when dealing with multifunction processes, achieving this precondition can be challenging (*Ekvall & Finnveden 2001, Fleischer 1996*). Multifunction processes are activities which either produce more than one product or a process which provides more than one service. Especially in the field of waste management this is quite common as many processes provide energy or secondary resources additionally to the main service, namely “disposal” of the waste.

This is also the case in the system we investigated in our study. By a cascading utilization of waste wood, different wood products are provided, followed by an energy production step at the end of the cascade. In order to compare this system to the production of functional equivalent products out of primary wood, the same "benefit" has to be achieved by both systems.

A methodology suitable to compare complex systems by LCA is the "basket of benefit" approach as described by *Fleischer (1996)* and applied by *Bystricky et al. (2010)*. It enables different products to be comprised into one functional unit. Imaginary baskets which all contain products equivalent to this same functional unit can thereby be compared. Figure 1 gives an overview of the possible composition of two comparable baskets, filled with different, yet functional equivalent goods from waste wood and primary wood.

Efficiency of wood consumption

In addition to the impacts on the environment assessed by LCA, we compared the differences in wood consumption by the waste wood cascades and the reference systems with primary wood in order to determine if cascading, indeed, substantially increases the efficiency of resource use.

Systems under study

The starting point of each cascade was 1000 kg of waste wood at the sorting facility. We investigated two different scenarios, both comparing a cascading utilization of waste wood to products out of primary wood.

The scenario "Full cascade" contained the production of OSB, followed by collection and processing of the waste wood and the subsequent use of the waste wood for particleboard production (Fig. 2).

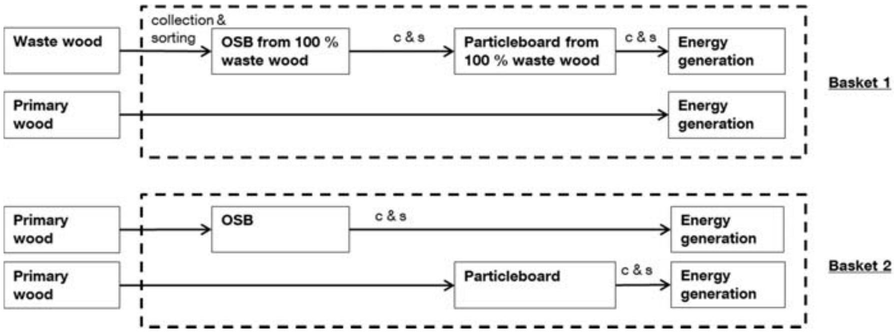


Figure 2: *Cascading system (top) and reference system (bottom) for the scenario "Full cascade".*

The scenario "Particleboard" comprises three cycles of particleboard production and subsequent collection and sorting of the waste wood (Fig. 3).

The chosen end-of-life option in each case was incineration with energy recovery in a CHP plant.

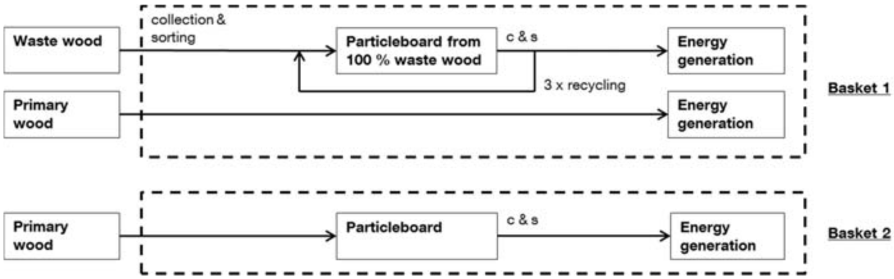


Figure 3: *Cascading system (top) and reference system (bottom) for the scenario "Particleboard".*

Results

Life cycle assessment of waste wood cascading

Figure 4 summarizes the differences (in %) of four impact categories. In both scenarios, the baskets containing the products provided by cascading of waste wood create slightly fewer environmental impacts compared to the baskets containing the products from primary wood. The differences range between 2 % and 11 %. The impact category "Global Warming Potential (GWP)" does not contain carbon stored in the wood products as it can be assumed to be the same for both baskets in the respective scenarios and therefore, would have no impact on the assessment of the systems.

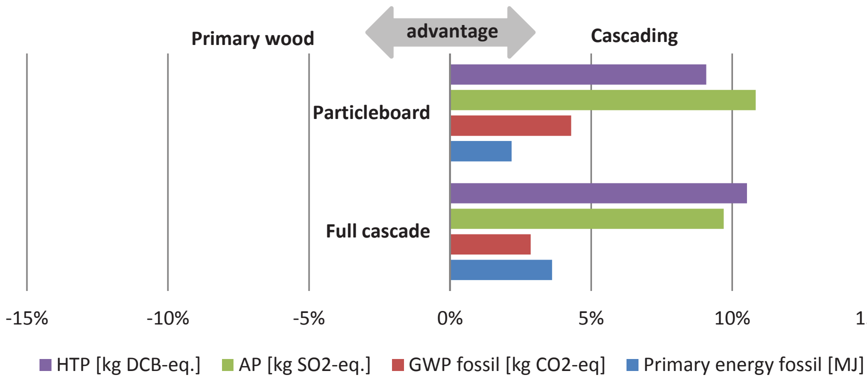


Figure 4: *Results of LCA of cascading of waste wood in comparison to products from primary wood (differences between the two systems in percent).*

Resource efficiency of wood consumption

The two baskets compared in each of the scenarios provide equivalent benefits as they contain the same amount of the different products (boards, energy). Therefore, differences in resource consumption to produce the basket contents directly indicate differences in the efficiency of resource use. Table 1 summarizes the amounts of waste wood as well as primary wood required for each of the baskets, including losses during production, sorting, chipping and transportation. No relevant difference was obtained for the "Full cascade" scenario. However, the cascading utilization of wood leads to a substantial increase in resource efficiency in the "Particleboard" scenario (-11.3 % wood consumption).

	Baskets of benefit	
	Cascading utilization	**Primary wood**
Scenario “Full cascade”	**[kg dry]**	
Waste wood	1186	--
Primary wood	583	1804
Sum	**1769**	**1804**
Scenario “Particleboard”		
Waste wood	1456	
Primary wood	1278	3082
Sum	**2734**	**3082**

Table 1: *Wood consumption of the different baskets for the scenarios “Full cascade” and “Particleboard” in kilogram dry matter.*

Discussion

The results of the life cycle assessments indicate that a cascading utilization of wood leads to no significant reduction of environmental impacts when comparing the cascading utilization to functionally equivalent primary wood products. The main reason for this outcome is the similarity of the two product systems. Differences mainly occur in the amount of energy needed for drying the wood inputs of the boards and the changes in the production process when using waste wood as raw material for OSB. *Gärtner et al. (2013)* found significant benefits of cascading when comparing wood cascading to non-wood products.

Another fact explaining the minor difference between the systems is the environmental impact caused by collection and sorting of waste wood in the cascading systems. It is in a similar range to the impacts caused by growing and logging of primary wood. Therefore, no significant differentiation is possible.

The chosen approach of modelling system expansion with the “basket of benefit” method also contributes to the insignificant results. When only considering the production phase of the wood boards, cascading leads to significantly reduced environmental impacts. Yet, due to the differing amounts of energy produced during the end-of-life phase in the waste wood and primary wood systems, production of additional energy has to be accounted for in order to fill the cascading “basket” and achieve functional equality. The way this additional amount of energy is produced (type of fuel, plant specifics) has a remarkable influence on the results. In the presented case study we assumed production from only primary wood.

The comparison of wood utilization efficiency indicates an advantage for the production of particleboard out of waste wood. The higher quality requirements concerning the input material of OSB in comparison to particleboard, which lead to higher losses and therefore a higher overall input of wood, is one of the main reasons attributing to this advantage.

Conclusion

We conclude from this presented study that a cascading utilization of wood cannot per se be assumed to be environmentally beneficial. The benefits in our scenarios were minor, however apparent in both scenarios. When additionally taking into account the efficiency of resource use, especially the most common case, the application of waste wood in particleboard, leads to promising improvements in resource efficiency.

The “basket of benefit” methodology enabled the comparison of the different production systems in LCA. However, it has a significant influence on the results, as the effects of the choices of how the system expansion is carried out, could disguise the actual effects caused by a cascading utilization of waste wood. The calculated scenarios are not sufficient to allow a general conclusion regarding the ecological benefits and efficiency of cascading. Inclusion of more products as well as further options regarding energy generation and end-of-life treatments are necessary. Equally important would be a comparison of different solutions dealing with the difficulty in comparing multifunction processes in order to determine their influence on the results.

5. Investigating the life-span of cork products through a longitudinal approach. Overview of two years results

Ana Carina Pereira, Helena Pereira

Abstract

Products with long life-spans are generally acknowledged to have a significant contribution towards sustainability. This paper provides an overview and discussion of the two years results of a longitudinal study performed with users and several cork products. The research aimed to tackle the process of life-span, and the results include: 1) the identification and interrelation of the aspects influencing the life-span of the products; 2) the evolution of life-span over time; and 3) new knowledge and guidelines arising about the material. Overall, most cork products are still being used, have a very good life-span, and most issues arising are material related.

Keywords: product life-span, users, longitudinal study, cork products and materials.

Introduction

Products with long life-spans are generally acknowledged to have a significant contribution towards sustainability (Meadows et al., 2004; van Nes, 2003; Vezzoli and Manzini, 2008; Cooper, 2010). Longevity is influenced by several factors, ranging from intrinsic product aspects, to user related, and socio-cultural dimensions of use. Materials are an influencing product feature, where technical and experiential aspects interact in the formulation of replacement decisions.

Cork is a renewable resource, the bark of the cork oak, and can be removed without a significant alteration of the vitality of the tree. These forests occur in the Mediterranean region and provide multiple important functions, such as preventing soil erosion and the protection of biodiversity (Pereira et al, 2009). In the context of cork, since re-growth is slow, the use of the material in long life-span products is particularly relevant as a resource conservation strategy (Pereira et al, 2011).

While the aspects influencing life-span have already been well identified in previous research (van Nes, 2003; van Hinte, 2004; Fisher, 2004; Evans and Cooper, 2010), the process of how these aspects are interrelated and evolve over time still deserves further attention. This understanding should be well captured through a longitudinal approach, and this paper provides a general overview of the outputs of such a study after 2 years of using the products, as well as a critical discussion on its relevance and implications.

Methodological approach

An explorative longitudinal study was performed with several cork products and users, to investigate their longevity. The sample includes 18 different products for household and personal use (plus some scale of each – two to six), and made of several cork materials. Information from users was collected at multiple moments over time through interviews and photographs. Amongst others, five influencing aspects were selected for a specific evaluation (1 - 5 quantification): performance, quality, durability, aesthetic appreciation, and attachment.

Results – 2 years

The study provided a wide variety of results. Overall, most cork products are still being used, have a very good life-span, and most issues arising are material related. After two years, users declared to be satisfied in 88% of the cases (product-user situations). Here only a general overview is provided, and which includes:

the identification and interrelation of the aspects influencing the life-span of the products;

the evolution of life-span over time; and

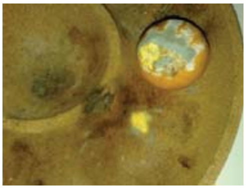
new knowledge and guidelines arising about the material.

Identification and interrelation of aspects influencing the products life-span

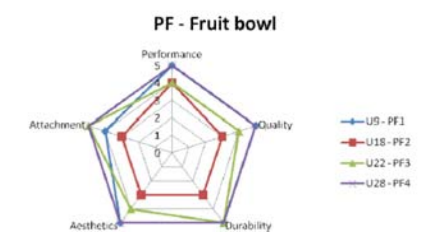
In the cases studied, the main aspects influencing product life-span were related with technical aspects of the products. These were often material related, and had repercussions in one or several of the parameters evaluated, such as quality or aesthetic appreciation. In a few cases the products life-span actually ended before the two years moment, but in others use continues despite significant changes in the product appearance.

This is the case of a fruit bowl (PF2-U18) where some reactions of the material to fruit interaction were found (image below). This was perceived mostly as a quality issue, which then had repercussions in performance, durability and aesthetics; this is illustrated in the interrelations graphic below. Although, these severe changes only happened in one out of four cases; in PF1-U9 and the others only some minor stains can be observed after two years of use. This also becomes clear by comparing the assessments of the four products in the chart below. Nevertheless, this suggests an opportunity for improvement.

Fruit bowl PF1 – U9



Fruit bowl PF2 – U18



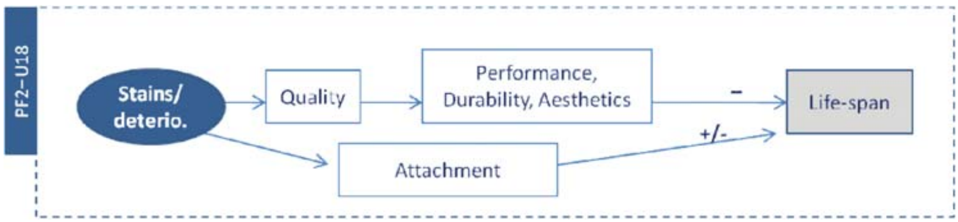


Figure 1: *Fruit bowl cases after two years: Images, evaluation chart, and interrelations graphic*

Besides technical issues which in a few cases actually lead to the end of life-span, there were also some cases of aesthetic depreciation influencing the assessments of the five aspects (variables), and which therefore has the potential to influence life-span negatively.

This happened namely in some personal use products such as the purse coins, but it is by no means perceived equally among users. For instance, in the case of the PK purse coins, while U11 observes dirt in the product surface, and which has a negative influence on aesthetics, U18 acknowledges this as an ageing process which may actually enhance the product appearance, or that at least does not depreciates it (images below).

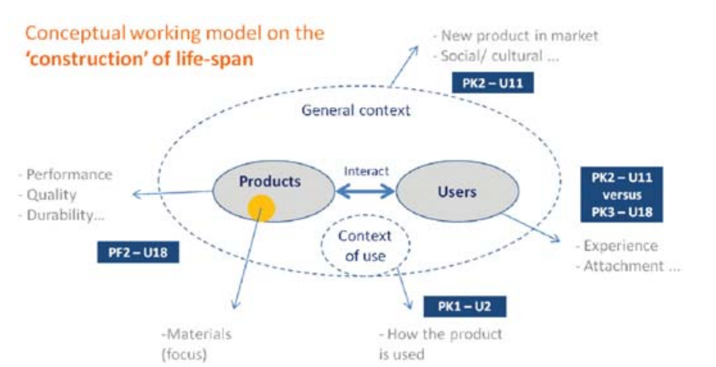
<table>
<tr><td></td><td rowspan="3">
</td></tr>
<tr><td>Purse coins PK2-U11</td></tr>
<tr><td></td></tr>
<tr><td>Purse coins PK3-U18</td><td>Examples of life-span influences at different levels in the model</td></tr>
</table>

Figure 2: *Images of PK purse coins after 2 years and placement of examples in the conceptual model*

In addition to mainly *product* or *user* related issues, there are also other contextual circumstances which may influence the life-span of the products. In the case of PK1-U2 a new *context of use* arose when the user acquired a new wallet. Since this was smaller, there was only space for the larger money purse, and the product being studied (PK purse coins) became obsolete. Furthermore, U11 using PK2 received a new similar competing product (*general context*), and now alternates use between the two purses; in this case the product still continues to be used, though with a lower intensity. These influences at different levels are graphically illustrated in the conceptual working model presented above.

Overall, it can be concluded that technical issues were the main aspect influencing the life-span of the cork products studied, but that other more soft or intangible issues such as aesthetic appreciation or contextual changes also have an important role and influence.

Evolution of life-span over time

With regard to how life-span evolved over time, this understanding is based on the visual differences observed in the products, and on the evolution of the assessments over time.

Evolution of differences observed – changes in the products visual appearance over time

In most products studied changes evolved gradually or continuously over time. Here examples of two products are given to illustrate this: these are a soap dish, made of a cork white agglomerate of small particles size (connected with a binder); and a keychain made of cork skin (where a thin layer of cork is attached to a supporting textile).

In the case of the soap dish deterioration (darker areas) occurred in two of the products (PC1 and PC3), and with serious implications for the life-span of PC1 (life-span ended at the 16 months moment). The others are still being used. Furthermore, by comparing the condition of the three products after 16 months or two years of use, it also becomes clear that the same product can have very different life-spans depending on users and contexts of use. While the life-span of PC1 ended after 16 months of use, PC2 still has a seemingly new appearance after two years of use, even though it was used differently and with some care (water was purred off after use in the bath). PC3 also started to get deteriorated but only later and to a lesser extent so far.

Soap dish	3 months	8 months	16 months	2 years
PC1-U5				(end of life-span at 16m due to deterioration – also crumbling on the side)
PC2-U9				
PC3-U23 and U27				

Figure 3: *Evolution of differences observed over time – soap dish*

In the case of the keychain, significant colour differences were observed in some cases already at the 3 months moment, and the more extreme ones are presented below. At the 3 m moment, the image of PJ1 shows a colour comparison of the inner and outer faces of the product, and in PJ6 the used product is compared to a new one. This darkened appearance continues to evolve or progress over time in these cases, but just slightly – the main difference was noticed in the first moment. PJ1 is also an example of deterioration with end of life-span after 16 months of use. The other cork skin products studied have also darkened gradually with use, but not as sudden as these examples of the keychain.

Overall, it can be concluded that in most cork products there was a gradual continuous evolution of the differences observed over time. Changes observed were often either related with deterioration, or with a darkened appearance, which was sometimes also referred to as dirt or ageing. In general most products exhibit a good condition after two years of use.

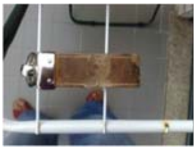
Key-chain	3 months	8 months	16 months	2 years
PJ1-U3				(end of life-span at 16m due to deterioration – ripped face as in image)
PJ6-U30				

Figure 4: *Evolution of differences observed over time – keychain*

Assessments – aggregated results (over 50 cases – product-user situations)

With regard to the evolution of the assessments of the variables, from an aggregated perspective the evolution is positive over time. In the charts below it can be noticed that most ratings are of [4] or [5] in all moments, and a shift from [4] to [5] evaluations occurred early in all of them, between the 3 and 8 months moments. Furthermore, despite some variations, after two years the assessments are relatively similar to those at the 8 months moment. Durability was the aspect with the higher assessments (of [5]) after two years of use. It seems that 2 years is already a good time-span for users to assess confidently these aspects. These results support the high levels of satisfaction and general appreciation of most cork products studied after two years of use.

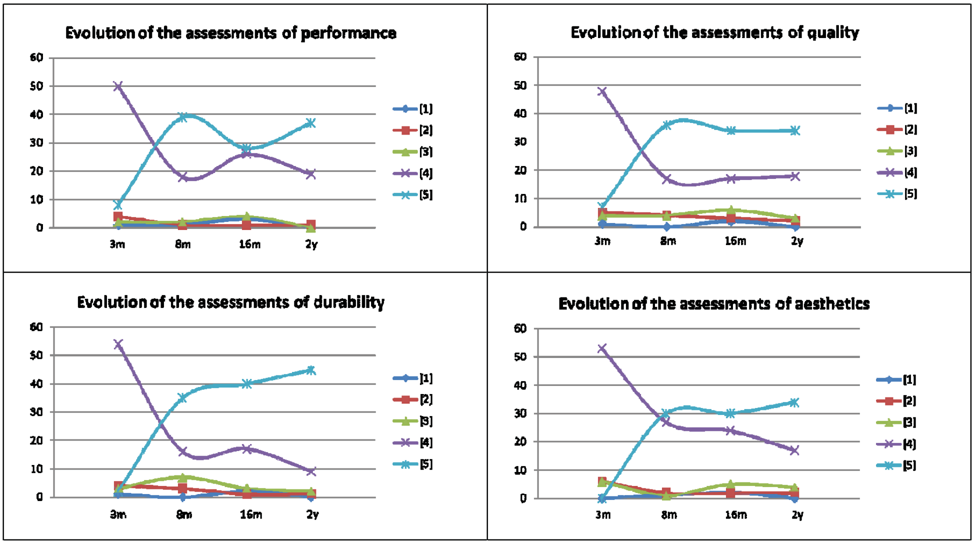


Figure 5: *Aggregated results; evolution of the assessments of the four aspects/ parameters*

New knowledge and guidelines arising about the material

Finally, from a material perspective, this study enabled the generation of new knowledge about these cork materials, which is relevant in a design context but not generally available. For instance, considering the examples of the previous section – the soap dish and keychain, it provided evidence of the susceptibility of cork materials with water interaction and towards darkening; these are opportunities for further research and improvements.

Overall, three general design guidelines arose from the analysis of the multiple cases:

The susceptibility of cork materials for surface changes during use should be expected and contemplated in the design as an ageing process. This may suggest being selective about certain applications or otherwise enhance some surface characteristics.

When applying derivative cork materials, one should take into account that cork properties change, fade, or become mixed with the ones of other constituent materials. These are composites and are therefore new materials as such, and with new characteristics/ properties (physical, chemical, aesthetical, biological, environmental…).

In cork products, corners and edges should be rounded to minimize signs of wear

Discussion

The fact that most issues arising were material related, emphasizes the need to apply materials appropriately, and reconsider new materials based innovations. The use of new materials in unconventional contexts can result in highly uncertain product life-spans.

Even though the methodological approach provided interesting results, such a longitudinal study is difficult to implement in a business context. For that purpose, a shorter study of e.g. one year should be more feasible, and may already provide interesting outputs.

Furthermore, taking into account the variability of the products condition after a certain period of time (soap dish), it is suggested that product life-span needs to be balanced/ articulated with other concepts such as Cradle to Cradle based on a pre-specified product life-span. While this might enable economic feasibility through constant material resource flows, collecting products in good condition should be counter-productive/ avoided, and may have a negative impact in the product-user relations, in particular for more soft intangible aspects such as aesthetics and attachment, which have the potential to amplify the use momentum.

Conclusions

The cork products studied have a very good life-span; after two years most are still being used, are in good condition, and are well assessed and appreciated by users. With regard to the aspects influencing the life-span of the products, most issues arising were material related. These were mainly technical aspects which should be improved, and there are also significant colour changes (darkening) which can influence aesthetic appreciation.

Furthermore, in most cases the life-span of the products evolved gradually and continuously over time. Despite significant visual changes, the evaluation of the products remained high. Therefore, it may be concluded that even though some cases require reformulations, most cork products studied ‘age with dignity’. In other words, the appearance of the products changes over time, but most continue to fulfil the expectations of the users.

Additionally, the approach provided new knowledge and guidelines about the cork materials. From the above, one may concluded that the longitudinal study provided valuable results, and an interesting insight into the process of product life-span.

6. Resource efficient product provision – Closing the resources loop for waste mobile phones and smartphones

Prof. Dr. Jan C. Bongaerts, MBA Nicoleta Gurita

Abstract

Scarcity of natural resources and supply chain risks represent one of today's most vital topics. 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 is predicted to reach 12 million tonnes in 2020 (Computer Aid International, 2010). WEEE is expected to increase by roughly 11% between 2008 and 2014 (European Commission, 2011). The paper analyses the monetary value of metals in mobile phones and smartphones sold during 2004-2013 in Germany, as well as the value of the valuable metals stock which is not being put to use. Furthermore, issues and challenges in the management of WEEE; in particular of mobile phone and smartphone waste streams with the goal of identifying the potential of closing the resources loop will be assessed.

Keywords: WEEE, Germany, waste mobile phones

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 ~~is~~ predicted to reach 12 million tonnes in 2020 (Computer Aid International, 2010). WEEE is expected to increase by roughly 11% between 2008 and 2014 (European Commission, 2011).

As aforementioned, for EEE, various precious and critical metals are needed, and, as such, there is an essential need for better collection and recycling of WEEE to ensure better access to those metals for closing the materials loop. This is in particular important for countries such as Germany, which have no natural reserves for the production of EEE (Fechner et al., 2012). One way to raise interest in this issue is to assess the monetary value of valuable and critical metals in selected electronic equipment sold during 2004 - 2013 in Germany, as well as the value of the metals stock which is not being put to use. This paper analyzes this issue and it presents first results.

Furthermore, the issues and challenges in the management of WEEE with a closer look at mobile phone and smartphone waste streams with the goal of identifying the potential of closing the resources loop will be assessed. Critical and precious metals stocks from global sales of mobile phones and smartphones will also be assessed.

EEE has become more complex in the functions it can perform, and this can only be achieved through a mix of various materials, metals and other substances in their composition, many of which are highly toxic[3]. For example up to 60 elements can be identified in the composition of a smartphone (Meskers, C.E.M., Hagelüken, C., et al., 2009). WEEE represents a problem from both environmental and health issues point of view as it contains numerous hazardous materials. However, the inappropriate disposal of electronic waste leads also to a major loss of secondary materials. This enormous resource impact of EEE and WEEE has been widely overlooked (Schluep, M., et al., n.d.). According to a United Nations Environment Programme & United Nations University study, in 2007 approximately 1.2 billion mobile phones were sold globally (UNEP, 2009). Therefore, proper management of WEEE has the potential to recover valuable secondary materials while reducing environmental and human health damage (Hagelüken, C., Meskers, C.E.M., 2008). In the next section the critical and precious metals content in selected electronic equipment as well as the monetary value of these metals will be assessed.

Valuable metal stocks in mobile phones and smartphones

During 2004 – 2013, more than 156 million mobile phones have been sold in Germany, accounting in total to more than 47 tonnes of critical and special metals. The following valuable metals stock can be identified from the multiplication of the mobile phone critical and special metal composition with the total number of mobile phones sold during 2004-2013: 37.6 tonnes Silver, 6.2 tonnes Gold and 3.1 tonnes of Palladium (Table 1).

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[3] Toxic substances in electrical and electronic waste include plastic and heavy metals such as lead, nickel, chromium, arsenic and mercury (Herat, S., Agamuthu, P., 2012)

			Mobile phones			Smartphones		
Sold units between 2004-2013			156.746.000			65.950.000		
Monetary value of sales between 2004-2013 (€)			267.189.232			84.917.029		
Collection rate: 5%			5%			5%		
Not used material value			253.829.770			80.671.178		
Metal		Metal price (€/g)	Mobile phone critical metals composition (g)	Metals potential of mobile phones (t)	Monetary value of one mobile phone (€)	Smartphone critical metals composition (g)	Metal potential of smartphones (t)	Monetary value of one smartphone (€)
Cobalt	Co	0,00160				6,300	0,00000	0,010
Silver	Ag	0,50000	0,240	37,61904	0,12	0,305	32,10184	0,153
Gold	Au	30,95000	0,040	6,26984	1,24	0,030	7,74872	0,929
Palladium	Pd	17,33000	0,020	3,13492	0,35	0,011	2,43531	0,191
Neodymium	Nd	0,0843444				0,050	0,00000	0,004
Praseodymiu	Pr	0,16502				0,010	0,00720	0,002
Total				47,02380	1,70460		42,29307	1,28760

Table 1: *Monetary value of metals stocks in mobile phones and smartphones in Germany (2004-2013)*[4]

Further, the monetary value of metals in one mobile phone can be estimated at around € 1.7, based on average metal prices as of March 2014[5]. Hence, total monetary value of metals in all mobile phones sold during 2004 - 2013 can be estimated at € 267 million. Since only around 5% of all mobile phones are recycled (Oeko-Institut e.V., 2012), resulting in an amount of 7,837,300 mobile phones, an estimated monetary value of € 253.8 million is not put to use. For smartphones sales data could be retrieved for the period 2009 - 2013, accounting 14,547,000 units. The critical and precious metals stock contained in the sales during 2009 - 2013 is of more than 442 tonnes, with the highest value coming from the Cobalt content (aprox. 415 tonnes), followed by aprox. 20 tonnes Silver, and 1.97 tonnes Gold.

Similar to the case of mobile phones, the monetary value of metals in one smartphone is estimated at € 1.28 and the total monetary value of metals in all smartphones sold during 2009 -2013 is set at around € 84.91 million, which is three times less than that of mobile phones (but the timeline of the analysis is much shorter). Assuming the same 5% collection and recycling rate (representing about 3,297,500 smartphones), an estimated monetary value of € 80.67 million is not put to any use.

Further an analysis of the precious metals potential of mobile phones sold worldwide during the same time period of 2004 – 2013 has been done (Table 2). More than 2,879 tonnes of Silver are contained in almost 12 billion sold mobile phones (11,999,425,200), followed by 479.98 tonnes Gold and 239,99 tonnes of Palladium. The estimated monetary value of these metals is calculated at almost € 20.5 billion (20,454,220,196).

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[4] CEMIX, Bundesverband Technik des Einzelhandels e.V. (BVT), 2013. CEMIX Consumer Electronics Markt Index. Retrieved February 10, 2014 from http://www.bvt-ev.de/bvt_cm/der_markt/cemix.php

[5] Sources for metal prices as of 3rd of March 2014: Silver, Gold, Palladium, Copper, Aluminum, Nickel, Zink, Tin, Lead: http://www.finanzen.net/; Cobalt: http://www.infomine.com/investment/metal-prices/cobalt/; Neodymium and Praseodymium: http://institut-seltene-erden.org/en/current-and-historical-market-prices-of-rare-earth-gangigsten/; Chromium: http://www.infomine.com/investment/metal-prices/ferro-chrome/; Indium, Yttrium, Europium, Lanthanum, Cerium, Gadolinium, Terbium, Tantalum, Dysprosium, Platinum: http://institut-seltene-erden.org/en/current-and-historical-market-prices-of-rare-earth-gangigsten/

				Mobile phones	
Worldwide Sold units between 2004-2013				11.999.425.200	
Monetary value of sales between 2004-2013 (€)				20.454.220.196	
Collection rate: 5%				5%	
Not used material value				1.022.711.010	
Metal		Metal price (€	Mobile phone critical metals composition (g)	Metals potential of mobile phones (t)	Monetary value of one mobile phone (€)
Silver	Ag	0,50000	0,240	2.879,86205	0,12
Gold	Au	30,95000	0,040	479,97701	1,24
Palladium	Pd	17,33000	0,020	239,98850	0,35
Total				3.599,82756	1,70460

Table 2: *Monetary value of metals in global sales of mobile phones (2004-2013)*

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. Considering an annual growth rate of sales of smartphones of 11.1%[6] for Europe as equivalent for Germany, all smartphones sold during 2010-2017 will account for a value of € 168,210 million which is not used (Table 3).

	2010	2011	2012	2013	2014	2015	2016	2017	Total
Smartphones (units)	7,702,000	14,547,000	18,380,000	15,485,000	17,203,835	19,113,461	21,235,055	23,592,146	
Monetary value of smartphones (€)	9,935,580	18,765,630	23,710,200	19,975,650	22,192,947	24,656,365	27,393,221	30,433,868	
5% Collection for smartphones (units)	385,100	727,350	919,000	774,250	860,192	955,673	1,061,753	1,179,607	
Monetary value of collected smartphones (€)	496,779	938,282	1,185,510	998,783	1,109,647	1,232,818	1,369,661	1,521,693	
Not used material value in smartphones (€)	9,438,801	17,827,349	22,524,690	18,976,868	21,083,300	23,423,546	26,023,560	28,912,175	168,210,288

Table 3: *Monetary value of material stock in smartphones sold in Germany (2010-2017)*

The major reason for the unused value of materials in mobile phones and smartphones is clearly the currently very low collection rate, as consumers are not compelled to return products at the end-of-life stage. Consumers are, however, vital for the creation of circular material supply chains but they lack incentives for acting appropriately.

Inspecting Table 1, one can see that the highest monetary value in a mobile phone or smartphone comes from the precious metals content. However, the current European WEEE Directive contains mass-based recovery rates. This contradicts with the objective of increasing the collection of small WEEE and the recycling rates of valuable materials in low concentrations, such as found in mobile phones and smartphones. Obviously, obligatory mass-based recovery rates motivate the recovery of materials which dominate in terms of

[6] Source: http://mobithinking.com/mobile-marketing-tools/latest-mobile-stats/a#subscribers

weight, at the expense of valuable materials which are lost along the recycling chain[7] by ending up in material fractions from which they cannot be recovered. In this context, the mass-based recovery rates of the European WEEE Directive have a prohibitive effect on the recovery and recycling of mobile phones and smartphones.

Apart from having highest monetary value, the metal concentrations of precious metals, for example gold, are much higher in the selected electronic equipment than in primary gold mines. For instance, in primary mining between 1 to 5 grams of gold can be extracted per tonne of ore. In the selected types of electronic equipment the gold concentrations are much higher (Table 4):

Electronic equipment	Gold content (g/unit)
Mobile phones	0,04
Smartphones	0,03

Table 4: *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 ton of mobile phones, a total amount of 353,98 g gold/tonne of mobile phones can be calculated. This is 70 times more than in a tonne of primary ore with 5 grams of gold per tonne. Based on a similar computation, and assuming 169g (SpecTRAX, 2012) as average weight of a smartphone (resulting in a number of 5.917,15976), 177,51 g gold/ton smartphones can be calculated. With over 8,17 tonnes of gold in the selected electronic equipment sold during 2004-2013, the potential secondary supply is very high.

The monetary value of the precious metals gold, silver and palladium account for 95 - 98% of the total monetary value of the selected electronic equipment. From Table 1 it can be noticed that the monetary value of the metals contained in one unit of electronic equipment is not so high; however, the total monetary value of all units sold is more than € 351.9 million.

Management of WEEE

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, C., and Corti, C.W. (2010), due to inefficiencies in collection, dismantling and pre-processing "less than 20% of the gold recycling potential from European WEEE is realized". As such, better collection rates can have a positive impact on recycling of these devices. The collection rates for mobile phones and smartphones are only around 5%, and, consequently, potentials for improved collection rates have to be investigated for all types of electronic equipment. In 2003, the WEEE Directive (2002/96/EC) came into force at European level, with the goal of achieving higher reuse, recycling and recovery rates for WEEE. The WEEE Directive is based on the principle of producer

[7] 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).

responsibility (PR), which is supposed to set incentives to producers to design products which are easier to reuse, disassemble, recycle and recover. Apart from that, an even bigger focus has been given to the principle of individual producer responsibility (IPR), attributing the financial responsibility for collection, recovery and recycling to individual producers for their own products. In 2012, the WEEE Directive has been amended and the new WEEE II Directive came into force on 12th of August 2012. Member States had to transpose the new WEEE Directive into national legislations by February 2014. The amended WEEE II Directive contains higher collection targets for WEEE (Besiou, M., et al., 2012), but one still unsolved problem of the WEEE Directive remains the mass based collection targets.

One suggestion to achieve higher collection and recycling quantities might consist in a separate collection of mobile phones by service providers and producers, and the development of dedicated sorting systems where mobile phones could be tested for their functionality and divided into different categories such as reuse mobile phones, spare parts and mobile phones which could be sent to recycle (Figure 1). Another suggestion might consist in individual contracts between producers and end-of-life management companies, through which producers negotiate for the unit costs of recycling according to the characteristics of their own products, leading to greater incentives for better environmental design of products. The economic viability of such a system depends on various factors such as collection costs, cost of sorting and recycling, as well as revenues from selling secondary materials, and needs to be further analysed for particular case studies. However, in order to set up a sustainable circular loop supply for these products, innovative incentive-based business clusters are needed through which deliveries of new products towards users and of end-of-life products towards suppliers are established at economically attractive conditions and with lowest possible environmental impacts.

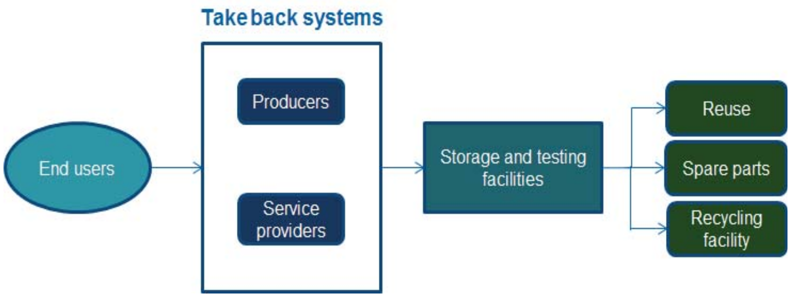

***Figure 1** – Take back system for separate collection of mobile phones*

Conclusions

The outcomes of the study are: a) the critical and valuable metals stocks in selected electronic equipment have been identified; b) the monetary value of the critical and valuable metals in selected electronic has been calculated; c) the value of metals not put to any use due to existing collection rates and inefficient pre-processing has been estimated; 4) 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.

7. The future of energy efficient buildings: learning from the past

Joanne F Robinson, Prof. S.W.Garrity and Prof. P.G.Taylor

Abstract

Changes in building design during the twentieth and twenty-first centuries have been largely focussed on driving safety and reducing capital expenditure, with less attention given to improvements in building energy efficiency. However, energy efficiency in buildings and the associated supply chain should be a vital consideration as almost half of the UK's carbon dioxide emissions are attributed to their construction and operation.

Today, the city landscape is faced with a growing number of smart buildings that are designed to operate at an optimum performance level. However, the performance gap between the anticipated energy use and actual consumption is increasing. This paper explores the possible justifications for this and suggests that the gap can be primarily attributed to the interaction between design and user behaviour. Clues to how this performance gap problem can be reduced may come from traditional or vernacular design, where the design ethos evolved around the requirements of the user.

This paper offers a brief appraisal of traditional construction methods and materials. Specific aspects of traditional design have been highlighted for recommended integration into contemporary design. This is a qualitative assessment which focusses on the UK case and recommendations for quantitative analysis, as part of potential further study, are also included.

Keywords: construction, energy efficiency, performance gap, vernacular

Introduction

The global energy crisis in the 1970s has led to an increased concern for energy efficiency across all sectors, including buildings (International Energy Agency 2007). Whilst initially driven by economic motivations, due to the increased cost of oil, for the last twenty years concerns about the environmental impacts of energy use, notably climate change, have been the principal drivers for increased energy efficiency in buildings. The Kyoto Protocol laid the groundwork for national greenhouse gas emissions reductions in developed countries. In the UK this has been followed up by the introduction of the Climate Change Act (2008) which commits to an 80% reduction in greenhouse gas emissions (GHG) by 2050 based on 1990 levels. The UK is one of a small handful of countries that have committed such a long-term reduction to law. Within the EU there is a recommended target of 60% reduction by 2040 (European Commission 2011).

Designing buildings for improved energy efficiency is a relatively new concept and has meant that various aspects of design, from preferred materials to the designer-customer relationship, have changed drastically over the last forty years (Gann et al. 1998; Best and de Valence 2002). In 2001 it was predicted that cost effective energy efficiency measures alone could achieve half the potential global emissions reductions needed by 2020 (to limit GHG to 550ppmv) (Intergovernmental Panel on Climate Change 2001). This was further confirmed in 2007 (International Energy Agency 2007). The impact that high levels of energy efficiency in buildings could have on UK emissions is significant. Currently, construction and buildings account for almost 47% of the total UK emissions (BIS 2010). In order to achieve the 2050 reduction target it is evident that savings must be made in this sector.

This paper will discuss one of the largest barriers to energy efficiency in building, the energy efficiency performance gap. This gap results from a disparity between the predicted energy performance of a building and its in-use energy performance. A consideration of traditional building design is made and suggestions are included which may help to close the gap. This is a qualitative assessment with a focus on the case in the UK. Recommendations for quantitative analysis, as part of potential further study, are also included.

Performance Gap

Evidence of the performance gap in buildings has only come to light comparatively recently since construction professionals were required to measure energy efficiency in order to demonstrate compliance with performance targets (Cohen et al. 2001). It is not clear exactly when the performance gap was first identified from the published literature. It is possible that buildings have never performed to their full potential energy efficiency and it is likely that the performance gap still would have existed even if energy performance targets had been set much earlier.

The performance gap should not be confused with the perception gap. The perception gap refers to the perceived gap in design and in-use energy use due to the omission of unregulated loads in the energy-related design calculations. Unregulated loads refer to small loads and the energy usage due to air conditioning and computing - in offices this is substantial. In the UK, the Code for Sustainable Homes was amended in 2011 so that it was no longer necessary to consider unregulated loads when designing a building to meet the building standards (DCLG 2010). Whilst the perception gap and the performance gap refer to different issues they are both equally important and lead to a higher than expected energy consumption if not communicated properly.

Indeed, poor communication was cited as a primary cause of the performance gap in a 2007 report by the International Energy Agency. It was suggested that Principal Agent (PA) problems are some of the major barriers to bridging this gap. “Principal Agent problems” refer to the issues which “arise when two parties engaged in a contract have different goals and different levels of information” (International Energy Agency 2007, p 11). This is an on-going problem in the case of buildings as, when ownership changes, these problems are likely to worsen rather than improve. Time exacerbates PA issues as the changing societal culture impacts on the requirements of the building (Shohet et al. 2003; Shohet et al. 2002).

The first well documented study into the performance gap was the PROBE study which evaluated 23 UK projects between 1995 and 2003 (Leaman and Bordass 2007; Cohen et al. 2001; Gill et al. 2010; Menezes et al. 2012; Menezes 2012). Using design data and post-occupancy evaluation, it was found that the average in-use energy consumption was double the predicted estimate (Menezes 2012). Furthermore, research published by the Carbon Trust (2012) showed that, in the most extreme cases, the in-use energy consumption can be up to six times greater than that predicted at the design stage.

The sources of the performance gap are not clear. Studies have shown that both technical failings and differing user-building integration can both contribute (Thomsen et al. 2013; Gill et al. 2010). A study of 18 occupants in 15 dwellings found that “A total of 51%, 37%, and 11% of the variation in heat, electrical, and water consumption, respectively, were explained by occupant behaviour" (Gill et al. 2010, p. 506). Research has shown that around 94% of energy use related to a building through its lifetime is due to its heating, ventilation and air conditioning (HVAC) and electricity usage (Scheuer et al. 2003). Figure 1 demonstrates how internal and external temperatures have risen since the 1970s. Homes with central heating are shown to be consistently warmer than those without; however, both internal temperatures have risen, demonstrating that the increase can most likely be attributed to user comfort levels. This could suggest that the performance gap is exacerbated by the changing demands of the consumer, e.g. a building which is designed to operate efficiently at the current recommended temperature, may not be as efficient if the average temperature was to rise in the future.

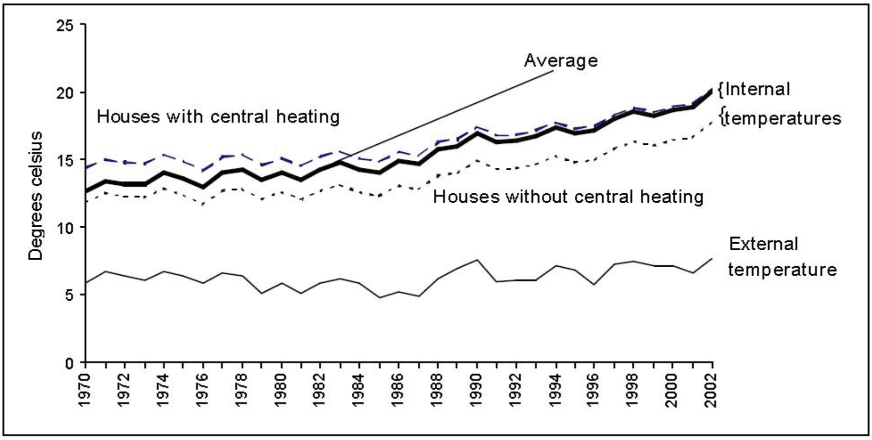

Figure 1. *Change in internal and external temperatures since 1970 (DTI 2006, p. 6)*

Addressing the Performance Gap

The performance gap in buildings can be partially attributed to the form of construction and the materials used. The way in which a building fabric is designed today is very different to that forty years ago. In energy efficient buildings the fabric is insulated to keep the cold air out and the warm air in, or vice versa. In more traditional, solid wall construction, the walls, floors and roofs acted as breathable thermal membranes. The thermal mass of the walls acted as a thermal store to moderate the temperature. Moisture was also allowed to pass through the cladding of the building (Ryan 2011).

The major step change in design has resulted from the way in which buildings are heated. In larger, commercial buildings heating systems have been common place since the Victorian age. However, in homes the increase in popularity of central heating and the associated cost of that has led to a desire to conserve the inputted energy. This is achieved through high levels of insulation. U-values ($W/m^2 \cdot K$) are used as a measure of the quantity of energy that is transferred through a particular building element (windows, walls, roofs etc.). Current UK Building Regulations specify that the U-values for walls for new domestic construction should be no greater than 0.20 $W/m^2 \cdot K$ (HM Government 2010). For the purpose of comparison, research by Historic Scotland (Baker 2011) reported measured U-values for plasterboard lined, 600mm thick traditional solid masonry walls to be 0.9 $W/m^2 \cdot K$, greater than four times that of modern standards.

The stringent regulatory targets have led to the development of innovative construction systems. Passivhaus is one such system and approach to design that originated in Germany. It aims to reduce the need for space heating and cooling through a “fabric first” philosophy, resulting in buildings which are 5 to 10 times more airtight than the standard UK building (Cutland 2012). The internal temperatures are regulated using thermal mass, much like the methods used in traditional buildings. However, to achieve this, natural ventilation is substituted in favour of mechanical ventilation with heat recovery systems (MVHR). Case studies from Germany, Switzerland and Austria have demonstrated that MVHR can reduce space heating requirements by around 80% (Feist et al. 2005).The system is a lot more simplified than the majority of heating and cooling systems used in alternative modern constructions and requires very little control or management. However, research into the benefits of natural ventilation has shown that users, who are able to control the temperature of their immediate surroundings, suffer the least discomfort (Raja et al. 2001). Passivhaus design is an example of an attempt to optimise traditional methods on the one hand yet it leads to a compromise on the other.

Passivhaus and its fabric first philosophy is in its relative infancy, with the first project completed in 1991 (Schiano-Phan et al. 2008). Post occupancy evaluations have thus far shown that the gap related to passive buildings is much smaller than those found for non-passive buildings. This is due mainly to the reduced energy use overall. However, the success of these buildings is centred on air tightness. Initial findings for one set of case studies have shown that two thirds of the buildings considered became less air-tight within 1 to 3 years after construction (Phillips et al. 2011). Whilst there have been no specific studies on the degradation of the fabric of Passivhaus buildings, this research raises concerns over their long-term efficiency.

Other approaches to closing the performance gap apply less to the design and more to the execution of the building construction and its management. The idea of a “feedback loop” manifests itself in many design approaches, including post occupancy evaluation (such as PROBE), the BSIRA soft landings approach and it is also the idea behind the development of the Carbon Buzz software (CarbonBuzz n.d.). The feedback loop is a system of ever decreasing circles consisting of analysis, correction and observation (Bordass et al. 2001). Lessons learnt from the process are shared, in the case of Carbon Buzz, or used internally to aid with similar constructions.

The BSIRA advocates the use of a “soft landings” approach which targets similar issues to the PA issues identified by the IEA. “Soft landings” is a design method which is included from the initial brief stage of the design process through to post occupancy evaluation. The approach encourages communication between the design team, housing developers and end users so that the building may operate at its optimum. The building is monitored for a period of three years, post-occupancy, and amendments are made where necessary to increase energy performance (Way and Bordass 2005). The inclusion of the scheme from inception is done so with the aim to promote communication so that the clients might have a better understanding of the mechanics and operation of the building. Whilst this approach is useful for as long as the clients remain the owners/occupiers of the building, in the long term it is unknown how well the building might perform under the jurisdiction of others.

Learning from the Past

Traditional construction methods are comparatively simple; they can be considered to be passive in that it is not necessary to utilise an active management system for the operation of the building. As has been discussed, modern standards far exceed the levels of energy efficiency that traditional buildings can achieve. However, the knowledge base and understanding surrounding these buildings is much greater than new technologies. Consideration of thermal mass, site orientation, natural ventilation and the limitation of windows, is often ignored in current design practices. User needs are often the largest drivers in design decisions; for example, plentiful windows to aid the aesthetic of a building which can be detrimental to the energy performance.

The resilient nature of traditional buildings means that they can aid in reducing the performance gap by increasing predictability in design. Contemporary buildings strive for simplicity and speed in construction, to reduce capital costs. At the same time, the materials and methods used in the building fabric have become ever more complicated. Cladding systems demonstrate this problem. The interface between frame and cladding must be tailored for each project, carried out by specialised Interface Management (Pavitt and Gibb 2003). Resilient design aims to establish a building which can operate at its highest level of energy efficiency over its entire lifetime.

Conclusion

Traditional methods still have a place in today's society. HVAC is the largest source of energy use in a building's lifetime. The thermal mass, site considerations and inclusion of natural ventilation can all reduce the energy use and close the performance gap.

Traditional buildings are a lot less energy efficient than airtight buildings built to comply with current UK building regulations. However, they did not require the same levels of consistent heating and cooling to regulate the temperature. In modern day society are we too reliant on the ability to control our surroundings?

Passivhaus design promotes traditional ideals of using the fabric of a building to regulate its temperature. Natural ventilation is compromised to obtain the best performance. This has been proven to help reduce the performance gap. The authors look to build upon this study of a hybrid traditional modern design to assess whether using information from post occupancy evaluations, such as those carried out for the PROBE project, can be used to identify best practice construction methods and materials, both traditional and contemporary.

Passivhaus and the Soft Landings approaches both raise concerns over the long-term performance of buildings. They are relatively new techniques and in the long term it is yet to be verified whether the fabric will degrade in the case of Passivhaus, or whether knowledge transfer will continue in the case of Soft Landings.

Le Corbusier said that "a house is a machine for living in". Like many machines that started out as mechanisms, buildings have become digital. They have far greater high performance potential but are much harder to amend and repair when they fail. The performance gap signifies this failure. What we need to take from traditional buildings is their robust nature. With buildings where the correct management framework is in place to ensure that the best can be obtained, high level energy efficiency is then achievable. However, for the majority of buildings, this cannot be ensured and those which are simple to operate are more likely to behave effectively over a longer period of time, particularly where there is a high turnover of building users.

8. Basel on its way to the 2000-Watt-Society

Till Berger, Dieter D. Genske, Ariane Ruff

Abstract

Energy demand and renewable potentials need to be synchronized in time and space. Energy has to be provided at the right place at the time of demand and in the quantity needed. This means, that a spatial model of the region has to be elaborated that is based on a geographic information system (GIS) and linked to an expert system (a spreadsheet). The Space Type Energy Model (STEM) developed is such a GIS-based expert system. For the Canton of Basel-City it was applied to model the demand-supply structure for a 2000-Watt-scenario. It was also used to access the capacity of Basel-Stadt to become energetically self-sufficient. In addition, greenhouse gas emissions as well as CO_2-reduction potentials were mapped. Finally, investments and savings associated with the introduction of renewable energy options were assessed.

Keywords: spatial modelling, renewable energy, urban planning, efficiency, greenhouse gases, GIS.

Introduction

The challenges of diminishing energy resources and forthcoming climate changes call for action. Cities and regions are preparing action plans to face these challenges. The City of Hamburg, for instance, is staging an International Building Exhibition focussing on climate change and renewable energies (IBA-Hamburg 2011).

The City of Basel is aiming at implementing the idea of a 2000-Watt-Society. In a 2000-Watt-Society resources are used in a sustainable way. The energy consumption is reduced to 2000 Watt *per capita*, the greenhouse gas emissions are reduced to 1 ton CO_{2eq} *per capita*. The share of fossil energy shall not exceed 500 Watt. Today, the energy demand in Switzerland and Western Europe is in the order of 6000-7000 Watt *per capita*. In the United States more than 12000 Watts are being consumed, whereas in Africa the demand is less than 1000 Watt *per capita* (www.2000watt.ch).

In order to model the energy future of a city or a region, a spatial energy model has to be established. Based on this model, the present energy consumption pattern can be assessed, efficiency potentials to reduce demand can be defined and renewable energy potentials can be mapped.

Approaches

A number of studies to analyse energy consumption patterns and renewable potentials have been carried out on a national level (BMWFJ/BMLFUW 2010b, a; BFE 2012b, a; BMU 2012). When zooming into a given region or urban space, the analysis becomes more detailed and, in fact, more complex: Regional and local energy inputs and renewable outputs have to be identified and implemented into a spatial energy model. In addition, the consumption and production patterns have to be extrapolated along the time line. Based on this, recommendations have to be formulated that fit into the regional and local context.

The Space Time Energy Model (STEM) developed for Basel-Stadt constitutes a tool that juxtaposes the demand side with the renewable supply side and considers all energy forms (power, heat, fuels) as well as all energy parties (living, working, mobility). Other approaches rather focus on individual buildings (e.g. Bidlingmaier & Hanfler 2011; Eickner 2012b), consider only the demand side (e.g. Navarro 2012), cover only certain energy sectors (e.g. Hegger 2012) or consider only certain renewable sources (e.g. Eickner 2012a). The Eco-Region-Approach (ECOSPEED 2012) stresses the emission aspect based on regional statistics, whereas the approach of the Convent of Mayors (EC-IE 2010) implies rather general assumptions.

The STEM methodology

The Space Type Energy Model (STEM) is based on dividing the model space into energetically homogeneous sectors that have a comparable energy demand as well as a comparable capacity to produce renewable energy. This fragmentation applies to both city prototypes and rural prototypes. The sectors communicate with each other in time and space to utilize renewable resources in an optimized way.

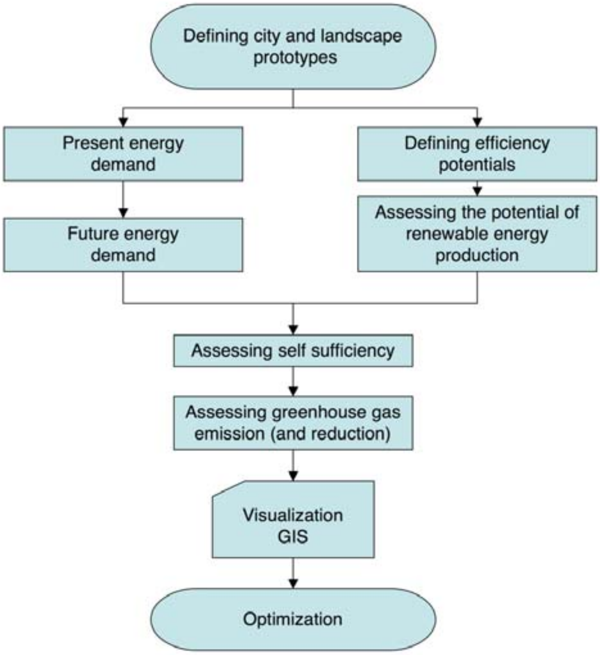

Figure 1: *The Space Type Energy Model (STEM).*

Figure 1 illustrates the approach: After defining urban and rural prototypes the present and future energy demand is accessed, efficiency potentials and renewable potentials are identified, the self-sufficiency (with regard to renewable energy supply) is calculated and greenhouse gas emissions are determined. The results are illustrated by means of a geographic information system (GIS). Based on these results, the investments into renewable energy options can be calculated as well as the benefits (increase of tax income for the community, savings from fossil fuels, job opportunities).

STEM has been applied at various scales from city quarters to regions in four different countries. The energy maps for the International Building Exhibition IBA Hamburg have been prepared with this tool (IBA-Hamburg 2011). In addition, the City of Villach, the Bundesland Thuringia and the Principality of Liechtenstein have been mapped with STEM (TMWAT 2011; Genske et al. 2012; Droege & Genske 2013). At the moment, the Bodensee-Alpenrhein-Energy-Region (BAER) is analysed with this tool. This paper presents the results for the Canton Basel-City, where a 2000-Watt-scenario was simulated.

Basel-Stadt on its way towards the 2000-Watt-Society

Urban and rural prototypes

The Canton of Basel-Stadt has a population of almost 200000 and an area of 37km^2. About half of the space is covered with buildings (30% households, 14% business, trade and industry), almost one fifth (17%) is occupied by traffic infrastructure, the rest are green spaces, forest, agriculture and water courses.

Figure 2 shows the different urban and rural prototypes. The oldest buildings are located in the city centre, with Gründerzeit-style developments of the time of industrialization forming concentric circles. The high portion of individual homes (37% of all built-up land) is typical for the 20th-century city expansion.

Scenarios

Two scenarios are considered: (1) A reference scenario and (2) The 2000-Watt-scenario. For both scenarios the *intra muros*-principle is applied, i.e., only renewable resources within the Canton of Basel-Stadt are being considered.

The reference scenario follows the present energy politics of Switzerland and applies it to Basel. They are based on the scenario II of the official "Energy Perspectives for Switzerland" (BFE 2007), including efficiency potentials and renewable energy potentials. A 1%-renovation rate per year for all buildings is assumed. In addition, the present planning and strategy development of the Canton as of 2010 is adopted. For the sector mobility the reference scenario of the region Basel was applied.

The 2000-Watt-scenario utilizes the given renewable energy resources of Basel. Renewable energy options are, however, limited with regards to the protection of historic buildings and facades as well as the protection of the environment (e.g. shallow geothermal heat shall not be extracted from protected aquifers and biomass shall be used in a sustainable way). A 2%-renovation rate per year for all buildings is assumed, respecting the 2000-Watt-standards for renovation and for new buildings of the Swiss Society of Engineers and Architects (SIA). The efficiency increase in power demand, warm water demand and process water demand as well as for fuels (except mobility) is adopted from the innovation scenario of the WWF-study (Prognos & Öko-Institut 2009). For the mobility sector a considerable increase of public transport is assumed. By 2050, 80% of all automobiles shall be electro-cars.

For both scenarios distance heating with municipal waste is being considered, given that half of the waste is interpreted as a renewable resource.

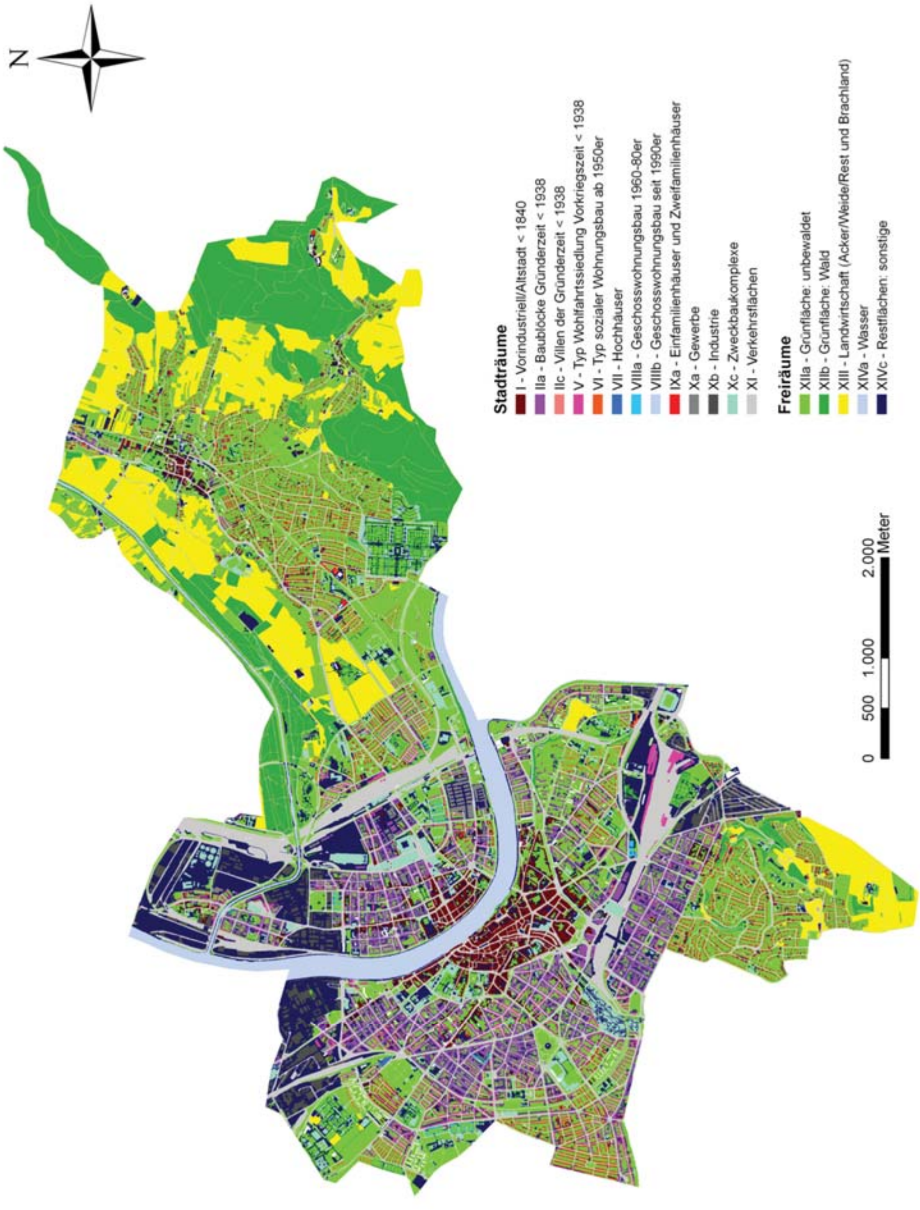

Figure 2: *The urban and rural prototypes of the City of Basel.*

Present and future energy demand

An important part of the work was the identification and assessment of the present energy demand and to extrapolate the demand into the future. Figure 3 shows the present energy mix (2010), still heavily depending on fossil fuels. Figure 4 indicates the primary energy demand *per capita* until 2050 for both scenarios. The columns indicate the energy parties living, working and mobility. The 2000-Watt-target is also pointed out. No grey energy was considered (for Switzerland is was identified to be in the order of 3000 Watt primary energy per person).

It should be kept in mind that, in 2010, the money spent on fossil fuels (manly natural gas, diesel and gasoline) was in the order of 300-400mio Swiss Franks.

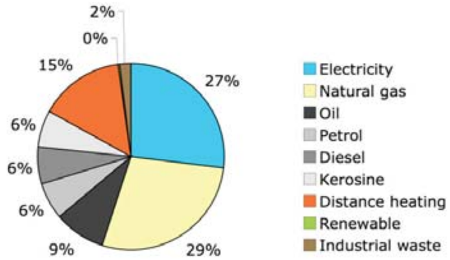

Figure 3: *Energy mix (end energy) of the Canton Basel-Stadt. In 2010, the total end energy consumption reached 5902 GWh.*

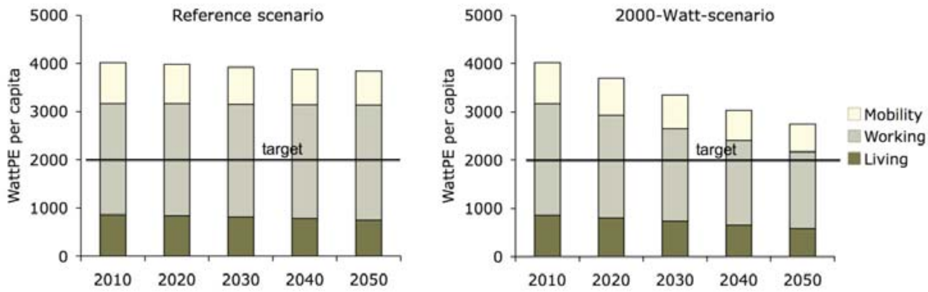

Figure 4: *Present and future end energy demand per capita for the City of Basel for the reference scenario and the 2000-Watt-scenario.*

Present and future renewable energy supply

The renewable potentials were assess in different ways. Firstly, the diffuse input connected with buildings was determined. This includes power from photovoltaics to be installed on roofs and facades. To assess the potential, solar quality factors associated with urban prototypes were applied (Everding 2007). Solar collectors (roof, facades) were also considered, but only where appropriate (e.g. individual homes). In addition, shallow geothermal heat was considered where appropriate as well as heat from wastewater.

Furthermore, concrete inputs like hydropower (run-of-river within Basel), deep geothermal power and heat, biomass and municipal waste incineration was taken into account. No wind power was considered.

Figure 5 shows the power demand and the renewable power production for both scenarios. Figure 6 shows the heat demand and the renewable heat production for both scenarios. In the 2000-Watt-scenario the power gap 2050 can be closed to a considerable degree whereas the renewable heat gap stays important.

As far as fuels are concerned, no production of bio-fuels within the project area was considered.

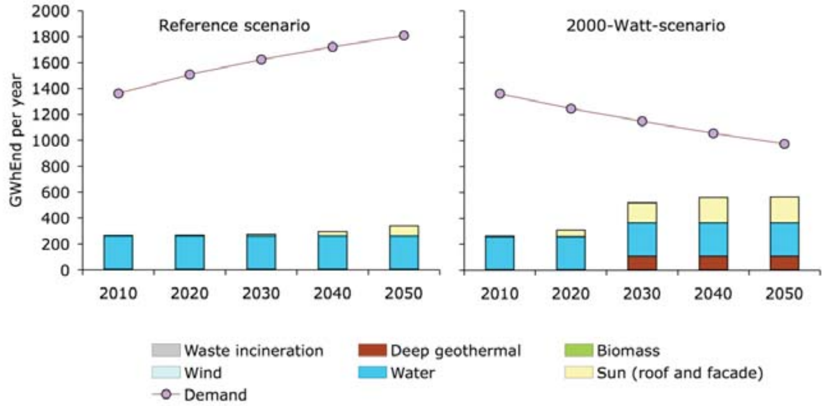

Figure 5: *Present and future power demand (end energy) and renewable power production for the City of Basel for the reference scenario and the 2000-Watt-scenario.*

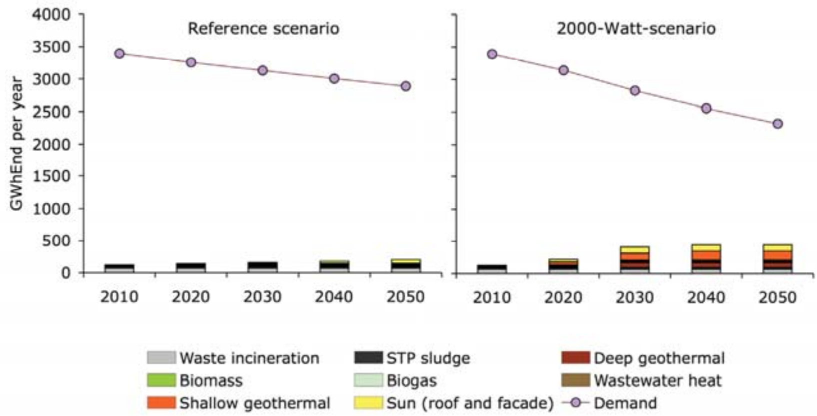

Figure 6: *Present and future heat demand (end energy) and renewable heat production for the City of Basel for the reference scenario and the 2000-Watt-scenario (STP sewage treatment plant).*

Present and future greenhouse gas emissions

With decreasing demand of fossil fuels and increasing replacement with renewable energy the greenhouse gas emissions will decrease. This effect is especially pronounced in the 2000-Watt-scenario, as indicated in Figure 7. The target of 1 t CO_2eq *per capita* and year is also indicated. Both scenarios fail to meet the target.

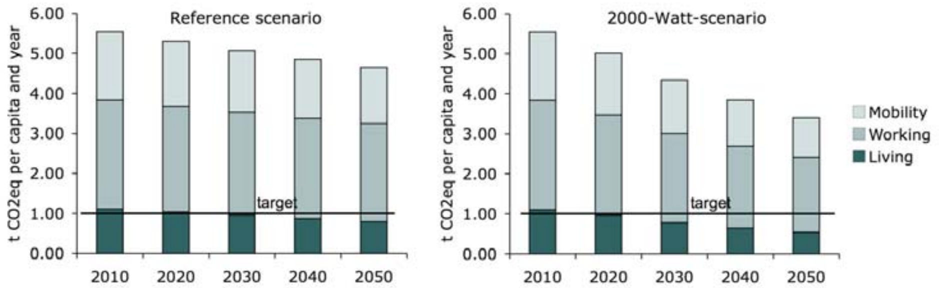

Figure 7: *Present and future greenhouse gas emissions in CO_2-equivalents per capita and year for the City of Basel for the reference scenario and the 2000-Watt-scenario.*

Investments

An important aspect was the estimation of the costs of the transformation process. The investments into building up a renewable energy mix for Basel had to be juxtaposed with the savings from buying fossil fuels (Table 1). For Basel, the costs *per capita* were compared with other typical expenses. As indicated in Figure 8, the individual investments of a citizen of Basel are in the order of 130 Swiss Frank per year.

Recently, the assessment of so-called differential costs has advanced and has become an integral part of the official German strategy report for renewable energies (BMU 2012).

	Investments into renewable energy options: Heat[1]	Investments into renewable energy options: Power[2]	Total costs	GHG-emission cost[3]	Saving from fossil energy purchases: Heat[4]	Saving from fossil energy purchases: Power[5]	Total savings	Delta[6]
	Mio CHF per year							
Reference scenario								
2010	0	0	0	0	0	0	0	0
2020	-2	-1	-3	1	2	0	3	0
2030	-4	-6	-10	2	4	1	7	-3
2040	-6	-10	-16	3	9	3	14	-2
2050	-9	-13	-22	4	17	8	29	7
2000-Watt-scenario								
2010	0	0	0	0	0	0	0	0
2020	-17	-26	-42	2	9	4	15	-27
2030	-36	-63	-100	5	28	13	46	-54
2040	-37	-53	-91	7	43	18	68	-23
2050	-33	-29	-62	9	57	20	86	24

[1]Solar collectors, shallow geothermal heat, wastewater heat (heat pumps), deep geothermal, municipal waste incineration, biomass and biogas; [2]photovoltaics, hydropower (run-of-river), deep geothermal, waste incineration, biomass and biogas; [3]emission rights spot (EUA) of 21 CHF/t (2010); [4]savings from avoiding non-renewable heat (based on the heat mix of 2010); [5]savings from avoiding non-renewable power (based on the power mix of 2010); [6]balance investments-savings.

Table 1: *Annual expenses and savings in the reference scenario and the 2000-Watt-scenario.*

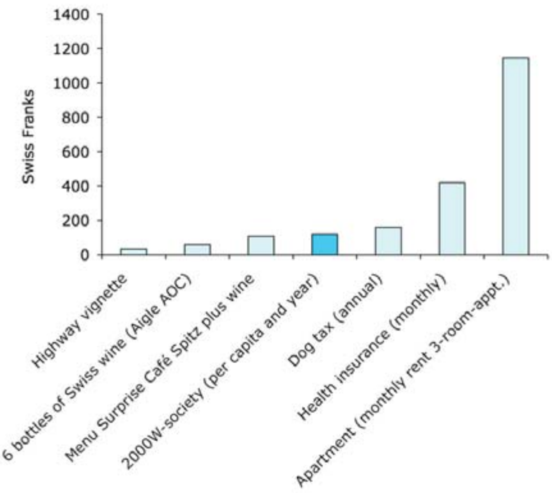

Figure 8: *Typical expenses of a citizen of Basel, including the costs for the 2000-Watt-Society.*

Conclusions

The study indicates that in the reference scenario Basel shall stay largely dependent on fossil fuels. On the other hand, the 2000-Watt-scenario may meet the emission target of 2000 Watt per inhabitant by 2075. The ambitious goal of implementing the 2000-Watt-Society may thus be reached, and that even with moderate costs.

Based on this study a master plan for the energy future of Basel shall be developed. This plan includes in increase of the renovation rate of all buildings to 2%. Push-and-pull measures (promotion and obligation) shall stimulate the process. Additional effort should be spent on measures of increasing efficiency (households, businesses). Inefficient appliances shall be banned. Push-and-pull measures shall also be applied to promote renewable energy options. For instance, if roofs or facades apt for solar utilization are left unused, fees shall be charged and paid into a fund to finance the transformation process. The existing distance heating grid shall be extended. Public transport shall be promoted, as well as biking and walking. The introduction of electro-cars shall be prepared. The regional cooperation with regard to developing the 2000-Watt-society shall be reinforced.

A detailed report on this project has been prepared for the City of Basel (Berger et al. 2011b). The basic findings are also published in a summary (Berger et al. 2011a).

9. Covering the last mile in the Brazilian Amazon – The role of knowledge-sharing strategies in the provision of universal electricity access

María Fernanda Gómez Galindo, Marianne Salomon

Abstract

Remote areas are becoming a topic of increasing international interest as they can provide insights in the transition towards a more sustainable energy future. Being geographically isolated and distant from different services (e.g. energy, health and education), remote areas have seen their development delayed for decades. This paper focuses on the particular case of the Brazilian Amazon, where important but insufficient efforts have been made to provide universal electricity access to remote communities. About 930000 people are still without electricity access. How can the current rural electrification structures be improved to effectively implement and operate off-grid solutions in remote areas of the Amazon region? In pursuing answers to this question, we address the main challenges for achieving universalization goals, identify leverage points, and highlight the relevance of knowledge-sharing to overcome current hurdles. We conclude that knowledge-sharing provides the basis for a new model in which remote communities, municipalities, NGOs, concessionaires and other rural electrification agents can contribute with their particular knowledge to agree on targets and procedures for the design, implementation, and operation of off-grid solutions. This model implies not only adapted institutions and solutions based on local resource based technologies, but also reduced costs resulting from operational efficiency. In this way, the model enables the system either to reduce its impact on electricity tariffs in other regions or to release resources that can be used to support local development.

Keywords: remote areas; universal electricity access; off-grid solutions; knowledge-sharing; Amazon region.

Introduction

Remote areas, that is, those that i) are scarcely populated, ii) are not connected to a centralized electricity system, and iii) are recurrently classified under a low human development category, impose significant challenges to achieve universal electricity access. Lack of connection to a centralized electricity system usually means that communities living in remote areas depend on diesel and, unless local energy resources are explored, this dependence is likely to continue impacting upon a very sensitive ecosystem (IEA-RETD, 2012). Off-grid systems providing electricity access in remote areas of the Amazon include power generation facilities in the order of tens to hundreds of kW that supply communities or households, usually reachable only through fluvial access. Thus, off-grid systems arrangements comprise: (i) mini-grids connected to small-scale power generation units that provide electricity to small and remote villages, and (ii) stand-alone systems that provide electricity to household units. Unfortunately, existent off-grid systems do not fully cover the Amazon region. In addition, as the grid reached its physical and economic limits, extension has become more difficult and even unfeasible in some areas. As a result, remote areas of the Amazon region are yet to be supplied with electricity services (IBGE, 2011). This situation is recognized as the “last mile” or the final stage in the process of providing electricity access to final users. Official statistics indicate that the last mile in the Brazilian Amazon region amounts to approximately 930,000 people (IBGE, 2011). How can the current rural electrification structures be improved to effectively implement and operate off-grid solutions in remote areas of the Amazon region? In pursuing answers to this question, we address the main challenges for achieving universalization goals, identify leverage points, and propose one potential way that can help to overcome them. The research process was designed to consider a variety of qualitative and quantitative data sources, gathering techniques and analysis approaches including an extensive literature review, and the collection of in-situ evidence in the form of structured observations and semi-structured interviews. This paper presents partial results obtained during a PhD research project conducted in the field of energy access at KTH Royal Institute of Technology.

Challenges for the Brazilian rural electrification initiative in remote areas

The Brazilian Amazon covers an area of about 3.8 million square kilometers, which is equivalent to seven times the surface of France. The region is characterized by a very low population density (about 4 inhabitants/km^2) and low income levels. These factors together with a complicated topography pose specific challenges for electricity provision. *Figure 1* shows typical isolated households in the state of Pará. These households can only be reached by boat, after long journeys from the closest city. There are no roads. In some cases, houses are close to each other and the use of a small-scale power generator and a mini-grid can provide the necessary electricity services. However, smaller villages consisting of groups of less than ten houses are in many cases scattered in a large area, which makes the use of mini-grids difficult. Often, local communities operate diesel generators that, depending on the power capacity and maintenance routines, can provide electricity for a period of up to 5 hours per day (Pinheiro, et al., 2011).

Figure 1: *Typical remote households in the Brazilian Amazon*

Three main challenges lying ahead for the rural electrification initiative have been identified. First, there is a need to adapt the existing institutional structures. Second, the harmonization of technologies with the regional context is essential. Third, a more effective use of government funds within the context of the actual subsidy scheme will be crucial to promote the rural electrification initiative in the region (Gómez, 2014).

In terms of institutional structures, the Brazilian rural electrification initiative has evolved based on a centralized system in which concessionaires are responsible for providing full electricity access in the country. In fact, they provide electricity to around 99% of the national population. However, concessionaires are not as relevant for the Amazon region where they supply only 62% of the rural households or about 2.4 million people. Around 14% of the rural population in the region, or approximately 550,000 people, are supplied through other kinds of organizations and 24%, or about 930,000 people, are not supplied at all (IBGE, 2011). Despite their obligation to fully supply electricity services to citizens living in their concession area, and guaranteeing low tariffs for low-income population, concessionaires have not effectively delivered the required off-grid solutions. As a result, a group of new organizations have emerged to supply electricity to rural and isolated communities. Generally, these organizations operate off-grid systems during 4 to 5 hours per day, which provide electricity services but do not fulfill national standards (Van Els, et al., 2012). Despite recent governmental efforts to guide actions from existent and new agents, a formalized decentralized institutional framework is yet to be materialized and remains as the first challenge hereby identified (ANEEL, 2011; MME, 2012; 2013).

In terms of technology structures, a significant challenge emerges for universal access in the Amazon with regards to the need for harmonization with the regional context, which is a vast and unique environment. The way communities occupy the land is critical for the design and dimensioning of off-grid solutions. Also, a detailed description of the energy demand is required to precisely design suitable systems. The required off-grid solutions for remote areas will have to consider the broad variety of resources available in the Amazon and alternative small-scale renewable technologies to harness the existing potential. In this sense, renewable energy technologies and hybrid systems present a number of advantages for application in isolated areas of the region (Nerini, et al., 2014). Simplicity, reliability, flexibility, robustness, environmental benefits, and low operational and maintenance costs are all important factors for the selection of the appropriate technological solution or mix of technological solutions to be implemented. Yet, neither locally and widely available renewable sources nor off-grid technologies have been systematically explored in the Brazilian Amazon. Technologies such as solar photovoltaic, wind power, small hydropower and biomass power plants remain as interesting alternatives to be further explored in isolated communities in the region.

In terms of funding structures, there is a strong political commitment, which will be essential but not enough to guarantee the required funding to achieve universalization in the Amazon region. A subsidy scheme combining capital, operation and consumption subsidies provides the financial basis for the LPT. The scheme relies on sectorial funds replenished by electricity consumers who all contribute via tariff (MME, 2012; 2013). There is a cost reduction for project implementers to provide the connection and operate the systems, and specific tariffs for poor final consumers of electricity. These subsidies are perceived as essential to reduce inequality, ensure development and bring benefits to the most impoverished groups. Yet, the required funds have not been secured yet. In terms of funding structures, this is a major challenge.

Identified leverage points for the Brazilian rural electrification initiative in remote areas

According to Meadows (1999), leverage points are “places within a complex system (a corporation, an economy, a living body, a city, an ecosystem) where a small shift in one thing can produce big changes in everything. Based on this definition, we identify two leverage points within institutional and technology structures.

Connections created among institutions during the implementation of the Brazilian rural electrification are important but not enough to provide electricity access in remote areas; especially because it is not clear how potential new agents could interact with communities. In this sense, new relationships must be built to successfully achieve universalization goals in the region. During the first phase, which was focused on the extension of the grid, concessionaires were close to the final users. The physical proximity facilitated interaction between them. Simple communication channels such as written requests for the service, which were delivered in concessionaires' offices, allowed a reasonably simple interaction that provided the information required to extend the grid (Gómez & Silveira, 2010). The situation is different in remote areas where potential solutions are more diverse and complex than the grid-extension. It is important to highlight that even though a number of decentralized organizations have co-existed with concessionaires, they have operated within a context in which a lack of rules adapted to the local reality prevented the delivery of reliable electricity services. The provision of these services is primarily based on traditional diesel systems which are not fully effective. Also, new agents that have not had a physical presence in the region are expected to enter the system in response to the new set of rules that promotes off-grid technologies. Thus, the need for rules guiding relationships among new agents and communities is a key leverage point within institutional structures. These rules are particularly important to define a framework in which communities are empowered to participate in the design, implementation, and operation of the system.

During its first phase, the Brazilian rural electrification initiative has achieved important results, which have been based on large-scale power generation technologies that enabled the extension of the grid (Gómez & Silveira, 2010). In addition, at local level, small-scale power generation technologies are mainly diesel-based and operated by decentralized organizations or final users. As significant challenges arise in connection with the implementation of off-grid solutions, the Brazilian government has promoted a number of pilot projects in remote areas of the Amazon including solar photovoltaic, small-scale wind, solar-wind-diesel hybrids, biodiesel generators, hydropower plants and biomass gasifiers. These projects have built up knowledge of off-grid technologies in the face of universalization goals but have not been scaled up yet. In this context, the leverage point within technology structures is the implementation of local-resource based technologies that are essential to put in place the required off-grid solutions.

To summarize, two key leverage points were identified: first, in connection to the institutional structures, the need for rules guiding relationships among new agents and communities is essential, and second, in connection to the technology structures, the design and implementation of local-resource based technologies will help to ensure the sustainability of the solutions. The question is how to activate this leverage points? (See *Figure 2*). Next section discusses the importance of knowledge-sharing in pursuing sustainable energy solutions for remote areas.

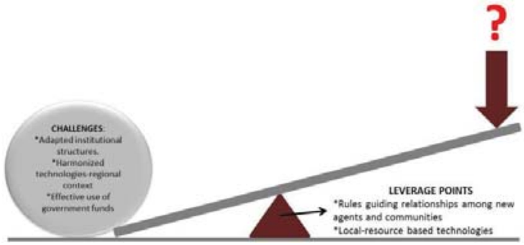

Figure 2: *Identified challenges and leverage points within the Brazilian rural electrification initiative for off-grid solutions*

Discussion: how to activate the identified leverage points?

Challenges faced by the Brazilian government are not unusual. Previous studies have shown that creating effective institutional structures is one of the key parameters that contributes to successful project implementation and operation in the long term (Barnes, 2011). Another key issue is the design and implementation of technologies based on locally available resources (Barnes, 2011; Gómez, 2014; IEA-RETD, 2012). We argue that knowledge-sharing about local resources, energy demand, patterns of occupation, and small-scale technologies are pivotal components in pursuing effective institutions and operative technologies as it allows a better dimensioning of the off-grid solutions by considering local resources and realities and an optimized operation of the off-grid solutions (See *Figure 3*). Knowledge-sharing is hereby understood as the process of exchanging skills, experiences, and understanding. It is part of a complex system, in which agents interact with the common purpose of effectively establishing and operating electricity access projects. Interactions do not necessarily follow a temporal sequence.

Figure 3: *Knowledge-sharing has the potential to activate identified leverage points*

There is an important knowledge base including skills, experience, and understanding about local realities, technologies and processes among rural electrification agents and communities that is essential to achieve universalization goals in remote areas. In this sense, knowledge-sharing can act as catalysts in the construction of a proper framework to effectively implement and operate off-grid solutions. The institutional structures that have supported successful off-grid programs have taken various forms. For example, hydropower-based mini-grid systems in Nepal and Sri Lanka, which are operated by communities, have been quite successful (Barnes, 2011). In Bangladesh, designing the system according to public needs has been essential to increase system reliability and the life of the system.

Community ownership has also proved worthwhile. This practice has reduced maintenance costs and overuse, and has maximized benefits (Rahman, et al., 2013; Botes & Rensburg, 2000). In Bolivia, research conducted in 2010 concluded that constant interaction with communities on a long-term basis can have a higher relevance than access to finance, proper technologies, and management capabilities in a successful implementation of off-grid projects (Drinkwaard, et al., 2010). In Colombia, remote areas are also characterized by lack of development and, consequently, there is an increasing need for access to electricity services. Available institutions and funding resources seem insufficient to achieve universalization in the short term. According to the National Energy Planning Unit – UPME, there are about 56 000 households without access to electricity services in remote areas. In order to overcome these challenges, the Colombian government has recently defined the Sustainable Rural Energization Plans (PERS) which rely on the concept of energization instead of electrification. In this way, the use of all potential energy sources are considered to cover energy needs in transport, domestic, and productive activities. The strategy PERS include i) characterization of the demand (including potential productive projects); ii) identification of energy resources; and iii) selection of the alternative that best matches the identified demand and the potential supply (UPME, 2014). In summary, there is no universal solution but there is a common principle: institutional structures providing off-grid solutions need to consider participatory processes in which all the involved agents contribute with their particular knowledge. In general, participatory processes require the preparation of activities to systematize existing information, share, and build knowledge based on skills, experiences, and understanding of the agents involved in the initiative.

Knowledge sharing implies serious challenges particularly within a context such as the Amazon region, in which diversity is the norm. In the particular context of remote areas, interpersonal forms of communication are essential. Face-to-face conversations, workshops and discussion sessions have the potential to facilitate interaction with communities, improve the flow of information, and enhance knowledge-sharing. It is important to use a language all participants are comfortable with. Sharing knowledge implies by definition the involvement of different disciplines and perspectives that need to have a common, straightforward language to facilitate communication. For instance, technology providers and project implementers tend to use a very technical language that is not appropriate for end users, who are often unfamiliar with technical terms. Questions such as how to enhance demand driven off-grid projects, where to locate the power generation project, what are the most convenient ways to collect electricity services fees, how local communities can support the operation and maintenance of off-grid systems, or how to make good use of others' experiences, skills and understanding are good examples of how to guide discussions about the implementation and operation of the rural electrification initiative in remote areas.

There are a number of methodologies to formally represent, systematize, and share knowledge. For instance, Dixon et al. (2001) propose a methodology to acquire and represent knowledge from communities living in rural areas. The methodology has been used in Africa, Asia and Latin America. It is based on the premise that most knowledge can be broken down into short statements and associated taxonomies of the terms that are used in them. These can then be represented on a computing platform as a knowledge base using a formal grammar and a series of hierarchies of terms. Connections amongst statements can be explored by viewing sets of related statements as diagrams (Dixon, et al., 2001). In other contexts, mathematical models have demonstrated the convenience of using software tools to find solutions to public infrastructure issues that had remained unresolved for a number of years (Danielson, et al., 2007). Interactive maps, Geographical Information Systems (GIS) and content management systems are some of the possible ways to map, collect, present, systematize, and analyze existing knowledge (Rantanen, 2007; Adinarayana, et al., 2008). Also, the Food and Agriculture Organization of the United Nations (FAO), the KM4Dev Community, the United Nations Children's Fund and the United Nations Development Programme created a web based resource of knowledge sharing tools and methods that can provide ideas on how to encourage agents to share their skills, knowledge and experiences.. One important aspect to consider when applying a particular method to share knowledge is to involve all the electrification agents from the design, to the construction, and permanent use of the systematized knowledge base. Otherwise, there is a risk of people losing interest and abandoning an initiative that has the potential to develop new capacities and promote specific actions to effectively implement and operate off-grid systems.

Conclusion

Promoting knowledge-sharing provides the basis for a new model in which remote communities, municipalities, NGOs, concessionaires and other rural electrification agents can contribute with their particular knowledge to agree on targets and procedures for the design, implementation, and operation of off-grid solutions. We do recognize that institutions and technology structures need to be supported by proper financial arrangements. A highly subsidized scheme is in place in Brazil. Sectorial funds are the main providers of the required resources and rely on electricity consumers at national level since they generate the resources via tariff. However, it is important to mention that effective institutions and operative technologies imply a more efficient operation that has a direct impact on the operation cost. As a result, reduced costs resulting from operational efficiency enable the system either to reduce its impact on electricity tariffs in other regions or to release resources that can be used to support local development.

10. Economic impact analysis of agricultural insurance as a mechanism for climate change adaptation in three crops: potatoes, corn and broad beans. A 2030 study. Junin Region (Peru).

Bryan Gutierrez and Mario Rivera

Abstract

This paper analyzes agricultural insurance, considered as a mechanism for climate change adaptation. We have the hypothesis that indexed insurance is an optimal mechanism for adaptation due to its benefits and because it minimizes the possibility of moral hazard. The agricultural production of three crops (corn, potatoes, broad beans) in a future context of changes in various climatic variables is estimated. For this purpose, we develop a panel data model that incorporates economic and meteorological factors. Then, through a cost benefit analysis we evaluate the profitability on the use of indexed agricultural insurance. This paper is focused on Junin region located in Peru; however, the results also allow a greater understanding of the domestic situation. Therefore, the main contribution of this paper is to present the importance of an instrument for adaptation to climate change that benefits farmers, that is not widespread in Peru and Latin America in general, and that may be part of a comprehensive plan for adaptation to climate change.

Keywords: climate change, agricultural insurance, production, corn, potatoes, broad beans.

Introduction

Climate change is a global phenomenon that affects various economic activities such as agriculture, which in developing countries is highly important. In Peru, in 2011, agriculture accounted for over 7.6% of GDP; was also a source of income for 34% of Peruvian households. Moreover, this country, because of its geographical location, is very vulnerable to climate change: it presents four of the five characteristics of vulnerability recognized by the United Nations Framework Convention on Climate Change (UNFCCC) and seven of the nine countries whose characteristics related to needs and concerns must be addressed, according to the provisions of Article 4.8 of the Convention (Mendoza, 2012). To address this situation, adaptation and mitigation measures have been taken in consideration.

Watson identifies two important effects of climate change on crops, one negative and one positive: increased CO2 benefits the crops while the temperature harms them. The net effect on the crops will depend on which effect is larger but also on the type of crop (Watson, 1997). Also other problems such as lack of water and water stress is also identified. Furthermore, in the mountains, droughts could lead the development of pests which would in turn increase production costs for farmers as well as the risk to the health of consumers (Vargas, 2009). In this context the following question arises: how should farmers adapt to climate change? In this way, the paper hypothesizes that agricultural index insurance can be an important mechanism for climate change adaptation, because it is profitable for farmers to acquire them and reduces risk of moral hazard.

Methodology

Estimation of the Production

In the case of agricultural production in a context of climate change, one of the first contributions was performed by Mendelsohn and Nordhaus (1992), which basically suggests that the production of goods depends on two variables: the first is composed of all inputs that are used in the production process as capital or labor, and the second is contains the environmental factors such as temperature and relative humidity. One of the main assumptions in this model is that environmental factors are exogenous: they are given by nature and that farmers only control the amount of input they use. This assumption is very plausible, especially when agriculture is for subsistence. Furthermore, according to the National Household Survey (ENAHO) between 2007 and 2011, over 85% of farmers have produced in the same land, indicating that there is no control over the temperature, due to the fact that temperatures are taken as given.

It is also important to note that in agriculture, many producers choose what to produce according the production of the previous year because they do not know the market conditions. To estimate the production function a simple but widely used form is chosen: ordinary least squares (OLS). In the literature to estimate agricultural goods there is a wide variety of authors who use it as Echevarria (1998), Nasir (1990) and others.

With this conceptual framework the endogenous variables will be expenditure in capital. Within expenditure in capital, as a proxy we will consider expenditure on fertilizers, seeds, fertilizers, pesticides and insecticides used by farmers.
The exogenous variables, in this case climatic, are disaggregated into maximum and minimum temperature. Also average temperature or precipitation could be considered, but intuitively they are correlated with maximum and minimum temperatures. The following model will be estimated by OLS:

$$\mathrm{Q_{it}} = \mathrm{f}\left(\mathrm{Q_{i(t-1)}}, \mathrm{k_{i(t-1)}}, \mathrm{tmax_{i(t-1)}}, \mathrm{tmin_{i(t-1)}} \right)$$

Where:

$\mathrm{Q_{it}}$: Production of the crop "i" in the period "t"

$\mathrm{k_t}$: Capital expenditure of the crop "i" in the period "t"

$\mathrm{tmax_{it}}$: Anual average of the maximum temperature in the period "t"

$\mathrm{tmin_{it}}$: Anual average of the minimum temperature in the period "t"

Cost-Benefit Analysis

The cost-benefit methodology has the objective to evaluate the profitability of a project. In this case, the project evaluated includes agricultural insurance. The insurance will be effective if, with the climate conditions projected in the long run, the scenario with insurance is more profitable than the scenario without insurance. In this line, we evaluate an indexed agricultural insurance that is based on the probability of occurrence of the damage, and not on the compensation of the damage.

First of all, we define the farmer's incomes and expenditure. Income: income from the sale of products, expenditure: cost of agricultural activity. This expenditure in agricultural activity incorporates expenditure in land; seeds; manure and fertilizer; pesticides, insecticides and fungicides; laborers salary; bags and baskets for products, transport (gasoline, lubricants, etc.); products storage; irrigation water; subproducts elaboration; technical assistance; and others (rents, machinery, tractors, etc.)

In second place, we determine the impacts of climate change on the main crops in Junin. We place two scenarios: one with climate change and the other without climate change. Both will be described further in this document. After that, we compare the profitability of both scenarios using the net present value (NPV) of the cash flows. We work with the SNIP's suggested discount rate (9%), although we also do a sensibility analysis in this variable.

In third place, in case the previous analysis shows a drop in profitability in the climate change scenario, then we propose as an adaptation mechanism the use of indexed agricultural insurance. This type of insurance is understood as a mechanism that allows the reduction of farmers loses and that does not generate risk transfer. The importance of this relies in the existence of variables that are not controllable by the farmers, and that are more uncertain under the effects of climate change.

For this section, we add two accounts to the incomes and expenditures previously defined. In that way, the cash flow is defined as follows. Incomes: income from the sale of products and pay out of insurance; expenditures: cost of agricultural activity and cost of the insurance. We compare the profitability of the farmer under a no-adaptation mechanism scenario and under an insurance scenario. Again we use the NPV.

In fourth place, we use a sensibility analysis of the discount rate. Because the environmental projects generate benefits in the long run, to estimate the NPV we evaluate how modifications in this variable change the project profitability.

In fifth place, we use a sensibility analysis in the uncertainty generated on temperature by the effects of climate change.. In the previous analysis we assumed a moderate scenario. This analysis is important because it shows the possible changes for the farmer. In this line, we add two possible scenarios: Scenario with minimum variability (low climate change effect) and scenario with maximum variability (high climate change effect). Finally, we determine the situation were the farmer's profitability is maximized for each type of crop.

Results and Discussion

Results

Production Function

In order to estimate the quantities produced we have considered the ENAHO database for the period 2007-2011. The data for meteorological variables was obtained from the database of the National Institute of Statistics and Information (INEI) for the same period. It is important to see that our sample does not include farmers that practice subsistence agriculture. The reason for this is that a farmer that only subsists will not be able to buy the agricultural insurance. So, we establish the following condition: Annual sale value > Annual expenditures in the dataset.

After completing the process described in methodology, the following results were obtained:

$$logpotato_t = 0.58logpotato_{t-1} + 0.15logk_{t-1} - 0.29logtmin_t + 0.22logtmax_t$$

$$logcorn_t = 0.5logcorn_{t-1} + 0.384logk_{t-1} - 0.04logtmin_t - 0.09logtmax_t$$

$$logbroadbeans_t = 0.46logbroadbeans_{t-1} + 0.09logk_{t-1} + 0.05logtmin_t - 0.08logtmax_t$$

The fit of the model is moderately good as regular adjustment predicts the production of the three crops. In the case of the potato the R-square is 35%, in the corn 33% corn and 29% in the broad beans. All the variables are statistically significant at 95%.

With this information, amount for 2030 have been estimated and are going to be used in the next section. It is assumed that capital spending will grow each year at the same average rate as in the 2007-2011. Regarding climatic variables, it has been determined that these will grow linearly until the estimated increase of the Second National Convention.

Cost-Benefit Analysis

We will work with the following scenarios based on the temperature projections of the "Segunda Comunicación Nacional del Perú a la Convención Marco de las Naciones Unidas sobre Cambio Climático 2010".

Temperature change to 2030	No climate change	Moderate climate change	Maximum temperature variability	Minimum temperature variability
T max	+0ºC	+1ºC	+1.2 ºC	+0.8 ºC
T min	+0ºC	+1.2ºC	+1ºC	+1.4ºC

In the Moderated climate change scenario vs. No climate change scenario, we achieve the following results.

Effect of moderate climate change in profitability	
Potato	-5.7%
Corn	-2.2%
Broad Bean	+563.0%

As we can observe, in potato and corn, loss is generated because of the effect of climate change. The situation for the broad bean is different; its profitability gets better with climate change. This happens mainly because of two reasons. The first one, if we see the coefficients of the broad bean regression, we can see that although temperature is significant at 95%, the magnitude of the betas is low. The second reason is that bean's optimum range of temperature is between 5ºC and 28ºC, and with the effect of climate change, temperature gets nearer this range. So in this scenario, there is no need for agricultural insurance in broad bean, the study will focus its analysis in potato and corn.

The next step is to introduce the agricultural insurance in the climate change scenario. This is an indexed insurance, with minimum temperature as a trigger (we do not use the maximum temperature because even with the effects of climate change it is still in the crop's optimum range). There is no payment if the effective minimum temperature is above today's minimum temperature. There is a percentage of payment that is between today's temperature and the minimum temperature in the maximum variability scenario. Finally, there is the whole payment if it is below the minimum temperature in the maximum variability scenario. This payment is calculated over the expected loss of climate change, in other words the difference of income in a climate change and without climate change scenario.

Comparing with the scenario with no climate change, we have the following results:

Effect of moderate climate change in profitability		
Crops	**Without insurance**	**With insurance**
Potato	-5.7%	-2.1%
Corn	-2.2%	-0.8%

As we can see, the farmer's profitability increases if he incorporates insurance, although it is not as profitable as the scenario without climate change. Then a first affirmation is that indexed agricultural insurance is profitable in a climate change scenario, and it does not eliminate the effects of climate change, but it minimizes them.

In the sensitivity analysis, the insurance scenario still is profitable. First of all, profitability maintains when changing the discount rate from 0% to 30%. Second, analyzing the extreme climate change scenario (maximum temperature variability) and the low climate change scenario (minimum temperature variability), we obtain an increase in profitability (because of the insurance) in potato and corn of +6.2% and +2.4% in the first case, +0.9% and +0.3% in the second one. It is plausible that there is more effect in the maximum variability scenario, where the insurance has a more significant effect.

Discussion

Potato crops lower their profitability in 5.7% because of the effects of temperature increase and the variability of it. Hijmans finds similar results in the potato crop, lowering its productivity in 5.7%. Although it decreases, it is not as extreme as the effects predicted for the United States (-32.8%) and China (-22.2%). In this line, many studies have predicted that the negative effect in higher grounds will be lower. This happens because the frequency of droughts and inundations is detrimental, and it will take place mostly in lower grounds. Hijman's work also proposes an adaptation scenario. It also finds better results with adaptation to climate change (as we find profitable with the agricultural insurance), but the difference is that in that study the adaptation scenario shows to be more profitable than the scenario without climate change. This depends on how we define "adaptation", but corroborates another of our hypothesis. The agricultural insurance helps minimizing the effects of climate change, although it needs to be part of a greater adaptation plan to assure even better conditions.

Corn crops lower their profitability in 2.2% with the effects in temperature of climate change. In this line, Hawkins and others, Schlencker and Roberts, Jones and Thorton, also predicted negative effects for this crop in the future, they studied France, United States and Peru respectively. Jones and Thorton's prediction for 2055 is a reduction of 21% of corn production, although it seems high, compared to Venezuela (predicted cero production) it shows Peru's advantage of higher grounds.

In this case, the insurance also shows to be profitable. In this line, studies of Ballesteros-Becerra in Mexico and Hawkins in France assure the need of adaptation mechanisms for this crop. The work also mentions that the irrigation program is a good mechanism. However, it also assures that it is not good at high temperature variability. In this context, agricultural insurance acquires importance, and it corroborates the need of an adaptation program and not only separated mechanisms.

Broad beans crops show a different situation, they increase their profitability with the effects in temperature of climate change. In this line, the FAO assures that Bolivia has developed climate change resistant broad beans, and that they are used as a mechanism of adaptation. Other studies state that climate change will increase the propensity of some crop diseases, but that will not affect broad beans.

The optimum range of this crop showed by Ruiz (between 5ºC and 28ºC) allows us to see that with the climate variability predicted, the temperature will be nearer to this optimum range. According to this, it is plausible to think that the positive effects overcome the negative ones, giving the broad beans crop a higher profitability with climate change.

It should be noted that the design of insurance is essential for this mechanism because it should not be a simple transfer of risk that generates moral hazard, that is, the insured farmers care less for their production than if they did not have insurance (Kim, 2012). For example the payment of indexed insurance is according to the probability of an adverse event occurring. It has a trigger, not controllable for the farmer such as temperature, and it is this trigger that will determine the payout percentage of the insured amount.

Conclusions

The use of agricultural insurance is still in little practice in Peru and Latin America. This work predicts that it could be a mechanism of efficient adaptation and maintenance of safe profitability for farmers facing the adverse effects of climate change. The design of the insurance is very important to avoid moral hazard situations. A comprehensive adaptation plan is necessary, and agricultural insurances should be included in it.

11. A whole systems approach to modelling low carbon urban heat provision

Ruth Bush

Abstract

The dense heat demand of cities provides a challenging environment for developing low carbon heating. Deployment of a mix of technologies will be needed at both an individual building level and a district level, using heat networks in high demand areas to open up options for waste heat and combined heat and power plants.

This paper uses the UK as a case study to argue that a systems-thinking approach is vital for considering urban heat provision. Scenario modelling is increasingly used by decision makers to understand the long-term implications of policies. However, scenarios largely focus on techno-economic aspects and do not capture important barriers to heat, including infrastructure planning and investment, the regulation of the heat market, and the perceptions of consumers and investors. This paper proposes a methodology that aims to integrate the social, technological and economic aspects of the urban heat system to more effectively inform decision makers for a transition to low carbon heating.

Keywords: heat, modelling, renewables, socio-technical, techno-economic

Introduction

A major challenge for energy policy makers today is how to create a low carbon, affordable and secure energy system in the future. This will require a radical change in technology use with uptake of renewable or extremely efficient energy generation technologies as well as demand reduction and energy efficiency measures. The scale of change required demands an understanding or vision for what such a system might look like. Policy makers and academics use scenarios to understand how a low carbon transition might take place. However, current use of scenario models have had limited impact on policy decisions to date (Hughes, 2012). This paper considers the factors influencing uptake of low carbon heating in cities and whether these are currently reflected within scenario models. It outlines a methodology for scenario modelling which aims to effectively inform national and local decision makers to take action on low carbon heating.

The complex challenge of low carbon heating

Heat accounts for nearly half (47%) of the world's energy consumption and was described by the IEA as the "sleeping giant of low carbon energy potential" (IEA, 2007, p.5). In the UK, heat energy is responsible for 38% of the UK's carbon emissions (DECC, 2013). The domestic sector has a particularly significant heat demand accounting for 25.9% of the total UK energy consumption. The majority of this is generated using natural gas (65%) with the rest coming mainly from electricity and a small proportion from oil and wood (DECC, 2013). Current UK government scenario modelling envisages a highly electrified energy system where heat is eventually delivered using electricity (DECC, 2010, Committee on Climate Change, 2010). However, energy efficiency standards within UK housing are generally poor compared to other European countries (Hawkey et al., 2013), making uptake of technologies such as electric heat pumps difficult.

Heat energy has its own unique social, economic and technological characteristics which make decarbonisation more challenging than electricity generation in isolation. Heat is generated within each individual building as opposed to the centralised generation plants primarily used for electricity generation. This means that a large-scale retrofit will need to take place to install new heating technologies. The unfamiliarity of district heating within the energy system makes investing in such projects riskier to investors. There are also significant social implications of energy system change in terms of potential price rises or lock-out of technology access for vulnerable members of society. Therefore low carbon heat generation requires engagement with a large and disparate group of stakeholders; posing a particularly complex challenge for meeting the UK's legally binding decarbonisation targets of reducing carbon emissions by 80% by 2050 (HM Government, 2008).

Low carbon heating in UK cities

There are a range of technology options capable of generating heat from renewable sources or more efficiently than current technologies, and it is likely that a mix of these technologies will be required. The options include household-level technologies such as air-source and ground-source heat pumps, biomass boilers, bio-gas within natural gas infrastructure, solar thermal hot water heating and also district heat networks. In urban areas, the density of heat demand combined with the mix of housing types, ages and efficiency-levels creates a unique mix of challenges. District heating is thought to have an important role to play due to the lack of space and density of heat demand in cities (DECC, 2013).

The need for a mix of community-level and household-level technologies in urban areas adds further complexity to low carbon heating. The physical and social characteristics determine the specific technology solutions for each locality. These vary hugely from place to place. Decisions are often influenced by local relationships including local authorities and community organisations which are regarded as trustworthy sources of advice (Bale et al., 2013). For example, the technical and economic viability of district heating projects are not only highly dependent on the physical characteristics and resources of a site, but also require the cooperation of multiple and disparate stakeholders from consumers to owners of heat sources such as industrial companies (BRE et al., 2013a). At present the role of local coordination is taken on by local governments. However, they have not traditionally been involved in strategic energy development and their staff are often under resourced and inexperienced in this area (Bale et al., 2012, BRE et al., 2013b). As a result there are now significant efforts to offer support and development tools to assist local authorities to take on the role of a local strategic energy body, using scenario modelling, heat mapping tools and training support (CHPA, 2013, DECC, 2012, DECC, 2013, Keirstead and Calderon, 2012).

The importance of scenarios for informing low carbon energy policy

Scenario thinking allows consideration of how a transition to a future low carbon energy system might take place and forms an important part of research to inform public policy development (DECC, 2010, Committee on Climate Change, 2010, Gouldson et al., 2013). However, the development of relevant scenarios that have an impact on public policy making is challenging. This is particularly the case for low carbon transitions where the time frames under consideration span several decades and their implications often conflict with short term interests of decision makers today (Hughes, 2012). A review of public policy scenarios by Volkery and Ribeiro (2009) highlighted the difficulty of creating influential scenarios for policy makers since “the heterogeneous nature of objectives and interests faced by governments makes it difficult to establish a key-client, frame the purpose and gain the participation of all relevant participants” (Volkery and Ribeiro, 2009, p.1205).

Hughes (2012) identifies three levels of analysis which are used for scenario thinking for low carbon transitions:

A broad, high-level perspective on the system, taking into account how evolving values and cultures might influence a transition over time;

The interactions of actors within the system to consider the motivations and networks or relationships which affect development trajectories;

Technical or techno-economic feasibility analysis to consider the implications of scenarios for optimal energy efficiency or minimum cost for a desired low carbon system. These are normally considered using a form of techno-economic modelling.

Hughes argues that thinking from each of the three levels can inform understanding about the other levels, offering a fuller and more realistic picture than by considering any one of them on their own.

At present in the UK, scenario work within the public policy realm is dominated by techno-economic modelling. This paper will go on to review the existing use of scenario thinking for low carbon heat policy formation and make recommendations for a methodology to improve this thinking for more effective impact on public policy in this area.

Current use of scenario modelling

Scenario work for low carbon heating technologies within the policy community predominantly uses techno-economic modelling to identify technically feasible and cost-effective sites for technology deployment (Finney et al., 2012, Gouldson et al., 2013, Girardin et al., 2010, Li, 2013). This work has recognised the need for local scenario work and local models are used with the aim of informing local decision makers, such as local government or energy companies, about optimum scenarios for future energy systems; often in terms of lowest financial cost at the local level. The models also include a spatial dimension to identify potential sites that would be suitable for district heat networks. They reflect factors such as housing type, the optimum routes for heat networks and required capacities for generation technologies. Foxon (2013, p.11) argues that this demand for techno-economic scenario work relates to “the predominant influence of economic thinking on policy making in this area, such as the requirement to identify market failures in order to justify government action”. At present there is a move by national and local governments to increase the use of such techno-economic models within low carbon heat development (Scottish Government, 2013, Energy Technologies Institute, 2013).

Limitations of techno-economic modelling for low carbon heat scenarios

Techno-economic modelling techniques do not consider some of the more complex barriers to deployment of heat technologies already outlined in sections 2 and 3. For example, techno-economic models do not represent the multiple local stakeholders who need to cooperate to get a district heating project to happen. Equally, they cannot represent the political dynamics, public perceptions, or the challenges of affordability and energy security which influence the development trajectory of low carbon heating. This is beginning to be recognised by some local practitioners (e.g. see the Vanguards Network report (2013)); however, little work is being done at present to model and understand scenarios for the more complex areas of the local energy system. To create a more realistic and relevant view of future urban energy systems there is a need to consider the complex factors of social perceptions, networks of actors, governance and culture alongside technical and economic dimensions.

Methodological suggestions for a systems thinking approach to urban low carbon heating

A suggested methodology for creating relevant scenarios for low carbon heating policy is to use socio-technical transitions theory alongside techno-economic modelling focusing at a local level. The complexity of low carbon heating within cities calls for this novel application of the methodology, which has never been conducted at a local-level. This would enable consideration of all three perspectives highlighted by Hughes (2012) for effective development of scenarios for informing policy questions; combining analysis of the broad, high-level perspective on development, the interactions of actors, and the techno-economic feasibility of scenarios. This would also capture the important local characteristics of an urban energy system which are so critical to low carbon heat delivery.

Socio-technical theory

Socio-technical theory aims to consider many of the social factors that affect technical change which cannot easily be represented within quantitative analyses. The Dutch academic Frank Geels has been particularly influential in developing the school of thought (Geels, 2002, Geels, 2010, Geels and Raven, 2007). The socio-technical system is conceptualised as a ‘configuration’ of elements which enable a service, such as personal transportation, to be delivered (Geels, 2002). For example, for a train to successfully offer a transportation service it needs more than the technological elements of an engine, wheels, brakes, steering, seats, lighting etc. It also needs rail infrastructures, fuel supply chains, skilled workforce, maintenance and distribution networks, financial investment options, markets and users for its service, and ‘culture and symbolic meanings’ (e.g. freedom and desire to use the train), (Geels, 2002. p.1258). To explain this socio-technical configuration further Geels quotes T.P.Hughes’ metaphor of a ‘seamless web’ (Hughes, 1987) where “physical artefacts, organisations, natural resources, scientific elements, legislative artefacts are combined in order to achieve functionalities” (Geels, 2002, p.1257).

Socio-technical analyses of low carbon heating to date have looked at the history of the energy system to understand how existing district heating projects have successfully overcome lock-in of gas and electric systems (Foxon, 2011). An historical perspective offers a useful insight into why the energy system is in its current situation and therefore how changes might be made in the short term, but it does not offer a long term perspective about how change may occur leading up to a time frame such as the year 2050.

A co-evolutionary framework

In order to look at future scenarios for low carbon heat using socio-technical theory, the co-evolutionary framework developed by Foxon (Foxon, 2011) offers a suitable analysis tool. The framework considers five dimensions (Figure 1) which each evolve under their own dynamics but are also influenced by each other. They therefore co-evolve together. Foxon's definitions for these five dimensions within the framework are detailed below and can be considered as a starting point for any analysis (Foxon, 2011).

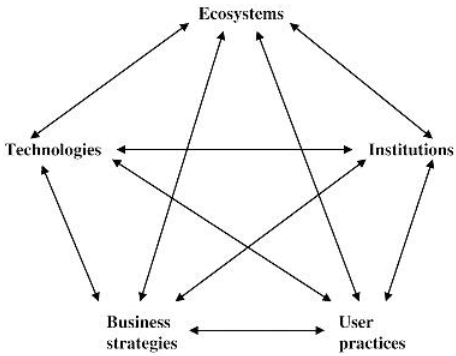

***Figure 1**: Foxon's Co-evolutionary framework (Foxon, 2011)*

Ecosystems are defined as the "natural flows and interactions that maintain and enhance living systems" (Foxon, 2011, p.2262). For example, this could refer to natural renewable resources such as wind or solar energy, or fossil fuels such as oil and coal.

Technological systems are defined as "systems of methods or designs for transforming matter, energy and information from one state to another in pursuit of a goal or goals" (Foxon, 2011, p.2262).

Institutions are "ways of structuring human interactions" (Foxon, 2011, p.2262).

Business strategies are "the means and processes by which firms organise their activities so as to fulfil their socio-economic purposes" (Foxon, 2011, p.2262).

User practices are "the routinised, culturally embedded patterns of behaviour relating to fulfilling human needs and wants" (Foxon, 2011, p.2263).

The dimensions of the framework enable a holistic view of the city-level energy system, and consider the interactions of actors as well as a broad, high-level perspective highlighted by Hughes (Hughes, 2012). Scenarios for different local, low carbon heat transition pathways can be developed based upon a detailed characterisation of these five dimensions. Pathways describe possible narratives for a city to develop to a low carbon energy system from the present day to a future date. These narratives can be iteratively refined and informed from consultation processes with expert stakeholders.

Scenarios informed by techno-economic modelling

The results of techno-economic modelling can then be used to inform the physical and economic viability of proposed pathways. This ensures that the physical realities of delivering low carbon heating in cities are reflected within the pathways. An applied example of this methodology at a national level considers transition pathways to a low carbon electricity system (Foxon, 2013). The process of using the results from techno-economic models to inform the development of transition pathways is critical to integrating all three scenario-levels proposed by Hughes (Hughes, 2012). Using this approach results in pathways that are based upon not only technical and economic realities, but also feasible scenarios of development for the wider society and network of actors which support this process.

In his initial application of this methodology at a national level, Foxon proposes that the resulting scenario pathways are useful to policy makers in a number of ways (Foxon, 2013). They identify challenges for different actors in realising the pathways; for example highlighting the influential role of local authorities for delivering low carbon heat and the need to develop their capacities in energy system development. They give a sense of the scale of the challenge and what might be required to meet it, not only in terms of quantified numbers of technology deployment, but also in terms of cultural and institutional roles within the system. Based upon this broader understanding of possible development pathways, policy makers at the national and local level can make an informed and conscious decision about the implications of their policy decisions for future decades.

Conclusion

Low carbon heating poses many complex challenges which are distinct to low carbon electricity and need local solutions. Support tools such as scenarios modelling for low carbon heat is particularly important at the local level in the UK where actors are inexperienced in development of the energy system. Going beyond a techno-economic modelling approach to low carbon heating scenarios is essential since many of the barriers to its deployment are not captured by this type of modelling. The methodology proposed in this paper enables the development of scenarios which consider multiple dimensions of the energy system and the complex influences on its development. This systems-thinking approach offers policy makers a view of plausible future scenarios, technically, economically and socially, to inform decisions and develop a fairer and more sustainable energy system. In future work, the author will apply this methodology for case study cities in the UK.

12. Development prospects of China's shale gas resources in light of global warming

Yanyang Wu, Xia Li, Bei Wang, and Stanley Laskowski

Abstract

Before 2013, it was widely believed that China's shale gas resources could radically alter the dynamics of supply for the world's biggest energy consumer, and there would be a shale gas boom in China, for two major reasons: China has a policy of encouraging gas use to replace coal to reduce its carbon intensity, and Chinese recoverable resources of shale gas are estimated to be the world's largest. However, the Chinese government is under a dual pressure caused by global warming: addressing its growing water scarcity; and reducing its carbon dioxide emissions per unit GDP. The exacerbation of water shortage will become a significant barrier for hydraulic fracturing to recover shale gas; and leakage of methane gas from the fracking process may even form a greater carbon footprint than conventional natural gas. Through comparisons of shale gas developing situations between China, Europe and the U.S., this research pointed out that China is difficult to replicate the previous success of shale gas in the U.S., mainly due to the oligopolistic structure in Chinese gas industry; current nonmarket-based pricing system; and uncertainty of shale gas production decline rate. That's why in the current situation, China is experiencing serious bottlenecks in the development of shale gas, and that so-called "shale gas revolution" is overly optimistic, or even just a speculative bubble. Therefore, how to balance the pressures of global warming and inner demands of shale gas, and strengthen enforcement to curb speculative bubbles of shale gas should be carefully considered by China as it puts in place a sound framework governing shale gas and minimizing the risk.

Keywords: shale gas, global warming, horizontal drilling, pricing system, speculative bubble

Introduction

According to the 2°C Scenario (2DS) in the 2012 edition of Energy Technology Perspectives (ETP 2012), to limit long-term global temperature increase to 2°C, reducing coal use and improving the efficiency of coal-fired generation are important first steps. Although the window of opportunity is closing rapidly on achieving the 2DS target, the emergence of "shale gas revolution" brought the world a glimmer of hope on the horizon. Over the past decade, rapid development of innovative new techniques involving the use of horizontal drilling with hydraulic fracturing allowing the recovery of natural gas from shale formations are deeply remapping the energy future of the World. The shale gas production in U.S. is spurring its economic activity, and steadily changing the role of U.S. in global energy trade. Its impact has also already surpassed North America to all the world, especially to China.

In 2006, China overtook the United States as the world's top annual emitter of carbon dioxide. In response to growing energy demands and heightened concerns over the environmental impacts of coal-fired power generation, the core of the policy objectives for Chinese government is how to temper the use the coal and boost cleaner alternative fuels to replace coal in the energy mix. Therefore, developing its natural gas supply, including its domestic unconventional gas reserves, has become a top priority for China. China's commitment to reduce its carbon intensity (carbon dioxide emissions per unit GDP) by 40-45% below 2005 levels by 2020 is a major factor driving its thirst for natural gas-burning natural gas produces only 37% of carbon dioxide as burning coal for the same electricity output, requires low or even no subsidy, and has less environmental externalities than other fossil fuels. The other issue concerned by the Chinese government is enhancing China's security of energy supply. China is currently facing a high import exposure-it is projected to become the world's largest net oil importer in October 2013, and China's gas import dependency will rise from 23% in 2011 to 36% in 2016. Shale gas comes at a timely point in the evolving global warming debate. China has the largest proven reserves of shale gas worldwide-25.08 trillion cubic meters (Y. Chang, 2012). It is widely believed that the exploitation of this natural gas reserve could reduce China's reliance on coal as well as foreign oil or liquefied natural gas (LNG) imports. Furthermore, in the absence of an explicit cap and trade mechanism for CO_2 abatement, shale gas would be more competitive than high-cost renewable energy sources in China (H. Rogers, 2011). That's why both Chinese government and industry believe that unconventional natural gas, especially shale gas, should continue to increase its share of China's energy mix at the expense of coal for the foreseeable future.

Developing Process of China's Shale Gas Resources

While China is already the world's fourth largest gas consumer, natural gas accounts for only 4.3% of China's primary energy mix in 2011, and the government plans to derive 8% of its primary energy consumption from natural gas by 2015. On December 18, 2009, the first hydraulic fracturing well using US technology was performed in China. Nearly one year later, China's first drilling of shale gas was conducted on January 10, 2011 in Sichuan Province. Then, an initial tender for four blocks of shale gas exploration acreage in the Sichuan Basin was held in June 2011, with participation limited to six eligible state-controlled companies. In March 2012, the National Energy Administration (NEA) unveiled an ambitious plan to produce 6.5 billion cubic meters of shale gas by 2015, accelerating to 60-100 billion cubic meters per year by 2020. After that, China's 2^{nd} shale gas bidding round was held in July 2012. An expanded group of bidders, including privately-owned Chinese companies, are allowed to participate in this round of licensing (Fig. 1).

It was widely believed that China's shale gas is poised to enter a golden age, even including the *World Energy Outlook 2012*. However, after entering 2013, the development of China's shale gas has begun to face a dilemma. While in January 2013, 16 companies finally won 19 shale gas resource blocks after 2^{nd} bidding round, until mid-2013, only one block has been started drilling. From 2009 until end-2012, China has only completed 129 shale gas rigs, and the total shale gas production of China in 2012 is 25 million cubic meters-far lower than the 2015 target. According to the data of China's pilot horizontal wells, the average daily gas production is 11000 cubic meters per well, which means if China still wants to achieve its 2015 target (6.5 billion cubic meters), it needs to build 700-800 wells each year in the next two years (2014-2015). Therefore, it is gradually believed by China's industry that, based on current developing speed, to achieve such goal is almost impossible. The prospect of China's shale gas development is again on the cusp of debate. The similar dilemma also occurred in Europe, especially in Poland. Despite around 40 wells being drilled in Poland since 2010, no company has to date announced that it can extract gas for commercial purposes. In 2012, ExxonMobil and two other companies announced they would withdraw from Poland, doubting the gains they could make. Even in the United States, the recent data of shale gas production from EIA shows signs to be declining. As a result of these realities-high depletion rates, the need to drill ever more wells to maintain production, decreasingly productive wells as the best locations are drilled and depleted, and the higher prices required to justify this investment-currently, more and more people believe that the so-called "shale gas revolution" is nothing more than a bubble. Such drilling frenzy is driven and hyped by oil and gas majors (almost from the United States) in order to profit from mergers & acquisitions, and shale gas is far from the solution to our energy woes.

Figure 1: *Blocks for 1st and 2nd Shale Gas Bidding Round*

Hurdles facing Development

Previous forecasts pointed out that due to China's highly centralized regulatory and policy-making framework, and the high priority placed on industrial and economic development, shale gas projects may face fewer hurdles stemming from environmental concerns than those in Europe or the United States (IEA, 2012). In both Europe and the US, there has been strong opposition to shale gas drilling on environmental grounds. Unlike Europe and the US, the scale of the regulatory and public acceptance risk in a Chinese context is not high. Compared with the US, one critical difference in China is that mineral rights are vested with the state rather than the landowner, which is similar with Europe. The difference between China and Europe is that all land in China is governed by government, which means there is no private landowner in China. Therefore, shale gas drilling will trigger lower NIMBY responses in China than in Europe or the US. But there are still many problems worthy of attention, including large land use footprint during building period; huge quantity of water use; surface and ground water contamination; atmospheric emissions of $PM_{2.5}$, VOCs and GHG; potential radioactive contamination; seismic activity; and noise/light pollution. Compared to those in the United States, Chinese shale-gas extraction operations are poorly developed.

The chances of poor well construction and hence of contamination are higher, and monitoring programs are largely absent (H. Yang, 2013a).

In this research, among the above environmental concerns, water availability and GHG footprint are the most important aspects for current Chinese situation. The main reason for China exploring its shale gas resources is spurring domestic natural gas use, and then gradually replacing coal in China’s energy portfolio to help controlling its GHG emission. Under global warming background, the development of shale gas may pose China under a more serious dual pressure: hydraulic fracturing may exacerbate water shortage problem within a certain period of time for a particular area; and leakage of methane gas from the fracking process may even form a greater carbon footprint than conventional natural gas.

China is one of 13 countries that is experiencing serious water shortage. In the 12th Five Year Plan (12FYP), global warming had already been highlighted as a threat multiplier to China’s already stressed water resources. Water availability may prove to be one of the biggest obstacles to unconventional gas development in China, particularly in the north and west, where water is scarce and may be already strained by agricultural or urban needs. Due to complex geological conditions, Chinese shale-gas wells each consume 10,000 to 24,000 m^3 of water (H. Yang, 2013b). To water use of hydraulic fracturing, perhaps the issue is not so much the quantity of water used per unit of energy output, but rather the availability of suitable water sources in the vicinity of shale drilling sites and the competing uses of such water which might result in a potential conflict and ultimately a constraint on shale gas activity in a specific location. In terms of GHG footprint of shale gas lifecycle, a shift from coal to shale gas would not bring benefits to the GHG footprint. The average leakage rate in shale gas lifecycle is 2-3%, and the comparative impact of CH_4 on global warming is over 20 times greater than CO_2 over a 100-year period, so the shale gas lifecycle has a bigger GHG footprint than the conventional gas lifecycle (S. Jenner, 2013).

The other reason for China to use shale gas instead of coal is reducing air pollution such as SO_2 emission. However, Chinese shale structure contains hydrogen sulphide, with concentration generally no less than 1%. So the exploration of shale gas may produce serious air pollution problems, which is currently one of China's most concerns.

All the problems mentioned above are the potential barriers that could hinder the development of shale gas in China. Currently, unlike the traditional view, the biggest hurdle for current China’s shale gas development is not from the Chinese government or the public acceptance, but from the shale gas industry itself. Although China has the world’s largest shale-gas reserves, the features of China’s gas resources are generally deeply buried, highly dispersed and low-grade. Despite two rounds of shale gas bidding, the best blocks of shale gas are still controlled by the "Big Three and a Half" (CNPC, Sinopec, CNOOC, and Yanchang) national oil companies (NOCs) in China, in total, account for about 80% of all recoverable shale gas resources. Chinese shale gas industry is characterized by an oligopolistic structure dominated by such four NOCs. In most parts of the gas value chain, other players have limited roles. In order to break the monopoly, the Chinese government set a legal classification of shale gas as a separate mineral resource in late 2011, which means the current regulations that give the "Big Three and a Half" exclusive rights for exploration of onshore gas resources do not apply to shale gas, and this step may presage an intention to grant greater access to others. However, the blocks controlled by the "Big Three and a Half" are also the major conventional natural gas fields, which means under the name of "conventional natural gas", the Ministry of Land and Resources (MLR) can hardly cut the cake of those four monopolists and share them with other companies who want to participate in shale gas development, even with that legal classification. Since these big NOCs still have huge recoverable resources of conventional natural gas to tap, plus the unstable geological features, as well as the barriers of core technology transfer such as horizontal drilling, it is not surprising that they all took a wait-and-see attitude to invest in shale gas drilling.

Besides the oligopolistic structure in gas industry, the pricing issue is by far the most important issue as it interacts with all the other aspects. This includes dealing with more expensive imports, incentivizing future shale gas production, and avoiding cross-subsidies between large users and residential users. Although the Chinese government is often criticized by over interference in the pricing system, the influences from the four NOCs in the setting of policy decisions should not be ignored. China has an overall regulated approach based on cost-plus for the production and pipeline tariffs. With growing LNG imports and potential massive shale gas production, the spread between cheaper domestic gas production and expensive spot LNG cargoes is growing wider. This issue should be tackled rapidly as China is set to become increasingly import dependent over the coming decades, and LNG arbitrage may decelerate the development of domestic shale gas. The Chinese government has already engaged a pricing reform in two provinces taking a netback approach based on oil products priced indexation. China needs to think carefully about whether oil is appropriate as being the only linkage to be used in the formula. Oil products are pertinent when it comes to residential/commercial use and also for some industry, but coal is also an important competitor to natural gas, notably in the power generation sector (A.-S. Corbeau, 2012).

Another critical factor that hinder the progress of Chinese companies in shale gas development is the concern about decline rate of shale gas production. Although there is still considerable disagreement over how rapidly shale gas production declines, it is true that decline rates of shale gas production are much higher than for conventional gas wells. Despite productivity variations, all shale gas wells have very similar production profile characteristics: an early production peak followed by a rapid decline. Because most of China's current horizontal wells just start working, the average decline rate is still unclear, so that’s why many companies choose to wait, even those who had already acquired shale gas blocks after two tenders.

Conclusions

Therefore, shale gas development in China could help it to improve its energy security and address global warming and air pollution impacts from its heavy reliance on coal, but the benefit of massively exploring shale gas resources in China is limited in the short term, mostly due to the oligopolistic structure in Chinese gas industry, current nonmarket-based pricing system, and uncertainty of shale gas production decline rate. At the same time, careless shale gas development could lead to significant environmental impacts, including large-scale depletion of water resources, and air, water and soil pollution. In the long term, China should remain vigilant to the possibilities that water scarcity and GHG footprint may be exacerbated by shale gas development. Because of these problems, China is difficult to replicate the previous success of shale gas in the US. How to balance the pressures of global warming and inner demands of shale gas, and strengthen enforcement to curb speculative bubbles of shale gas should be carefully considered by China as it puts in place a sound framework governing shale gas and minimizing the risk. And it is the time for the world to ponder whether shale gas development is a sustainable business, and can serve as a bridge from conventional fossil fuels to renewable energy to finally mitigate global warming.

13. Influencing REDD+. Stakeholder participation in Ghana's REDD+ process

Abdul-Razak Saeed

Abstract

Reduced Emissions from Deforestation and Forest Degradation (REDD+) is designed to curb the 12%-17% of global greenhouse emissions from forests. Though the mechanism emanated from international UN climate platform, the implementation is realized locally. This has implications for present activities of local communities/Indigenous Peoples who depend on these lands and forests. In addition, the livelihoods and land use decisions of the communities will interface with REDD+. The impacts both REDD+ and livelihood objectives may mutually produce, challenges the dichotomous perspectives of a carbon-centric REDD+. In localizing international REDD+ decisions, it is crucial that stakeholders participate within the design and processes of a mechanism that invariably (re)shapes power relations and affects their interests in the forest resource. Using Ghana's REDD+ 'readiness' process, this paper examines stakeholder participation in the programme. The paper explores and analyses the views of Ghanaian REDD+ stakeholders on participation; how stakeholder groups assert their influence in the process and makes a case for the need to have effective participation for sustainable REDD+ and associated development.

Keywords: REDD+, forest, participation, climate change, livelihood, local community

Introduction

Developing countries are engaging in climate change mitigation through the mechanism of **R**educing **E**missions from **D**eforestation and Forest **D**egradation, conservation, sustainable management of forests and enhancement of forest carbon stocks collectively referred to as REDD+. The inclusion of forestry in mitigation emerged in 2005 in Montreal under the United Nations Framework Convention on Climate Change (UNFCCC) Conference of Parties (COP). As a proclaimed cost-effective yet effectual way of reducing emissions, REDD+ has become a central pillar to a post-2012 international climate regime (Corbera and Schroeder, 2011).

Yet, given the slow and incomplete process of the UNFCCC in finalising agreements on the mechanism, the outstanding complexities and various national 'readiness' actions needed for effective implementation, REDD+ has been deemed to be "*neither fast, nor easy*" (Hansen et al, 2009). The essence of improved forest governance for REDD+ implementation to achieve emission reductions, reduce poverty, conserve biodiversity of both flora and fauna is widely acclaimed (Corbera and Schroeder, 2011; Mayers et al, 2010; Hansen et al, 2009). These positive possibilities are not without challenge, as REDD+ has the potential to unleash negative consequences on local communities and worsen existing governance structures due to the mechanism's often rushed and forced implementation without full reforms of laws, policies and institutions for REDD+ 'readiness' (Dooley et al, 2008, Kanowski et al, 2011).

Implementing REDD+ requires progress towards decision-making arrangements that reinforce socially just and sustainable management of forests (Angelsen et al, 2012). However the "de facto prioritization of economic growth over forest conservation [and it's socio-economic value to local forest communities]" is a threat (Hansen et al, 2009; p. 451; Kanowski et al, 2011). Compounding this issue is the power imbalance that allows the political and administrative elites to capture resources and “wealth over more equitable outcomes” (Kanowski et al, 2011; p. 113). Scholarship demonstrates this aspect of the political economy of forest resource use and access (See Bryant and Bailey, 1997; Kanowski et al, 2011, Hansen et al, 2009; Latour, 2004). This paper therefore maintains the importance of conscious political and legal improvement of governance processes focusing on stakeholder participation (i.e. procedural rights) to institute a REDD+ that reduces emissions and addresses community needs and priorities (Visseren-Hamakers et al, 2012). Improved governance involves principles of participation, transparency, accountability, coordination and capacity (Menzel and Teng, 2010; Chhatre et al, 2012). Achieving substantial efficiency, effectiveness, equity and legitimacy hinges on embedding and enforcing these principles.

Ghana and REDD+

Facing a deforestation rate of 2% per annum, Ghana as one of the most deforested countries globally, welcomed the idea of REDD+ to salvage its forests and mitigate climate change (FC, 2010). In Ghana, forest is recognized as both reasonably vulnerable and as a carbon sink (Kalama et al, 2009). The ‘Ghana Goes for Green Growth’ Policy discussion document identifies REDD+ as an important low carbon strategy (Narasimhan, 2011).

Agriculture and illegal logging in the country have been identified as two main drivers of deforestation, with an increasing local demand for agricultural and wood products and limited technology development in Ghanaian farming systems (Narasimhan, 2011; FC, 2010). Ghana has increased its activities on REDD+ since 2007 with two programmes managed by the World Bank called the Forest Carbon Partnership Facility (FCPF) and Forest Investment Program (FIP). The country has recently joined the UN-REDD programme as an observer. The FCPF and UN-REDD are parallel programmes to the UNFCCC process that provide technical and financial resources for REDD+ ‘readiness’ in developing countries that have opted to implement the mechanism.

Ghana’s national REDD+ process kicked off with its submission of a Readiness Project Idea Note (R-PIN) to the FCPF in 2007, followed by a Readiness Preparation Proposal (R-PP) which was provisionally accepted in 2010 pending certain requirements including higher political support for REDD+ at the cabinet level and clarifying stakeholder engagement in consultation process (FC, 2014; FCPF, 2010). Ghana has cumulatively (in tranches) received $3.6 million from the FCPF till date for its ‘readiness’. The country submitted a mid-term review report in July 2014 in Peru to the Participants Committee, which was accepted as progress and led to a further grant of $5 million for it’s 2015 implementation of REDD+.

Ghana is currently defining its REDD+ strategy. The R-PP formulation phase identified, 13 strategy options, which have been consolidated into 3 strategies with the facilitation of Pricewater House Coopers Ghana Ltd. The 7 Forestry Commission (FC) approved pilots across the country and the FIP’s Engaging Local Communities in Reducing Emissions jurisdictional project (ELCIR+) will test-run the strategy(ies). There are contracted expert consultants working on the grievance redress mechanism, benefits sharing, Social and Environmental Strategy Assessment and the Reference Emissions Level plus Monitoring, Reporting and Verification.

Methods and Materials

Primary field data was collected via semi-structured, face-to-face, in-depth interviews averaging 60 minutes with key stakeholders from government agencies involved in REDD+ and climate change adaptation, donor agencies, NGOs (social, rights and conservation) and pilot proponents. The semi-structured interview approach enabled new and emerging areas to be freely and flexibly interrogated to further shape researcher's understanding of REDD+ processes in Ghana. All interviewees were selected based on a combination of criterion and snowball sampling (Reed et al, 2009). Interviewees comprised actors actively involved in the REDD+ process at policy, scientific, technical and implementation levels.

The initial fieldwork conducted in August 2012 and January 2013, involved interviews with 12 key REDD+ experts and funded by the Walker Institute of the University of Reading. Subsequent interviews with 23 key REDD+ experts were carried out from July to September 2014 to update and augment the study. All interviews were audio recorded, transcribed and coded into themes and sub-themes in NVivo for analysis and discussion. Based on methodology, we recognize the need for further research that extracts REDD+ forest community perspectives so as to analyze against those of key REDD+ experts.

This paper employs Reed's (2008) 8 philosophies of best practice for "service contract" participation as the framework for discussion. The "service contract" view of participation sees participation as a dynamic process over a set-in-stone toolkit approach. This framework highlights the need for flexibility and adaptation in participation to differing and changing situations and environments, which are what REDD+ faces in implementation in varied geographic areas. The framework consists of key features for best practice stakeholder participation including empowering, equity, trust and learning; early consideration of participation throughout the process; clear and agreed stakeholder objectives from outset of process; local and scientific knowledge integration and institutionalizing participation.

Findings and Discussions

This section presents and discusses stakeholder participation in Ghana's REDD+ process. It includes views expressed in the field on what REDD+ implementation (must) mean(s) in local context.

Findings

The Forestry Commission (FC), as the agency in charge of REDD+ undertook activities to inform stakeholders on REDD+ concept, its origins and Ghana's activities in REDD+ during the R-PP formulation phase (FC, 2010). Sharing of information was primarily done through workshops and meetings at zonal and national levels. Though information sharing was the primary activity undertaken, the FC captured this process including question and answer sessions as consultation and participation. Each 'consultation and participation' meeting lasted between a few hours to two days (FC, 2010). Another unique challenge involved with information sharing was the uncertainty over the scope and shape of REDD+.

Currently, the FC is planning a mass information sharing and awareness raising roadshow, which seeks to ensure that REDD+ becomes a 'household name'. The REDD+ unit has also identified the youth as key actors to be informed, intrigued and empowered through the REDDEye campaign. Some empowering and learning activities on REDD+ have been particularized for stakeholders, such as the FC's National House of Chiefs. These targeted information sharing activities for certain stakeholders is the result of the FC's limited funding. Information from the field however showed that the information sharing by the FC is prominent at the national level but porous as one descends to the local communities. For instance, the government approved REDD+ pilot communities (5 of 7) do not have knowledge on REDD+, less the understanding and capacity to engage on it.

Moving on to the second finding, in 2007, when the World Bank invited interested countries to submit REDD+ Readiness Project Idea Notes, the FC on behalf of Ghana submitted without the knowledge of the broader stakeholder groups in forestry and climate change. This trend continued with the initial formulation phase of the R-PP. Civil society actors, such as Civic Response, CARE International, iADI, as members of the Forest Watch Ghana network, empowered in part by the Voluntary Partnership Agreement process, which strengthened consultation and participation in the natural resource Sector, pushed-back on the process, calling for it to be participatory to allow all relevant stakeholders influence REDD+ policy.

Faced with this pushback, FC and the World Bank mission slowed the REDD+ process to accommodate the concerns expressed. These concerned CSOs also had the regional Africa Community Rights network support, strategy and bottom-line agreed documents on REDD+ engagement as points of their advocacy. The FC attributed the quick pace of their actions devoid of stakeholder participation to limited timeframes of operations stipulated by donors.

Post civil society pushback, the FC consulted stakeholders on key drivers of deforestation and degradation, actions to address drivers and the potential impacts on stakeholders (FC, 2010). In addition, smaller units of multi-stakeholder working groups were established under the then National REDD+ Steering Committee (now National REDD+ Working Group). These groups worked under the umbrellas of REDD+ policy and strategy, REDD+ consultation and participation and REDD+ monitoring, reporting and verification. The R-PP reports that outcomes from the consultation and participation portray local stakeholders primarily interested in fair benefits sharing whilst that of government was on broad policy reforms to ensure successful REDD+ implementation.

Due to the stage of the REDD+ 'readiness' process in Ghana, which requires expert opinions and faced with limited resources, consultation and participation has employed a targeted approach in the last year and a half. Between March 2010 to April 2012, consultation and participation wholly slowed due to the delayed transfer of funds from the World Bank to Ghana Government. The Ghana FCPF REDD+ mid-term report submitted to the Participants Committee states that civil society has "moved from resistant to supportive" in Ghana's REDD+ process and this is attributed partly to effective stakeholder engagement (FC, 2014).

Thirdly, this study found that the due process of REDD+ mechanism in Ghana does not incorporate discussion on integrating adaptation needs or efforts into the mechanism. Policies and early strategy documents formulated including the R-PP do not mention efforts on how to leverage the benefits of REDD+ for both adaptation and mitigation. The view expressed by some interviewees was that within forestry, adaptation and mitigation are complementary and irretrievably interlinked. For instance, it was claimed that increasing forest cover as mitigation naturally and inadvertently creates an enabling environment for crops like cocoa and plantain and this can be regarded as adaptation. In addition, others identified that adaptation benefits were needed more in the savannah regions as opposed to the high forest zone, which has more vegetative cover. Interviewees expressed the needed view that REDD+ should have people at the center of its design and not natural resources at its center. It was argued that a carbon focused REDD+ makes it difficult to factor in adaptation angles. Most experts called for a REDD+ that revolves around the livelihood of the people to ensure that adaptation is well catered for within it. REDD+ adaptation benefits must include peoples' livelihoods, planned land uses, building forest resilience, building on connectivity with agriculture and improving agriculture. One expert rebutted this assertion on the basis that no donor will pay for adaptation/land use and that carbon is the only element with demand for payment. REDD+ experts in Ghana are of the view that to facilitate the link between adaptation and mitigation in REDD+, the Monitoring, Reporting and Verification (MRV) system must contain indicators for the totality of development; that is the social, environmental and the economic.

Discussions

The REDD+ process poignantly demonstrates the power dynamics between local stakeholders, State Government and the International. It further points to centrality of embodied organizational practices in enforcing/challenging/transforming these relationalities of power between these groups. An examination of the Ghana process, establishes not only the need for a discourse of participation, but praxis that is attuned to the varying levels and forms of knowledge, interests of stakeholders, and the capacities of stakeholders, given power inequalities tend to serve as an important barrier to meaningful stakeholder engagement (Reed, 2008).

The Ghana process as commenced under the FCPF readiness scheme was evidently lacking in consideration of the need for participation from the outset. This myopia meant that Ghana failed to accurately build into its process, both the financial and time-cost of undertaking stakeholder analysis and 'consultations'. The unappreciated role of stakeholder participation led to a budget deficit in planning and therefore made it difficult to engage the myriad of stakeholders in the REDD+ forest sector (Saeed, 2011). For a participatory process, a stakeholder analysis needs to be carried out from the onset. Such analysis according to Reed (2008) does not need to include the active participation of stakeholders if the analysts have first hand knowledge of individuals and groups that are affected or affect the decision at hand. Given the dynamism of REDD+, identifying stakeholders needs to be carried out iteratively whether by the FC or in conjunction with other stakeholders. This analysis ought to address inter alia the base-line knowledge and capacities of the stakeholders and the steps and processes need to equip stakeholders to adequately influence the agenda, and the contents of the process going forward.

The knowledge-level of stakeholders on the contents and process of REDD+ affects their ability to confidently engage in deconstructing, discussing and making decisions on REDD+. The variance of 'consultation and participation' modalities and varied levels of knowledge translated into power differentials from the onset. The failure to iteratively address these inequalities in the schemas of participation, limited the effectiveness of the process. The importance of accurate information sharing as a base-line practice, with ample time to allow for proper assimilation and the impact of the failure to do so, demonstrates the importance of embodied practice in shaping the contours of participation. It is evident that 7 years into the REDD+ process, the Ghana FC's appreciation of stakeholder engagement has palpably transformed, to open up new geographies of participation as evidenced by the plan for mass outreach to the public. There is however still a question of the depth of understanding that a mass awareness programme will achieve. Moreover, there are limits to this type of communication strategy, insofar as the immediate impacts of REDD+ will not be felt by the general Ghanaian public but by key stakeholders like local forest communities, migrant farmers and landowners, who must be acutely engaged and capable of reflexively and iteratively engaging the process.

Thus, beyond building on the base-line element of knowledge and information sharing, the capacities of the various stakeholder group representatives differ and steps to strengthen then must also be reflexively built into the process. Thus, for example, even though there is a multi-stakeholder platform, the National REDD+ Working Group, at the ministerial level for decision-making, it cannot be taken for granted the relative strengths of the constituent elements of the NRWG. In view of this, in order to build equity, trust and empower stakeholders, the FC needs to strengthen institutional capacities including NRWG especially owing to REDD+'s evolving nature. Without such capacity building opportunities, decisions by stakeholders can be harmful, based on temporally outdated information they possess. Knowledge exchange and information sharing between and across stakeholders at horizontal and vertical scales needs to be built into REDD+ process to streamline the understanding and capacity of stakeholders.

In referencing knowledge exchange across horizontal and vertical scales, it is argued that these varying forms and types of knowledge must each be able to 'speak' within the context of the REDD+ paradigm if there is to be any realization of equity. That is to say, in dealing with a common resource such as forests under REDD+, it is imperative that community knowledge of their dynamic forest issues and local knowledge on climate change merges with the scientific and technical knowledge that government elites and other policy level stakeholders possess in keeping with the UNFCCC COP Cancun safeguards adopted in 2010 (Lockwood et al, 2010). Moreover, as a signatory to the United Nations Declaration on Rights of Indigenous Peoples (UNDRIP), Ghana is expected to exercise Free Prior Informed Consent (FPIC). REDD+ despite being a climate change mechanism affects a whole stream of actors and sectors including forestry and wildlife, energy, livelihoods and agriculture (FC, 2010).

This multi-faceted nature of REDD+ and its undefined evolving nature, make it complex and dynamic, and thus a need to engage in "flexible and transparent decision-making that embraces a diversity of knowledge and values" (Reed 2008, p. 2417). All stakeholders, inclusive of their variable interests should through conscious knowledge be empowered to genuinely influence the process. These varied interests operate across scales, both temporal- long-term and short-term, and across the global-local dynamic and must therefore be structured within the REDD+ framework. Carbon for example, is majorly deemed not to be first and immediate income for communities, but is central to the REDD+ discourse. Community livelihoods that are immediate and everyday fall within the short-term category and need to be achieved before long term goals of emission reductions and carbon payments. REDD+ should therefore be tackled on a group approach basis with first group priority and attention being to ensure rights, stakeholder participation, local knowledge recognition, improving and sustaining livelihoods and safeguards implementation whilst second group priority will be carbon. Even as the first group priority largely leverages issues of adaptation, mitigation must also be streamlined. Failure to do so will cause unforeseen trade-offs and mal-adaptation in some instances; the greater of which is expected with agriculture/food production. In view of the link between agriculture/food production and community development, REDD+ in Ghana as focusing largely on the mitigation element, needs to be redefined in scope to prioritize community development. Initiatives situated within the local communities must be tailored to community realities, dynamism and needs to ensure community ownership and sustainability. In this instance, it is best to localise REDD+ than a direct handpicking from the international level and imposing on community space of influence.

Conclusion

Governments with diminished forest cover need forestlands for mitigation via REDD+, whilst local communities majorly need forests for their livelihoods and adaptation to climate risks. Outside these profound interests of these two actors towards mitigation and adaptation, the forest itself needs to adapt to potential climate risks (Somorin et al, 2012). Therefore genuinely and effectively involving communities, including a heterogeneity of groups including women, youth and other stakeholders in planning, decision-making, implementation and a system to monitor and feedback their concerns into the REDD+ process is key towards ensuring permanence of emission reductions and sinks, which also caters for community empowerment and development. REDD+ must drive local agenda of communities as opposed to the sole interests of donors and state governments. Without attention to the institutionalization of stakeholder engagement/participation, there is the possibility of REDD being in vogue but vague, visible but valueless, and at worst, villainous for both communities and the climate. Local stakeholder participation in REDD+ is essential for localizing internationally agreed mechanisms. The documentation and knowledge management on REDD+ issues, lessons and processes is important for posterity. Not focusing solely on carbon in REDD+ requires a process that disallows 'projectisation' of REDD+ for carbon to one that builds a holistic programme of emission reductions and community development and needs.

Acknowledgements

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14. Greenhouse gas emissions from animal husbandry and strategy for their reduction in indonesian villages

Alexandr Iscenco

Abstract

The animal husbandry sector is a large contributor to greenhouse gas (GHG) emissions, particularly the emissions of methane and nitrous oxide. It is possible to reduce these emissions through better livestock management, composting of animal manure or turning it into biogas. Such initiatives are now implemented in a number of villages in Indonesia, one of them being the Indrokilo village in Ungaran, Central Java. However, no quantification of GHG emissions and their reduction through these initiatives has been done until now. So, the rural communities and the government supporting climate change mitigation did not know how much the animal husbandry there contribute to climate change and how successful are the initiatives implemented for its mitigation.

The present research work fills in this gap of knowledge. It presents the results of estimating GHG emissions from livestock and manure management in Indrokilo during the period of 2008 – 2012, suggests strategies on emissions reduction to be realized there, assesses their potential to decrease emissions of methane and nitrous oxide, proposes the optimal strategy to pursue by the village community and concludes with recommendation on ensuring sustainability and success of the climate change mitigation program in Indrokilo village, as well as other rural communities.

Keywords: animal husbandry, biogas, climate change, compost, greenhouse gas, Indonesia, Indrokilo, livestock, manure management, village

Introduction

The Indrokilo village situated on the slopes of the Mount Ungaran in Central Java, Indonesia, has a good and diverse agricultural potential as a source of economic activities (Indrokilo Village, 2012). The village community comprised of approximately 600 inhabitants includes rice farmers, foresters and cattle breeders. They use the local fields for farming and pasture for cows and sheep. However, these activities contribute to the release of greenhouse gases (GHG), in particular methane (CH4) and nitrous oxide (N2O), into the atmosphere, therefore contributing positively to climate change (Renewables International, 2012). At the same time the Indrokilo residents suffer from the effects of climate change: changes in microclimate and reduced availability of water for agriculture decrease the area of wet agricultural land by turning more and more areas into dry barren land.

Since 2008 Indrokilo is part of the program “1,000 Kampung Iklim” (“1,000 Climate Villages”) launched by the Ministry of Environment in Indonesia and serves as a good case practice for other villages. The GHG emissions mitigation activities supported by the BINTARI Foundation (www.bintari.org) and the Indonesian government include agroforestry, biogas and compost production. The villagers possess 2 fixed-dome bioreactors – a large one with the capacity of 12 m3 per day and a smaller one with the capacity of 4 m3 – and 1 compost production facility with the production capacity of around 100 kg of compost per month. And the Indrokilo village also offers eco-tourism services (Dreamups, 2012).

However, during the whole period of this GHG emissions mitigation program in Indrokilo no estimation of emissions generated and reduced in the agriculture and animal husbandry sector has been done. The reason is mostly the lack of the necessary data about the situation in the village and no monitoring of the progress of the program. As a result, so far there has been absolutely no information on how much GHG is emitted by agriculture and livestock in Indrokilo, how much emissions reduction has been achieved due to biogas and compost production, and what GHG emissions reduction strategies should be applied by the village community in the future.

This is why the research initiative on GHG emission profile and strategy for Indrokilo on animal husbandry sector has been conducted, as this sector is a significant contributor to methane and nitrous oxide emissions (Jun et al. 2000). It is still based on many assumptions due to the difficulties in obtaining all data needed, but nevertheless can serve as a basis for further studies on climate change mitigation in Indrokilo and other villages in Indonesia.

Goals of Research

The main goal of the present research was to make the GHG emissions profile of Indrokilo and suggest feasible strategies for their reduction with the focus on the animal husbandry sector.

- The concrete objectives here were the following:
- Determine the situation of GHG emissions (CH_4 and N_2O) during the GHG emissions reduction program implementation in 2008 – 2012;
- Estimate future GHG emissions (until 2020) by the business-as-usual scenario;
- Suggest strategies for GHG emissions reductions in livestock for the future until 2020;
- Determine the optimal strategy for GHG emissions reduction in Indrokilo;
- Find out whether the GHG emissions reduction potential of the strategy will be in accordance with the overall national goal of 26% emissions reduction by 2020.

Methodology

Due to the lack of data necessary for estimating GHG emissions there was a need to travel to Indrokilo, observe and analyze the situation and conduct interviews there. Overall, there were 2 trips done to the village: the first one to get to know it and its initiatives and the second one to get measurements and conduct survey with the community leaders. These questions asked to them included the information about livestock population in the village and the share of it owned by each resident, manure management, compost and biogas production and usage, etc.

The model used for GHG emissions calculation was the 2006 IPCC Software for National Greenhouse Gas Inventories (IPCC Inventory Software) with the Tier 1 approach, i.e. based on default emission factors (Jun et al. 2000). The calculations were done with the climate data specific for Indonesia during the period 2008 – 2020 with the necessary modifications for each strategy analyzed.

Strategies

There are 4 different strategies proposed for Indrokilo to be implemented from 2013 till 2020 (Table 1).

#	Strategy	Description
1	Strategy A: Biogas Management	2 more biogas production facilities are installed in Indrokilo: one in 2013 and another one in 2017. Thus, the fraction of manure for biogas increases to 0.5 in 2013 and 0.9 in 2017.
2	Strategy B: Compost Management	1 more compost facility with the production capacity of 100 kg per day is installed in Indrokilo in 2013. The fraction of manure in system for in-vessel composting increases to 0.9.
3	Strategy C: Livestock Management	Starting from 2013 livestock growth rate in Indrokilo is limited to 100 cattle per year, and from 2017 - to 80 cattle per year.
4	Strategy D: Combination A-C	The combination of biogas, compost and livestock management. In 2013 1 biogas and 1 compost facility are installed; plus since then the livestock growth rate is limited to 100 cattle per year. In 2017 a second biogas facility is installed and the growth rate is managed at 80 heads per year.

Table 1: *Strategies for Reducing GHG Emissions Proposed for Indrokilo*

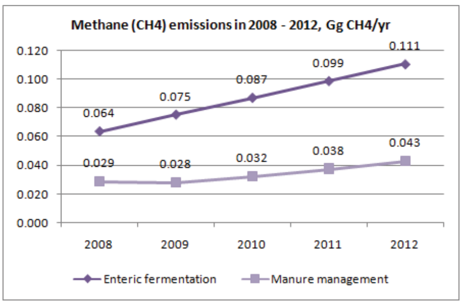
The GHG emissions reduction potential of each strategy throughout 2020 was compared with the business-as-usual scenario and with each other to determine their performance and effectiveness, as well as find out the optimal strategy for the Indrokilo village to pursue.

Results

Situation during 2008 – 2012

The results of estimations show that the GHG emissions have been increasing during the period of 2008 – 2012. From 2.313 Gg of CO2 equivalents per year the emissions rose to 3.882 Gg. This is explained mostly by the growth in the number of livestock. Even the installation of bioreactors and compost facility could not offset the increase of emissions.

The effect of installing biogas and compost production facilities is more obvious when we consider methane emissions from manure management (Figure 1). However, as we do not consider GHG emissions savings from reduced wood and fuel consumption, the positive effect of introducing biogas production is very low.



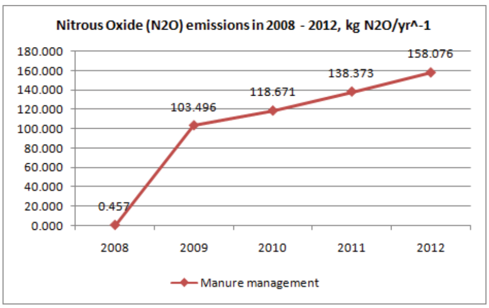


Figure 1: *Methane and Nitrous Oxide Emissions in 2008 – 2012*

The introduction of compost production seems to contribute to the increase of nitrous oxide emissions. They are produced during the nitrification-denitrification of nitrogen within animal waste (Jun et al. 2000). From about 0.5 kg of N2O per year in 2008 the emissions have risen to more than 150 kg. This is associated with the aerobic fermentation process of the manure during compost production under the dry conditions of Indrokilo. Still, due to the fact that N2O as greenhouse gas is less potent than CH4, its higher emissions are offset by the reduction of methane emissions due to the use of manure for compost.

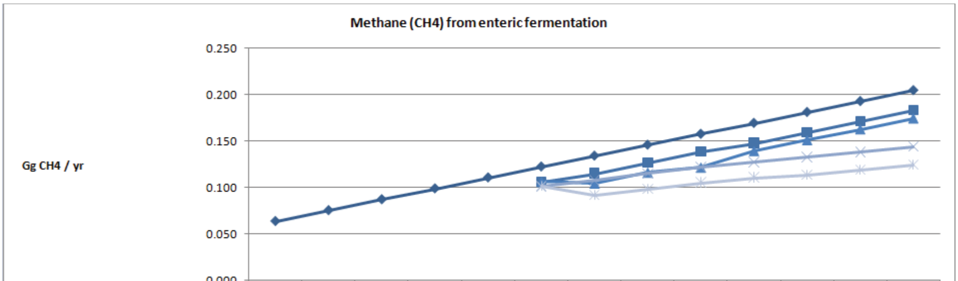
All in all, the GHG emissions from animal husbandry sector in Indrokilo are in constant increase with the main driving factor being the growth of the numbers of livestock. Biogas and compost production have been able to slow down this increase rate, but have not managed to reverse it or at least maintain GHG emissions under certain limit. More facilities need to be installed to achieve better results. All this should be considered in strategies for climate change mitigation in the village.

Emission Scenarios and Strategies until 2020

GHG emissions from livestock in Indrokilo will continue to grow. The estimates for the business-as-usual scenario show that they will reach 5.2 Gg of CO2 equivalents per year by 2015, 6.0 by 2017 and 7.3 by 2020.

Although it is hardly possible to reverse the increase of emissions or even stop it, the growth rate can still be reduced significantly through application of the strategies described earlier.

In terms of methane emissions from enteric fermentation, which are expected to reach 0.15 Gg per year by 2015 and 0.21 Gg by 2020, the limitation of the number of cattle in the village (strategy C) has the most impact on reducing these emissions. By implementing this solution, the Indrokilo community can reduce its CH4 emissions by 30% in 2020 and keep them at the level of emissions in 2015 compared to the business-as-usual scenario. More biogas and compost production (strategies A and B respectively) achieve only 10 – 15% by 2020. But, of course, the highest reduction is achieved by the combination of all initiatives (strategy D) – it can slash methane emissions by almost 40% in 2020 (Figure 2).

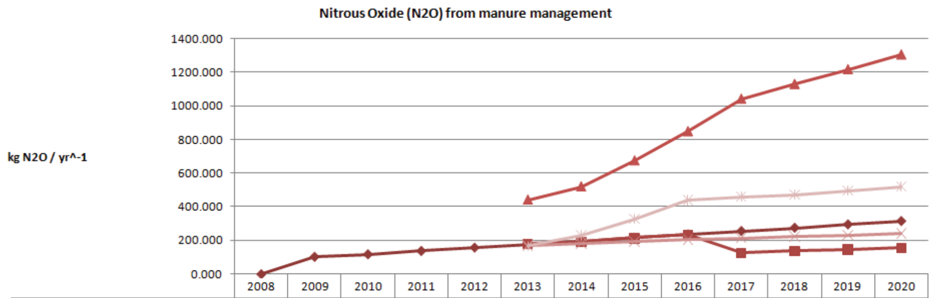


	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Business as Usual	0.064	0.075	0.087	0.099	0.111	0.122	0.134	0.146	0.158	0.169	0.181	0.193	0.205
Strategy A: Biogas Management						0.106	0.115	0.127	0.139	0.148	0.159	0.171	0.183
Strategy B: Compost Management						0.106	0.104	0.116	0.121	0.139	0.151	0.163	0.175
Strategy C: Livestock Management						0.101	0.108	0.115	0.122	0.127	0.133	0.138	0.144
Strategy D: Combination A-E						0.101	0.092	0.098	0.105	0.111	0.114	0.119	0.125

***Figure 2:** Methane Emissions from Enteric Fermentation until 2020*

Methane emissions from manure management are significantly lower: according to the business-as-usual scenario they will equal 0.06 Gg per year by 2015 and 0.09 Gg by 2020. The GHG emissions reduction potential is similar to the previous case: the highest reduction (about 30% by 2020) is achieved by strategy D, followed by C (20%), B (5%) and A (3%).

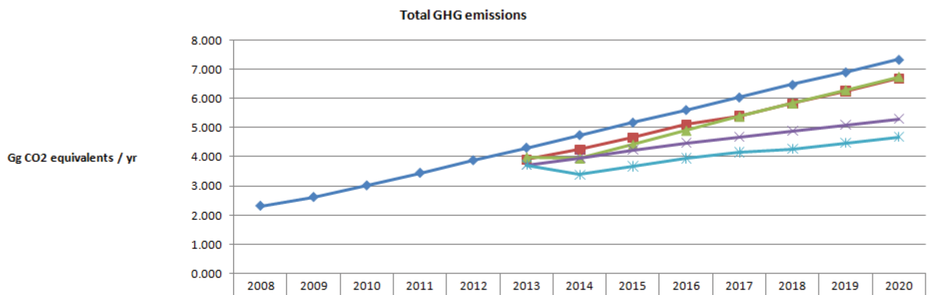
The situation is different with nitrous oxide. Its emissions are expected to rise to 217 kg of N2O per year by 2015 and by 316 kg by 2020. However, with the introduction of more composting (strategy B) they may rise as high as 1306 kg of N2O per year, i.e. by approximately 70%. The best strategy to cut off N2O emissions is biogas production – it allows the emissions to be kept below the 2012 level (Figure 3).



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Business as Usual	0.457	103.496	118.671	138.373	158.076	177.779	197.482	217.185	236.888	256.591	276.294	295.997	315.700
Strategy A: Biogas Management						177.779	192.953	212.656	232.359	125.252	135.218	145.184	155.150
Strategy B: Compost Management						441.362	519.941	674.606	848.746	1042.35	1130.22	1218.08	1305.94
Strategy C: Livestock Management						169.627	181.178	192.729	204.280	213.566	222.853	232.139	241.426
Strategy D: Combination A-E						169.627	229.864	328.597	438.652	461.525	473.076	495.949	518.822

Figure 3: *Nitrous Oxide Emissions from Manure Management until 2020*

The most useful picture of GHG emissions reduction potential is obtained when we turn all GHG into CO2 equivalents. Here we see that although compost initiative (strategy B) performs better than the biogas-oriented one (strategy A) in the short term, they achieve almost the same results in the long term – around 10% by 2020. Livestock management option (strategy C) performs much better, reducing emissions by almost 40% by 2020. Only the combination of all activities (strategy D) brings higher reduction potential – about 45%.



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Business as Usual	2.313	2.616	3.016	3.449	3.882	4.315	4.748	5.181	5.614	6.047	6.480	6.913	7.346
Strategy A: Biogas Management						3.907	4.240	4.673	5.106	5.402	5.832	6.262	6.692
Strategy B: Compost Management						3.986	3.941	4.415	4.894	5.378	5.832	6.285	6.738
Strategy C: Livestock Management						3.727	3.979	4.231	4.484	4.686	4.888	5.090	5.293
Strategy D: Combination A-E						3.727	3.400	3.678	3.960	4.166	4.270	4.476	4.682

Figure 4: *Total GHG Emissions in Indrokilo until 2020*

Conclusions and Recommendations

Based on the information obtained during the visits to Indrokilo and the results of the GHG emissions estimations it is possible to formulate certain recommendations for the BINTARI Foundation, the Indonesian government and rural communities regarding climate change mitigation at Indrokilo and other villages in Indonesia. These are the following:

1) The most GHG emissions reduction result is achieved when biogas and compost production and livestock limitation initiatives are combined together. The strategy assessed here included the installation of 2 more bioreactors, 1 more compost production facility and livestock growth limitation to 100 and later 80 heads per year.

2) Among all strategies, only livestock management and the biogas + compost + livestock management combination have the potential to meet the 26% GHG emissions reduction target for 2020 in Indonesia. Compost and biogas production achieve only 10% emissions reduction. So, in order to achieve the target only strategies C and D need to be pursued.

3) The principal factors affecting methane emissions are the number of animals, the amount of manure produced by them and the portion of manure that decomposes anaerobically (Jun et al. 2000). The most emissions come from cattle with the ones from sheep and poultry are not so significant. Therefore, CH_4 emission reduction activities should firstly target the number of cows at the site and then divert attention to the manure management system.

4) The compost production strategy shows an increase of nitrous oxide emissions. This is because aerobic composting process used in Indrokilo in a hot dry climate of Central Java provides an environment more conductive for N_2O generation (Jun et al. 2000). But the nitrous oxide emissions increase due to composting is offset by the reduction of emissions of methane, which is a stronger greenhouse gas. This is why it is still suggested to proceed with compost production and develop the process in the way that it causes less N_2O emissions.

5) The implementation of the compost production strategy has a serious challenge in terms of selling the produced compost. Even at present time, i.e. in 2012, the local farmers cannot sell all the compost they created, which makes the production potential underutilized and poses a challenge to the sustainability of this initiative. Therefore farmers need support in finding the permanent buyer(-s) of their compost as soon as possible.

6) Regarding the biogas production, the challenge here is farmers' insufficient professional knowledge about operation and maintenance of bioreactors. This results in a low quality biogas production (Guo Guo, L. 2010). Hence, good technical and practical education needs to be delivered to the farmers in the village to improve the generation of biogas.

15. Reducing the material footprint of meals

Holger Rohn, Michael Lettermeier, Kristin Leismann, Sini Veuro, Jaya Bowry

Abstract

The global use of natural resources has been growing for many decades and has already exceeded a sustainable level. Nutrition is responsible for a significant share of the resource use of a society and results in considerable material footprints. In European consumption, the food sector accounts for a quarter of natural resource use. For the reduction of global resource use to a sustainable level, it is crucial to define a sustainable level of resource use for nutrition.

Dissolution of daily routines, demographic change and increasing demand for flexibility contribute to the rising percentage of food consumption in the restaurant and catering sector. On average, every German eats already over 100 meals outside the home every year. One third of food sales in Germany can be ascribed to the out-of-home catering sector.

The paper introduces the material footprint as a practical measure for assessing the resource use of meals. The material footprints of typical German meals and drinks are set in relation to the nutritional value (kcal) of the meals.

Resource-conserving meals can be promoted by supply (e.g. catering) as well as by demand (e.g. event organizers or consumers). Suggestions for resource efficient and sustainable food consumption and preparation for Food Chain participants are highlighted.

Keywords: material footprint, meals, food, resource efficiency, resource saving potentials.

Introduction

Our nutrition is facing numerous social, ecological and economic challenges. This will continue throughout the coming decades. An expanding population is placing a growing demand on food, while arable land is tending to decrease and e.g. energy crops are taking up more land. This causes price increases leading to social problems. More prosperous lifestyles foster environmental damage like soil degradation or biodiversity loss resulting from increasing crop demands. They also foster unhealthy nourishment, which affects individual and public health, thereby increasing costs and decreasing work productivity.

The global use of natural resources has been steadily growing for many decades and has already exceeded the sustainable level. If everybody in the world used a similar amount of resources as we are used to in the Western world, we would need the resources of at least 4 planets. However, resource use needs to take place within the limit provided by one planet in the long term and resources need to be shared among the world population in a way that ensures a satisfactory life for all (Dittrich et al. 2012, Bringezu 2015, Krausmann et al. 2015).

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. 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 lower global resource use to a sustainable level, a sustainable level of resource use has to be defined for nutrition (see Foresight 2011; Jungblut 2010; Koerber and Kretschmer 2006, Schmidt-Bleek 2009).

In the last decades a new food culture has evolved in western societies. Through long working hours and the demand for a high amount of personal flexibility, daily routines have dissolved and food preparation and consumption at home decrease. Today, fewer and fewer families eat a self-cooked lunch together as various, much faster options for eating out are provided in daily life suiting the modern lifestyles of people (e.g. Stieß and Hayn 2005).

With many forms of eating out (catering, communal eating e.g. in schools, companies, hospitals, etc.), the variety is predetermined by the supplier. Thus, suppliers have an opportunity to promote improvements that take into account environmental and health aspects. Consumers can therefore be exposed to meals and foodstuffs they have never tasted before and possibly reconsider their eating habits (see Rückert-John 2005; Koerber and Kretschmer 2006).

The Material Footprint

The material footprint measures the resource use of products and lifestyles. It covers the whole life cycle, from the extraction of raw materials to the processing industry, distribution, consumption, and end of life. All the resources 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 (Lettenmeier et al. 2014).

The material footprint is based on the MIPS concept (material input per unit of service). It can be used as an indicator for reducing present and future environmental challenges. The material footprint does not concentrate on specific environmental or health problems. It is a quantitative measure for natural resource use. The material footprint is also known as ecological backpack (see Schmidt-Bleek 2009, Lettenmeier et al. 2009, Liedtke et al. 2014).

The material footprint can be calculated for foodstuffs and their preparation. Foodstuffs can then be compared to each other on the basis of their material footprint. Material footprint data for numerous foodstuffs have been published in several studies (see Lettenmeier et al. 2012; Rohn and Lettenmeier 2012; Mancini et al. 2012; Rohn et al. 2010; Kotakorpi et al. 2008; Kauppinen et al. 2008). Figure 1 shows the material footprint in kg of resources per kg of the specific protein source. The differences amount to a factor of 10.

As Figure 1 illustrates, beef and cheese are especially resource-intensive, whereas beans require less resources when utilized directly as food. In general, meat and cheese tend to be resource-intensive but larger material footprints have also been reported e.g. for vegetables grown in greenhouses heated over longer periods. Studies using other indicators (e.g. carbon footprint or water footprint) have given similar results (see Kaskinen et al. 2011).

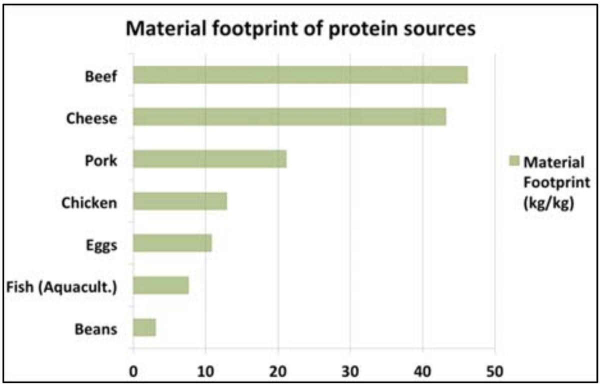


Figure 1: *Material Footprint of protein sources, Source: Kauppinen et al. 2008*

Typical meals and drinks offered for lunch in Germany and their material footprint

The material footprints of the meals and drinks shown in table 1 are examples of the differences in natural resource use. The table gives the material footprint and the nutritional value per meal and the share of the Guideline Daily Amount for both values. The Guideline Daily Amount (GDA) for the material footprint is set at 8.2 kg according to Lettenmeier et al. (2014). The calculation of the nutritional value is based on the recommendation and benchmark level of 2000 kcal per day as guideline (see: DGE 2011 or FDF 2013).

Resource-conserving meals can be promoted by supply (e.g. catering) as well as by demand (e.g. event organizers or consumers). The material footprints are calculated on the basis of earlier studies and include the production of the foodstuffs and the transportation up to the caterer but exclude the energy used for preparing the meals in the kitchen. Thus, the exact material footprint can differ due to the specific circumstances. For comparison, the nutritional value of the meals is also shown using kcal as the measurement unit.

Meal	Material footprint (kg/meal)	% of GDA (8.2 kg)	Nutritional value (kcal/meal)	% of GDA (2000 kcal)
Potato porcino cream soup	2.09	25%	239	12%
Bread (2 slices) and butter	1.04	13%	193	10%
Roast beef with red apple cabbage and little potato dumplings	6.78	83%	345	17%
Pikeperch piccata with carrots and dill gnocchis	2.57	31%	525	26%
Vegetable strudel with tomato sauce	1.7	20%	163	8%
Orange juice	1.59	19%	84	4%
Apple juice	1.24	15%	96	5%
Sparkling water	0.33	4%	0	0%
Tap water	0.002	0%	0	0%

Table 1: *Material footprint and nutritional values of typical lunch meals in Germany. Source: own calculations*

10 Suggestions for making food and its consumption resource-efficient and sustainable

The following list of 10 suggestions for resource-efficient and sustainable food consumptions is based on recent studies in the field (e.g Rohn and Lettenmeier 2012; Jungbluth 2010; Foresight 2010; Rückert-John 2005; Kotakorpi et al. 2008).

1. Reduced Meat Content
2. The reduction of the consumption of meat and dairy products (e.g. cheese) in favour of pulse, cereal, fruit and vegetable products generally has the greatest influence on the material footprint and other indicators.
3. Seasonality
4. The use of seasonal fruits and vegetables reduces the resource use of meals, e.g. by reducing the consumption of vegetables from heated greenhouses.
5. Waste Prevention
6. The prevention of food waste improves the conservation of resources significantly. Recent studies emphasize that approximately 17 per cent of food in out-of-home catering is thrown away. For ecological, ethical and economic reasons these numbers ought to be reduced in the short term.
7. Avoidance of Car Trips
8. The purchase or delivery by car of small food amounts can multiply the resource use of a meal.
9. Less Packaging
10. Even though the resource use for packaging in out-of-home catering is often significantly smaller than for the packed foods themselves, the reduction of packaging can lead to savings in production and waste management.
11. Optimizing Storage, Cooling, Preparation and Cooking
12. The reduction of the water and energy use in kitchens can minimize the resource use of dishes significantly.
13. Fresh and only Slightly Processed Foods
14. Fresh and only slightly processed foods decrease the resource use related to each additional production step. Reducing transportation and energy consuming cooling and processing steps further helps to maintain the freshness of vegetables.
15. Regionality
16. The purchase of regional products strengthens the regional economy. The transport of food by air is particularly resource intensive but also crossregional and regional overland transport can increase resource use.
17. Organic Farming
18. Although the material footprint of food from organic farming is often only slightly smaller than the material footprint of conventional foods, the purchase of organically grown products can, for instance, facilitate biodiversity and reduce toxic substances in the environment.
19. Fairtrade
20. The consumption of fairtrade products can support people in developing countries through better working conditions and wages. This does not reduce resource use in food but contributes to a fairer use of resources on a global level.

Conclusions: Resource Efficiency – An Opportunity for the Participants in the Food Chain

As the paper has shown, fields of improvement in the out-of-home catering sector can be identified by looking at the material footprint of meals.

Producers and retailers in the Food Chain can optimize supply chain management and achieve technical, product and service innovations by increasing their resource efficiency.

Caterers can reduce the material footprint by their product choices, as well as by reducing their energy consumption and their waste production. They can nudge consumers towards new eating habits by supplying resource efficient meals. In addition, labelling the material footprint of meal components or dishes at the consumption site could have a direct impact on the choice of consumers.

Additionally, consumers can discover modern lifestyles by adapting their diets towards smaller material footprints.

Lastly, politics and administration can promote resource efficient and sustainable nutrition through less resource-intensive nutrition recommendations, by setting waste prevention targets, and by other political interventions focusing on natural resource conservation.

16. Food waste in Abu Dhabi's hospitality industry: how much is too much?

Sanaa I. Pirani and Hassan A. Arafat

Abstract

The hospitality sector in the United Arab Emirates (UAE) is forecasted to grow at more than 10% annually over the next four years. The Abu Dhabi Tourism Authority (ADTA) aims to reduce the amount of hotel waste going to landfills by 20% as a first step in its environmental program. In 2012, 2,063 tons of solid waste was disposed of in landfills by hotels and hotel apartments in Abu Dhabi. This waste includes food waste, which is the most significant component of hospitality waste. The issue of food waste in the hospitality industry (hotels and restaurants) is a global problem, and is an area on which little research is done, relative to other types of waste. What is more, food waste is an important material to divert from landfills since it decomposes to create methane, a potent greenhouse gas.

In this work, data was collected from chefs/EHS (Environment, Health and Safety) personnel at UAE hotels through interviews which helped identify the roots and dimensions of this issue and underline the regulatory, cultural and economic perspectives involved. In addition, materials flow analysis (MFA) of the food waste in an Abu Dhabi hotel was utilized as a tool to quantify the amounts of the different categories of food waste produced, thereby defining the scale of the current food waste problem in the UAE's hospitality industry. This has been a ground-breaking study since previously no such data was available in this region. The values obtained have proven that the amount of food waste generated is greater than that of other countries; and that in order to improve the situation, the strategies by which restaurant managers determine how much to cook need to be addressed along with the public's habits.

Keywords: food waste, materials flow analysis, hospitality industry, municipal solid waste, sustainable development

Introduction

The hospitality sector in the UAE is forecasted to grow at a rate greater than the predicted rate of the growth of the overall GCC hospitality market (Jones, 2012). Abu Dhabi and Dubai are similar to other Gulf cities such as Doha and Muscat from the perspective that they have seen rapid development in their hospitality sectors, and oftentimes the simultaneous advancement in their waste management sectors has not been as quick. As an example, the Abu Dhabi emirate has already lost 1,800 hectares of land to landfills (Abdul Kader, 2011) and currently more than 75% of the waste produced in the UAE ends up in landfills (Yassine, 2012). Consequently, as these GCC cities aim to further develop their tourism sectors as a means by which to diversify their economies, it is imperative that they address their waste management sectors simultaneously.

Food waste is the most significant component of hospitality waste, and can account for more than 50% of it (Curry, 2012). The issue of food waste is a global problem. For example, of the 600,000 tonnes of food waste disposed of in the UK in 2009, two-thirds could have been eaten if the food had been better portioned, managed, stored and/or prepared (WRAP, 2012). As with other types of waste, wasting food also implies the wastage of the resources used to create the food products the first place. For instance, in the United States, "food waste now accounts for more than one quarter of the total freshwater consumption and approximately 300 million barrels of oil per year"(Hall, Guo, Dore, & Chow, 2009).

By targeting the hospitality industry this research is able to target a smaller sector (relative to households), but one that tends to produce more food waste per customer. Along the same lines, the initial implementation of policies and subsequent follow-up inspections would be easier in the hospitality sector than in households.

Current Food Waste Management Scenario in the UAE

In the area of waste management, much effort is being exerted, by both the UAE Government and private environmental solutions-providing companies, towards encouraging the public to segregate their waste thereby facilitating recycling. Different colored bins have been provided for different types of materials (Ahmad, 2013). A number of MRFs (Material Recovery Facilities) have also been constructed in the country (Hilotin, 2011; The IuT Group, 2012).

As far as food waste management is concerned, the Red Crescent Society UAE has started the "Hefth Al Ne'ma" program by which the public can call the Society and ask them to pick up any leftover food after any large event such as a wedding. The food left over must be enough to feed 50 people. The Society then distributes this food to needy families.(Todorova, 2010) In addition, awareness of composting is also increasing in the UAE with various composting technology having become available in the recent past. There is technology available for small-scale composting such as in houses (McQueen, 2011) and for large-scale composting such as in hotels (Baldwin, 2012).

Moreover, with respect to Abu Dhabi in particular, recently the Centre of Waste Management implemented the "Nadafa Program" which helps to monitor and control all waste-related activities and uses technology to tackle the environmental and economic damages related to waste generation (Center of Waste Management - Abu Dhabi, 2012). As part of this program, a tariff system that charges per ton of waste produced has been launched. It is only applicable to the commercial, industrial and construction sectors. In addition, the top 5% of waste producers (which each generate more than 250 tonnes of waste per year), have been asked by the Centre of Waste Management to provide a standardised report policy. Whether or not they need to pay a penalty in addition to the tariff, and the amount of the penalty, depend on their performance as documented in the report (Radan, 2013).

Methodology

As part of this research, the authors have conducted five different interviews at various hotels/hotel management companies. These interviews shed light on the operations of 37 different hotels in the UAE. The questions asked in all the interviews were the same.

The MFA portion of this paper consisted of conducting a study at a small-sized hotel in Abu Dhabi city. The data was gathered for a lunch buffet at this hotel. The authors were provided with a list of all the ingredients used (along with their respective masses) for the food served during the buffet. The amount of waste generated during the washing of the ingredients and then during the preparation of the food was measured. The kitchen staff was therefore contacted in advance and instructed about where to dispose of the various waste so that it could be weighed later on and recorded. At the conclusion of the buffet, the authors were present to ensure that the leftover food was correctly segregated into the amount saved for giving to staff, and the amount left on customers' plates and in serving dishes (both of which were disposed of), and that each of these categories were then weighed.

Results and Discussion

Interviews with Chefs/EHS Personnel at UAE Hotels

These interviews helped the authors to gain a much better understanding of the state of food waste management in the hospitality sector ofn the UAE. The interviews made clear the ground reality in terms of clarifying how things operate currently, what efforts are being made to make things more sustainable, and what challenges are faced as part of these efforts. Some of the findings of the authors are displayed in Figure 1.

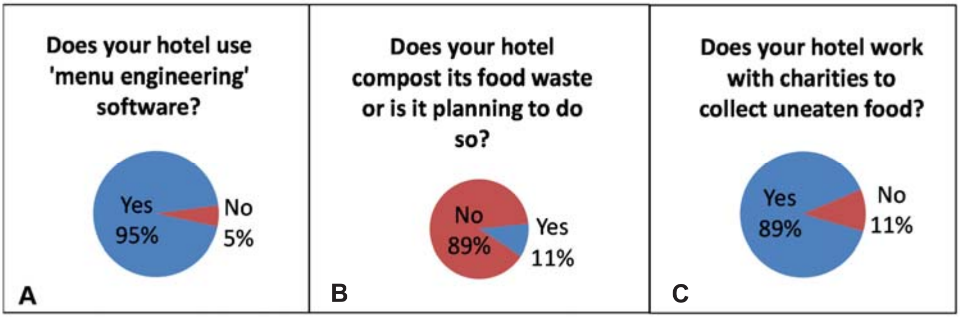


***Figure 1:** Results of the interviews with chefs/EHS personnel at UAE hotels.*

Figure 1(A) shows how the majority of the hotels considered in this study claimed to use some form of menu engineering software. This software assists in making hotel operations more profitable by rating the performance of individual menu items as a result of discussing their "popularity and gross profit percentage (GP) contribution" (Bird, 2013). The software thus allows restaurant managers to view the cash contribution position for each menu item and make decisions accordingly (Bird, 2013). Though the purpose of such software is financial gain, it is well-known that as a result of its implementation, food waste is reduced as well (Agilysys, 2013; Boonyakiat, 2012). During the interviews it was clear that there was some confusion on the part of the interviewees with regards to what menu engineering software is. What is more, though most of these hotels clearly use some type of software to keep track of their food inventory and monitor the amount of ingredients needed as part of different recipes, it is not as probable that the technology that they use is true menu engineering software.

Figure 1(B) shows how most of the hotels considered in this sample are not considering utilizing any composting options for the processing of their food waste. The commercial composting equipment mentioned previously in this paper demands a certain amount of food waste to make it feasible, thus not being a viable option for smaller hotels. In larger hotels, on the other hand, an impediment to its implementation is its high cost and the large space requirement. Though the small-scale composting options available in the UAE (in the form of composting bins) can also be used at the commercial level, they are generally seen as being a tedious and therefore impractical solution for properties serving large numbers of guests.

Figure 1(C) shows how a significant portion of the hotels included in this study donate uneaten food from their hotels to charities. Those hotels that do not donate cite HACCP (Hazard Analysis and Critical Control Point) restrictions as being a barrier. However, as was learned by other hotels, this barrier can be overcome by making sure the charity signs a disclaimer that would not hold the hotel accountable if a recipient of the food is taken ill. Moreover, many of the hotels tend to store the cooked food in what is known as hot and cold cabinets. This ensures that the food is kept at the desired temperature as long as it has not been served, drastically reducing the chance that such food would get spoiled.

Materials Flow Analysis (MFA) for the lunch buffet at a UAE hotel

A MFA was performed during the lunch buffet at a small-sized UAE hotel. This hotel acknowledged using menu engineering software as part of its operations. The number of people cooked for was 30, though only 15 people actually attended the buffet.

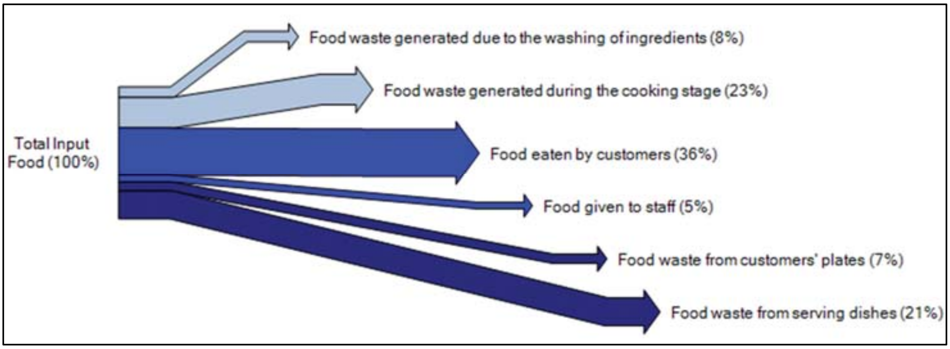


Figure 2: *Materials Flow Analysis for the lunch buffet at a UAE hotel*

Food waste generated due to the washing of ingredients	6.3 kg
Food waste generated during the cooking stage	17.85 kg
Food eaten by customers	28.5 kg
Food given to staff	3.7 kg
Food waste from customers' plates	5.5 kg
Food waste from serving dishes	16.1 kg

Table 1: *Mass values for the different food waste categories measured as part of the MFA.*

The results of this study are shown in Figure 2, in which the percentages of each of these food categories are shown. The corresponding mass values are shown in Table 1. As is clear, the amount of food which is actually consumed by the guests is only 36% of the total. Though this may be considered an acceptable value in light of the fact that only 50% of the expected guests actually attended the buffet, it cannot override the fact that there was a large amount of wastage (46kg in terms of absolute values). This wastage was divided into the following categories:

- The light blue arrows in Figure 2 are classified as unavoidable wastage and together they account for 53% of the total wastage (and 31% of the total input food).

- The dark blue arrows represent (theoretically) avoidable wastage and together they account for 47% of the total wastage (and 28% of the total input food).

It is important to note how the leftover food that was saved for staff was not considered wastage, though the authors were not able to measure how much of this food was actually eaten by the staff and how much of it was disposed of at some later stage. What is more, the food leftover could not have been donated to a charity as it was not enough for 50 people, especially since the charity would only take the food from the serving dishes. The food leftover on the guests' plates could only be disposed of as it had already been touched.

This MFA helps show that though the amount of food wasted by the customer is significant, hotels in the UAE could generate much less waste by planning better and cooking accordingly, and a solution that could be pursued is the implementation of a true menu engineering software which monitors previous trends and helps restaurant managers make future plans accordingly. In addition, the amount of waste generated per cover (person served) for the MFA is around 3kg, and this is much greater than that for restaurants in the UK which have a value of about 0.5kg per cover (Sustainable Restaurant Association, 2010).

Considering that the number of hotel establishments in Abu Dhabi and Dubai combined is approximately 750 (Abu Dhabi Tourism and Cultural Authority, 2013; HRQUnited, 2013), and assuming this number to be representative of all of UAE, and assuming that each hotel in the country generates the same amount of food waste three times a day, an annual amount of food waste of approximately 38,000 tons for the UAE hospitality sector would be calculated. This can provide around 38,000 MWh of electricity or approximately 19,000 tons of compost (Brown, 2013). Thus there is much potential in the food waste generated by the hospitality sector of the UAE, especially when considering that the value stated here is most certainly much smaller than the actual value, since it has been calculated using values for a small-scale hotel, and it does not even consider special events such as weddings where wastage tends to be much more.

Conclusions

This study is novel in the way in which it has approached the issue of food waste in the hospitality sector in the UAE. The interviews conducted as part of the first phase of this research help establish the current scenario in the UAE, in general, and Abu Dhabi in particular. Despite the waste restrictions recently imposed by the Centre of Waste Management in Abu Dhabi, many hotels are not considering composting their food waste. In addition, many hotels do claim to use 'menu engineering' software; though as proven by the results of this study, this software is not very effective in helping to limit food waste. Furthermore, many hotels are willing to donate their uneaten food to charities, though it seems that this is easier said than done. The MFA conducted as part of this study shows how such a significant component of the original ingredients ends up as waste, and how the amount of waste that is avoidable is just as much as that which is unavoidable. Absolute mass values of the food waste also give an approximation of the total food waste generated by the UAE hospitality sector. The large values thus obtained have made it clear that it is imperative that a formal system be put in place in the UAE hospitality sector to discourage the generation of so much food waste, and that the needed infrastructure be established for viable waste treatment options. It is only then that Abu Dhabi can reach its target of a 90% diversion rate by 2018 (Abdul Kader, 2011).

17. The nutritional footprint – assessing environmental and health impacts of foodstuffs

Melanie Lukas, Holger Rohn, Christa Liedtke

Abstract[8]

The food sector accounts for huge environmental impacts caused by production, processing, final consumption and waste treatment in private households or in out of home catering settings. Further, the field of nutrition inextricably links environmental and health aspects to each other. Thus, the domain of nutrition has to be considered intensively if environmental aspects and health considerations should be further examined. By now a few scientific concepts address this topic and are available to relate the sustainability dimensions with each other, if it comes to nutrition and the food sector. One of these newly invented instruments will be introduced within this paper: the *Nutritional Footprint*. This approach is formed in detail by setting a data assortment of available environmental data (e.g. material footprint or carbon footprints within the life cycle) in relation to available nutrition data (e.g. salt content or calorie specifications). Recommendations (e.g. WHO recommendations or valid scientific recommendations) and sustainability assessment levels are estimated, to enable a comparison of environmental and health impacts of foodstuff. Therefore the instrument presents a way to match and communicate environmental and health impacts, using a selected amount of indicators, to stay transparent and clear. It is available and useful for companies to expand their internal data and their external communication performance. Two examplary dishes are estimated to illustrate the concept of the instrument.

Keywords: food, sustainable nutrition, footprint, environmental indicators, health indicators

Introduction

Every kind of diet has a certain impact on the environment and health-related effects (Lukas et al. 2015, Rockström et al. 2009). Two of the biggest problems of western eating habits are related to the environmental and health damage they cause (Lettenmeier et al. 2012). On the one hand, so-called ‘prosperity diseases’ like obesity, hypertension or diabetes mellitus are increasingly common in many industrialized countries caused by eating too much sugar, fat and salt (Wirsam & Leitzmann 2011). On the other hand, nutrition accounts for enormous environmental impacts – caused by the high consumption of animal proteins and its high impact on resource use and climate change, but also its impact on land use patterns, water consumption or loss of biodiversity (MacDiarmid et al. 2012).

However, the criteria of healthy and environmentally friendly diets often remain too abstract for consumers and producers, despite the indicators for sustainability in the field of environmental sciences (Meier 2015). Until today both fields of investigation – nutrition science and environmental science – are largely independent, although both present a great range of scientific work and publications considering the described examination above.

[8] The manuscript is based on the WRF conference paper „The Nutritional Footprint – assessing environmental and health impacts of foodstuffs“ (Oktober 2013) and the paper Lukas et al. (2015). The authors revised the data base for the sustainable levels in the health dimension based on the work of Scheiper et al. (2015).

The method of the nutritional footprint assessment

The general approach

The Nutritional Footprint is originally based on the quantitative approach and tries to figure out levels of health and environmental impacts. Adapted from the Hot Spot Analysis, the life cycle's perspective is applied to take all phases into account (Liedtke et al. 2010; Kuhndt 2002), such as the raw material extraction/production, processing and use. Therefore the conceptual draft consists of three basic steps:

a. *Estimation of health and environmental issues related to the specific food products*
b. *Allocation and evaluation of the results in comparison to the basic references (Assessment of all relevant indicators/ ranges 1-3)*
c. *Identification (calculate and displayed as the nutritional footprint) and quantitative comparison of results*

Considering the current situation of establishing a new innovative method and trying to outline the analysis of impact data, we would like to point out and demonstrate the two preparation steps A and B (see: 2.2 and 2.3), which have to be carried out to create a basis for a comparison of both dimensions.

Assessment of relevant health and environmental indicators

The assessment and selection of relevant health and environmental indicators to validate results is essential basis for this method. The following eight indicators are estimated to display a detailed view on the life cycle of the current food product components and thus, their environmental and health impacts. During the first development phase of the concept (Lukas et al. 2013), a few more indicators were selected, but after a scientific revision it became obvious to decrease the amount of indicators, as shown in Table 1. In general, the selected indicators represent health and environmental core indicators and will be able to give a decent overview of the overall impact of foodstuff. Thus, a few indicators provide a broad overview, while the instrument stays transparent and but at the same time scientifically.

The mixture of indicators was selected for two reasons. The indicators should cover a high amount of health implications triggered by nutrition in general. Thus, the authors decided to use a selection of the main validated indicators used by international and national agencies (e.g. FDF 2013, DGE 2011, WHO 2012). The assortment of environmental indicators was based on the background of our requirement to illustrate the whole value chain and its direct and indirect effects. Thus, the four indicators – material, carbon and water footprint and land use - should display a complete, but quick glance at the value chain of food products (Bringezu et al. 2009, Giljum et al. 2009, Mekonnen & Hoekstra 2010a/b). For instance, the indicator 'material footprint' displayed here is based on figures considering abiotic and biotic inputs and erosion (Lettenmeier at al. 2009). Currently the amount of indicators is considered as a first step to evaluate both impacts. In the future, a modification of indicators may be conceivable, considering the latest evaluations made by Scheiper et al. (2015) the health indicators may be revised using a more wider perspective. For instance the "amount of raw fruit and vegetables" per meal is considered to be valid indicator, instead of using and measuring the amount of salt or saturates in meals.

Health indicators	Environmental indicators
Calorie content	Material footprint
Salt content	Carbon footprint
Content of dietary fibre	Water footprint
Saturates	Land use

Table 1: *Indicators included in the nutritional footprint*

Sustainable Level for Nutrition – Setting out reference data and determining threshold levels

As a second preparation step, national and international recommendations were investigated to indicate “sustainable levels” or even have a first clue for a range of assessment levels. For health impacts, this evaluation was straightforward due to approved recommendation data. More vague remains the status of environmental data, where specific recommendation levels were not generally approved (Lukas et al. 2015). Hence, we decided to use data, which is preferably recognized at the international level, to approve and calculate the sustainable assessment level for food (Table 2). The calculation of environmental indicators is based on current recommendations, (e.g. made by Lettenmeier et al. forthcoming, Rockström et al. 2009 or UBA 2010) which were judged as minimum level with small impact and the todays’ recent consumption rates in Germany under a discount of 25% (e.g. UBA 2010 or Röckstrom et al. 2009), which were considered as high levels with a *strong* impact. The calculation of the health data is based on general nutrition guidelines (see: DGE 2011 or FDF 2013), which were treated as a *small* impact. The levels of strong impact dataset are based on the presumption that the current intake levels are often higher than the official recommended intake are and thus the shown maximum levels are based on these data (e.g. MRI 2008).

Health indicators	**Ranges of data** (per day/cap // per meal)			**Environmental indicators**	**Ranges of data** (per day/cap // per meal/cap)		
	Small impact	**Medium impact**	**Strong impact**		**Small impact**	**Medium impact**	**Strong impact**
Calorie content (kcal)	<2000 // <718	2001-2500 // 718-833	>2500 // >833	Material footprint (g)	<8200 // <2670	8000g – 12000 // 2670 – 4000	>12000 // >4000
Salt content (g)	<5 // <1,7	5.1-5.9 // 1.7-1.9	>8 // >2	Carbon footprint (CO_2 eq) (g)	<2400 // <800	2400 – 3600 // 800 - 1200	>3600 // >1200
Content of dietary fibre (g)	>27 // >9	26.9-24.1 // 8.9-8.1	<24 // <8	Water footprint (l)	<1950 // <640	1950 – 2925 // 640 - 975	>2925 // >975
Saturates (g)	<20 // <6	20-30 // 6-12	>30 // >12	*Land use* (m^2)	*<3.75 // <1.25*	*3.76- 5.625 // 1.25 – 1.875*	*>5.625 // >1.875*

Table 2: *Sustainable level - assessment of daily intake and a lunch meal (qualitative assessment) [revised based on Scheiper et al. (2015) and Lukas et al. (2015)]*

Step 1: Estimation of health and environmental issues related to the specific foodstuff

All food products for one meal have to be considered in the calculation, thus every ingredient has to be examined from both the health and environmental perspective. Therefore, the several ingredients have to be selected in their content of calories, salt, dietary fibre, saturates and by all displayed environmental impacts considering their amount of the general weight of the product. For calculating the environmental impacts, common databases such as ECOINVENT were used.

Step 2: Allocation and comparison of products

Subsequently, in step 2, the relevant data has to be compared with the numerical values created in the preparation steps A and B. In order to enable comparisons, a range of numerical values from ‘1’ to ‘3’ has been defined. This range covers – very roughly – the different levels of impact a product may have, thus, an ‘1’ stands for a minor environmental impact, whereas a ‘3’ signifies a major environmental impact. The health impact of foodstuff is evaluated in a similar way. For a high amount of calories and therefore a high percentage of the tolerable daily intake, the food products earn a higher rate, such as ‘2’ or ‘3’. The same was done with the content of fibre, but the other way around. If the content of fibre is high – which is considered to be proficient for a human diet – the indicator receives a lower rate such as ‘1’ due to its positive impact. Consequently, the newly obtained data has to be linked with the existing ranges (preparation step B).

Step 3: Quantitative assessment of results[9]

Step 3 comprises the identification of the Nutritional Footprint. In order to give equal weight to the health and the environmental perspectives, an average of the several categories is formed. This is a rough estimation made by three ranges. The method is suitable for all product groups, such as raw products, processed or highly convenient foodstuffs. In the next section, two nutritional footprint calculation schemes are demonstrated to illustrate the methodical approach. The following formula (1) and (2) provides an overview onto this step:

Formula (1) and (2)

$$NF_{health} = \frac{I_{h1} + I_{h2} + I_{h3} + I_{h4}}{\sum I_h}$$

$$NF_{environment} = \frac{I_{e1} + I_{e2} + I_{e3} + I_{e4}}{\sum I_e}$$

This step leads to an equitable ranking of the two sets of indicators in relation to each other. In the final step of the calculation, both effect level set are summed up and the average is determined again (formula 3).

Formula (3)

$$NF = \frac{NF_{health} + NF_{environment}}{2}$$

Results from the current calculation of two contrasting menus

To display the great variation of food products and menus available, we decided to calculate within this paper a vegetarian dish and a beef-based dish. Following the method described above, both menus were compared. As displayed here in table 3 both dishes first are

[9] For more detailed information regarding the calculation steps, please see: Lukas et al. (2015)

evaluated seperately, for the health and environmental dimension. For instance, the vegetarian dish contains 680 kcal and therefore, the calorie content is estimated with the level of 1.

Health indicators	**Vegetarian dish***	**Beef-based dish****	**Environmental indicators**	**Vegetarian dish***	**Beef-based dish****
Calorie content	1	1	Material footprint	1	3
Salt content	2	2	Carbon footprint	1	3
Content of dietary fibre	1	3	Water footprint	1	3
Saturates	2	2	Land use	1	3
Nutritional Footprint (average per dimension)	1,5	2		1	3

Table 3: *Assessment of results (based on several data, e.g. Lukas et al. 2014, Mekonnen/Hoekstra 2010a/2010b, Kaupinnen et al. 2008, Wirsenius et al. 2010)* [10]

Consequently, the nutritional footprint is than calculated by summing up the categories and estimate the average to receive a reference value:

Vegetarian dish = 1,25 [(1,5+1)/2]

Beef-based dish = 2,5 [(2+3)/2]

The results display that the Nutritional Footprint can be seen as an assessment instrument that helps identifying the indicators of a product along its value chain and which also includes the consumption perspective by using direct health indicators. The numerical values were allocated on a quantitative basis. Having a look at the overall Nutritional Footprint, the beef-based dish variation has a greater negative impact on the environment, than on the individual health dimension. The beef-based menu contains a high amount of processed animal protein, which is rated to be highly resource-intensive (Kaupinnen et al. 2008, Lettenmeier et al. 2012, Wirsam & Leitzmann 2011). In general, the environmental impact – in comparison – varies greatly (Tab. 3). Thus, the vegetarian menu is slightly the better choice, especially if environmental impacts are considered. On the other hand the beef dish does not obtain a fairly high rate of calories and saturates, only the amount of fibres is not sufficient. Considering the dietary recommendations the vegetarian menu meets the recommendations for a healthy lunch, the beef-based dish may be recommend as a unregularly dish once a week.

Conclusion

The Nutritional Footprint is a transparent concept to evaluate environmental and health impacts of food products by combining quantitative indicators. At the moment the assessment is based on a conservative appraisement of the current available data and the development of the concept is still in progress (e.g. determining the levels for land usage). The tool seems to be a good opportunity to include two significant features that so far have not been compared directly. Numerous studies show that foodstuffs based on animal

[10] Vegetarian dish: vegetarian casserole topped with cheese, ** beef-based dish: beef goulash with potato and vegetables; both recipes are choosen due to their popularity in the food catering sector in Germany.

products are connected to higher resource consumption than those based on vegetable origins, but do not rate health impacts (see more: MacDiarmid et al. 2012, Wirsam & Leitzmann 2011). The here presented approach is underlining these results. Furthermore the follwoing questions appear, when this instrument has been developed:

How can companies deal with new data-based indicators to influence their own product portfolio?

Companies could address both their environmental and health potential of food products with the help of this method. With respect to the current discussion about sustainable development of companies, a nutritional footprint can also be considered as an efficient and flexible management tool to improve internal information systems, precisely because this indicator includes more than one aspect of sustainable development. The tool could also provide an internal guideline and benchmark for the product development, e.g. a benchmark of about 1,6 must not be exceeded, otherwise the product is not going to be listed in new product ranges.

How can instruments such as the nutritional footprint affect consumer choices?

The tool could provide an understandable tool to help and guide the consumer towards a more healthy and eco-friendly diet. Companies could guide consumers' choices into a more environmentally friendly and healthy choice, if management and communication tools are adequate to support these decisions. More often, communication tools remain quite indistinguishable to the consumer or do not address their needs. Therefore, the nutritional footprint is designed in a comprehensible way (only ranges of 1-3) and tries to limit its results in one numerical value. The consumer is able to understand if the ranking structure is communicated in a well-defined way. Prospectively, the concept has to be expanded from three to possibly six ranking levels to present a more detailed view. Different ways of communication could represent a complete view on a Nutritional Footprint (e.g. inspired by the traditional efficiency classes A+++ to C or an innovative network structure as Rockström et al. (2009) propose), available in Lukas et al. (2015).

Future perspective

As a next step, the authors are going to evaluate how an economic calculation could be included within the instrument. Also a valid indicator for measuring social impacts is needed. Generally it has to be assessed, how the Nutritional Footprint may be used as an internal tool supplement for the product development and on the other side for consumers as a rough guide for the final purchasing decision. A scientific development and a detailed estimation of further advantages, challenges and barriers for this and comparable instruments in practice is carried out during the current running project NAH_GAST (Lukas et al. 2015).

Part II.

Technological Innovation, Business and Finance

18. Mineralisation of CO_2 using serpentinite rock - Towards industrial application

Ron Zevenhoven, Inês S. Romão, and Martin Slotte

Abstract

In Finland one (and maybe the only) option for large-scale CO_2 capture, utilisation and storage (CCUS) seems to be mineralisation, also known as mineral carbonation. Mineral resources in the country should allow for the fixation of quite a few Gt CO_2. The process route that is currently being developed towards industrial application involves the production of reactive magnesium in the form of $Mg(OH)_2$ from serpentinite rock material followed by conversion into $MgCO_3$ using a pressurised fluidised bed (PFB) reactor. Iron, present in the serpentinite rock material is released during the $Mg(OH)_2$ production. Although the rate of carbonation of $Mg(OH)_2$ particles is satisfying, the final level of conversion to $MgCO_3$ must yet be brought closer to 100%. The carbonation chemistry competes with undesirable calcination of $Mg(OH)_2$ to less reactive MgO. As for the $Mg(OH)_2$ production, the best result obtained so far is 80%. In this paper our recent results obtained with this CO_2 mineral carbonation process route are summarised. Progress on the scale-up and application of the process route at an industrial demonstration scale are addressed, with process heat integration and the operation on flue gases directly (without a CO_2 pre-separation step!) being key features for economic viability.

Keywords: CO_2 long-term storage, CCS/CCUS, mineralisation, scale-up, serpentinite.

Introduction

In Finland one of the most feasible (and maybe only) option for large-scale CO_2 capture, utilisation and storage (CCUS), or CCS (CO_2 capture and storage) seems to be mineralisation, also known as mineral carbonation. Mineral resources in the country should allow for the fixation of quite a few Gt CO_2 (Zevenhoven and Kohlmann, 2002; Zevenhoven et al. 2007). The process route that is currently being developed at Åbo Akademi University (ÅA) towards industrial application involves the production of reactive magnesium in the form of $Mg(OH)_2$ from serpentinite rock material using recoverable ammonium sulphate (AS) salt. This is followed by gas/solid conversion into $MgCO_3$ using a pressurised fluidised bed (PFB) reactor. The heat released in the carbonation reactor may provide much of the heat needed to extract Mg from the serpentinite rock, aiming at an auto-thermal process.

$Mg(OH)_2$ produced from serpentinites was found to be carbonated faster and to a higher carbonate content than a commercial, precipitated $Mg(OH)_2$ sample. Iron, present in the serpentinite rock material is released during the $Mg(OH)_2$ production and, in fact, this can be optimised as to obtain a by-product suitable for iron- and steelmaking (Koivisto, 2013).

Although the rate of carbonation of $Mg(OH)_2$ particles reaching 65-70 % in 15-30 minutes is satisfying, the final level of conversion to $MgCO_3$ must yet be brought closer to 100%. The carbonation chemistry competes with undesirable calcination of $Mg(OH)_2$ to less reactive MgO. As for the $Mg(OH)_2$ production, the best result obtained so far is 75-80% (using Portuguese and Finnish serpentinites). In this paper our latest results obtained with this CO_2 mineral carbonation process route are summarised.

Also, progress on the scale-up and application of the process route at an industrial demonstration scale are briefly addressed, where process heat integration and the operation on flue gases directly (without a CO_2 pre-separation step!) are key features for economic viability.

The Åbo Akademi route for serpentinite carbonation

Process description

A process under development at ÅA – see Fig. 1 for an overview of the process route – uses recoverable ammonium sulphate (AS) salt to extract Mg from grinded serpentinite rock, at elevated temperatures. The extraction has shown conversions of up to 80% of Mg into reactive $Mg(OH)_2$ or $MgSO_4$, depending on the desired intermediate (Nduagu, 2012a, Aarnio, 2013). $Mg(OH)_2$ reacts directly with CO_2 under elevated temperature and pressure, whereas $MgSO_4$ can be reacted with aqueous ammonium (bi-) carbonate, in both cases producing magnesium carbonates. Here, the route that involves $Mg(OH)_2$ carbonation in a pressurised fluidised bed, aiming at obtaining the reaction heat from the carbonation step at a useful temperature level is considered.

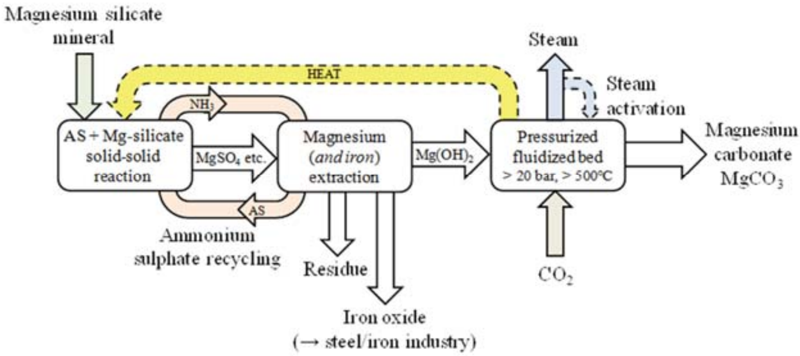


Figure 1: *A schematic illustration of the mineral carbonation process under development at ÅA.*

In the first process step, the serpentinite rock reacts with ammonium sulfate (AS) at 350-550°C, preferably <450°C (to avoid the ammonium salts decomposition) and atmospheric pressure in order to produce XSO_4 salts (X=Mg,Ca,Fe), as first described by Nduagu (2012a), Nduagu et al. (2012a,b). During the reaction considerable amounts of NH_3, water vapour and possibly SO_2/SO_3 are released. The solid products are put in water and the insoluble fraction (mainly unreacted serpentinite and SiO_2) is discarded. The NH_3 produced in the first step is used to raise the pH of the aqueous solution to ~8-9 in order to precipitate the iron in the form of (oxy-)hydroxides. These are separated and possibly redirected to the steelmaking industry creating the opportunity to reduce the net CO_2 emissions and replace raw materials (Romão et al., 2012a, Koivisto 2013). Using the NH_3 produced in the first step, the pH of the aqueous solution is further raised to ~10-12 and the magnesium precipitates to form $Mg(OH)_2$. AS is recovered from the residual solution and the $Mg(OH)_2$ is carbonated at 500°C and 20 bar of CO_2 partial pressure, in a pressurized fluidized bed reactor. The carbonation method is described in more detail by Fagerlund (2012), Fagerlund et al. (2011, 2012).

Results on $Mg(OH)_2$ production from serpentinite and its carbonation

As for the production of As for the $Mg(OH)_2$ production, the best results obtained so far are 78% (Portuguese serpentinite) and 80% (Finnish serpentinite, Aarnio (2013)); for Lithuanian rock a maximum of 55% was obtained (Stasiulaitiene et al., 2013). The optimal range of parameters for $Mg(OH)_2$ production from serpentinites is given in Fig. 2, compiled by Nduagu (2012b). Three types of reactors, i.e., an aluminum foil cup, a porcelain crucible and a quartz rotary tube were used for the Mg extraction reaction. The reactors were heated up in ovens of different configurations; more detail is reported elsewhere (Zevenhoven et al., 2013a). The ideal processing time to $Mg(OH)_2$ can be kept below one hour and no significant differences in carbonation rate - see below - have been found between $Mg(OH)_2$ produced from different rock.

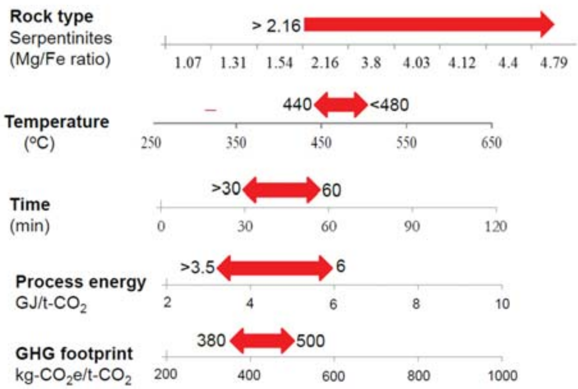


Figure 2: *Summary for process parameters optimal range for $Mg(OH)_2$ production (Nduagu, 2012b)*

Much recent attention has been paid to scale-up for processing larger batches of material, and the extraction of Mg from olivines and “less attractive” rock that is available at or near large CO_2 point sources. Also, the use of either ammonium sulphate (AS) or bisulphate (ABS) is being assessed, as also the impact of added moisture to the initial AS(or ABS)/rock mixture (mass ratio AS:rock:water = 3:2:1) on Mg extraction was studied. Depending on the rock these can have a beneficial effect, as reported in (Zevenhoven et al., 2013a) and, in a study to co-extract Mg, Ni, Cu and other species from Finnish nickel mine overburden rock ore as well as from the mined ore, in (Romão et al., 2013a).

As for the carbonation tests, reported extensively elsewhere, it was shown that $Mg(OH)_2$ produced from serpentinites carbonated faster (and to a higher carbonate content) than a commercial $Mg(OH)_2$ sample (Dead Sea Periclase, DSP). Although the rate of carbonation of $Mg(OH)_2$ particles with a size of ~300 µm is impressive, reaching 40-70 % in 10-30 minutes, conversion (to $MgCO_3$) needs to approach 100%. The results from over >100 tests, show various relations with, e.g., particle size and structure (porosity and internal surface area, SA), fluidisation velocity, temperature and pressure. (Fagerlund and Zevenhoven, 2011, Fagerlund et al. 2012a,b, Fagerlund, 2012).

The best results were obtained using serpentinite-derived $Mg(OH)_2$. This was due to the superior texture of the extracted (brucite) forms, being typically highly porous and well-dispersed, with surface areas (40-50 m^2/g) one order of magnitude higher than commercial material. The carbonation chemistry competes with undesirable calcination of $Mg(OH)_2$ to less reactive MgO while in some experiments magnesium oxycarbonate (MgO•2$MgCO_3$) was also identified in the products (Fagerlund, 2012). Recently, Romão achieved 70% carbonation after 30 minutes at 510°C, 20 bar, with an $Mg(OH)_2$ produced from Portuguese (Bragança) serpentinite (Romão et al., 2013b). Using somewhat higher pressures, Stasiulaitiene reported 65% carbonation at 51 bar CO_2, 535°C, 15 minutes, with an $Mg(OH)_2$ produced from Lithuanian (Varena) serpentinite. All these tests were made at ÅA.

Process scale-up and industrial application; operation on flue gas

The gas entering the carbonator may be a pure stream of CO_2 but may also be the complete flue gas stream from a process. Two R&D projects that involve large-scale application of staged magnesium silicate carbonation processing are 1) at a lime kiln as can be found in Finland, and 2) for natural gas-fired electricity production in Singapore, aiming at land reclamation with the solid products (with rock material imported from, for example, Australia). Importantly, for both cases, the CO_2 capture stage will be omitted: mineralisation would be applied to flue gases directly. For case 1) the process can run without external heat input by making use of waste heat from the lime kiln, while for case 2) a recent LCA study showed that direct operation on the flue gas is a requirement for an economically attractive process (Khoo et al., 2011). For the Portuguese rock found in the north-east of the country, storage of CO_2 separated at the CIUDEN Oxyfuel combustion plant near Ponferrada, north-west Spain, at 135 km from Bragança, may be an interesting source-sink combination for large-scale CCUS.

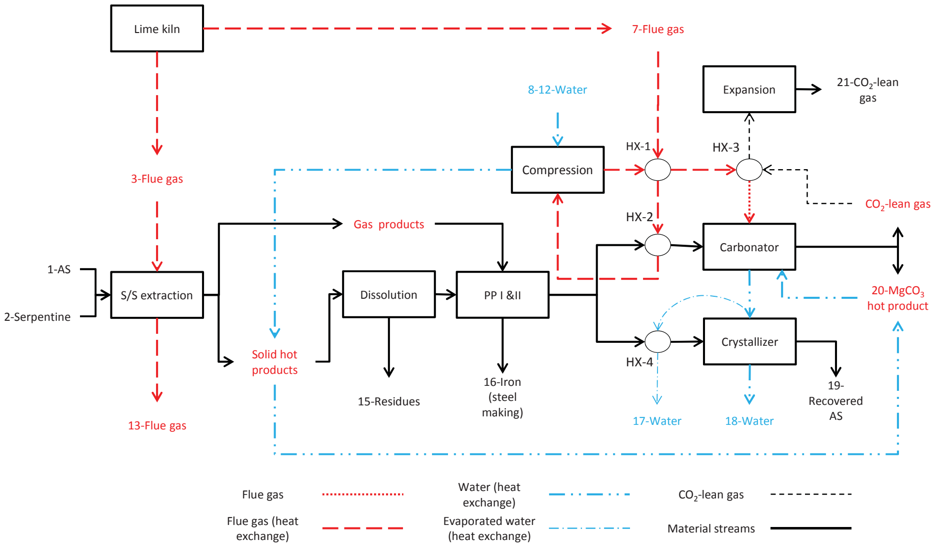


Figure 3: *Process schematic for serpentinite carbonation applied to an industrial lime kiln gas without CO_2 pre-separation (Slotte et al, 2013)*

Important for economic viability is the implementation of carbonation on the flue gases directly, removing the somewhat problematic (for oxygen-containing gas streams) and (energy-) expensive CO_2 capture step from the CCUS process train. A set of PFB carbonation experiments where CO_2 was mixed with nitrogen up to a certain CO_2 partial pressure was conducted for comparison with results from tests with the same undiluted CO_2

pressure. Tests (using DSP-$Mg(OH)_2$) showed that the results found for pure CO_2 aren't different from what is obtained with CO_2 diluted with 26-72 %-vol N_2. In an additional study, simultaneous removal of CO_2 and SO_2 from flue gases during $Mg(OH)_2$ carbonation was assessed which may make a separate unit for flue gas desulphurisation (FGD) at power plants operating on sulphur-containing fuel obsolete. The results showed that SO_2 indeed shows significant reactivity towards $Mg(OH)_2$. Unfortunately this may put a strong penalty on carbonation performance. More detail is given elsewhere (Zevenhoven et al, 2013b.)

The lime kiln – 210 ton/day lime production, flue gas CO_2 content is 21%-vol (dry) – application was addressed in two recent studies (Romão et al., 2012b, Slotte et al., 2013). Process waste heat allows for ~200 kg/h CO_2 using ~550 kg/h serpentinite (type Hitura, Finland) against a power input requirement (mainly for complete flue gas compression) of 0.71 ~ 0.89 MJ/kg CO_2 and 2.85 ~ 2.60 MJ/kg CO_2 waste heat (first number Romão, second number Slotte.) A process block diagram for this is given in Fig. 3 (Slotte et al., 2013)

Conclusions

This manuscript summarises progress towards industrial scale application of the "Åbo Akademi route" for stepwise carbonation of serpentinite. Both the production of reactive magnesium as $Mg(OH)_2$ and its carbonation are yet to be further improved to > 90% for both process steps, now standing at 80% and 70%, respectively. The fact that step-wise serpentinite carbonation conversion times have been reduced to less than one hour is highly encouraging. Developments are supported by scale-up of the method for application at an industrial scale lime kiln in Finland and possible use for land reclamation in Singapore. With progress on CCS/CCUS application to flue gases stagnating worldwide, operating on flue gases directly and energy efficiency are a key feature of this CCS/CCUS approach, where also the produced carbonate materials are considered to be of use and have market value. For an ongoing industrial lime kiln case study, carbonation applied to kiln gas directly would have a power penalty of ~0.9 MJ/kg CO_2, further using waste heat from the kiln process.

Acknowledgements

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19. Producing precipitated calcium carbonate (PCC) from steelmaking slags using the slag2pcc concept

Hannu-Petteri Mattila, Ron Zevenhoven

Abstract

Calcium-containing slag material is produced in iron- and steelmaking worldwide, including Finland. One process route utilizing this calcium, being developed towards large-scale application, is the so-called slag2pcc concept. Using ammonium salts, up to 50% of the calcium content is selectively extracted from steel converter (BOF) slags in a two-stage aqueous process operating at ambient temperatures and pressures. Precipitated calcium carbonate (PCC) is produced by reacting the dissolved calcium with CO_2, thereby also regenerating the ammonium salt for recovery and re-use. Process optimisation involves the efficient production of PCC material with a certain quality, requiring effective separation of the solids from the solutions as well as maximal extraction of slag calcium against minimal solvent salt losses. In this paper the performance of the process, the possibility of continuous operation and the progress towards larger scale operation are reported. In addition, the consumption of process commodities such as energy and water is addressed by life-cycle assessment (LCA) approach, in comparison with traditional PCC production technologies. The slag2pcc concept combines the advantages of converting an industrial by-product into a valuable material, reducing use of natural material and streams to landfills while binding some of the CO_2 produced by the process generating the slag.

Keywords: steelmaking slag, valorisation, precipitated calcium carbonate (PCC), CO_2 storage and utilization.

Introduction

Worldwide, the iron- and steelmaking industry produces significant amounts of calcium-containing slag materials of varying quality. As an example, in 2013 the Finnish steel industry generated 0.47 Mt mineral aggregates while manufacturing 2.2 Mt steel. Much of these by-products are still directly landfilled, though markets for waste-derived products are becoming increasingly important. One process alternative for utilization of the bound calcium present in the slag is the so-called slag2pcc concept. Up to 50% of the slags calcium is selectively extracted with aqueous ammonium salt solutions from steel converter (BOF) slags in a two-stage process operating at ambient temperatures and pressures; precipitated calcium carbonate (PCC) is produced by reacting the dissolved calcium with CO_2, thereby also regenerating the ammonium salt for recovery and re-use. Ammonium salts buffer the solution so that calcium stays in solution, at the same time suppressing the dissolution of silica while the alkaline pH levels prevent the dissolution of metallic species.

The slag2pcc concept combines the advantages of converting an industrial by-product into a valuable material, reducing streams to landfills and use of natural material, while binding some of the CO_2 produced by the process that generates the slag. After pioneering work at Helsinki University of Technology, currently Aalto University (Teir, 2008, Eloneva, 2010), and patenting of the concept (Finnish patent 122348, 2011) for several ammonium salts for selective extraction of calcium, current work aims at larger scale operation. Work on a demonstration-scale system (reactor vessels á 250 litres) at Aalto University is supported by work at Åbo Akademi University (ÅAU) with an 8 times smaller, more versatile sub-demo scale demonstration unit. Results obtained with this smaller unit are reported here.

A description of the two-step process is given, operating at ambient conditions and, contrary to the conventional route to PCC, possibly as a continuous process. The continuous operation is motivated by simpler adaptation to the variations in the properties of the input slag. The description is followed by optimisation of process performance with respect to residence time for the process steps, solvent salt concentration and particle size, and finally the control of the PCC quality (purity, particle size, crystallinity) is addressed. Also touched upon are the use of energy and water, which are compared with conventional routes for PCC production using a life-cycle assessment (LCA) approach.

Process description

The lay-out of the slag2pcc process is given in Fig. 1. The scaled-up process may also involve a third reactor: a small part of the calcium-rich solution from extraction is mixed with the regenerated solvent stream as to remove dissolved CO_2 and (bi-)carbonate ions that would otherwise interfere with the extraction chemistry.

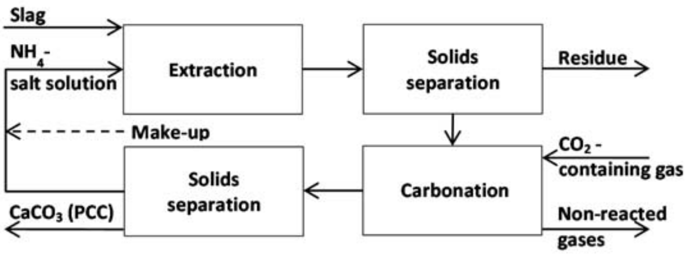

Figure 1: *The slag2pcc process for PCC manufacturing from steelmaking slags.*

Materials used in experimental work

Most tests reported here were done with steel converter slag, obtained during 2008-2012 from a basic oxygen furnace (BOF) process at Ruukki Metals Oy in Raahe, Finland, capable of binding ~ 0.1 kg CO_2 / kg slag. The calcium content of the slags, expressed as CaO, ranges from 42.2 to 47.5 %-wt as analysed using XRF (X-ray fluorescence); XRD (X-ray diffraction) identified silicate, ferrite and magnesium iron silicate phases besides lime (CaO) and portlandite ($Ca(OH)_2$. Also manganese (Mn) and vanadium (V) were found at 2.1-2.6 %-wt and 1.3-2.6 %-wt, respectively (XRF). More detail on slags composition and analysis is given elsewhere (Mattila and Zevenhoven, 2014, Mattila, 2014).

Pure CO_2 was used in all tests reported here: the presence of other gases (inert with respect to the carbonation reaction) was earlier found to merely increase volumes or reaction times (Eloneva, 2010). If flue gas is used as an input in the process, the standard flue gas cleaning operations (desulphurization and particulates filtration) are necessary prior to the slag2pcc process.

Process chemistry

The governing reaction for calcium extraction is simplified as reaction (R1), describing the effect of the ammonium salt solvent on the dissolution of calcium oxide.

$$CaO(s) + 2NH_4X(aq) + H_2O(l) \rightarrow CaX_2(aq) + 2NH_4OH(aq) \quad \text{(R1)}$$

CaO represents all NH_4-salt soluble calcium regardless of the actual crystal form in which it is bound. The crystal forms from which calcium is most easily extracted are free calcium oxide or hydroxide ($CaO/Ca(OH)_2$) and dicalcium silicate (Ca_2SiO_4) (Mattila, 2009, Mattila et al., 2012).

For the carbonation step, the main reactions can be summarized as (R2) and (R3):

$$2NH_4OH(aq) + CO_2(g) \leftrightarrow (NH_4)_2CO_3(aq) + H_2O(l) \quad \text{(R2)}$$

$$(NH_4)_2CO_3(aq) + CaX_2(aq) \leftrightarrow CaCO_3(s) + 2NH_4X(aq) \quad \text{(R3)}$$

"X" in reactions (R1)–(R3) represents CH_3COO^-, NO_3^- or Cl^- ions, (acetate, nitrate or chloride) even though only ammonium chloride was utilized as a solvent in the experiments discussed here, the choice being motivated by the lowest cost for the salt. It was recently reported (Said et al. 2013) that of the three solvents nitrate gives somewhat better calcium extraction, while chloride shows the strongest decrease in extraction efficiency while increasing the slag solids loading from 5 to 100 g/L solvent. Acetate has the drawback that besides ammonia vapour also an acetic acid vapour is produced, while nitrate requires extra safety measures. Ammonium chloride is hardly a health, safety or environmental risk though contamination of the PCC with ammonium- or calcium chloride must be controlled.

As for the chemical kinetics: for extraction the reactivity of the slag material defines a suitable residence time. Regarding carbonation, initial calcium concentration and CO_2 gas flow rate determine the time needed, but in lab-scale the conversion can be completed in 10-20 min. Residence times of up to 60 min have been used in the research for both reaction steps. The extent of reaction has been followed via the pH value in the different reactors.

The sub-scale demonstration unit and experimental procedure

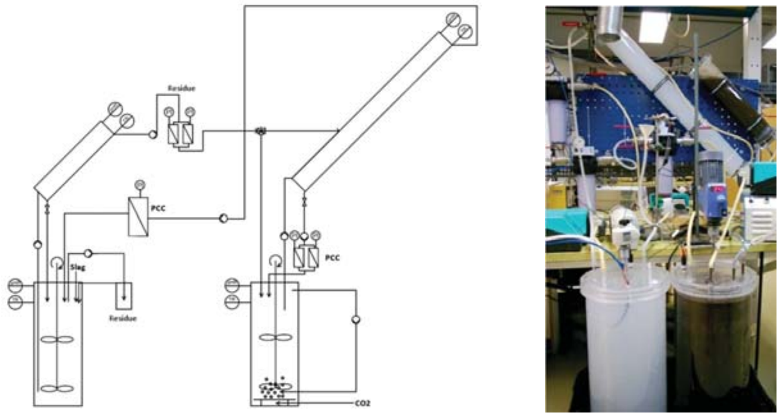

Figure 2: *Process scheme and picture of the constructed demonstration setup at ÅAU*

A schematic and picture of the sub-demo scale unit at ÅAU is given as Fig. 2. The extraction and carbonation reactors consist of cylindrical Perspex tubes (volume 29.4 L) equipped with suitable stirring equipment and baffling along the walls. At the bottom of the carbonation reactor a porous polyethylene sheet of 3.0 ± 0.10 mm thickness and a mean pore size of 39 μm is installed through which CO_2 gas is introduced from a gas bottle, giving bubbles of ~1.2 mm with initial rise velocity of ~0.8 m/s (according to theory for CO_2 and water). For particle removal (spent slag, PCC product) from the aqueous streams combinations of an inclined settler and a barrier (candle) filter are used, where the first is to thicken the slurry before the filter unit. For the spent slag, at ~100 μm, this is easier to accomplish than for the PCC with particle sizes down to a few μm, hence the settler for PCC is longer.

During an experiment, pumps were set to give a defined residence time in the extractor, and pumping was started after the pH in the extraction reactor had stabilized. At the same time the CO_2 feed to the carbonator was started. Temperatures and pH levels were measured and recorded on-line, while pressure drop across the filters was followed using manometers. After an experiment, solid products and solutions were analysed using several methods (SEM/EDX, XRF, ICP-OES, ion selective electrodes).

Process scale-up

Scaling-up of the process involves aspects such as operating the process in a continuous mode instead of batch processing as well as separation of solids from the process solutions. As noted above, several parameters affect the calcium extraction efficiency; among these are the fractions of calcium, iron and silicon in slag, but also slag particle size and the chosen slag-to-liquid ratio.

From work so far (Eloneva 2010, Said et al., 2013, Mattila and Zevenhoven, 2014a) it can be concluded that depending on the content of silicon-bound calcium in slag, solid-to-liquid ratios in the extraction step should not significantly exceed 100 g/L, higher values resulting in a rapidly decreasing calcium extraction efficiency. The content of free lime (CaO) is an essential parameter for choosing the best solid-to-liquid ratio for efficient calcium extraction, since its dissolution is not affected by silica. Too high solvent concentrations (> ~1.8 mol/L) result in extraction of impurities, such as Mn and Fe that miscolour the process solutions, but also of Mg, V, Na and K. These elements accumulate in the process solutions, and may eventually precipitate with the calcium carbonate. The PCC should not contain any compounds of ammonia or chlorine, or trace elements/heavy metals.

Fig. 3 summarizes these observations, and the most beneficial area of process operation from the point of view of selective calcium extraction is indicated by the double arrow in the lower-left of the graph. However, too low solvent concentrations result in slow kinetics, again non-beneficial for the overall process.

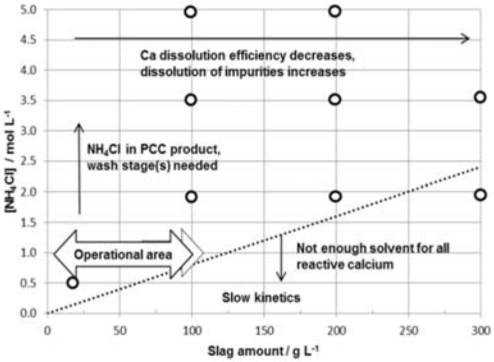

Figure 3: *Observed limitations for selective calcium extraction with ammonium chloride solvent, the experiments listed (Mattila and Zevenhoven, 2014) are marked with circles. The shown stoichiometric limit is calculated for a slag containing 45% CaO, of which 50% is in reactive form.*

Even though process solution recycling is an environmentally and economically feasible target, complete recovery and reuse of the solvent is challenging. Considerable amounts of ammonium salt solution leave the process both with the slag residue and the produced PCC. Also, ammonia vapours may leave the system together with the purge of unreacted gases from carbonation. The losses can be decreased by washing the solids leaving the process, and reintroducing the ammonium salt to the system together with a fraction of the washing water as a make-up stream. A gas scrubber is possibly required to capture the ammonia vapours, increasing the process water consumption while making the process more complex in general.

Product quality

Comparison of the composition of PCC samples produced with the slag2pcc method (Table 1) with commercial PCC qualities shows that elements such as iron and magnesium are present in lower amounts in the slag2pcc carbonates, while sulphur and chlorine contents can become higher than in commercial products. Besides product purity, obtaining a commercial particle quality requires attention at the process design level. Because the concentrations of calcium and carbonate species as well as the solution pH in the carbonation stage differ from those used in traditional carbonate manufacturing, the precipitated particles do not necessarily have the same morphology and particle size as the commercial PCC products. This problem can be solved by adjusting the process parameters.

%-wt (dry)	CaO	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MgO	K_2O	Na_2O	MnO	P_2O_5	S	Cl	950 °C losses
1	55.3	0.02	0.01	<0.01	<0.01	0.03	<0.01	0.03	<0.01	<0.01	0.08	-	43.9
2	54.0	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	0.02	-	44.4
3	53.3	0.02	<0.01	<0.01	0.02	0.03	<0.01	0.02	0.03	<0.01	0.04	2.8	44.3

Table 1: *The chemical composition of various PCC samples produced with the slag2pcc method (XRF analysis): 1) 0.50 mol/L NH_4Cl, 2) 0.65 mol/L NH_4Cl, 3) 1.84 mol/L NH_4Cl. (Mattila, 2014). (For entries labeled “-“ the element was not detected by the analysis instrument.)*

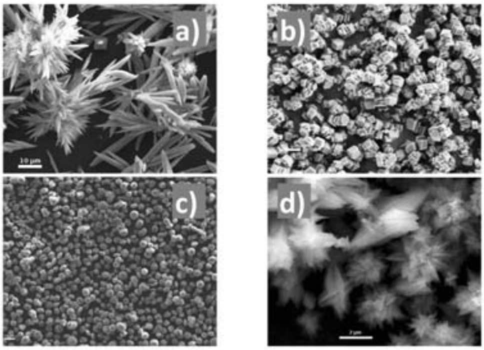

Figure 4: *Scanning Electron Microscope (SEM) pictures of a) aragonite, b) rhombohedral calcite, c) vaterite and d) scalenohedral calcite particles, produced with the slag2pcc process. Scale bars 10 μm in a and c, 1 μm in b) and 2 μm in d).*

Of the main $CaCO_3$ polymorphs aragonite, calcite and vaterite, calcite is the most stable. Aragonite only forms at elevated temperatures (> 50°C), and the metastable vaterite rapidly transforms to calcite or aragonite, depending on $[Ca^{2+}]/[CO_3^{2-}]$ concentration ratio and time (higher ratio and longer time favour calcite). Fig. 4 shows examples of the polymorphs, as produced using the slag2pcc process, as well as of the different crystal structures of calcite polymorph. For production of scalenohedral PCC, an initial pH of ~ 13 is favourable, lower pH values giving rhombohedral crystals. Longer reaction times yield larger particles, while rapid mass transfer of carbonate ions into the solution (using elevated CO_2 pressure or producing very small CO_2 bubbles) favours formation of small crystals. The favoured PCC particle properties depend on the application, for example, different fillers in coated and uncoated paper qualities affect mechanical strength or optical properties differently. In general, the particle sizes of commercial products are below 2-3 μm, in special cases of nanometer scale.

Comparison with conventional PCC production

Traditionally, PCC is manufactured in a batch process from limestone, which is first calcined to calcium oxide, emitting large amounts of CO_2. Prior to carbonation, CaO is then slaked with water to a calcium hydroxide slurry, resulting in lower calcium concentrations during precipitation than in the slag2pcc concept. With CO_2 emissions reduction and good quality PCC product as the main targets, it is, according to a partial life cycle assessment study comparing the environmental effects of the slag2pcc and commercial PCC manufacturing (Mattila et al., 2014c), beneficial to utilize low concentration ammonium salt solutions for PCC production also in the slag2pcc process. In this manner the extensive use of washing and drying equipment (and water and energy use) resulting in CO_2 emissions during product post-treatment is avoided.

On the other hand, it is possible to manufacture less valuable ground calcium carbonate (GCC) – quality products instead. An example of this approach is described by Mattila et al. (2014d): in a one-step process, introducing CO_2 directly to the mixture of steel slag and ammonium salt solution, the product would consist of 60-75 wt.-% pure carbonate that could be used to partially replace limestone-based compounds in steelmaking. While the carbonation process would become simpler, the economic viability of the process could be challenged by the lower product value.

Conclusions

A method for production of PCC from steelmaking slag, being currently scaled-up is presented, offering an alternative to conventional routes using virgin limestone rock as the starting material. The concept combines waste valorisation with CO_2 emissions reduction and reduced use of natural resources. The amount of steel slag may be too small for a substantial mitigation of global warming, but the process could have significance for individual steel manufacturers as a means to reduce the amounts of emitted CO_2 and landfilled steel slag. Compared to other CO_2 emission reduction approaches studied, the process has the advantage of existing markets for the products, giving a financial incentive for a practical implementation. Market values of high quality PCC may be 350 US$/ton, for low-value carbonates the technology offers an on-site "calcium recycling" method for iron- and steelmaking industry.

Acknowledgements

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20. The potential of alternative biomass based gas turbine cycles in Latin America

Arturo Manrique Carrera, Maria Fernanda Gomez Galindo

Abstract

The environmental and geopolitical concerns encourage governments towards the utilization of renewable energy sources (RES). Finding CO_2 zero/near-zero power production techniques is imperative. Biomass, a carbon neutral fuel, can be used in Joule-Bryton power cycle; however, this will require novel strategies to adapt the gas turbine proven techniques to biomass utilization.

In this work, we evaluate two possible alternatives to use biomass in modern gas turbines and the perspectives for their implementation within the Colombian context: First, the indirect fired gas turbine which allows a wide variety of fuels and simple operation. Second, low heating value fuel gas turbines could use gasified biomass and maintain high levels of single cycle efficiency, although a previous gasification stage is required.

In terms of technology, the comparison is done using a single cycle 18MWel engine. Technical parameters, as total fuel consumption, total cycle efficiency, heat rate, maintenance intervals, and replacement cost of vital components are considered. In terms of implementation, the analysis focuses on potential policy instruments that promote the deployment of these technologies in Colombia. Thus, the study provides the basis for further analysis of biomass-based gas turbines in other Latin American countries with similar realities. Economical key parameters are estimated.

Keywords: gas turbines, biomass, power production, indirect fire cycle, low heating value, policy instruments.

Introduction

The modern society is driven by energy; the world demanded approximately 12,32 Gtoe in 2010 [World Bank, 2013] and 80% of this energy is derived from non-renewable sources of energy. This produces a negative impact on the environment due to emissions of greenhouse gases, which could have devastating consequences due to the increase in global average temperatures. Therefore is achieving sustainable economic growth decoupled from fossil fuels is of the most importance

Renewable energy sources (RES) such as biomass, solar and wind power faces great challenges to overcome for their utilization, as they are intermittent and sometimes seasonal. In the specific case of biomass two strategies for utilization are important: Power generation and Liquid biofuels for transport. For power generation biomass needs to be integrated in a thermodynamic cycle with pre-processing, through gasification/pyrolysis/liquefaction, or through direct combustion.

Biomass based power plants are limited by the supply of biomass raw material; the maximum calculated size of thermal input in Europe is 50MW [McKendry, 2002]. In Latin

America higher level of thermal input can be found close to the megacities[11] from Municipal Solid Waste (MSW) without excluding agricultural and forest residues in large operations.

There are two basic approaches discussed here to use a gas turbine based on biomass as energy input: Externally Fired Gas Turbine (EFGT), in which the combustion chamber is replaced by a high temperature heat exchanger and biomass furnace. And Biomass Gasification-Gas Turbine process (BGGT), in which a gasifier produces a Low Heating Value (LHV) gas, that is utilized it in a Gas Turbine. Both alternatives are reaching commercial stages although there are still technical challenges to overcome for higher power output. Furthermore, to promote the use of biomass for power production is necessary a policy framework to incentive and reach the full potential. In this case different strategies can be applied.

Externally Fired Gas Turbine Cycle

The EFGT cycle is depicted in Figure 1. The cycle consists in replacing the combustion chamber by a gas to gas high temperature heat exchanger. Several studies have been done in small scale power generation (< 1MWel output) and the electrical efficiency level varies from 13% to 25% in different configurations [S. Soltani; 2013, A. Datta; 2010]. The major disadvantage is the low turbine inlet temperature, below 850 °C, due to material limitations on the high temperature heat exchanger. Other important factor is the heat transfer / biomass furnace efficiency that depends on characteristics of fuel utilised. The maintenance costs of these components are high. The major advantage of using this approach is the flexibility in fuel operation. It is also possible to use standard fuel for additional firing in case of low supply of biomass.

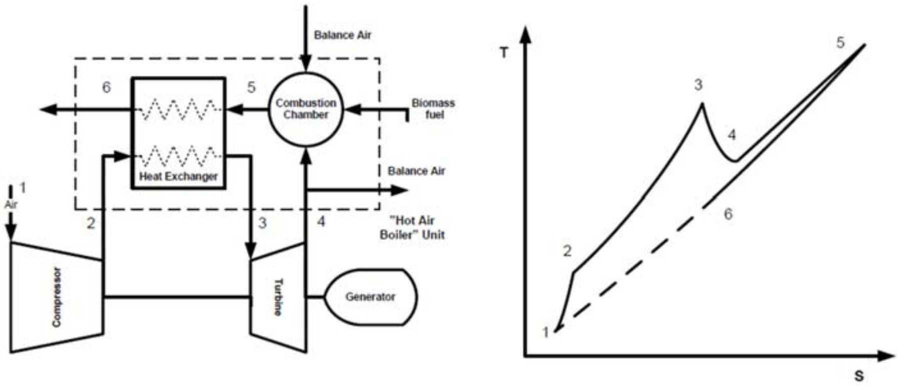

Figure 1: *Schematic of an Indirect Fired Gas turbine Cycle and the corresponding T-S diagram.*

Biomass Gasification and Low/Medium Heating Value in Gas turbines

Biomass gasification produces a gas with low/medium heating value (product gas) that can be used in a gas turbine cycle for power production. There are several gasification approached that could be used in the range on 60 - 80 MWth. Circulating Fluidized Bed Gasification, Plasma Gasifiers, and Pressurized Gasification techniques.

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[11] Cities with about 10 million inhabitants

The present work considers an atmospheric gasification strategy. There are two important aspects in case of linking atmospheric gasification and gas turbines: firstly, the requirement of a conditioning stage (cleaning, compressor booster for the injection of the "product gas" in the pressurized combustion chamber). Secondly, the possible mass imbalance between the compressor and turbine due to the relatively large mass flow flowing in the combustion chamber. Both aspects have been addressed in demonstration stages of this technology (cooling and compressing product gas), compressor bleeding and air balance (Figure 2). The gasifier conversion cold efficiency is in the order of 54 to 68 % including primary conditioning and compressing stages [USEPA, 2007]. Depending on the type of gasification the product gas, mostly a mixture of CO; H2; CH4; CO2 and N2, and it could be used not only for power production, but also for biofuel production.

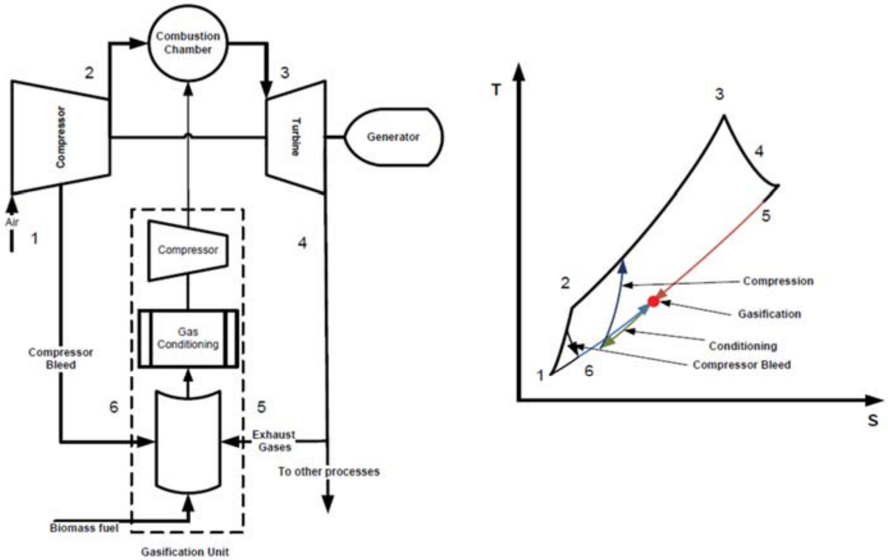

***Figure 2**:* Schematic of an atmospheric gasification integrated with a single Gas turbine Cycle and the corresponding T-S diagram.

Most of the technology required is available in commercial basis, however, the large high temperature heat exchanger for the EFGT, and the low heating value burners for the BGGT have not reached commercial applications only because of market limitations.

Policy instruments to incentive renewable utilization

In Latin America, the idea of creating sustainable renewable energy markets is becoming increasingly attractive. However, adopting and implementing renewable energy policies imply significant challenges. For example, the recently issued Renewable Energy Law 1715/2014 (REL) provides an opportunity for biomass-based alternative gas turbine cycles to be integrated into the Colombian energy system. This law encourages small and large-scale distributed self-sustained power producers to sell surplus electricity to the national grid. Mega cities such as Bogotá could benefit from this law through the use of Municipal Solid Waste (MSW). For that, the establishment of proper policy instruments and incentives is required not only on the energy side but also in connection to the current waste management framework. Table 1 summarizes the main policy instruments considered by the REL.

Quantity based incentives	Renewable Energy Credits (based on surplus electricity produced by small and large scale distributed power producers)
	Targets for renewable energy penetration in non-interconnected areas
Fiscal and financial incentives	50% deduction of income tax for investment in renewable energy technologies.
	Exemption from payment of VAT and duties.
	Accelerated depreciation
Others	Creation of the national fund FENOGE (Fondo de Energías no Convencionales y Gestión Eficiente de la Energía)

Table 1: Policy instruments and incentives considered by the REL in Colombia [Colombian Congress, 2014].

Methodology

The technical comparison of the two described alternatives is done based on a fixed electrical power output of the Gas Turbine. The maximum power is limited to 16,5MWel as biomass input reaches the approximated maximum recommended of 60-80 MWth fuel input [McKendry, 2002], and the Turbine inlet Temperature remains below 850ºC. The total mass flow intake is calculated using a biomass Low Heating Value of 16 MJ/Kg assuming 30% moisture content [USEPA, 2007]. The total electrical efficiency is established by computing the electric output divided by the energy input.

The economic estimation is based on the present approximate investment cost including operation and maintenance in a time frame of 15 year, no decommissioning cost is considered. A standard running profile is selected for an operation of 7200 hours per year (see Table 4). The variables used are the price of dry biomass per ton (from -50 to +100 U$/ton) and price of electricity. The control variable used is the Yearly Internal Return Rate for 15 year period. It also was assumed an average base electricity sale rate of 0,115 U$/kW-h [ECSIM, 2011] that is constant in the studied period, is assumed. Finally, a brief technical discussion comparing both alternatives is done taking into account possible off-design conditions.

Policy implication is used to define favourable conditions in which these power production strategies could flourish. The Colombian framework is used as start point to draw a brief analysis on the particular requirements.

System Description

Gas Turbine

The gas turbine model is an 18MWel gas turbine, triple shaft configuration, with no wall or film cooling in the high temperature turbine stages. The engine has a relatively low Turbine Inlet Temperature (TIT) and has an electrical efficiency of 33% at full load operation at ISO conditions on Natural Gas. This turbine is easily retrofitted to handle LHV gases, by using compressor bleeding and/regulating operational parameters and specially adapted burners.

Gasifier

There are several different options for the gasification system to be used in the thermal power range of 60 to 80 MW. Fluidized Bed Gasification and Circulating Bed Gasification systems are recommended in this range, both atmospheric and pressurized are proven technologies. The efficiency conversion of the system ranges from 60% to 80%, this depending on various parameters. In the present case an Atmospheric Circulating Fluidized Bed Gasification has been chosen. However, due to the latest development in Plasma gasification this alternative must be reviewed as possible option.

The gasification will be treated as a unit that deliver the fuel (Low Heating Value) at acceptable conditions of the turbine (quality, pressure and temperature). In the Gasification stage the "product gas" has to be cleaned, cooled down to be compressed to the required pressure to be injected in the combustion chamber. Previously the biomass entering the gasifier has to be classified, dried, and pulverized. Energy for drying might come from the exhaust gases of the gas turbine and compressor bleed. The gasifier will require a mass flow input in the order of 230 to 460 ton/day and would produce a low heating value gas of 4,6 - 6,3 MJ/kg.

Heat exchanger/Hot air boiler unit description

The heat exchanger and the biomass combustion chamber or furnace form the "hot air boiler unit". The pressurized air is driven by the gas turbine. Inside the heat exchanger flows pressurized air (12-14 bara) from the compressor of the turbine. In the combustion chamber/furnace the biomass is burnt. Several options could be used for both proposes. The heat exchanger is simulated as a counter flow shell and tube unit with two passages, the material chosen is a high Cr, Ni alloy that withstand 900ºC [Sanvik, 2014]. The maximum inlet temperature of flue gases is estimated in the range 850 to 875ºC and the exit temperature is in the 300-415 ºC range. For the pressurized side, the air enters at 280 to 350ºC and leaves at 650 to 830ºC. The biomass combustion chamber is characterised by the high sensitivity to moisture content, in this respect 30% moisture content in biomass is assumed. This requires a drying stage using the hot streams from the process, such as the exhaust flow from the hot air boiler unit. The efficiency of the system is estimated 57% - 66% [Overend, R, 2014].

Fuel supply

The fuel supply model was initially intended for energy crops, but during the curse of the study it was clear that the amount of biomass required would be larger. Therefore a large source of biomass, as it is the Municipal Solid Waste from large cities, is considered in the scope. The 230-460 ton/day of available biomass is easily reached in large urban centres were already exist a recollection structure. The burnable biomass potential of Bogota is in the order of 3000 ton/day [CEMPRE, 2011]. This approach does not exclude the use of agricultural/forestals residues or energy crops input.

BGGT		
Component	**MU$**	**Description**
Gas Turbine	9,2	18 MWel engine
Gasifier	25,0	70 MWth CFB gasifier
Auxiliary Equipment	7,2	Cleaning/Conditionin g Systems
Maintenance	34,0	35%GT; 38% CFB; 27% Aux
Operation	7,9	Staf + Administration
Others	15,0	
Initial investment	98,3	

EFGT		
Component	**MU$**	**Description**
Gas Turbine	9,2	18 MWel engine
Furnace + Heat exchanger	16,0	90MWth
Auxiliary Equipment	5,2	Cleaning/Conditioning Systems
Maintenance	48,0	27%GT; 58% F&HE; 15% Aux
Operation	7,9	Staf + Administration
Others	9,0	
Initial investment	**95,3**	

Table 2**:** Approximated initial investment cost of the BGGT and IFGT alternatives [USEPA, 2007; World Bank Group, 2009]

Cost structure

Table 2 shows the comparative hardware, operational and maintenance cost of the Biomass Gasifier-Gas Turbine (BGGT) and the Externally Fired Gas Turbine (EFGT) options. The costs of the component were approximated from different sources [USEPA, 2007; World Bank Group, 2009]. These costs do not consider payment of VAT and duties as they are part of the incentives in place, It was also included the fix operational cost of personal and maintenance cost for the 15 year period. Although the approach could be coarse in some items, the final values could be used for the analysis. As the initial analysis does not include the income tax over profit, which is 37%, this tax is latter deducted from the total internal rate of return.

Results and Discussion

Efficiency Comparison

The thermal efficiency of the gasifier sets the trend of the total efficiency of BGGT cycle, as the electrical efficiency of the turbine is defined. The filtering and cooling of the “producer gas” are the most important thermodynamic loss in the system. The compression work of the producer gas is recovered during the expansion stage in the gas turbine. In the case of EFGT, there are two factors that affects the thermal efficiency; the highest allowable temperature in the heat exchanger, and the efficiency of the biomass furnace. This efficiency of the biomass furnace is influenced dramatically by excess of air, (25% air excess in this case), the exit temperature and moisture content of biomass account.

Load	Gasifier	Hot air boiler
%	η thermal	η thermal
30	54,0%	66,0%
40	56,7%	64,4%
50	59,4%	63,4%
60	63,0%	61,7%
70	64,8%	60,6%
80	66,6%	59,4%
90	67,5%	58,3%
100	68,4%	57,6%

***Table 3:** Thermal efficiency of the Gasifier and Hot air Boiler*

Table 3 shows the estimated efficiency of the gasifier and the "hot air boiler". In the hot air boiler the ability to transfer heat reduces as the maximum operation temperature in is reached, at the same time the streams leaving the hot air boiler are hotter at higher loads, these affects negatively its thermal efficiency at high loads. The gasifier shows an expected efficiency increase with load. Observe that the load is referred to the electrical load of the turbine operating on gasified biomass.

Figure 3 shows the total electrical efficiency comparison between EFGT and BGGT power.

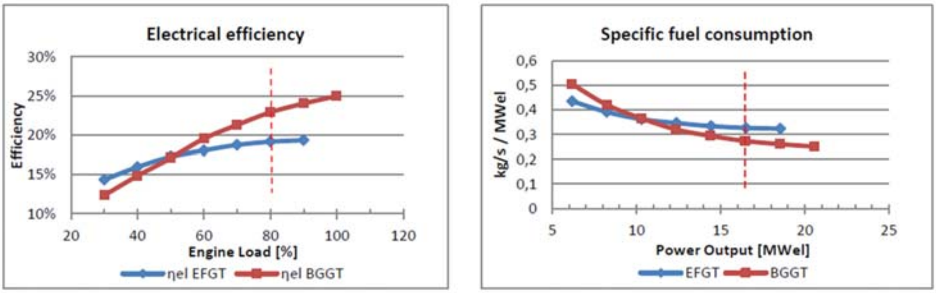

***Figure 3:** Electrical efficiency and Specific biomass consumption per MWel of the EFGT and BGGT cycles.*

At approximately 50% load both alternatives have similar electrical efficiency and at lower loads the EFGT is more efficient that BGGT. The situation reverses for higher loads than 50%. This can be seen in the specific fuel consumption. For higher loads the BGGT uses less kg/s dry biomass per power output in MWel, on the contrary at lower loads the EFGT uses less fuel per MWe delivered. The balance is reached at aprox. 10MWel. he dashed red line signals the maximum design conditions. The reference in this case is the gas turbine load. The EFGT efficiency levels at 80% turbine load, at this conditions the maximum operation temperature and mass flow in the heat exchanger is reached and further increase in both only will degrade the material. In contrast, the BGGT has still room for increased power and efficiency.

Economic Comparison

The economic comparison is calculated assuming that the power plants will operate 300 days/year and the load profile is described in Table 4. The price of the electricity is taken as

0,115 U$/kW-h, and the increased price conditions of 25% (0,144 U$/kW-h) and 50% (0,173 U$/kW-h) higher.

Time fraction	MWel	% Load
2,5%	6,2	30
2,5%	8,2	40
5,0%	10,3	50
30,0%	12,3	60
50,0%	14,4	70
10,0%	16,5	80

Table 4: *Load profile for IFGT and BGGT*

The parameter that varies is the price of burnable dry biomass in U$/ton. This price could be negative if recollection of Municipal Solid Waste is included in the scope. This price could vary from -50 U$/ton to -20 U$/ton [Pan-American health Organization, 2005]. In the case of purchasing the burnable fraction from the recollection system, the price will be positive.

The control variable chosen is the yearly internal return rate over 15 years, which is the yearly average interest that balance the initial investment divided in 15 years minus the income for the operation. The results are shown in Figure 4 for the EFGT and BGGT considering three electricity prices. In Figure 4 is possible to see that there is an equilibrium point between EFGT and BGGT for all cases. From the equilibrium point towards the negative cost of biomass, the EFGT offers a higher yearly internal return rate, while from the equilibrium point towards the positive cost of biomass fuel the BGGT gives a better yearly internal return rate. For all cases the yearly internal return rate decreases with increased price of biomass as fuel.

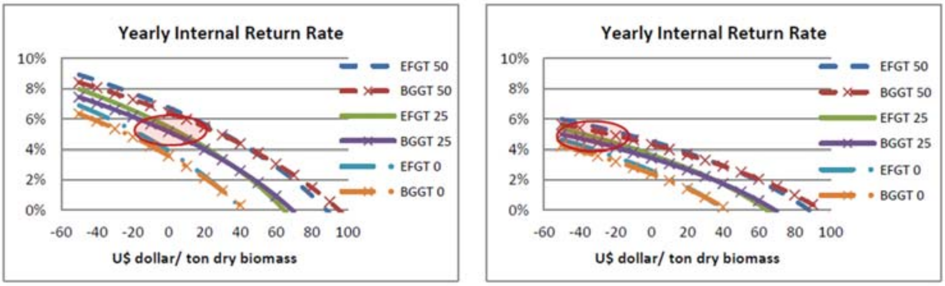

Figure 4*: Yearly internal return rate for different electricity prices without (left) and without (right) considering income tax.*

To be considered economically attractive the yearly internal return rate should be between 4 to 6%, interest rate. In case of not considering income taxes the price of biomass should be between -20 to +35 U$/ton (red area in Figure 4, left). If the biomass price is higher than 35 U$/ton, the EFGT system gives marginally higher yearly internal return rate. At higher biomass price than 35 U$/ton the BGGT gives better yearly internal return rate. The picture changes dramatically if income taxes are applied, in Figure 4, right, income taxes are applied (33%), the price of the initial fuel has to be negative to be economically feasible.

Technological Aspects

Economically, the best alternative is the EFGT; however, the technical possibilities of further development of this approach are limited. The major advantage is the hot flue gases stream coming from the hot side of the heat exchanger, which at higher loads reaches up to 415 ºC. This stream might be used for drying purposes and in the best case; it could be used to drive an Organic Rankine cycle for further power production. Furthermore, the heat exchanger material limitations reflects in the maximum power output on the system to the design conditions (e.g. 16,5 MWel). In order to increase this power output it is necessary significant investment to change material in the heat exchanger. On the contrary, the BGGT, has technically more scope for further development. The BGGT approach produces a hot stream of gases, although colder than in the case of EFGT, it might be used for drying and also could drive an ORC, but in contrast to EFGT, the power output could be increased if the capacity of the gasifier increases; furthermore, The gasification technology could be adapted to produce high quality "producer" gas that could be used for bio-fuel production or biomaterials in addition to the gas turbine fuel supply. Finally, updated gasification technology could be integrated in the gasification stage, such as plasma torches for gasification, hot candles filters for gas fuel cleaning, catalytic cracking of tars, etc.

Policy aspects

The volume of the required financing resources and the sources themselves are issues of great concern. Despite the fact that the Colombian government has considered fiscal and financial incentives, the implementation of biomass-based gas turbines requires additional support to be effectively put in place. On the one hand, this additional support might be provided in the form of price based incentives. Yet, this option requires an extra effort from the government that seems unfeasible in the short term as it is not included in the recently issued REL. On the other hand, exploring potential synergies with the waste sector offers one alternative to ensure the implementation and operation of the analysed technologies without involving resources from FENOGE and attracting potential investors.

In Colombia, urban solid waste represents a local, secure energy source with a prospective of more than 5500 ton/day [CRA, 2013]. An initial estimate indicates that a biomass price below 35 U$/ton has the potential to attract investors. This price is within reach for some locations that imply collection and transport costs of about 29 U$/ton [CRA, 2013]. However, biomass price levels higher than 100 U$/ton are observed in other locations. In the absence of price-based incentives, an interesting alternative for those locations to help the effectiveness of the REL is on-site power generation.

Current waste management practices in the country do not fulfil international standards. To date, there is not an integral approach to waste management [Cempre, 2011]. Also, the importance of waste prevention and separation at the source is not recognized. In short, there is an urgent need for harmonizing waste management processes and adapt them in order to help the effectiveness of the REL.

On the waste management side, public-private alliances can provide technology and knowledge and help not only to assure that waste management is conducted in a sustainable way but also that waste-to-energy practices are put in place. On the energy side, there are still a number of issues to be analyzed so that the REL can be fully implemented. For example, there is a need for establishing a clear definition on small and large scale power producers. Also, the detail of how energy credits are to be allocated is still pending.

Further, clear rules and procedures describing how FENOGE will operate are important. As these challenges are addressed, Colombia is now moving towards the regulation of the REL. Two out of seven decrees are already under final stages for approval.

Final Remarks

Although at the beginning of this work, it was considered to focus in energy crops, forestall and agricultural residues, it come clear early that Municipal Solid Waste in Megacities offers a sounding alternative both economically and organizational for biomass utilization. This does not exclude that the EFGT and BGGT could use biomass sources mentioned in this lines, both options are fully feasible. Furthermore, there are important aspects that are not treated in this work, such as the emissions benefits, the impact on health and the institutional demands. Neither benchmarking projects around the world that tries to utilize biomass in medium scale for power production, these subjects might be theme for future studies.

Conclusions

Electricity price is determining factor for the viability of the EFGT and BGGT alternatives, it is necessary to have a fix preference price for electricity during the lifetime of the plant. Market price in Colombia varies from 0,9 to 1,9 U$/kW-h, which makes much difficult any long term commitment for possible investment.

The EFGT alternative is economically more attractive but limited for power/technology updates. In contrast, the BGGT option is more efficient, but financially less attractive, however, it offers larger scope for future updates. BGGT could be updated either for higher power output or to produce high quality product gas for chemical feed-stock that would make it economically feasible.

Policy incentives will be necessary to promote either EFGT or BGGT alternatives, although there are other actions that could bring this application to realization. Institutionalization and regulation of Municipal Waste Management seems to be essential to bring together public-private alliances to extract the benefits of this potential energy sources.

Finally, the possible emission reduction, the impact on the environment, and the social consequences (public health and organizational) are not considered in the current scope.

21. Preliminary techno-economic, environmental and risk assessments of a hybrid solarised gas turbine concept

Karamveer Singh K., Vishal Sethi, Giuseppina Di Lorenzo, Fernando Jimenez Ugarte

Abstract

In the power generation sector, substituting fossil-fuels with near-zero carbon alternatives is one viable option identified for curbing CO_2 emissions. Solar energy is one such alternative and it's valued for being inexhaustible in nature. This study examines the technology of solarised gas turbines in a hybrid configuration, i.e. use of concentrating solar power (CSP) systems in Brayton cycle equipped with conventional combustion systems. Such a technology allows for a stable supply of energy, thereby alleviating the intermittency problems associated with renewables only system. A techno-economic environmental risk analysis (TERA) methodology was conceived to assess the potential of a commercially available recuperative engine that was selected for solarisation. Its conventional fossil-fuel only counterpart was used as a baseline engine for this study. Thermodynamic performance analysis at design point operation revealed the solar-hybrid unit to have a fossil-fuel efficiency of 72% in comparison to 43% of the conventional engine. In terms of environmental impact, the solar-hybrid unit was found to have specific CO_2 emission levels of 0.284 kg/kWh, which is approximately 40% lowerthan the CO_2 emissions generated by the baseline engine. Additionally, NO_x emissions of the solar-hybrid machine were also approximately 40% lower relative to the baseline engine. In the financial analysis, as expected, the cost of electricity (COE) for the solar-hybrid alternative (17.1 €cent/kWhr) was found to be higher than the fossil-fuelled engine (5.9 €cent/kWhr). A 2^k factorial design experiment further revealed capacity factor and variable costs as the primary factors affecting the COE produced by a power plant. A short note discussing the maturity level of the technology is also included. It is perceived that this technology has a high-potential for market introduction in the mid-term view.

Keywords: concentrating solar power, central receiver, solar tower, heliostats, levelised cost of electricity, solar energy, solarised gas turbine

Introduction

Over the past few decades, global warming due to climate change has become of significant concern to the scientific community. Anthropogenic activities have been identified as the major cause for rise in global temperatures (IPCC, 2001). The greenhouse gas making the largest contribution from human activities is carbon dioxide (IPCC, 2005). Many recent studies share a common view that: some action needs to be taken in order to avoid potential harmful effects originating due to global warming (S. Wu, 2088). Among the several anthropogenic activities that emit GHG emissions, the power generation sector has been identified as the largest emitter of carbon dioxide (R. A. Battista, 2000). Hence a determined effort is required to mitigate the effect on climate change emanating from the rapidly growing energy industry.

Replacing fossil fuels with near-zero carbon alternatives is one of many technological options available to help reduce CO_2 emissions to the atmosphere (IPCC, 2005). Renewable energy (RE) resources like: wind, hydro, biomass, geothermal and solar, provide for the desired characteristic of zero CO_2 emissions. Deployment of RE in the power generation has been growing rapidly over the past few years (W. Moomaw, 2011). This is due to their unique advantage of producing electricity at one to two orders of magnitude of lower CO_2 emissions than fossil fuels (W. Moomaw, 2011). Furthermore, RE is believed to have enough theoretical potential to meet the needs of energy consumption of all economics on Earth (W. Moomaw, 2011). However, its full-fledged deployment in the power generation sector is impeded by the challenge to first capture the RE source, and then to utilise it to meet the desired energy services in a cost effective manner (a truism for any power systems). The RE considered in context of this paper is solar energy.

According to the IPCC report, the technical potential of solar energy is ranked amongst the highest in RE sources, circa 1600 to 5000 EJ/year (W. Moomaw, 2011). This vast potential by itself is considerably larger than the current primary energy consumption in the world (IEA, 2008). As of today, solar energy can be converted to electricity by two means: photovoltaic or solar thermal conversion. This paper focuses on the latter process whereby the heat generated by the solar radiation is added into a thermodynamic Brayton cycle (via use of CSP systems) for conversion into electricity.

A CSP system, in short, is an emerging renewable technology which can be implemented in thermal-electric conversion systems to help curb significant amount of CO_2 emissions, if not all. The basic concept of CSP systems is that they function by concentrating energy from the sun‘s rays to heat the working fluid (which is flowing through a receiver) to temperatures, between 400°C to 1000°C (IEA, 2010). This heat in the working fluid is then used in a downstream process for electricity generation, like in a gas turbine (GT). The minimum threshold for Direct Normal Irradiance (DNI) required by CSP technologies is set at a value of 2,000 kilowatt hours (kWh) of sunlight radiation per square meter annually. Below that, the photovoltaics technology is known to have a better competitive advantage (IEA, 2010). DNI is the beam radiation of the sunlight which reaches the Earth’s surface in parallel beams for concentration . Favorable DNI conditions for use of CSP related power systems is typically found in arid & semi-dry regions of the Earth, ideally located within 40 degrees of latitude north or south (IEA, 2010).

Majority of world’s electricity today – whether generated by coal, gas or oil – comes from creating a hot fluid. As CSP simply provides an alternative heat source, it is able to leverage and build upon the exisiting know-how of power generation (D. Arvizu, 2011). It is predicted that CSP systems could cover 7% of power demand by 2030 and roughly 20% by 2050 (IEA, 2010). In context of the power generation industry, CSP systems have distinct key advantages over photovoltaics (IEA, 2010; D. Arvizu, 2011).CSP systems do not require exotic materials and can be installed in a wide range of capacities, from tens of kWs to multiple of MWs. Also a CSP system has the capability to be integrated with thermal storage to provide for peaking and intermediate load. Most importantly, a CSP solution has the unique flexibility to be installed in a hybrid configuration (i.e. in combination with fossil fuel generation) to produce high and reliable electrical capacity. This also allows it to generate fully dispatchable power to provide for base, shoulder and peak loads throughout its 24hr operation. Thus allowing for a secure supply of stable energy to meet the varying needs of the grid.

This study looks into the assessment of solarised gas turbines, where solar technology is integrated into a Brayton cycle gas turbine in a hybrid configuration. Currently, most power plants are primarily supplied with fossil fuels for generating power and it is very likely that fossil fuels will continue to remain a key ingredient in meeting the future energy demands. Therefore in the medium term, development and implementation of solarised gas turbines equipped with fossil fuel combustion is believed to have the potential to achieve the combined goals of mitigating climate change, reduction in fossil-fuel dependency and security of energy supply.

Brayton Cycle for Solar Thermal Power Plants (STPP)

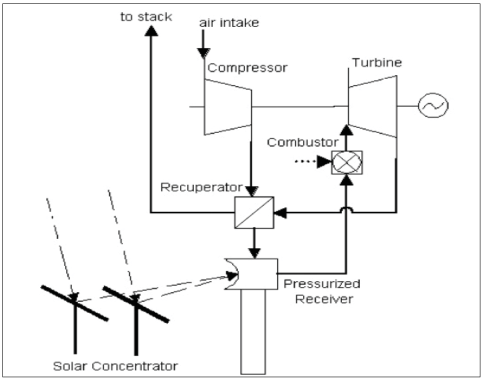

Figure 1: *Schematic of solarised GT (P. Schwazbözl, 2006).*

STPP with optical concentration technologies have been recognised as an important candidate for providing a major share of the clean and renewable energy needed in the future .One of various types STPPs is a configuration where a CSP system is integrated into Brayton cycle gas turbine, also referred to as solarised gas turbine in this publication. Heat from a CSP system is used to heat the compressor discharge air before it enters the combustion chamber of the gas turbine. CSP system of heliostats and pressurised receiver is used in solar power plants to heat the compressed air to temperatures up to 1000°C [9]. Figure 1 illustrates a solarized gas turbine in a solar-fossil hybrid configuration. The combustion chamber closes the temperature gap between the receiver outlet temperature (circa 800-1000°C) and the required turbine inlet temperature (circa 950-1300°C) and provides constant turbine inlet conditions despite fluctuating solar input [9]. The pluses of such a hybrid-configuration over a solar-only system include : (i) lower additional costs as solar energy provides for 40%-90% of the required heat input , (ii) reduced technical and economic risk due to provision of back-up power from the combustion system , (iii) higher power system efficiency because of reduced part-load operation and fewer start-up and shutdown losses , (iv) use of modern GTs in recuperation mode increase the conversion efficiencies of solar heat from 30% to 50%. This last advantage was a key motivation behind selecting a commercially available recuperative GT Mercury M50 (ISO 4.6 MW) as a representative prototype for solarisation in this study. Solarisation here means coupling the GT with a central receiver CSP system or in other words adapting the GT to a solarized unit.

Techno-Economic Environmental and Risk Analysis (TERA) Framework

In this study a TERA concept for industrial gas turbines has been applied to evaluate the technology of solarized gas turbines. Figure 2 illustrates the basic philosophy of TERA, which constitutes of a four-step analytical tool.

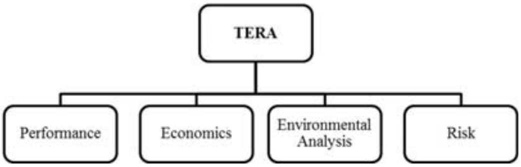

Figure 2: *Basic Philosophy of TERA*

TERA is a multi-disciplinary concept used as a tool at the preliminary design stage for analyzing and evaluating various technologies. TERA can be used to undertake numerous studies including: design space exploration studies, parametric/sensitivity analysis, multi-disciplinary design optimizations or trade-off studies. TERA has been successfully used to evaluate novel power plant technologies for aerospace , power generation, marine, and oil and gas applications (G. Di Lorenzo, 2013; G. Di Lorenzo, 2012; M. Maccapani, 2014).

Evaluating Solarised Gas Turbines using TERA

As a first step towards the development of the TERA framework for this study, the scope was limited to developing a preliminary model to simulate the design point performance of a representative solarised gas turbine engine. The representative machine selected for solarisation in this study is the Mercury M50 engine.

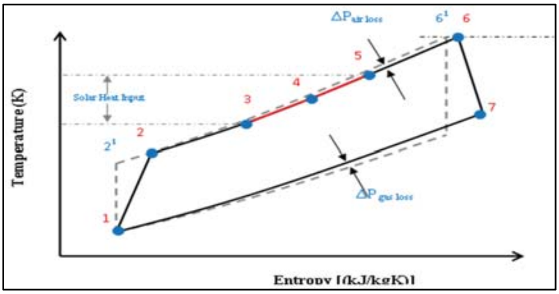

Figure 3: Temperature-Entropy diagram of a solarised gas turbine system.

Figure 3 illustrates the power cycle, which is based on a modified Brayton Cycle concept . Atmospheric air enters the system at Station 1. The vertical line 1-2^1 depicts ideal adiabatic compression. In reality, there is an increase in entropy due to various components loses. Hence the real compression line is 1-2. Heat addition to the working fluid takes place in 3 stages. Line 2-3 represents the heat addition in the recuperator. Line 3-4 and 4-5 represent the heat addition of solar energy concentrated by the heliostats onto the two pressurized receivers. Additional heat is added to the flow in the combustion chamber illustrated by line 5-6. The ratio of heat provided by the solar energy (3-5) over the total external heat input provided to the cycle (3-6) is termed as ***solar share*** or ***solar fraction.*** In fossil-only operation, the combustion chamber provides the heat input to the cycle from 3 to 6 (no solar share). However for the purpose of this study the solar-fossil operation, temperatures at points 4 and 5 are assumed to be fixed at design point. The temperature at station 5 regulates the maximum solar share of the total heat input to the cycle.

The pressure loss occurring in the recuperator, recievers and the combustion chamber is depicted as $\Delta P_{air\ loss}$ in the figure and shifts the point of maximum temperature from 6^1 to 6.

The pressure loss in the working fluid occurring through the post-combustor components is depicted by $\Delta P_{gas\ loss.}$ The area under the T-s curve is proportional to the useful work derived from the system (Figure 3).

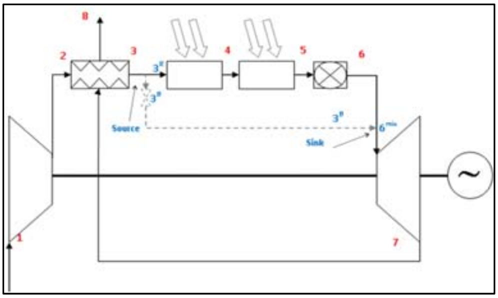

Figure 4: *Schematic of the M50 solarised representative engine.*

The thermodynamic model was developed as a sequence of interconnected modules representing individual components of the engine (Figure 4). Standard Physical and thermodynamic laws from the literature have been used to describe the system dynamics (P. P. Walsh, 1998).

For validation of the performance model developed in this study, a simulation was conducted using the engine data from a similar study available in the literature, called the SOLGATE project (European Commission, 2005). Not all assumptions and details were available from the SOLGATE report, which didn't allow for a true comparison to be made. To avoid arriving at biased and incorrect results, more emphasis was placed on validating the behavior of the model, i.e. the results being consistent with the thermodynamic principles from which it was developed. This objective was successfully achieved with the attempt to match the power output and thermal efficiency of the M50 unit studied in the SOLGATE project. This approach resulted in the minimum differences between the simulation results and the results published in the SOLGATE report. More details on the model, assumptions made and the validation approach can be made available upon request to the corresponding author of this paper.

Technical Analysis

Design Point performance comparison has been made between the solarised M50 engine and its fossil fuelled counterpart. The primary assumption made was that the adapted M50 solar-hybrid GT engine is to provide the same power output and similar thermal efficiency as that of it's fossil-only counterpart for a given TET (1115°C) , with inlet mass flow of (17.69 kg/s) and at standard ISO conditions.

Table 1 and Table 2 tabulate the input parameters and component efficiencies assumed for the two configurations. For the real M50 engine, the air is actually bled off from the compressor exit and is in the range of 3-6% (Gas Turbine World, 2010). The model developed in this study was configured to account for bleed after the recuperator, where the air is relatively hotter. Hence a higher percentage of bleed was evaluated for the fossil-only configuration. The development of models for the optical sub-systems wasn't included in the scope of this study. Thus, the receiver area and pressure loss values for the solar-hybrid configuration were assumed to be same as that used in the SOLGATE project (P. P. Walsh, 1998).. The auxiliary work of 1 % was included to account for the energy required by the CSP systems (receiver window cooling, heliostat tracking) .The design point receiver outlet temperatures for the LT and HT receivers were defined as 710^{0}C and 860^{0}C respectively. The subsequent results of the absorbed flux density for each of the receivers are provided in Table 2.

Other Simulation Characteristics	Unit	M50 Solar-Hybrid Configuration	M50 Fossil-Only Configuration
Recuperator Air Side Pressure Loss	(%)	5	5
Recuperator Gas Side Pressure Loss	(%)	7	7
Bleed Flow	(%)	10	12
Low Temp. Receiver Pressure Loss	(mbar)	150	N/A
High Temp. Receiver Pressure Loss	(mbar)	20	N/A
LT Receiver Area	(m^2)	7.19	N/A
LT Receiver Area	(m^2)	4.99	N/A
Fuel Type	(-)	NG (CH_4)	NG (CH_4)
LHV	[MJ/(kg/K)]	48.1	48.1
Combustor Pressure Loss	(%)	5	5
Mech. Transmission Loss to Compressor	(%)	1	1
Mech. Transmission Loss to Generator	(%)	2	2
Power for Auxiliary systems	(%)	1	0

***Table 1**: Input Parameters*

Component Parameters	Unit	Solar-Hybrid Configuration	Fossil-Only Configuration
Compressor Isentropic Efficiency	(%)	90	90
Pressure Ratio	(-)	9.9	9.9
Recuperator Effectiveness	(%)	91	91
Absorbed Flux Density Low Temp Receiver Flux Density	(kW/m^2)	167.96	N/A
Absorbed Flux Density High Temp Receiver Flux Density	(kW/m^2)	645.61	N/A
Turbine Isentropic Efficiency	(%)	92	92

***Table 2**: Input Component Efficiencies*

Table 3 shows the design point simulation results of both the configurations. Use of solar energy in the GT unit, reduces the amount of fuel consumption by approximately 40%. This difference is equivalent to the proportion of heat input provided by solar energy in the solar-hybrid configuration, represented by the solar fraction parameter. The fuel efficiency parameter of the solar-hybrid unit is significantly higher and represents a reduction in dependency on the amount of fuel required for heat input to generate a given power output.

Performance Parameters	Unit	Solar-Hybrid Configuration Results	Fossil-Only Configuration Results
Total Solar Power Input	(kW)	4429	N/a
Fuel Heat Input	(kW)	6358	10752
Fuel Use	(kg/s)	0.132	0.224
Solar Fraction	(%)	41.1	N/a
Fuel Efficiency	(%)	72.4	42.8
Electrical Power Output	(MW)	4.6	4.6
Thermal Efficiency	(%)	42.7	42.8

***Table 3**: Performance results of M50 solar-hybrid vs fossil-only unit.*

As a second part of technical analysis, a sensitivity study was carried out to investigate the effect of following parameters on the performance of the solar-hybrid M50 unit: Compressor Efficiency, Turbine Efficiency, Recuperator (or the Heat Exchanger) Effectiveness and TET.

Figure 5 illustrates the results of the sensitivity study. The representative M50 solar-hybrid engine described in Table 1 was selected as the base line model for comparison .The variance is displayed as a percentage change from the baseline model. For each case only the value of the parameter defined for that particular case was changed, while the rest of the input parameters were kept same as that of the baseline model.

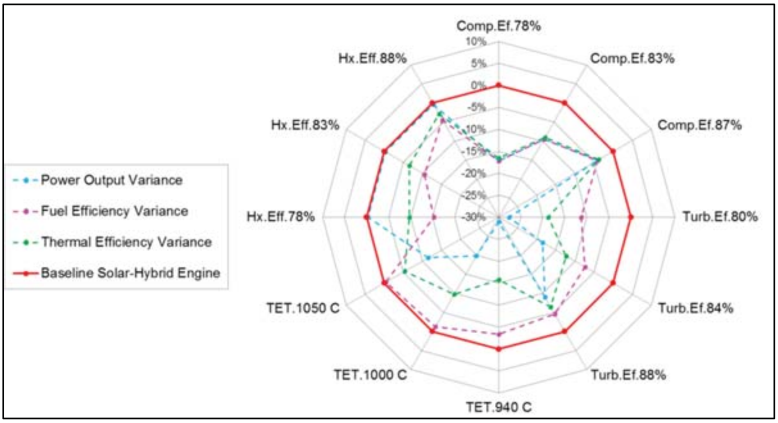

Figure 5*: Results summary from sensitivity analysis*

The results of the sensitivity cases were assessed to gain an initial understanding about the phenomena of degradation for the solar-hybrid GTs. The recuperator, compressor and turbine components are perceived to undergo fouling due to suction of foreign objects along with the air-stream into the solar-hybrid GT units (especially sand and dust particles present in arid/dessert like places). Any degradation in real sense will have to be modelled as a detailed off-design performance simulation as it will accordingly affect other parameters including (intake mass flow, pressure ratio, non-dimensional mass flow etc). Nevertheless, for a preliminary study conducting a design point modelling of these cases, the variation in performance observed due to change in component efficiencies, is indicative of the degradation phenomena.

In certain places of the world, government incentives are offered to power plant operators encouraging them to produce a portion of their electricity from greener/renewable sources of energy (G.R. Timilsina, 2012). To qualify for such incentives, some policies require the power cycle to exhibit a certain minimum percentage of heat input to be provided by a renewable source of energy (for instance solar energy). In context of this study, the modification of the M50 into a solar-hybrid unit may be constrained if such a product is to qualify for the incentive program. If the receiver technology is already at the advanced level, one approach the designer may use to increase the solar fraction to the desired level is to reduce the design point TET and maintain the same temperature rise provided by the receivers (constant solar input). This reduction in TET would mean a reduction in fuel flow, and therefore giving a higher share of heat input from the solar energy. Cases of varying

TET examine the implications of this approach (reducing only the design TET for a given solar input) may have on the performance of the engine.

Figure 5 illustrates that , in comparison to the baseline model, the reduction in values of the turbomachinery efficiencies is observed to decrease the power output, fuel efficiency and thermal efficiency of the plant. The recuperator effectiveness has no effect on the power-output, but reduces the thermal efficiency and fuel efficiency of the cycle. The change in TET was seen to have a same effect on performance as that of the turbomachinery components. Nevertheless at a reduced TET the solar fraction was observed to be relatively higher.

Environmental Analysis

The environmental performance of the solar-hybrid unit in comparison to the fossil-only unit was evaluated in terms of CO_2 and NO_x emissions.

The amount of CO_2 emissions given off by the power generation system was evaluated using its direct relationship with fuel composition and the amount of fuel burned (A. H. Lefebvre, 1983). The approach implemented in this study assumes that complete oxidation of fuel (i.e stoichiometric combustion of fuel) is taking place and does not account for any dissociation effect of combustion products (as dissociation has a very negligible impact on the amount of CO_2 emissions (A. H. Lefebvre, 1983)). For a given fuel composition and based on complete combustion of 1 kg of fuel (which in this study is CH_4), the emission index of CO_2 in this study has been calculated using the following relationship (Eqn. 1):

$$C_m H_n S_r$$

$$\boldsymbol{EICO_2} = \frac{(\mathbf{1000})(\boldsymbol{m})[\mathbf{12.011}+(\mathbf{2})(\mathbf{15.9994})]}{(\boldsymbol{m})(\mathbf{12.011})+(\boldsymbol{n})(\mathbf{1.0079})+(\boldsymbol{r})(\mathbf{32.06})} \qquad \text{Eqn. } \mathbf{1}$$

The unit of 'specific carbon dioxide emissions' has been used as the units of measurement in this study .It supports the comparison of emissions of different power plants having different power-outputs.

Oxides of nitrogen (NO_x) have been identified as one of the prime pollutants of concern present in the exhaust gases released by the GT unit (A. H. Lefebvre, 1983). At ground level, NO_x emissions are considered to be a toxic pollutant. .Ground level NO_x is of particular importance to regions where topographical features prevent the local climate from removing the ozone formed due to combustion, and where strong sunshine can promote the photochemical reactions that lead to smog (A. H. Lefebvre, 1983). The latter being the region where solarised gas turbines are very likely to be installed. Therefore a preliminary assessment of NO_x emissions of solar-hybrid gas turbine units was also investigated in this study.

To estimate the NO_x emissions from gas turbines, many empirical and semi-empirical models obtained from correlation of experimental data are in wide-spread use (G. D. Lewis, 1991; N. K. Rizk, 1994). One such semi-empirical expression developed by Rokke et al. for NO_x emissions was selected for this study (N. A. Rokke, 1993). Rokke's expression has been derived from experimental testing of five different natural gas-fired industrial engines operating in the power range of 1.5 to 34 MW . The model is expressed as follows:

$$\boldsymbol{NO_x} = \mathbf{18.1}\boldsymbol{P}^{\mathbf{1.3}}\dot{\boldsymbol{m}}_{\boldsymbol{A}}{}^{\mathbf{0.3}}\boldsymbol{q}^{\mathbf{0.72}}\ \boldsymbol{ppmv} \qquad \text{Eqn. } \mathbf{2}$$

Where P is the combustion inlet pressure (in atm); $\dot{m}_A$ combustor mass flow rate; and q is the fuel to air ratio at the operating conditions. The absence of the combustion temperature may be apparent (as NO_x is primarily dependent on the flame temperature) but its influence on NO_x emissions is accounted for by inclusion of the fuel/air ratio term.

The implication of this model is that it does not account for the effects of fuel atomization, equivalence ratio, fuel evaporation and mixing characteristics of the fuel in the primary zone. Each of these specific combustion related mechanisms can have significant effect on the overall emissions of NO_x emanating from a stationary gas turbine engine. Additionally, Rokke's model is based on relatively old technology engines (around the year 1993). The combustion technology has undergone significant advancement since then and the current level of NO_x emissions for the fossil only M50 engine is in the range of around 10 ppmv (Solar Mercury, 2012).

Nevertheless in context of this study, the aim is to only analyze the percentage difference in NO_x emissions between the two configurations . Therefore selection of Rokke's model was deemed appropriate for this study.

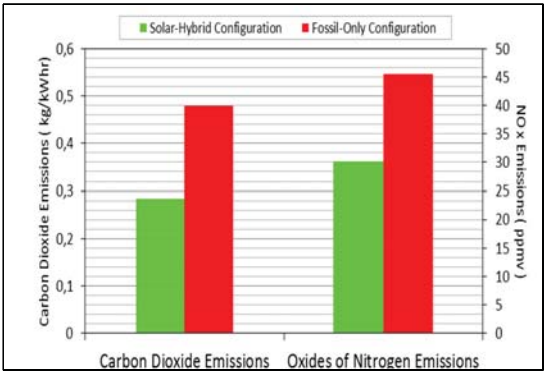

Figure 6: *Solar-hybrid and Fossil-only configuration emission results*

The results of CO_2 and NO_x emissions of the solar-hybrid and fossil-only configurations of the M50 engine are illustrated in Figure 6. For the carbon dioxide results (as it is modelled to be proportional to fuel burn) and with both engines having the

same power-output , the percentage reduction observed for the solar-hybrid unit is equal to the percentage reduction in fuel flow (~50%). A 40% reduction in NO_x emissions is observed for the solar hybrid unit in comparison to the fossil unit.

Economic Analysis

The cost of electricity (COE) for the two power-plant configurations under consideration (solar-hybrid & fossil-only) was evaluated using the levelized cost methodology (NEA/IEA/OECD, 2010). The COE was calculated with the parameters and costs adapted from a reference published literature (P.P. Walsh, 1998). The referenced data was available only for the former variant of M50 engine(4.2 MW). Hence it was assumed that the cost of the new representative engine M50 (4.6 Mw) would remain the same as it's predecessor

For the solar-hybrid unit, additional costs were included to account for the cost of solar equipment and the capital required for modification of the engine. The plant lives for both the engines were taken as an average of the plant life of various power-plants in the power range of (4-8MW) [22]. The value of discount rate was assumed to be the same for both configurations. The solarised unit is in a hybrid configuration has the capability to provide continuous power in a 24 Hr operation. Hence for initial cost estimates a full capacity factor of 100 % for both the engines was assumed. The fuels cost is based on the average price in 2002 available in the literature (P.P. Walsh, 1998). The fuel costs for the solar-hybrid was computed in terms of 75 % of the total electricity produced in a year. In the power-plant industry the fixed cost is calculated as a percentage of the capital cost (NEA/IEA/OECD, 2010). Due to extra maintenance required for the solar technology (heliostats and power tower), a higher percentage for the solar-hybrid configuration was assumed.

At full capacity(with a solar fraction of 25%) ,the COE calculated for the M50 solar-hybrid unit (17.1 €cent/kWhr) is found to be at least three times more than COE for the fossil-only unit (5.9 €cent/kWhr), Figure 7. This provides as initial estimate of the significant difference in the cost of generating electricity from a renewable technology in comparison to conventional technologies.

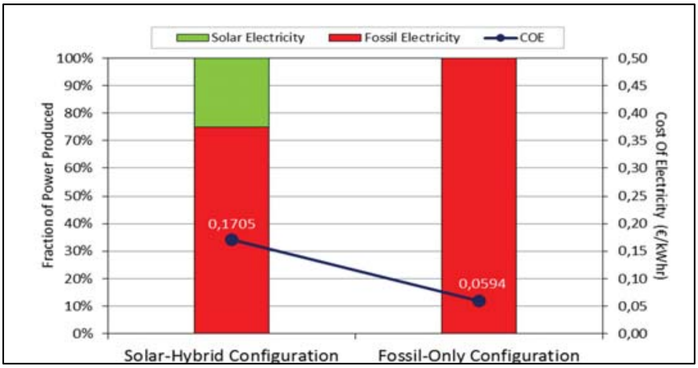

Figure 7: *COE results-Solar-hybrid unit vs fossil-only unit*

As a second part of the economic study, a preliminary risk analysis tool based on the 2^k factorial design analysis (R. Gabrielli, 2004) theory was developed for the investment community. When evaluating new concept power-plants, it is difficult to correctly identify the true cost of the total final investment. Already at the pre-feed stage, the model is able to assist power-plant operators to identify specific cost-factors, which could then be flagged and further scrutinized in detailed design phase of the project to ensure that a minimum or appropriate COE is evaluated. The factors included in this study are: capital costs, variable costs, discount rate factor, fuel price and capacity factor.

The 2^k factor design of experiment is a tool that has been widely used to analyze the average effect of variation of each input factor on the output variable The tool addresses the uncertainty involved by evaluating what independent variables have the most influence on the response of the system. Once an admissible range of variation for each independent factor is established, the 2^k factorial tool, for each combination of inputs, evaluates the output variable when the input factors assume their minimum and maximum values. "Then, the average change of the output variable when a generic input factor changes within its specific range is calculated using as follows (R. Gabrielli, 2004):

$$\boldsymbol{e_j} = \frac{\sum_{i=1}^{2^k} a_{ij} \cdot o_i}{2^{k-1}} \qquad \text{Eqn. } \mathbf{3}$$

where: k is the number of input variables, j is the index related to the input variable j, $2^k$is overall number of combinations of k variables, e_j is the main effect of the input variable j on the output variable, o_i is the value of the output variable for the combination *i* of the input factor, a_{ij}, is equal to +1 or -1 if the input variable j assumes, respectively, its highest or lowest value in the combination *i*.

Capacity Factor	Fuel Price Factor	Variable Cost Factor	Capital Cost Factor	Discount Rate	Solar-Hybrid COE € / kWhr	Fossil-Fuel COE € / kWhr
0.3	1	0.7	0.6	0.08	0.1968	0.0542
0.3	1	0.7	0.6	0.12	0.2076	0.0566
0.3	1	0.7	1.4	0.08	0.2429	0.0645
0.3	1	1.3	0.6	0.08	0.2688	0.0782
0.3	1.6	0.7	0.6	0.08	0.2028	0.0623
0.5	1	0.7	0.6	0.08	0.1557	0.0491
0.3	1	0.7	1.4	0.12	0.2684	0.0702
0.3	1	1.3	0.6	0.12	0.2796	0.0806
0.3	1.6	0.7	0.6	0.12	0.2137	0.0647
0.5	1	0.7	0.6	0.12	0.1622	0.0505
0.3	1	1.3	1.4	0.08	0.3149	0.0885
0.3	1.6	0.7	1.4	0.08	0.2490	0.0726
0.5	1	0.7	1.4	0.08	0.1834	0.0553
0.3	1.6	1.3	0.6	0.08	0.2748	0.0863
0.5	1	1.3	0.6	0.08	0.2277	0.0731
0.5	1.6	0.7	0.6	0.08	0.1617	0.0572
0.3	1	1.3	1.4	0.12	0.3404	0.0942
0.3	1.6	0.7	1.4	0.12	0.2744	0.0782
0.5	1	0.7	1.4	0.12	0.1986	0.0587
0.3	1.6	1.3	0.6	0.12	0.2857	0.0887
0.5	1	1.3	0.6	0.12	0.2342	0.0745
0.5	1.6	0.7	0.6	0.12	0.1683	0.0586
0.3	1.6	1.3	1.4	0.08	0.3210	0.0966
0.5	1.6	0.7	1.4	0.08	0.1894	0.0633
0.5	1	1.3	1.4	0.08	0.2554	0.0793
0.5	1.6	1.3	0.6	0.08	0.2337	0.0812
0.3	1.6	1.3	1.4	0.12	0.3464	0.1022
0.5	1	1.3	1.4	0.12	0.2706	0.0827
0.5	1.6	0.7	1.4	0.12	0.2047	0.0667
0.5	1.6	1.3	0.6	0.12	0.2403	0.0826
0.5	1.6	1.3	1.4	0.08	0.2614	0.0873
0.5	1.6	1.3	1.4	0.12	0.2767	0.0907

Figure 8: *Input Data for the 2k factorial design sensitivity analysis of the COE*

With reference to the 2^k factorial design analysis described above, the extreme input values of the five input parameters and the corresponding value of the COE are displayed in Figure 8.

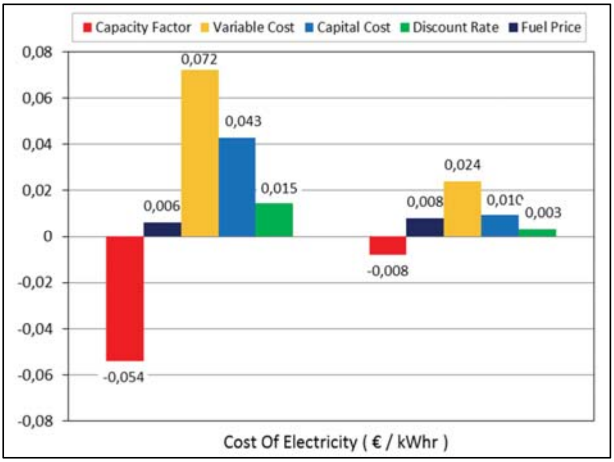

Figure 9: *2k factorial design scenario analysis*

Figure 9, reports the main effects of the variables on the COE. In the ranges considered for this study, variable cost is observed to be the most important variable for both configurations. Any increase or decrease in the variable cost will have a dominant effect on the COE of the power-plant. For the solar-hybrid configuration, capacity factor is the other dominant variable observed to influence the COE of the unit. The results imply that with any reduction in variable costs and the selection of optimum value of capacity factor will result in a reduced COE of the power unit. Also in terms of risks, the result indicates for a further investigation or valuation of the variable cost associated with the plant.

Risk Analysis

The evaluation of the technological risk and maturity level of new concept plants is of high relevance when studying about their feasibility. As a brief review of risk analysis associated with solarised gas turbines, a qualitative evaluation based on NASA's "technology readiness levels" (TRL) is included in this publication (G. Di Lorenzo, 2010).

Block	Maturity Level
GT Compressor	1
GT Recuperator	0
Heliostat	1
Power Tower	0
Solar Receiver	2
GT Combustor	1
GT Turbine	0

Table 4 : *TRL Levels of solarised GT components*

In the core of the GT engine, the compressor and the combustor components are perceived to have limited operating experience due to the new configuration with the solarized adaptations. Hence they have been given the score of 1. Due to excess piping required for connection with the receivers, there will be an increase in dead volume at the aft of the compressor section. This may cause minor implication in transient mode o operations and may compromise the surge margin of the compressor component. The combustor in a solarized GT will have to be continuously regulated due to the intermittency of the available solar energy. Furthermore the combustor will have to accept a relatively higher combustor inlet temperature of the working medium. This may necessitate a re-evaluation of the burner technology as it will have to perform and both full (non-solar) and part-load operation (solar-hybrid). For the CSP systems, heliostats are already being installed intensively in solar-thermal demonstration plants world-wide. The experience gained with such installations will soon allow for it to considered as a standard off the shelf-component. A wide variety of solar volumetric receiver designs and prototypes have been tested and reported. The development of the technology is still ongoing and the challenge at the moment is to demonstrate the efficiencies predicted in conceptual studies and improve the durability of the absorber material in the receiver (R. Buck, 2000). As the author's personal view on the technology, the maturity level of 2 is assigned for the pressurized receiver.

Conclusions

Comparison of design point simulations showed the solarized GT unit consumed 50% less fuel than the fossil-only GT engine. Consequently, resulting in fuel efficiency of 72% for the solarized units opposed to 43% of the standard GT. Hence, indicating a larger power output per unit of fuel burned for the solar-hybrid M50 unit. A sensitivity analysis was also conducted to analyze the phenomena of degradation. The evaluation showed that the degradation of these components can have an adverse result on the performance of the gas turbine engine. In terms of emissions, the results highlighted that potential of solarised gas turbines for use as a low CO_2 emissions power generation unit. The cost analysis was only done at full capacity, and the COE for solar-hybrid unit was found to be more expensive. his result indicates an interesting perspective of the greener renewable technology. Though it exhibits the potential of reducing fuel consumption and consequently the emissions of CO2, but the large value of COE does not make it attractive option for power-plant operators. For a more detailed investigation it is recommended that the COE should be evaluated at capacity factor of 40-50%. This would be a better representative as it will take into account the intermittent nature of the supply of solar energy. The results from the 2k factorial analysis imply that a higher capacity factor and a minimum variable cost would reduce the cost of generating electricity from solar-hybrid gas turbine units. As part of further work that could be done, it is recommended that the off-design performance of the gas turbine be developed for the TERA framework. This would then provide a more comprehensive and detailed analysis of the annual performance of the solarised gas turbine engine. The results of which could then consequently assist in better analysis of the environmental, economics and risk analysis of the solarised gas turbine engine concept.

22. Heavy hydrocarbon mixtures as fuels for SIEMENS DLE gas turbines

Manrique Carrera, Arturo; Larsson, Anders; Andersson, Mats; Larfeldt, Jenny

Abstract

Associated gases at oil wells are often rich in heavy hydrocarbons (HHC, here denoting hydrocarbons heavier than methane). HHC may cause handling and combustion difficulties as their properties are different from standard natural gas, therefore HHC rich associated gases are often flared or vented, wasting an enormous amount of useable energy and contribute importantly to pollution and emissions of CO_2 and other greenhouse gases. A major improvement is to use these gases efficiently in a gas turbine, producing mechanical or electrical power at much lower environmental impact.

Another application where HHC rich gases often are abundant is in the refining of natural gas (including liquefied natural gas, LNG, and shale gas). Furthermore, off-gases produced in petroleum refineries or other chemical industry may contain HHC, often in combination with hydrogen which is an even more reactive fuel component than HHC.

To address these issues Siemens Industrial Turbomachinery AB (SIT AB), Sweden, has tested the standard DLE combustion systems, used in the engine range 25 to 50 MW, with HHC rich gas. In one experimental campaign, pentane was chosen as a model substance for HHC and mixed with natural gas. In another test campaign, 100% ethane was tested without major adaptations to the engine. The unmodified standard SIT AB DLE gas turbines proved to be very tolerant to the tested HHC rich gases.

Both SGT-600 and SGT-700 with DLE combustion system has operated on propane. The SGT-700 will soon also operate commercially on ethane rich gas. The conventional combustion systems have gained extensive experience operating on refinery off-gases and the possibility to use such fuels in the DLE systems is also being explored.

Avoid flaring or direct release to the atmosphere of associated gases will reduce both pollution and greenhouse emissions importantly; furthermore, it will increase the efficient use of non-renewable energy resources. Gas turbines in the 25-50 MW power range could, in this way, contribute to reduce the environmental impact of conventional power generation technologies.

Introduction

The main sources of HHC rich gases are associated gas from oil wells or hydrocarbons from processing of natural gas, including LNG and shale gas. Associated gas often contains significant fractions of HHC (such as ethane, propane and heavier). Due to problems related to utilization and transportation it is common that an important part, and sometimes the whole stream of the associated gas is being flared, wasting a valuable feedstock for energy production and contaminating the environment.

Global gas flaring has been estimated to be in the range of 140 to 170 billion cubic meters annually (C. D. Elvidge, 2009) between 1997 and 2012. The 2008 gas flaring estimate represents 21% of the natural gas consumption of the USA and added more than 278 million metric tons of carbon dioxide equivalents into the atmosphere. A sounding approach to the problem with gas flaring and venting is to burn the associated gas in gas turbines for power generation. The NOx emissions from a modern gas turbine correspond to approximately ten percent of the NOx released from a utility flare stack. There is a potential reduction from 2.4 million tons NOx, down to 0.24 million tons NOx per year. In 2008 the total amount of fuel flared is enough to deliver 60 000 MW of electrical power from gas turbine technology.

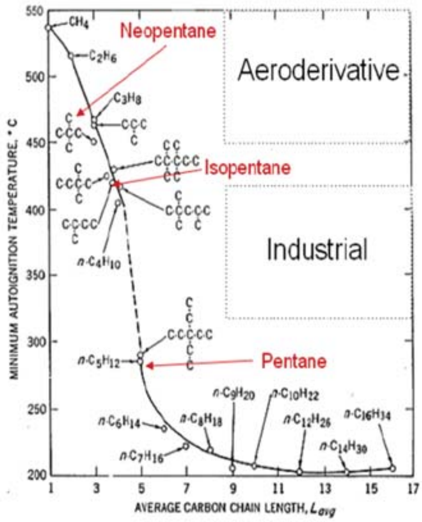

Figure 1: *Minimum autoignition temperature vs carbon chain length (A. Hellberg, 2009).*

Another source of potential gas turbine fuel that may contain high fractions of HHC, mainly pentane, is some gases from processing of liquefied natural gas, LNG. In order to fulfil LNG requirements, most of the HHC have to be removed from the raw gas. Also, to fulfil vapour pressure requirements it may be necessary to extract the most volatile fraction, i.e. pentane, from the condensate product and route this stream to a dedicated pentane fuel system. For the LNG plant it could be an attractive option to add the pentane to a gas turbine fuel stream.

Another important example is the shale gas industry which has created an enormous oversupply of ethane and propane, which are also interesting gas turbine fuels. Furthermore, oil refineries have waste streams of gases from their processes that could be used in gas turbines. These refinery off-gases could, in addition to HHC, also contain high amounts of H_2, which is a highly reactive fuel component. Other chemical industries, such as PDH (propane dehydrogenation) plants also produce off-gases rich in HHC and/or hydrogen.

HHC rich gases as fuels in gas turbines

There are several potential problems using gases containing high amounts of HHC in gas turbines, especially in premixed low NOx combustor systems. In general, HHC have higher burning velocities than methane or pipeline quality natural gas. Also the autoignition temperature (see Figure 1) is lower and the ignition delay time is shorter. Adiabatic flame temperature is also higher for HHC. These things result in a quicker and more intense combustion which may have an effect on:

- Flame stability and combustion dynamics.
- Flame position and the risk for autoignition/flashback and ultimately the mechanical integrity of the combustor/gas turbine system
- Temperature distribution in the combustion system
- Emissions of NOx and CO

Addition of hydrogen to a fuel gas could have the same effect due to very high burning velocity and high flame temperature.

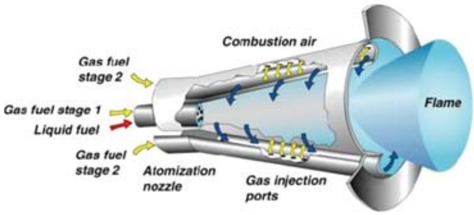

Figure 2. *The 2nd generation DLE burner used in SGT-600.*

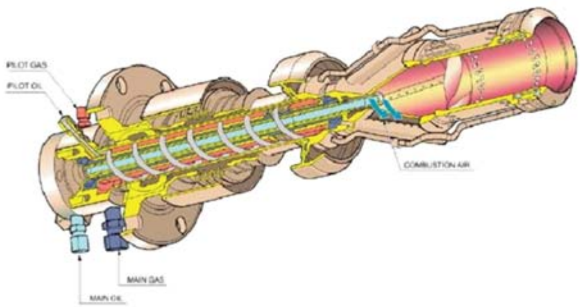

Figure 3. *The 3rd generation DLE burner for SGT-700 and SGT-800.*

Combustion systems

Dry Low Emissions (DLE) combustion systems are used in 25 MW SGT-600, 33 MW SGT-700 and 50 MW SGT-800. The 2nd generation DLE burner (Figure 2) is a split cone with two main fuel pipes. The combustion air enters in the two slots at rather high velocity, where also main fuel (stage 2) is injected. The injection of pilot gaseous fuel (stage 1) as well as main liquid fuel is positioned in the centre of the burner. The 2nd generation DLE burner was introduced in the SGT-600 gas turbine in 1991. The SGT-600 system is capable of emission levels as low as 25 ppm NOx using natural gas fuel. In contrast, conventional (non-DLE, see Figure 4) combustion is applied on liquid fuel, where water injection is used to lower the flame temperature and achieve emission levels as low as 42 ppm NOx (J. Sundberg, 2008; M. Blomstedt, 2004).

In the 3rd generation DLE system (Figure 3), the DLE technology was brought one step further. The burner consists of a split cone forming four air slots where main gas is injected followed by a mixing section with film air holes. Near the base of the cone, central gas or main liquid is fed and intensively mixed with the compressor air. The pilot fuel injection is positioned at the burner tip. The 3rd generation DLE burner was tested and verified in a SGT-800 gas turbine first fired in 1998. Similar burner is used in the SGT-700 and delivers 15 ppm NOx on natural gas and 42 ppm NOx on liquid fuel (A. Hellberg, 2009).

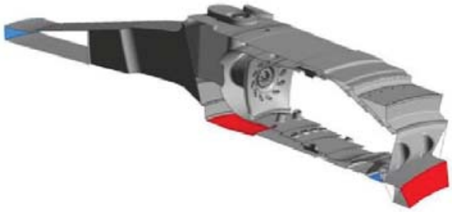

Figure 4. *SGT-600 non-DLE (Conventional Combustion system).*

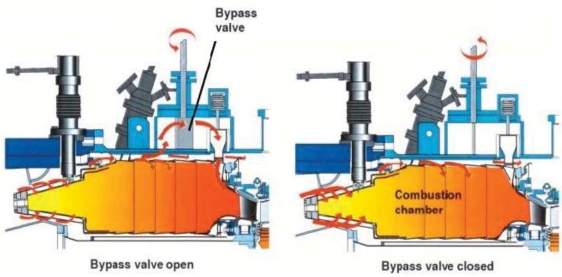

Figure 5.*SGT-600 bypass system used to increase the flame temperature between 0 and 90 % load.*

To achieve the optimum emissions and low levels of combustion dynamics and combustor stability it is crucial to control piloting and the flame temperature. Flame temperature can be influenced via controlling the airflow to the burners. Increased flame temperature can be achieved by variable compressor guide vanes or by using a combustor bypass or through bleeding compressor air. The latter is of course negative for GT efficiency. The combustor bypass can increase the flame temperature by reducing the air flow through the burners without affecting the GT efficiency. The SGT-600 combustor bypass system, as illustrated in Figure 5, is integrated with the turbine casing and consists of 6 valves controlled by one actuator.

Siemens Industrial Turbomachinery in-house experience

Full engine test

To investigate HHC issues SIT AB tested both a SGT-600 DLE and SGT-700 DLE gas turbine with simulated HHC rich natural gas using pentane, C_5H_{12}, as a model substance for HHC. The full scale engine tests were performed in the test facility in Sweden, Finspong. Both engines could operate on this fuel mix without any problem. The main effect observed was an increase of NOx emissions with the increase of pentane content in the fuel on both engines (Figure 6 and Figure 7). It should be noted that the NOx emissions are still very low compared to conventional non-DLE combustion. Inspection of the engines after the test did not show any sign of flashback or degradation in the combustion chamber. The results and test rig are extensively described in (M. Andersson, 2011).

All indicators showed that it is possible to operate the SGT-600, SGT-700 and SGT-800 with a gas fuel containing up to at least 10% by volume of pentane, meaning approximately 33% by weight or 30% by heating value. The engines showed great capability to accept important variation in the Wobbe index of the fuel.

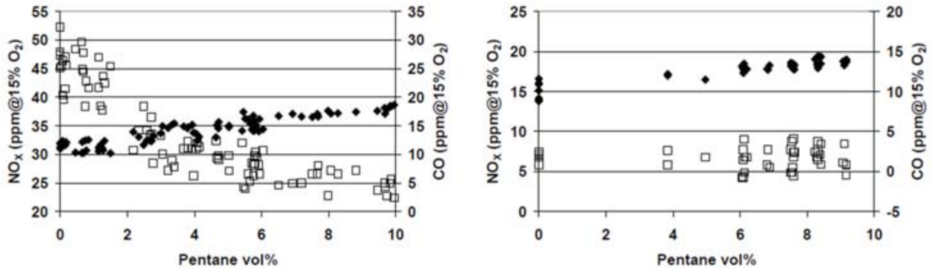

***Figure 6 and 7**: SGT-600 at full load and 21% PFR. NOx (♦) and CO (□) vs pentane content in fuel (M. Andersson, 2011).*

Experimental burner in turbine (EBIT)

Further investigation was done in the SGT-700 (with DLE combustion system), this time using a special arrangement in a full engine test. In this arrangement one of the burners in the engine is isolated, and it is controlled separately. The system is called EBIT. Detailed description of EBIT can be found in (M. Andersson, 2012). The setup allows testing burner concepts at real engine conditions. Pentane, hydrogen and ethane have been tested. In the latter case it was possible to reach 100% ethane operation (M. Andersson, 2012; A. Bonaldo, 2014).

The pentane test showed that it is possible to reach more than 20% by volume of pentane in the mixture with only a 20% increase in NOx emissions (Figure 8), no operational parameters were outside the normal values. Subsequent tests on H_2 were performed with two different burner configurations (Figure 9). Hydrogen concentrations of up to 20-40% by volume were tested. In the case of ethane, it was possible to use 100% ethane in EBIT. Emissions increases approximately 15% (Figure 10), no other parameters outside the normal operational range could be detected.

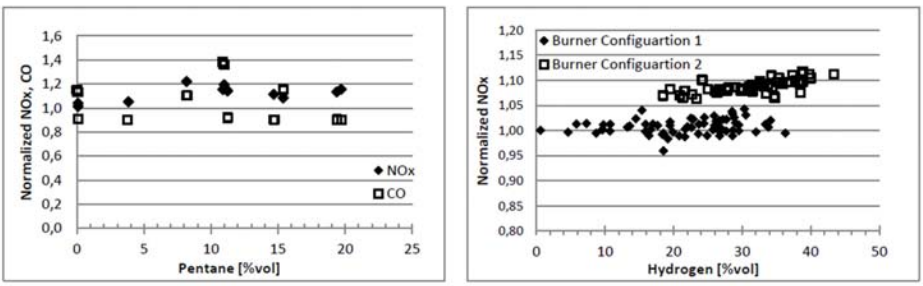

***Figure 8 and 9**: SGT Normalized emissions of NOx and CO from the experimental burner as a function of pentane content in the fuel [6] and Normalized emissions for different burner configuration (A. Bonaldo, 2014).*

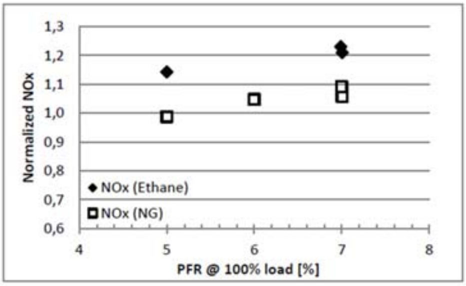

Figure 10. *Normalized NOx at 100% load on Ethane* (A. Bonaldo, 2014).

Field experience

Commonly, conventional combustion systems are used for refinery-off gases. Water or stem injection is normally used to control NOx emissions. There is extensive experience of operation on H_2 rich refinery gas in the SGT-600 with conventional combustion system. As an example, one engine in Spain operates with active water injection for NOx control due to variable NOx demands depending on the fuel composition. H_2 content varies between 0 and 55%vol. Detailed information could be found in (P. Geipel, 2012).

Several SGT-600, 700 and 800 engines with DLE systems are operating on associated gas One example are 2xSGT-600 engines, offshore Denmark, that have accumulated more than 120 000 equivalent operating hours (EOH). The content of HHC has been at least 45% at some occasions.

An example of field experience on propane (>95% C_3H_8) is a SGT-600 in Sweden that operated around 10 000 hours before changing to natural gas. Also, a SGT-700 in a mechanical drive application for a PDH plant in China is currently operating on propane. It has accumulated 1500 EOH. The same engine will also operate on another fuel which contains around 70% of ethane.

Conclusions

Systematic testing in-house and field verification showed that Siemens Industrial Turbomachinery AB (SIT AB) DLE engines in the range 25 to 50 MW could use HHC rich fuel streams without major modifications, neither in the combustion nor in the control system. The demonstrated fuel capability includes ethane, propane and even high fractions of heavier hydrocarbons. This feature makes it possible to use fuel streams for power production with much smaller impact on the environment in comparison with venting/flaring techniques commonly used in oil-extraction or/and petrochemical industries.

High levels of H_2 in the fuel, normally from oil refining process, can be used in the SGT-600 with conventional combustion system, but testing also indicates a potential use in the DLE systems.

23. Small hydropower potential from sewage water case study for an andean city

Edmundo Villacorta

Abstract

This is a feasibility study that evaluates the use of collected sewage water from modern Andean city for small hydropower production. Arequipa, a Peruvian city located at 2335 meters above the sea level, has been selected as case study. The geographical conditions (mountains and canyons) around Andean cities are suitable for the electricity production in a small hydropower stations. The produced electricity could be used for the energy needs of the treatment facilities or for commercialization in the electrical system (Distributed Power Generation). Synergy effects between the water supply industry and electricity energy production, based in Hydropower, in cities at high altitude are analyzed. A similar facility located in Stockholm (Sweden), The Hammarbyverket an energy plant (315kW Hydropower), is used as model for future integration of Sewage Treatment Plants and Hydropower Production. The study case for Arequipa is presented, where two new sewage treatment plants are under construction.

Keywords: small hydropower, sewage water, distributed power generation.

Introduction

The aim of this theoretical paper is to show a study case for an Andean city where the sewage industry could be integrated with the small power production. The possibility to use sewage water (that needs to be collected) and the geographical conditions (mountains and canyons) around Andean cities for electricity production in small hydropower stations were studied. The electricity production could be used for the energy needs for the fresh water supply, sewage treatment facilities or for selling directly to the electrical system (Distributed Power Generation). In these cities the geography is very abrupt with different altitude levels. The fresh water is supplied for the citizen needs. After the water is used in the city the sewage water needs to be collected and treated for discharging into the rivers and further down to the ocean. The study was inspired from a Swedish example however there are others facilities which were constructed for using the purified sewage water after treatment for hydropower production around the world: In Dresden city the Waste Water Treatment Plant (in operation since 2005) has one Kaplan turbine installed in the outflow to the Elbe River. The characteristics of the Micro Hydropower Plant are: 138 kW with 5 meters of head. About 650 MWh per year is produced using the water from the sewage treatment plant. In Mexico the sewage water is directly used to impulse Kaplan turbines due the high value of flow rate in the sewage water’s collector.

The Hammarby Plant in Sweden

Stockholm is considered a cold place with extremely long and cold winter thus hot water is intensively used for the population needs. The hot water is supplied a constant temperature of 50°C. The sewage water, that the city of Stockholm produces, has a temperature between 5°C and 22°C, and this temperature is quite high in comparison with 6.6°C which is the mean annual outdoor temperature in Stockholm. During winter time the outdoor temperature is near cero or below zero. Since the sewage water needs treatment and has a stable temperature around the year, the collected sewage water is considered as a source of energy for recovering heat (otherwise it will be waste energy) in order to fulfill the demand of district heating in Stockholm.

The Hammarbyverket is a two steps energy plant and an energy-efficient facility. In the first step heat is produced and in the second step cold is produced; in addition electric energy is produced by a water turbine for the internal energy needs. The owner of the plant is the Fortum AB Company. The plant delivers district heating and district cooling. Fortum AB buys purified sewage water (in Henriksdal waste water processing plant), electricity and bio diesel and sells district heating and district cooling for the population needs around the year. The efficient utilization in Hammarbyverket make possible that for 1 part of drive energy and 2.5 parts of waste heat, it is obtained 3.5 units of useful thermal energy for District Heating and 2.5 units of District Cooling. After recovering heat the water is stored in small basin underground and it is discharged (the water falls back) into an outlet tunnel. The turbine and the electric generator are installed on 10 meter drop - hanging at the bottom of a pipe that is approximately 10 meter long. The turbine is powered by the falling water. The average water flow for the turbine is 3.5 m3/s and there is recovered more than a quarter part of the energy input. The turbine, which is a unit manufactured from ITT Flygt with a special design for the specific application in Hammarbyverket, has 315 kW power and was installed in 1987. About 1110 MWh per year is produced using the water from the sewage treatment plant.

The pumping system used in Hammarby has two stages of pumping where for the first stage 4 pumps of 220 kW and 960 l/s each are found and in the second stage 5 pumps of 110 kW and 700 l/s each. The pumps have two purposes: firstly to produce a current flow in the purified water (the current flow increase the heat transfer from the purified water to the heat pumps) and secondly to pump up the water from the bottom (tunnel) to the level where the heat pumps are located (ground level). When the water returns back to underground a 10 meters net head for the hydropower production is provided. It is interesting to notice that the 10 meters head is not produced for any geographical condition; it is artificial produced as a part of the pipe and pumping system design in the energy plant.

Synergies between Sewage Treatment and Small Hydropower (SHP)

Typically the sewage treatment could be divided in three steps. The first step is the physical treatment where solids are separated or sediment. The second step is a biological treatment, where a progressive conversion of biological matter, diluted in water, is converted in solid matter (using bacteria). The last one is a chemical treatment, where an additional disinfection is done using chemical and physics process. The infrastructure of a sewage treatment plant shows that there is a trash-rack at the entrance of the sewage treatment plant and a sediment area both elements are part of the physical treatment.

The same both elements (a trash rack and a sediment area) are used in SHP too and are used in the intake. The intake in SHP is a structure to divert water (mainly from rivers) into a conduit leading to the power plant. The finality of these elements in a SHP is to avoid solid elements which can pass through the turbine and can damage it.

Another similarity is the small lagoons or tanks for the different steps of treatment. These lagoons are like a small reservoir, and could be used as a daily reservoir for a SHP. These lagoons store the sewage water in different steps of the treatment and at the same time regulate the final volume flow rate of treated sewage water thus a constant flow rate of treated sewage water is obtained after treatment.

A very important thing is that both industry apparently separated are connected thus synergies are possible. The sewage treatment plants require electric energy and it is evident that this common infrastructure (trash-rack, pipes, small reservoirs, etc.) is designed using the same tools and the same knowledge. The most interesting approach is to be able to integrate both industries in a common system.

The proposed system in this paper is considered the implementation of small hydropower together with the sewage water facilities. The innovation that is proposed by the author during planning sewage treatment plants is to evaluate the possibility to use the purified sewage water as a permanent flow for small hydropower production. The energy produced could be delivered to the system as a Distributed Power Generation or could be used for the own consumption of the sewage treatment plant. The aim of the author is set the basis to analyze the possibility of making this kind of integration.

Other possibilities like producing biogas could not be excluded on this scenario. The water after use for hydropower could be used again as industrial water, for irrigation, or return to the rivers eliminating the pollution that sewage water (without treatment) is producing.

Water Systems in Andean Cities and Further Development

The water system in Andean cities is not a complicate system. The water is taken from superficial water sources like rivers, lakes, artificial lagoons and in some cases water is taken from underground sources like aquifers. In general terms the intakes are in the upper level of the cities and in rare cases water need to be pumped up. The fresh water is treated and then is storage in small reservoirs, actually fresh water tanks. The tanks are located in the uppers level of the city. Water is supply from the tanks to the population, which has access to the water network, by gravity. There is a lack of infrastructure in Andean cities that means less than 100% of the total population in the city has access to the fresh water supply network and sewage water network. The water utility does not supply the fresh water service during the 24 hours of the day. Most of the cities do not have a sewage treatment plants and the sewage water is discharged directly to the rivers producing environmental problems to the populations located downstream to the rivers.

Integration Schemes between Sewage Water and Small Hydropower (SHP)

Three possible schemes were discussed by Villacorta as alternatives to integrate sewage water with SHP. First a direct integration was proposed that means that after the sewage water is treated a SHP is located in a lower level with a connecting pipe this scheme is called SHP-WAS (Small Hydropower in Water Abstraction System). Second an intermediate storage was included between the sewage treatment plant and the SHP; that means that after the sewage water is treated a daily reservoir (a regulation tank) is constructed in order to collect the treated water further the SHP is located in a lower level with a connecting pipe this scheme is called SHP-DR (Small Hydropower with Daily Reservoir). The third scheme called SHP-PSR (Small Hydropower with Pumped Storage Reservoir) mixed two concepts (SHP and pump storage hydropower) and in this scheme is necessary to build two purified water reservoirs at two different levels.

The regulation tank makes possible to regulate the energy production where energy is needed. The tank is used to storage the water (in fact the potential energy of the water) in the upper level. On this scheme the SHP can produce energy during a specific time for example during peak hours when the energy price is high. The additional infrastructure, that makes more costly the integration between the sewage treatment plant and SHP, can be rewarded with a higher price of electricity if the energy sells to the network. The sewage water goes into power production during peak hours (6 hours per day, 17:00h to 23:00h five days per week according with the Peruvian regulation). The daily incoming volume flow of purified sewage water is the same amount of water that will produce energy but in less time (6 hours per day, 5 days per week and 52 weeks per year).

Arequipa Study Case

Antecedents

Arequipa is the second city in importance in the national context in Peru and has a population of 958 351 inhabitants. It is located in southern Peru and is also the capital of the Arequipa Region and Arequipa Province, the city is located at an altitude of 2335 meters above the sea level (m.a.s.l.). Past figures shows that the access to the fresh water supply system was only 84% with 180 050 fresh water connections, the city had an average of 23,49 hours/day of water supply. There was 74% of the city with access to the sewage water system with 165 748 sewer connections. The sewage water production was estimated considering that the 80% of the fresh water production is converted in sewage water. Actual figures shows that fresh water is produced at 1,57 m^3/s. A new fresh water plant with a capacity of 1,5 m^3/s was constructed (Planta “La Tomilla 2”) and the sewage treatment plant called PTAR “Chilpina”, which has a treatment capacity of 0,1 m^3/s, is receiving 0,18 m^3/s of sewage water thus the sewage water is not adequately treated.

Figure 1: *Sewage Treatment Plant Projects: (A) PTAR “La Enlozada”, (B) PTAR “Escalerilla”*

The city authorities were involved in the analyses of the sewage treatment plant systems during the last years in order to eliminate the lack of sewage infrastructure and sewage treatment. Some projects were formulated and some projects were abandoned. The project PTAR “Pampa La Estrella”, where sewage treatment was combined with SHP, was abandoned because was too expensive. The project PTAR “Los Hurtados” was abandoned because the location of the sewage treatment plant was not approved by local neighbors. Fortunately to new Sewage treatment plant projects are developed called PTAR “Escalerilla” and PTAR “Enlozada”.

PTAR “La Enlozada”

PTAR “La Enlozada” is a joint venture between, a mining company Sociedad Minera Cerro Verde (SCV) and the public water utility Sedapar. This plant was an alternative solution after local neighbors were against to the location of PTAR “Los Hurtados”. The solution was to move the sewage treatment plant to a new location (near the mine) that required that the sewage water need to be pumped up to the new location (the pumping cost will be assumed by the mining company). SCV is in charge to construct the sewage treatment plant which has a capacity of 1,4 m^3/s. SCV is going to use 1 m^3/s of sewage treated water to its mining process in order to do that a regulation tank (steel tank with 50m diameter, 20m height and approximately volume 35000m^3) is going to be built. The rest of the sewage treated water will be discharged in the Chili River.

PTAR “Escalerilla”

The Sewage treatment plant is already constructed but is not working at the moment of this paper was written. There is under constructed a new sewage pipe which will collect the sewage water to the plant. The plant is expected to process 50 l/s at the end of 2014 and has the maximum capacity of 250 l/s. There is estimated that in 5 years the PTAR “Escalerilla” will work at full capacity.

Hydropower Potential from Sewage Water

In the case of the area of the sewage treatment plant project “PTAR La Enlozada” shows that the geographical conditions make an available head (H_n) between 200 meters and 300 meters depending of the final discharging in the Chili River Figure 1 (A) for further calculations 200 meters is used and it is estimated an average volume flow ($Q_{average}$) of 0,4 m^3/s. The area of the sewage treatment plant project “PTAR Escalerilla” shows that geographical conditions make possible an available head (H_n) of 65 meters and it is estimated an average volume flow ($Q_{average}$) of 0,25 m^3/s. The possible location of a SMHP is shown in the Figure 1 (B).

The hydropower potential was evaluated with two parameters. The Power production, where the equation 1, was used assuming a total efficiency of 0,75. The yearly Energy production was calculated whit equation 2 assuming 8000 hours for a yearly operation in the case of SHP_WAS. The results of the evaluation are shown in the Table 1 where 0,709 MW could be continuously produced generating 5,665 GWh per year using a SHP-WAS. If the purified sewage water is using to produce energy just during the peak hours the same amount of energy is produced but more power can be produced 2,832 MW. There is a difference of electric energy prices in Arequipa both in power and in energy, according with the regulation authority energy price at peak hours is 21% more expensive than the rest of the day and the power price is 103% more expensive during peak hours.

$$P = \gamma Q_{average} H_n n_{total} \qquad \text{Equation (1)}$$

$$\mathrm{E}_{\mathrm{year}} = \mathrm{P} * \mathrm{h} \qquad \text{Equation (2)}$$

PTAR	SHP-WAS		SHP-DR	
	Power [kW]	Energy [MWh]	Power [kW]	Energy [MWh]
Escalerilla	120	956	478	956
Enlozada	589	4 709	2 354	4 709
Total	709	5 665	2 832	5 665

***Table 1**: Estimated Power and Yearly Energy Production from Sewage Water*

Conclusions

The synergies from water supply, sewage treatment facilities and small scale hydropower could be achieved in the Andean cities which have a geographical suitability for building small scale hydropower plants.

The sewage water is inevitably collected and this water after the purification could be used for hydropower production and used again thus the water management in the Andean cities could be improved. The purified sewage water must not be considered disposable water.

The sewage water after purifying could be stored for running small hydropower plants during the peak hours. The reservoirs for storage purified sewage water could be tanks like in the case of PTAR “Enlozada”.

The energy produced from SHP using purified sewage water could be used for the internal consumption of the sewage treatment plants. The construction of sewage treatment plants in Andean cities integrated with SHP, for internal energy consumption, could reduce the cost of treatment of sewage water and become economically feasible.

There is a lack of sewage water infrastructure in Peru thus infrastructure needs to be built and similar cases could be found in other developing countries with geographical suitability.

The SHP using sewage water could be designed to sell energy as Distributed Power Generation. The SHP can reduce in small amount the power production of conventional power plants running with fossil fuels during peak hours. The SHP with a regulation tank is an interesting tool for demand management even in small scale.

In Arequipa study case the sewage treatment plant is located in an upper level while the sewage water is collected in a lower level and pumped up to an upper level. A SHP can be constructed in a lower level. The energy production works as SHP with pump storage reservoir where the “upper reservoir” is the sewage treatment plant itself.

From the investment point of view the simple solution to integrate a SHP in a water abstraction system is the easiest way for an implementation. The additional investment in the case of SHP with regulation tanks can oriented the decision to implement a SHP in a water abstraction system disregarding the benefits of the energy storage.

Acknowledges

The information received from engineer Americo Saravia, who works in the water utility Sedapar S.A., in several private comunications is greatly apreciated.

24. Anaerobic digestion as a technology to optimize the management of municipal organic waste in Colombia

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Abstract

A two stage dry-wet anaerobic digestion system pilot project, fed with the Organic Fraction of Municipal Solid Waste (OFMSW) of a municipality of Antioquia, Colombia, is being developed. The system produces as byproducts: biogas with high methane content (55%-60%), organic mineral liquid fertilizers and Renewable Solid Fuels (RSF), with significant positive environmental and economic impacts such as reduction of emissions of greenhouse gases (GHG), optimization of the lifetime of landfills, production of alternative energy, improvement of the environmental conditions of agro-ecosystems, possible reduction in waste management costs, environmental leadership, among others benefits to the municipalities. With a load of 1000 kg per week of OFMSW in the system, the pilot plant has shown a production of up to 2.4m^3 biogas/day, which means yields of 33 liters of biogas and 0.3 liters of effluent per kg of organic matter.

Keywords: municipal solid waste, anaerobic digestion, renewable solid fuels, biogas, Colombia.

Introduction

Today's consumption-driven society produces an enormous amount of waste. This large amount of waste creates a huge pressure for the city authority to manage waste in a more sustainable manner. Waste management systems have not received as much attention in the city planning process as other sectors like water or energy. Therefore, gaps can be observed in waste management in current city planning (Zaman & Lehmann, 2011).

The organic fraction of municipal solid waste (OFMSW) in many Urban Latin American cities can be up to 70%; the lack of strategies for recovery and comprehensive utilization of OFMSW is the most determinant problem in management of MSW. Studies have shown that the biodegradable fraction of municipal solid waste present in the mass of waste disposed is the cause of most of the environmental impacts from landfills like leachate generation, emission of greenhouse gases, offensive odors, the risk of fire and landslide by false compaction (Forero Gonzalez, 2011). Since the organic matter flow is going to the landfills, agro-ecosystems are not getting back the organic matter and nutrients for maintenance they need, generating another negative environmental impact associated with Colombian soils. The incorporation of stabilized organic matter can fulfill a constitutional, social and productive obligation of the municipalities, ensuring the preservation of natural resources for use and enjoyment of future generations.

In Colombia, appropriate final disposal systems are: landfill, Integral plants and contingency cells. For their part, inadequate systems are: transitional cell, dumps, burials, dumps in water bodies and other disposal technics that do not comply with the established definitions by the rules and required permissions by competent authorities (Rodríguez & Ramos Higaldo, 2013).

According to the 2013 Final Disposal report, compiling information from 32 departments and 1,102 municipalities, the average amount of waste produced for this period in the country was 26,726 tons/day, 8.4% more than in 2012. 72% of municipalities are disposing in landfills, 15% in dumps, 5.2% in integrated plant, 4.6% in transitional cell, 2% in cell contingency, 1% in water bodies and 0.1% still burning waste. 67% of municipalities in Colombia have regional landfills and 55% of those have a lifespan calculated between 0 and 10 years at most. The remaining 33% have individual or municipal landfills with an equivalent a lifespan (Rodríguez & Ramos Higaldo, 2013)

Anaerobic digestion is a promising technology to handle the large organic fraction of the MSW with the additional benefit of producing biogas as well as organic mineral fertilizer at reasonable costs while closing ecological cycles, offering opportunities to modern society to reduce greenhouse gases (GHG) emissions, produce electricity, increase the life of landfills, among other economic and environmental benefits.

The aim of this paper is to describe the performance of a pilot OFMSW treatment system based on a two stage dry-wet anaerobic digestion plant in a municipality of Antioquia – Colombia and its positives impacts in the management solid waste.

Anaerobic digestion with OFMSW

The Organic Fraction of MSW is one of the substrates most used in anaerobic digestion processes. This organic fraction, when is obtained separated at the source, is particularly interesting to anaerobic digestion, due a high contents of Volatile Solids (VS) than the organic fraction sorted mechanically (Bolzonella, Fatone, Pavan, & Cecchi, 2005; Mata-Alvarez, Mace, & Llabres, 2000).

There are several methods for the treating of organic waste but anaerobic digestion appears to be a promising approach. Anaerobic digestion involves a series of metabolic reactions such as hydrolysis, acidogenesis and methanogensis (Khalid, Arshad, Anjum, Mahmood, & Dawson, 2011). Optimizing these reactions separately in different stages or reactors may lead to a larger overall reaction rate and biogas yield (Mata-Alvarez et al., 2000).

For the anaerobic treatment of organic solid waste, types of bioreactors commonly used can be classified in two categories, in the first type the degradation of organic material occurs in one step, in this category batch systems or single-stage systems continuously fed are used; a second category can be made if degradation occurs in two or more stages the system is two-stage or multi-stage (Vandevivere, Baere, & Verstraete, 2002).

The bio-solid that leave from the anaerobic process is used to produce combustible fraction, Renewable Solid Fuels (RSF), which can be used as a neutral fuel or as a raw material for the ceramic industry. As a neutral fuel, RSF has a significant calorific value, which can be higher than the calorific value of low quality coal (above 1,800 kcal/kg); this condition makes RSF a suitable fuel that can substitute non-renewable fuels or be combined with them to reduce GHG emissions (Castells , 2000) However, this option will be discussed in upcoming projects.

Methodology

Diagnosis of the organic waste management in the municipality of El Carmen de Viboral, Antioquia

The Carmen de Viboral is set in the east of Antioquia, Colombia, to 2,150 meters above sea level and has an average temperature of 17 °C. It has 44,992 inhabitants, 27,823 live in urban areas. Monthly, it produces approximately 417 ton/month of waste of which 130.26 ton/month (31.20%) corresponds to organic waste. Production Per Capita (PPC) solid waste is 0.469 kg /day /person. MSW are disposing in the Alto Grande landfill that has 1.1 hectares and has a lifespan of 18 years since 2012 (Cimarrona, 2013)

The municipality has run a successful MSW separation program for more than 14 years, with selective routes and by composting, aerobic biological process, currently is processed 130 ton/month of organic waste. The process takes 45 days, in which 50-60% of the weight is lost, leaving approximately 60 ton/month of product, then goes through a grinding process and packaging and finally is delivered through agreements peasant associations and with the municipality for gardening of common areas. It should be noted that the composting process is a complementary activity of the final disposition, increasing useful life of the landfill as it is reducing the volume of final disposal of MSW (Cimarrona, 2013).

Currently, compost does not generate any profit for the municipality in economic terms, nevertheless, in environmental terms there are benefits as the return of nutrients to the soil promoting the biogeochemical cycles. For technical reasons, however, it is nearly impossible to take advantage of waste heat while composting (Edelmann, 2002).

Description of a pilot plant

Pilot plant have one mill for wet wastes, six (6) reactors that conform two work lines (L1 and L2). Each line has one hydrolysis reactor (HR1 and HR2), one Sludge Blanket Reactor (SB1 and SB2) and an Anaerobic Filter Reactor (AF1 and AF2). The effluent produced in the two work lines, goes to one storage tank and the biogas is collected in a geomembrane bag for 90 m^3 of capacity after cleaning and measurement. About 50% of the volume of the methanogenic reactors (SB and AF) was inoculated with stabilized sludge from a water plant treatment. An overall system model is presented in the figure below. (Figure 1)

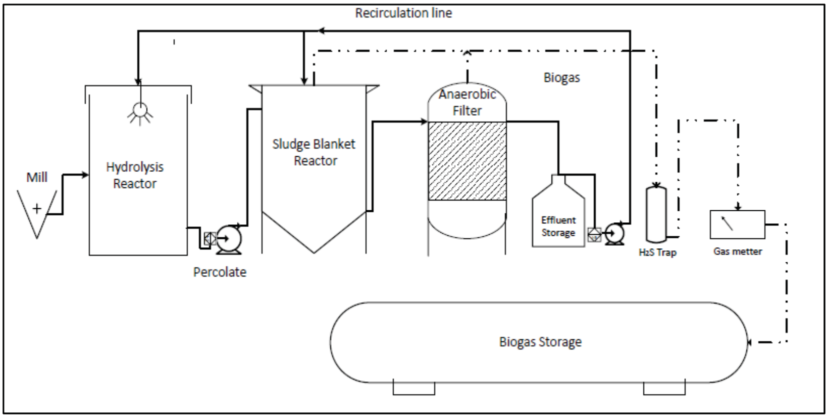

Figure 1. *Two Stage (dry-wet) Anaerobic Digestion System for OFMSW*

At present, the system is operating semi-continuously, with weekly loads of 400 -500 kg for maintaining a charge within the HR´s of 1000 kg in total. As a control parameter, the rate Volatile Fatty acids / Alkanity (VFA/ALK) is maintained inside the reactors below 0.8 and is determined by Kapp Method (Kapp, 1984). The biogas is cleaned by a trap hydrogen sulfide (H_2S) which corresponds to a minor component of biogas and can corrode the metal parts of the internal gas meter. Biogas is storage in the geomembrane bag and was characterized using Biogas GeoTech 2000 meter (LANJTEC ®). The remaining solid from the hydrolysis reactor is discharged after 20 days and incorporated to the compost process of the landfill.

Results

OFMSW was characterized: Total Organic Carbon (46 g/L), pH (5.66), K_2O (2.068 g/L), Total N (2.43 g/L), P_2O_5 (0.431 g/L) were determined by (APHA, AWWA and WEF, 1989). After a started and stabilization time of 90 days, the system is in a metastable state, the results indicate a production of 2.4 m^3 biogas/day. Table 1 reports the performance of the pilot plant for anaerobic digestion of OFMSW.

Parameter	Result
Amount supplied in each line work	400-500 (kg OFMSW/ week)
CODt (SB) inffluent	118,500 (mg/L O_2)
Percolate pH without recirculation	4-5
Percolate pH with recirculation	5.5- 6.2
*SRT and HRT	20 days and 40 days
OLR in SB and AF reactors	2.7 (kg COD/m3-d)
COD (AF) inffluent	3870 (mg/L O_2)
CODt (AF) Effluent	1160 (mg/L O_2)
Biogas yield per kg OM	33 (L/kg OM)
Volume Effluent /kg OM	0.15-0.30 (L/ kg OM)
% Total Remotion	91% SB and 96% AF
Biogas production	2.4 (m^3/day)
%$CH_{4\ max}$	54-60%

**STR: Solid Retention Time, HTR: Hydraulic Retention Time. OLR: Organic Load Rate. SB: Sludge Blanket. AF: Anaerobic Filter. OM: Organic Matter, COD: Chemical Oxigen Demand*

Table 1: *Performance of Pilot plant*

The effluent from the AF Reactor is collected in a tank and about 50% of this effluent is recirculated and sprayed over the surface of the fermenting wastes inside the HR's reactors and when is necessary over the SB reactors. This is a good strategy to increase organic matter extraction and avoid acidification, maintaining relationship VFA/ALK < 0.8. With recirculation, pH values are between 5.5 and 6.2 in the percolate of the hydrolysis and in SB and AF reactors are between 7.2 and 7.8.

Discussions

(Tauseef, Abbasi, & Abbasi, 2013) says that the performance of the acidogenic reactor was enhanced by the recirculation of the leachate. In the pilot plant, when the recirculation of the effluent to HR is used, the system performance is better in terms of VFA / ALK, pH values and COD values between 120,000 and 90,000 mg/L O_2, which is a recommended organic load for the SB reactor. As (Vandevivere et al., 2002) explain, in the sequential batch design, the leachate of a freshly-filled reactor, containing high levels of organic acids, is recirculated to another more mature reactor where methanogenesis takes place. The leachate of the latter reactor, freed of acids and loaded with pH buffering bicarbonates, is pumped back to the new reactor. (Zuo, Wu, Zhang, & Dong, 2013) reports that effluent recirculation in two-stage anaerobic digestion alleviated the effect of VFA inhibition and improved biogas production in the acidogenic reactor at high OLR because of the effects of dilution and pH adjustment.

There is a significant removal of organic matter in SB reactor than in AF filter, due an over dimension in the design of this reactor. This allows increasing the amount of methane produced in liquid-phase reactors. Regarding the design of the system used, in accordance with (Verma, 2002) multi-stage processes provide biological stability by keeping the acidogenesis and methanogenesis separately and allowing higher organic loading rate without shock to methanogenic bacteria. The discussion and evaluation of reactor designs will greatly vary depending on whether one takes a biological, technical, economical, or environmental view point. (Vandevivere et al., 2002) report, empirical knowhow is the rule and there certainly does not exist a consensus over the optimal reactor design to treat municipal solids.

The most important impact generated by the operation of the pilot plant is the energy efficiency achieved through anaerobic digestion, compared to composting which recovery of organic matter is achieved. The biogas produced will be delivered to residents affected by the landfill that live nearly and to a school nearby for domestic consumption, it is estimated that about 36 people will directly benefit from the biogas produced of this pilot plant. (Deublien & Steinhauser , 2008) Report that is possible produce 6.0 to 6.5 kW.h/m^3 biogas with 60-70% of CH_4 content. According to the above, if the amount of OFMSW treated is greater, more biogas will be produced and there will be a greater number of beneficiaries. The operation of the biogas plant minimizes environmental impact caused by emissions, further ensuring proper disposal of effluent that can be formulated as organic fertilizers because their origin and treatment.

Concerning the production of biogas, (T.Z.D. de Mes, A.J.M. Stams, 2003) public in their book that from OFMSW it can obtain yields between 80-200 m^3/ton in highly optimized and technically advanced systems. Thus far in the pilot plant has been registered a production of 2.4 m^3/day with a yield of 33 liters of biogas per kg, the next challenge is to get closer to that range of biogas production by adjusting variables such as OLR, improving strategies for biomass retention and decrease the percentage of recirculation until enough values to maintain proper VFA/ALK.

Anaerobic digestion, such as discussed in the (Edelmann, 2002) book, is a first and big step in a better direction in management of OFMSW, because it is a solution that closes ecological cycles and is friendly to the environment. But solutions valid for a future mankind have to be even more integrated and based on holistic, long-lasting concepts. In the future, similar integrated concepts have to be developed. Then, anaerobic digestion of biogenic wastes will probably play a very important role in education, because it is an excellent example for interdisciplinary thinking while closing ecological cycles, reducing pollution and grading household wastes up to precious new products.

Conclusions

Operational difficulties are common when an anaerobic digestion process is escalated to a pilot plant. The most important challenge will be to improve the Solid Retention Time and Hydraulic Retention Time. The best operating conditions in mesophilic range, corresponding to a Solids Retention Time of 20 days with a effluent recirculation of 50%, to maintain a rate of VFA / AKL <0.8 and 20 more days for the methanogenic phase.

Experimental results show that a system of two-stage anaerobic digestion (dry-wet) to treat OFMSW can be an option to optimize the management of MSW from an environmental point of view. However, is required an economic evaluation of the system for make it more attractive to municipalities from the economic point of view.

Biomethanation systems should not be considered as independent plants or as the solution to the whole problem of municipal solid waste, but as a module of the comprehensive treatment of waste, being one of the steps between proper segregation and disposal of waste. All this initiatives improve the management of MSW in these municipalities. Composting plants may serve as a contingency plan in case of an unexpected increase in organic waste or in the case of system maintenance anaerobic digestion.

25. Recovery and refining of precious metals alloys by oxi-nitrogen leaching

Renato Bonora, Luciano Morselli

Abstract

In recent years the demand for gold and other precious metals has increased dramatically, insomuch as in the last decade gold prices have quintupled. In the contest of the lack of trust in the traditional financial market, recovery and refining of precious metals from e-waste, automotive catalysts, and scrap jewellery and waste generated by jewellery manufacture have become increasingly more important.

Controlled recovery of precious metals reduces additional waste production and helps prevent the need for supplementary mining. Metal recovery and refining processes can also have adverse effects on the environment when not conducted properly, especially when the pressure of the precious metals market price makes the refining companies speed up production. Separation technology described here is the hydrometallurgical method whereby gold-bearing alloys are obtained from gold scraps and wastes. Different metal grades are refined by aqua-regia or nitric acid dissolution in the presence of oxi-nitrogen species.

Keywords: precious metals, hydrometallurgy, oxi-nitrogen species, leaching.

Introduction

The research effort was carried out with the purpose of industrially implementing improvements in the hydrometallurgical leaching of low and high-gold grade alloys for pure metal production. Nitrogen gaseous species, produced during oxidative leaching of low and high-grade gold-bearing alloys, respectively by nitric acid and *aqua-regia*, instead of being released into the atmosphere or cleaned, have been properly oxided with pure oxygen thus generating high oxidant solutions. The on site generated nitrogen species are more powerful oxidizing agents in comparison to conventional acid leaching processes; the “catalytic” oxidant property of nitrogen species (nitrate and nitrite) enhances the oxidation rates at a relatively lower temperature in a slightly pressurised-leaching reactor. Consequently, the modified process has shown unmistakably important improvements in terms of reduction both of relative quantity of the reagents used in the refining process, and the reaction times. Furthermore a reduction of relative process costs has been observed, due mainly to the far less consumption of reagents, with greater benefit for environmental impact and the costs of the whole process itself.

The full-scale test performed with the regenerated solutions, in the refurbished and adapted existing plant, demonstrated important advantages in reducing the consummation of nitric acid and reducing subsequently the consummation of other reagents and waste produced.

The full-scale processes and related equipment used in the research permitted treatment of about 100 kg alloy per cycle.

Background

The manufacture of gold jewellery always generates scraps and waste, whether made by traditional techniques in a workshop or by mass production in a factory, such as gold sweepings, ashes, polishing dusts, crucibles, exhausted solutions, etc. electronic-waste is also a rich source of precious metals and its recycling business is rapidly growing. Table 1 reports the typical content of gold in different scraps and wastes. All of those materials need to be recycled back to pure gold and other metals.

Material	Gold content (wt %°)
Old and defective jewellery	250– 832
Dental-crown	600 (Au, Pd and/or Pt), >250 gold
Bench scrap	150–550
Sink trap settlings	50–100
Polishing dusts and sweeps	5–150
Carpets	1–100
Old crucibles	5–50
Gold-filled scraps	1–50
Emery papers, brushes, shop dirt	1–50
Electronic scraps (cladding)	5-30

Table 1*: Representative gold contents for scraps and waste*

Most recycled materials may contain, in addition to gold, all sorts of metals, depending on scraps and waste origin, such as: Silver, Palladium and sometimes Platinum, Copper, Nickel, Aluminium, Zinc, Tin, Lead and Iron. In addition, small amounts of elements like Beryllium, Barium and others have to be considered.

Precious metal extraction or recovery from scraps commonly requires a combination of comminution, hydrometallurgical, and pyrometallurgical processes to be performed on raw materials in which they are contained.

When precious metals are sufficiently concentrated there are several methods used to separate them. The most common methods used in the gold refining industry are the *inquartion and parting* and *Aqua Regia* processes respectively, for low and high gold content.

Refining processes

Inquarting and parting process

The process is used for the treatment of low gold concentration scrap, 250/1000 (%°) or less. When the gold concentration is higher then 250%°, the refinable material is melted with additional silver to produce the alloy containing the designed concentration (*inquarting)*. The dilution ensures that all the base metals and silver can be dissolved in nitric acid, leaving a gold sludge (*parting)* on the filter.

The silver leaching reaction by nitric acid can be summarized by the follow equation:

$$4\ Ag(s) + 6HNO_3(aq) = 4AgNO_3(aq) + NO(g) + NO_2(g) + 3\ H_2O(l) \qquad (1)$$

Copper, as well silver, is oxidized by concentrated nitric acid, to produce Cu_2^+ ions; the nitric acid is reduced to nitrogen dioxide:

$$Cu(s) + 4HNO_3(aq) = Cu(NO_3)_{2(aq)} + 2NO_2(g) + 2H_2O(l) \qquad (2)$$

In dilute nitric acid, the reaction produces nitric oxide, NO, instead:

$$3Cu(s) + 8HNO_3(aq) = 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(l) \qquad (3)$$

The gold sludge is washed, filtered, and dried.

Any Platinum present will also be dissolved, but insoluble platinum group metals (PGMs) will remain. Aqua Regia refining is necessary if pure gold is needed.

The outline of the process is given in Figure 1.

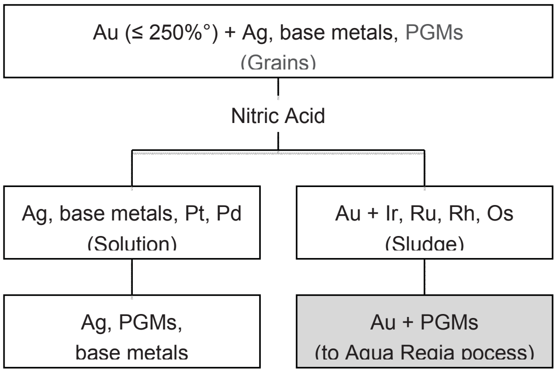

***Figure 1**. Outline of the inquarting and parting process.*

Aqua Regia refining process

The aqua regia process is used to produce gold of up to 999.99 %° purity; by this process the purity of gold obtained by *inquartation* can be increased.

The alloy is grained to increase surface area, and aqua regia is added.

The feed material, from the *inquartation process*, or Gold with > 250 %° with silver content of 100%° or less so that Aqua Regia (mixture is formed by freshly mixing concentrated nitric acid and hydrochloric acid, usually in a volume ratio of 1:3) dissolves gold into soluble gold chloride, each acid performs in a different way according to the following equations:

$$Au(s) + 3\ NO_3^-(aq) + 6\ H^+(aq) \rightarrow Au^{3+}(aq) + 3\ NO_2(g) + 3\ H_2O(l), \text{ and} \qquad (4)$$

$$Au^{3+}(aq) + 4\ Cl^-(aq) \rightarrow AuCl{-}4(aq). \qquad (5)$$

Nitric oxide can be produced rather than nitrogen dioxide according to the following reaction:

$$Au(s) + NO_3^-\ (aq) + 4\ H^+(aq) \rightarrow Au^{3+}(aq) + NO(g) + 2\ H_2O(l). \qquad (6)$$

When the gold is completely dissolved, the insoluble silver chloride can be separated from the solution, along with the insoluble Platinum, Palladium, and other Platinum group metals. The gold can then be selectively precipitated using a number of reducing agents available, more often by sodium bisulphite, after the gold solution has been basified.

Platinum group metals, Silver, and Copper will be successively separated.

Inquarting and aqua regia processes both emit brown vapours of nitrogen oxide while metals are being dissolved. Fume abatement systems are generally required to reduce emission of these toxic fumes and to comply with pollution laws. The nitrogen oxide vapours, instead of being wasted, can be profitably recycled to produce the highly reactive oxy-nitrogen species solution that can be used in metal leaching.

The outline of the process is given in Figure 2.

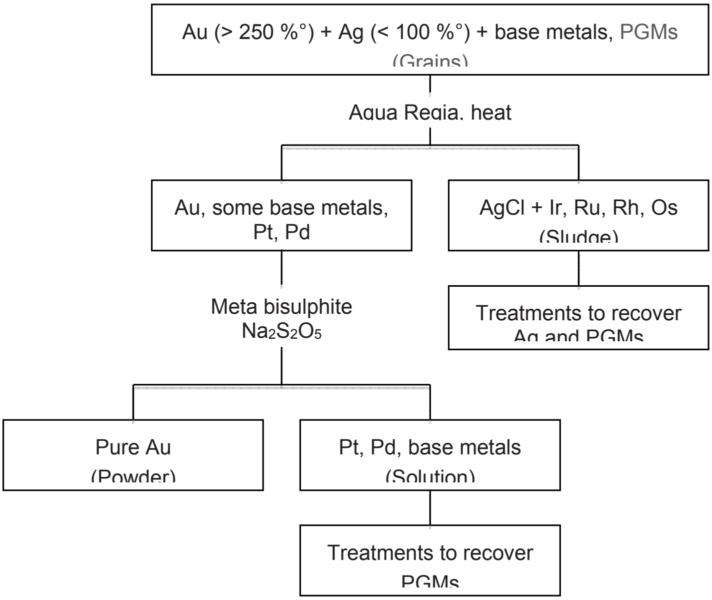

***Figure 2**. Outline of the aqua regia process.*

The reaction of the nitric acid and the aqua-regia processes with the metals generates fumes of nitrogen oxide, these fumes are acrid, choking and extremely toxic and fume abatement systems is needed to reduce emission to comply with pollution laws. Commonly, the NOx-containing gas is sucked by standard blowers together with atmospheric air to a packed column washed by caustic solution. The alkaline resulting solution containing nitrates and nitrites periodically requires to be disposed of in accordance with law. Absorption of NOx, at the partial pressures of 300 Pa, with the addition of oxygen was experimented at 10°C with water. The utilisation of the resulting acid solution in both, *inquarting and parting* and *aqua regia* processes were investigated.

Leaching with oxy-nitrogen species

The principle of precious metals leaching with oxy-nitrogen species is based on that nitrogen species (NO, NO_2, etc.) being powerful oxidizing agents for metals (Gok, Ozge, 2010). The NO(g) produced in the reactions (1) shows low solubility in the aqueous leaching solutions and consequently it will be accumulated in the head space of the reactor and, due to the positive pressure in the oxidation reactor, where it can be rapidly oxidized by an oxygen rich atmosphere to produce nitrogen dioxide. Consequently, NO_2 can be absorbed into the water at a high rate. In the leaching reactor NO is continuously generated and consequently the oxi-nitrogen species are continuously produced. The regeneration of the oxidant can be efficiently performed in absorption columns during leaching according to the simplified following reactions:

$$2NO(g) + O_2(g) = 2NO_2(g) \quad (7)$$

$$2NO_2(g) = 2NO_2(aq) \quad (8)$$

$$2NO_2(aq) + 2NO_2(aq) + H^+ = 4NO^+(aq) + 2H_2O \quad (9)$$

Under these conditions, nitrite originally presented as NO is rapidly converted into N_2O_4 (dimer of NO_2 species) (H. H. Awad, 1993). It is assumed that the actual leach reaction is due to NO^+ and not NO_3^-. Redox couple of NO^+/NO in high hydrogen-ion activity solution shows an extremely high oxidation potential as shown in Table 2 (E. Peters, 1992; Anderson, 1992; Anderson, 2003).

Oxidant	Redox Equation	E°h (pH = 0, H_2 ref.)
HNO_3	$NO_3^- + 4H^+ + 3e^- = NO + 2H_2O$	0.957 V
HNO_2	$NO_2^- + 2H^+ + e^- = NO + H_2O$	1.202 V
O_2 (g)	$O_2 + 4H^+ + 4e^- = 2H_2O$	1.230 V
Cl_2 (g)	$Cl_2(g) + 2e^- = 2Cl^-$	1.358 V
NO^+	$NO^+ + e^- = NO$	1.450 V

***Table 2**: Potentials of hydrometallurgical redox potential (Anderson, 2004)*

Industrial application of oxi-nitrogen leaching

The application of oxi-nitrogen oxidative leaching has been tested in a full-scale plant evaluating the main economic aspects in comparison to the conventional process.

Figure 3. shows the outline of the oxi-nitrogen leaching species recovery (red) in the *inquarting and parting* process. The amounts of nitrogen chemicals are reported as mole of the nitric acid solution that generated them, and referred to 1 kg of alloy.

Figure 4. Shows the outline of the oxi-nitrogen species recovery (red) implemented in the *Acqua Regia* process. The amounts of nitrogen chemicals are reported as mole of the nitric acid solution that generated them, and referred to 1 kg of alloy.

The dissolution of the gold in the *aqua regia* process was conducted under atmospheric pressure in an open vessel equipped with a condenser to minimize loss of water.

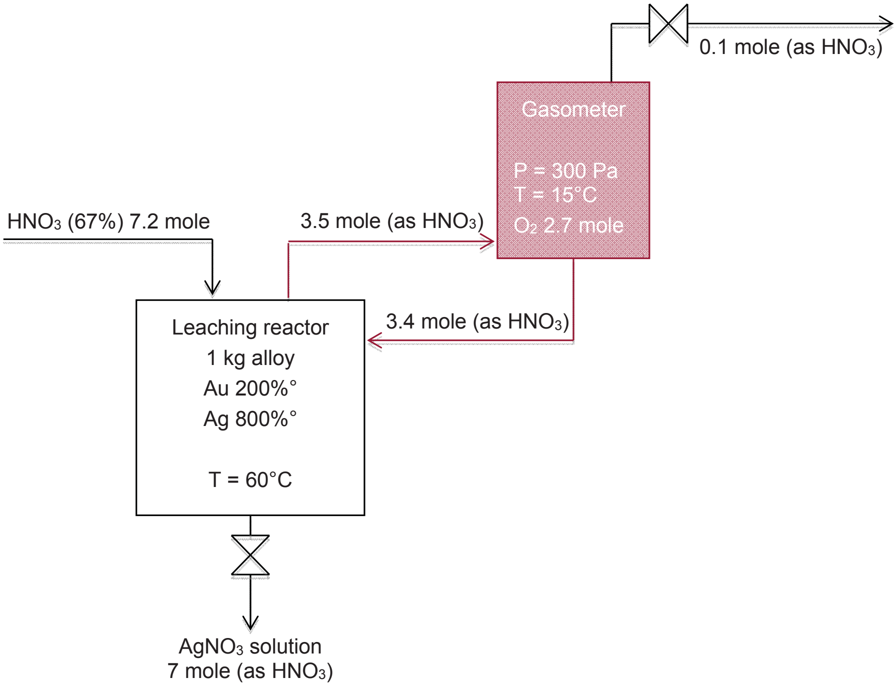

Figure 3. *Outline of the inquartation and parting process.*

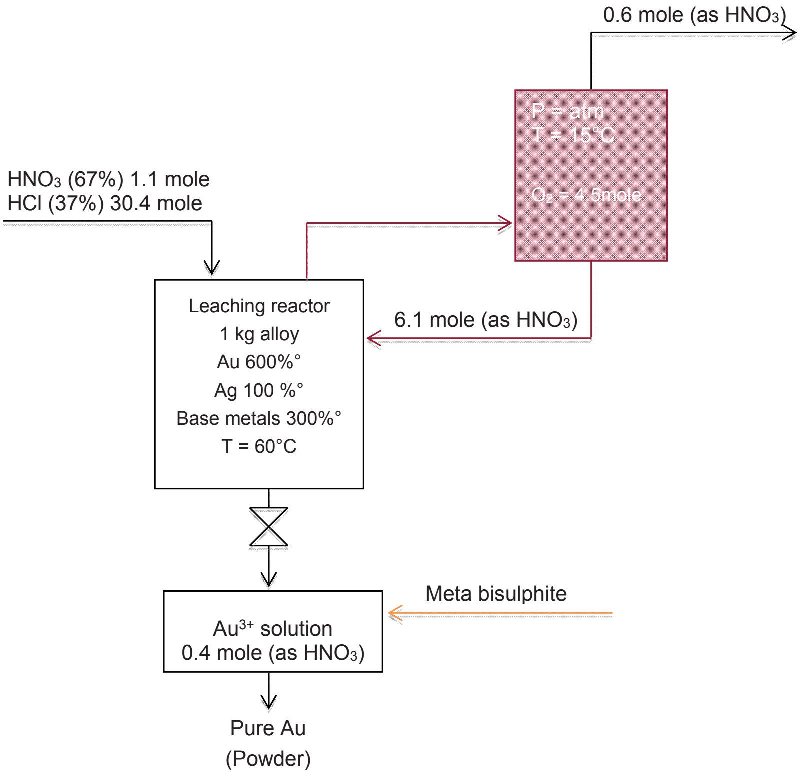

Figure 4. *Outline of the Aqua Regia process.*

Results

The results of the full-scale test performed with both processes are summarised in Table 3.

Parameter	*Inquarting and parting* (Au 200%°, Ag 800%°)			*Aqua Regia* (Au 600%°, Ag 100%°, Base metals Cu 300%°)		
	Old	New	Variation %=-100(old-new)/old	Old	New	Variation %=-100(old-new)/old
Solubilisation yield (3h) (%)	90	98*	+8	95	98	+3
Reaction temperature (C°)	80	80	0	85	60	-29
Nitric acid consumption ($mole_{nitric\ acid}/kg_{alloy}$)	10.6	7.2	-32	10.5	1.1	-89
Meta bisulphite consumption $kg_{Meta\ bisulphite}/kg_{alloy}$	-	-		1.2	0.6	-50
Oxygen consumption $Nlitre_{O_2}/kg_{alloy}$	-	48	+100	-	80	+100
Exhausted solution production $litre/kg_{alloy}$	5.5	4.2	-24	7.9	5.8	-26

*Higher purity of gold.

Table 3*: The operating conditions used both in the conventional (old) and modified (new) leaching processes and the compared results.*

The results change with the different alloy leached.

Conclusions

Industrially proven and applied nitrogen species leaching has been utilized to treat a number of different alloys. The data reported represents the working condition practically utilised with the considered alloys. This technology offers many advantages in both processes, including primarily, sizable reduction of nitric acid used in the leaching phase and consequently a proportional reduction of the reducing agent solution, such as bisulphite in the *aqua regia* process for gold reduction. This very process shows a dramatic reduction in the use of nitric acid; in fact the system, related to the nitrogen compounds, is almost folly closed. Uncondensable gases are periodically discharged. The lower amount of bisulphite is mainly due to the less amounts of nitrogen compounds needed to be reduced and the residual acidity to be neutralised. The reduction in the production of wastewater was practically evaluated for both processes around 25%. The reduction of the consumption of reagents permits low capital costs and low operating costs in the running of the processes and in the depuration of fumes and disposal of wastewater.

26. Pyrolysis for coffee pulp valorization

Jürg Schmidlin, Hannes Zellweger and Martin R. Schmid

Abstract

Much literature about the use of pyrolysis in the coffee production sector focuses on a stationary plant design. We evaluate the benefits of a mobile plant to also serve small coffee farmers where the harvesting season lasts only about three months. In such situations most other treatments/ valorizations methods cannot be economically applied. Thousands of tons of coffee pulp are therefore not valorized and left to rot. This not only means releasing the potent greenhouse gas (GHG) methane but also contaminating seeping water, polluting rivers and ground water resources. Not valorizing readily available resources means also ignoring a competitive advantage. For this study, the technology component of the joint global UNIDO-UNEP Resource Efficient and Cleaner Production (RECP) program, identified pyrolysis as a potential technology for step-reductions in terms of byproduct treatment and their valorization. The sectorial study included a top down and bottoms up approach to cross check the findings. This included a desk review of existing RECP assessment and conducting five new RECP assessments in representative agro-industrial coffee companies. Furthermore additional information was attained through first-tier surveys with entities like chamber of commerce, regional government or coffee equipment manufacturers.

Keywords: pyrolysis, coffee, biochar, innovation, cleaner production

Introduction

In Peru alone, thousands of tons of coffee pulp are not valorized and left to rot because of a lack of proper treatment. This not only means releasing the potent greenhouse gas (GHG) methane but also contaminating seeping water, polluting rivers and ground water resources. But this is not only a Peruvian problem. The Guatemala-based Instituto Centroamericano de Investigación y Tecnología Industrial estimated that over a six month period during 1988, the processing of 547,000 tons of coffee in Central America generated 1.1 million tons of pulp and polluted 110,000 cubic meters of water per day, resulting in discharges to the region's waterways equivalent to raw sewage dumping from a city of four million people[12].

At the same time authorities, environmental organizations, neighbors and label organization demand for sustainable production without giving practical solutions.

The technology component of the joint global UNIDO-UNEP Resource Efficient and Cleaner Production (RECP) program, identified pyrolysis as a potential technology for step-reductions in terms of byproduct treatment and their valorization. The main advantages are as follows:

- Production of renewable energy, which can be used for the drying process with a reduction of their traditional thermal energy consumption of around 40-70%. In Peru the drying process is usually the bottleneck and key for coffee quality.
- Reducing the need for wood, coffee husks or fossil energy and hence a reduction in CO_2 emissions
- Fast, appropriate and clean solution for their coffee pulp “disposal”.

[12] Gilberto Amaya H., Appropriate Technology International, personal communication, January 22, 1996.

- Production of Biochar, a product to improve soil characteristics, especially of tropical soils, to achieve higher yields and save costs for expensive and scarce fertilizer.
- Biochar is also regarded as a carbon sequester.

Study/ Project scope and purpose

Scope:

While there is undoubtedly several potential severe environmental impacts along the value chain of coffee production like deforestation, overuse of agrochemicals or soil deterioration etc. this study focuses on the in Latin America most common, wet process.

Figure 1. *Generic flowchart of coffee production in Peru*

Purpose:

This project aims to provide agro-industrial companies a Cleaner Production Technology to maximize the valorization of their organic waste (coffee pulp) and minimize its negative environmental impact. A mobile Pyrolysis plant is a very interesting solution as it turns the coffee pulp into biochar, a soil enhancer, and gas, which in turn can be used for the drying process. Additionally the production costs in Peru must not exceed 20’000$ for the mobile plant.

Figure 2. *Unused coffee pulp*

Innovation for Resource Efficiency

Research and design of a mobile pyrolysis plant

During five CP-Assessments in three typical coffee growing regions, it was soon realized that a stationary pyrolysis plant would not be economically feasible because if the short harvest seasons and therefore short operational time.

The main factor for the time of year of the harvest is altitude. In Peru coffee is grown at altitudes 800-1’500 MASEL. Thus a mobile plant, which can be easily driven to different altitudes, could be run almost throughout the year. Knowing that the pyrolysis plant can be also used in other agro-industrial sectors i.e. cacao, banana, sugar cane, gives exiting options for different business models.

Industrial pyrolysis plants do already exist i.e. the Pyreg500, an industrial plant from Germany, which can convert 1’700 tons per year in heat and coal. This system is very expensive and very time-consuming and has a big drawback: The reactor is heated from the outside with the hot exhaust gases from the pyrolysis gas combustion. This then demands for very high heat and high-temperature corrosion resistance of the used material. Because of this, expensive heat resistant steel must be used and furthermore the temperature must be accurately controlled for these delicate heat exchangers. The idea is to exchange the expensive and complicated reactor with a simplified technology. This chosen process, FLOX burner, with recirculation of exhaust gases for heating is still comparatively new, but is already applied in torrefaction.

Unfortunately for the time being there is no such mobile pyrolysis plant commercially available. For this reasons a prototype plant, that can process 90 kg coffee pulp per hour is being developed and planned to give results by November 2014.

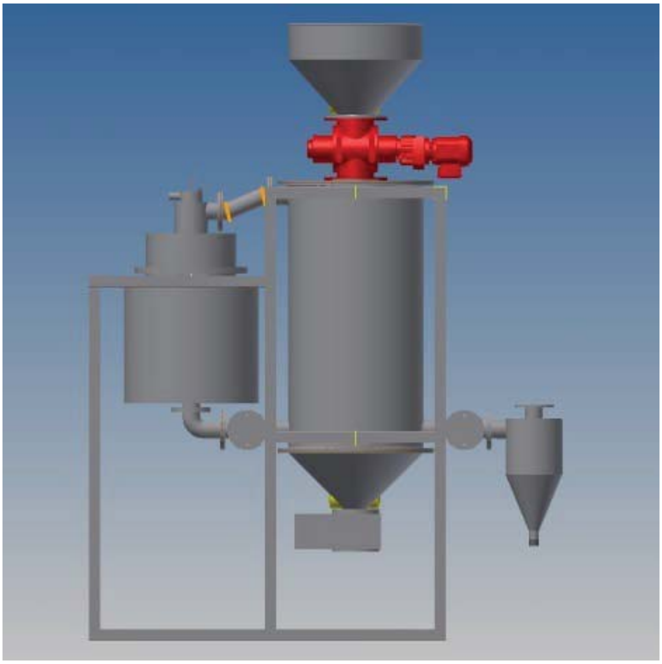

Figure 3. *CAD Modell of the pyrolysis prototype including FLOX burner, reactor and cyclone separator*

A major advantage of this system is the production of renewable energy, which can be used for the drying process. It is expected to save around 40-70% of their traditional thermal energy consumption. In Peru the drying process is usually the bottleneck and key for coffee quality.

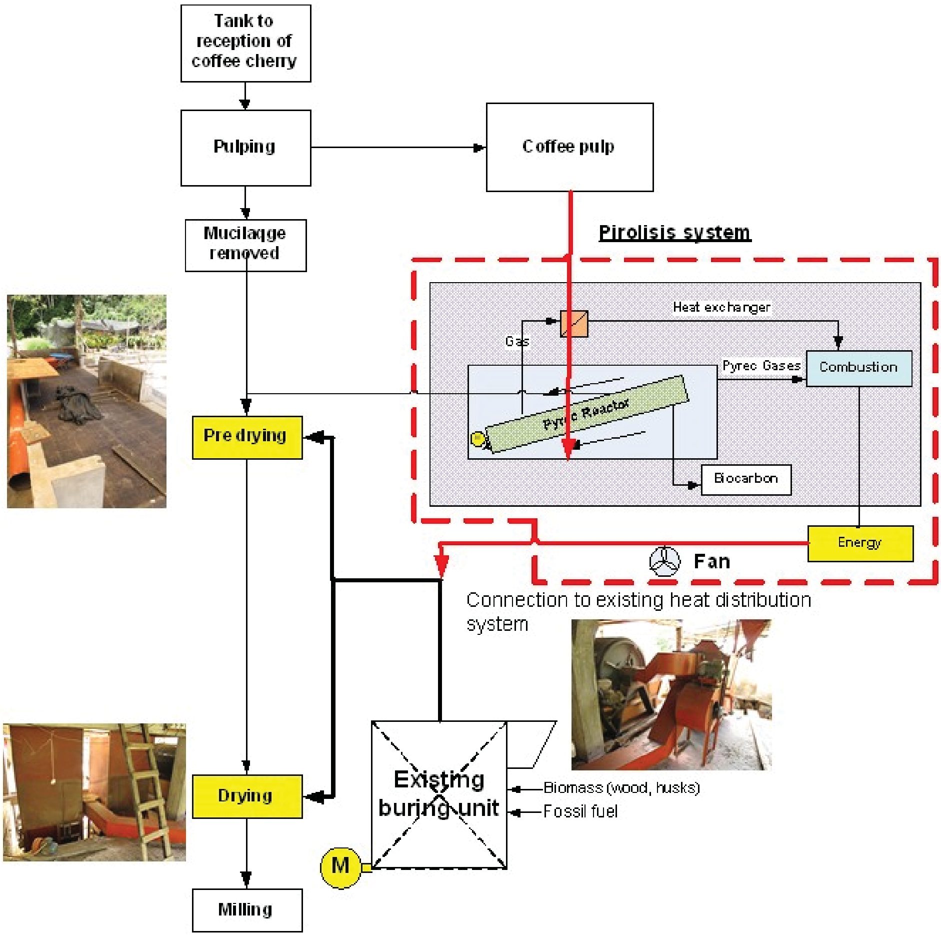

Figure 4. *Connection of the pyrolysis plant to the existing burning unit (wood, fossil fuel or coffee husks) as well to the existing pre-drying and drying process.*

For the time being CATSE states: “From technical and economical point of view, it seems to be feasible to operate mobile pyrolysis plants as a solution for the coffee pulp wastes highlands of Peru. Creating an environmental benefit without costs and while creating jobs”

Simplified biochar field tests

While there is abundance of information available on biochar and its effects on soil, there is little knowledge on its specific application and benefits in the coffee growing sector. As biochar is one of the main benefits of the pyrolysis plant it is important to estimate its effects on the coffee plant. More accurate data will facilitate acquisition of additional funding which is needed for the next step: Technology transfer and practical implementation (more information: see 2.3).

In consequence a plan for simplified biochar field tests was elaborated. Included but not limited to:

- define and finding a suitable sample field,
- conduct several analysis for: soil, fresh and dry pulp, and compost
- Production of biochar
- Activation of biochar with compost
- Actual insertion of the “nueva terra preta”
- Follow up and analysis of the results

One major challenge was the lack of biochar from a pyrolysis plant which was substituted by biochar produced with a handcrafted kiln (see below).

Figure 5 *Simple Biochar production with a double cylinder oven*

Technology transfer and practical implementation

Often, projects are made with technology that is hard to understand and too difficult to repair, resulting in unavoidable failure over time. To avert this, a local “coffee processing machinery” company was involved and consulted. Before the final technical drawings will be created, a “technology transfer mission” with the key engineer, who is responsible for the fabrication of the plant, will be held. This will assure the local availability and understanding of the proposed technologies, materials and spare parts.

Subsequently the Swiss made pilot plant will be shipped to Peru and tested within the chosen coffee producer. Dissemination of the project results will be done through various well established channels. If the results are as expected there will be little challenges for commercialization through our local counterpart.

Conclusions

A mobile pyrolysis plant can decrease the need of traditional heat energy by 40-70%. With the byproduct biochar, a soil improver, the consumption of often scarce and expensive fertilizer can be reduced by 25-30%. The building cost of a mobile pyrolysis plant in Peru is around 15'000 USD. While this study/ project focuses on coffee pulp valorization in Peru, the technology can easily be adapted to other biomass and therefore has a high replication potential worldwide. A mobile pyrolysis plant is an innovative way to improve competiveness, productivity and resource efficiency while at the same time, minimizing the negative environmental impacts of the coffee production.

27. Directed bioprospecting as a strategy for the enhancement of waste and microbial diversity valorisation

Janeth Sanabria, Mauricio Rodriguez, Alejandra Tobón

Abstract

The search for new metabolisms and study of microbial diversity has spread worldwide in the past 20 years through the use of molecular techniques. A strategy employed to achieve expression of enzymes with a useful function is genetic engineering applied to the transformation of known cultivable strains. However, such strategy is of difficult application in bioremediation due to the complexity of pollutants. This has spurred the search for bioprospecting alternatives, in which microorganisms and their useful metabolisms are selected through a process of continuous adaptation. This strategy proposes adapting microbial consortia allowing evaluation of a higher number of species and their genetic potential for waste recovery. The following paper discusses two examples where the strategy have proven to be effective in the Colombian context: A microbial consortia for nitrogen fixation, adapted to 59 gr.L-1 of Ammonia, and the transformation of anaerobic effluent into biopolymers at a rate of 1.12 g / L PHB.

Introduction

The acquisition and use of pure cultures has enabled researchers to know microorganisms in detail, in order to control their harmful effects and use them for their own benefit, especially in pharmaceutical medicine and disease control (Bull et al 2000). Bioremediation has used since its origins microbial communities capable of transforming pollutants into less environmentally harmful chemical compounds (Sanabria 2014). More recently, when combining the need to control pollution and the use of pure cultures, many studies have aimed at searching for specific microorganisms. The methodology for obtaining useful microorganisms from a consortia has focused on the media enrichment, consisting in successively passing a group of organisms to the same culture media, decreasing the population to gain a pure culture from a single colony. However, when comparing the number of microorganisms described and the applications derived from they (represented as patents), the results seem out of proportion, see complementary material. This might be related to the complexity of the pollutants and the little understanding of the ecological relationships between microorganisms involved. Furthermore, in the case of Latin America and especially Colombia, we find there is difficulty in microbiology and biotechnology laboratories for design, acquisition and operation of special devices such as reactors. The directed prospection strategy, in continuous or semi continuous, differs in that bacteria are never taken out of the bioreactor, in a way that consortia are obtained as the very same product of the continuous feed, i.e. they are the result of a designed adaptation. For this purpose the supply media must be continuously adjusted to obtain the desired metabolic outcome. This adaptation strategy allows the expansion of the microbial diversity range, and therefore finding microorganisms and combined biochemical processes adapted to the stressful conditions of residues, so they can generate a product with high added value. One of the biggest challenges towards transformation of wastes is their complexity, due to the convergence of organic and inorganic pollutants. Consortia design can be use as a separation mechanism, working in one or more reactors and coupled processes; see figure

1. In the process, it is possible to obtain pure cultures of bacteria that have been previously described as non cultivable (Hu et al, 2013). The use of mixed cultures and low-cost substrates such as waste, can reduce the production cost which may generate a real interest in diminish the impact of pollutant discharge. Recent studies show that cellular content of PHA in mixed cultures from activated sludge can achieved 67% and 78.5% of its dry cell weight (Liu et al., 2011, Serafim et al., 2004), such values flanking those obtained with pure cultures using high cost raw material.

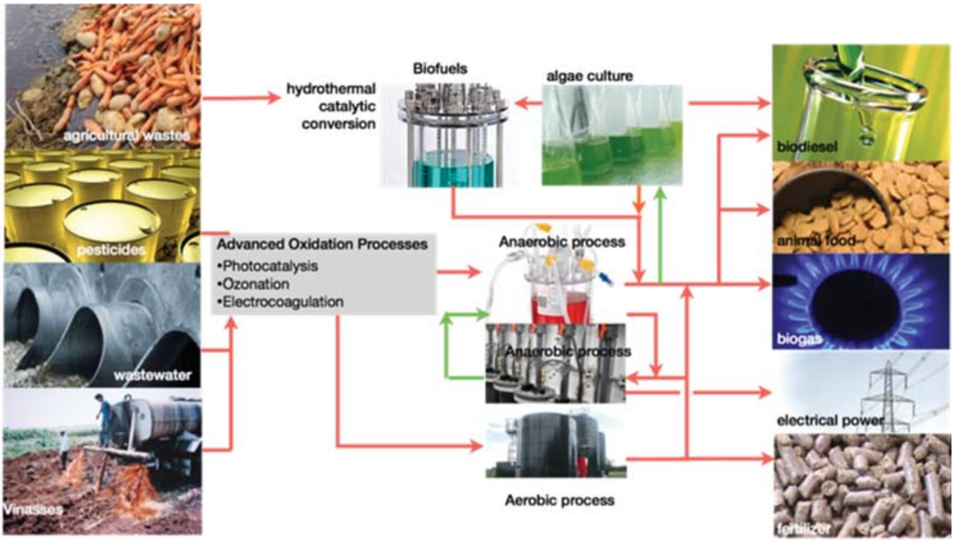

Figure 1. *Cluster scheme of processes that can be coupled to enhance microbial diversity.*

Mixed culture biotechnology' (MCB), was first defined by Kleerebezem and Loosdrecht (Kleerebezem, 2007). Owing to the use of undefined mixed cultures, process development in MCB can only be based on natural/ecological selection by manipulating the operation of the bioprocess or by varying the source of the natural inoculum, useful for transformation of a substrate into value. This combination of approaches has been used to improve the efficiency of biofuels production (hydrogen and methane), as well as for the production of biopolymers, the latter being one of the most promising (Keshavarz & Roy, 2010;. Queiros et al, 2014). In this approach, energy flows and stoichiometry play an important role (Rodríguez, 2006), and genetic changes will no longer be needed (Agapaskis et al 2012). One of the keys to success of consortia is represented in the naturally established biodiversity and temperature. Surely, if tropical countries possessing the largest diversity on the planet (many of them in conditions of delayed development), could indeed take advantage of this, they will have better options for competitiveness and development.

Using this model we obtained Consortia, from a domestic wastewater treatment facultative pond with high ammonium loads, in a SRB type reactor with a substrate free of nitrogen source. The result was a microbial consortia of nitrogen-fixing organisms. This consortia was tested on degraded soils with high salinity and exhibited a better ability than conventional organic fertilizers to adapt to these conditions. Moreover, it was also possible to adapt Consortia from activated sludge, to use a mix of VFA typical of anaerobic effluents rich in organic matter.

Methodology

Selection of inoculum.

The chosen inoculum came from closed and open wastewater treatment systems- WWTS (constructed wetlands, ponds, activated sludge, UASB, etc.). These systems have features that promote adaptation to various extreme conditions. 1) Contain variety of organic and inorganic chemical compounds, forcing an organization of metabolisms in several steps in a coordinated manner (Agapakis et al 2012); 2). Due to engineering practices, these organisms pass from one treatment system to another , which isolates them for long periods of time, sometimes decades, a factor of speciation already discussed (Hreggvidsson, et al 2012); 3) They adapt to sudden changes in pH, dissolved oxygen, radiation, etc. 4) The successful associations found may remain for long periods being more stable.

Reactor Operation

The reactors are operated in continuous or semi continuous. The reactor operated in batch or semi-sequential, has five cyclical phases:

1) The filling, consisting of wastewater or mixture of nutrients entering to the reactor; 2) the reaction, phase in which the substrate is consumed under controlled conditions, whether oxic or anoxic; 3) the sedimentation, phase in which the biomass is allowed to precipitate obtaining a clarified supernatant; 4) the draining, involving the careful removal of the supernatant to avoid dragging of biomass; 5) adjustment of the media considering the consumption or expected products, see Figure 2.

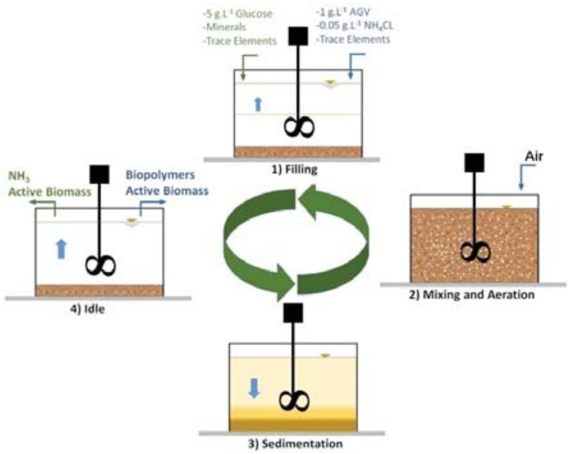

***Figure 2**. Description of the basic reactor operational processes for adapting microbial consortia.*

The reactors are operated with continuous gasification. The injected gas depends on the process (N_2, CO_2, CH_4, O_2), separately or in mixture. The nitrogen source depends on the amount and quality of the stoichiometry described for the process (NO_2, NO_3, NH_3, N_2, N_2O, etc.). Examples of the stoichiometry described above are:

Nitrogen fixation

$N_2 + 16\ ATP + 8e^- + 8H^+\ 2NH_3 + H_2 + 16\ ADP\ 16Pi$ (Burgess et al, 1981)

Using this stoichiometric parameter consortia from different WWTS have been feed with media devoid of Nitrogen; (Organic compound +trace elements+NH_4).

Carbon sources are the main component of solid and liquid waste, and therefore these residues are an important source of organic compounds with added value. Biofuels such as: Methane and alcohols, Biopolymers, Biomass, Fatty acids, etc. However these may require various bioprocesses to establish a new methodology that can lead us to gain a better product. For the production of Biopolymer the use of two steps has been implemented. In the first, part of the organic matter of vinasses is transformed into volatile fatty acids (VFA). This VFA are converted, in a further biological transformation, onto biopolymers. In both cases the microorganisms are adapted in a continuous or semi continuous feeding process.

In a first Bioprocess: Organic compound + mineral salts → VFA + biomass;

→ Alcohol + biomass;

→ H_2 + VFA + biomass.

In a second bioprocess: VFA+NH_4 → Biopolymer

VFA+NH_4 → Glycerol

Promising results

As functional results we obtained microbial consortia for nitrogen fixation, adapted to 59 gr.L-1 of Ammonia. This Nitrogen fixing consortia was tested on degraded soils with high salinity and exhibited a better ability for Nitrogen fixation and adaptation to salinity conditions than conventional organic fertilizers. On the other hand the transformation of VFA into biopolymers at a rate of 1.12 g /L PHB has been achieved. As a result, new consortia and species are described.

Conclusion

The new context of global environmental degradation, implies new social, scientific and economic challenges in the development of sustainable technologies. The use of biological processes remains as one of the most efficient approaches to that purpose. However, biological processes must also evolve and adapt exploring sustainable options. The design of consortia and microbial ecosystems involves the use of microbial biodiversity in a way advantageous to the conditions of tropical countries, since methods can be adapted with no require of using genetic engineering of difficult access. This could also reduce the impact of environmental degradation and create options of competitive biotechnological innovation in a global context. However, the development of knowledge and technologies applicable in metabolic engineering require a detailed knowledge of the microbial metabolic map and development of devices capable to generate information in real time and in a short time.

Acknowledgements

To Lucia Castano for review and style, to Luc Patiny for the design of Figure 2.

28. Sustainable use of biofertilizers: A novel approach to the management of land resources

Dilfuza Egamberdieva and Stephan Wirth

Abstract

Many countries in the world are faced with the problem of land degradation, water shortage, soil salinity and these conditions are likely to contribute to increased food security risks. Drought and salinization is recognized as the serious threat to sustainable food production and to our natural resources. In addition, the massive use of agrochemicals has degraded natural resources and environments in a manner which is not further tolerated by the international community. Improving soil quality and managing its fertility by novel technologies are of fundamental importance for future agricultural production and environmental management. Many soil management practices such as application of compost or manure, mulching, legume or intercropping evolved over centuries have been proven to be effective under various agricultural systems. Organic agriculture is already widely used as a method for soil fertility management – and other options are arising such as promotion of composting using fungi, vermi-composting, and use of bio-fertilizers which hold the potential to protect the environment as eco-friendly and cost effective inputs for the farmers. Efforts to better understand the role of biofertilizers in nutrient uptake and plant response to environmental stress are more compelling now since the continuous use of high amounts of chemical inputs are generating environmental problems, and are not sustainable in the long-term. This chapter discusses prospects of using biofertilizers for better agricultural productivity and increased food security, especially possible roles in better plant nutrient uptake, reduced use of chemical fertilizers, enhanced or induced systemic tolerance of plants towards detrimental environmental stress factors.

Keywords: biofertilizers, rhizobia, biochar, crop, abiotic stress, drought, salinity

Introduction

The World Food Security Committee holding meeting in October 2012 addressed the effects of climate change on food security and invited world leaders to integrate food security and climate change concerns in order to increase resilience of food systems to climate change; to develop agricultural strategies that take into account the need to respond to climate change and to safeguard food security (Committee for Food Security, CFS 2012/39/3). Major hindrances against agricultural development are socioeconomic, political, cultural, and environmental factors, low technological development, bad agricultural methods and policies in many developing economies (Graham and Vance 2000). These facts represent a serious threat to sustainable food production and to our natural resources worldwide. Climate change may lead to an extension of saline landscapes in many non-irrigated regions since it is accompanied by less rainfall and higher temperatures in most agricultural regions. Drought and salinity are likely to result in a reduction of nearly 7% of world agricultural land, and low crop productivity will adversely affect soil carbon stocks, nutrient storage, and the carbon (C) energy inputs. Consequently soil fertility is reduced and land degradation will increase (Cotrufo et al. 2011). Another important consequence of climate change is increasing temperature which might besides other abiotic stresses increase infection/infestation from pathogens and pests (Korus et al. 2015). For example, high temperatures drive crops to grow faster with a reduced seed maturity time and reduced yields and thus may help certain pathogens to spread. The sustainable use of natural resources is one of several approaches in preventing global climate change and improving food security (Smith et al. 2015). Land rehabilitation is a solution for increasing the arable land area and must make use of ecologically sustainable methods and also take into account the life circumstances of farmers. Improving soil quality and managing its fertility by novel technologies are of fundamental importance for agricultural production and environmental management (Egamberdieva and Lugtenberg 2014). Owing to population growth and increasing food demand, intensive and environment-friendly agriculture integrating the use of bio-fertilizers and bio-pesticides have become the ideal model for many regions in the world (Adesemoye and Egamberdieva 2013). The utilisation of organic, or biofertilizers (manure, composted urban wastes, plant extracts, organic compounds etc.) opens further advanced technologies for combating drought, salinity and improving soil health (Adesemoye et al. 2008). Biofertilizers are usually prepared as carrier for inoculants such as effective microorganisms. Plant beneficial microorganisms including nitrogen fixing bacteria, phosphate solubilizer, or mycorrhizae are important examples for biofertilizer (Maheshwari et al. 2011; Hashem et al., 2014; Egamberdieva et al. 2013, 2015). Biofertilizers using PGPR hold the potential of environmental benefits, support resource–poor farmers in crop cultivation, and hold further prospects in improved sustainable plant production (Adesemoye and Egamberdieva 2013). The use of beneficial microbes in agricultural production systems started a long time ago and there is increasing evidence that beneficial microbes can enhance plant tolerance to adverse environmental stresses, which include salt and drought stress, weed infestation, nutrient deficiency, and heavy metal contamination (Berg et al. 2010, 2013). Based on these capacities, microbial inoculants are considered as environmentally friendly microbial technologies for sustainable agriculture (Hashem et al. 2014). Incorporation of microorganisms in carrier material enables easy-handling, long-term storage and high effectiveness of biofertilizers (Mohammadi and Sohrabi, 2012). The roles of bacterial fertilizers in nutrient uptake, stress and disease management are emerging areas in agriculture not yet fully understood; consequently, the benefits are yet to be maximized anywhere in the world (Adesemoye and Egamberdieva 2013). The arbuscular mycorhizal fungi (AMF) are developing a symbiotic relationship with the roots of most plant species and help their host plant to restore the uptake of mineral nutrients and hence promote plant growth and development. Furthermore, the application of AM fungi can improve the resistance of host plants to a wide variety of abiotic and biotic stresses (Hameed et al. 2014). Previous reports also indicated that AMF play an important function in the reduction of plant pathogens and protect plants against various fungal disease (Tahat et al., 2008).

Biofertilizers

Biofertilizers are products containing effective microbes such as rhizobia or plant growth-promoting rhizobacteria belonging to genera such as *Bacillus, Pseudomonas, Azotobacter, Azospirillum, Bradyrhizobium, Enterobacter, Mezorhizobium*, among others. which when applied to seed or soil, may colonize the rhizosphere or the interior of the plant and promote growth, nutrient uptake and also protect plants from various diseases (Egamberdiyeva et al. 2007; Rokhzadi et al., 2008). Formulation of microorganisms with various carrier materials enables a long-term storage and increased effectiveness of biofertilizers (Trivedi et al. 2012). The different carrier materials for bacterial inoculants such as peat, charcoal or biochar, methylethylcellulose and vegetable oils are especially important for plant production systems in arid and semi-arid soils, which often suffer from high salinity, water stress, temperature stress, and low soil organic matter and nutrients contents (Ardakani et al. 2010). Calcium alginate (CA) gel, a biodegradable microcapsule is another material that has been widely utilized as a carrier for bacterial immobilization, which may protect the cells and has a long-term effectivity under hostile environments (Wu et al. 2011).

In recent studies biochar-type materials have been suggested as inoculant carriers, which may protect bacterial inoculants against environmental stresses such as desiccation, adverse pH, or salinity (Deaker et al. 2004). Biochar application also enhances soil physical, chemical and biological characteristics by retaining water and nutrients, which may reduce fertilizer demands, or irrigation requirements (Sohi et al. 2010). These environmental benefits have potential economic value in the form of increased agricultural productivity, as well as indirect impacts such as water quality protection, and reduced GHG emissions, in addition to the sequestration of carbon (Lehmann et al. 2006). Khavazi et al. (2007) described biochar as an effective carrier material for *Bradyrhizobium japonicum*, allowing the strain to survive in biochar pores more than six months. From those reports it seems that biochar is a suitable carrier material to protect bacterial inoculants against environmental stresses such as desiccation, adverse pH, high salinity, or toxic substances in soil, effectively releasing the organisms and being abundant in supply (Deaker et al. 2004).

Plant response to microbial fertilizers

Mutualistic interactions between microbes and agro-forestry, horticultural and medicinal plant cultures have been attractive for many years (Berg et al. 2013). There have been many reports describing potential uses of bacterial fertilizers, biofungicides as agents stimulating plant growth and protecting plants from diseases under diverse field conditions (Mia et al. 2007). The beneficial effects of *Azotobacter* biofertiliser on cereals, vegetables, cotton and sugarcane under both irrigated and rainfed field conditions have been reported. An application of this biofertiliser has been found to increase the yield of wheat, maize, cotton and mustard by 0-30% over controls (Egamberdiyeva 2007). Anjum et al. (2007) observed that bacterial inocula significantly increased plant growth and yield of cotton over control plants. Similar results were observed by Yasari and Patwardhan (2007) who applied of biofertilizers based on *Azotobacter* and *Azospirillum* strains, increasing canola yield (21.17%), pod per plant (16.05%), number of branches (11.78%) and weight of 1000 grain (2.92%). This rationale is consistent with the observation that plants inoculated with PGPR take up N, P, K and microelements more efficiently from the soil (Cakmakci et al. 2005). Elkoca et al. (2008) demonstrated increased P, K and micro-nutrients in chickpea as a result of *Bacillus* and *Azospirillum* inoculations. Peat-based inoculants of Pseudomonas fluorescens increased plant height (58.1%), number of cobs per plant (19.5%) and number of grain rows per cob (28.2%) in a corn cultivation as compared to the control plants grown under drought conditions (Zafar-ul-Hye et al. 2014). Evidently, the use of a combined inoculation for crop production could result in a significant improvement with respect to various growth parameters (Egamberdieva et al. 2013; Yasmin et al. 2013). Mixed applications of inoculants have been shown to be more effective as biocontrol agents and plant growth stimulators under various environmental conditions (Malusá et al. 2012; Adesemoye et al. 2008, 2009). The application of BioGro biofertilizer based on various PGPR strains resulted in increased rice growth and yield (Nguyen 2008). Formulated microbial inoculants (AMF and *Pseudomonas*) increased plant growth and uptake of of N, P, K, Ca and Mg in sunflower under saline (EC = 7.6 dS m-1) calcareous soil condition.

Rajput et al. (2013) showed that the microbial inoculant *Planococcus rifietoensis* enhanced plant height (29% over the control), biomass (36% over the control), straw weight (50% over the control), and yield (38% over the control) of wheat by alleviating the toxic effects of salinity. Another biofertilizer based on a phosphate solubilizing bacterial (PSB) inoculant *Rhizobium meliloti* combined with phosphorite showed a significant effect on dry matter accumulation in leaves, shoot and root of cotton. Higher yield was obtained after treatment with PSB Rhizobium meliloti, when yield of cotton increased up to 68% (275.0 g-1 plant).

The Rhizobium-legume associations can fix up to 100-200 kg nitrogen per hectare in just one crop season and in certain situations can leave behind substantial amounts of nitrogen for the following crop (Tilak et al., 2005). The reduction of chemical fertilizers by using biological fertilizers based on bacteria involved in nitrogen fixation is one of the most effective steps in sustainable agriculture (Egamberdieva et al. 2013). *Rhizobium leguminosarum* bv. trifolii was reported to colonize rice roots endophytically in fields where rice is grown in rotation with Egyptian berseem clover (*Trifolium alexandrinum*) and can supplement 25–33% of the recommended rate of N fertilizer for rice (Yanni et al. 1997). Mixed inoculation with PGPR and Rhizobium or arbuscular-mycorrhizal fungi creates synergistic interactions that may result in a significant increase in growth, in symbiotic performance and an enhancement of phosphorus, nitrogen, or potassium uptake (Adesemoye and Kloepper 2009; Egamberdieva et al. 2010). In another report, Verma et al. (2010) observed that chickpea inoculated with *Rhizobium leguminosarum* subsp. *ciceri* annually produced up to 176 kg N ha-1 as a result of significant stimulation of plant growth. The peat-formulated *Mezorhizobium ciceri* significantly induced nodule numbers on the roots of chickpea cultivars which showed a high correlation with increased shoot and root weights (Egamberdieva et al. 2014). Zahir et al. (2010) observed that peat-based inocula of *Rhizobium phaseoli* mitigated salt stress in mung bean and improved growth and yield under saline conditions. The plant height was improved by 28.2%, the number of nodules by 71.4%, plant biomass by 61.2%, and grain yield by 65.3% compared with the untreated control. Evidently, the application of a combined inoculation for crop production could result in a significant improvement in various growth parameters (Egamberdieva et al. 2013; Yasmin et al. 2013). Under various environmental conditions, mixed applications of inoculants have been shown to be more effective as biocontrol agents and plant growth stimulators (Malusá et al. 2012; Adesemoye et al. 2008).

Conclusions

The present review indicates, that biofertilizers based on beneficial microbes hold the potential to significantly increase yields of various agricultural crops and thus can be important components of an integrated nutrient management system. The development of stable formulations of PGPRs in sustainable agricultural systems will increasingly replace the use of chemical fertilizers. However, studies on the ecology and activities of bacterial fertilizers in various soils in different regions will require more detailed knowledge. The future trend points to the development of more effective and longer shelf-lived microbial strains to supplement and/or complement chemical fertilizers and pesticides in agricultural practice. If the potential benefits of PGPR in crop production can be maximized, this will improve soil ecological conditions, plant development and resistance against diseases and certainly support strategies in the fight against hunger.

Part III.

Lifestyles and Education

29. Modeling societal transition: introducing a scheme that could serve as a reference-point within the transition-community

Gerhard Frank

Abstract

Collective endeavors require a joint vision; something that people can use as a reference point or guideline that enables them to coordinate their individual activities. There is no doubt that the transition towards a sustainable global culture is a collective endeavor; one that involves people worldwide in lastingly reorganizing their life-style; people from different countries, people of different origins, age and professions. But how do all these people coordinate their activities? Do they bear anything in mind that helps them go into the same direction thus promoting their efforts by reciprocal reinforcement? Do they share a joint understanding of the endeavor they are globally engaged in?

From the point of view of the presenter's scientific work (Frank, 2011, 2012, 2013) such a shared understanding has to take three different parameters of change into account: a psychological-conceptual one, an institutional one, a technical one. Under the circumstance of radical cultural change and reorganization these three parameters form a system of reciprocally interlinked "actuators" or change factors. The psychological-conceptual parameter thereby refers to the cultural paradigm, the worldview that underlies the mindset of the people. The institutional parameter refers to the organizational means by which people coordinate their activities in accordance with their worldview. The technical parameter refers to the technical means of a culture that shape daily life and express and reconfirm the dominating cultural paradigm.

By using these three parameters as interacting coordinates the presenter outlines a holistic transition model that could serve as a reference-point and guideline within the transition-community; one that is still missing to date.

Keywords: experiencing, experiential domains, mind, matter, metabolism.

Introduction

Let me first outline the arguments that form the theoretic basis of the scheme presented in this paper (Fig.1). Arguments number 1 + 2 refer to the psychological-conceptual parameter mentioned in the abstract; argument number 3 regards the processual nature of transition, a point that has been skipped in the abstract due to its shortness; argument number 4 eventually sheds light on the institutional as well as the technical parameter of societal change.

Argument Number 1

I regard human experiencing as the operational substratum of everything that happens in our world. By experiencing we interact with our physical environment and with each other. By experiencing we learn and differentiate our competencies. By experiencing we develop new solutions and technologies. By experiencing we form the rules that underlie our recurring social interactions and institutions. Repeated experiencing eventually brings forth our habits that organize our daily life. These habits form our individual behaviour that by social interaction and coordination amounts to the life-style of a community. Many regard the global crisis as a life-style issue. A point with which I totally agree. According to the preceding line of thought experiencing hence has to be treated as the operational substratum of the societal change many experts postulate for a sustainably balanced world culture.

Before moving on to our next argument I have to detail one point. That is the self-organized nature of human experiencing resulting from its specific structure (Frank, 2012): Human experiencing includes different autonomous processes that are systemically interlinked. I refer to these autonomous processes as the experiential domains. These are: the emotional domain (feeling), the sensorimotor domain (the cycle of action + perception), the communicational domain (conversing), the mental imagery domain (the ongoing process unfolding in my mind´s eye), the rational domain (logical reasoning). Each one of these domains gives birth to a specific type of knowledge consisting of interlinked viable experiential patterns alias knowledge elements: our emotional knowledge, our sensorimotor knowledge, our communicational / social knowledge, our mental imagery / narrative knowledge, our rational knowledge. By being interlinked these domains reciprocally synchronize their knowledge elements thus forming a more or less coordinated overarching cognitive entity: our habitus.

Argument Number 2

Mind and matter.

The Cartesian dualism is *the* conceptual cornerstone of the modern habitus, whether one is aware of it or not. It shapes our experiencing in a profound way. Phenomena either are material or immaterial, the western mind says. There is no third category. And, the dualism subdivides the world in two realms; one that can be measured and described in objective, scientific terms and one that cannot be handled in that way. Matter is measurable, whereas the mind is not. A point that deeply influences the way we react to the current crisis, as will be demonstrated later. Hence we use the Cartesian dualism as an important reference point.

Argument Number 3

Cultural development.

The current crisis undoubtedly ushers in a new era. The culture itself is about to undergo a specific development triggered by the crisis. Cultural change is nothing new. No culture is immortal. Ancient Greece died out. Ancient Rome fell apart. And not to forget the European Middle Ages that eventually turned into a modern follower, the culture we Cartesian people belong to. Is there a pattern of cultural evolution? I would say yes, there is one, from a cognitive point of view, again a dualistic pattern: differentiation and reorganisation; two phases that alternate.

Cultures are based on worldviews, narratives that explain the unexplainable. Where do we come from? Where do we go? Etc. Out of this worldview and in line with its assumptions the operational knowledge of the people develops, the means that help them organize their societal metabolism. In the beginning these means consist of a few competencies: base technologies, social base choreographies etc. Sooner or later new skills and technologies evolve from the existing ones thus multiplying the people´s capabilities. In other words, the cultural knowledge differentiates. Hence I call this phase differentiation. But on certain points in history, serious metabolic problems arise, often provoked by the culture itself, that cannot be solved by the traditional means. The European Middle Ages are a good example in that respect. Their end – among others – was induced by widespread deforestation, provoked by an overshooting resource use (Rifkin, 1980). Timber was a prime resource in these days, the crisis was indeed severe. By reorganizing their worldview from a monotheistic (geocentric) forerunner to a mechanistic (heliocentric) follower, people eventually found a way out of their dilemma (Capra, 1982). The transition from medieval to modern times was hence based on a mental and associated societal reorganisation fuelled by a radical change of the energy environment.

Argument Number 4

I regard technologies and institutions as key formative factors of collective experiencing. We modern people identify ancient cultures by prime technologies like stone axes or iron tools assuming that these technologies were central factors of everyday life that shaped the experiencing of the people, the way they approached and made use of natural resources, the way they organized their coexistence, the way they reasoned about their problems and possible solutions. For the same reason a future archaeologist in 2.000 years will probably get an idea of our modern civilisation by reference to the computer scrap he will find in the waste deposits of our time. Undoubtedly, computers are the stone axes of our age and have a deep impact on our worldview!

Similarly we study institutions like knighthood or priesthood to find something out about medieval life and experiencing. Again, we assume that institutions or functional systems, as the German sociologist Niklas Luhman (1986) put it, have a formative impact on the way how people handle their daily life. Their respectively specific logics and communication patterns define the ways how specific problems are perceived and dealt with (Luhman, 1986). Modern economy as a functional system for instance can only “perceive” and handle what is expressible in financial terms. From an economic point of view, peace for instance, does not exit. You can´t buy peace. War instead can be “bought”: weapons of destruction, machine guns, missiles, bombs etc. Yes, these technologies shape the experiencing of people, their conversations, their dreams, their fantasies, and last but not least their problem solving!

An interesting line of thought, isn´t it? I will pick up on it by implementing and making use of both factors in my scheme.

Results and Discussion

The scheme now (Fig.1) combines the preceding arguments in a coherent manner. In the following I will give some additional explanations regarding its key elements before I will say something about the transition-process itself.

The relationship between mind and matter / metabolism

Due to its key role in our mental development as modern human beings I have used the Cartesian dualism of mind and matter as a base category of the scheme. For the sake of a better understanding I suggest adapting the dualism slightly as follows.

Instead of matter I recommend using the term metabolism since “metabolism” means clearly a process that includes (the exchange of) matter and energy. The term matter instead appears very static whereas life, the base phenomenon we are talking about, is not static at all. Hence a process oriented perspective from the beginning appears to be more appropriate.

We can now define the relationship between mind and matter / metabolism. It is a circular relationship: The (human) mind organizes the metabolism that reciprocally enables the mind to operate. There is no mind without a metabolism. If I starve, my mental operations, e.g. my perception and my reasoning would immediately stop. And there is no (human) metabolism without a mind. No mind - no plan - no execution of a plan that could be executed in order to maintain the metabolism, i.e. the exchange of energy and matter that is indispensable for life.

In other words, the scheme is about organizing our human metabolism, the life-giving flow of energy and matter. We need energy and matter to live, individually and collectively. Hence this flow has to be appropriately organized. In that regard we have to distinguish three different operational levels which are closely interlinked with each other:

- Mental operations (mental problem solving), these underlie and are affected by
- communicational operations that eventually organize
- the handling of the metabolic flow, i.e. the exchange of energy and matter.

How institutions and technologies come into play

Why communication? Because I am not alone. I am part of a community. Hence I coordinate my doing with my mates from next door, from the next street, from the neighbouring town, from the neighbouring country etc. We communicate. If the community gets too big and complex effective communication gets increasingly difficult.

To make it still manageable institutions are introduced which, according to Niklas Luhmann (1986) reduce complexity by functional differentiation. Communication is thereby split up in functional systems like for instance Legislation, Politics, Education, Religion, and Economy. Each one of these systems follows a specific communicational code that simplifies the organisational processes.

Technologies eventually provide specific tools. That can be a (material) means like a hammer for example but also (immaterial) means like an algorithm. A hammer – among others - brings matter into a form so that we can use it. The hammer is hence a means of making matter available. It therefore belongs to the exchange-of-energy-and-matter level.

The algorithm instead as a tool belongs to the mental-operations level. It helps me calculate a price, for instance: Multiply these two numbers and you know what 5 kilos apples cost. This is clearly a mental operation. It helps organize my personal metabolism aka nutrition.

What change as a phenomenon adds to our understanding

What happens when, let´s say, mental patterns change? When mental patterns change, the patterns of my doing / experiencing change as well. When the patterns of my doings change, the patterns of my acting upon my environment change as well. When my acting upon my environment changes, the structure of the environment changes. When the structure of the environment changes, the impacts of the environment on my senses changes. When the impact of the environment on my senses changes, the internal relations change that underlie my mental operations; in other words, the status of my mind, my mental patterns change/s. We have returned to the beginning.

My doing acts upon my physical environment. My physical environment impacts my mind … my mind fuels my doing etc. etc. The question now is: Where to intervene in this endlessly revolving cycle in order to make a difference with regard to our crisis.

Where to intervene?

Theoretically, intervention can take place on each of the three organizational levels; the mental level by addressing the mind; the communicational level by addressing the institutions, the metabolic level by addressing and involving new technologies.

Is there one level that is more important than the others? I would say yes. It is the mind. Why? Because without a mind no institutions and no technologies either could exist, whereas mental operations necessarily have no institutional nor technical requirements. This is one reason. The second reason is: The mind is easier accessible than any institution or technology. It is the point in the cycle I myself can individually and directly touch.

Due to the importance of the mind I feel obliged to the following (very) brief introduction.

How does the mind work?

The mind works conceptually. The mind forms theories and concepts that in a next step are used for organizing its own operations. Here is an example: The reader is probably familiar with the cause-effect logic. A basic concept which underlies and guides our experiencing. How was it acquired? Like any other mental concept. By continuous learning and then repeated application. Being repeated again and again it eventually turned into a fix element of our mental software. Now we can make use of it by letting it organize our mental operations and experiencing; the sensorimotor action-and-perception cycle, our communication, our reasoning, and last but not least the endless flow of images in our mind´s eye.

What about the scheme now?

One last remark before I can address myself to the transition process that the scheme delineates. I equate the mind with the process of experiencing. This might be philosophically questionable. I am aware of it. But operationally it works, since there is no experiential coordination that does not use the cellular wetware of the mind. The operating mind brings forth my experiencing. Accordingly we can identify the mind with the five experiential domains I have briefly outlined above: the emotional domain (EM), the sensorimotor domain (SM), the communicational domain (CO), the mental imagery / narrative domain (NA), the rational domain (RA). These domains will serve as a guideline for my following line of thought.

The scheme expresses the relationships outlined in the preceding text. The mind and its operations (experiencing) form its bottom half. The mind´s operations induce corresponding processes in the human metabolic sphere (upper half). These processes manifest in specific technologies and institutions that by shaping human experiencing reciprocally reinforce the operations of the mind (circles with arrows indicate reciprocal feedback).

The scheme´s time axis spans between the 11th century and the 26th century. It comprises late Middle Ages, the modern age, and our future. A precise timeline including successive centuries has been deliberately omitted, since I wanted to avoid any specific temporal correlations.

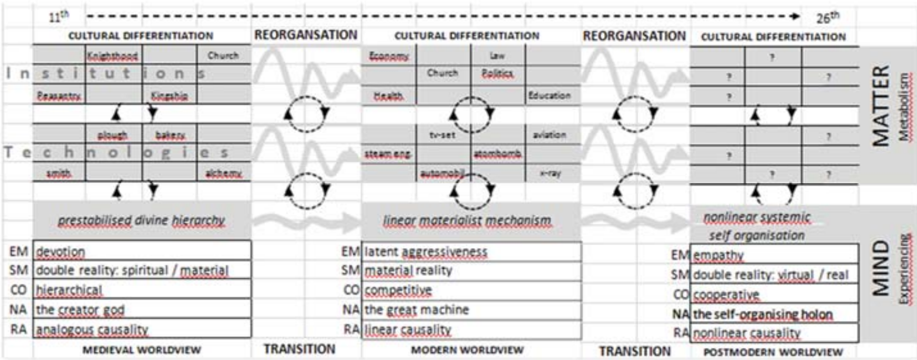

Figure 1: *The Sustainability Transition Scheme. Alchemy, knighthood, church ... are examples without raising a claim of completeness. Further explanations see text.*

Medieval mind and metabolism

Medieval life was characterized by a mind-set with a mighty god as the universal creator in its middle.

Everything on earth – both natural and societal order - was perceived as being part of a pre-stabilised divine hierarchy that could not be altered. The underlying cultural narrative (NA) explained everything from the beginning to the end; how *god in the beginning created the heavens and the earth*, including plants, animals and men; and how in the end all living creatures will be admitted into his kingdom of heaven, provided they had led a decent, faithful life.

In accordance with this underlying cultural narrative people organized their daily experiencing. They experienced their world as a place where angels and men side by side existed; a spiritual, material concept that deeply shaped their doing and perception (SM). Similarly their logical reasoning that explained everything by putting it in analogy to the pre-stabilised, divine hierarchy (RA). A habit, which was reflected by their recurring communicational patterns shaped by a hierarchical society and by hierarchical institutions (CO). This all was affect-logically supported and nourished by a culturally emotional undertone or ethos (Berman, 1981) that could be best referred to as devotion (EM).

The medieval worldview fuelled a life that metabolically was based on low-tech agriculture and livestock farming. It was a world where people made use of what god has given them: animals, fruits of the earth, water, wind, and not to forget timber, the main energy source and building material of these times.

As the living conditions got worse through increasing exploitation of the medieval resources, people started reorganising their worldview and mind-set. A radical societal transition set in that eventually turned the medieval society into its modern follower.

Modern mind and metabolism

Other than its medieval forerunner, the modern narrative depicts the world as a great material machine governed by mechanical laws and forces (NA). Its parts can be analysed and understood by applying a linear cause-effect logic (RA). Reality is treated out and out as a quantifiable material issue (SM) with living entities in it (species) that compete for resources. Consequently competition is a predominant attribute of human social life (CO). A fact that is enforced by an appropriate ethos: latent aggressiveness (EM).

The modern mechanist worldview fuelled an unprecedented cultural success story powered by an incredible expansion of material knowledge and techniques. Based on the exploitation of planetary matter and once huge resources of fossil energy the materialist human mind seemed almost unstoppable for a long time.

But now a similar situation, like the one at the end of the Middle Ages, has occurred again: a crisis induced by our overshooting life-style. We hence are well advised to reorganize our mind-set once again, like our forerunners did over the course of the medieval-modern transition.

The postmodern mind

Latest scientific developments foreshadow the mental attractors that will probably underlie the postmodern mind-set. The linear logic of modern people will in all likelihood be replaced by a non-linear reasoning (RA) (Maturana and Varela, 1998) with a self-organising living planet earth at its centre (NA) (Lovelock, 2000). Ruled by symbiotic principles (Margulis, 1998) it will serve as model for a cooperative life-style (CO) (Eisler, 1988) affect-logically fuelled by an appropriate ethos: empathy (Rifkin, 2009). Based on the appearance of virtual technologies at the end of modernity the postmodern mind-set will learn to combine the best of both realities, virtual reality and sensorimotor reality (SM).

Conclusions

A new epoch dawns. Where will we journey this time?

I don´t know yet which effects the outlined mental reorganisation will have on both institutions and technologies in the future. The reason for this appears understandable: The mental reorganization on a large scale has not occurred yet. The great majority of people worldwide still makes use of the outdated modern mind-set since they have no alternative available; they simply got no chance to develop an alternative so far.

Hence, in the long run the crisis is not an expert-issue; it is an issue of the majority of people, of laypeople and their learning process.

One final remark: A materialist mind tends to overestimate matter and quantification, while at the same time underestimates itself, the mind and with it the unquantifiable qualities of life. To overcome this bias might be the biggest challenge on our way to a sustainable life-style.

Time will tell whether we will make it or not.

30. Sustainable energy systems in developing countries – The implications of Sen's capability approach and Lund's choice awareness theory

Claudia J. Kuhnke

Abstract

Two of the main problems in the realization of sustainable development are a comprehensive energy supply and the consequences related to energy use. Sen's Capability Approach (1985) for a life worth living and Lund's Choice Awareness Theory (2010) are analyzed as to their implications for the integration of an energy system in developing countries orientated on sustainability. While all people should have the opportunity to live a life worth living, each individual must also be responsible for their own choices. However, individuals can only be held responsible if they are aware that they do have a choice. The paper argues that the successful establishment of the idea of sustainable development requires more than just a few people in a society being aware of the choice. Rather, it is essential in a successful development process aimed at sustainability that a general awareness of the choices be present. The theoretical implications discussed in this paper support the implementation of a sustainable energy system in developing countries.

Keywords: energy systems, sustainable development, capability approach, choice awareness, developing countries.

Introduction

The challenges developing economies have to meet while working on the development of a comprehensive modern energy supply system are diverse and the implementation of an energy system aligned on the concept of sustainability that simultaneously enforces a sustainable development is even more complex. This paper first highlights the importance of energy systems in the concept of sustainable development and specifically, the problems in developing countries seeking to transition to sustainable energy systems. Sen's capability approach and Lund's idea of choice awareness can be related to the situation in developing countries making a transition to a sustainable energy system. These two approaches are analyzed and connected to the concept of sustainable development. Conclusions are then drawn regarding the implications for the transition towards a sustainable energy system.

Sustainable Development and Sustainable Energy Systems

In 2012 the UN General Assembly (2013: 2) declared the period from 2014 to 2024 as the "United Nations Decade of Sustainable Energy for All." This declaration and a broad body of literature[13] emphasize the relevance of sustainable development and the related urgent need to change current energy systems more towards sustainability. Two of the main issues in the scientific discussion are the perils for the climate and environment (which are proceeding from energy dependence on fossil fuels), and energy security issues (Chen et al., 2014: 2). Security questions emerge from the potential danger of an energy shortage caused from the

[13] Among others: UN (2002), Hammond (2004), Jefferson (2006); Bhattacharyya (2012) and Mainali et al. (2014).

finiteness of fossil fuels and the worldwide dependency on a few fuel-exporting economies (Winzer, 2012: 37 & pp 42).

The designs of existing energy systems in developing countries present even more problems: for example, infrastructure problems in some regions and countries are already or are still causing a steady shortage of energy (IEA, 2012: 532) and there are also severe health risks associated with the energy sources currently used (IEA, 2012: 532; Sovacool, 2013: 393; Terrapon-Pfaff et al., 2014: 6).

The concept of sustainable development urges a development that addresses all these problems, while taking the social, environmental, and economic dimensions into consideration to ensure intra- and intergenerational justice.

Additional obstacles to change in the energy systems of developing countries

Implementing an energy system aligned with the concept of sustainability is a complex process while promoting sustainable development. There are some major issues regarding the implementation. These are driven by the complexity of the idea as well as the requirements of an energy system in addition to the normative character of the idea of sustainability. But there are greater problems regarding the transition of energy systems in developing countries. In the past, many renewable energy projects have failed and the reasons for this failure are multiple. Cultural differences were ignored, traditional solutions were not well-suited for the local situations, participative decision-making was denied in different project stages, and finally, there are questions regarding the maintenance of new energy technologies and devices. The projects often failed to see the importance of knowledge transfers and often faced institutional, political, and financial barriers (Martinot et al., 2002: pp. 13).

Another important point is that establishing a new energy system could be especially risky for those countries or regions because they will face relative high sunk costs through path dependency compared to people in more developed economies or regions (Bhattacharyya, 2006: 662). Those obstacles can induce anxieties and possibly lead to retaining the current energy system. However, preserving a status quo energy system is rather short-sighted, considering the problems of current energy systems and the promise of sustainable development.

How to accelerate the transition towards sustainable energy systems in developing countries

A sustainable energy system has to meet demands regarding availability, affordability, adequacy, convenience, and reliability (IEA, 2012: pp. 541) while considering the three dimensions of sustainability both for present and future generations.

Sen (2013: 9) notes that people are the “ultimate agents of change.” Consequently, in terms of this case, individuals and institutions must be familiar with the concept of sustainable development and the potentials presented by the implementation of sustainable energy systems before the various aspects of sustainable development can be addressed. An informed population is critical for the successful implementation of a sustainable energy system. Knowledge or awareness of future technological, economic, social, environmental, and health related benefits is an essential element in real sustainable development. Such development also demands the individual have freedom of choice and the opportunity to exercise it.

Implications of Sen's Capability Approach

The two terms freedom and development are strongly interrelated in Sen's Capability Approach. In "Development as Freedom" Sen argues that development can be seen "as a process of expanding real freedoms that people enjoy" (Sen, 1999: 3). In this context freedom must be understood as the ongoing processes that allow people to have the freedom of their actions and decisions and the real opportunities. Those opportunities depend on the personal and social circumstances of the people (Sen, 1999: 17).

The Capability Approach

Sen distinguishes between freedom as both the primary end and means of development. As a primary end, freedom symbolizes the constitutive role of choice in development. This kind of freedom is crucial for people's well-being and includes fundamental capabilities. But there is also an instrumental side that implies those freedoms can contribute to achieving "ends" (Sen, 1999: pp. 36).

Capabilities or a capability set are a person's real freedoms. Capabilities are the opportunity to combine and achieve alternative living conditions. The alternative lifestyle can be described as achieving a "combination of alternative functionings" (Sen, 1999: 75).

In this concept, the term functioning represents a person's achievements in being or doing what they have reason to value. Functionings are the use each individual makes out of the commodities at their disposal (Clark, 2006: 34). They can range from basic ones, like being well nourished, living under a roof, or having light to more complex ones, like having self-respect or the impression of being able to contribute to the society, for example, by protecting the environment through decisions regarding the kind of energy used.

According to Sen there are five types of instrumental freedoms – political freedoms, economic facilities, social opportunities, transparency guarantees and protective security. These five freedoms are necessary instruments to enhance human capabilities (Clark, 2006: 40; Sen, 1999: 38).They can also be identified as being relevant to achieving a development that is considered sustainable.

The Capability Approach and Sustainable Development

Sustainable development can be defined as a development that promotes inter- and intra-generational justice within social, economic, and environmental boundaries. The Brundtland Report calls for the fulfillment of the needs of present generations without narrowing the needs of future generations (WCED, 1987: 37).This means achieving a situation in which present and future generations can live the life they value and enjoy. To achieve this implies having the freedom to choose the way of life those generations want (Sen, 2013: 9).

According to this concept, there is a possibility to redefine sustainable development as development that gives freedom to the present without compromising the freedom of future generations.[14]

To address the obstacles to sustainable development it is essential that individuals and institutions be familiar with the overall concept of sustainable development. This includes knowledge of the obstacles and opportunities that coincide with the implementation of an energy system based on sustainability. This is because people should have the same capability to enjoy a life worth living. Nevertheless individuals should also be held responsible for their choices (Robeyns, 2006: 353; Sen, 1999: 288; 2009: 19).

With this in mind, when there is a decision to be made between traditions or the status quo and up-coming possibilities such as a new energy project, it should not be only cultural experts or local elites that decide (Clark, 2006: 38). Instead, "it is the people directly involved who must have the opportunity to participate in deciding what the choice will be" (Sen, 1977: 329). This is only possible if individuals are aware that there is a choice to be made. There has to be a real opportunity to choose and act.

In addition to being responsible for their own choices, Sen stresses the idea of a social responsibility as inherent in human beings. He refers to "acts of commitment agency"[15] (Leßmann, 2011: 55), whereas, the notion of commitment is strongly related to the importance of choice following 'one's morals' (Sen, 1977: 329). Both, responsibility for oneself and social responsibility depend on the possibility to choose and the awareness of the choice.

The Capability Approach and Implications of Lund's Choice Awareness

Being aware of opportunities at the individual level is important for a transition process towards a sustainable energy system. But it is not sufficient to encourage a transition towards sustainable development or sustainable energy systems when just a few individuals participate in the decision-making process. However, the first step towards change in the system is when a few individuals are aware of their capability to choose. There must be a general social perception of having a true choice, which Lund (2010: 6) calls a "collective perception of having a true choice" or "choice awareness." This is because the social climate and institutional framework constrain the power and capabilities of individuals (Sen, 1999: 288). This is why a successful change in behavior – which is essential for a transformation towards sustainable development – does not only require individual freedoms, it is also heavily reliant on social processes (Sen, 2013: 17).

Social processes as mentioned in Sen (2013: 17) are essential to Lund's Choice Awareness Theory. Lund stresses two theses regarding radical technological change: First, a successful implementation of a new technology depends on a discourse with and the influence of existing institutions (Lund, 2010: 28). Secondly, overcoming old structures to generate choice awareness – making the society aware that there are true choices – is essential (Lund, 2010: 32). This is because the notion of having no real choice is critically significant. The absence

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[14] Sen (2013: pp. 9) argues that there are arguments to broaden the need-based concept of sustainable development into a freedom based one. For critical analysis regarding a linkage between the concept of sustainable development and Sen's Capability Approach, see Leßmann (2011) and Spillemaeckers et al. (2011).

[15] Leßmann (2011: pp. 44) describes Sen's concept of well-being and agency.

of individual choice can lead to the perception that people are lacking power. This can lead to resignation and is a fatal problem on the individual level. But Lund addresses choice awareness on a social and not on an individual level (Lund, 2010: 14).

When addressing choice awareness on a social level, there are serious negative effects on the development processes of a society if there is a feeling of no choice within the society. On the contrary: if individuals in the society experience that they indeed do have a choice – even if just the choice to say no – Lund claims there is the possibility that they start to think of real alternatives (Lund, 2010: 15). Those real alternatives are necessary to promote sustainable energy systems in developing countries. Moreover, it is important that those ideas and freedoms to choose are recognized not just by some individuals but rather by a critical portion of the society. Those real alternatives can also be called capabilities.

Sustainable Energy Systems through Choice Awareness

If the ideas from Sen's Capability Approach and Lund's Choice Awareness are accepted, there is a possibility to accelerate a successful transformation towards sustainable energy systems. Dincer (2000: pp. 172) pointed out that to achieve sustainable development innovative energy strategies promoting renewable energy resources, adequate financing, monitoring and evaluation tools are essential. He also identified the importance of public awareness, information, environmental education, and training for a successful transition.

On the individual level, three stages have been identified regarding the decision to transition from traditional to modern energy forms[16]: The first stage is the decision to transition (should the household switch or not). The second step involves the decision about the type of appliance that should be used. The last decision to be made concerns the issue of the consumption profile (Bhattacharyya, 2006: 660).

These three individual decisions require knowledge about possible options, the pros and cons, and the freedom to choose the best suited option. This means there has to be an information process that shows people the real opportunities and that they indeed have a choice (Lund, 2010: 32).

In the context of sustainable development this also includes knowledge about the impact these decisions have on all three dimensions – social, economic, and environmental – and on intra- and intergenerational justice.

According to Lund, it is important that the process of raising choice awareness takes place on a social and not just an individual level. Lund (2010: pp. 33) identifies four strategies to raise choice awareness: (1) identifying technical alternatives, (2) performing socioeconomic feasibility studies, (3) providing statutory regulation, and (4) empowering democratic infrastructure. Together, those four strategies can be taken into account when planning new energy projects in developing countries. In particular, to eliminate the additional obstacles to change mentioned above, steps (2) to (4) have to consider the socioeconomic factors in the transition process towards a sustainable energy system.

[16] There are additional questions that have to be answered during these three stages e.g. how the transition should be financed.

Conclusions

Achieving sustainable development is heavily dependent on a transition to sustainable energy systems. The ultimate decision what to make out of an opportunity is a responsibility of each individual. Individual capabilities are not only essential for a transition process, they are also important to raise choice awareness and to increase the social knowledge about energy systems oriented on sustainable development. Still, it is the society and the state that have a responsibility to enable freedom of choice. There has to be a measure of choice awareness in a society that promotes crucial decisions, which are more easily made in a social context than outside of it. The focus of further study will be on Lund's strategies (2) to (4) and placing the four steps into a context with sustainable energy indicators.

31. Life quality and sustainability for hog breeders

Msc. Ing. Alberto Huiman Cruz & Ing. Ana Hummel Miñano

Abstract

Located in Cajamarquilla, district of Lurigancho - Chosica, the project area is characterized by informal, unhealthy and high pollution hog breeding; generating low incomes and no competitiveness. Therefore, intervention strategies have been designed for the development of hog breeding: (i) Implementation of a sustainable breeding system; (ii) Development of production chains to improve the sanitary and commercial *status* of the farms, through associativity; (iii) Promote the efficient use of waste generated in farms, reducing the rates of local environmental pollution through the production of bio fertilizers.

Keywords: hog breeding, efficiency, agricultural solid waste, bio fertilizers.

Introduction

Local Issues

Hog breeding has been introduced in urban and peri urban areas in Lima due to three conditions (i) Economic inequality, which has generated the migration of people from the provinces to the capital of the country in search of opportunities; (ii) Excessive production of organic solid waste without treatment which, according to PIGARS Lima 2014, 52% of the municipal solid waste comes from organic origin, which in turn is used for feeding pigs; (iii) the need of protein source in food since it is estimated that per capita consumption of pork increased from 3.6 kg / person / year to 5 kg / person / year.

The project is developed in the associations of Saracoto Alto and Haras el Huayco, jurisdiction of the district of Lurigancho - Chosica, both associations contain a total of 255 informal hog breeders with farm size from 5 to 80 sows, who face problems such as (i) inadequate facilities, either overcrowded or sub utilization of the space, without comfort conditions and animal welfare; (ii) Zero or near zero application of good livestock practices leading to high mortality and morbidity of animals, especially piglets; (iii) No treatment of agricultural solid waste generating high local pollution; (iv) Feed of pigs based on municipal solid waste of organic origin without thermal treatment and poor conditions of preservation; (v) No sanitary conditions; (vi) Inadequate marketing mechanisms; and (vii) Lack of coordination of municipal and state policies for formalization and inclusion in the production chain. All these problems contribute to an informal breeding, with high levels of environmental pollution, low quality products which in turn are poorly marketed through intermediaries that undermine the limited economic gain, in addition to auto social exclusion of the breeders for fear of being rejected because of the economic activity they develop.

Objectives

General:

Contribute to improve the living standards of the hog breeding families in Cajamarquilla, through the insertion into formal production chains.

Specific:

- Implementation of a sustainable hog breeding system
- Develop associativity as an insertion model to the production chains, improving the sanitary and commercial status of the farms.
- Promote the efficient use of waste generated in farms, through the production of bio fertilizers

Methodology

The Project aimed at improving the production infrastructure at its most critical point, the maternity area, for which movable maternity cages would be provided in order to reduce the high mortality of piglets that reached 70% and in exchange the beneficiaries would implement the external modifications of the area. A baseline was developed, determining: access to public services, quantifying hog breeding, amount of organic agricultural waste produced and its treatment, and the characterization of the beneficiary hog breeding families in the social aspect.

Then group and individual goals were established; productive, environmental and social indicators; and methodological strategies: (i) custom-made technical assistance aimed at improving the productive and environmental critical points of each of the 36 beneficiary hog breeding farms, maintaining the individuality of the hog breeders, which allowed an approach to their lifestyle and experience, develop a profile of each one and gain their confidence towards the technical team; (ii) training workshops as a group strategy, in order to exchange experiences, teamwork allowing the collective good over the individual, leadership development, recognition of the image of the hog breeder; (iii) incentives program, based on field trips for the recognition of successful experiences elsewhere, improvements in internal competencies at farms, recognizing the achievement of goals within the group where the effort and good practices were acknowledged as a strategy for improving their self-esteem, developing social relationships with external participation in technical and productive events.

Achieved Goals

Hog Breeding

Hog breeding has achieved a notorious growth with regard to the improvement of production indicators, as the following Table No.1 shows

Indicators	Baseline 2013	Indicators 2014
Mortality of piglets being crushed	70%	2.5%
Mortality of piglets due to diarrhea	40%	6.32%
Morbidity of diarrhea in piglets	80%	11%
Fertility of sows	50%	93.62%
Proper handling at birth	10%	100%
Prevention of anemia in piglets	20%	100%

Table 1: *Comparison of production indicators Baseline – today (Source: Peru Waste Innovation S.A.C., 2014.)*

The improvement process of hog breeding through the application of Good Livestock Practices during the period 2013 - 2014 established different programs together with strategic allies that would provide sustainability to the improvement process and present the following results:

- Health disease prevention program implemented by the National Service of Agrarian Health (SENASA): decreasing the morbidity of diarrhea in piglets up to 69%, 100% implemented program of vaccination and disease prevention based on Regulation of Porcine Health System and Immunization Schedule.
- Genetic improvement program implemented by the Pig Experimental Unit - La Molina National Agrarian University (UNALM): 70% increase in the implementation of artificial insemination and improved pigs purchase with a 27.5% genetic improvement and a future advancement of quality in 89% with the birth of new litters.
- Promotion Program and encouragement of entrepreneurship by the Regional Agrarian Sub Management of the Metropolitan Municipality of Lima (MML): a formal partnership with a view to marketing was obtained, with negotiation skills for improving marketing channels.

All these results are routed to two basic indicators of the project as shown in Table No.2.

Agricultural solid waste management

Municipal organic solid waste treatment as source of pig feed

In peri ruban hog breeding, the use of municipal organic solid waste as source of feed is regulated under the Regulation of Porcine Health System, which indicates the thermal treatment at 90° C for 60 minutes, constantly stirring.

The hog breeders utilizing organic waste were all local pig farmers, as the project was implemented and as cost-cutting measure, the use of organic waste was reduced to 40% in the areas of pregnancy and 20% reduction in the fattening area, these being 100% treated waste, protecting the health and sanitary conditions of the pork.

Agricultural solid waste treatment

The term agricultural solid waste refers to those coming from agriculture, forestry, livestock, poultry and animal slaughtering centers activities under Article 5 of the Regulation on the Management of solid waste in agriculture. The project initiated a program of bio fertilizers in order to treat organic type waste (excreta), for this, the proposed treatments, should be accepted in three ways; (i) technically, easy implementation and maintenance, with a manageable product. (2) economic aspect, low investment and profitable product; (iii) social aspect, acceptance of the hog breeder in the management and marketing of the product. Under these aspects the following treatments with their respective outcomes were assessed:

- Composting: four parallel samples of 1.5 t of excreta, with water, efficient microorganisms and plant waste from local pruning and / or donation of this material by the local municipality, were made, the temperature parameters (°C), pH and humidity were evaluate. The product resulted in an intermediate quality due to physicochemical characteristics. It was not socially acceptable because the demand for the implementation and management of labor did not justify the market price or the space used.

- Anaerobic Bio-digestion: This process was implemented in order to treat the excreta to produce biogas, and biol (liquid effluent); treatment because the initial investment is too high, too low biogas production (does not cover even 1% of energy requirements) and the effluent has high fecal coliform counts.
- Briquettes: based on the mix of excreta, water and combustion material such as wood and/or paper. The product is used as combustible material, but technically it was not accepted by the rejection of hog breeders to handling of materials.
- Lactic Fermentation: based on the mix of excreta, water, efficient microorganisms and source of carbohydrates. The products are used as liquid foliar bio fertilizer, this was the most widely accepted treatment that presented no health risk for fecal coliforms. Currently being conducted on farms.

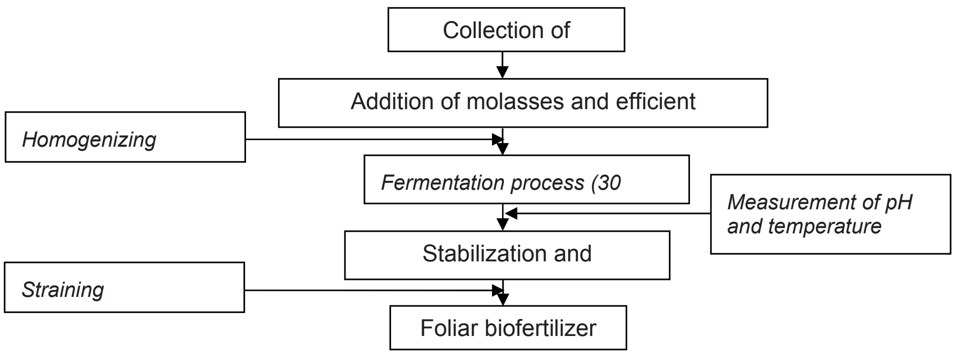

Figure 1: *Lactic Fermentation Process for foliar bio fertilizer production*

Currently, the foliar biofertilizer is being commercialized as an additional income for the hog breeding families.

Social Aspect

70% of the beneficiaries are women family mothers who take care of parenting and of the administration of the farm. 14.7% are elders and they cannot obtain a job anymore, so they saw hog breeding as a form of subsistence. 19.4% present some type of disability that does not allow them to find a job.

The project, through team work strategies, developing self-esteem and leadership, has achieved the goal of improving the image of the hog breeder as an entrepreneur, has empowered women in decision-making in their small businesses, has included people with disabilities as well as elders to a decent work with corporate vision.

Economic Indicators

The economic indicators have been determined to direct most of the activities towards sustainability of the project, at productive, environmental and social levels. Table N° 2, shows us the results obtained to date.

	Baseline 2013 (Annual accumulated data)	Current Result (Accumulated data to Sept 2013 – July 2014)
Sales (A)	S/. 98,473.54	S/. 131,502.97
Costs and Expenses (B)	S/. 89,458.49	S/. 86,609.84
Cash Generation (A-B)	S/.9,015.00	S/. 44,893.13

***Table 2:** Economic indicators*

Conclusions

- The non-treatment and bad disposal of agricultural solid waste generates environmental pollution problems despite the existence of legislation.
- The program of bio fertilizers, aims to provide a sustainable solution in time for agricultural solid waste (excreta), with the production of foliar bio fertilizer, the same being articulated to the principles of food safety being a product free of chemicals applicable to any type of agriculture.
- The anaerobic treatment for biogas production has weaknesses in the face of a society close to the cities where the use of natural gas at a lower price and higher heat capacity is a more attractive and economical option.
- The bio produced by the anaerobic biodigestion treatment presents health complications to be marketed, by the presence of fecal coliform that limits the application and handling of it.
- The sustainability of an integrated project should have the main elements of value creation and revenue growth, production of goods and services, promotion of citizenship and promotion of social capital, with the transverse axis generating positive environmental impacts.
- The increased visibility and dignity for low-income sectors as well as building trust (within the group and the individual), reciprocity and cooperation are fundamental to the empowerment of women and excluded population, make of the project an opportunity for improving the quality of life through social and worthy recognition of people.
- The project provides tools of production, environmental management and productive commerce and marketing based on business plans, marketing and image, validated by the beneficiaries in order to generate membership guidelines to be followed to ensure the success of social entrepreneurship and businesses.
- The strategic public - private partnerships enable productive-environmental development projects to generate a multiplier effect, not only locally, but nationally with the possibility of replicating validated management models.

32. Spatial assessment of subjective value of forest cultural ecosystem services, a case study in Japan

Kiichiro Hayashi, Makoto Ooba, Yasuhiro Hasegawa

Abstract

The purpose of this study was to do a spatial assessment of the subjective value of cultural ecosystem services (CESs) as a case study in a Japanese forest. Mountain rural towns in Toyota City, Aichi Prefecture, Japan were selected for this study. A three-phase approach was used and comprised a face-to-face questionnaire, a web-based questionnaire, and a drop-off and pick-up method (DOPU). The results of the study revealed that each forest site had a different combination of CES values. Regarding spatial distribution of subjective value, the importance of CESs inside towns may be higher than that of the adjacent area in some ESs. Residents recognized the wider scope of the CES values than visitors did. The importance of CESs may depend on people's experiences at the relevant site.

Keywords: ecosystem service, biodiversity, forest, cultural ecosystem service.

Introduction

Cultural ecosystem services (CESs) are an ecosystem service category of the Millennium Ecosystem Assessment (MA), which was created in response to the United Nation's initiative in 2005(Millennium Ecosystem Assessment 2005). Ecosystem services (ESs) include CESs and provisioning, regulating, and supporting services. The spatial distribution of CES beneficiaries may depend on the value people subjectively assign to various CESs. For example, for people who enjoy autumn leaves, the aesthetic value of the mountain forest is very important even if they must drive a long way to enjoy them. Few studies have addressed the spatial characteristics of ESs (including CESs) according to their subjective values (Garcia-Nieto et al. 2013, Martín-López et al. 2012, Ota et al. 2013, Raymond et al. 2009, Sherrouse et al. 2011).

The purpose of the current work was to use a case study in a Japanese forest to understand the spatial characteristics of the subjective value of CESs. Mountain rural towns in Toyota City, Aichi Prefecture, Japan, were selected for the study. This paper presents a general overview of this study.

Study method

Toyota City is located in Aichi Prefecture (Figure 1). Overall, approximately 68% of the total area of the city is covered by forest and the towns Inabu (Inabu branch of the City: N35.216, E137.509) and Asahi (Asahi branch of the City: N35.232, E137.362) are located in the northeast part of the city, where the approximately 84% of the area is covered by forest (Toyota City 2010).

The current study comprised the following phases (Table 1). First, a simple face-to-face questionnaire survey was conducted in Inabu and Asahi to prioritize several forest-related sites in these towns; to identify the cultural value of each site; and to categorize each site according to CESs based on the MA category (detailed in Hayashi et al. (in press)).

For the second phase, a web-based questionnaire survey was developed by using the first-phase results (detailed in Hasegawa and Hayashi (2014)). The survey was conducted to evaluate the selected sites according to the residents' subjective value assessment and to identify factors that contributed to the subjective value of the sites. A total of approximately 2000 responses were collected from residents of Aichi Prefecture. However, the most of respondents were concentrated on the urban regions so that the number of responses near source forest was limited.

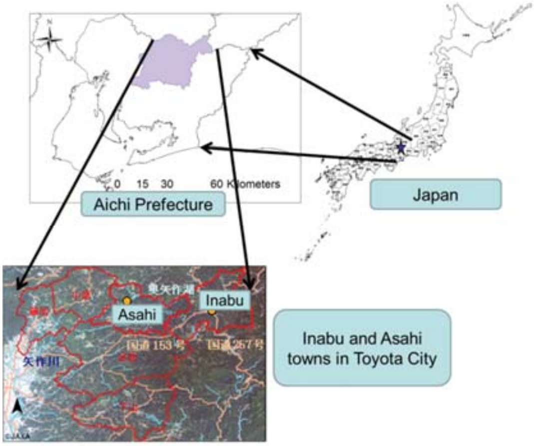

***Figure 1**: Map of the study area: Japan(upper right side), Aichi Prefecture and Toyota city (Upper left side) and Inabu and Asahi towns in Toyota City(lower left side). Satellite image: ©JAXA*

The third phase used the DOPU method to conduct a questionnaire survey in the rural area of Toyota City, focusing on forest sites in and near Inabu and Asahi. 1,246 residents were randomly selected, taking into consideration the population per 1-km mesh within an approximate 19-20 km radius from the geographic center of both towns. The samples were collected utilizing Zenrin maps by ZENRIN dataCom CO.LTD. This included the whole regions of Asuke, Shimoyama, Obara towns and one part of Fujioka town as well as Inabu and Asahi towns in Aichi Prefecture. The survey addressed 12 ESs, including provisioning services (food, timber and energy, and water), regulating services (CO_2 absorption, preventing soil erosion, water purification), cultural services (aesthetic value, recreation and ecotourism, cultural heritage value), and species and habitat conservation (habitat for wild life, endangered species, common species). Respondents were asked to assess the subjective value of the ESs both to the individual respondent and to society as a whole.

The statistical analysis was conducted using Excel ver. 2010 (Microsoft corp.), SPSS statistics ver.22 (IBM corp.). The ArcGIS 10.1 (ESRI Japan Inc.) was used for the spatial analysis.

Contents	Face-to-face questionnaire survey	Web-based questionnaire survey	Drop-off and pick-up (DOPU) questionnaire survey
Target area	Forest sites in Inabu and Asahi towns	Forest sites in Inabu and Asahi towns	Forest sites in Inabu and Asahi towns
Number of samples	92 valid answer sheets by visitors and residents in the sites	2000 from residents in Aichi Prefecture	761 of the 1246 distributed in an around 19-20 km radius from the geographic center of both towns
Survey topics	Reason for the importance of each site	Knowledge of CESs Experience of CESs Future expectation of CESs Recognition of benefits from CESs Importance of each CES (for the individual and for society, now and future)	Experience of ESs Future expectation of ESs Importance of each ES (for the individual and for society, now and future)
Target ESs	Cultural services	Cultural services (aesthetic value, recreation, education value, cultural heritage value and social relations)	Cultural services (aesthetic value, recreation, education value, cultural heritage value and social relations) and other ESs
Research period	October through November 2012	January 2013	March through May 2013
Source	Hayashi et al. (in press)	Hasegawa and Hayashi (2014)	

Table 1: *Main contents of each survey*

Results

The first phase of the study revealed that as a whole CES values with highest importance (in descending order) in Inabu were aesthetic value, recreation and ecotourism, and cultural heritage value. Cluster analysis revealed that the main CESs provided by Inabu were: aesthetic value, recreation and ecotourism, and others (Figure 2).

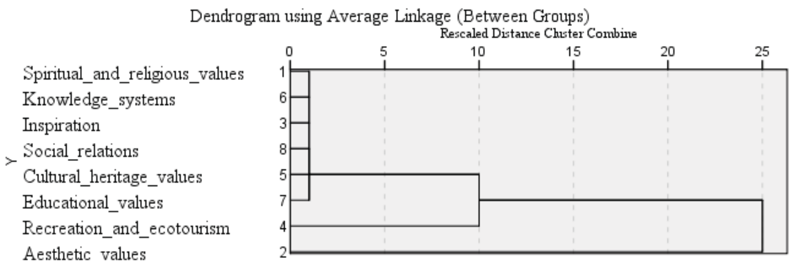

Figure 2*: Cluster analysis for forest sites by CES in Inabu (Source: Hayashi et al (in press))*

However, the CES receiving the highest value score differed among sites. For example, Ooidaira Park, a popular destination for viewing autumn leaves in Inabu town, scored highest in aesthetic value. On the other hand Natsuyakejyoga mountain, a hiking spot in Inabu town, scored highest in recreation and ecotourism. In addition, the reason given to support the importance of each site differed between residents and visitors. For example, visitors had more focused value of CES in each site than that of residents who recognized the wide scope of the CES values on the same site. The detailed results were summarized in Hayashi et al.(in press).

According to the results of the web-based questionnaire (phase 2) based on Hasegawa and Hayashi (2014), the experience visiting a site in the area might be one of the important factors of the subjective value of CESs. The importance of CESs to frequent visitors was higher than that to occasional visitors (Figure 3).

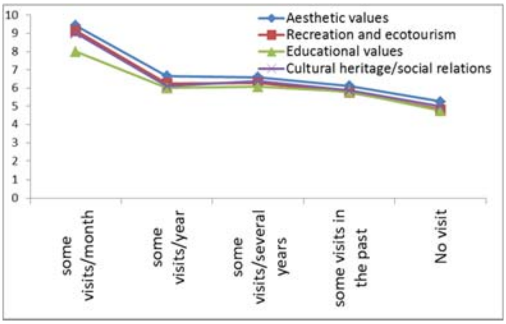

***Figure 3**: The importance of each CES subjective value by experience level visiting a site. The vertical scale shows the average score of the importance by respondents. The score 10 is the highest value.*

In most cases, respondents said that the CES values for society as a whole were higher than those for individual citizens. This follows the same tendency as those of Ota et al. (2013). In addition, the spatial distribution of the subjective values differed among CESs. However, sampling from Inabu and Asahi towns was limited because most of the residents in these areas are elderly people who did not have access to the Internet.

To overcome the above sampling issue, the third phase of the study focused on people who lived close (i.e., within around 19-20 km) of the source forest. That included towns adjacent to Inabu and/or Asahi within Aichi Prefecture. These findings revealed that many part of the subjective importance values of ESs including CESs in Inabu and Asahi were somewhat higher in importance than those outside these towns. Figure 4 showed the spatial distribution of subjective value of water supply service as an example. And in the most of ESs including the CESs, the subjective importance to society was higher than that for individual citizens, consistent with the results of the second phase.

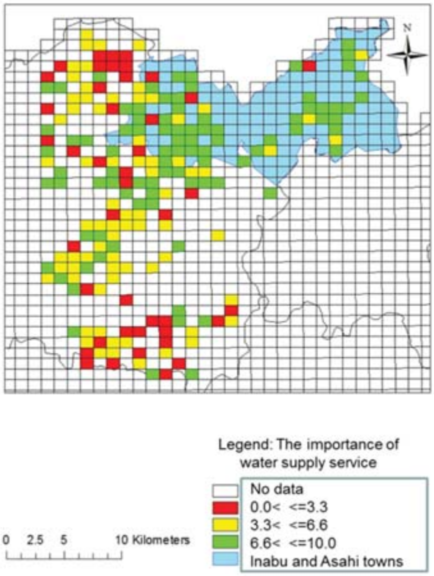

Figure 4*: Spatial distribution of the subjective value of water supply service provided from Inabu and Asahi towns(tentative results). The range of the subjective value is 0 to 10 point. The 10 is the highest importance.*

Conclusion

According to the results, each forest site had a different combination of CES values. In addition, residents recognized the wider scope of the CES values on the site than visitors did. The importance of CESs may depend on people's experiences, in this case, visiting frequency, at the relevant site. Furthermore, the importance of each CES to society in general was higher than that for individual citizens. The spatial distribution of subjective value was geographically diverse, but if focused near the source area, the importance of CESs inside towns may be higher than that of the adjacent area in some ESs. More detailed results will be presented in the future.

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33. Innovations for protecting ridge and reef: a CSR strategy and practice

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Abstract

This paper will describe and analyze the innovations adopted by a Filipino businessman and his family corporation in order to protect the forest and rehabilitate coral and marine life. The first innovation involved the engagement of villagers in forest protection via fire prevention. Known as social cultivators, villagers were given cropland in strategic locations around the company's plantation. This approach gave the villagers a stake in preventing forest fires, the scourge of tropical forests during the dry season. After the implementation of this approach, forest fires dramatically decreased in the area. The second innovation entailed the development of underwater nurseries to grow corals which were later transplanted in damaged areas to rehabilitate marine and coral life. This innovation contributed to the reappearance of marine species in the marine protected area where the corporation runs a beach resort. The significance of these innovations will be discussed in terms of their contribution to the triple bottom-line of this corporation or to the People, Planet and Profits conceptual framework.

Keywords: corporate social responsibility (CSR), social innovation, triple bottom line, sustainability, family corporation

Introduction

People Planet and Profit Framework for Corporate Social Responsibility

The triple bottom line framework of people, planet and profit began as an accounting concept developed by John Elkington in the 1990s to include environmental and social dimensions to financial reporting (Slaper & Hall, 2011). It is a sustainability concept that focuses on economic prosperity, environmental quality, and the often overlooked social justice. It has the capacity to change the way governments, corporations and individuals operate as citizens, customers, or investors (Elkington, 1997). Over the last twenty years, it has been the go-to word used by corporations when referring to sustainability in their operations.

Huffington (2013) stated that the pursuit of pure short-term profit over everything else is no longer working of the long-term sustainability of most organizations. A strategy focusing on people, planet and profit runs on the belief that what is good for the planet and society is good for the company's financial bottom line as well. Therefore, private businesses have the unique opportunity to become instigators of fundamental change. This can be done through CSR initiatives.

Dixon and Clifford (2007) signified that entrepreneurship and CSR are closely linked. Entrepreneurial traits in top management allows the pursuit of environmental, social and economic goals. Dubbed as ecopreneurs, these people can create an economically viable business without sacrificing their core environmental and social values.

CSR has evolved over the last few decades. Visser (2011) identifies five stages in the evolution of CSR in relation to economic periods: Defensive CSR in an era of greed;

Charitable CSR in an era of philanthropy; Promotional CSR in an era of marketing; Strategic CSR in an age of management and finally, Transformative CSR in the age of responsibility.

Family Corporations and CSR

Research linking family corporations and corporate social responsibility has emerged in the last few years. According to the International Finance Corporation (2008), this is significant because family firms are the world's oldest and most dominant form of business organizations. Family firms make up more than 70 percent of businesses in many countries, making them key economic drivers.

Traditionally, family corporations are seen as those that protect their own interest above those of society in general. However, Deniz Deniz and Suarez (2005) found that family firms were not a homogenous group regarding their orientation towards CSR. Dyer and Whetten (2006) argued that family firms were found to be more socially responsible than nonfamily firms along several dimensions due to the family's concern about their image and reputation as well as using CSR to protect the family assets.

According to Uhlaner, et.al. (2004), certain factors affect the level of CSR orientation in a family firm. These include generation of family at the helm, size of the community, tenure of the family firm within the community, and having the family name as part of the company name. The authors suggest that when family corporations support causes or groups, they choose the ones that are close to home and family. Those that are geographically farther or located in larger communities are considered less priority.

CSR Practices from the Pelaez Group of Companies

Data was primarily gathered from key informant interviews and focus group discussions of the various stakeholders of the two corporations owned by the Pelaez family: Emmanuel Pelaez Ranch, Inc. (EPRI) and Duka Bay Resort, Inc (DBRI). Stakeholders include family members, employees, community members, officials from local government units, and other partner organizations. Company documents were also gathered for analysis. The researchers also conducted field visits to both locations to personally observe the innovations in action. The site visit for EPRI in Mapawa was conducted on horseback while the different coral reef rehabilitation modules in DBRI were observed via SCUBA diving.

Social Cultivators at Emmanuel Pelaez Ranch, Inc. (EPRI)

EPRI, located in Mapawa, Cagayan de Oro City, Philippines, started out as a working ranch in the 1960s. By the 1990s, most of the 2,418 hectares of land was overgrazed and the family decided to shift the focus from ranching to forest management. Two tenurial instruments were applied for and issued based on a multi-use forestry concept in 1995. 1,920 hectares became part of Integrated Forest Management Agreement (IFMA), the tree plantation, while 498 hectares were devoted to Forest Land Grazing Lease Agreement (FLGLA), which is a pasture lease. Both tenures have a duration of 25 years. At the end of 2020, EPRI can apply for a renewal of another 25 years. EPRI formed a partnership with STEAG State Power to establish a carbon sink within the property. A seedling bank was established, and reforestation commenced.

Two challenges of forest management are tree loss and human intervention. Ten years ago, EPRI lost 232 hectares of planted area as a result of fire cause by locals picnicking at the edge of the property. The trees were also in constant danger of being cut down by the locals for firewood or for selling.

Instead of taking a combative stance against members of the community, EPRI saw the value of a multi-stakeholder approach to forest prevention and launched the Social Cultivator Program that same year. The program is based on the concept of firebreaks. EPRI identified crucial fireline areas and allowed members of the nearby communities to plant crops such as corn, cassava and various vegetables to act as a firebreak. These cultivated crops can then be utilized by the locals for their own food or to provide additional livelihood to the residents of the barangays.

Using the name "social cultivator" allows EPRI to convey their recognition and respect for the farmers as equal partners in the agreement. EPRI does not require the social cultivators to pay for the use of the land nor do they share in the income from selling the produce. However, they are required to sign a contract that itemizes the rules that they need to follow. The rules act as the criteria for performance evaluation and will determine renewal as a social cultivator for the following year. Aside from planting crops, social cultivators assist in the reforestation efforts. They are required to plant at least one hundred trees per assigned area annually. They also act as watchers for incidences of fire.

The social cultivation program proved to be successful and mutually advantageous. The positive results caused the number of social cultivators to increase from an initial 32 to 122 in 2012. They benefit from having a steady source of food for their own consumption, an additional source of livelihood, and education on superior farming techniques.

EPRI also reaped numerous benefits from the program. Social cultivators greatly enhanced the manpower needed for the IFMA project since they assisted in the monitoring and planting processes. The company now enjoys a more harmonious relationship with the local community.

The IFMA area experiences improved protection with the presence of social cultivators. Mortality of the trees lessened. Fire incidents and other illegal activities like timber poaching, river poisoning and bird shooting were greatly reduced. Trees located in social cultivation areas are noticeably more robust and taller than trees of the same age in non-cultivated areas.

The reforestation efforts increased the supply of groundwater within the property, allowing EPRI to provide a source of potable water to the nearby communities. The enhanced beauty of the property prompted a new business venture for the family firm. EPRI set up Mapawa Nature Park to provide guests with ecotourism and adventure experiences such as canopy walks and river treks, generating additional revenue for the company.

The Coral Reef Rehabilitation Project at Duka Bay Resort Inc. (DBRI)

Duka Bay Resort, located in Medina, Misamis Oriental, Philippines, has its roots as a Pelaez family vacation spot in the 1950s. By 1997, third generation family members transformed the property into a full-service beach resort. A couple of family members saw this as opportunity to provide guests with an educational leisure experience by conducting tours on a glass bottom boat. The family also worked with the local government that led to the establishment of Duka reef as a marine protected area.

In 2000, Ernesto Pelaez partnered with Severo Eduardo Yap to open a dive shop within the resort. Together with a marine biologist, Duka Reef Divers initiated the coral transplantation project to see if they could improve the coral cover within Duka Reef. The project initially made use of concrete as artificial substrates for large coral fragments (LCF), primarily Acropora corals, to propagate in.

Over the course of thirteen years, the design of various modules for coral nurseries and several transplantation techniques became the focus of the research. Modules that were developed and tested included square concrete blocks (2000 – 2002), Acanthasia modules (2002 – 2004), quincunx (2004), A-frame beams (2008), A-legged coral nursery modules (2011 – present), out-planting with concrete substrate (2011), direct-reef transplantation (2012), and modified coral nursery module (2013). Later nursery designs and transplantation techniques were tailored for economic and more efficient technology transfer intended for large-scale rehabilitation effort.

The concept of growing corals in nurseries was adopted from the experience of EPRI's practices of forest management that needed a steady supply of seedlings for massive or large-scale reforestation effort. Without these coral nurseries to supply the amount of coral fragments, rehabilitation efforts cannot be sustained as sourcing of coral fragments from the wild will only further contribute to coral damage. In the beginning, transplanted materials to the nursery were sourced from the wild and only a maximum of ten percent coral biomass were taken from donor colonies with full biomass recovery of coral donors within one year. The transplanted corals showed good growth even up to the third generation and the regenerative ability or biomass recovery of donor coral colonies were unaffected. By carefully monitoring the rate of regeneration, three generations were sourced and transplanted, with another coral nursery currently being deployed for the fourth-generation transplantation. The nursery became the only source of nursery-reared, large coral fragments (LCF) 12 – 15 inch in size for 18 coral species.

In-depth experiments were conducted to determine the adaptability of nursery-reared corals to higher temperatures and more volatile weather conditions such as typhoons and monsoons brought about by climate change. Results showed that transplanted coral colonies indicated better growth at the shallow than at deeper nurseries.

Coral nurseries add to the biodiversity in the sandy portion of Duka reef and also serve as sanctuary to juvenile and mature fishes. Reef fishes and other invertebrates now colonized the coral nurseries which made the once barren sand teeming with marine life. The results of the various experiments indicated that reef rehabilitation through coral transplantation was a viable tool for reef managers and should be replicable in other areas.

The results of the project created significant impact not only in the scientific community but also to various stakeholders. The increase in coral cover increased the popularity of the resort as a snorkeling and diving destination. It also furthered the crafting of local government policies. The current version of the ordinance declares the waters of Duka as a marine protected area (MPA) for fish reserves, educational research and special management purposes. The Duka experience allowed the local government to propose a second marine protected area to be established with the municipality.

In 2013, the resort worked with members of the Philippine Marines to police the MPA. The team deployed at the resort caught a group of minors illegally fishing inside the protected zone. The incident prompted the civil military division of the Marines and DBRI to initiate an education and information campaign at the school the minors attended. DBRI hopes to further this campaign in the near future. The Marines also acted as additional manpower for the deployment of the next experiment, concrete wave breakers that would lessen the impact of waves on the corals and act as future substrates for transplantation.

The project experienced some challenges along the way, with funding as the primary issue. Throughout the years, the coral rehabilitation project has been funded by the income from the dive shop. It also relies on personal funding from a member of the Pelaez family. Since the project holds no official status as a foundation of DBRI, it is not able to claim incentives or apply for external funding. Hence, the innovations start and stop depending on the availability of funds.

Significance Of These Social Innovations as a Form of CSR

Social innovation recently gained popularity as a way to create both economic and social benefits. It is centered on the idea that innovative social action can create new value for various stakeholders. This includes community as well as enterprise development in the public sector and CSR initiatives in the private sector (Adams & Hess, 2010).

Saul (2010) asserts that social innovation is a new era where companies are learning to profit from social change. This requires a transformation of a company's CSR practice into that of social innovation that produces economic value. At the same time, it solves social problems and addresses market failures in a scalable and sustainable manner. This is in line with Visser's (2010) strategic and transformative character of CSR as the way to go forward in this century devoid of the problems of the other forms of CSR in the last decades. His definition of CSR is about doing business in a way that does not erode but build social, human and natural capital. Bill Gates (2008) calls this creative capitalism, a methodology where the three sectors – public, private and civil society groups – work together to make profit and ease the world's inequities.

Using these definitions, it can be said that the social cultivator program at EPRI and the coral reef rehabilitation project at DBRI exhibit characteristics of using social innovations to create a business value for the Pelaez family, together with social value for the people and the environment.

The social cultivators program is innovative because the approach to fire fighting and prevention is a deviation from a purely technical standard approach utilizing equipment and know-how. EPRI's approach is primarily social, and relies heavily on the mobilization of people and communities. The process used is equally innovative in the sense that it is inclusive; it transforms people who were formerly spectators and outsiders into key players who play an important function of combating a threat to the organization.

This approach is a win-win strategy since the community benefits from the arrangement in terms of using company land to grow food crops without taxation nor sharecropping rent, practices that were prevalent in feudal rural society. At the same time, the company benefits in terms of additional hands on the ground for firefighting and prevention and firebreaks on the ground which act as buffers against the threat of forest fire. Ground presence is important in early detection and warning, and quick response in the event of fire which can engulf the plantation in a few hours given the state of the area aggravated by climate change. The program answers EPRI's need for sustainability and survival.

The DBRI experience is just as socially innovative. A beach resort relies on natural capital as its selling point. The coral reef rehabilitation aimed to improve and add to the natural capital of the resort. This resulted in increased marketability for the resort, therefore improving on its bottom line. At the same time, the upsurge in guests enabled the resort to continuously provide employment for the local community.

The success of DBRI in protecting Duka Reef has acted as a springboard for the local government to improve its local ordinances regarding their marine resources. This embeds and institutionalizes what DBRI accomplished into the political and social system of the municipality.

The innovations allowed DBRI to work with various members of society – both civil and military – that volunteer. It is a win-win situation for both groups, since DBRI is granted additional manpower for any project tasks that need to be accomplished, such as transplanting and monitoring. At the same time, the groups get to contribute in the environmental efforts of the resort. In the case of the civil military operations of the Marines, they were able to include environmental protection as part of their advocacy and earn free SCUBA certification training and coral transplantation technology by the dive shop. One of the biggest contribution of the project was in the form of environmental education. Guests who opt for the aquatic activities of the resort receive a briefing about the project. There are also tentative plans to initiate environmental education for the youth. As a result, the mindset of the community was gradually transformed throughout the years, from that of take-whatever-you-can-from-the-sea attitude to one that recognized the need for sustainable fishing practices.

The continuous experimentation to improve on the modules and transplantation technique aimed at making transplantation replicable on a larger scale and in multiple locations fulfills one of the criteria for social innovation. The initiatives of DBRI to protect and rehabilitate the reef give true meaning and not just lip service to the idea of ecotourism.

Conclusions

The CSR efforts at EPRI and DBRI to protect both the forest and the ridge provides significant value as social innovations. They act as evidence in the evolution of CSR into its strategic and transformative form wherein economic and social value are simultaneously created. The innovations contribute to a triple bottom line for the companies wherein people, planet, and profit are accounted for.

The social value created by social cultivators and coral nurseries contributes to the planet and people side of the equation through livelihood creation, environmental protection, and collaboration with the different stakeholders found within the community. Both innovations also create a business value for the corporation; the social cultivators program lessens the operating cost of the company in fighting fire through the mobilization of the community. It also lessens the threat of the destruction of the plantation. Likewise, the coral experiment has improve the conditions of the reefed, thereby increasing the tourism potential of the resort.

The innovations in both locations have added value because they are replicable on a larger scale. Social cultivators can be established in any area that is being reforested with timber-stand trees. Likewise, establishing coral nurseries to be a source of large coral fragments for transplantation is a viable solution for extensive reef rehabilitation for resorts that are engaged in tourism.

This paper is not without its limitations. It only studies the practices of two corporations under a single family umbrella. Further research can be done with a bigger sample to identify the level of social innovation in CSR practices of family corporations in the Philippines.

34. Developing an environmentally aware University

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Abstract

We present the experiences of research-action for developing an environmental aware and responsible university at the Institución Universitaria Colegio Mayor de Antioquia in Medellín, Colombia. Academic exercises are proposed from the classrooms and developed by students and staff. Final results are presented, in order to achieve environmental awareness not only to the administrative levels of the Institution, but also to the academic community composed of students and professors. In this paper we present six experiences in the frameworks of cleaner production, clean and sustainable energy and risks assessment. The implementations of such initiatives have produced gains not only in knowledge and technological transference but also in costs and energy consumption reductions. Here we have clear examples that synergies between the planning offices/dependences at the administrative level and the research communities in Universities may redound in better practices.

Keywords: air pollution, environmental noise, risk reduction, cleaner production, clean energy.

Introduction

As a strategy for comprehensive training of students in the programs of the Architecture and Engineering Faculty of the *Institución Universitaria Colegio Mayor de Antioquia,* we have generated two spaces in which they reach investigative skills through the formulation and implementation of research projects either by participation research groups or classroom projects in regular courses. Outside the professional and personal development through their participation in such training activities in research, the study of particular topics and the generation of initiatives implemented regarding the proper use of natural resources have led to the exchange of academic experiences with other members of the *Ambiente, Hábitat y Sostenibilidad* research group, other institutional research groups or external researchers.

Universities are large consumers of natural resources, and are affected by the misuse or contamination of these. We present three initiatives for the diagnosis and understanding of the impact of resource management in a University Campus. All experiences presented were developed with students of different programs our faculty, which are being formed as professionals in the field of management and management of natural resources. It is intended to feed back with the academic community of the institution the results of research being generated and as a result to expand the awareness of the responsibility in the use and management of natural resources.

The paper presents six different research experiences in the order proposed next. The first research experience dealt with the estimation of atmospheric emissions due to trips made for work and study to the institution, with the results it was possible to calculate the contribution of the institution to the emissions at the whole geographic region where is located. The emissions were estimated with a bottom-up based on surveys. In a second energy-related research initiative we have implemented a brand new exterior illumination powered with solar energy and LED luminaries patented by a student of our University. The third initiative main purpose was to diagnose risks (physical, chemical, biological, environmental, insecurity and ergonomic) of greater impact on the university campus, for a further proposal of permanent solutions to structural risk causes. The importance of the risk reduction process, in the context of sustainable local development and knowledge generation is that it becomes in a pedagogical strategy for developing corporate environmental culture that permeates all members of the institutional community.

The fourth experience is related with the analysis of rainfall harvesting as an alternative to supply water in the activities that not necessarily need drinking/potable water in the campus. Our fifth experience is a second air-related research initiative developed with measuring campaigns to assess qualitatively and quantitatively the impact of environmental noise on the institution, and also to identify the most sensitive areas to this pollutant. And the last experiences have conducted to ultra efficient LED luminaire, that have been patented and that emulates some cinema features. Finally we draw some concluding remarks about our experiences.

Experiences at the Institución Universitaria Colegio Mayor de Antioquia

The experiences presented next have been developed in the Campus since the year 2011 and involved professors and students in a collaborative effort to gain more knowledge and to directly evaluate, assess and propose better practices for the way the University carry on its functions of teaching, research and social projection.

Estimation of pollutants emission and reduction initiatives

As long as we use transportation in a daily basis to commute there will be an extensive use of fossil fuels and the emission of pollutants to the air. In order to estimate the pollution generated by our University due to study and work travels we developed an small-scale bottom-up model adapted from the *SEEM* model developed in Concepción-Chile (Tuia, et.al. 2007), the primary information recollection was based in electronic surveys and we use the International Vehicle Emission Model as the emission factor source (Davis, et al., 2005; IVE, 2008) emission factors developed for third world cities. According to the results presented in the Figure 1, the main source the Particulate Matter (MP), Sulphur Dioxide (SO_2), and Nitrous Oxide (NOx) pollutants are the public modes of transportation and of Carbon Monoxide (CO) and Volatile Organic Compounds (VOC) the private ones (Valencia, et al. 2015). These results are related with the kinds of fossil fuels used in each vehicle (diesel in public transportation and petrol in private vehicles).

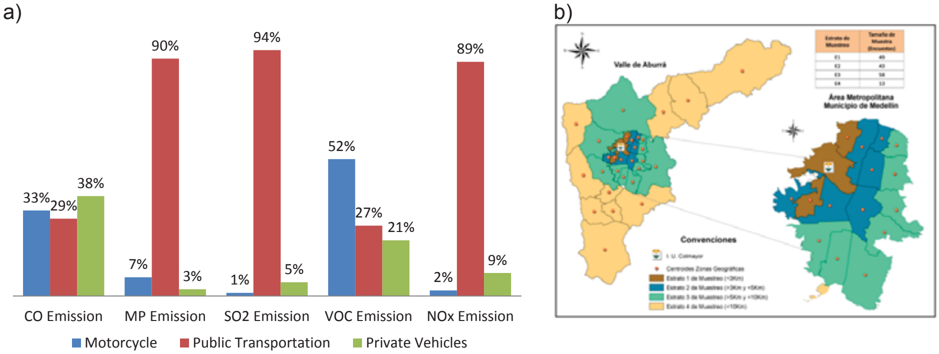

***Figure 1**: a) Percentage of the emissions according to type of vehicle in the University. b) Geographical coverage of the study (Academic population converging from 28 different geographical zones).*

In the surveys we asked to people using private vehicles about the number of persons on each trip, and with the information of the vehicle characteristics we compute an occupation factor, defined as the percentage of seats occupied in each trip. We found that 76% of the trips made with private vehicles that only have one seat occupied so only the occupation factor was of 25%. Students proposed three scenarios of occupation, each scenario had a lower bound of occupation (50%, 70% and 100%) and all trips below were aggregated until reaching the bound. In Table 1 we show the reductions that may be achieved by in case of the implementation of the car pooling scenarios.

Scenario	CO Reduction	MP Reduction	SO_2 Reduction	VOC Reduction	NO_X Reduction
1	15.2%	0.5%	1.6%	8.8%	2.9%
2	23.5%	0.9%	2.5%	13.6%	4.7%
3	29.6%	1.2%	3.3%	17.0%	6.0%

***Table 1:** Percentage of emission reductions compared with the base line results.*

Clean Energy in Campus

Research in energy efficiency and clean energy has been of main interest in order to reduce the impact of human activities (Gevorkian, 2007). There is a growing interest of becoming in a sustainable energy consumer at the *Institución Universitaria Colegio Mayor de Antioquia*, and for the achievement of such an objective we have taken two steps, to gain knowledge about our consumption behavior and to implement alternatives to reduce such consumption or to switch it to cleaner energy sources. As a pilot it was decided to begin with the external illumination, because it was considered as the most expensive, high-maintenance and of less quality in the Campus, in Figure 2 we present the panel structure and the luminaries installed.

After a thorough diagnosis it was possible to estimate that the nominal consumption of external illumination in 21 light points was of nearly 4 kw/h with an approximately cost of de 3080 $USD that can reach up to 4600 $USD with maintenance. After the diagnosis was done it was time for the intervention which was done with ultra-efficient LED technology (Díaz, 2014) that consumes only 1.19 kw/h in illumination out of which 0.48 kw/h are powered with photovoltaic panels becoming in autonomous lamps. For the improvement of the external illumination the light points were augmented to 46 and the annual cost of energy is reduced to 420 $USD that will need maintenance after the third year, increasing the costs up to 1000 $USD. The return of the investment is expected in two years mainly through energy consumption costs reduction.

Figure 2*: left) Photovoltaic panel installed in the University Campus. right) External ultra-efficient LED illumination point, powered by photovoltaic panel.*

Disasters risk map

The University has a student population of approximately 3200 students in 4 faculties (Social Sciences, Management, Health Sciences and Architecture and Engineering), without counting the rest of the population that makes up the academic community. Activities related with teaching and research are carried out in the university campus and it is necessary to implement preparations to reduce the risk at which population is exposed, based in a full knowledge of its causes and consequences. Additionally we wanted to expand the knowledge of institutional risks that are covered by the map of institutional risks, strengthen education hitherto taught about the risks and disasters, and promote prevention for a change of attitude in people about to risk reduction.

We intended to increase awareness of the risks, i.e., understanding the dynamics inherent to the configuration of risk scenarios and vulnerability reduction in the institutional community; provide methodological and analytic tools to institutional processes to strengthen the capacities of decision, planning and implementation of sustainable institutional development; and expand the scope of the policy of institutional risks.

The diagnostic allowed the assessment of corporate risks from three stages: identification, analysis and evaluation, which identified and prioritized orderly and systematic institutional risks in inventory according to the national regulations (Icontec 2004a, Icontec, 2004b; Congreso de la República de Colombia, 2012). For practical purposes the work was divided into 3 sections (teams): Historical Building, Academic Building and Library Building by the description of each, its location and the possible consequences. Also, determine the degree of importance of risks for making treatment decisions and propose the incorporation of the results on the Institutional Risk Matrix.

This project also relied on a combination of quantitative and qualitative data, involved the participatory action of teachers, students, employees, contractors and senior management that become actors or receivers of this diagnostic. From the consolidation of primary and secondary information (routes and physical inspections, architectural surveys, sampling, laboratory analysis, interviews / group discussions, conducting surveys, photographic record) and secondary information (collection from historical investigations developed by teachers Faculty of Architecture and Engineering, technical specifications, auditing reports, etc.), it is possible to determine in a systematic way what the risks of most incidence and degree of importance at the University.

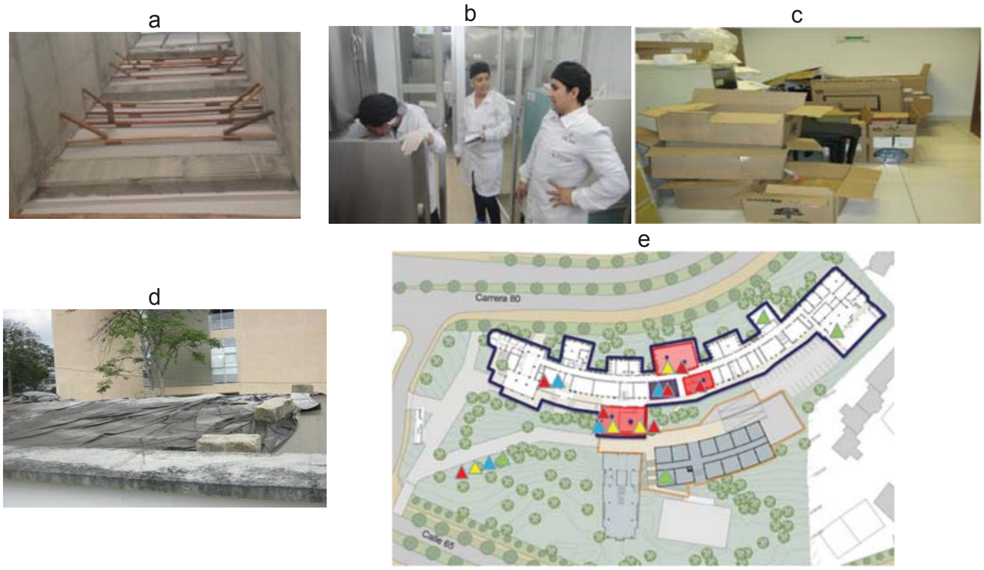

Figure 3: *a to d) Risk identification in Campus. e) Schematic of the new risk map at the Institución Universitaria Colegio Mayor de Antioquia*

Additionally a risk map was developed; a scale graphical representation is presented to visualize the location of the risks diagnosed in the Historical Building through the use of symbolism. This map shown in Figure 3e is the picture of the risks situation at the University before the implementation of controls and is useful as a warning to their effective management.

Rainfall harvesting analysis

With 3500 m^2 of roof and (Figure 3e, white area) an average annual mean of precipitation above 1500 mm/year in Medellín (Pabón et. al, 2001) is plausible to think in the recollection of rainfall as a possibility. We decided to evaluate technically and economically rainfall harvesting as an alternative water source in Campus. The results showed that it is possible to reduce the use of 384 m^3/month and approximately 300 $US in water bills of treated water if it is implemented a recollection, storage and distribution system devoted to the rainfall harvesting.

Environmental noise estimation

Noise is one of the pollutants associated with decreased quality of life in residents of large cities (Rivera & Guerry, 2011). While communities are often accustomed to high sound pressure levels, there are rules and standards for maximum allowable noise pollution. In Colombia the resolutions 627 of 2006 (Ministerio de Medio Ambiente, 2006) and 8321 of 1983 (Ministerio de Salud, 1983) regulate the permissible levels of this pollutant in Colombian cities. These regulations make a classification of noise according to the use to which the land is designated, and inside buildings. Investigations have been developed that seek to infer the effects of noise pollution on health (Daniels and others, 2007), and has come to relations between noise levels and all kinds of affections, especially the reduction of students concentration and the performance at work (IDEAM, 2012). We conducted surveys in order to estimate the perception of students about discomfort related with environmental pollution. A statistical representative sample of the population and campus filled the surveey and according to the 55% of academic population noise at the University tends to be a serious bother, and 74% blames the vehicles crossing nearby for the noise pollution. Perception is a key result in order to establish priorities for the control and further research. Furthermore in recent measurements of environmental noise results shown that the University experience levels of more than 65dBa, which is the maximum permitted noise level for academic facilities according to the national regulations.

Ultra low consumption LED (ULCLED)

With the optical principle of the cinema in mind, Juan Camilo Díaz one of our students developed an Ultra low consumption LED (Diaz, 2014). As in the cinemas only one image is presented by instant of time but it seems in constant motion, in this case each LED lights at a time for a moment of time and sequentially, as do the television screens. The invention was designed to be powered with 6 and 15 volts DC and to replace incandescent or fluorescent lamps between 700 and 1400 lumens. It is based on the principle of multiplexing, where only one of the LEDs composing the matrix lighting comes on for a split second at such high speed that for the human eye is presented as if they were all on.

Conclusions

The proposed reduction scenarios functions as a tool to minimize the emission of air pollutants generated by the University, and directly impact private transportation as these vehicles are easier to control due to the access of information needed to generate the aggregation of people with common routes. The results found in this study are a benchmark for corporate environmental management, because to achieve significant reductions in the emissions of pollutants by the weekly activities of the institutions initiatives from the administration are needed.

Our concerns in terms of energy consumption have lead not only to patent a new technology but to implement it in the campus. The use of ultra efficient luminaries and solar generated electricity made possible a reduction of the 70% of the energy needed to illuminate the campus exteriors and a reduction of the 78% energy costs. These results are more than positive and have a strong influence in decision making towards the implementation of more photovoltaic energy sources, that can reach up to 3000 m^2 of roofs, and that may transform the University in an entire energy self-sufficient one.

The most common risks in the new Academic Building are the risks of insecurity, ergonomic, physical, biological and environmental, in Library Building predominate ergonomic, physical insecurity and risks, while the assets referenced block all risks are presented, because this is the oldest block of the institution and where they are located lots of spaces for different uses such as classrooms, workshops, laboratories, plant materials, auditorium, computer rooms, staff rooms, staff offices administrative, gym, cafeteria, study areas, cafes, storage rooms, living alcohols and commissary.

The main consequences are generated by the presence of these risks are the environmental, human health, ecosystems, loss of property and cultural heritage, public reaction, legal problems, fines, impacts to institutional reputation, difficulties with regulatory authorities, the loss of economic resources or implementation of corrective actions requiring the allocation of resources, continuity of service provision from the activities of the institutional mission (teaching, extension, research) , etc.

To the extent that specific controls very effectively to generate these risks, its application have a significant impact on the entire university institution, to make decisions regarding the treatment to follow and the effects that would be incurred if not. However, in the first line should be placed those risks that are scattered throughout the organization, ie the risk of generalized frequency. Awareness of the impact over natural resources and the risks associated is achieve with the construction of knowledge, from classrooms to the field.

35. Education for resource preservation and efficiency: identifying and developing opportunities for all areas of education in Germany

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Abstract

The pressure on natural resources and raw materials is continuously rising. Especially advanced industrialised nations show a significantly high usage and, therefore, action is required. Building up awareness for an efficient and conservative use of resources is an important step to a more sensitized society. This paper introduces the research project “BilRess” which has the objective to develop a Roadmap to integrate education for resource efficiency and resource preservation in all areas of education as part of the German Resource Efficiency Programme “ProgRess”. Central aspects comprise the composition, structure and proceeding of the project as well as some methodical approaches and intermediate results of the ongoing research project.

Keywords: education, competencies, resource preservation, resource efficiency, roadmap resources education

Introduction

Natural resources, especially raw materials are key factors for value adding processes and, therefore, foundations of our prosperity. In recent years the consumption of these resources has increased to 68 billion tons worldwide in 2009. This is an increase of more than 60 percent compared to 1990 and more than 30 percent compared to 2000 (Krausman et al. 2009). With focus on global population growth and an increasing economic growth, especially in emerging markets, the pressure on natural resources will be continuously rising (Meyer 2008; Buchert et al. 2009; Rockström et al 2009). In addition, the use of raw materials along the entire value chain is causing impacts on the environment by the release of greenhouse gases and other emissions into air, water and soil. Detriment of ecosystems and loss of biodiversity are the consequences (Görlach/Schmidt 2010; Lettenmeier et al. 2009; Ritthoff et al. 2007; Van der Voet et al. 2005; Liedtke/Busch 2005; Bringezu 2004; Schmidt-Bleek 2004). The consumption of natural resources is not evenly distributed and currently four times higher in industrialized nations than in less developed countries. Due to these developments a more responsible and efficient use of natural resources within the meaning of an absolute decoupling combined to social welfare is necessary (Schmidt-Bleek 2007; Barbier 2009; Jackson 2008). In this context the Federal Government of Germany has launched the German Resource Efficiency Programme called “ProgRess” with the aim to structure the extraction and use of natural resources in a sustainable way and to reduce associated environmental pollution as far as possible (BMU 2012: 7).

An important step towards a more resource efficient society is the formation of public awareness, which 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. ProgRess emphazises this necessity and asks for educational changes which affect all areas in the educational system. 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 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 is the development and design of a network called „Education for ProgRess“ as a communication platform as well as a portal for events, meetings and conferences to link stakeholders and to promote professional exchange of knowledge.

Resource efficiency and resource conservation (R&R) requires a social change and a rethinking in existing paradigms and patterns (Kristof/Hennicke 2008). Reducing consumption of raw materials by increasing resource efficiency, therefore, has to be achieved by a resource policy which focuses on awareness-raising combined with a qualification among actors of economy, politics and society. In this context the long-term goals of the project are the design and establishment of specific resource competencies (i.e. Bliesner and Rohn 2013; Stengel et al. 2008) in various fields of education as a contribution to support the ProgRess strategy by establishing a corresponding culture to protect resources. Developing competences for resource preservation can also support change of established routine social practices in all societal areas, which often involve a high level of resource consumption (Liedtke et al. 2013).

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.

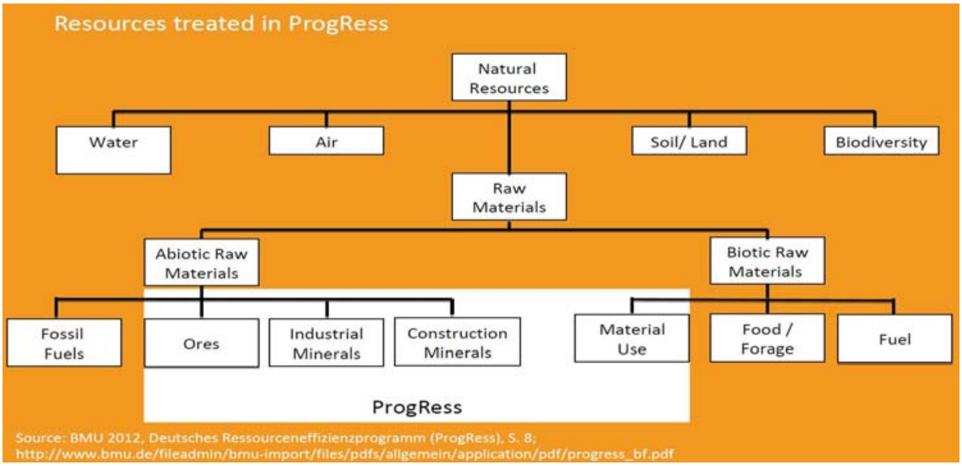

Figure 1: *Resource definition*

Structure of the project

The project runs over a period of four years from 2012 to 2016 and is divided into four work packages (WP) (see Figure 2). Currently, the project is in process of defining the scope and obtaining an overview of present educational opportunities in addition to the resource definition of “ProgRess”. The inventory comprises an assignment and mapping of competencies, actors and the identification of existing learning materials, subjects and studies. Therefore, it is necessary to circumscribe and define which resources are addressed (see Figure 1) and which reasons and drivers for resource efficiency exist in different fields of education. For this purpose the research has a focus on key areas, structures and actors in the educational system of Germany as well as on specific objectives and issues, which are highlighted in the context of “ProgRess” (resource definition etc.). In cooperation with experts and stakeholders in politics, education, science and economy the next steps of the project contains the conduction of „focusgroups“ to evaluate the “need for action” and building on the formulation of policy guidelines as basis for a Roadmap to R&R (see Figure 2). Pivotal issues are:

1. The current situation in relation to resource conservation and the formation of a corresponding culture on the national level.
2. Co-ordination and implementation of an “Educational Roadmap for R&R” with the aim to establish resource competencies in the various fields of education and in order to initiate a “Change in thinking” (Kristof/Hennicke 2008) for R&R.
3. In long term view to establish a corresponding culture to protect resources.

For the inventory, the individual fields of education were defined into “school education”, “apprenticeship”, “university/college” and further education in sense of “advanced vocational training”. In the first step for each educational field relevant actors, competences and structures were identified. After designating the responsibilities for specific actors the second step comprised the determination of relevant school subjects, training courses and study programs with a special reference to the resource topic. Additional to the topic of R&R experts from each educational field were interviewed. Stakeholders listed in this pool are primarily members of education committees, academic institutions, educational networks, deans, preceptors and representatives from vocational training. Furthermore, an internet research for existing educational opportunities like educational material and projects with focus on R&R was conducted. Therefore, a valuation matrix which allows a systematization and analysis was created. Besides descriptive information (content, source, date, price) also qualitative elements were used such as appropriateness for target audience, didactical composition and accordance with the aims of „ProgRess“.

The systematization and identification of relevant competencies and actors, as well as the conducted interviews allow a differentiated access (from the perspective of each educational field) and shape the basis for a deeper discourse (see issue 2&3). In the course of analysis around 45 experts and 40 to 50 training materials and projects with a reference to R&R were selected and identified.

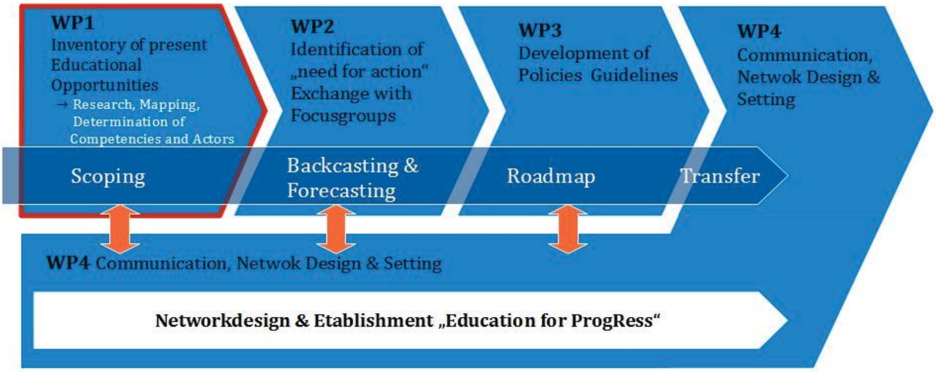

***Figure 2:** Proceeding of the Project*

The further process (WP2) consists of an identification of existing „needs for action“ and the development of „proposals for action“ in various education sectors, on basis of the research (inventory, interviews) in WP1. The methodological approach is based on the formation of „focusgroups“ (interviewed experts and identified stakeholders) and an integrated scenario analysis based on „backcasting and forecasting“ of existing developments in context of education combined with R&R. Currently nine „focusgroups“ are planned aligning on the different fields and classifications of education (see also Table 1). The main objectives are:

- Determination of „need for action“ in different sectors of education,
- development of „proposals for action“ designating responsibilities and scopes of actors,
- the consolidation of network building between educational experts,
- the further development of a roadmap in the educational context (backcasting and forecasting).

Referring to the identification of existing “needs for action” the project focuses on the design of a conceptual framework in the sense of a strategic policy guideline (WP3). The emphasis is on R&R combined with the question for a deeper implementation in the various fields of education. The whole conceptual framework is to be understood as a Roadmap and will be published in a paper called “Roadmap for Resource Education”. The paper serves as a first conceptual guideline and also provide the basis for further developments and discourses with experts and stakeholders. The roadmap will comprise:

- the use of present educational opportunities and proposals for action to support R&R,
- a co-ordination strategy of teaching and curriculum contents for R&R in different educational contexts,
- suggestions to support R&R as an overarching topic in society.

General education schools	Apprenticeship	University / College	Advanced vocational training
• Primary school • Secondary school • Extracurricular education	• Technical training occupations (e.g. electrician, systems mechanics for sanitary and heating engineering or air conditioning technologies) • Non-technical training occupations (e.g. office activity)	• Academic study paths with focus on technical fields including „green jobs“ (e.g. technical-scientific subjects, energy efficiency, recycling economy etc.; incl. the field of postgraduate and dual study paths) • Academic study paths with focus on non technical fields including „green jobs“ (e.g. business economics, regional and land use planning, agricultural study paths etc.)	• Formal advanced vocational training (e.g. master craftsman diploma or technical diploma) • Non-formal advanced vocational training (e.g. in firm agents for sustainable issues, environmental protection officer, energy efficiency consultant etc.)

Table 1 Planned focusgroups in the different fields of education

The entire communication part (WP4) has the focus on network-building and is designed to collaterally accompany and support each process (inventory, expert-interviews, focusgroups, roadmap) throughout the project’s running time of four years (see Figure 2). The intention is to build a network “Education for ProgRess” that represents and comprises important actors, experts and stakeholders from the educational system in Germany as networks can be a decisive setting to support change at regional and societal level (Baedeker 2012). Besides building up a network, a web portal will be implemented for the exchange of ideas, developments and for specific events, meetings and conferences in the context of R&R.

Intermediate Results

Currently, the inventory of present educational opportunities in addition to resource efficiency and resource conservation as it is defined in “ProgRess” is almost completed. At the moment more than 270 learning opportunities could be identified with a relation to the R&R topic and around 40 expert-interviews were conducted. In the following, first findings for each educational field are presented.

School System

The school system in Germany is characterized by a heterogeneous structure through curricula. Each German federal state has the eligibility to define his own content in the different subjects and type of schools. Only in specific cases like high school graduation (Fachhochschulreife/Abitur) a cross-national regulation exists. The analysis of 135 curricula of potentially relevant subjects like geography, politics, technical and scientific disciplines shows that the topics "resource efficiency" and “resource preservation" are virtually unknown. Resources are almost associated with the idea of energy resources and renewable energies. In primary school resources are often treated in the context of waste and recycling. However, the research also revealed that a link to resource-efficiency and resource preservation to existing curricula is possible through the topic of sustainability, which is commonly used. In this context our research on concrete educational opportunities shows a wide range of various offers which are mainly developed in cooperation with research projects. 18 examples for teaching units (e.g. Ecological Footprint or Green IT) could be identified. In addition, there are national competitions for schools related to the topic of R&R and the question for a suitable implementation. Furthermore there are various teaching materials, which cover the topic in its wide range and provide a link to R&R (e.g. use of second hand clothes, gold-recycling from electric and electronic waste, paper waste, aluminium cans and land use through maize and cotton cultivation). In conclusion it can be said that there is already the opportunity to teach R&R in school but only on the basis of dedicated teachers pushing the topic by their own conviction. R&R has not the level of proliferation and integration into the curricula like the topic of renewable energy.

Apprenticeship

The apprenticeship in Germany comprises about 350 training courses and is characterized by a uniform structure based on national curricula and vocational training regulations. In the project 250 training courses were checked in the context of R&R. The analysis shows that the definition of “resource-efficiency” and “material savings” are not represented in the national curricula. Exceptions are some technical occupations where a note for “resource preservation” is established as a necessity (e.g. Production and Media Technologists). The picture is similar to the topic of “recycling”. Only a few training courses make use of this topic (e.g. Road and Traffic Engineering Specialists, Water Management Specialists). Two training courses could be identified with a focus on R&R: “Assistant for Energy and Resources” and “Specialist for Environmental Services and Waste”. However, there is a paragraph in all training regulations for environmental protection, which are pointing out the potential for economic and environmentally friendly energy and material use as an educational goal. The question, if environmental protection can be a link to R&R, has to be pursued in further research. Nevertheless in the field of apprenticeship just a few educational materials related to the issue of R&R could be identified. In contrast to these results interviews with occupational trainers have shown, that R&R is an important topic in corporations against the background of economic competitiveness and costs. Summing up, it can be determined that resource efficiency and resource preservation are not explicitly covered in apprenticeship. The topic is mainly addressed for economic reasons and in the fields of material knowledge.

University / College

The concepts of resource-efficiency and resource preservation are partly known and represented in the higher education system of Germany. Especially technical fields focus on R&R, while other courses of studies link the topic through sustainability and environmental studies. Even in academic studies that do not touch upon the issue of R&R directly, some students have the opportunity to integrate the topic through a modular structure of minor subjects and courses, according to the offers of the universities. The research reveals a wide range of different educational opportunities and materials especially in the fields of sustainability and environment. Some courses of studies and training materials with an explicit focus on R&R are also available but not in a large quantity, which is necessary for a wide mainstreaming of R&R. As many identified studies have a prevailing technical or economical background and therefore a high degree of specialization in each subject, an assimilation of training materials as comprehensive learning material for different courses of studies is rather difficult to achieve.

Advanced vocational training

The field of further education is distinguished through a heterogeneous structure of providers (e.g. enterprises, universities, local governments, private or public organizations, foundations association and initiatives). The missing of central requirements and hierarchical structures leads to low occurrence of formal learning opportunities and to a demand-driven market in private sector. Additional to that context, the research could not cover firms with in-house training programs as well as training materials which are not open (with costs) to public. The research shows that R&R plays a minor role in this field of education. Isolated learning opportunities are often related to broader issues like sustainability or sustainable economics. The specific topics of "resource efficiency" and "resource preservation" do not seem to play an important role. Interviews have shown that mainly small and medium enterprises (SMEs) lack in the topic of R&R. But especially SMEs do not have the resources to implement in-house management systems to cover such issues. Building up awareness for these actors is, therefore, a chance to increase the demand for educational approaches for R&R particular with regards to cost savings. In the public sector already structures and initiatives especially with focus on SMEs exist, such as VDI ZRE (centre for resource efficiency) or demea (German material efficiency agency) or NeRess (network for resource efficiency), which provide knowledge, learning materials, seminars and other tools in the context of R&R. But the lack of awareness still avoids a further dispersion in this field of education.

Outlook

The next step will be to identify "need for action" in collaboration with "focusgroups". This process is accompanied by an integrated scenario analysis through „backcasting and forecasting“. Important issues will be the further development of „proposals for action“ combined with designating responsibilities and scopes of actors and the continuing process of network-building.

With regard to the international level it should be considered if there is a possibility to connect "BilRess" as a part of the "German Resource Efficiency Programme" with similar projects in Europe. In the context to the flagship initiative "Resource Efficient Europe" as part of the "Europe 2020 Strategy" there are appropriate connecting factors for a transnational cooperation to establish a common strategy for an efficient and conservative use of resources in Europe in the future.

36. Rail revolution or carbon creator? Assessing the potential for high speed rail to replace domestic flights worldwide

Holly Edwards

Abstract

Connecting cities is vital for society as well as the economy. Since the introduction of domestic flights, expectations of short travel times between city-pairs have substantially increased. However, carbon emissions from aircraft are a concern, especially as there are few options to decarbonise this sector at present. This study looks at the potential for high speed rail (HSR) to replace the busiest domestic air passenger routes worldwide and assess whether there are net carbon savings as a result. The routes are split into three categories; existing, planned and potential HSR routes. This study focuses on the potential use of air-rail partnerships on these routes to enable significant reductions in short haul domestic flights. The outcome of this research will help to inform policy makers of whether HSR is a sustainable mode of intercity transport or whether it is only viable on limited routes.

Keywords: high speed rail, domestic air travel, carbon emissions, air-rail partnerships, intercity travel.

Introduction

The era of high speed rail (HSR) began on 1 October 1964 with the opening of the first high speed passenger service between Tokyo and Osaka in Japan. Since then HSR has been implemented by a number of other countries worldwide (Givoni, 2006). A formal definition of HSR is still lacking, but one way to describe it is by the service it provides. The focus of this study is the provision of a fast, efficient transport mode between cities being the service in question. New transport modes, such as HSR, have increasingly opened doors for regional development. Not only have improvements in intercity transport helped countries' economies develop, but they have also provided important societal links that we have come to rely on. Therefore, an important question for the future is whether these links can sustainably be maintained.

This study focusses on the potential for HSR to be introduced as a new mode of intercity travel on selected routes worldwide, focussing on the potential to replace domestic air travel. In many countries air travel is the only way to quickly move between different cities. However, this cannot be considered sustainable in the long run due to the impact the industry is having on the climate. Carbon dioxide emissions from aviation make up 2% of total anthropogenic carbon dioxide emissions, and it is predicted that that they could increase by between 1.6 and 10 times this by 2050 (IPCC, 1999).

Previous literature provides a mixed view on the benefits of implementing HSR systems. A number of studies have found that carbon emissions from HSR operations are significantly lower than that of air travel (Alvarez, 2011; Baron et al., 2011; Givoni, 2007). However, others are less convinced by the potential for HSR to reduce carbon emissions (Nash, 1991; Kageson, 2009). It is clear from such studies that one of the most important factors in whether emissions reductions will be seen is the source of electricity needed for HSR traction.

Another important contributor to the amount of carbon that can be saved from switching from air travel to HSR is how much modal shift can be expected between the two modes. Experiences from Europe show that this can be significant (Vickerman, 1997), but this still remains an area that is hard to predict. One way of ensuring increased modal shift from air travel to HSR is through the use of air-rail partnerships. This involves airlines replacing their flights with HSR services on certain routes. Benefits can result for all parities involved with airlines benefiting from additional capacity, freeing of expensive slots at airports to use for other services or to sell and through improved economies of scale, whilst railways benefit from the increased demand that is generated. This is not a new concept, with the first air-rail partnership being introduced in France in 1994 followed by Germany, with Lufthansa's partnership with Deutsch Bahn, completely replacing several short-haul domestic flights (Givoni, 2007; Lopez-Pita and Anton, 2003).

This study aims to evaluate the change in carbon emissions that can result from the implementation of HSR on a selection of routes worldwide when air travel is entirely replaced with the help of air-rail partnerships. The aim is also to highlight the areas that require the most consideration when assessing whether to implement HSR, or in the planning stages of a HSR route.

Methodology

Choice of Routes

Eight city pairs were chosen for analysis, based on the busiest air routes in their area of the world (Amadeus, 2013), feasibility of replacing air travel with HSR and a provision of a mix of operational, planned and potential HSR routes. A summary of these routes can be seen in Table 1.

Route	Status	Distance (km)		Number of flights per day	Year HSR operational
		Air	Ground		
Tokyo-Sapporo	Planned	819.2	1154.9	36	By 2035
Rio de Janeiro-Sao Paulo	Planned	365.3	442.4	70	TBC
Shanghai-Beijing	Operational	1075.0	1229.1	24	2011
Sydney-Melbourne	Potential	706.5	875.6	90	N/A
Johannesburg-Cape Town	Potential	1271.4	1398.0	40	N/A
Barcelona-Madrid	Operational	484.4	624.8	32	2008
Los Angeles-San Francisco	Planned	542.4	614.5	22	By 2029
Mumbai-New Delhi	Potential	1134.6	1452.4	20	N/A

Table 1: *Summary of study routes*

Air travel CO_2 emissions calculation

Emissions were calculated using the number of flights between each city-pair carried out by the airline with the biggest market share on that particular route (FlightAware, 2013). All flights on the route were not included as an air-rail partnership is likely to include only one airline. The aircraft used for each flight was also obtained.

Fuel use data for each flight was obtained from the European Environment Agency Air Pollution Inventory (EEA/EMEP, 2009), which gives fuel use for each aircraft type based on distance flown. Fuel use for the landing and take-off cycle was added to this as this is constant for all flight distances. Annual emissions could then be calculated as of Equation 1, using the standard emissions factor of 3.157 kgCO_2/kgfuel (Jardine, 2009).

$$E_{air} = N_{flights} \text{ x } ((F_{CCD}+F_{LTO}) \text{ x } EF) \quad [1]$$

Where: Eair = total amount of CO2 emissions (kg) between a city pair in one year; Nflights = total number of services between a city pair in one year; FCCD = Fuel use (kg) for climb/cruise/descent stage of flight for given aircraft type; FLTO = Fuel use (kg) for landing and take-off cycle of flight for given aircraft type; EF = emissions factor for carbon dioxide of 3.157 kgCO2/kgfuel

HSR CO_2 Emissions Calculation

HSR CO2 emissions were calculated using Equation 2. As HSR will rely on the electricity grid for traction, energy consumption of 0.033 kWh/seat-km was used based on the future design of high speed trains (Network Rail, 2009). To convert this to the resulting CO2 emissions, carbon intensity of the country's electricity grid were obtained from the IEA (2013). The distance for each route was taken from the ground route between city-pairs. As this analysis is looking at the potential carbon reduction by moving all air passengers to HSR, the number of annual flights was also taken as the number of HSR services required.

$$E_{HSR}=(EC \text{ x } (LF\text{x } S) \text{ x } CI \text{ x } d)\text{x } N_{flights} \quad [2]$$

Where: EHSR = total emissions for HSR; EC = energy consumption (kWh) per seat-km; LF = load factor (%); S = number of seats required by passengers shifting from air travel; CI = carbon intensity of electricity grid (kgCO2/kWh); d = distance (km); Nflights = number of flights per annum that HSR would be replacing.

Scenarios

As many of these routes will not be operational for many years to come, a number of scenarios were analysed representing an increase in fuel efficiency of aircraft and an increase in passenger demand. Aircraft fuel efficiency is predicted to increase by between 0.8% and 1.5% per year, therefore were taken as lower and upper values with an additional middle scenario of 1.15% (Committee on Climate Change, 2009). As these routes are already well developed, demand increases of 1%, 2% and 3% are taken as lower, middle and upper scenario values (Airport Commission, 2013).

Information for possible decarbonisation of the electricity grid was not available for every country, therefore carbon intensity values were calculated that would be needed in order for parity between air and HSR emissions to be reached. Results were compared to 2050 as it is feasible that all HSR routes analysed could be operational by then. The low scenario used in this analysis represents where the lower value for aircraft efficiency improvement is used and where there is a 1% demand increase. The high scenario represents where there is a 1.5% fuel efficiency increase in aircraft and a 3% demand increase.

Results

From Figure 1 it is clear that, at current levels of carbon intensity and aircraft efficiencies, all routes could see savings in CO_2 emissions by switching from air travel to HSR. By far the biggest potential lies in the Rio de Janeiro-Sao Paulo HSR route, where a 96.9% saving in CO_2 emissions could be achieved. Even in the high scenario, this route could still achieve a 75.1% saving. It is also evident that Mumbai-New Delhi is the route that shows that least potential in terms of carbon savings.

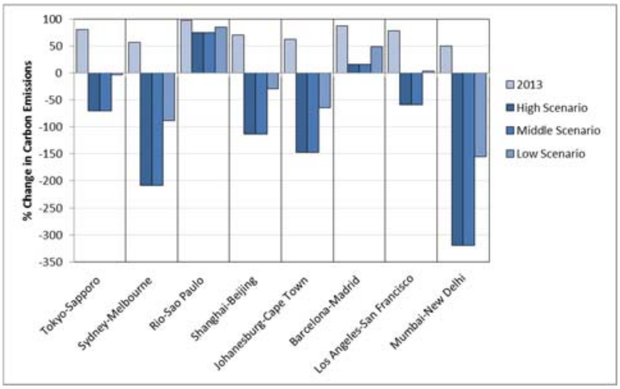

***Figure 1**: Per cent change in carbon emissions from moving from air to HSR for study routes*

Even though under current circumstances, there would be a 49.3% saving through switching to HSR, there is likely to actually be an increase in carbon emissions of up to 320% under the high scenario.

It can be seen from Figure 2 where carbon intensity of electricity grids needs to be in order for parity to be reached between air travel and HSR carbon emissions. It is clear that some countries are in a better position than others, when it comes to decarbonising their electricity grids enough to make HSR a suitable mode of transport for intercity travel. The country that faces the biggest challenge is clearly India, whilst Brazil's grid carbon intensity is well below where it needs to be, even in the highest aircraft efficiency scenario. There are some countries that could reach parity with a reasonable amount of decarbonisation of their electricity grids, such as Tokyo-Sapporo and Los Angeles-San Francisco.

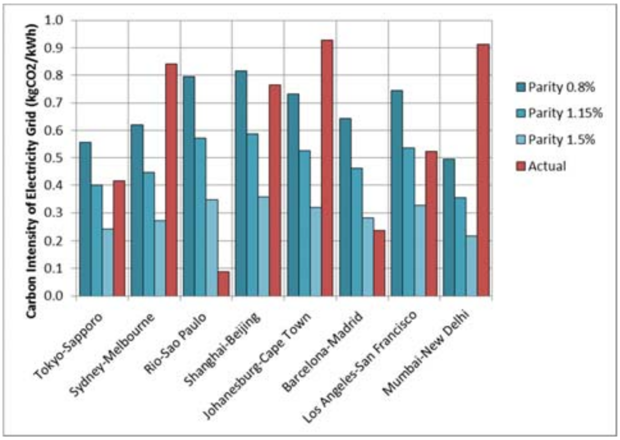

***Figure 2:** Parity values for carbon emissions between HSR and air travel carbon emissions at different future annual aircraft efficiency improvement*

Discussion

It is clear from these results that there is a large variation in the potential for HSR to reduce CO_2 emissions worldwide. Whilst some countries show strong potential with the help of air-rail partnerships, others do not seem to be viable options at present. It is evident that the primary reason for this is the variation in the carbon intensity of a country's electricity grid. Brazil's Rio de Janeiro-Sao Paulo line is a strong candidate route for HSR development as the carbon intensity of the grid is only 0.087kgCO_2/kWh, with the country strongly relying on hydroelectric generation. On the other hand, India and South Africa strongly rely on coal for their electricity generation and this is reflected in these countries showing the weakest potential to reduce CO_2 emissions through the use of HSR.

Another important factor is the route distance and resulting journey time compared to air travel. It is generally agreed that between 400km and 800km is the optimum route distance for HSR to compete with air travel (Steer Davies Gleave, 2003). Table 2 shows that certain routes fall within this competitive bracket i.e. Rio de Janeiro-Sao Paulo, Barcelona-Madrid and Beijing-Shanghai. Others could be competitive, i.e. Sydney-Melbourne and Los Angeles-San Francisco, given that air travel times are the minimum times taking into account flight time and a standard check in time for domestic flights of 30 minutes. However, egress and access times will often take much longer than this. Whilst it is evident that even though Tokyo-Sapporo, Mumbai-New Delhi and Johannesburg-Cape Town HSR lines drastically reduce conventional rail times, they are unlikely to compete with air travel.

Route	Rail Travel Time	HSR Travel Time	Air Travel Time
Tokyo-Sapporo	16 hr	5 hr	2 hr
Rio de Janeiro-Sao Paulo	N/A	1 hr 25 min	1 hr 30 min
Shanghai-Beijing	9 hr 45 min	4 hr 48 min	4 hr 30 min
Sydney-Melbourne	10 hr 54 min	3 hr 8 min	2 hr 5 min
Johannesburg-Cape Town	26 hr	4 hr 30 min	2 hr 30 min
Los Angeles-San Francisco	9 hr (inc. bus)	2 hr 48 min	1 hr 49 min
Barcelona-Madrid	6 hr	2 hr 36 min	2hr
Mumbai-New Delhi	16 hr	4 hr 6 min	2hr 36 min

Table 2: *Travel times on study routes*

Whilst one of the main reasons to implement HSR in a country should be to reduce carbon emissions of intercity transport, there are also other reasons why these links may be increasingly important in the future. The first is that air transport is facing a significant challenge in reducing its CO2 emissions. Whilst there are continuing small changes being made to efficiencies, there is currently no viable solution that will enable air travel to become independent of its use of oil. A lot of reliance has been placed on using biofuels as a substitute for oil. Although there have been a number of successful test flights, land availability remains a constraint, with it being estimated that only 23% of the land needed for all liquid transport biofuels will be available (Upham, 2009).

Not only is a reduction in carbon for airlines an issue, but there is also an increasing financial pressure from the use of oil as fuel for aircraft. In 2013, the global aviation industry is set to receive a $214 billion fuel bill. This is not only 31% of the operating cost of airlines but is also five times higher than the fuel bill decade ago (IATA, 2013). With this trend set to continue there is a risk that domestic services may be cut in favour of the more profitable long haul routes for airlines.

Therefore there is a real concern that relying on air services into the future could not only have a significant effect on climate change, but also reliance on oil could result in the loss of important intercity connections by air. With congestion issues for many routes being faced on railways and roads, this could result in these links being drastically degraded.

Conclusion

High speed rail has the potential to be a sustainable mode of transport in terms of reducing carbon emissions and reliance on air travel for quick and efficient intercity travel. However, it is clear that HSR may not be suitable for every intercity route, with a number of factors contributing to the amount of carbon that can be saved from switching to this mode. The results of this study indicate that one of the most important factors is the carbon intensity of the electricity grid of the country in question, as HSR will rely on this for traction. It is also highlighted that carbon emissions are not the only issue that needs addressing, with the airline industry's reliance on oil being a factor which could significantly affect the provision of intercity transport in the future. This study proposes that the decision to implement HSR should give these factors significant consideration. It is also proposed that where HSR is deemed a suitable mode for intercity transport, air-rail partnerships should be used to maximise carbon reduction potential and benefit both railways and airlines.

Part IV.

Circular Economy and Decoupling

37. Business models for a circular world: the case of metals

Nick Florin, Samantha Sharpe, Simon Wright and Damien Giurco

Abstract

New wealth is increasingly being created by implementing business models which promote circular flows of resources and de-couples growth and resource use. For the case of metals, the declining availability of natural resources and the environmental impacts of continued extraction of primary resources for production activities have forced greater focus on waste streams and recycling activities. However implementing new business models for circular material flows require system-wide changes that will likely involve radically different approaches to doing business and the adoption of disruptive technologies. These new business models will fundamentally challenge the existing view of business models as a way of understanding *how businesses do business*, and how they create and appropriate value.

This paper has two purposes; the first is to present an overview of new 'circular' business models, in particular their relevance to metals. By modifying a typology for sustainable business models we define circular business models as a subset of sustainable business models and consider two exemplary cases to examine the varied characteristics that define such business models for circular flows of metals.

Keywords: business models, circular economy, and metals.

Introduction

The concept of a circular economy holds promise as a model for promoting new modes of production and consumption that are based on a circular flow of resources that de-couples growth and resources use. This is opposed to more traditional linear flows of resources from production to waste disposal.

There is contention around the definition of a circular economy, which is not a new idea, and draws connections to the fields of industrial ecology, cradle-to-cradle, and bio-mimicry, for example (Ellen Macarthur Foundation, 2014; Giurco et al., 2014; Yuan et al., 2006). New ways of doing business that promotes circular flows of metals can improve material use efficiency and is important for reducing the demand for primary inputs. However, in the context of continuing growth for metals and alloys, as well as improving material efficiency, business activities that promote sufficiency are also important to reduce total demand and are a necessary part of transitioning to a sustainable future for metals.

A circular economy in the metals sector is conceived as the ideal case recognising that it is impossible to achieve complete circularity of material flows owing to cycle losses(Reuter et al., 2013), e.g., associated with the energy inputs required for material separation and reprocessing, and the increasing complexity of industrial activities and products. However, a range of factors including resource scarcity, climate change, and other adverse environmental impacts give emphasis to the importance of increasing resource-use efficiency. The non-renewable nature of metals and minerals, combined with their long-term value in the economy means a shift towards a higher rates of circular material flows is inevitable. The challenge is how to create and capture value to accelerate this shift.

Developing a typology of new business models for a sustainable metals

There is a substantial body of literature considering the definition and characteristics of ‘sustainable business models’ (Bocken et al., 2014) and ‘business model innovation’ that is relevant to circular material flows for metals (e.g., Sharpe & Agarwal, 2014; Roos, 2014). For example, Bocken et al (2014) define 8 sustainable business model archetypes based on a comprehensive review of literature (academic and grey literature) and business practice. These include: (1) maximise material and energy efficiency, (2) create value from waste, (3) substitute with renewable and natural processes, (4) deliver functionality rather than ownership, (5) adopt stewardship role, (6) encourage sufficiency, (7) repurpose for society and the environment, and (8) develop scale-up solutions. They further categorised these in terms of three broad groups: technology (1-3), social (4-6) and organisation (7-8) (revised for Figure 1).

In this work, we have modified this typology considering circular business models as a subset of sustainable business models (Figure 1). In considering business models for circular flows we suggest that Bocken ’s archetypes (6-8) may be conceived as necessary precursors, or underlying principles, for delivering sustainable outcomes in a circular world and thus applicable to all categories.

Recognising the complexity of the metals recycling sector (Reuter et al., 2013), and the complexity of metal bearing products, significant advances towards an ideal circular economy likely necessitates new collaborations across the supply chain, and, new modes of consumption. Hence, those examples of business models that are aligned with consumption are shaded, compared to those that are more aligned with production, including design and manufacturing processes. In order to improve the efficiency of material flows and encourage sufficiency it is likely necessary that new circular business models cut across both production and consumption systems. On this basis we suggest that a further distinguishing criterion for circular business models is that they must be oriented towards consumption, or consumption and production.

Given the focus on metals, Figure 1 includes key business model examples considered to be of high relevance to metals and metal bearing products. A key observation is that many business models examples that promote circular material flows may be associated with technological innovation and there are clear incentives to maximise material and energy efficiency, or create value from waste based on industrial symbiosis. While it is clear how material efficiency improvements create profits, if it has ‘rebound effects’ then the environmental and social benefit may be undermined (Bocken et al., 2014).

While it is expected that novel technologies will play an important role in future supply and demand (Giurco et al., 2014), technology innovation that is strongly focussed on increasing the resource base, including reprocessing and recycling technologies, can not deliver sustainable outcomes in isolation. For example, while recycling efficiencies of > 95 % are achievable for platinum group metal containing materials, this is only possible if these materials reach the state-of-the-art facilities. In many instances it is not the technical recyclability of a material but stakeholder interactions (e.g. collection and delivery systems) within the material life cycle that is the limiting factor (Hagelüken, 2012). This does not discount the importance of technology, for example: the potential of 3D printing to both reduce material intensity and enable the development of distributed production/manufacturing systems; and, advances in digital technology as an enabler for tracing material flows in secondary cycles to monitor quality and efficiency, and assign value. This discussion highlights the importance of the production-consumption system innovation, and business models that move across a range of categories are required to deliver 'radical' system wide change and enhanced stakeholder interaction and collaboration.

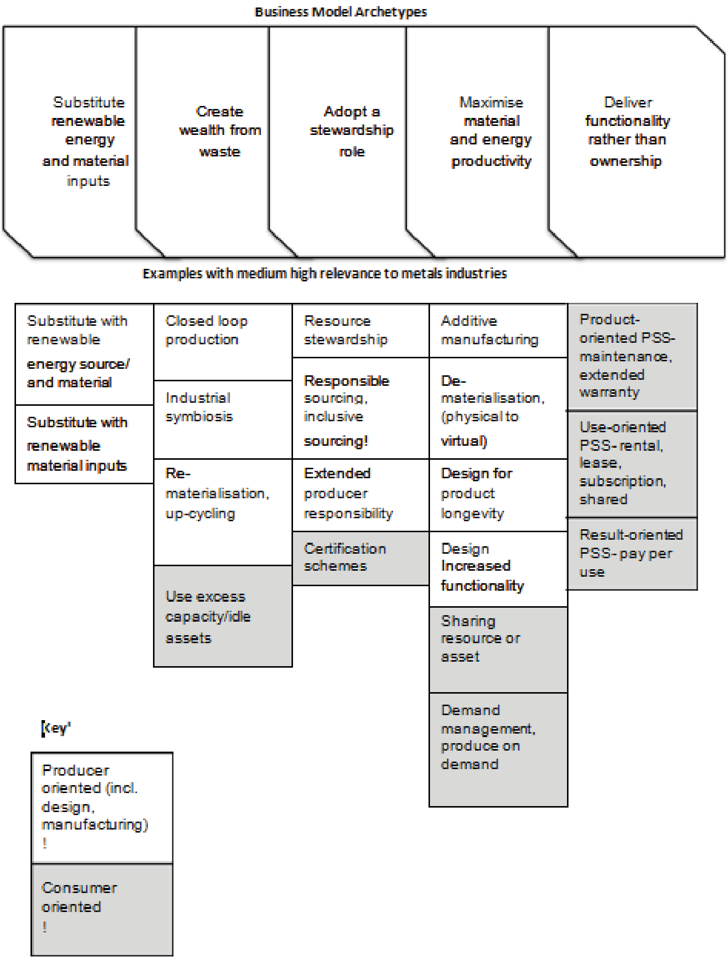

***Figure 1:** Categorisation of sustainable business model archetypes after Bocken et al., (2014). Examples included indicate those identified to be most applicable to creating and attaining value from circular flows for metals.*

Application of typology to Australian metals sector

In order to examine the varied characteristics that define business models for incentivising circular material flows we consider two exemplary cases. These cut across the technology, social and organisation groups and offer the potential to deliver radical system-wide change underpinned by new stakeholder collaborations.

Metals leasing

Description

The concept of metals leasing is a relatively novel idea that has received limited critical reflection (Morrison & Giurco, 2011). The concept has been explored in more detail in the context of the chemical industry (Lozano et al., 2014). For example, the Global Chemical Leasing Program was launched in 2005 in the context of the UNEP Strategic approach for International Chemicals Management (SAICM) (UNIDO, 2011). According to UNIDO, the leasing model is defined as "a service-oriented business model that shifts the focus from increasing sales volumes of chemicals, towards a value-added approach"(UNIDO, 2011). More efficient resource use may be promoted because value is no longer linked to volume of sale/production, instead a miner or producer might generate value from the service that the metal provides. There are likely benefits in terms of encouraging resource sufficiency and quality.

Enabling factors

Metals that may be most applicable for leasing have a high capacity for recovery and a high price as opposed to products with a low value or a low capacity for recovery. Certain metals streams (gold, copper, platinum group) are ideal candidates for leasing with enablers for leasing including a high value, a high concentration in the waste stream, and the capacity for a high percentage of recovery (e.g. greater than 75 % has been suggested by (Lozano et al., 2014).

A key factor is collaboration, including the requirement of companies to share information and engage in long-term cooperative activities with producers/suppliers.

Implications and challenges for circular material flows

The leasing model provides a strong driver for circular material flows. For example, if ownership is retained with a producer then there is a strong driver for recycling and monitoring material flows in the economy. There are limited example of metal leasing, e.g., recovery of nickel and iron in electroplating (Schwager & Moser, 2006), platinum recovery from fuel cell vehicles has been evaluated (Kromer, et al., 2009), it has been proposed for lithium (Prior et al., 2013) and Morrison & Giurco (2011) discuss metal leasing as an alternate taxation strategy.

Further research is required to identify which types of metals may be most suitable for leasing, considering: recycling efficiency, proximity of producer and user, and reasonable durations for leasing arrangements (Lozano et al., 2014). This necessitates better data acquisition to measure the efficiency of use and percentage of recovery, which is critical for apportioning value (for materials, services, labour, and energy). There are further questions in terms of what type (and size) of companies may be most suited, and how to establish new collaborations and interactions in the supply chain, including the changing role of producer to service provider and new customer expectations (Lozano et al., 2014).

Supply Chain Certification schemes

Description

A range of supply-chain certification schemes have been developed in recent years for metals with the aim to derive a competitive advantage by differentiating metals/ metal products on the basis of superior environmental and social impacts across the whole life cycle. The importance of this type of approach is apparent considering that engagement with environmental impacts across the whole lifecycle of materials or products is frequently overlooked, e.g., the majority of emissions from value chains are not currently measured (Carbon Disclosure Project, 2012). This is most relevant to metals given the energy intensity of production and reprocessing.

An example is the Australian Steel Stewardship Forum (SSF) and the development of a certification scheme for Australian ‘Responsible Steel’. Other certification schemes are reviewed elsewhere (Table 1, Benn et al., 2014). Key stakeholders from all major sectors of the Australian steel product lifecycle from mining, processing, product fabrication, use, re-use and recycling are involved; as well as government, non-government organisations (NGOs) and industry associations(Benn et al., 2014).

Enabling factors

Managing risk is seen as a major driver, including legal and health and safety issues, e.g., for miners this is about maintaining a ‘social license to operate’ avoiding disruption from protests, changing worker safety conditions, or adverse environmental releases. Benn et al. (2014) also observe an emerging phenomenon of a ‘social license to market’.

However, these schemes are also being pursued as a proactive strategy to secure market advantage, i.e., where opportunities for value creation arise from consumers being willing to pay a premium. That said, the added-value of Australian ‘Responsible Steel’ may be limited given that global demand is driven by consumers in developing countries who may not have the same consumption preferences and priorities(Benn et al., 2014)

Implications and challenges for circular material flows

For the SSF, the first activity has been the mapping of commodity flows and emission intensities across the supply chain with data voluntarily supplied by the companies involved. Currently much of the scrap in Australia is melted down to be used in low-grade products and this is unlikely to incentivise an increase in the share of recycled materials relative to demand (Benn et al., 2014).

While the extent to which the initiative will increase circular material flows, the promotion of better communication across the supply chain, increased understanding and awareness of sector-wide benefits of material efficiencies, and development of consistent data acquisition and interpretation protocols are important precursors towards creating value for secondary material flows.

Conclusions

Recycling and reuse activities are increasingly complex because of the complexity of production activities and consumer products. Owing to this complexity, new business models for incentivising circular material flows will likely exploit synergies across the technological, social and organisational dimensions to deliver radical system-wide change in the sector towards a sustainable future.

This is still very much an emerging field of research and as a result, concepts and principles are still in flux. Circular business models logically fit in the broader range of sustainable business models, but as this article has demonstrated the boundaries and characteristics of sustainable business models are still up for discussion.

Section 2 identified five archetypes of sustainable business models:

1. Substitute renewable energy and material inputs
2. Create wealth from waste
3. Adopt a stewardship role
4. Maximise material and energy efficiency
5. Deliver functionality rather than ownership

In each of these business models there are elements of circularity including closed loop production, industrial symbiosis and re-materialisation or up-cycling in the *Creating wealth from waste archetype*; use oriented product service systems such as rental, leasing, subscription and shared services in the

Deliver functionality rather than ownership archetype; and extended producer responsibility, resource stewardship and certification schemes in the *Adopt a stewardship role archetype*.

Two broad underlying principles from this analysis of sustainable business model archetypes were also identified including; i) promoting new modes of consumption to alleviate total demand for raw materials by encouraging sufficiency, and ii) developing scalable solutions. In order to encourage sufficiency it is necessary that new circular business models influence consumption systems. Thus, an important criterion for circular business models that might distinguish these models from other sustainable business models is that that must be oriented towards consumption, or consumption and production systems.

Two of these circular business models were profiled in Section 3 including the enabling and limiting factors of adopting these circular business models. In each case the enabling factors involved the creation of value by addressing waste streams. Accessing previously discarded yet valuable metals and materials, as well as with waste streams in a way that positively reflected on corporate responsibility and other risks to ‘social licence to operate’ creates value in each case. In both cases the challenges of applying these business models related to information deficits of material flows, and the need for collaborative competencies across the supply chain in being able to address these deficits in a meaningful way.

This highlights a number of knowledge gaps in our understanding of these business models. At the individual business level accessing information on material flows across the supply chain requires internal strategic knowledge of processes and material input needs, as well as external knowledge of their supply chain to identify stocks of needed materials and arranging means of access. This in turn highlights a more system-level knowledge gap of stocks and flows of materials, and indeed the material components of products in a standardised way.

A further and more abstract knowledge gap is an understanding the performance of sustainable and circular business models within the economy, and the degree to which businesses can be more or less sustainable (or circular). These business models exist on a spectrum from less to more sustainable, but on what basis can the discernment of more sustainable be made, and how does this interact with other performance indicators that are commonly used to assess business activity, including revenue, profitability and returns to shareholders. The degree of application of the two underlying principles identified earlier (promoting new modes of consumption to alleviate demand for raw materials and encourage sufficiency, and developing scalable solutions) offers a reasonable starting point.

The importance of understanding the dimensions of sustainable business models lies in the criticality of these models to realigning our production and consumption cycles to enable resources scarcity, climate change and other adverse environmental impacts of our current production patterns to be addressed. Understanding these business models better allows us to be able to create a supportive environment for these businesses to establish and thrive.

38. The role of resource efficiency in the German transformation of the energy system

Sebastian Schmidt

Abstract

With its Energy Concept and the related decisions taken by the government, the road is paved for the transformation of the German energy system. The strategic documents include measures, indicators and targets in the fields of greenhouse gas emissions, energy efficiency, buildings, transport and renewable energies. The implementation of the transformation has strong implications for overall resource use, and resource efficiency plays a crucial role for the success of the transformation. This paper is dedicated to analyse this relationship in more detail.

Keywords: resource efficiency, energy, raw material, natural resources, transformation.

Introduction

The German government has elaborated a first draft of an Energy Concept in the year 2009 which was laid down in the documents concluding the results of the Meseberg summit. The concept was further discussed and developed until its adoption by the Federal Cabinet in September 2010. In the meantime different amendments of laws have been decided by the government to implement a Transformation of the German Energy System (in German "Energiewende"). The Energy Concept has been complemented by decisions on accelerating the Transformation in 2011. Together these documents provide specific targets and encompass a monitoring process, a financing plan and about 180 individual measures.

"The German government decided that Germany's energy supply should be generated primarily from renewables by 2050. This requires our energy supply system to be fundamentally restructured, presenting Germany with economic and technological challenges." (BMU 2013a). The BMU states that energy efficiency is "the key factor" for the success of the Transformation (BMU 2013a).

We argue, that in the light of the implications of the Transformation for the necessary development of related infrastructures – industrial production facilities, energy grids, housing, mobility – it will not be enough to focus on energy alone. Large quantities of mineral resources and metals are needed as well as other resources. They all will have to be used as efficiently as possible. As energy demand strongly depends on the general mode of consumption and production, the Transformation has to go hand in hand with a transition to a more resource efficient economy.

Resource Demand induced by the Transformation of the Energy System

While the main motivations of the Transformation of the German Energy System lay in the achievement of a situation of increased independence of fossil fuel imports and the reduction of greenhouse gas emissions, other resources play crucial roles as well. According to the European Environment Agency (EEA), most European Countries use a "broad interpretation of the term 'resources', corresponding loosely to the all-encompassing definition of natural resources given in the EU Thematic Strategy on the sustainable use of natural resources", which is in line with the European Commission's communication of January 26th, 2011 entitled 'A resource-efficient Europe — Flagship initiative under the Europe 2020 Strategy' and the subsequent communication of 20 September 2011 on a 'Roadmap to a Resource Efficient Europe' (EEA 2011, p. 17). The Thematic Strategy defines the notion of natural resources as follows (EC 2005, p. 3): "raw materials such as minerals, biomass and biological resources; environmental media such as air, water and soil; flow resources such as wind, geothermal, tidal and solar energy; and space (land area). Whether the resources are used to make products or as sinks that absorb emissions (soil, air and water), they are crucial to the functioning of the economy and to our quality of life."

The Transformation of the German Energy System will have an impact on all the resources mentioned in this definition. We show that the nexus of both challenges leads to the compelling conclusion, that they should be handled in close coordination.

The German Ministry for the Environment (BMU) has identified nine "key fields of action for implementing the transformation of our energy system," of which some can be used as orientation for this analysis (BMU 2013a):

- "Renewable energies as a cornerstone of future energy supply
- Energy efficiency as the key factor
- Nuclear power and fossil-fired power plants
- An efficient grid infrastructure for electricity and integration of renewables
- Energy upgrades for buildings and energy-efficient new build
- The mobility challenge
- Energy research towards innovation and new technologies
- Energy supply in the European and international context
- Acceptance and transparency".

In 2012 the German Ministry of Economics (BMWi) has published the first monitoring report for the Transformation of the Energy System, which shows current targets and achievements:

	2011	2020	2050		
Greenhouse gas emissions					
Greenhouse gas emissions (compared with 1990)	-26.4 %	-40 %	2030 -55 %	2040 -70 %	2050 -80 % to -95 %
Efficiency					
Primary energy consumption (compared with 2008)	-6.0 %	-20 %	-50 %		
Energy productivity (final energy consumption)	2.0 % per annum (2008-2011)	2.1 % per annum(2008–2050)			
Gross electricity consumption (compared with 2008)	-2.1 %	-10 %	-25 %		
Share of electricity generation from combined heat and power plants	15.4 % (2010)	25 %	-		
Buildings					

	2011	2020	2050		
Heat requirement	no data	-20 %	-		
Primary energy requirement	no data	-	around -80 %		
Rate of modernisation	approx. 1 % per annum		Doubling of levels to 2 % per annum		
Transport					
Final energy consumption (compared with 2005)	approx. -0.5 %	-10 %	-40 %		
Number of electric vehicles	approx. 6,600	1 million	2030 6 million	-	
Renewable energies					
Share in gross electricity consumption	20.3 %	at least 35 %	2030 at least 50 %	2040 at least 65 %	2050 at least 80 %
Share in gross final energy consumption	12.1 %	18 %	2030 30 %	2040 45 %	2050 60 %

Table 1: *Targets of the Transformation of the German Energy System (BMWi 2013, p.3)*

Expected Reductions in Resource Demand

First of all, the measures directed to increase energy efficiency and to reduce primary consumption of energy will result in reductions of resource demand. This holds true for fossil fuels as well as for raw materials that will not be needed for the required level of capacity of renewables, grids and storage applications. Other aspects are reductions in land use and the use of environmental sinks, which have a positive impact on biological resources, too.

The shift from fossil to renewable energy production will lead to a reduction in the use of fossil fuels, while at the same time resulting in an increased demand for the raw materials needed for the production, storage and distribution of renewable energy. But as the resource intensity of energy production by e. g. wind or solar power is significantly lower than that of e. g. coal, the overall resource demand for energy production is assumed to decrease in the middle and long run.

If and under what conditions a shift from fossil to biotic raw materials for energetic and material use will lead to an overall reduction of resource use or not has been debated lively. Germany laid down criteria for the sustainable supply of biomass in a regulation. The European Biomass Association and the Union of the Electricity Industry have recently published a position paper calling for EU-wide binding sustainability criteria for biomass (AEBIOM/ EURELECTRIC 2013). We assume that if such criteria are well designed to avoid burden shifting – between resources and geographically – a reduction in overall resource demand through the substitution of abiotic by biotic resources will be possible.

Expected Increases in Resource Demand

Increases in the use of resources can be expected due to the expansion of renewable energy infrastructure: energy production facilities, grid and storage infrastructure. The corresponding technologies require an increasing amount of raw materials and space.

Moreover their production and installation has an impact on environmental media and biodiversity.

Recent studies show that the global demand for raw materials induced by future technologies will increase manifold over the next two decades (Angerer et al 2009). Different raw materials are essential for renewable energy technologies like photovoltaics or wind mills. The European Parliaments Science and Technology Options Assessment has analysed the future metal demand from photovoltaic cells and wind turbines (EP/STOA 2012). Other studies have elaborated the raw material requirements for electric mobility (Angerer et al 2010).

Another aspect which is sometimes raised in discussions is the need to use more raw materials for the insulation of buildings. Both energy-related refurbishment and new buildings complying to high level thermal insulation standards require the use of a higher amount of raw material than conventional buildings.

Synthesis: Reductions vs. Increases in Resource Demand

As there is neither a systematic qualitative analysis nor a quantitative analysis of the balance of resource demand developments related to the Transformation of the German Energy System, we can only recur on fragmented information of the kind mentioned above and the common sense, that the transformation will have both positive impacts on the economy and the environment.

While we expect increases in resource demand in the transformation phase, the resource demand of the energy system, the transport and the buildings sector is expected to decrease in the middle and long term compared to the status quo. The infrastructure investments which are implemented in the next years are perceived to lead to a less resource intensive infrastructure. The longer e. g. a surplus amount of thermal insulation is installed in a building, the higher is the cumulated amount of reduction in energy use. The longer resource efficient technologies are in place, the higher are the returns resulting from increased efficiency which are thus increasingly outweighing the initial cost of installation.

Nevertheless, resources will be required to realise the transformation and it will become more difficult to get access to them as they get increasingly scarce. Their efficient use will be essential for the successful Transformation of the German Energy System.

The Nexus of Raw Materials and Energy Efficiency

Although often cited, the causal relationship of the use of raw materials and the use of energy along the whole life cycle has not been systematically assessed on a broad scale so far. On the one hand it seems convincing, that every ton of raw material, which is not needed for the provision of a good or a service, will not have to be mined, refined, transported, manufactured, distributed, consumed, recycled or disposed of. On the other hand, the substitution effects are often unclear and would have to be analysed to prove real progress towards increasing resource efficiency.

A recent study in Germany concludes that an increase in material productivity has the potential to significantly reduce energy consumption and emissions of CO_2: The evaluation of the public support programme „r²: Innovative Technologien für Ressourceneffizienz – Rohstoffintensive Produktionsprozesse“ of the Federal Ministry of Education and Research (BMBF) led to the conclusion that if the results of the r² programme would be fully implemented in Germany, the following reductions could be realised on an annual basis (Fraunhofer ISI 2012):

- About 80 million tons of material use,
- about 75 terawatt hours of energy use and
- about 60 million tons of CO_2-equivalents.

At the same time the raw materials productivity – measured in gross domestic product per domestically extracted and imported material – would increase by at least 5 %.

Another indication that increased raw materials efficiency leads to reductions in energy demand is provided by the fact that recycled materials need much less energy per unit of output than comparable primary materials. Recycling aluminium e. g. is said to need 95 % less energy than producing aluminium from raw materials and does moreover save 97 % of greenhouse gas emissions produced in the primary production process (Alupro 2013). One of the reports of the International Resource Panel of the United Nations Environmental Programme gives an overview on the assumed energy savings of recycling (UNEP 2013):

Metal/Product	% Savings	References
Aluminium	90 - 97	Norgate & Rankin (2002), Gaballah and Kanari (2001), Quinkert et al. (2001), International Aluminium Institute (2011), Chapman and Roberts (1983)
Copper	84 - 88	Norgate and Rankin (2002), Gaballah and Kanari (2001)
Gold	98	ecoinvent v2.2
Lead	55 - 65	Norgate and Rankin (2002), Gaballah and Kanari (2001)
Magnesium	97	USEPA (1994)
Nickel	90	Norgate and Rankin (2002)
Palladium	92 - 98	ecoinvent v2.2
Platinum	95	ecoinvent v2.2
Rhodium	98	ecoinvent v2.2
Silver	96	ecoinvent v2.2
Steel	60 - 75	Norgate and Rankin (2002), Gaballah and Kanari (2001)
Stainless Steel (304)	68	Johnson et al. (2008), Eckelman (2010)
Titanium	67	Chapman and Roberts (1983)
Zinc	60 - 75	Norgate and Rankin (2002), Gaballah and Kanari (2001)

Table 2: *Targets Ranges of energy savings of recycling for various ferrous and non-ferrous metals (adapted from Norgate 2004 by UNEP 2013).*

Conclusions

Besides the goals of the German government concerning the Transformation of the Energy System mentioned above, there are also government goals concerning the improvement of raw materials and energy productivity. Other goals relate to other resources such as land, biodiversity and sinks. They are laid down in the National Sustainability Strategy (Federal German Government 2002, p. 93) and will among others be implemented by the German Resource Efficiency Programme ProgRess (Federal German Government 2012).

The nexus of the resource challenge and the transformation challenge of which important features have been described above leads to the compelling conclusion, that they should be handled in close coordination. This conclusion has not only a strong significance for Germany, but also for many other countries, as they engage in the transformation of energy systems as well. The establishment of a “Renewables Club”, consisting out of ten countries and aiming at scaling up the deployment of renewable energy worldwide, is just one indication showing that the development in Germany may be taken up in other countries and regions (BMU 2013b). An even stronger indication is maybe the existence and high acceptance of the IRENA – the International Renewable Energy Agency (now over 100 member states).

The efficient use of resources will be crucial for the successful implementation of the Transformation of the Energy System. It must be one of the key elements in the planning, design and implementation of new infrastructures, processes and products. Technological breakthroughs will play a major part in delivering the necessary fundamental changes.

39. Complex human-nature system interactions in a resource constrained world – Systems analysis of problems associated to resource use and scarcity, and potential solutions aiming at resource efficiency

Deniz Koca, Harald Sverdrup and Kristin Vala Ragnarsdottir

Abstract

This paper provides a systemic analysis of complex dynamic issues associated with resource use, scarcity and efficiency by applying systems thinking with respect to sustainability criteria. Casual loop diagramming methodology is adopted to create a conceptual model to better understand the interconnected patterns, cause effect relations and feedbacks between the three dynamic complex systems that constitute the world we live in – namely, the biophysical world system (with all natural resources that it encompasses i.e. water, air, land and soil, as well as abiotic and biotic raw materials), the human system (from individual, to group to society) and the human built support system (covering all physical, legislative and institutional infrastructures: e.g. ranging from economy to government, to technology to agriculture etc.). The conceptual model provides a holistic view and it is essential in identifying and assessing; i) the main driving forces behind environmental degradation and resource scarcity problems; and ii) associated existing and potential future alternative solutions (ranging from cleaner technology and pollution prevention practices, to sustainable consumption and production policies, to decoupling of economic growth from environmental degradation, all of which aim at resource efficiency by means of technology-ICT, innovation, regulations, legislations, taxes etc.) to these problems.

Keywords: resource use, resource scarcity, resource efficiency, systems thinking, systems analysis, sustainability

Introduction

The human system with ever increasing demand for resources lies on the heart of the biophysical world system, which provides all the resources that the human system is dependent on i.e. water, air, land and soil, as well as abiotic (metal ores, industrial and construction minerals, fossil fuels) and biotic (biomass for food, feed and fuel, and fishery) raw materials (Figure 1). Provision of these resources is ensured through a human built support system, which consists of several subsystems covering all physical, legislative and institutional infrastructures (i.e. economy, agriculture, government etc.). Some of these subsystems have been designed primarily to sustain the provision of these resources (i.e. agriculture for food, or mining industry for minerals and metals supply), where as others to maintain the social sustainability of the human system (i.e. religion, art, culture etc.). Majority of the subsystems in the support system, however, serve for two of the mentioned purposes (i.e. economy, government, institutions etc.).

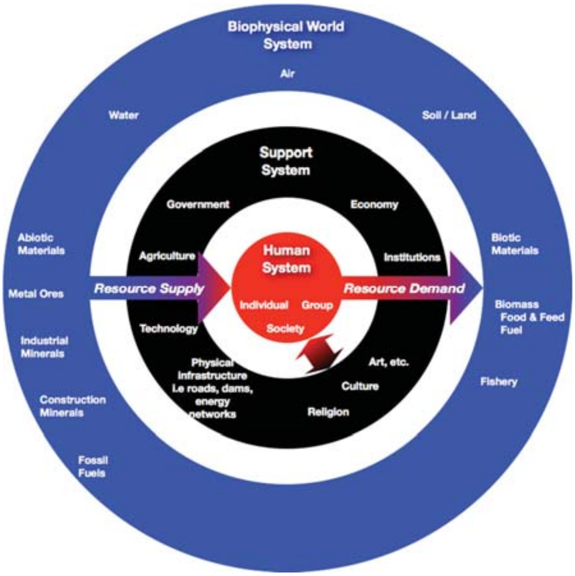

Figure 1: *The complex interconnected human – biophysical world systems through a support system. (Developed based on Bossel, 1999; BMU, 2012)*

The demand for natural resources, especially abiotic and biotic raw materials, has grown substantially over the last century. The amount of resources extracted and used per year globally, has increased by 50 percent reaching to about 60 billion tonnes/yr in the last 30 years (Behrens et al., 2007). Declining ore grades, rising extraction costs, increasing market prices and occasional scarcity of some of the key metals and other resources have been observed in the last two decades (Heinberg 2011). With all of these diagnostic signs, it is clear that the biophysical world system is slowly going towards an over-exploitation of metals reserves, fossil energy resources and other key resources. Scientifically based predictions (Meadows et al., 1972, 1992, 2005; Ragnarsdottir et al., 2011a, b; Sverdrup et al., 2012a,b; Sverdrup et al., 2014a,b; Kifle et al., 2013) suggest that the situation will become more serious in the next two decades with real global resource scarcity becoming evident. Hence, concerns about security of supply and resource scarcity have been growing in the political agenda (e.g. Mancini et al., 2013).

Objective and scope

The main objective of this paper is to adapt systems approach in order to identify and assess: i) the main driving forces behind environmental degradation and resource scarcity problems; and ii) associated existing and potential future alternative solutions to these problems with a holistic view.

Causal Loop Diagramming Methodology

Casual loop diagramming methodology is adopted to create a conceptual model to better understand the interconnected patterns, cause effect relations and feedbacks between the three dynamic complex systems that constitute the world we live in – namely, the biophysical world system, the human system and the human built support system. The conceptual model provides a holistic view in identifying and assessing the main driving forces to environmental degradation and resource scarcity, and the alternative potential solutions to tackle with these issues.

In the Causal Loop Diagram (CLD) as presented in Figure 2, the arrows that link each variable indicate places where a cause and effect relationship exists. The plus or minus sign at the head of each arrow indicates the direction of causality between the variables when all other variables conceptually remain constant. More specifically, the variable at the tail of each arrow causes a change in the variable at the head of each arrow in the same direction (in the case of a plus sign), or in the opposite direction (in the case of a minus sign). The overall polarity of a feedback loop - that is, whether the loop itself is positive or negative - in a causal loop diagram, is indicated by a symbol in its centre. An “R” sign indicates a reinforcing loop (or equivalently known as positive feedback loop), and a “B” sign indicates a balancing loop (or negative feedback loop). In a reinforcing loop the action of the loop is to influence the parameter in the same direction as it is already moving, where as in a balancing loop it is to return the parameter to its initial value.

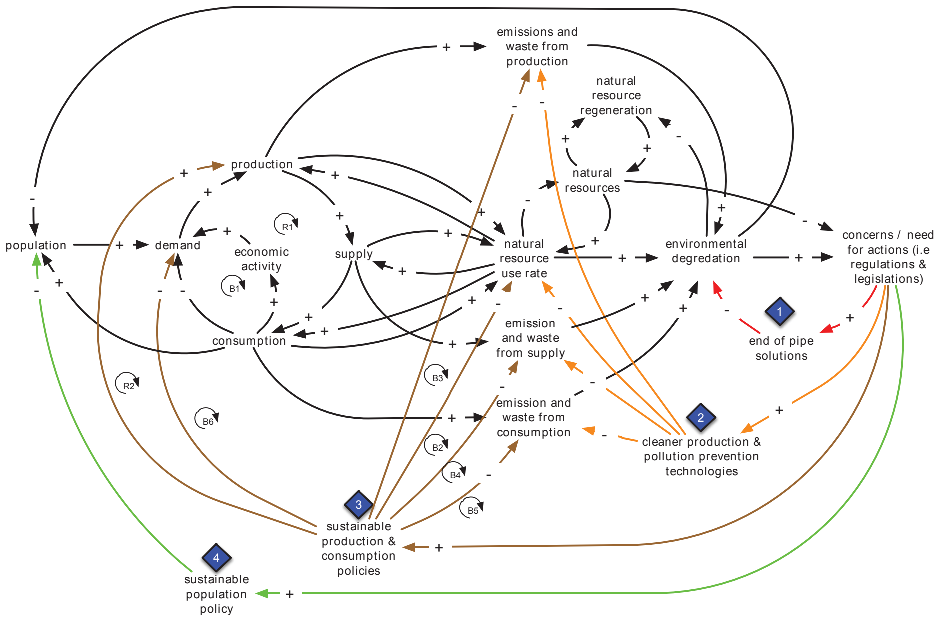

Figure 2: *Causal Loop Diagram showing the main driving forces to environmental degradation and resource scarcity, and the alternative potential solutions to tackle with these issues. A detailed explanation of the figure is given in the next section.*

Systems Analysis of Complex Human – Nature System Interactions

As Figure 2 shows, with increasing population, the demand for all type of goods and services increases. This demand, in turn, increases the production and supply of these products and services. Once the consumption increases, the demand is satisfied and eventually it decreases (B1). However, increased consumption also leads to growing economic activities, which in turn increases the demand (R1). An increase in production, supply and consumption leads to higher levels of emissions and waste generation, as well as resource use rate, all of which cause environmental degradation. Increasing natural resource use rate leads to a decrease in the natural resources. Decreasing natural resources and increasing environmental degradation lead to a decrease in natural resource regeneration. Thus, increased resource use rate and decreased natural resource regeneration are the two factors behind resource scarcity.

Environmental degradation and depletion of natural resources lead to increased public awareness and concerns, which ultimately have an effect on political actions. This leads to the development of four different policy options ranging from end of pipe type solutions to cleaner production and pollution prevention practices, to sustainable consumption policies, and to sustainable population policy, all of which aim at resource efficiency by means of technology/ICT, innovation, regulations, legislations, taxes etc.

End of Pipe Solutions

It is recognized that human activities have contributed to the deterioration of the environment and to the loss of natural resources over the last century. As a first response to increased public awareness and concerns, the governments introduced policy actions favouring the end of pipe type solutions (Figure 2, diamond no.1). Such solutions refer to added technical installations for environmental control of emissions (UN, 1997). They reduce or prevent the spread of pollution and environmental degradation, however, do not affect the production process, thus have no positive effect on the resource efficiency. Some examples to such solutions include construction of wastewater treatment plants before the drainage of wastewater from industrial processes, or installation of catalytic converters on vehicles to reduce the emission of pollutants to the atmosphere.

Cleaner Production and Pollution Prevention Practices

After realising the economic value of raw materials, a paradigm shift from end of pipe solutions to pollution prevention strategies and cleaner production practices have occurred during the 90's. Different from end of pipe solutions, pollution prevention strategies and cleaner production practices increase the efficiency in production process. Hence, they not only reduce the use of natural resources, but also reduce or eliminate emissions and waste generated (OECD, 2007) (Figure 2, diamond no. 2). Cleaner production is particularly applied in production process in manufacturing sector. Pollution prevention, on the other hand, is a general approach and can be adopted within all sectors and not only in production, but also in supply and consumption phases. Hence, pollution prevention practices decrease the emissions and waste generations during the supply and consumption phases as well.

Sustainable Consumption and Production Policies

With the emergence of natural resources scarcity, implementation of sustainable consumption and production policies has increased during the last decade. The main objective of such policies is to decouple econometric growth from environmental degradation (UNEP, 2012) meaning that with increased resource efficiency, more goods and services are delivered, less resources are used (B2), and emissions and waste generation are reduced (B3, B4, B5). This leads to an improvement in environmental degradation. However, increased resource efficiency gains are often offset by the rebound effect, which means that reductions in the costs of products due to enhanced resource efficiency leads to more production (R2), supply and consumption of these products. As a result of increased activities in existing economic system, the demand for those or other products increases (R1). Hence, for decoupling economic growth from environmental degradation, there is a need for supporting sustainable consumption policies with behavioural, communication/information provision, economic and regulatory tools that can change the consumption patterns with respect to sustainability criteria (BIO Intelligence Service, 2012) and ultimately leading to a reduction in the demand (B6) for the products and services. It should also be noted that an infinite economic growth is only possible theoretically if it is not linked to the biophysical world system, which is not the case in reality simply because of two reasons: 1) All natural resources used throughout the economic system originate from the biophysical world system and vast majority of these resources are finite. Moreover, humans are consuming these resources faster than ecosystems can regenerate; 2) All emissions and waste generated as a result of growing economic activities return back to the biophysical world system faster than ecosystems can absorb it.

Sustainable Population Policies

As the CLD given in Figure 2 suggests, one of the main root cause for today's increasing environmental degradation and resource depletion, is the increasing world population. It is essential to introduce sustainable population policies (Figure 2, diamond no. 4), especially in the developing countries, in addition to other policies discussed above. There are several examples of effective reproduction policies implemented across the world, which not only reduce the birth rates, but also support an educated and economically active society. The main challenges for a wide spread implementation of such policies are religious and cultural resistance, as well as political infeasibility (Engelman, 2012).

Conclusions

Increasing global population and affiliated demand for all goods and services are the two major driving forces for resource scarcity and environmental degradation. In a biophysical world system of finite resources, humans can not continue to use resources with a rate faster than the ecosystems can regenerate. If no policy actions are taken to reduce these two main driving forces, collapse of the biophysical world system on global level is inevitable in the long run.

40. Dynamic material flow analysis of steel: state of art and methodology development

Daryna Panasiuk, Bertrand Laratte, Sébastien Remy

Abstract

Modern society has accumulated a huge amount of metals in form of metal-containing products. This stock-in-use represents a significant source of a secondary raw material and its future availability could be evaluated quantitatively and qualitatively. Steel is an important material for economic development; it is present in most sectors of economic activity. Steel recyclability makes it a good case study for this kind of evaluation.

Material Flow Assessment (MFA) is an appropriate tool for physical accountability of materials flows and stocks through and in a system. Dynamic approach of MFA (DMFA) considers also lifetime distribution to quantify changes in stocks. Basing on the current DMFA studies, a methodology for steel industry in Europe is described. It aims to consider all process flows from material extraction to waste management. The realization of the analysis helps to understand the use of steel, its stock as a secondary raw material per industrial sector. Using this data enables to describe scenario of future trends of steel consumption.

This analysis could be a policy support within sustainable material management framework. It is a part of a project "Life Cycle Assessment and Recycling" of a French governmental investment initiative within IRT M2P.

Keywords: dynamic model, material slow analysis, steel.

Introduction

The economic development of the 20th century relied, among other resources, on the use of metals. Steel is the most used metal material in the world (Allwood and Cullen, 2011). Even if there is actually no scarcity issues for iron ore, mining activities and steel production have a negative impact on the environment. In fact, the primary production of steel is energy-intensive, hence has a great impact on climate change issues. Actually steel industry is estimated to be responsible for 25% of world industrial CO_2 emissions (Allwood and Cullen, 2011).

Metal recycling uses less energy than raw material extraction and transformation. Accumulated metal stock in form of products in use represents a significant source of secondary raw material. A more comprehensive study of metals life cycles is necessary to improve sustainable economic development through resource management, emission reduction and progress in urban mining management.

Meanwhile, Europe, aiming to be a recycling society, sets sustainable management of resources and eco-efficiency as one of its core objectives within its strategy for sustainable development (*COM (2001) 264. 15.5.2001*.). In this framework, a closed-loop economy could be a solution to enforce the strategy. It enables to diminish the use of raw materials and to reduce the raw material dependency by consuming local scrap. Industry is one of main actors of transition toward this new type of economy and has to benefit an appropriate tool.

Hence, industrials related to steel supply chain and scientists, supported by French governmental investment initiative, defined a project “Raw material and recycling in Life Cycle Assessment” within IRT M2P. The project aims (i) to establish a closed-loop economy for the main materials used in economy and (ii) to diminish environmental impact related to materials. As a part of this project, the present works focuses on evaluation of flows of steel in Europe.

The objective is to carry out a methodology for dynamic material flow assessment for all process flows from material extraction to waste management. The methodology enables a characterization of the evolving use of these metals within the European economic system.

State of art

Material flow analysis (MFA) is a systematic assessment of the flows and stocks of materials within a system defined in space and time (Brunner and Rechberger, 2004). Dynamic approach of MFA is considering a lifespan of materials within the system boundary and shows stocks accumulations over the time. It enables to quantify the flow in the past, apply corresponding lifespan to products and to study the changes in the flow through the time. There is no standard method for realization of MFA/DMFA. Many dynamic studies were conducted to describe steel flows. All these studies are different by their objectives, processes included, approach of stock evaluation, level of flow characterization, spatial and temporal scales, etc.

Table 1 presents the comparison of DMFA studies according to objective of study, spatial and temporal scale, system boundaries and approach used for stock estimation. Spatial and temporal scale describes the geographic extent and studied year/s. Column “system boundaries” shows simplified structure of the system. The next column indicates weather the flow of semi-products was quantified within the study.

Author, publication year	Objective	Spatial & temporal scale	System boundaries	Semi-products	Stock estimation
(Davis et al., 2007; Geyer et al., 2007)	stock assessment	UK, 1970 - 2000	Extraction→ EoL	no	top-down
(Michaelis and Jackson, 2000a, 2000b)	stocks assessment, exergy evaluation	UK, 1954 - 1994	Extraction→ EoL	no	top-down
(Park et al., 2011)	stock assessment and forecast	South Korea, 1993-2020	Extraction→ EoL	no	top-down
(Müller et al., 2006)	stock assessment and forecast	USA, 1900-2004	Extraction→ EoL	no	top-down
(Igarashi et al., 2007)	stock assessment (stainless steel)	Japan, 2002	Extraction→ EoL	no	top-down
(Hatayama et al., 2010)	estimation of steel use in future	World, from 2005	Extraction→ EoL	no	Top-down

Table 1: *Summary table of steel DMFA studies review*

In this review, a particular attention was paid to different methods of stock estimation – bottom-up and top-down. In bottom-up approach the total material stock is equal to the sum of material contained in the most relevant products. Top down method uses data on production, import/export and existing stock to calculate the stock (Müller et al., 2006). All of further mentioned studies use top-down approach for stock estimation. However (Hirato et al., 2009) compared both approaches to evaluate the automobile steel stock on Japan. The study shows that both of them could be used, they are complementary, while having uncertainties. (Daigo et al., 2007) proposes a method for estimating steel stocks in Japan putting into evidence the difference between stock in use, obsolete products and overall stocks.

Based on the review of static and dynamic MFA studies, this work develops a methodology for evaluating European steel cycle. All studies have similar elements: definition of objectives and system boundaries, choice of stock estimation approach, data collection and evaluation. Present study is different from previous works by geographic boundaries and time period considered. Also it considers the whole industry of steel production – from extraction of iron ore to the waste management, including flows of semi-products of steel and final goods. As indicates Table 1, no DMFA studies are considering semi products. Their distribution through end-use sectors will map the consumption behaviour, will give an information concerning quality and quantity of materials stocked within different industrial sectors. All data are gathered on the annual basis per country.

Methodological framework

Definition of scope, boundaries and time frame

The focus of this study is devoted to the material, hence its total industrial sectors should be taken into account. The spatial extent is identical to geographic borders of EU-27 in order to be coherent with a common European legislation framework. Moreover, with the common market, industrial flows are not anymore on a national scale, so the European level is considered more adapted.

The chosen time boundaries are from 1950 to 2014. The realisation of a study through a long period of time enables to observe the evolution in the past and to consider metal-containing products with a long lifespan.

The system boundary includes the 4 life stages, as defined in STAF project (Wang et al., 2007) (fig. 1): production, fabrication & manufacturing, use and waste management & recycling. In order to use this generic model for industrial sectors of steel every stage will be subdivided into re2levant processes.

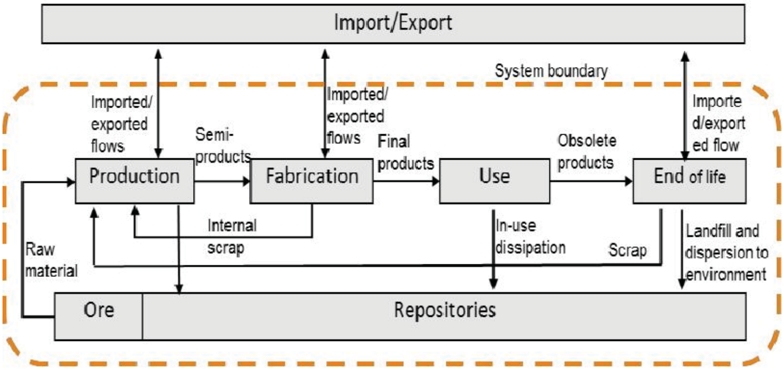

Figure 1: *Generic system definition*

Identification of flow and processes

As indicated on Figure 1, four stages were defined. Production stage includes processes of raw material and scrap transformation to the metal and further production of semi-products.

The stage of fabrication and manufacturing includes two groups of processes: (i) manufacturing of steel final products and (ii) manufacturing of steel-containing goods. It is necessary to consider the repartition of final steel products within industrial sectors, since the waste quantity formed during goods production is dependent on sector. Generally, processes and flows within this stage are neglected. However they enable a better understanding of steel industries structure.

During the Use stage, the steel containing products represent an in-use stock of the materials. The period of time between input and output could vary from several months to decades depending on use sector.

The End-of-life stage includes processes of product treatment necessary for recycling, e.g.: collection, disassembling, sorting, etc. A part of the scrap is considered as lost and some part is landfilled.

The studied material flows consist of raw material, semi-products, final products, obsolete products and metal scrap. Raw material flow includes materials mined within and outside geographic boundaries of EU-27, as far as they are consumed on the studied territory. Exported raw materials are not accounted for. Semi-products of steel are produced in form of ingots, billets, blooms, slabs, sheets, plates, etc. Like in case of the raw material, imported and exported flows are considered. Final metal-containing product groups are used within the corresponding industrial sectors. At the end of the lifespan goods become obsolete products and are sent to waste management facilities. The scrap produced while transformation of semi-products to final goods, as well as the scrap originated from waste management are used as a secondary raw material for metal production.

Stock estimation

The stock of steel is evaluated using top-down approach. This approach allows better consideration of historic flows than bottom-up. This second approach is considered to offer more details about reservoirs (Müller et al., 2006) by quantifying material-containing products and material concentration. In this study, steel distribution through different industrial sectors is determined by distribution of semi-products. The stock is characterizes by products being in use only. Semi-products and final goods located at producers are not considered as a stock since this time is quite short. These products are included in the flow. The data on historic production of steel and semi-products comes mostly from statistics of WorldSteel Association, compared and completed with statistics published by The European Steel Association (EUROFER) and Eurostat. Historic trade data are coming from WorldSteel statistics too and economic input-output tables.

In order to gather data on flows and processes parameters were identified for stages of production, fabrication & manufacturing, use and waste management & recycling. These parameters represent corresponding processes of steel cycle (Figure 2).

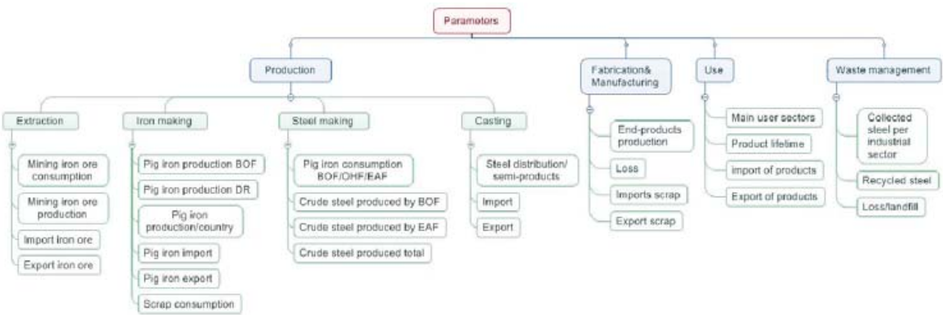

Figure 2: *Parameters for data collection*

Data collection and its time consuming character is referenced as the main challenge by many authors. The biggest part in this work is to consider the exhaustive quantity of flows on the large territory and during a long time period. Data on raw materials extraction, their processing to steel, import and export are well documented in statistics. While semi-products distribution in different economic sectors are less considered.

Product lifetime of main steel containing products are compared according to scientific publications, discussions with experts and Lifespan database for Vehicles, Equipment, and Structures (Murakami et al., 2010).

Challenges

On the way to the sustainable development, this methodology could be really useful by addressing challenges of resource efficiency and closed-loop economy. European Union, having long term objectives, have to make prospective decisions. The methodology puts into evidence current stocks, flows and makes a linkage between raw materials and their life cycle. This knowledge doesn't give a solution, but is an essential step for further planning.

Anthropogenic stock of materials is already important and keeps to increase. This stock. Secondary materials are already replacing the use of natural resources. Data collected within this methodology enables to understand the recent use of secondary materials, products lifetime and current in-use stock. Basing on this, it is possible to make forecast concerning future available stock and the demand of main end-users. Consideration of these issues enables a better resource management and recycling policy.

Conclusions and Discussion

The present work proposes a methodology for dynamic study of anthropogenic material flows. The methodology was elaborated basing on the literature review of existing frameworks. The review was compared according to several parameters of ODD Protocol.

The further work consists in methodology application to the steel industrial sector in Europe. This work has already started by definition of industry-specific processes and data collection. Next questions the study will be facing are: the approach for lifespan distribution, stock estimation and forecasting; how to evaluate uncertainty and balance the model. Of course, the most tremendous work is data gathering, considering the scope defined in the methodology. The elaborated methodology is quite exhaustive and comprises a big number of flows and processes.

41. Wealth from waste in the circular economy

Damien Giurco, Samantha Sharpe, Nick Florin, Stuart White

Abstract

Generating wealth from waste is a central tenet of the circular economy and innovations in production systems and resource management are emerging globally as products, supply chains and business models are being redesigned to harness this opportunity.

This paper presents recent findings from the Wealth from Waste Cluster, a $9m research collaboration (2013-2016) which joins University of Technology, Sydney (UTS), Yale University, Monash University, The University of Queensland and Swinburne University of Technology to build knowledge networks, assemble evidence, and develop new science to identify opportunities for Australia in a circular-economic world.

Findings from the research are grouped in four themes (i) technical and non-technical challenges to successful urban mining of metals, including e-waste (ii) an estimate of the value of the urban mine in Australia, namely $5b annually, only 35% of which is recycled locally (iii) innovative directions in responsible supply chain business models to capture the value of this untapped resource in Australian firms and (iv) elements of a transition path and policy recommendations to facilitate the acceleration of realizing wealth from waste.

Keywords: recycling, urban mining, industrial ecology

Introduction

In addition to a global rise in population and intensity of material consumption, the future use of materials in the economy is being shaped by a range of disruptive forces – these include resource and energy constraints and the digital age – changing economies of scale for production, consumption (including via 3D printing) and the lowering barriers to innvoation across borders and unlocking new business models. Whilst Japan and China have have embedded principles for a sound material cycle society and circular eocnomy respectively, elsewhere the circular economy discourse (e.g. in the UK) has largely been focused on corporate and educational activity and has a strong focus on cradle-to-cradle design. In Australia the related concept of industrial ecology has been applied suuccesfully both in geographical precincts (e.g. Kwinana, Gladstone) but is yet to strongly influence national indsutry policy. Given that Australia's top two export destinations of China and Japan have technologies, practices and polices oriented towards the circular economy – how Australian industry adapts to thrive in a circular economic world is a key question.

Aim

The aim of this paper is to articulate the state-of-play and challenges associated with realising the goal of generating wealth from metal-bearing waste in a circular-economic future, illustrated for the context of Australia. It breaks the discussion into (i) competing conceptualisations (ii) barriers and enablers (iii) dimensions of economic and other value (iv) responsible mineral chains (v) transition pathways.

Competing conceptualisations on future resource use in the economy

Theoretical tensions: industrial ecology and circular economy

Whilst the principles underpinning the circular economy and industrial ecology have much in common, there are pertinent differences in conceptualisation, emphasis, intellectual tradition and impact. Industrial ecology draws on a biological analogy and systems view to conceptualise the inter-relationships between industries and the environment and to a lesser extent consumers; it puts emphasis on understanding the impacts of material and energy flows and the roles of technology and policy for decoupling economic growth and material intensity consistent with one-planet living. Over several decades, it has developed an intellectual tradition, including via the *Journal of Industrial Ecology* established in 1997. Tools and research have been developed relating to different industrial ecology types (see for example Boons and Baas, 1997) on (i) geographical areas, such as eco-industrial parks or sites of symbiosis (ii) product life cycles, using for example LCA (ii) material cycles (such as steel, including using MFA) (iv) sectoral approaches, including using input-output analysis. Regarding impact, the work on geographical areas has inspired companies and regions to try to replicate the iconic example of Kalundborg, Denmark with mixed success (see Corder et al., 2014 for a recent overview of activities in Australia); LCA has had an influence on promoting eco-labelling and life cycle thinking in product design, but in its early days LCA struggled with a lack of credible inventory data and in more recent times the move to standardization has heralded a focus on definitional rigour ahead of an agenda with effective resource use for sufficient service-provision (offset partly by the evolution of consequential analysis). Material flow studies have achieved some policy impact in Europe and Japan, including prompting discussions of decoupling (and degrowth), but not in Australia. Sectoral approaches (e.g. chemical sector) may not involve input-output analysis, but the development of environmentally extended input-output analysis have sectors at their core and whilst data are aggregated, the system boundary problems of LCA are less troublesome. There are also hybrid approaches with LCA, however I/O has more been descriptive than normative. Social context, the role of design and corporate strategy and finance are less emphasised in industrial ecology than circular economy.

Concepts of circular economy emerging from China focus on both the eco-industrial park dimensions of industrial ecology and on developing regional and national industrial policy agendas with circular principles in mind. Japan makes a subtle but powerful distinction in describing its national policy as that for a “sound material cycle society”. Recently, the concept of the circular economy has been effectively introduced at the global level (including at the World Economic Forum) by the Ellen Macarthur Foundation, UK. Like industrial ecology, it emphasises the importance of education, but thus far does not have a long intellectual tradition. This stems from it ambitiously seeking to encompass fields spanning biomimicry, industrial ecology, cradle-to-cradle and blue economy. Unlike industrial ecology, it puts corporate leadership, design, innovation and economic opportunity at the heart of creating change more than technological change which was emphasised in industrial ecology. Some portrayals of the circular economy suggest economic growth being desirable as long as it is circular.

Australia: developing a vision for resources and innovation

Regarding the application of the theory described in 2.1 to the resources sector in Australia, industrial ecology at the geographical scale has been successful in heavy industrial regions which include minerals processing (e.g. Kwinana, Gladstone). At the product scale, historical successes (e.g. EcoReDesign program) have stalled. At the level of materials and sectors – the dominance of Australia's exports being unrefined commodities (dominated by coal and iron ore) biases the focus on the resource chain to the upstream lower-value-add dimensions. In response to the absence of a national vision for resources, a research-led collaboration on Mineral Futures developed the elements of a national strategy building on *Vision 2040: Innovation in Mining and Minerals* (Mason et al. 2011, 2013). This puts a focus on transformational technology (such as coupling production to clean energy) and responsible supply chains.

In cities, resources can be derived from waste. The waste sector has targets to divert material from landfill and product stewardship legislation has been introduced nationally (beginning with televisions and computers). The sector is professionalising. The intersection is illustrated in Figure 1.

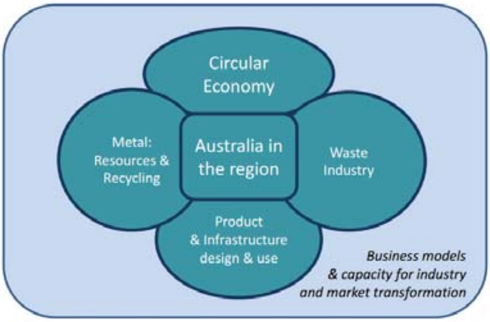

Figure 1*: Intersection of fields of activity*

Wealth from Waste Cluster

Arising from Vision 2040 was an acknowledgement that valuable stocks of metal-bearing resources in Australia sit both above and below ground. Whilst the much larger share in Australia sits below ground, other countries are rapidly developing the technology and know-how to derive value from above-ground stocks of resources. The Wealth from Waste Cluster is a 3 year collaboration between UTS, CSIRO, University of Queensland, Swinburne University of Technology, Monash University and Yale – together with an international industry and government reference group.

With a focus on undertaking research with impact, work is divided into four programs :

- Program 1: Recycling systems: barriers and enablers for industrial ecology in Australia
- Program 2: Future resource value: characterising stocks and mapping impacts
- Program 3: Developing business models for future value chains
- Program 4: Transition pathways for leadership in resource stewardship

Economic size of above-ground resource flows and broader value

The size of resources sitting in above-ground urban mines in Australia (with a current population of 23 million people) is being estimated. That which is currently flows into the waste stream annually is approximately $5b and 7m tonnes (shown in Figure 2), the vast majority of which is iron, then aluminium, copper and other metals.

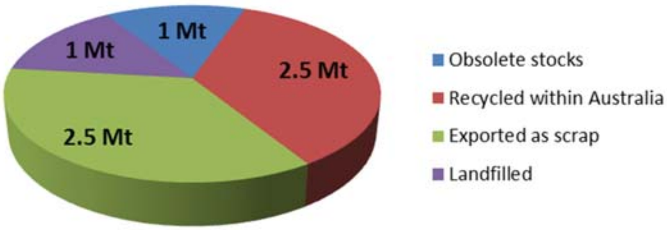

Figure 2*: Destination of metal-bearing waste streams in Australia (source: Corder et al. 2014)*

At an aggregated level Figure 2 illustrates the ptential for further value capture in Australia. However, a significant enabler for value capture is understanding the location of stocks via GIS (Zhu, 2014). For terrestrial resources, this is currently the responsibility of Geoscience Australia, and for above ground stocks, the Wealth from Waste Cluster is developing an online resource atlas “Australian Urban Mine Atlas” http://wfw-atlas.monash.edu/apps/atlas/

Lane (2014) highlights the inherent tension between industrial ecology and economic articulations of value and the need for a greater awareness of „*the actors and organizations that accumulate these materials and their current practices around disposal. Information is needed about existing collection systems, their logistical elements, how economic value is currently captured in collection of used goods and materials, and the formal and informal institutional frameworks that influence current arrangements. Also required is a better understanding of the informal frameworks of social values, norms and knowledge that influence current disposal practices*.“

Barriers and enablers – technical, policy and beyond

The technical challenge of recovering metals from products and infrastructure increases for complex urban ores (such as e-waste) which contain combinations of metals not common in naturally occurring ores. The economics of processing depends on being large enough to blend feed streams towards a homogenous supply and whilst design-for-disassembly can assist, there is a trade-off between ‘lightweighting’ the product and containing sufficient metal to make recovery worthwhile.

In a review of e-waste processing routes comprising collection, pre-processing and final processing, Khaliq et al. (2014) find that whilst hydrometallurgical routes have been used to recover precious metals, pyrometallurgical routes (e.g. lead smelting route or copper smelting route such as that used by Umicore, Belgium) are more economic, although iron and aluminium recovery is not easy as they end up in the slag. Furthermore, large (scale) investments are currently required for integrated plants which can recover metals and control emissions. Importantly, *“To extract small quantities of PMs from e-waste, thermodynamic knowledge of more than one BMs including copper, lead, nickel and zinc is required. Australia is a world leader in the mineral and mining industry and possesses the capability of copper, lead, zinc and PM processing. There is an opportunity to optimize the existing non-ferrous extraction processes to recycle e-waste and recover PMs.*” (Khaliq et al. 2014). A pertinent question for e-waste recycling in Australia is whether the future of processing lies only in large scale integrated facilities, or whether smaller, distributed plants can be developed economically. Policy drivers also influence the development of recycling systems.

As described by Giurco et al. 2014, national product stewardship legislation was enacted by the Australian Federal Government in 2011 (*Product Stewardship Act 2011*), providing a framework for accreditation of voluntary schemes, and establishment of co-regulated and mandatory schemes. The *Product Stewardship (Televisions and Computers) Regulations 2011*, require large importers and manufacturers of television and computer products to become members of an “approved co-regulatory arrangement” through which targets related to provision of collection services, recycling rates and material recovery must be met. Notwithstanding this partial enabler, collection systems have yet to be optimised to facilitate broader recycling and local processing is limited. Furthermore, Gumley (2014) concludes “*that the prevailing political agenda favouring deregulation and reduced taxation may be a major barrier to development of new styles of regulation and more effective use of taxation powers that is needed to support a more circular economy in metals*”, instead arguing for reflexive regulatory strategies informed by empirical studies.

Innovating responsible supply chains

Australia has the potential to lead in the development of technology and practices aligned with responsible primary and secondary supply chains. Mason et al (2011) have highlighted the potential of ‘Brand Australia: responsible minerals’ coupling renewable energy to minerals processing at the beginning of the supply chain, but responsible practices must extend through product use to formal and informal recycling practices and also consider the mineral-energy nexus (Giurco et al, 2014). In addressing responsibility, whole of supply chain approaches such as the Steel Stewardship Forum (steelstewardship.com) are aiming to facilitate market differentiation via aligning with responsible practice. In a digital future, not only will the location of obsolete stocks be more readily understood, but the advent of 3D production could mean that ‘responsible production’ could be enabled via cartridges of responsibly sourced metals in 3D printers which you rent from a company which also cross-checks the product design online to ensure design for disassembly had been appropriately incorporated.

Concluding discussion: transition pathways

To overcome the barriers and realise the economic and social value present in the circular economy described herein – including through innovating responsible supply chains – it is important to recognise that a significant transition is underway. Insights into the stages and processes of this complex, socio-technical transition can assist in developing and advancing a shared vision for the future (Jackson et al. 2014). The paper of Jackson et al. (2014) highlights that considering the implications of a transition to Wealth from Waste at multiple system boundaries, such as for a single commodity of steel, or for the waste industry as a sector, or for the interlinked sectors shown in Figure 1 can frame the role of important stakeholders. Additionally, it argues that for enabling action, the transitions management and socio-technical transitions literature could usefully be coupled with the work of critical futurists to assist in explicitly articulating the worldviews of stakeholders. In this way, through the example of metals, a transition pathway can be facilitated to deliver wealth from waste as the first step towards accelerating the realisation the circular economy.

Acknowledgement

This research was undertaken as part of the Wealth from Waste Cluster, a collaborative program between the Australian Commonwealth Scientific Industrial Research Organisation (CSIRO); University of Technology, Sydney; The University of Queensland, Swinburne University of Technology, Monash University and Yale University. The authors gratefully acknowledge the contribution each partner and the CSIRO Flagship Collaboration Fund. The Wealth from Waste Cluster is a part of the Minerals Resources Flagship and is supported by the Manufacturing Flagship.

42. Potential availability of secondary scarce metals from se-lected applications in Germany

Stefan Gößling-Reisemann, Till Zimmermann, and Knut Sander

Abstract

In the project ReStra (Recycling Potentials of Strategic Metals) – commissioned by the German Federal Environment Agency (Umweltbundesamt) – partners at the University of Bremen, Ökopol and other institutions analysed the use of scarce and strategic metals in a variety of products in Germany. In a first step, the secondary metals flows potentially available in 2020 have been estimated based on an analysis on the product level. In the succeeding work packages of this project, the existing recycling infrastructure will be analysed and policy recommendations will be developed.

Here, we report on the results from the secondary metals flows analysis. Among the analysed products are thin-film photovoltaic cells, automobiles including catalysts, NiMH batteries, industrial catalysts and others. These products have been analysed considering their historic and future deployment, embodied materials and – where relevant – exports and dissipative losses from the use phase. The potential waste streams in 2020 have then been estimated assuming a Weibull distribution for the life spans. Especially for products with dynamic sales figures this approach is considered much more accurate than the use of average life spans and an assumed simultaneous exit function. Our methodological approach and the amounts of secondary strategic metals in 2020 from the analysed products will be presented.

Keywords: scarce metals, strategic metals, secondary resources, recycling potential

Introduction

Saving non-renewable resources is a cornerstone of European and national sustainability strategies. Besides improving materials efficiency and substitution of scarce resources with more abundant or renewable resources, material recycling is one of the essential building blocks of sustainable resource management. If implemented cautiously, metals recycling in particular will save not only primary resources but also decrease the overall environmental impacts during the metals life-cycle. With the ever increasing material complexity of metal bearing products and the decreasing concentration of many economically and environmentally relevant metals in these products, setting up effective and efficient recycling systems becomes more and more challenging (cf. Reuter et al. 2013). Most issues in metals recycling do not stem from technological deficits; if there is enough of a certain waste material in one place and the metal price is right, technologies can be found to extract the most relevant metals. Problems arise for example when the recycling system in place does not fit the spatial and temporal discard patterns of end-of-life products, when waste streams have changing or largely unknown composition, when metal prices do not economically allow metals recovery from wastes, or when new products with relevant metal contents enter the market and it is unclear where and when they appear as wastes. For a closed loop metals economy it is thus ever more important to know where, when, in what amounts and in what concentrations metals in end-of-life products will become available in the future. Some of these questions are currently addressed in the ReStra project, commissioned by the German Federal Environmental Agency (UBA, FKZ 3711 93 339). The project has four main work packages: 1) determining current and future demand of strategic metals in Germany and selecting the most relevant strategic metals for further analysis, 2) determining recycling potentials of selected strategic metals in certain waste flows, 3) describing and evaluating available treatment, processing and recycling technologies for the selected strategic metals and 4) derive recommendations for resource efficient collection, treatment and recycling systems. In the following we will present methodology and results from work package 2.

Metals selection

The strategic metals analysed in this study have been selected based on 12 indicators in two broad categories: economic importance and supply risk. The indicators covered aspects of current consumption, expected future demand, substitutability, concentration of supply and production, co-mining, recyclability, potential for environmental relief, and environmental burdens of metals. The latter two indicators were chosen, because one of the goals of this study is to especially include metals that are relevant from an environmental perspective. In particular, two types of metals were of interest:

- metals which are of high relevance for future technologies with expected environmental benefits (indicated by future demand, estimated recycling potential and technological potential for environmental relief)
- metals with high environmental impacts from extraction, processing, refining and transport (indicated by cumulated energy demand)

Applying the selection criteria, the following strategic metals were selected for analysis: Ga, Ge, In, Rh, Pd, Pt, Au, Y, La, Ce, Nd, Sm, Eu, Gd, Tb, Dy, Er.

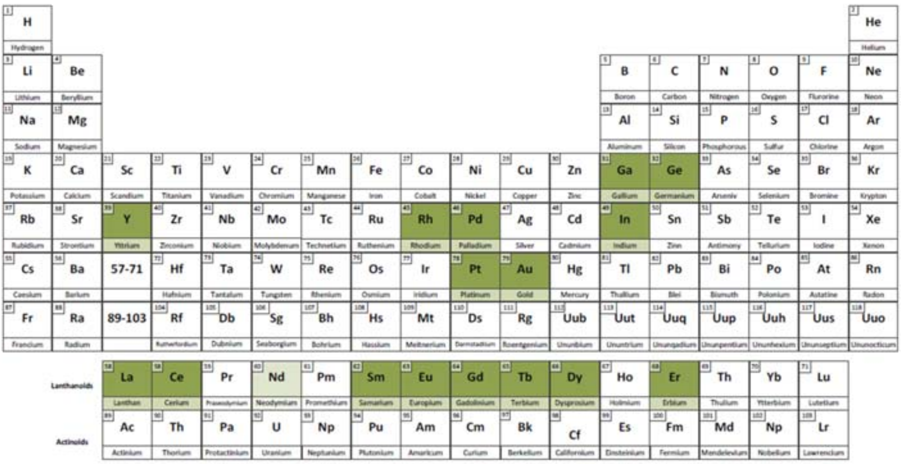

Figure 1: *Selected metals for assessment in ReStra*

Methodology

The analysis of secondary metals potentials proceeded along two major approaches:

1. assessment of future secondary metals potentials in selected end-of-life products
2. assessment of relevant current waste flows with potential for metals recovery

In this paper we only report on results from approach 1, mainly because approach 2 is focusing on current waste flows (instead of future ones) and because the data basis for estimating current metal loadings in certain waste flows is very weak.

Product selection

Approach 1 is based on end-of-life products, which means that relevant products have to be chosen. In order to identify the most relevant products, first the most relevant product groups or application groups for each metal were identified. This step was carried out by analysing the relevant literature on scarce or strategic metals flows (e.g. Buchert et al. 2009; Behrendt et al. 2010; Hagelüken und Meskers 2009; Graedel et al. 2011a, Schüler et al. 2011, and many more). The number of product groups was further reduced by excluding product groups with no classical end-of-life (e.g. jewellery) or product groups that were analysed in a companion project (RePro, also commissioned by the UBA[17]). In order to capture future market dynamics, product groups with an expected rise in sales and appropriate (i.e. short enough) life spans were added to the selection.

After the most relevant product groups were identified, they were decomposed into individual products in order to be able to assign uniform metals concentrations and life span data. Only products with relevant metal contents were chosen. The decomposition was based on analysing the relevant literature and further informed by expert interviews. Expert judgement was especially needed for products which might become relevant in the future and for ranking the products according to their respective metals contents. With the list of products and data on life spans and metal concentrations the modelling of the metal flows from the products could proceed.

Modelling end-of-life metal flows

Approach 1 was based on the following flow sheet and variables to estimate the potentially available amount of metals in end-of-life products in 2020 (the reference year), see Figure 2:

- Amount of products entering the use phase (P)
- Concentration of relevant metals in products (c)
- Life span: length of time in use phase (V), including its probability distribution
- Exports directly from use-phase (E)
- Amount of obsolete products leaving the use phase (A)

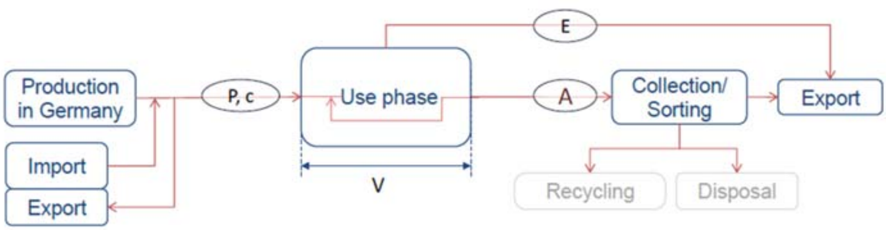

Figure 2: *Analytical frame for analysis in ReStra*

[17] Since the two studies are complementary, future publications will focus on combined results from both studies

For the life span distribution $V(t_i)$ the Weibull distribution has been chosen based on its discussion in the literature (see OECD 2001; Tasaki et al. 2004; Kagawa et al. 2006). It is given by

$$V(t_i, \lambda, k) = \lambda k (\lambda t)^{k-1} e^{(-\lambda t)^k},$$

with λ and k being the Weibull position and shape parameter, respectively.

Without considering exports (i.e. $E = 0$), th amount of products A coming out of the use phase at time t can be calculated to be

$$A(t) = \int_0^\infty P(t - t_i) V(t_i) dt_i$$

Since it is highly impractical to gather data on products put to market in the infinite past, a cut-off for the upper integral limit has to be chosen based on the average life span of the respective product. In order to capture at least 95% of all products, the cut-off was calculated to be approximately 1.5 times the average life span. For example, if a product has an average life span of 10 years, and the reference year for the calculation is 2020, market data from 2005 onwards has to be gathered including future trends.

When product flows in 2020 are corrected by export-from-use figures and then multiplied by average concentrations (or corresponding spans as found in the literature and other sources), the amount of metals expected from the selected end-of-life products can be calculated.

Results

The results from the selection process are the basis for the metals flows calculation and are presented first.

Selected product groups and products

Over 40 products from 18 product groups have been selected for further analyses following the approach described above. The product groups and the respective analysed metals are shown in Table 1.

Selected secondary metals potential in 2020

Based on the approach described above, amounts of strategic metals that are to be expected in 2020 from end-of-life products have been calculated for each of the products listed above. Selected material flows are shown in Figure 3. The preliminary results for the total amounts of strategic metals arising from all analysed products are shown in Table 2.

Product group	Analysed metals	Exemplary products
Industrial catalysts	Ge, Pd, Pt, Rh, Ce, La, Nd, Pr	Refinery cats., powder cats.
Automobile catalysts	Pt, Rh, Pd, Ce, La	Cats. from different vehicle types
Automobiles	Gd, Tb, Dy	Different passenger and utility vehicles
Metallurgy/ Alloys	Ce, La	Misc. applications of Mischmetall
Batteries	Ce, La, Nd, Pr	NiMH batteries
Applications of the optical industry	Ce, La	Polishing agents; special lenses
Laser applications	Er	Medical lasers (Er:YAG)
Wind energy	Nd, Dy, Tb	Gearless wind turbines
Medical devices	Nd, Pr, Dy, Tb, Gd	MRIs, CTs
Fuel cells & hydrogen storage	Y, La	SOFC
Optical fibre applications	Ge, Er	Glass fiber cables
Photovoltaic cells	In, Ga	CIGS, CdTe
LEDs	In, Ga, Ce, Y, Au	LED screens
Home appliances	Nd, Dy, Tb	Electric bikes, air conditioners
Ceramics	Y	Ceramic thermal barrier coating
Selected equipment in nuclear reactors	In, Gd	Control rods
High temperature super conductors	Y	Superconducting quantum interference device (SQUID)
Data centers	Pt, Pd, Au	Different sized data centers

Table 1: *Analyzed product groups and metals*

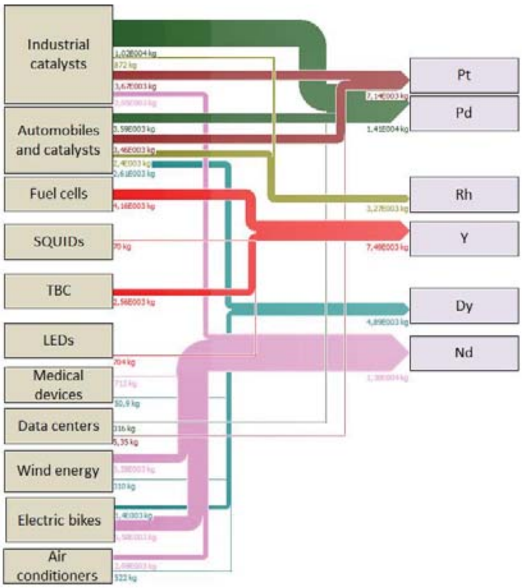

Figure 3: *Flows of selected strategic metals in 2020*

	Pt	**Pd**	**Rh**	**Au**	**In**	**Ga**	**Ge**	**Y**
Potential flow in 2020 [kg]	7,052	14,118	3,253	573	128	36	2.3	7,252
World mine production 2011 [t]	492,000			2,600,000	641	216	120	
Ratio	0.005%			0.00002%	0.020%	0.017%	0.002%	
	La	**Ce**	**Nd**	**Gd**	**Tb**	**Dy**	**Er**	**RE, unspec.**
Potential flow in 2020 [kg]	373,216	419,443	13,277	931	491	4,206	1.3	52,400
World mine production 2011 REO [t]	125,384							
Ratio	0.869%							

Note: RE = rare earths, REO = rare earth oxides, metal content in REO approximated to be 80%

Table 2: *Preliminary results for potential flows of strategic metals in EOL-products in 2020 and ratios between secondary potential in Germany and global production (data on world mine production from British Geological Survey 2013)*

Conclusions and outlook

In the project, flows of strategic metals arising in 2020 from various products and applications have been estimated. The preliminary results from the analysis of these future secondary sources indicate significant potential for recycling in 2020 for some metals, especially for the rare earths. However, estimated rare earth masses are dominated by the light rare earth elements La and Ce which are of less (environmental-economic) strategic concern than heavy rare earth elements as Dy. For many bulk metals, the German share of global consumption is in the range of 5%, which also holds approximately for rare earths (cf. BGR 2012). For a broader estimation of recycling potentials, however, the results of the companion project *Repro* need to be taken into account, too. Preliminary results from both projects indicate that assuming all products analysed here could be effectively recycled, Germany could cover a substantial part of this demand for some of the analysed metals from secondary sources. However, there are many challenges on the way towards a closed loop metals economy, e.g. incomplete collection, insufficient separation, dissipative losses during recycling, etc. These deficits will be analysed in further work packages within the ReStra project and conclusions for policy making and metals management will be developed.

43. Recovery of metals from waste, an example for the resource cycle

Franz-Georg Simon, and Olaf Holm

Abstract

Bottom ash from municipal solid waste incineration (MSWI) consists of elemental metals in considerable amounts. The fine fraction < 4 mm additionally contains chemically bound metals (oxides, carbonates, silicates). Separation prospects with techniques as in ore processing (flotation, density separation, bioleaching, hydrothermal solution) are discussed. During alteration after wet extraction mineral material with hydraulic properties form coatings on almost all particles of the bottom ash and complicate separation procedures. In addition bottom ash from MSWI is a heterogeneous material. For sufficient enrichment different concerted treatment steps seemed to be essential associated with an uncertainty of economic viability. The utilisation of metal compounds present in bottom ash as secondary raw material depends on the energy- and resource-efficiency of the enrichment processes. Therefore energy and material flow considerations are presented.

Keywords: recyclable material, recycling technology, environmental technology, waste management.

Introduction

Municipal solid waste (MSW) consists of elemental metals in considerable amounts. After waste incineration these metals are contained in the solid residues of the process. The largest residual fraction is bottom ash which comprises approximately 25 % by weight (10 % by volume) of the total. Almost 10 % of the bottom ash consists of elemental metals which can be easily separated with magnets (scrap iron) and eddy current separators (non-ferrous metals, primarily aluminium, copper, brass, etc.). To increase the efficiency of these techniques and thereby the recovery rate in numerous treatment plants nowadays three or four sieve fractions are processed in parallel. However, the fraction of approximately < 4 mm is of minor interest and is normally deposited. This is due to the lack of recycling prospects but also since established techniques are not yet suitable for fine grain sizes. Despite this, the fine mineral fraction of the bottom ash contains heavy metal compounds in concentrations which are in some cases higher than those of the respective ores. Prior to recovery of the chemical bound metals a treatment for enrichment of these compounds has to be performed. Here the same processes as in mineral processing can be applied (flotation, density separation, bioleaching, hydrothermal solution).

The total amount of metals in the bottom ash is frequently evaluated and thereby well known. Several elemental contents are independent of the grain size. For other elements per smaller grain sizes the concentrations are increasing but enrichment factors achieved by sizing would not be sufficient for economic recovery. On the other hand the proportion of elemental, oxidised and otherwise bound metals along with their speciation is not well known so far. However selection of the treatment technique as well as the terms and conditions should be based on this knowledge.

This paper evaluates some opportunities and limits of metal recovery from waste. Energy and material flow considerations will also be discussed.

Composition of MSWI bottom ash

Bottom ash is the largest residual fraction in the process of municipal solid waste incineration (MSWI). It consists of 1.) solid phases already contained in MSW such as glass cullet, ceramics, cinder and metals (iron and non-ferrous metals) and 2.) new phases formed during the incineration process (Bayuseno and Schmahl, 2010). Since bottom ash amounts to 20-25 % by weight MSWI is a substance concentrating process with an enrichment factor of 4-5 with regard to the metals (Rechberger and Brunner, 2002). The 5 most common elements in MSWI bottom ash are Silicon, Calcium, Iron, Aluminium and Sodium. Si and Ca appear as oxides, Al and Fe in both their elemental form and as oxides and Na as chloride (Chandler et al., 1997). Scrap iron and non-ferrous scrap amounts to 9 % and 1 %, respectively (Zwahr, 2006). In contact with water bottom ash (usually bottom ash is extracted by wet ash discharge systems) exhibits alkaline pH values of 12 and above due to the formation of $Ca(OH)_2$. Subsequent storage leads to carbonisation of the ash and lower pH values. These aging reactions are accompanied by hardening and hydraulic cementation reactions resulting in mineral attachments on elemental metals. Aluminium is partly oxidised under alkaline conditions forming $Al(OH)_3$ and hydrogen. Copper is present in elemental form and as chemical compound. Different to zinc it shows a uniform grain size distribution as displayed in *Figure 1*. However, bottom ash is an extremely inhomogeneous material which makes general statements difficult.

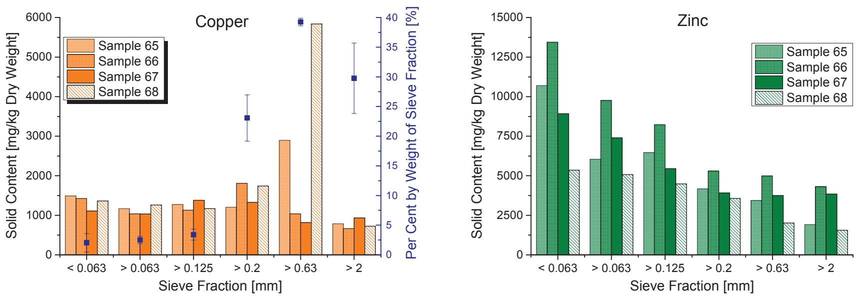

***Figure 1**. Grain size distribution of copper (left) and zinc in MSWI bottom ash. The mass fractions of the grain size distribution are displayed on the left side (second y-axis).*

Recovery processes

Applications and publications concerning the treatment of bottom ash with techniques like flotation, density separation, bioleaching and hydrothermal solutions are scarce. Fly ash is more often investigated using these techniques. Typically, the techniques are applied to fly ash to extract or immobilize undesirable contents like heavy metals, dioxins and furanes or un-burnt carbon for subsequent disposal (Bosshard et al., 1996, Huang et al., 2003, Jing et al., 2010). In contrast to this for bottom ash recovery of valuables is the major objective.

Pretreatment of bottom ash

It has to be considered that bottom ash from MSWI is a heterogeneous material strongly dependent on the composition of the treated waste. In addition, during the alteration after wet extraction from the incineration mineral material with hydraulic properties form coatings on almost all particles and complicate separation procedures. Hence a pre-treatment like milling and sieving seems to be essential to establish the aforementioned techniques. Techniques such as breaking up clustered materials with impact mills could be promising.

Recovery processes for elemental metals and metal compounds

Flotation

Froth flotation is a widely used technique for the selective enrichment of valuable contents especially in ore mining. The main challenge here is the prior mechanical separation of ore and gangue, which leads to a high energy consumption. Flotation as a three phase interaction process is affected by numerous factors such as the flotation reagents, pH-value, grain sizes, pulp density etc. and is still not completely understood (Shean and Cilliers, 2011). In ore mining flotation targets usually only a single or a few ingredients of the miscellaneous pulp. Due to this, it is comparatively easy to identify the most adequate chemicals and find out the best process conditions, which then results in high recovery rates.

Flotation of bottom ash is another unique issue. As pointed out bottom ash is an extremely inhomogeneous material. On the other hand the relative uniform mineral attachments on the bulk of the particles hinder the selective impact of flotation surfactants. The coatings should be detached and the grain size distribution constricted for a better performance, equivalent to a high preparation effort. For the flotation process it should be considered that there is not only a single target to be separated. At the expense of high recovery rates a more general approach is required to establish a favourable flotation process.

Density separation

In principle the densities of elemental, alloyed and chemical bound copper should enable a separation However a proportion of copper in bottom ash is mineral bound (e.g. in cuprite or tenorite (Arickx et al., 2008)) and is particularly associated with other ash components. Also mineral attachments reduce the density of such particles. As is the case in flotation, a prior treatment of the bottom ash might be necessary to achieve sufficient enrichment e.g. in a jig.

Bioleaching

In primary production of copper bioleaching is by now widely used for the low grade ores but similar to flotation mainly to process sulphide ores . Microorganism enhances then the oxidation of the sulphides and the copper is merged into the solution. In bottom ash copper mainly exists in elemental or in oxidised form. This is why applying enzymes may be more effective. Despite this, bioleaching is very slow procedure and the mineral coatings of the bottom ash hinder the reactions additionally.

Hydrothermal Solution

Under hydrothermal and alkaline conditions in bottom ash the formation of zeolite, tobermorite and other minerals with high potential for immobilisation were observed (Penilla et al., 2003, Jing et al., 2007). The hydrothermal treatment therefore should be applied in acid solutions. Different acids have been developed for the leaching of heavy metals from fly ash (Zhang and Itoh, 2006). According to the results hydrochloric acid is able to degrade chemical structures and thus enhance the leaching process of heavy metals accompanied with a decrease in acid consumption. However, the released heavy metals precipitate again and the concentrations in the solution decreases with time.

Energy and material flows

Recovered metals replace metals from primary production. For the production of the non-ferrous metals copper and aluminium from natural resources very large masses have to be processed. Furthermore reduction to the elemental form is highly energy-consuming. In Figure 2 the mass and energy flows for the production of 1 Mg of Aluminium and Copper is displayed in Sankey diagrams. In the case of Al 7.8 Mg of material have to be handled for the production of 1 Mg elemental Al, in the case of Cu even 204 Mg. Whereas bauxite, the raw material for Al contains between 55 and 65 % Al_2O_3, copper ores have today metal contents below 1 % (for the data in Figure 2 a concentration of 0.6 % was assumed). In the lower section of the figure the exergy flows are displayed. The input flow of the copper production has a considerable share of exergy. The reason is that roasting of sulfidic copper ores is an exothermic process (therefore CuS has high value of chemical exergy (Bakshi et al., 2011)) and the final product, sulphuric acid has a high value for chemical exergy. Exergy in the input flow of Al production arises almost completely from coke, which is consumed as electrode material in the electrolysis. Note the high value of chemical exergy of elemental Al in the output flow. Exergy accounting for primary Al and Cu is described in detail elsewhere (Ayres et al., 2006).

In the production of secondary metals much less material has to be handled and less energy is needed. Usually the scrap metals have to be remelted only. Energy consumption in secondary copper production is 4.45 GJ/Mg for scrap of excellent quality, for scrap of lower quality 20.15 GJ/Mg and for scrap of the lowest quality 49.16 GJ/Mg with only 25-35 % Cu present are quoted (Ayres et al., 2002). Secondary Al production requires around 25 GJ/Mg (Frischenschlager et al., 2010). Alloying elements cannot be removed easily. Therefore the application of secondary metals might be limited (Weber, 1990).

Production of secondary metals from metal compounds is of course more energy consuming. Although the Al_2O_3 concentration in bottom ash is in the order of magnitude of bauxite, utilisation of bottom ash as feedstock for Al production is neither economically nor ecologically feasible. The concentration of copper in bottom ash (see *Figure 1*) is in the region of copper ores (Mudd, 2007, Mudd, 2010). Thus, copper could be recovered from MSWI bottom ash with methods applied already in copper ore mining. For oxidised copper present in bottom ash (Wei et al., 2011, Yao et al., 2013) enrichment by flotation or application of the solvent extraction/electrowinning (SX/EW) process might be suitable. With the SX/EW process route considerably less energy is needed (app. -40 %), however, the resource utilisation efficiency (kg copper/ton of feedstock) is smaller (Marsden, 2008). Energy consumption in copper production is strongly dependent on the ore grade or concentration in the feedstock. Marsden showed that energy consumption is increased by more than 60 % in both SX/EW and flotation/roasting/electrorefining routes when the ore grade decreases from 0.5 to 0.25 %. Exergetic considerations on the recovery of metals from waste are discussed in detail elsewhere (Simon and Holm, 2015).

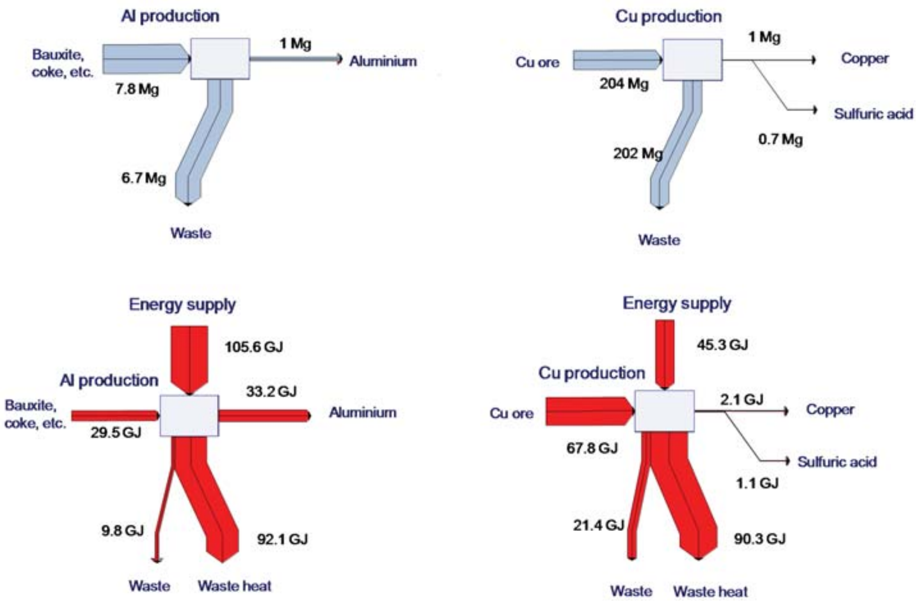

Figure 2. *Mass and exergy flows for the production of Al and Cu from natural resources (Ayres et al., 2006).*

Conclusions

The resource cycle start with mining of ores and preparation of (raw) materials which are used for the fabrication of products and goods. After the use phase the products are disposed of in the end-of-life phase. In all phases of this cycle waste is generated. Established recycling strategies already exist for most of production waste, e.g. scrap utilisation in metal working. The utilisation of mixed wastes in the end-of-life phase is more difficult. Although bottom ash from MSWI is a mixture of different materials the recovery of elemental metals is technically feasible and helps to close the resource cycle. To implement the fine fraction < 4 mm in the resource cycle several development works have to be done. It is expected that no stand-alone technique could handle this complex scope of work rather successions of concerted treatment steps are needed for sufficient enrichment. Doubling the yield of metals recovered from MSWI bottom ash seems to be possible (Simon and Holm, 2013) associated with an uncertainty of economic viability.

Substitution by secondary metals saves enormous quantities of energy because chemical reduction is not needed rather than in primary production from ores. The utilisation of metal compounds present in bottom ash as secondary raw material depends on the energy- and resource-efficiency of the enrichment processes.

44. Experience drawn from projecting critical material flows along the life-cycle of optoelectronic products

Max Marwede, Susanne Rotter, Otmar Deubzer, and Klaus-Dieter Lang

Abstract

This paper presents the research approach, methodology and challenges experienced when modelling future flows of critical materials along the life cycle of emerging opto-electronic products (cadmium telluride photovoltaics and LED products). When estimating future material flows, uncertainties about future technological, economical and political developments come into play. Therefore the method has to be complemented with foresight and sociological methods in order to develop scenarios which take various possible developments into account. The main challenges linked to emerging technologies are data gaps and uncertainties such as: future material content in the product, future efficiency of the processes (production, collection, recycling) and market developments. In this paper several foresight methods have been proposed to narrow down those uncertainties such as expert interviews, roadmap analysis, trend and policy analysis, wild card analysis and scenario workshops.

Introduction

This paper presents the research approach, methodology and lessons learnt from two dynamic material flow analyses (MFA) in order to present recommendations for future MFAs. The future flows of critical raw materials along the life cycle of cadmium telluride photovoltaics (CdTe-PV) and products containing light emitting diodes (displays, luminaires) were estimated (Marwede, Reller 2012; Deubzer et al. 2012). Those emerging green technologies dependent on a reliable supply of key technology metals such as indium, gallium, tellurium or rare earth metals (REMs) in order to maintain high market growth. However those materials are regarded as critical, which means that their supply is potentially restricted (APS/MRS 2011; COM 2010; NRC 2008; Moss et al. 2011; US DoE 2011).

In this context a material flow analysis for emerging technologies helps

- to determine future critical material demand as early warning system for a possible demand surge,
- to estimate future recycling flows as substitute for “primary” material,
- to assess whether at all and when to develop and scale up recycling systems and processes, and
- to detect material losses along the life-cycle to derive improvement potentials along the life cycle.

Previous works used and enhanced the method MFA to assess current and historical material flows on a national, regional of global level. For example, the STAF project is evaluating current and historical flows of important materials such as the base metals nickel, copper and zinc (Gordon et al. 2003; Spatari et al. 2003; Spatari et al. 2005; Reck et al. 2008; Graedel et al. 2004). Those works estimated material flows and stock on the basis of historical and present data. In case of emerging technologies one needs to look into the future in order to answer the questions above. Here uncertainties about future technological, economical and political developments come into play. Therefore the method has to be complemented with foresight and sociological methods in order to develop scenarios which take various possible developments into account.

Research approach and methodology

In order to model material flows, we followed the steps in Figure 1 which are based on the general procedure for material flow studies (Brunner, Rechberger 2004; van der Voet, Ester 2001).

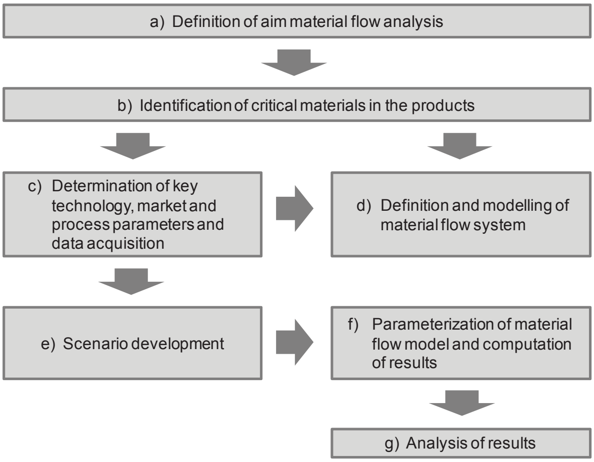

Figure 1: *Research approach*

a) Aim of both case examples was to estimate the flows of critical materials along the life cycle. In case of CdTe-PV the influence of material efficiency measures on the magnitude of the flows was assessed. In case of LED products the aim was to identify the magnitude of material required, recycled and lost at European level with current state of the art recycling and production technologies in order to discover “hot spots” for the optimisation of the materials flow along the life-cycle of LED products.

b) In the second step the composition of the products was analyzed. Then those materials regarded as critical were identified by a meta-analysis of criticality studies. In case of LED products it was also taken into account how economically important those materials are by estimating how much the electronic industry spends per year on those materials.

c) In order to define the material flow model in time and space, to set the system boundaries, and to identify relevant materials, processes, flows and stocks, key parameters influencing the material use along the life-cycle of the products were determined. The required data was collected via expert interviews and desktop research. The literature review included scientific research articles, technology reviews, conference articles and technology roadmaps in order to gain information about the status quo of processing technologies and product characteristics as well as their future development. To complement the picture, experts from various points in the value creation chain (equipment manufacturing, production, pre-treatment, end-treatment and research) were either interviewed or took part in the data acquisition in order to obtain data which was not publicly available and is based on the current state of the art.

d) Based on the collected information, the life-cycle of the products was modelled using the freeware STAN (TU Wien). The system for LED products is described in Deubzer et al. (2012), for CdTe-PV in Marwede, Reller (2012), respectively. Both systems include processes for the life-cycle phases “production”, “use” (stock), “collection”, “pre-treatment” and “end-treatment”. In the subsystem “production”, processes are included which influence the material demand the most (material utilization, yields). For reduction of complexity the phases “mining” and “extraction and refining” are neglected. For LED products the time span is 2010-2020 and the geographical scope is Europe. In case of CdTe-PV global flows along the life-cycle between 2010 and 2040 were computed.

e) Market scenarios and technology trajectories were developed for both dynamic material flow analyses. In case of CdTe-PV, a low material efficiency, mid-efficiency and high-efficiency scenario was developed. For each of the three scenarios a set of parameters (and flows) was determined, which reflect current and future market developments as well as process and product developments. Uncertainties were covered by using lower end, realistic and optimistic values for the scenarios. Each scenario was described in a storyline (Marwede, Reller 2012).

In the case of LED products the flows are based on just one market scenario, one for sold LED products and one for produced LED dies. Improvements of product efficiencies over time (less LEDs for the same performance) are taken into account. Contrary to the CdTe-PV MFA it was assumed that state of the art processes and technologies are also used in the future (business as usual). Typical average values were used for the processes and the material content (Deubzer et al. 2012).

In both cases the mean lifetimes defined as the time from shipment to collection as waste (use, reuse(s) and storage of unused devices) had to be estimated as statistics for those relatively young technologies are missing. To model the end of life flows lifetime probabilities were calculated using the normal distribution in case of LED products, the Weibull distribution in case of CdTe-PV, respectively.

f) The model was parameterized in order to compute results and **g)** the results were analyzed and discussed in order to answer the research questions.

Challenges and recommendations

In this section various uncertainties in estimating critical material flows of high-tech products are described without claiming to be exhaustive. Furthermore we attempt to give possible starting points or measures to narrow down those uncertainties (Table 1).

On product level various uncertainties about the current and future material content of the product exist. The content is not just dependent on the stoichiometric composition and share of weight, but also on technological developments such as efficiency improvements (e.g. conversion efficiency of a PV module). However a variety of manufacturers and designs make an estimation of the typical or average material content difficult. The current material content of products can be analyzed chemically; here it is important to analyse a range of products as experience shows that the content may vary widely. Mean and standard deviations of the measurements can then be used to define the spread/uncertainties in the model. However chemical analysis requires process know-how and is time-consuming and costly. Another way is to calculate the material content on the basis of physical properties and state of the art designs and estimate a spread by varying the factors. Here a deep knowledge and understanding of the technology are required. A third rough estimation is to divide the amount of material used for a technology (e.g. per annum) by the number of products put on market. This approach is easy but inexact. Furthermore, in case material inefficiencies during production are neglected this approach can lead to high overestimations of the recycling potentials because it is falsely assumed that all the material input ends up in the product. However, this estimation can be used to validate the product based calculations if material inefficiencies are known.

Emerging high-technologies are subject to fast development cycles, which make “predictions” for future technological developments even more difficult. Here technology roadmaps can be a good source for technical goals and timelines. It is also possible to deduce future technological developments from research papers and patents. The scientists and assignees can then point out the time to market. To deal with uncertainties upper and lower limits which can be reached at a certain point in time can be set (e.g. improvement of efficiency up to X percent by 2040) to develop the technology trajectories thither.

The material content is often not sufficient to model the material demand for production due to inefficient use of the materials. Material utilization is often not disclosed by the companies and is highly dependent on the used processes, process knowledge and factories. For example, scaled up processes are more efficient than pilot lines. Sometimes the material utilization is even dependent on the used materials. In LED manufacturing cheaper materials (As, P) are deposited quicker with a lower deposition efficiency in order to increase throughput whereas the cost intensive materials (In, Ga) are deposited slower with a much higher deposition efficiency (Illek 2012).

When using numbers from literature, terms such as material utilization, material efficiency and yield are used arbitrarily. This can be illustrated at the example sputtering: The terms can be used to define how much of the material is sputtered off the target, how much of the sputtered material deposits on the substrate, how much of the material input ends up in the product, or how much material is consumed, i.e. material which is bound in the product plus the production scrap which cannot be recycled. It’s advisable to be aware of the various uses of the terms and in the case of doubts to clarify the definition and to compare various information sources.

To estimate future material flows, historical market developments and future market scenarios are required. Historical data sets state production, shipments, stocks or market penetration rates. The more sources are available, the easier it is to narrow uncertainties down. For regional breakdowns of flows, import and export data are required. However, this is unfortunately often not available or not broken down to the subsystem or component level; especially in case products are new in the market. Regional breakdowns of production and sales data can help to determine export and import rates.

Future market developments are dependent on the macroeconomic situation, (economic) trends and policies which facilitate or direct the market (e.g. low interest loans or regulations). A change in one of those influencing factors can rapidly change the market outlook. Market forecasts, policy analysis and production expansion plans help to look into the near future (~5 years). Because uncertainty grows with time, different market scenarios should be modelled when looking into the farther future. In case of emerging technologies an s-curved market development is more realistic than linear or exponential growth: high market growth in the early stage which will level off when the market is saturated. In case technology substitutes come into the market which replace the old technology sales for the “outdated” product might even shrink. For example OLED screens which are self-light emitting are more and more replacing LCD screens equipped with LED backlighting (McKinsey 2011). This influences the LED market. This example shows that also technology substitutes have to be considered when developing market scenarios.

Unpredictable events such as break-through innovations or economic crises cannot be easily integrated into market scenarios as their time of occurrence is unknown. Nevertheless their possibility of occurrence and their impact on the scenarios can be described qualitatively (wild card analysis).

To calculate the end-of-life flows various methods exist (Elshkaki, van der Voet, Ester 2004; Melo 1999). Here the choice of the method depends on the known factors (inflow, outflow, stock, lifetime) and the type of market (emerging, saturated, declining). For example in case of a fast growing market the end-of-life flows are probably overestimated if using static lifetime approach instead of a lifetime distribution, whereas in a saturated market the static lifetime approach lead to reliable results.

The lifetime of the products is not just dependent on the possible technical lifetime, but also on innovation cycles, consumer trends and consumer behaviour as well as payback periods. For example Huisman et al. (2012) showed that the residence time of electronic equipment is decreasing, i.e. electronic products put on the market in 2010 are used shorter than those put on the market earlier. For emerging long-living high-tech products lifetime statistics are often not available. Here one needs to rely on (predicted) technical lifetimes and typical use patterns. Attention should be given to the definition of the technical lifetime, which could be performance dependent or stated as statistical average. For example, the lifetime of LEDs is specified as the operating hours of the LED until it reaches a specific performance-threshold. In case of statistical factors, the underlying statistical distribution is of interest to model lifetimes.

Product lifetimes should not be derived from the lifetime of single components in the product. For example, although the technical lifetime of a LED reaches up to 100,000 hours, the lifetime of the LED luminaire results from the reliability of all components such as cooling system and driving electronics. Lifetime distributions for some electronic products based on statistical analysis can be found in Huisman et al. (2012) and NIES (2010). If statistical information is not available, one can estimate a range for the end-of-life flows by choosing different distribution functions (Weibull, normal ...) and varying the required parameters.

The amount of end-of-life products collected depends on the regulations in place, the available infrastructure and the users' behaviour. In case of emerging products, the determination of collection rates may be difficult because the majority of the products have not yet reached their end of life. Here collection statistics for similar products (similar size, use patterns ...) can help to determine possible collection rates for emerging products. For example in Europe national electronic waste registers gather collection rates for different collection groups. Helpful are also collection rates which are legally required to be reached in the future, for example collection rates stated in the European e-waste directive for the years 2016 and 2019 (COM 2012).

However, even if those products are collected, end of life recycling rates for most critical materials are at the moment below 1 per cent (Graedel et al. 2011), mainly because pre-treatment and end-treatment technologies for most of those materials are not (yet) commercially available, still under research, and material concentrations in the products are low. Here one needs to look into recycling processes in the development and research stage to be able to assume recycling rates for future recycling systems. In case used products are (illegally) exported to developing countries, where state of the art recycling processes are not available, materials might be lost.

Phase	Data requirement	Narrow down uncertainties by
Product	Material content	• Chemical analysis • Theoretical calculation (state of the art design) • Material demand for sector
Production	Material utilization	• Analysing production technologies
Market	Historical data	• Comparing data about production capacities, sales, stock and market penetration
	Import export data	• Comparison of production and sales data
	Future market	• Trend and policy analysis
Use	Lifetime	• Technical lifetimes and reliability statistics • Balance input and output flows
Collection	Current and future collection rates	• Collection statistics for similar products • Legal requirements
End of life	Recycling rates	• Analysing processes in research and development
All	see above	• Scenario workshops • Wild card analysis • Expert interviews • Roadmap analysis • Monitoring technology research and patents

Table 1: *Measures to narrow down data uncertainties in material flow analyses*

Conclusions

This paper presented the research approach, methodology and challenges experienced when modelling future flows of critical materials along the life cycle of emerging high-tech products. The challenges lie mainly in data gaps and uncertainties such as: future material content, future efficiency of the processes (production, collection, recycling) and market developments. We like to remark that it is not possible to predict the future. However, scenarios can construct possible futures which can for example be developed in scenario workshops. In such workshops key influencing factors and their possible future values are identified by a group of experts. Thus scenarios are bound to conditions or incidents, which will have been fulfilled or happened between now and a future point in time. The macroeconomic, political and social boundary conditions and incidents can be described in consistent storylines.

Keeping this in mind, not only the outcome in numbers or magnitude of the material flows are important but also the conclusions drawn out of the MFA – e.g. recommendations to change the real system in such a way that certain goals can be reached. Those recommendations can often already be discovered during the research process and can then be visualized by the MFA. Therefore the whole process leads to new insights into processes, systems and economies.

Acknowledgements

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45. WatERP: Water Enhanced Resources Planning (ERP) "Where water supply meets demand"

Julia Ciancio, Catherine J. Chomat, Jorge Helmbrecht and Gabriel Anzaldi

Abstract

With an ever-growing water supply demand reaching ecological and economic limits, the need for innovative water management is acute.

Water supply management involves several actors. While many management tools exists, these are not used in a collaborative environment, thus a need for more integrated approaches is needed.

This paper presents a quality cost-benefit solution for these needs developed WatERP Project. WatERP consists of an open management platform (OMP) for water supply distribution systems that will integrate real-time knowledge on available water supplies and demand, across geographic and organizational scales, so that the entire water distribution network can be improved in an integrated and collaborative manner by the actors and users involved.

This platform will improve water governance and foster water-savings culture in Europe. If operations affecting water flows and storage can be viewed by all water regulation operators, increased cooperation results. If consumers can view their actual consumption along with water availability estimates, behavioural change occurs.

WatERP encourages water data accessibility and sharing for improving management of water supply systems, enabling dynamic and agile interactions among the different actors involved in the water supply chain.

WatERP provides water governance while maintaining the autonomy and independence of the actors involved.

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Keywords: enhance resources planning, IWRM, water cooperation, water governance, resource efficiency.

Introduction

As cities grow and environmental problems escalate, managing human demand for fresh water presents an increasing challenge. Increasing scarcity of supply, pollution, over-exploitation of resources and climate change are placing increasing stress on European aquatic systems and water supply systems. Meanwhile land use changes affect groundwater bodies and surface water ecosystems, putting more pressure on water reserves. With ever-growing demand reaching ecological and economic limits, the need for innovative water management is acute. The increasing number of cases where available water resources fail to meet "normal" water requirements manifests that conflict over the access and use of water will be a policy-making challenge in the near future (Assimacopoulos, 2008).

The need for Enhance Resource Planning for Water

Water supply management involves a wide array of actors, from water authorities to water regulators, water utilities and finally the end-users. While many optimization, governance, planning and monitoring frameworks have been developed and currently used, these are not currently used in a collaborative environment (Schevers, 2005). Yet water management is becoming increasingly more complex, with continual changes in human and natural systems affecting water availability, access, affordability and quality (Aquawareness Policy Forum, 2010) and therefore, there is a need for more integrated and adaptive approaches based on reliable technologies and a solid knowledge base (EU Council, 2011).

Thus, the better coordination among the water supply distribution chain should be addressed by applying the latest technologies to build a management platform that integrates real-time knowledge on available water supplies and demand, from water sources to users, and across geographic and organizational scales, so that information from each step of the process can be exchanged and accessed and the entire water distribution network can be viewed, understood and improved in an integrated and collaborative manner, which is the chosen approach for WatERP project.

To accomplish WatERP‟s objective, the resource manager will be supported by a tool providing continuous information regarding water supplies, and including historical, current and forecasted values of water availability and supply sources, distribution efficiency; and consumption across the entire water supply distribution network.

The novelty of WatERP is that in addition to saving water and energy, it will improve coordination among actors and will foster behavioural change.

Background and needs

Growing gap between water supply and demand

In recent years, water shortage has become an increasing concern, with a growing imbalance between water demand and availability reaching critical levels in many parts of Europe (Aquawareness Policy Forum, 2010). Yet current leakage of water from supply systems is significant in parts of Europe with losses of transported water ranging from 5% to 40% (EU Council, 2011).

The worldwide gap between water demand and availability is projected to grow significantly in the next 20 years, reaching nearly 40% by 2030. In Europe, climate change is causing increased water shortages and more frequent, more severe droughts, especially in Mediterranean countries (EU Council, 2011).

In order to secure water supplies into the future, there is an urgent need to transition towards a more water-smart society and develop water-wise solutions to improve water efficiency, reduce water consumption and preserve water resources (EU Council, 2011).

Lack of Information

There are currently significant data gaps and uncertainty in quantifying water usage making it difficult to estimate future water consumption and saving potentials or define economic instruments or policies. Member States water abstraction and consumption data originate from a variety of sources, are collected using different approaches, and are often incomplete

(Ecologic, 2007). Water scarcity impacts (EUROWATERNET, Eurostat) are also difficult to estimate due to a lack of information. There is a real need for an improved understanding of current water usage. In order to achieve this a monitoring system of water uses and demand needs to be established (EC, 2009).

New indicators are needed to assess water scarcity at the river basin, national and EU-level. A comprehensive set of indicators at appropriate temporal and spatial scale capable of linking phenomena is necessary to predict drought and water scarcity impacts throughout Europe (EC, 2009), deliver relevant and comparable data at river basin and national levels, and ensure that the aggregated data makes sense at the EU level. These indicators should enable the economic impacts of water scarcity to be determined, along with the social and environmental impacts as well (EC, 2011).

Need for increased information sharing, coordination and cooperation

Although water savings have been achieved in various sectors, each entity currently acts independently without much knowledge regarding the needs, constraints or operations of the others and information is not easily accessible. Yet net water savings and environmental improvements can only be realized if the water saved in one area is not used elsewhere by others or downstream (Ecologic, 2007), through a holistic approach. In order to achieve wide scale improvements, there is a need for enhanced coordination, cooperation between water supply actors across different scales, in order to address both long-term water imbalances and enhance resilience to drought (Kampragou et al., 2011).

In parallel, there is a need for increased information sharing. If information were shared among the various decision-makers and stakeholders, operations could be coordinated, better decisions could be made, water supplies could be prioritized according to needs and changing conditions, overall water use efficiency could be improved, and water shortages could be reduced. Strong partnerships are essential to enable long-term improvements. Public participation and awareness regarding efficient water use is crucial to ensure the effectiveness of the water policies. Clear, easily understandable and transparent information on the real costs of water is needed to support water pricing policies and motivate actions, not only in the domestic, but also in the industrial and agricultural sectors. Finally, easy access to information and water education are necessary to foster behavioural change among users (Aquawareness Policy Forum, 2010).

Problem Analysis and Methodology

The WatERP project address the previously described challenges in order to provide an innovative, integrated water supply open management system. In other words, an Enhanced Resource Planning for water as the solution for a better IWRM, water cooperation and governance; and for improving water and energy efficiency.

WatERP proposes the development of an advanced, integrated management system which enables water efficiency to be improved throughout the water supply distribution chain by enabling better matching between supply and demand from a holistic perspective. To that end, the subsystems in this chain that are consuming, managing or producing water, and which nowadays normally rely on separate monitoring and control solutions, will be connected through an open ICT architecture among themselves as well as to external third party applications. This will enable the design and development of higher level applications that will be able to control or guide the ongoing water-supply processes considering the different requirements of each subsystem.

In order to achieve project objectives, the following subsystems will be researched and designed:

- A standardized Open Management Platform to foster water management efficiency improvements utilizing cutting edge ICT technologies so as to provide a unified framework for water management activities, in line with IWRM. Indeed, a framework providing interoperability between loosely coupled software applications and data sources, enables integrated water resources management to be achieved with the new applications and web-based services supplementing existing applications within a joint collective network, greatly enhancing current water resource management capabilities.
- Identification of key variables tracked throughout the water supply distribution system to enable water supply and demand to be matched across the entire water supply network and in accordance with the new water scarcity, drought and vulnerability indicators being developed by JRC and the EC.
- Protocols for data collection to ensure data quality, reliability and consistency, including methodologies to ensure a continuous stream of information in real-time and storage of the necessary historical and metadata records.
- A generic ontology, taxonomy and water data information model to provide a unified vision of of the water supply distribution chain including human made alterations and natural resources influence, enabling better information understanding, exchange and representation of the various systems involved.
- Advanced data management tools for processing and storing consistent, continuous and useable water supply and usage data originating from heterogeneous sources in static, real-time and near-real time. This Water Data Warehouse will cover the whole water supply distribution chain.
- A comprehensive knowledge base on water sources and usage open to the different actors involved in the water supply distribution chain to provide accurate, comprehensive and timely hydrologic data to water managers and water users as well as to other stakeholders and general public
- Algorithms, procedures and methodologies to discover water availability and distribution datasets and usage consumption patterns, enable data to be compared to historical values, trends and indicators, analyze the socio-economic driving forces behind water usage (to support policy and water pricing) and to foresee future water shortage and water scarcity events (to enable risk management and planning). These will be done through:
    - A Decision Support tool integrating models and tools for provide i) recommendation based on inferred knowledge, ii) simulation environment in order to previously test the actions in a controlled setting, and iii) support to the multi-agents distributed intelligence with the overall objective of matching an accurate supply to the forecasted demand across the whole water supply distribution chain. At the same time, energy and costs could also be tracked to reduce their usage,
    - A Demand Management tool integrating models and tools for: i) supporting short-term demand forecasts across different spatial scales, ii) assessment of

the combined impact of economic and other instruments towards water conservation, iii) improved water use profiling, and iv) awareness raising on improved efficiency in water use.

- Scalable and customizable visualization tools to increase user awareness and promote behavioural change.

The balanced integration of all these components in an Enhanced Resource Planning for Water, can only results in an improvement in the matching between water supply and demand, addressing the urgent need to transit towards a more water-smart society and developing water-wise solutions to improve water efficiency, reduce water consumption and preserve water resources.

Discussion: Why WatERP's approach and not only smart metering?

With an estimated total price tag of around 6 billion Euros per year for EU countries, water scarcity and droughts represent a serious and growing threat to human health and economic development in Europe and it is widely recognised that efforts must be increased to cope with such challenge (EC, 2007; EC, 2011; WssTP, 2010). While the problems of water scarcity are most acute in southern Europe, the spatial extent and severity of water stress is growing in parts of the north also. With oncoming climate change, this situation will only be further exacerbated with major changes expected in annual water availability expected across Europe. Yet according to a study financed by the European Commission, water efficiency in the EU could be improved by nearly 40% with technological improvements with additional savings possible from changes in human behaviour and consumption patterns (Ecologic, 2007).

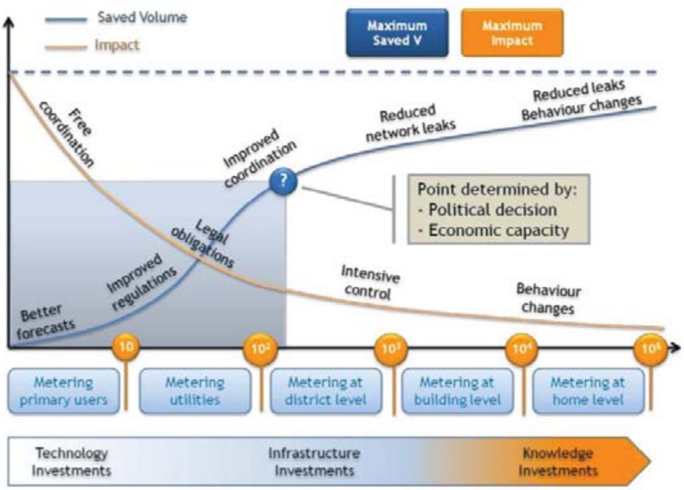

Figure 1: *Water Savings Potential*

There are three ways in which water can be saved and water efficiency improved:

a. through infrastructure investments;
b. through improved coordination;
c. through behavioural change;

These measures have different time scales, and associated costs. Each Member State or region of Europe is situated at a different point on the curve shown in Figure 1 depending on political decisions and economic capacity. Infrastructure improvements are very costly and require long-term investments. With the current economic crisis situation in Europe, there is a reduced ability to finance infrastructure improvements. However, given the small number of actors involved in water regulation and distribution, if they could better coordinate their activities, results would be seen immediately. Behaviour change requires time, but due to the very large amount of water consumers has a great potential. Consequently, the WatERP project address the latter responds, through its expected impacts, to the second and third approaches.

While the EC believes that 40% water savings could be achieved from technological improvements, this value is the sum of a series of different actions. Based on water resources management experience, it can be roughly estimated that improving coordination among actors could lead to water savings between 5 and 8%, with smart metering providing an additional 8 to 10%. The remaining savings would need to come from long-term infrastructure improvements, economic incentives, policies and land use changes. It should be noted that these water savings are accompanied by energy and cost savings since managing, moving and treating water requires a lot of energy and is expensive, as well as environmental benefits since reducing water demand allows more water to remain in the environment, thereby maintaining aquatic ecosystem needs and ensuring that the quality of the water sources is protected in the short-term (bad water quality increases treatment costs and decreases water availability) but also that these water sources will remain available in the future.

Conclusions

In response to the urgent need for increased integration of water resources management and the need for increased focus on demand management, diverse activities such as water provision, energy use, consumer behaviour, and land use must be integrated. For this, information must be exchanged in both directions, from suppliers to end users but also from consumers to the supply managers, forecasting and backcasting at the same time, and involving each actor, stakeholder and user. The proposed Enhanced Resource Planning for Water will make such an approach feasible.

Based on all of the above, the proposed WatERP project responds to the challenge of sizing the gap between water demand and water availability, recognized as critical in the upcoming Blueprint, by encouraging water data accessibility and sharing for improving management of water supply systems and enabling a more dynamic and agile interaction among the different actors involved in the water supply chain. At the same time, the WatERP Open Management Platform provides the capacity to support water governance improvements while maintaining the autonomy and independence of the actors involved. The proposed WatERP Open Management Platform offers a framework from which both technical and non-technical improvements can be obtained and is therefore an ideal solution for addressing water scarcity and improving water supply distribution efficiency.

As shown in Figure 2, WAtERP impacts are tremendous with benefits emanating in many different directions. Beyond the water and energy savings, the WatERP Open Management

Platform would provide water accountability (egovernment) and would provide a platform from which the environment could be better.

Figure 2: *WatERP Impacts Potential*

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